Appendix A.1

South Minneapolis Electric Distribution Delivery System Long-Term Study

SOUTH MINNEAPOLIS ELECTRIC DISTRIBUTION DELIVERY SYSTEM LONG-TERM STUDY

Scott Zima
Distribution Planning Department
Northern States Power Company
March 2009

List of Figures

List of Appendices

1.0 ABSTRACT

In recent years, the Distribution Planning Department ("Distribution Planning") of Northern States Power Company, a Minnesota corporation ("Xcel Energy"), observed an increasing frequency and length of overload conditions on the electric distribution delivery system in the south Minneapolis area during their review of distribution system load. In response, Distribution Planning conducted detailed analyses of the 39 feeder circuits in the geographic area of south Minneapolis that is experiencing the most significant overload conditions and determined that based on 2006 peak load levels, there is an existing deficit of 55 megawatts ("MW") and that by 2018 this deficit would increase to 74 MW. Distribution Planning further determined that common distribution system improvements, including adding new feeder circuits, extending existing feeder circuits and reconfiguring feeder circuits, have been exhausted and would no longer be able to provide the necessary system support.

Distribution Planning then conducted detailed analyses of a larger area of south Minneapolis, encompassing a total of 15 substation transformers and 110 feeder circuits, including the original 39 feeder circuits, to evaluate whether there was existing capacity that was available to address the identified capacity deficit. Distribution Planning determined that the distribution system in the greater south Minneapolis area was already at or beyond capacity and existing area substations could not be expanded any further to accommodate the electrical equipment required to provide the needed additional capacity. Distribution Planning concluded that a new distribution source would be needed to provide the additional required capacity.

Distribution Planning next looked at four "new source" alternatives that could provide the additional capacity needed in the Midtown area, which is the area with the most significant overload conditions in south Minneapolis. Distribution Planning found that the alternative that performed the best with respect to system performance, operability, future growth, cost, and electrical losses, consisted of a new Hiawatha Substation that would tap the existing Elliot Park – Southtown 115 kilovolt ("kV") transmission line between 26th and Lake streets near Hiawatha Avenue; a new Midtown Substation between 26th and Lake Streets and between Chicago Avenue and Interstate 35W that would also tap the existing Elliot Park – Southtown 115 kV transmission line; and two new looped 115 kV transmission lines connecting the two substations. The initial installation of this proposed configuration is estimated to cost $33.4 million and will provide an additional 120 MW of load serving support in the Midtown area. This additional capacity will meet the immediate distribution system needs and provide additional support for further demand growth in the Focused Study Area.

This document is a compilation of these various study efforts undertaken by Distribution Planning.

2.0 PRINCIPLES OF DISTRIBUTION PLANNING

2.1 DISTRIBUTION SYSTEM OVERVIEW

Distribution feeder circuits for standard service to customers are designed as radial circuits. Therefore, the failure of any single critical element of the feeder circuit causes a customer outage, which is an allowed outcome for a distribution system. Feeders are designed to facilitate restoration of mainline capacity and restoration of service to most customers with simple manual field switching with some exceptions. The distribution system is planned to generally facilitate single-contingency switching to restore outages within approximately one hour.

2.1.1 Distribution Substations

Xcel Energy plans and constructs distribution substations with a physical footprint sized for the ultimate substation design. The maximum ultimate design capacity established in Xcel Energy planning criteria is three transformers at the same distribution voltage.[1] This maximum size balances substation and feeder circuit costs with customer service considerations including limitations of feeder circuit routes emanating from substations, circuit exposure of long feeder circuits, ease of operation, cost of operation, customer outage restoration, and the electrical losses. Over time, transformers and feeder circuits are incrementally added within the established footprint until the substation is built to ultimate design capacity.

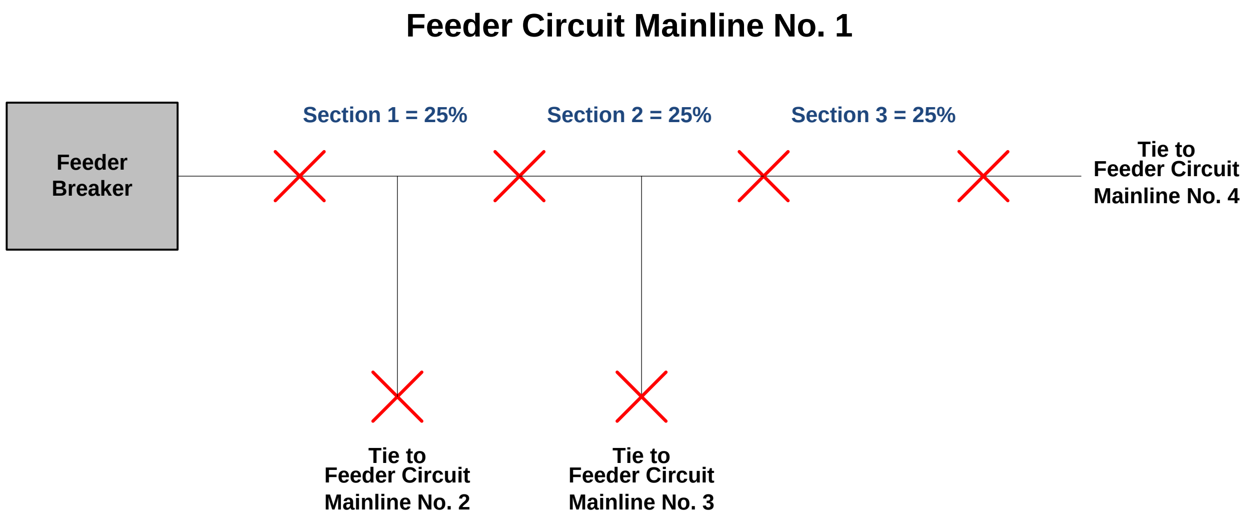
2.1.2 Distribution Feeder Circuits System Intact and First Contingency Planning

Normal operation (also called system intact or N-0 operation) is the condition under which all-electric infrastructure equipment is fully functional. First contingency operation (also called N-1 or contingency operation) is the condition under which a single element (feeder circuit or distribution substation transformer) is out of service. Each distribution main feeder is generally composed of three equal sections. A feeder circuit should be loaded to no more than 75% of capacity during N-0 conditions. For example, a 12 MVA feeder circuit is designed to be loaded to 9 MVA during normal operating conditions. To achieve this goal, a main feeder is generally designed so that each section is loaded to approximately 25% of the total capacity for the main feeder. This loading level provides reserve capacity that can be used to carry the load of adjacent feeders during first contingency N-1 conditions.

Figure 2.1 depicts a main feeder circuit, including the breaker and the three sections. The Xs in the diagram represent switches that can be activated to isolate or connect sections of a feeder lines.

[1] There is one exception to this criteria. In downtown Minneapolis, the Fifth Street Substation houses four transformers to serve the significant load.

Figure 2.1: **Typical Distribution Feeder Circuit Mainline with Three Sections Capable of System Intact N-0 and First Contingency N-1 Operations**



2.2 Distribution System Design and Operation

Distribution system load is planned, measured, and forecasted with the goal to serve all customer electric load under system intact and first contingency conditions. A distribution delivery system that has adequate N-1 capacity is one in which all customer load can be restored through distribution system reconfiguration by means of electrical switching in the event of the outage of any single element.

Adequate N-1 substation transformer capacity, no feeder normal (N-0) overloads, and adequate field tie capability for feeder first contingency (N-1) distribution restoration are key design and operation objectives. To achieve these objectives, Xcel Energy uses distribution planning criteria to achieve uniform development of Xcel Energy's distribution systems. Distribution Planning considers these criteria when identifying deficiencies with existing distribution systems and identifying improvements to address the identified deficiencies.

2.2.1 Planning Criteria, Distribution Feeder Circuits

While the distribution guidelines vary depending on the specific distribution system, there are several basic design guidelines that apply to all areas of Xcel Energy's distribution system. They are as follows:

- Voltage at the customer meter will be maintained within 5% of nominal voltage, which is typically 120 volts.

- Voltage imbalance goals on the feeder circuits are less than or equal to 3%. Feeder circuits deliver three-phase load from a distribution substation transformer to customers. Three-phase electrical motors and other equipment are designed to operate best when the voltage on all of the three phases is the same or balanced.

- The currents on each of the three phases of a feeder circuit are balanced to the greatest extent possible to minimize the total neutral current at the feeder breaker. When phase currents are balanced, more power can be delivered through the feeders.

- Under system intact, N-0 operating conditions, typical feeder circuits should be loaded to less than 75% of capacity. Xcel Energy developed this standard to help ensure that service to customers can be maintained in an N-1 condition or contingency. If feeder circuits were loaded to their maximum capacity and there were an outage, the remaining system components would not be able to make up for the loss because adding load to the remaining feeder circuits would cause them to overload. By targeting a 75% loading level, there is generally sufficient remaining capacity on the system to cover an outage of an adjacent feeder with minimal service interruptions. A typical feeder circuit capable of delivering 12 MVA, for example, is normally loaded to 9 MVA and loaded up to 12 MVA under N-1 conditions.

2.2.2 Limitations to Installing Feeder Circuits

Spatial and thermal limits restrict the number of feeder circuits that may be installed between a distribution substation transformer and customer load. Consequently, this limits substation size. Normal overhead construction is one feeder circuit on a pole line; high density overhead construction is two feeder circuits on a single pole line (double deck construction). When overhead feeder circuit routes are full, the next cost effective installation is to bury the cable in an established utility easement. Thermal limits require certain minimum spacing between multiple feeder circuit main line cables. Thermal limits for primary distribution lines are defined in Electric Distribution Bulletins ("EDB"): UND6 and CAL2 for underground and the Construction & Design Manual C-26 for overhead.

When new feeder circuits are added to a mature distribution system, minimum spacing between feeder circuit main line cables sometimes cannot be achieved because of right-of-way limitations or a high concentration of feeder cables. Adding express feeders to serve distant high-load concentrations requires cable installation across distribution service areas where they do not serve any customer load. Cable spacing limitations and/or feeder cable concentrations frequently occur where many feeder cables must be installed in the same corridor near distribution substations or when crossing natural or manmade barriers.

When feeder cables are concentrated, they are most often installed underground in groups (banks) of pipes encased in concrete that are commonly called "duct banks". When feeder circuits are concentrated in duct banks, those cables encounter more severe thermal limits than multiple buried underground feeder circuits. Planning Engineers use CYMCAP software for determining maximum N-0 and N-1 feeder circuit cable capacities for circuits installed in duct banks.

When underground feeders fill existing duct lines to the rated thermal capacity, and there is no more room in utility easement or street right-of-way routes for additional duct lines from a substation to the distribution load, feeder circuit routing options are exhausted.

2.2.3 Planning Criteria, Distribution Substation Transformers

Transformers have nameplate ratings that identify capacity limits. Xcel Energy's Transformer Loading Guide provides the recommended limits for loading substation transformers adjusted for altitude, average ambient temperature, winding taps-in-use, etc. The Transformer Loading Guide is based upon the American National Standards Institute/Institute of Electrical and Electronic Engineers ("ANSI/IEEE") standard for transformer loading, ANSI/IEEE C57.92.

The Xcel Energy Transformer Loading Guide consists of a set of hottest-spot and top-oil temperatures and a generalized interpretation of the loading level equivalents of those temperatures. The top-oil and hottest-spot temperatures in the Xcel Energy Transformer Loading Guide are the criteria used by Substation Maintenance engineers to determine Normal and Single-Cycle transformer loading limits that Capacity Planning Engineers use for transformer loading analysis. When internal transformer temperatures exceed pre-determined design maximum load limits, the transformer sustains irreparable damage, which is commonly referred to as equipment "loss-of-life". Loss-of-life refers to the shortening of the equipment design life that leads to premature transformer degradation and failure.

Transformer design life is determined by the longevity of all of the transformer components. At a basic level most substation transformers have a high voltage coil of conductor and a low voltage coil electrically insulated from each other and submerged in a tank of oil. Transformer operation generates heat; the more load transformed from one voltage to the other, the more heat; too much heat damages the insulation and connections inside the transformer. Hottest-spot temperatures refer to the places inside the transformer that have the greatest heat, and top-oil temperature limits refer to the maximum design limits of the material and components inside the transformer.

To ensure maximum life and the ability to reliably serve customers, Xcel Energy's loading objective for transformers is 75% of normal rating or lower under system intact conditions. Substation transformer utilization rates below 75% are indicative of a robust distribution system that has multiple restoration options in the event of a substation transformer becoming unavailable because of an equipment failure or required maintenance and construction. The higher the transformer utilization, the higher the risk that service will be interrupted in the event of a transformer outage.

2.2.4 Ongoing Distribution System Reliability Assessment

Distribution Planning regularly evaluates loads to determine overloads. Mitigations (projects) are developed to address the overloads. In general, infrastructure additions that address overloaded distribution system elements is an ongoing process.

Distribution Planning annually compares feeder circuit historical and forecast peak load demands to distribution feeder circuit maximum loading limits to identify feeder circuits overloaded under system intact (N-0) conditions and feeder circuits overloaded under single contingency (N-1) conditions during peak loading.

Distribution Planning also annually compares substation transformer historical and forecasted peak load demands on substation transformers to capacity load limits under system intact (N-0) and single contingency (N-1) conditions. Distribution Planning provides distribution substation transformer loads to the Transmission Planning Department ("Transmission Planning"). Distribution and transmission planners routinely coordinate to identify distribution load impacts to the transmission system.

Distribution Planning then quantifies the amount of overload and the duration of peak loading for feeder circuit and substation transformer overloads under system intact (N-0) and single contingency (N-1 conditions), determines the approximate cost of mitigating the overloads, and identifies the most critical distribution system needs.

When Distribution Planning determines that a distribution system requires additional capacity from a new distribution source, it makes a formal request to Transmission Planning to interconnect to the transmission system. Transmission Planning takes the request and Distribution Planning and Transmission Planning coordinate to develop several options that will address the distribution system deficiencies. Transmission Planning performs analyses to determine the impact of the selected options on the transmission system.

3.0 SOUTH MINNEAPOLIS STUDY AREAS

Distribution Planning conducted this detailed distribution area planning study of the south Minneapolis area distribution delivery system because the area was experiencing more frequent feeder circuit overloads due to an increase in the demand for power. To better isolate the problem, Distribution Planning developed two study areas. They are generally described as follows:

Focused Study Area: First, Distribution Planning examined an area of south Minneapolis, clearly defined by geographic boundaries, that is served electrically by 39 specific distribution feeder circuits and is experiencing the most severe overload conditions. Distribution Planning analyzed the loading levels on these 39 distribution feeder circuits.

Greater Study Area: Second, Distribution Planning examined a larger area of south Minneapolis, defined not by geographic boundaries but by the location of five distribution substations, which house an aggregate total of 15 distribution substation transformers, and the 110 distribution feeder circuits emanating from those five substations. Distribution Planning analyzed the loading levels of these 15 distribution substation transformers.

More detailed descriptions of the study areas are provided below.

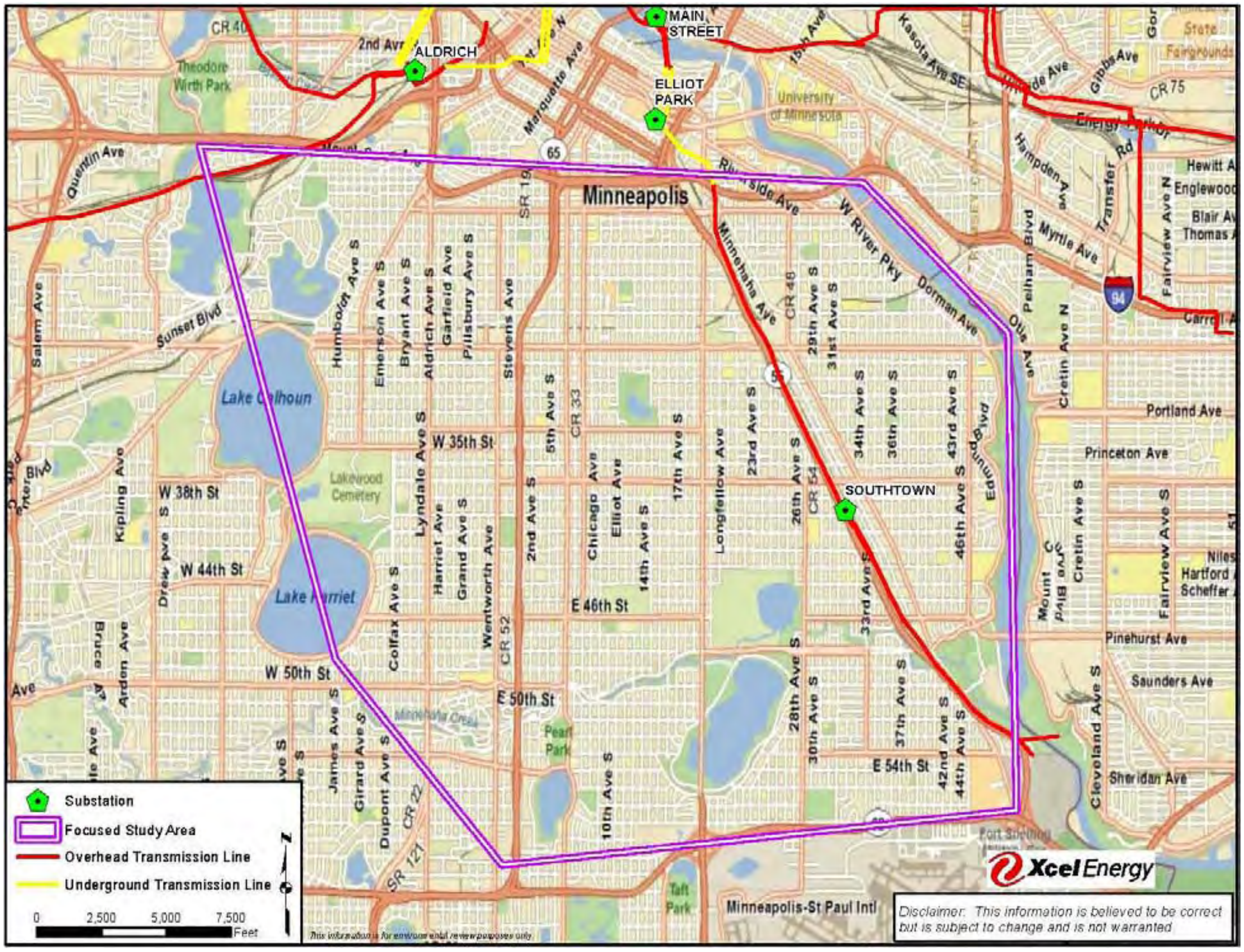
3.1 DESCRIPTION OF FOCUSED STUDY AREA

The Focused Study Area is an approximate 22-square mile area in south Minneapolis with the following geographic boundaries:

> North Boundary: Interstate 394 and Interstate 94 from Cedar Lake on the west to the Mississippi River on the east;
>
> East Boundary: Mississippi River from Interstate 94 on the north to the Crosstown Freeway (State Highway 62) on the south;
>
> South Boundary: State Highway 62 from the Mississippi River on the east to Interstate 35W on the west; and
>
> West Boundary: a line from the intersection of Interstate 35W and Crosstown Freeway to the south end of Lake Harriet at W. 47th Street to the north end of Cedar Lake near the junction of Interstate 394 and Theodore Wirth Parkway.

The Focused Study Area is illustrated in Figure 3.1.

Figure 3.1: Focused Study Area



The Focused Study Area distribution load is primarily fed from three 115 kV transmission lines: Elliot Park – Southtown, Southtown – Cedarvale and Southtown – Shepard, which make up part of the looped 115 kV transmission system that extends from downtown Minneapolis south to the cities of Eagan and St. Paul. Thirty-nine feeder circuits emanating from four substations serve the Focused Study Area. The four substations include Southtown, Aldrich, Elliot Park and Main Street substations. The 39 feeder circuits, all at a distribution voltage of 13.8 kV, provide power to the Focused Study Area.

The Southtown Substation is the only substation within the Focused Study Area. The Southtown Substation, which is located in the southeast quadrant of the Focused Study Area at the northeast corner of Hiawatha Avenue and East 38th Street, has 23 feeder circuits and currently serves the majority of the load in the Study Area. Aldrich, Elliot Park and Main Street substations, which are located outside of the perimeter of the Focused Study Area, serve the majority of the remaining Focused Study Area load. Wilson and St. Louis Park substations serve less than 1%, a statistically insignificant amount, of Focused Study Area load and, therefore, were not included in the analyses completed for the Focused Study Area. Figure 3.2 summarizes the amount of 2008 load that the four primary electric distribution substations and the associated 39 feeder circuits served in the Focused Study Area.

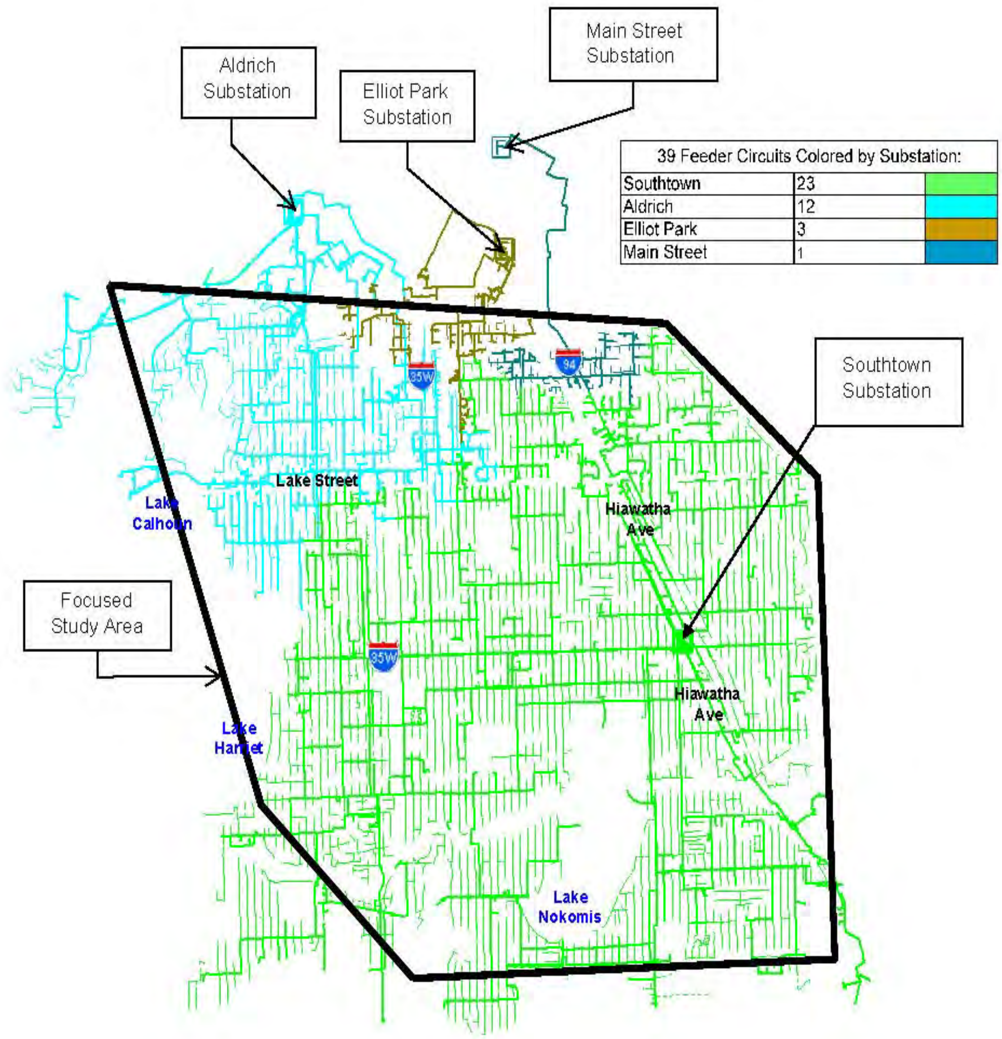
Figure 3.2: Electric Distribution Substations and Associated Feeder Circuits Serving 2008 Load in Focused Study Area

Substations	No. of Feeder Circuits	Amount of Load (kW) Served by Substation	Percentage of Load Served by Substation
Within Focused Study Area			
Southtown	23	184,418	60%
Bordering Focused Study Area			
Aldrich	12	90,430	29.3%
Elliot Park	3	22,954	7.3%
Main Street	1	8,935	2.8%
Total	**39**	306,737	99.4%*

*The remaining 0.6% of Focused Study Area load, which amounts to approximately 1,800 kW, is served by feeder circuits from the Wilson and St. Louis Park substations.

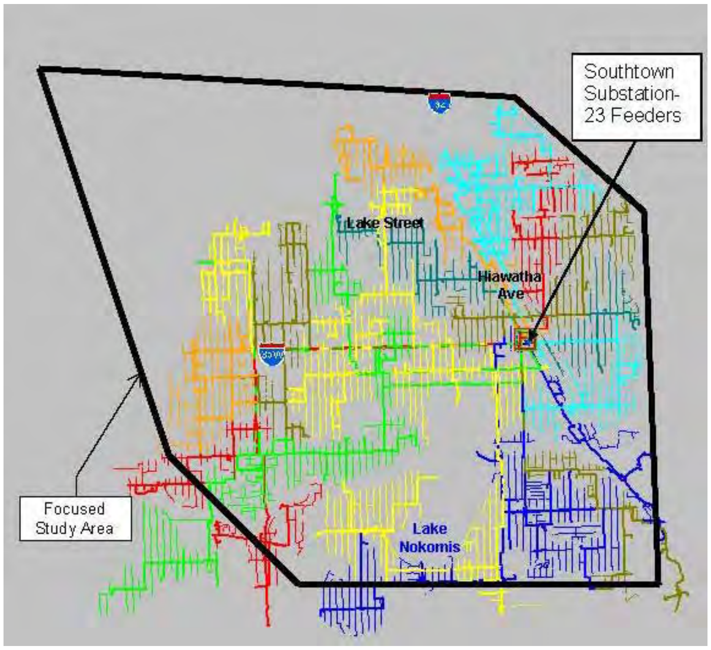
Each of these substations and its respective number of feeder circuits that serve the Focused Study Area load are depicted in Figures 3.3 through 3.7.

Figure 3.3: Primary Electric Distribution Substations and Associated Feeder Circuits Serving Focused Study Area Load



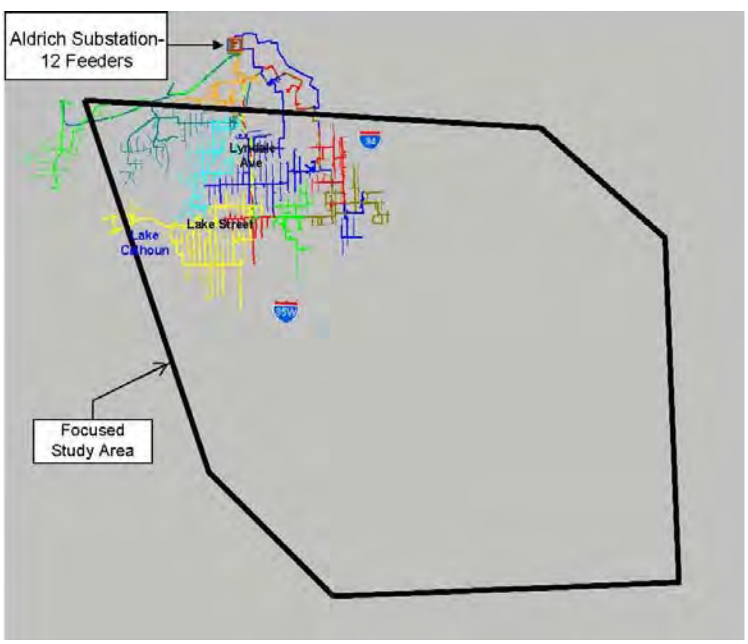
The above Figure 3.3 shows each of the distribution substations and their associated feeder circuits that serve Focused Study Area load. Green feeder circuits are served by the Southtown Substation. Turquoise feeder circuits are served by the Aldrich Substation. Dark yellow feeder circuits are served by the Elliot Park Substation, and dark teal feeder circuits are served by the Main Street Substation.

Figure 3.4: Southtown Substation and Associated 23 Feeder Circuits Serving Focused Study Area Load



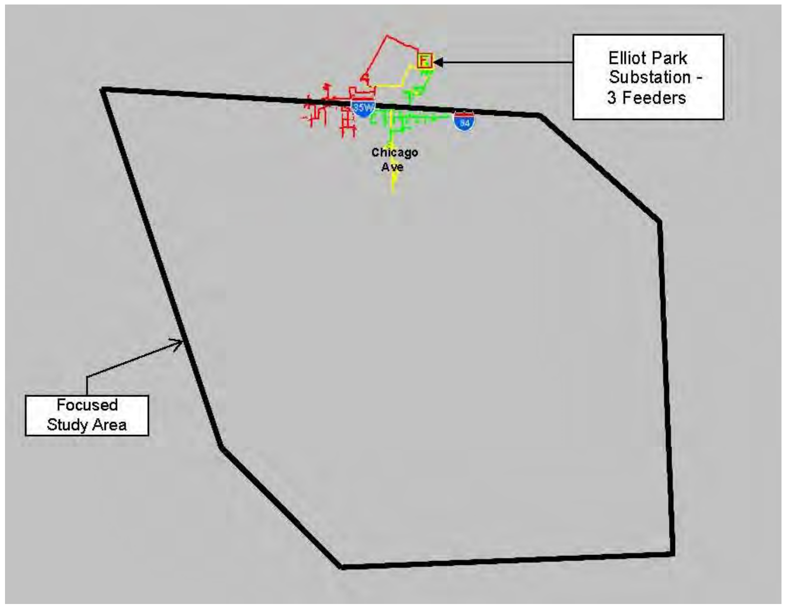
The above Figure 3.4 shows the Southtown Substation and the 23 feeder circuits, each highlighted in a different color, that emanate from that substation and serve Focused Study Area load.

Figure 3.5: Aldrich Substation and Associated 12 Feeder Circuits Serving Focused Study Area Load



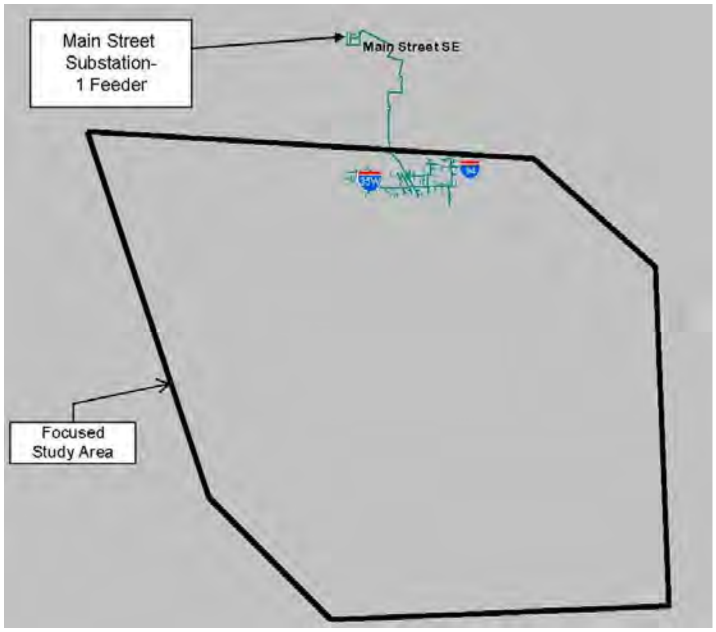
The above Figure 3.5 shows the Aldrich Substation and the 12 feeder circuits, each highlighted in a different color, that emanate from that substation and serve Focused Study Area load.

Figure 3.6: Elliot Park Substation and Associated Three Feeder Circuits Serving Focused Study Area Load



The above Figure 3.6 shows the Elliot Park Substation and the three feeder circuits, each highlighted in a different color, that emanate from that substation and serve Focused Study Area load.

Figure 3.7: Main Street Substation and Associated One Feeder Circuit Serving Focused Study Area Load



The above Figure 3.7 shows the Main Street Substation and the one feeder circuit that emanates from that substation and serves Focused Study Area load.

3.2 BACKGROUND OF THE SOUTH MINNEAPOLIS FOCUSED STUDY AREA

During the 1940s and 1950s, four 13.8 kV/4.16 kV substations were installed within the Focused Study Area. These four substations (Nicollet, Garfield, Hiawatha and Oakland substations), which were sourced from the existing 115 kV/13.8 kV Southtown and Aldrich substations, mostly served resistance loads, such as lights, irons, and small motors, as well as some larger loads, including a former Honeywell manufacturing plant near Interstate 35W and 28th Street, which is currently the location of the Wells Fargo Home Mortgage complex. Over the years, south Minneapolis experienced load growth, some of which was the result of increased use of new household technologies and a large amount of which was the result of new development and increasing population in south Minneapolis.

By the 1980s, the growth in the area outstripped the ability of the 4.16 kV distribution sources to support the distribution system. Distribution engineers also determined that the 4.16 kV distribution delivery system was too costly and inefficient to continue serving the growing loads in south Minneapolis, and in the 1980s, the 4.16 kV distribution voltage began to be phased out. Between 1990 and 2007, the Nicollet, Garfield, Hiawatha and Oakland substations in the Focused Study Area were retired, and their associated distribution lines were generally upgraded to the higher distribution voltage of 13.8 kV.

Since the installation of the 13.8 kV/4.16 kV substations, customer electricity usage has grown in south Minneapolis. There has been a great deal of development in the Focused Study Area, especially concentrated along Lake Street and Hiawatha Avenue, but also including the Abbott Northwestern Hospital, Anderson Open Elementary School, various medical offices, a hotel, condominiums, commercial and industrial buildings, and shopping centers.

Average residential usage has also grown substantially. The average residential home now uses more than twice the amount of power than it did 50 years ago. Information from the Minnesota Department of Commerce in a report titled "Energy Policy and Conservation Report 2004" shows that weather normalized electric consumption among Minnesota residential customers increased from just over 4.0 annual megawatt hours in 1965 to just under 9.0 annual megawatt hours in 2000. This report is available on the Minnesota Department of Commerce website at the following location: http://www.state.mn.us/mn/externalDocs/Commerce/Quadrennial_Report__2004_071404102049_2004-QuadReport.pdf. Weather is a major factor in the amount of residential electric load and the increased availability and use of air conditioning in private residences is a major reason for this load growth. This increase in annual usage is also partly due to the number of consumer electronics that are available and commonly in use in homes.

Land use trends in the Midtown area between 1990 and 2000 are summarized in Figure 3.8.

Figure 3.8: Land Use Trends in Midtown Area Between 1990 and 2000

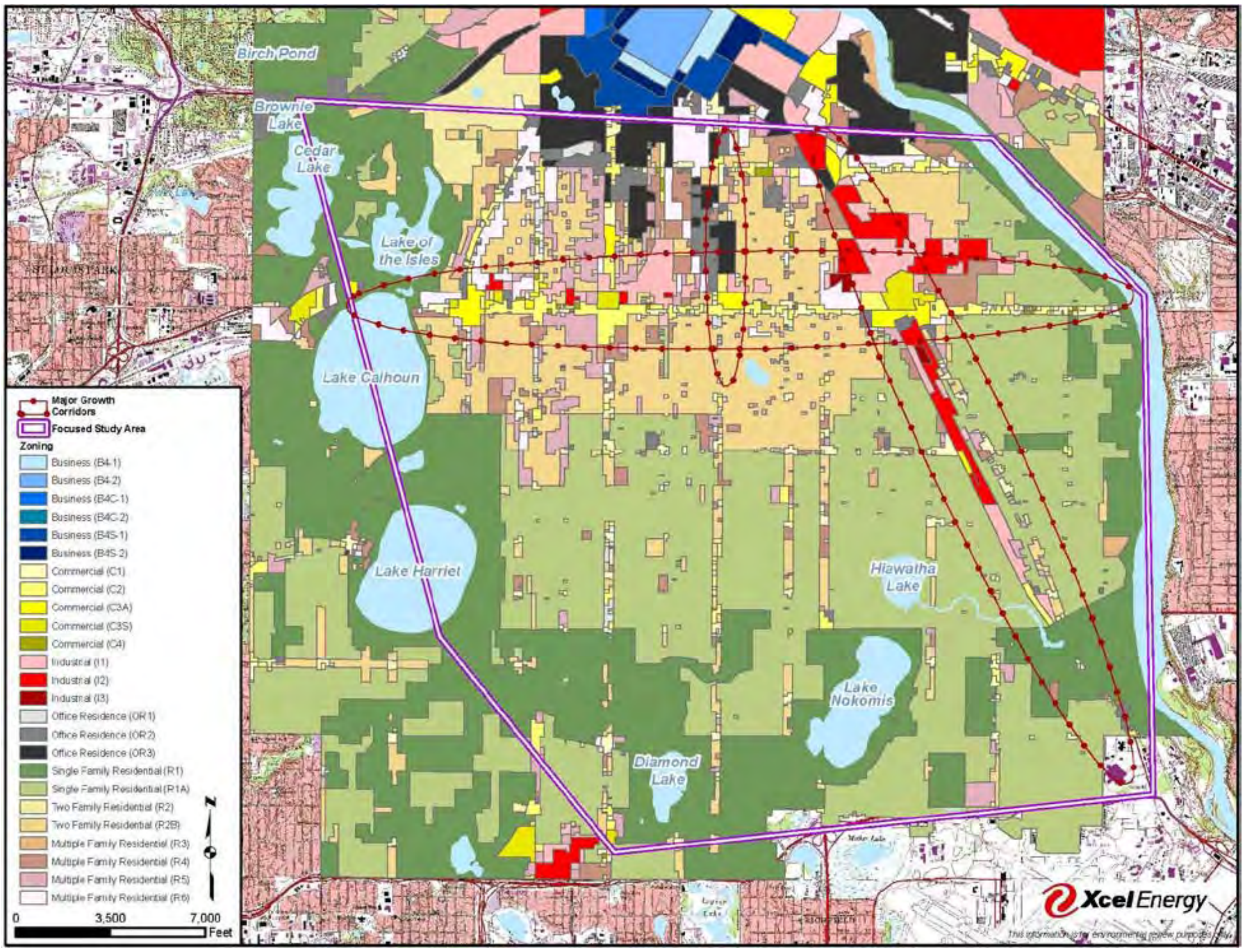
Land Use	1990		2000		Change	
	Acres	Percent	Acres	Percent	Acres	Percent
Retail/Office/General Commercial	182.7	23.2%	197.5	25.1%	14.8	8.1%
Institutional	50.2	6.4%	55.2	7.0%	5.0	9.9%
Commercial Total	**232.8**	**29.6%**	**252.7**	**32.2%**	**19.8**	**8.5%**
Industrial	146.6	18.7%	75.2	9.6%	-71.3	-48.7%
Industrial Total	**146.6**	**18.7%**	**75.2**	**9.6%**	**-71.3**	**-48.7%**
Single Family	131.5	16.7%	206.9	26.3%	75.4	57.3%
Multi-Family	210.3	26.8%	148.7	18.9%	-61.6	-29.3%
Vacant/Undeveloped	10.8	1.4%	17.2	2.2%	6.4	59.0%
Residential Total	**352.6**	**44.9%**	**372.7**	**47.4%**	**20.2**	**5.7%**
Park, Recreational, & Preserve	47.1	6.0%	72.0	9.2%	24.9	52.7%
Open Space Total	**47.1**	**6.0%**	**72.0**	**9.2%**	**24.9**	**52.7%**
Major Highway	3.0	0.4%	9.5	1.2%	6.5	216.3%
Water	3.6	0.5%	3.6	0.5%	0.0	0.1%
Other Total	**6.6**	**0.8%**	**13.1**	**1.7%**	**6.5**	**98.7%**
Grand Total	**785.7**	**100.0%**	**785.7**	**100.0%**	**0.0**	**0.0%**

*Source: Midtown Greenway Land Use Development Plan, The City of Minneapolis Community Planning and Economic Development Department, p. 21 (Feb. 23, 2007), available at http://www.ci.minneapolis.mn.us/cped/docs/Midtown_Greenway_full_plan_noapp.pdf.

The loads in south Minneapolis are expected to continue to grow. Planning reports issued by the City of Minneapolis planning department describe City plans to facilitate continued large-scale redevelopment in the south Minneapolis area over the next few years. Current and future redevelopment is concentrated along Lake Street and the Hiawatha Light Rail Transit ("LRT") corridors and in areas adjacent to those corridors (*e.g.*, Midtown Exchange, Abbott Northwestern Hospital, Minneapolis Children's Hospital and the Veterans Administration hospital). The Minneapolis Plan (Mar. 24, 2000; available at http://www.ci.minneapolis.mn.us/cped/mplsplan.asp) and the Midtown Greenway Land Use Development Plan (Feb. 23, 2007) designate planned land use along these two major growth corridors to include higher density housing, commercial, public/institutional, transportation/communications/utilities, light/medium industrial and other land use types. The Minneapolis planning reports also provides that the City intends to continue to promote business retention and expansion and residential growth within the City. The City plans to do this by developing and maintaining the City's infrastructure to help serve the needs of businesses and residents and to increase its supply of housing. These planned developments and improvements will increase load demand in the Focused Study Area.

Figure 3.9 delineates the existing major growth corridors in the Focused Study Area.

Figure 3.9: Existing Major Growth Corridors in Focused Study Area



Zoning Data Source: City of Minneapolis, Department of Community Planning and Economic Development, Planning Division. Revised March 5, 2009.

The 13.8 kV distribution delivery system in south Minneapolis has struggled to keep up with the increasing customer demand for electricity. And because the Southtown Substation is the only remaining distribution substation source in the Focused Study Area, the 13.8 kV feeders in that area are serving increasingly larger loads farther from the nearest substation source, resulting in higher electrical line losses and reduced customer reliability. In response to this load growth Xcel Energy has taken numerous steps to maintain reliable service in the Focused Study Area, including reinforcing existing feeder circuits, adding new feeder circuits, replacing equipment damaged by overloads, and rearranging feeder circuits to maintain service during overloads. See Appendix A for a summary of feeder circuit improvements completed in the Focused Study Area in recent years.

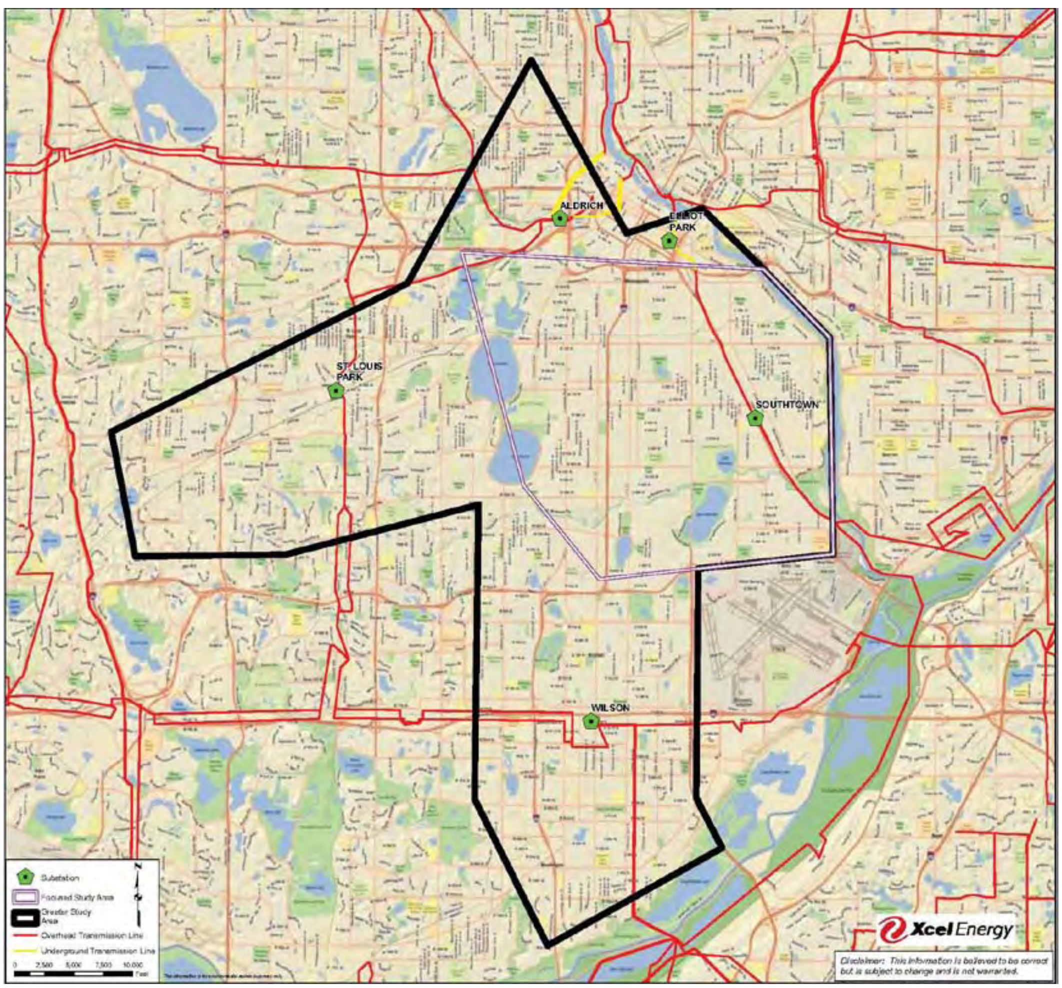
In 2005 and 2006, the south Minneapolis distribution delivery system experienced historical peak loads. It became apparent that the distribution delivery system in the area was becoming increasingly vulnerable to more and longer overloads. As a result, Distribution Planning Engineers in 2007 intensified their analysis of the south Minneapolis distribution delivery system, concentrating in particular on the Focused Study Area to develop a more robust, longer-term solution to address the continued growth in power demand.

3.3 DESCRIPTION OF THE GREATER STUDY AREA

Distribution Planning also examined the south Minneapolis electricity distribution delivery system within the Greater Study Area, in part, to assess the availability of existing capacity, if any, on distribution transformers near the Focused Study Area.

The Greater Study Area consists of the geographic area served by five substations, including Southtown, Aldrich, Elliot Park, St. Louis Park and Wilson substations, and their associated substation transformers and circuit feeders. The Greater Study Area, which covers an approximate 60 square-mile area, is illustrated in Figure 3.10.

Figure 3.10: Greater Study Area



The Greater Study Area distribution load is served by 110 feeder circuits, all at a distribution voltage of 13.8 kV. These feeder circuits are served from fifteen distribution substation transformers that are housed at a total of five substations (three transformers per substation). The five substations, in turn, are served from 115 kV transmission lines that loop the Greater Study Area.

Figure 3.11 summarizes the amount of 2008 load that the electric distribution substations served in the Greater Study Area.

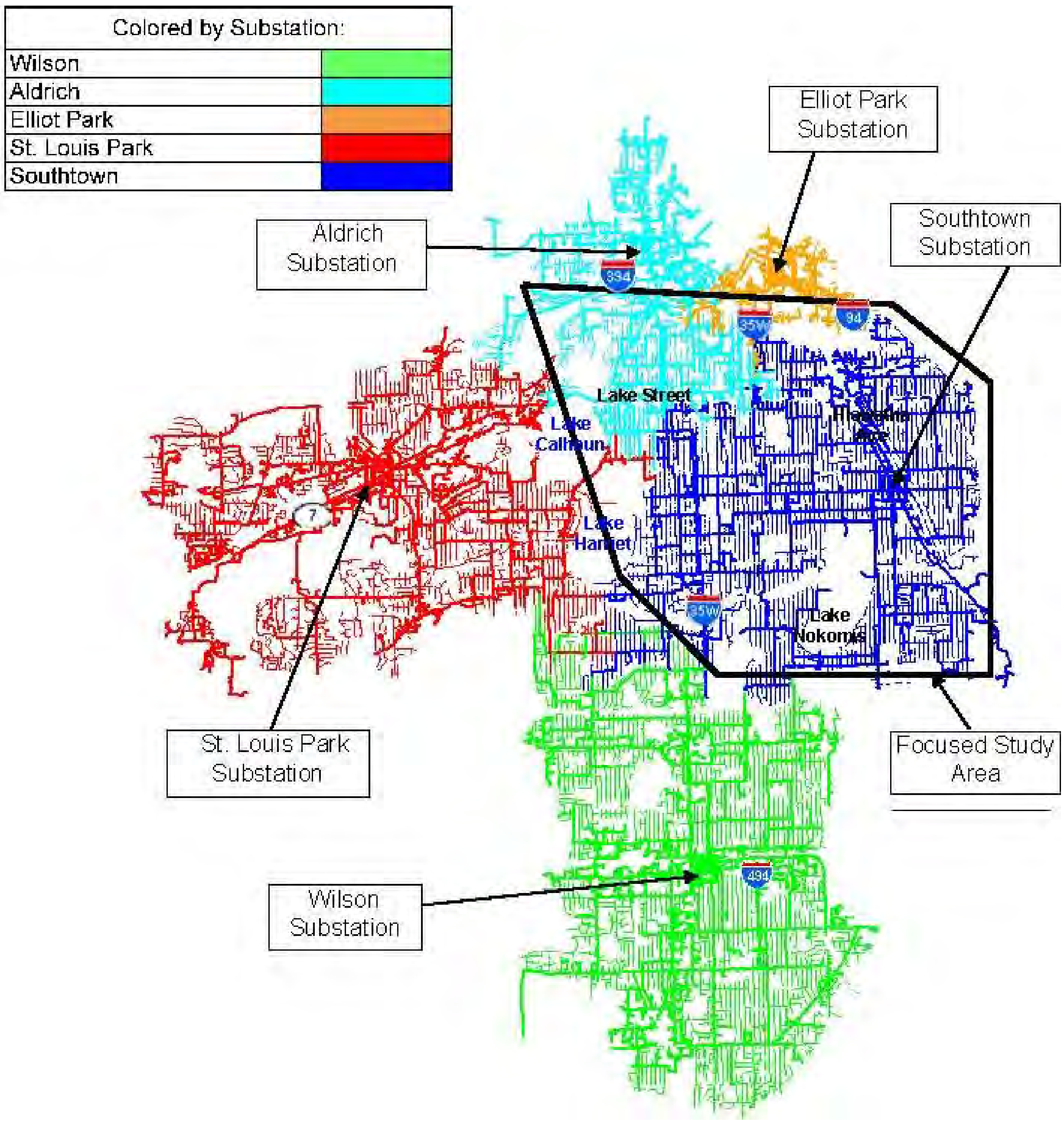
Figure 3.11: 2008 Non-Coincident Substation Transformer Load in Greater Study Area

Substations	No. of Feeder Circuits	Load (in kW) Served by Substation	% of Load Served by Substation
Southtown	23	169,070	22.4%
Aldrich	21	137,033	18.2%
Elliot Park	19	116,881	15.5%
St. Louis Park	21	142,149	18.9%
Wilson	26	188,348	25.0%
Total	**110**	753,181	100%

Main Street Substation was not considered in the Greater Study Area because the one feeder circuit from the Main Street Substation presently serving customer load in the Focused Study Area is not part of future plans to serve load in either the Focused or the Greater Study Areas. The one (1) Main Street Substation feeder circuit traverses several miles and crosses the Mississippi River to reach the study areas. All Main Street feeder circuits crossing the Mississippi River were damaged when the Interstate 35W bridge collapsed in 2007. As a result, 10,000 kW (or approximately 10 MW) of load that was normally served by the Main Street Substation was transferred to Elliot Park Substation and is accounted for in the above Figure 3.11. A total of 52,000 kW (or approximately 52 MW) of Greater Study Area load, however, is not accounted for in the above Figure 3.11. Between 2000 and 2008, an aggregate total of 52 MW of Greater Study Area load was transferred outside of the Greater Study Area to adjacent substations with available capacity because the Aldrich and St. Louis Park substations in the Greater Study Area were overloaded. In their analysis of substation transformer load growth in the Greater Study Area, which is summarized in Section 5.0 of this Study, Distribution Planning Engineers took into account load transferred out of the Greater Study Area to adjacent substations.

Each of the substations and its respective number of feeder circuits that serve Greater Study Area load are depicted in Figure 3.12.

Figure 3.12: Substations and Associated Feeder Circuits Serving Greater Study Area Load



4.0 ANALYSIS OF THE SOUTH MINNEAPOLIS ELECTRIC DISTRIBUTION DELIVERY SYSTEM IN THE FOCUSED STUDY AREA

4.1 FEEDER CIRCUITS

Distribution Planning assessed the electric distribution delivery system's ability to serve existing and future electricity loads in the Focused Study Area by evaluating the historical and forecasted load levels and utilization rates of the 39 feeder circuits that serve the Focused Study Area over a period of 20 years (*i.e.*, target year of 2028). The Planning Engineers then identified existing and anticipated capacity deficiencies resulting in overloads during N–0 (system-intact) and N–1 (single contingency) operating conditions.

In conducting this Study, Planning Engineers relied on the following resources:

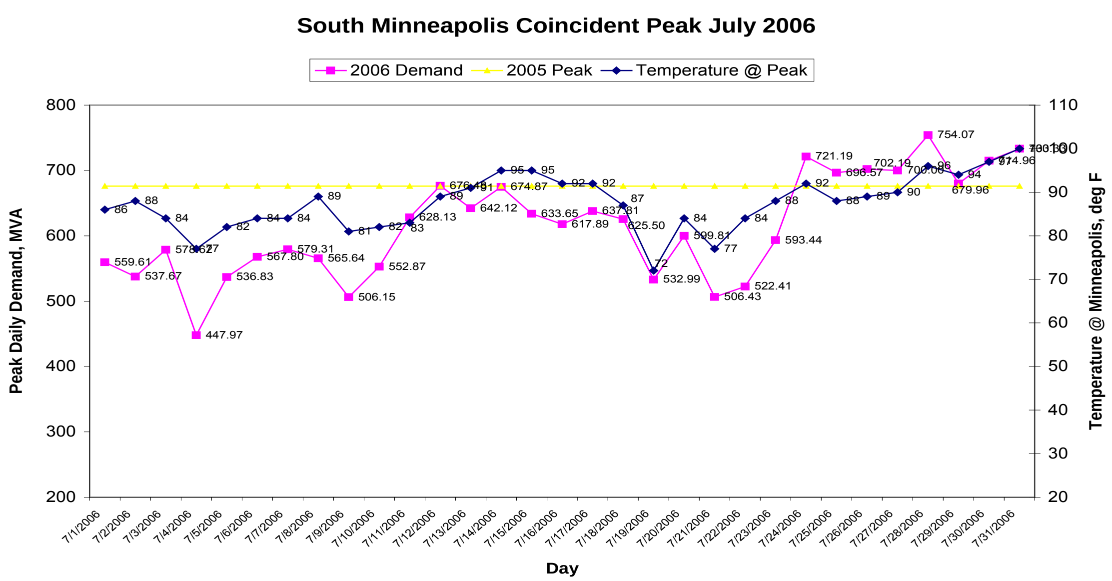
- <u>SynerGEE Electric software package</u>. SynerGEE is a software tool that can be used to explore and analyze feeder circuit reconfigurations. When historical peak load data is added from the Distribution Asset Analysis ("DAA") software package, SynerGEE is capable of providing load flow and voltage regulation analysis. SynerGEE is a tool that can generate geographically correct pictures of tabular feeder circuit loading data. This functionality has been achieved through the implementation of a Geographical Information System ("GIS") extraction process. Through this process, each piece of equipment on a feeder, including conductor sections, service transformers, switches, fuses, capacitor banks, etc., is extracted from the GIS and tied to an individual record that contains information about its size, phasing, and location along the feeder. All 39 distribution feeders that are part of the Focused Study Area were extracted from the GIS software and imported into SynerGEE.
- <u>Xcel Energy Distribution Planning Load Forecast for N-0 feeder circuit and substation transformer analysis</u>. Planning Engineers used DAA to record historical non-coincident peak loads on distribution feeder circuits and distribution substation transformers. Distribution Planning Engineers annually examine each distribution feeder circuit and distribution substation transformer for peak loading. They use specific knowledge of distribution equipment, local government plans and customer loads to forecast future electrical load growth. Planning Engineers consider many types of information for the best possible future load forecasts including: historical load growth, customer planned load additions, circuit and other distribution equipment additions, circuit reconfigurations, and local government sponsored development or redevelopment.
- <u>Xcel Energy Feeder Status Sheets for feeder circuit N-1 load allocation and N-1 analysis</u>. Planning Engineers used Feeder Status Sheet software ("FSS") to allocate measured peak loads to main line feeder sections. Engineers validate and record feeder main line additions and reconfigurations using this tool. They analyze the N-1, first contingency breakdown of each distribution feeder circuit for the forecasted years.

- Xcel Energy Substation One Line Drawings. Planning Engineers used Xcel Energy Computer Aided Design software ("CAD") to develop CAD drawings modified by substation engineers as needed to reflect present substation configurations.
- Xcel Energy Distribution Feeder Maps. Planning Engineers used Xcel Energy CAD software to develop CAD drawings to reflect present feeder circuit mainline and tap configuration.
- South Minneapolis Maps. Planning Engineers used Internet live search maps to make an ad hoc map of the area, GIS software and SynerGEE software tool to make geographic based pictures of the feeder circuit configuration and to illustrate feeder circuit loading levels.

4.1.1 Feeder Circuit Historical Load and Load Forecasts

Feeder circuit peak loading in the south Minneapolis area specifically and the Twin Cities metropolitan area are measured during the summer. Both feeder circuit and substation transformer load correlates to summer temperature based on customer air conditioning usage response to summer temperature. This is illustrated in Figure 4.1, which compares the Greater Study Area Substation transformer measured peak load and outside temperature during July 2006.

Figure 4.1: July 2006 Greater Study Area Substation Peak Load and Outside Temperatures



Coincident Peak July 2006 graphed with South Minneapolis Temperature

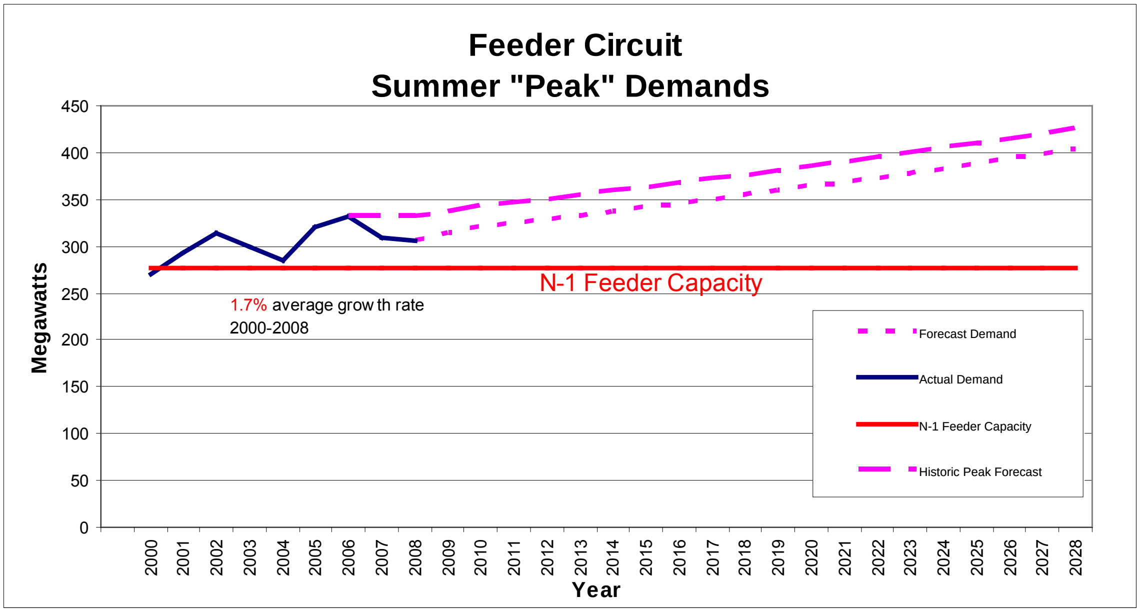
Each distribution feeder in the south Minneapolis area has three phase meters located in the substation which are read monthly and the data recorded in Passport, a record-keeping software. These meters record the monthly peak for the feeder. The 39 distribution feeders in the Focused Study Area also have a SCADA system that monitors the real time average or three phase amps on the feeder. This system feeds a SCADA data warehouse and the DAA warehouse where hourly data is stored so the feeder load history can be viewed by Electric Capacity Planning and Field Operations. When three phase load data is available, the highest recorded phase measurement is used in the distribution forecast. Each feeder circuit non-coincident peak history from 2000 through 2008 is used to forecast 2009 through 2028 peak loads.

Measured peak loads fluctuate from year to year due to the impacts of duration and intensity of hot weather and customer air conditioning usage. In the Focused Study Area, feeder circuit load fluctuates in a bandwidth of 15 MW to 22 MW from historic peaks occurring in 2002 and 2006 and successive cooler years. Even though the measured peak load decreases, the historic peak represents latent load levels that will recur in years that have higher temperatures than in 2008. The measured peak load for feeders increased an average of 1.7% per year in the eight years between 2000 and 2008, resulting in a peak load growth of approximately 37 MW. The historical and forecasted loads for the 39 feeder circuits serving the Focused Study Area from 2000 through 2028 are summarized in Appendix B.

Distribution Planning took a conservative outlook for forecasting feeder circuit load for this Study because of anticipated customer conservation and a soft economy. Distribution Planning used a lower than historical forecast growth rate of less than 1.3% to forecast load levels on the 39 feeders for the next 20 years, representing growth in demand of approximately 50 MW by 2018.

Figure 4.2 is a linear depiction of the load growth ("forecast demand") on the 39 feeder circuits in the Focused Study Area from 2000 through 2028, using the conservative peak loads forecast based on the cooler year peak loads from 2008. Figure 4.2 also shows the upper limit peak load forecast using 2006 historic peak loads ("historic peak forecast"), which is 22 MW above the conservative peak load forecast shown in the figure. Actual peak loads will likely fall between the conservative forecast and the historic 2006 peak levels.

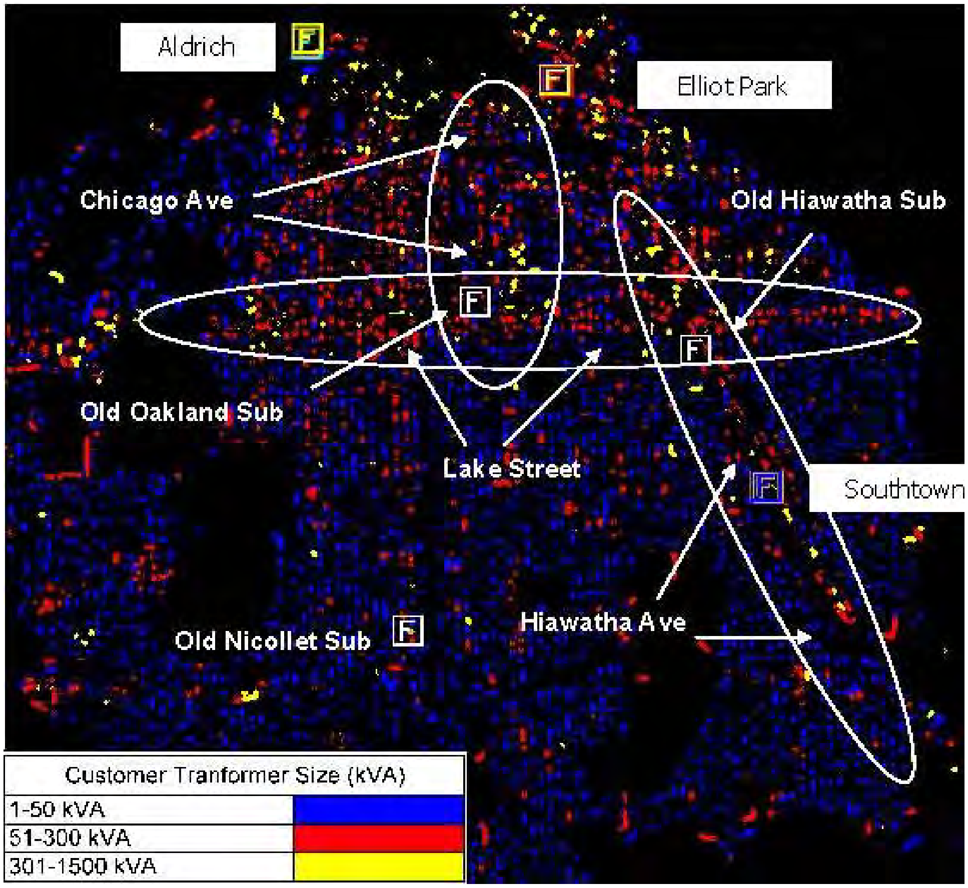
Figure 4.2: Historical and Forecasted Load Growth on 39 Feeder Circuits in Focused Study Area



Over time, demand on the distribution system generally trends upward, with some dips due to weather or economic downturns. The historic downturns have been followed by increases in demand that reach levels equal to or greater than the prior peak. For example, from the year 2002 to the year 2004, demand declined by approximately 30 MW. Then, from the year 2004 to the year 2006, demand increased again by approximately 46 MW, reaching a new peak of 331 MW. From year 2006 to 2008, there has been a similar decline in demand from the historical 2006 peak by approximately 22 MW. It can be reasonably expected that 2006 summer peak load levels will recur within the next several years once temperatures approach the same levels that occurred in the 2006 summer season as illustrated in the above Figure 4.2.

In addition to peak loads, Planning Engineers researched existing customer load density. As customer load grows in developed areas such as the Focused Study Area, distribution transformers are changed to higher capacity equipment when customer demand exceeds the capacity of the original transformer. Distribution transformers are an excellent indicator of customer electrical loading and peak electrical demand. Figure 4.3 is a graphic, developed using SynerGEE software, illustrating distribution transformer installation by size (which indicates present customer load density) in the Focused Study Area.

Figure 4.3: Distribution Transformer Sizes (Which Is Indicative of Customer Load Density) in Focused Study Area (2006)



The customer load serving transformers shown in Figure 4.3 are colored based on the size of the transformer. The largest commercial customers in south Minneapolis are shown in yellow. Customers in large multi-residence buildings (more than 100 units), large multi-use buildings (*e.g.*, Midtown Exchange), large retail stores (*e.g.*, K-Mart), or corporate data centers typically have one or more transformers depicted as yellow dots. Customers in small and mid-sized commercial buildings, including retail stores and restaurants are served by smaller transformers that are shown as red. Residential customers and other lowest usage customers are shown in blue. Red and yellow show high density load corridors along Lake Street, Hiawatha Avenue, Excelsior Boulevard, and Chicago Avenue.

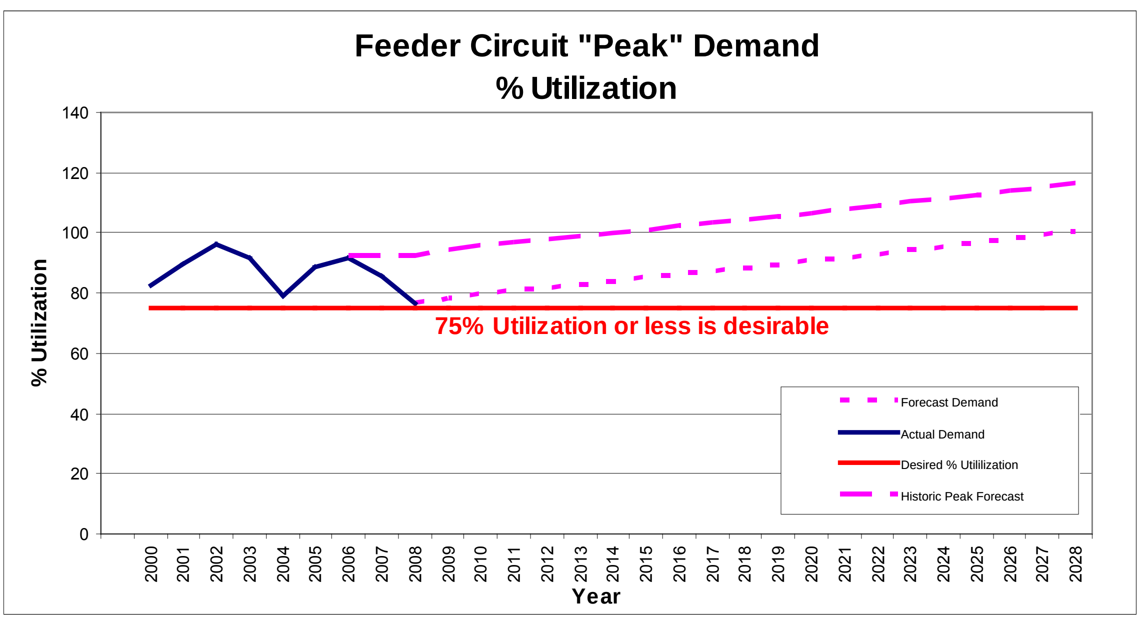
As shown in Figure 4.3 and discussed in Section 3.2 of this Study, the highest load density is concentrated along Lake Street, Hiawatha Avenue and Chicago and Park Avenue corridors. The load density in this area is due in part to various redevelopment projects that have been implemented in the area over the past years. The City of Minneapolis is several years into a redevelopment initiative demonstrated by the Sears Building redevelopment as Midtown Exchange with new high density residential, hotel and surrounding buildings. The State of Minnesota installation of light rail along Hiawatha Avenue is complemented by City of Minneapolis and contractor high density residential projects. Recent improvements along the Chicago Avenue corridor by Abbott Northwestern Hospital and Children's Hospitals and redevelopment north and south of these large hospitals have contributed to historical and continued electrical load growth in the area.

4.1.2 Feeder Circuit Overloads and Utilization Percentages

As discussed in Section 2.0, Distribution Planning aims to maintain utilization rates at or below 75% on distribution feeder circuits to help ensure a robust distribution system capable of providing electrical service under first contingency N-1 conditions. Therefore, to assess the robustness of the system in the Focused Study Area over time, Planning Engineers analyzed the historical utilization rates and projected utilization rates based on forecast demand. This analysis revealed utilization rates of feeder circuits above 75% in the Focused Study Area despite the addition of six (6) new feeder circuits between 2000 and 2008. Current average utilization rates remain above desired 75% levels. Forecast average utilization rates will exceed 90% by approximately 2015 unless system improvements are made.

Planning Engineers examined the historical loading and utilization of the 39 feeder circuits that serve Focused Study Area load. Figure 4.4 shows the conservative forecast linear growth ("forecast demand") of feeder circuit utilization for these 39 feeder circuits between 2000 and 2028 as well as the upper-limit peak load forecast ("historic peak forecast") based on 2006 peak load levels.

Figure 4.4: Focused Study Area - 39 Feeder Circuits, Utilization Percentage



The feeder circuit load history shown is actual average non-coincident peak loading of all 39 feeder circuits measured at the beginning of the feeder circuit in the substation. The sum of the individual feeder circuit peak loads is compared to the sum of the individual feeder circuit capacities to calculate feeder circuit utilization each year. Average load growth for the time period is calculated by comparing total non-coincident feeder circuit loads from the beginning to the end of the comparison period. Feeder utilization trended lower between 2000 and 2008 because of the addition of six new feeder circuits in the Focused Study Area.

A peak load forecast starting from the historic peak 2006 level provides an upper forecast limit of more than 16% above the conservative forecast utilization levels in Figure 4.4.

The feeder circuit load is forecasted for each feeder circuit. Feeder circuit load forecast evaluation, trending method, considers a combination of historical growth, customer reported load additions, local government and developer projects or plans, and any additional information that impacts the circuit load growth. The table entries were calculated using the 39 individual feeder circuit forecasts provided in Appendix B.

Figure 4.5 provides additional detail on the historical and anticipated utilization percentages and overloads for the 39 feeder circuits in the Focused Study Area for various years between 2000 and 2028.

Figure 4.5: Summary of Feeder Circuit Utilization and Overloads for Focused Study Area

Historical Feeder Circuit Utilization and Overloads And Forecast Using Trending Method

	2000	2004	2006	2008	2009	2013	2018	2023	2028
# of Circuits	33	36	39	39	39	39	39	39	39
MW Capacity	<327	<362	<402	402	402	402	402	402	402
Feeder Actual	2000-2008 Average								
% Growth	1.7%								
% Utilization	>83%	>79%	>83%	76%					
Forecast					2009-2018 Average			2019-2028 Average	
% Growth					1.28%			1.25%	
% Utilization					78%	83%	88%	94%	100%
N-0 Overloads									
# Severe >115%	5	6	4	2	4	4	8	12	15
# of Circuits	10	10	12	6	7	13	16	18	22
MW > 100%	15.8	17.0	12.2	7.6	9.2	14.1	24.3	37.2	52.6
N-1 Conditions									
# Circuits > 75%	21	21	24	24	25	27	27	28	31
MW > 75%	47.3	51.0	54.7	38.7	46.4	58.3	73.9	94.1	113.8

The information in Figure 4.5, which was extracted from the detailed feeder circuit forecast data in Appendix B, shows that the Focused Study Area distribution system experienced steady peak growth in the decade leading up to 2008 loads that increasingly exceeded circuit capacities with increasing numbers of circuits overloaded in both system intact N-0 and first contingency N-1 conditions. Even when the number of circuits overloaded does not increase, the quantity of overloads increases. Figure 4.6 summarizes the additional feeder circuit capacity (in MW) needed to mitigate the overloads detailed in Figure 4.5. A single new 12 MW feeder circuit will serve 9 MW of load at 75% utilization.

Figure 4.6: Summary of Feeder Circuit Capacity Required to Mitigate Overloads

Minimum Number of Feeders Required to Correct N-0 and N-1 Overloads									
	2000	**2004**	**2006**	**2008**	**2009**	**2013**	**2018**	**2023**	**2028**
N-0 Deficiency (MW)	15.8	17.0	12.2	7.6	9.2	14.1	24.3	37.2	52.6
Minimum # of New Feeders Needed	2	2	2	2	2	2	3	5	7
N-1 Deficiency (MW)	47.3	51.0	54.7	38.7	46.4	58.3	73.9	94.1	113.8
Minimum # of New Feeders Needed	6	6	7	5	6	7	9	11	13

Note: Minimum number of feeders assumes 12 MW feeder circuits loaded to 75% or less.

This analysis shows that there is currently a deficit of approximately 55 MW in the Focused Study Area based on the 2006 peak loading and the system capacity under N-1 conditions. 2006 loading levels represent established overloads for connected load that exists on the electrical system and peak loading that has been previously reached under the most recent hottest weather conditions. By 2018, these overloads are forecast to increase to 74 MW.

Areas like south Minneapolis that experience strong and steady growth and redevelopment go through several stages of overload operating conditions, starting with isolated feeder circuit overloads and progressing to widespread overloads that exceed substation transformer capacity limits.

Isolated feeder overloads, which can be characterized by average feeder utilization percentage less than 75% when substation transformer utilization is also 75% or less, typically occur when there is redevelopment that increases load demand within a small part of the distribution system. While the average utilization percentage generally indicates the loading level of the entire Focused Study Area, feeders that are located geographically distant from each other can have either satisfactory capacity to serve customer load or alternately measure severe overloads. This variant is often caused by customer load mobility that can be characterized by new load or area redevelopment and revitalization.

There are many locations over the past several years in south Minneapolis where several single-family homes in a primarily residential area have been redeveloped as a multi-story, multi-residence building with new commercial or retail businesses on the first floor. This can increase the distribution customer loads to as much as 10 times the previous load. There are examples of this near Franklin and Nicollet and near the Veterans Administration Hospital in the Focused Study Area. Load increases in existing commercial or industrial areas as new owners occupy and redevelop or expand an existing building or area. After a new customer purchased a former Midtown manufacturing facility and constructed a new building, existing load at the property more than doubled.

Widespread feeder overloads, which can be characterized by average feeder utilization percentage of more than 75% when substation transformer utilization is more than 75%, typically occur in distribution areas due to a combination of customer addition of spot loads and focused redevelopment by existing customers, developers or City initiatives. Distribution systems that start out with adequate N-1 and N-0 capacity, can quickly progress beyond isolated overloads when a large part of the distribution system is redeveloped or focused redevelopment is targeted in an area or along a corridor.

Expansion of medical related customers along Chicago Avenue north of Lake Street, the multi-year redevelopment of Lake Street progressing east from Interstate 35W, redevelopment along the new Hiawatha Avenue light rail corridor, and the area wide re-insulation accompanied by 100% air conditioning saturation along higher airport noise corridors are examples that resulted in widespread feeder circuit overloads in south Minneapolis.

To better illustrate the number, concentration and location of the historical and forecasted overloads, Planning Engineers developed distribution system maps depicting the overloaded feeders in N-0 system intact and N-1 first contingency operating conditions for loads above 75% of capacity limits in 2006 and future forecast years 2009 through 2028. These distribution system maps are in Appendix C. Two of those maps are depicted in Figures 4.7 and 4.8, respectively. The color codes in the distribution system maps represent rows in the Figure 4.5 table for the labeled years as follows:

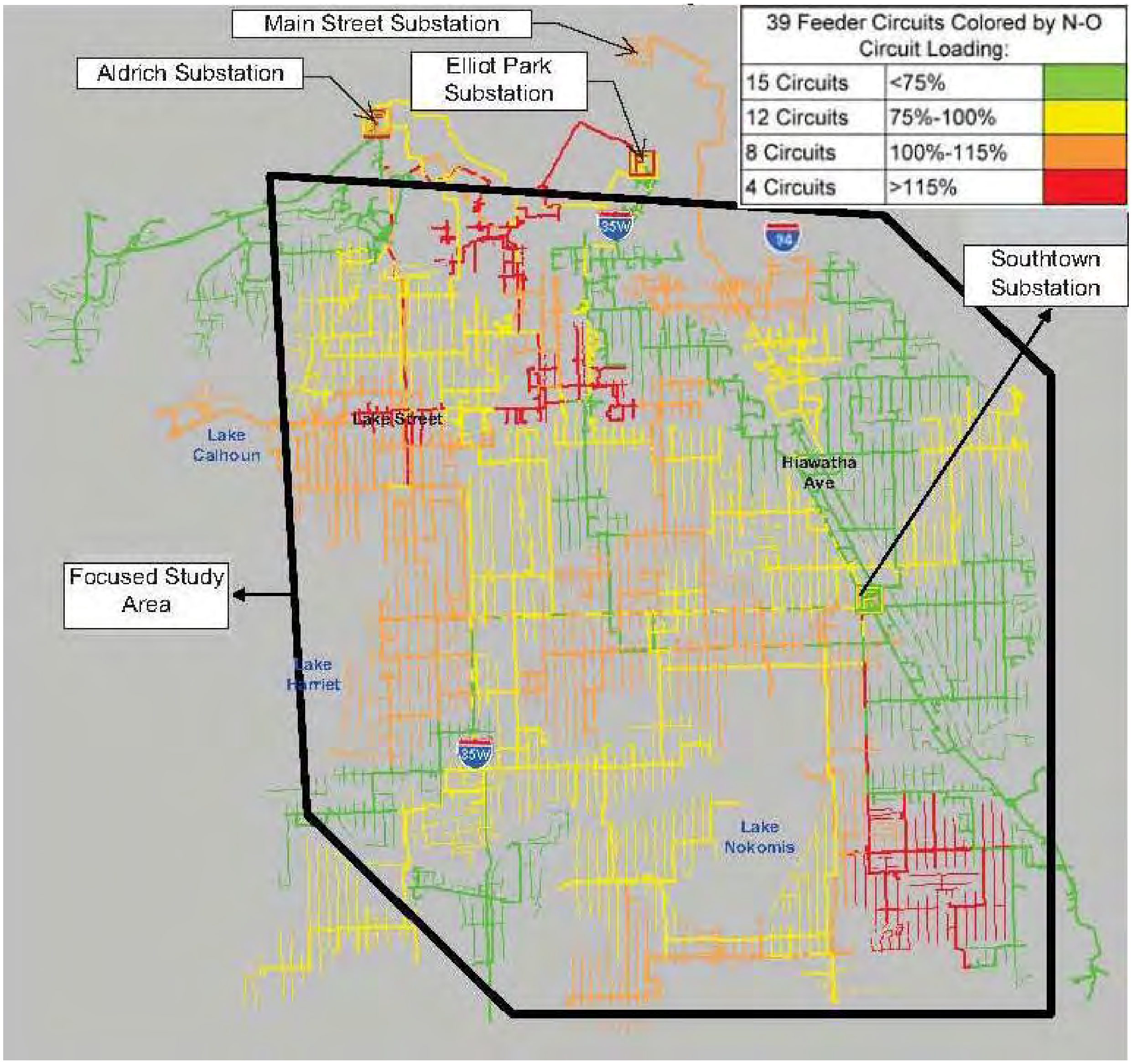
> <u># Severe > 115%, N-0 Overloads</u>: The quantity of feeder circuits that are severely overloaded under system intact conditions are identified as shown in red.
>
> <u># of Circuits, N-0 Overloads</u>: The quantity of feeder circuits that are overloaded under system intact conditions are identified as shown in orange and red depending on the severity of the overload with red feeder circuits having the most severe overloads.

MW > 100%, N-0 Overloads: The sum of the system intact overloads, in MW for the number of circuits that are identified as overloaded and shown in orange and red.

Circuits > 75%, N-1 Conditions: The quantity of feeder circuits that are loaded above 75% capacity indicating first contingency overload conditions are identified as shown in yellow, orange, and red. Yellow circuits are feeder circuits with first contingency overloads.

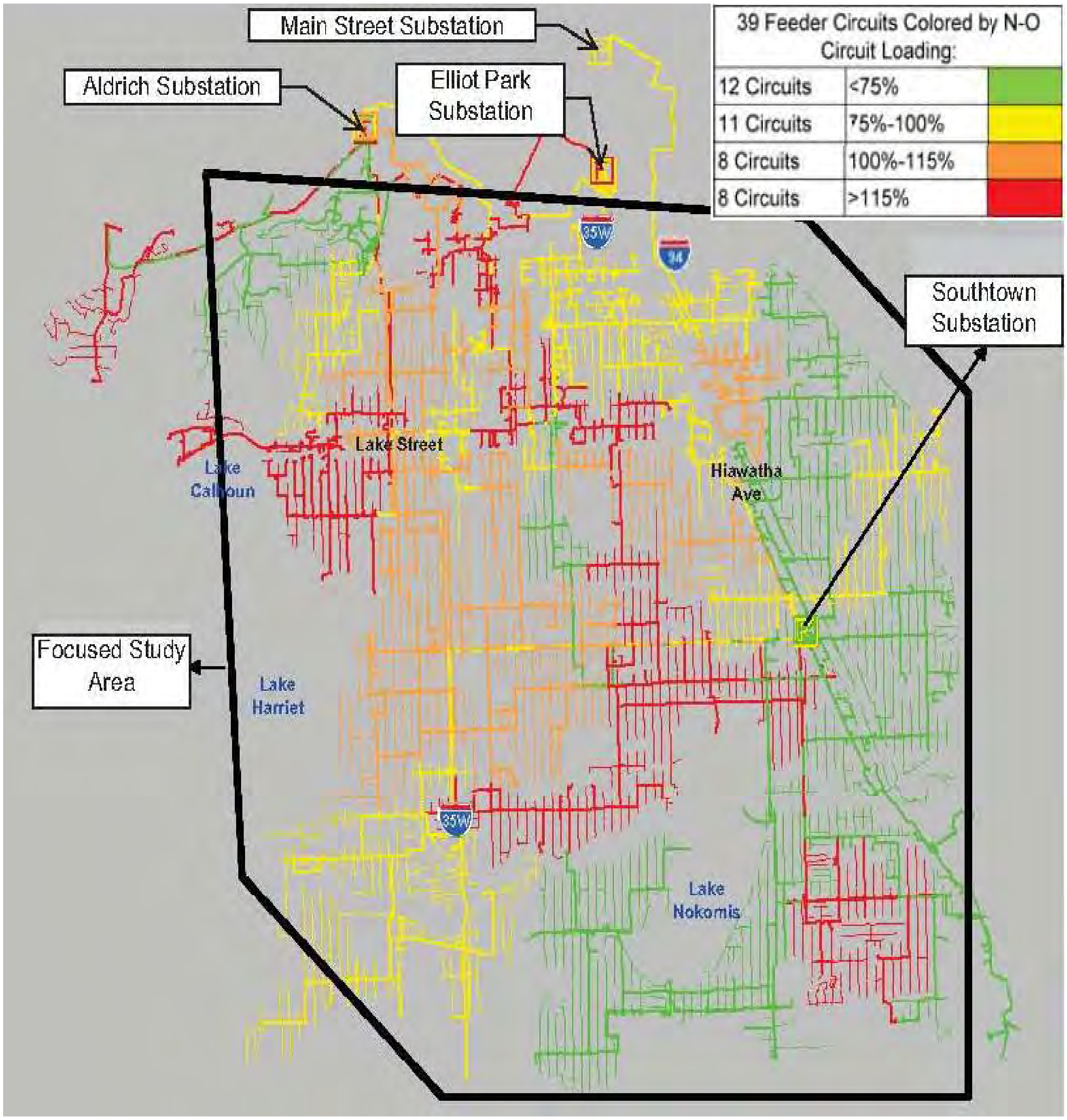
MW > 75%, N-1 Conditions: The sum of the first contingency overloads, in MW for the number of circuits that are identified as overloaded and shown in yellow, orange, and red.

Figure 4.7: Focused Study Area 2006 N-0 Feeder Circuit Risks – System Intact



Above Figure 4.7 shows that of the 39 feeder circuits in the Focused Study Area, in 2006 under system intact N-0 conditions, 15 feeders were utilized at less than 75%, 12 feeders were utilized between 75%-100%, eight feeders were utilized between 100%-115%, and four circuits were utilized at greater than 115%. Note that many of the most severe overloads occur along previously identified areas of more concentrated load and faster load growth.

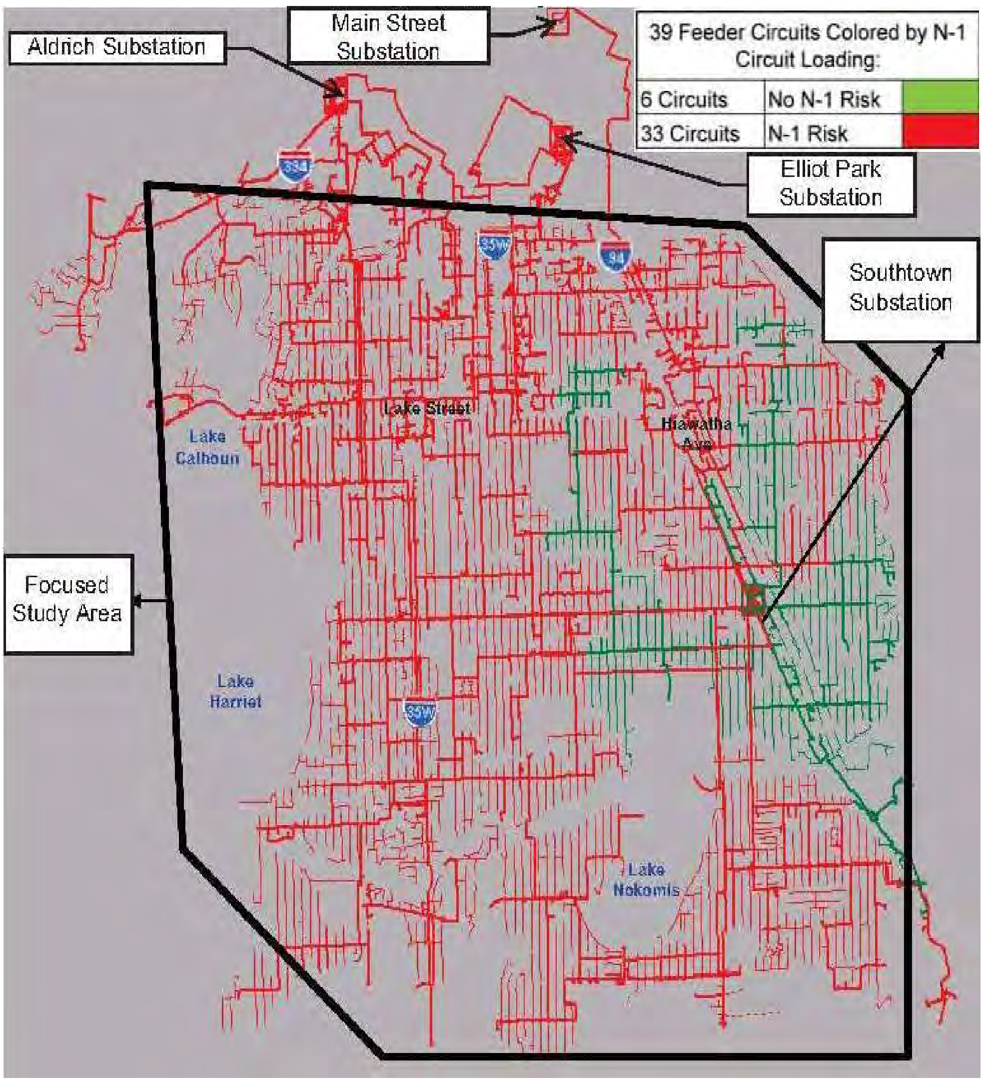
Figure 4.8: Focused Study Area 2018 N-0 Feeder Circuit Risks – System Intact



Above Figure 4.8 shows that of the 39 feeder circuits in the Focused Study Area, based on 2018 forecasted load under system intact N-0 conditions, 27 feeders will be overloaded. The 27 overloaded feeders consist of 11 feeders utilized between 75%-100%, eight feeders utilized between 100%-115%, and eight circuits utilized at greater than 115%.

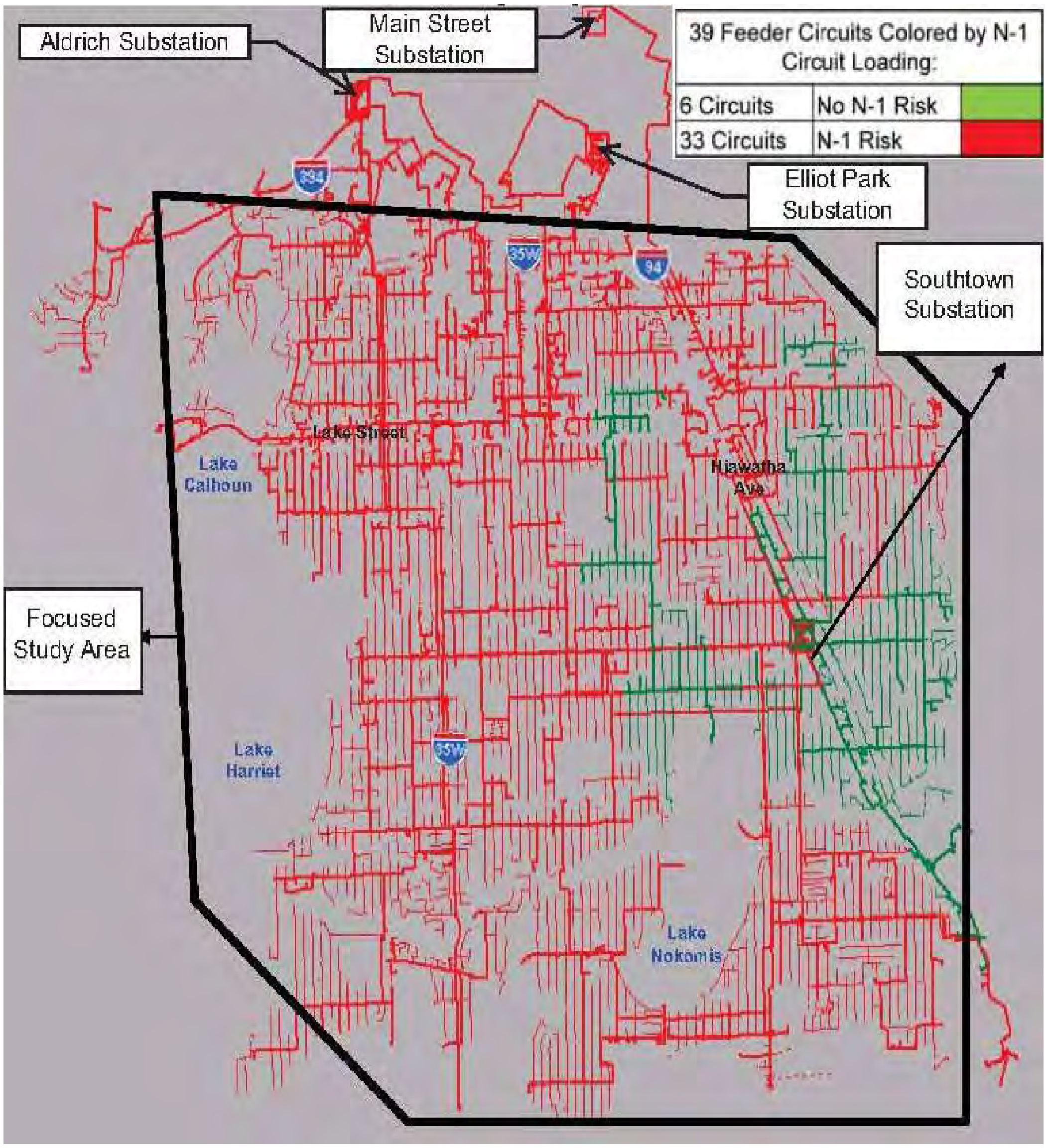
Overloads are even more widespread across the 39 feeder circuits in the Focused Study Area under N-1 loading conditions. Figures 4.9 and 4.10 color codes represent first contingency overloads existing for 2006 and forecasted for 2018. A comparison of Figures 4.9 and 4.10 shows that forecasted load levels, which are conservatively based on the cooler loads of 2008 and take into consideration possible customer conservation and the impacts of a slow economy, reach 2006 historic peak load levels again in 2018, resulting in the similar N-1 overload conditions. When a typical single feeder circuit fails during peak loading conditions, the main-line of the failed circuit is switched into three sections and each one of the three sections is transferred to a separate adjacent feeder circuit. Adjacent feeders must not be already encumbered by the load of a prior feeder circuit failure or scheduled switching event. The N-1 data provided in this section of the Study for the 39 feeder circuits serving the Focused Study Area are based on the loss of a single mainline feeder circuit. The 33 of 39 circuits that will experience an overload under first contingency conditions are shown in red. Feeder circuits shown in red demonstrate the cumulative affect on the 39 feeder circuits of switching the load from any single feeder circuit failure during peak loading conditions.

Figure 4.9: Focused Study Area 2006 N-1 Feeder Circuit Risks – Single Contingency



Above Figure 4.9 shows that of the 39 feeder circuits in the Focused Study Area, in 2006 under single contingency N-1 conditions, 33 feeders would be at risk for experiencing overload conditions.

Figure 4.10: Focused Study Area 2018 N-1 Feeder Circuit Risks – Single Contingency



Above Figure 4.10 shows that of the 39 feeder circuits in the Focused Study Area, under 2018 forecasted load under single contingency N-1 conditions, 33 feeders would be at risk for experiencing overload conditions. Figure 4.10 shows that 2018 forecasted load levels, which are conservatively based on the cooler loads of 2008 and take into consideration possible customer conservation and the impacts of a slow economy, reach 2006 historic peak load levels again and result in the similar N-1 overload conditions.

The data demonstrate that the Focused Study Area has been experiencing higher than optimal utilization rates on its feeders and transformers for the past decade. Absent additional system improvements in the area, these high utilization rates will increase the number and duration of overloads on feeders. Based on this analysis, Distribution Planning concluded that to ensure continued reliable service in the area, additional improvements are required.

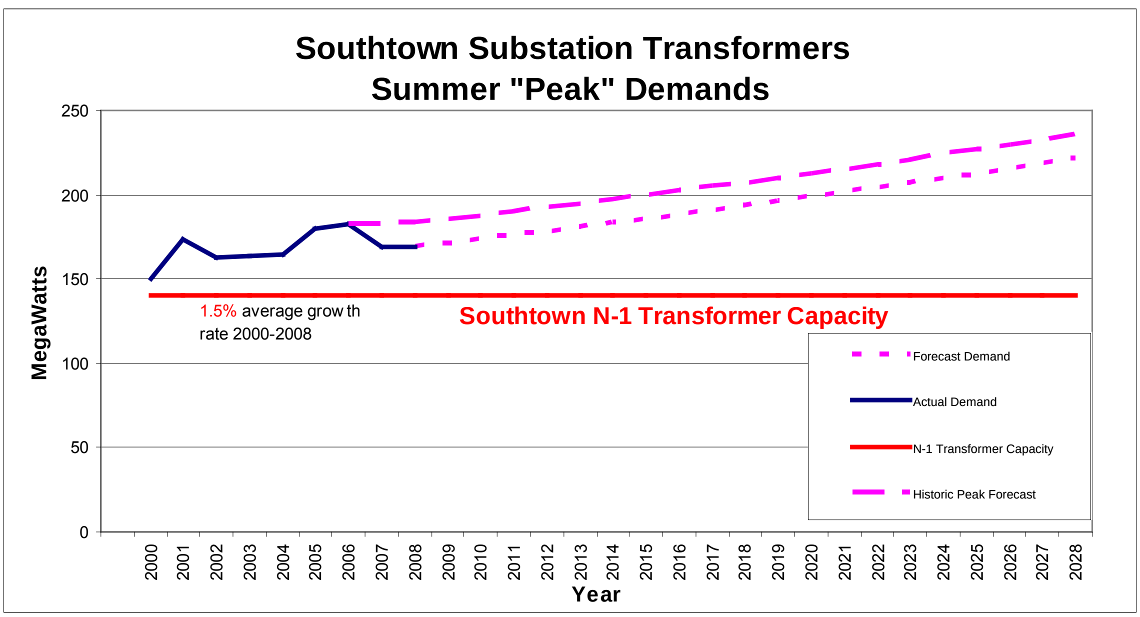
4.2 SOUTHTOWN SUBSTATION TRANSFORMERS

After examining feeder circuit peak demands, Distribution Planning Engineers looked at the loading levels for the three transformers housed at the Southtown Substation. Southtown Substation is the only substation that is in the Focused Study Area and is completely dedicated to serving Focused Study Area load.

4.2.1 Southtown Substation Transformer Historical Load and Load Forecasts

Figure 4.11 shows the conservative load growth ("forecast demand") on the three substation transformers at the Southtown Substation from 2000 through 2028 as well as the upper limit forecast load based on 2006 peak load levels ("historic peak forecast"). Southtown Substation transformer historical and forecasted load levels are similar to those for the 39 feeder circuits. The historical and forecasted loads for the three Southtown Substation transformers serving the Focused Study Area from 2000 through 2028 are included in Appendix D.

Figure 4.11: Historical and Forecasted Load Growth on Three Substation Transformers at Southtown Substation in Focused Study Area



Southtown Substation transformer loads fluctuate in a bandwidth of 11 to 14 MW between historic peak load years in 2001 and 2006 and lower peak load levels of succeeding years. Actual peak load levels will likely fall between the conservative forecast demand used in this Study and the historic peak forecast load levels illustrated in the above figure.

4.2.2 Southtown Substation Transformer Overloads and Utilization Percentages

As part of the analysis, Planning Engineers reviewed the loading and utilization rates of the Southtown Substation. The transformer utilization for the three Southtown Substation transformers from 2000 to 2028 is shown in Figure 4.12. This figure illustrates the range of overloads at Southtown Substation transformers according to forecast load levels based on lower peak loads of 2008 and forecast latent load levels of the 2006 historic peak load year. Even when using conservative peak load levels from 2008, forecasted load levels still exceed desirable loading levels for the Southtown Substation transformers. The range of likely transformer utilization falls between the dashed lines of the conservative forecasted demand and the historic peak forecast load levels.

Figure 4.12: Focused Study Area – Southtown Substation Transformers, Utilization Percentage

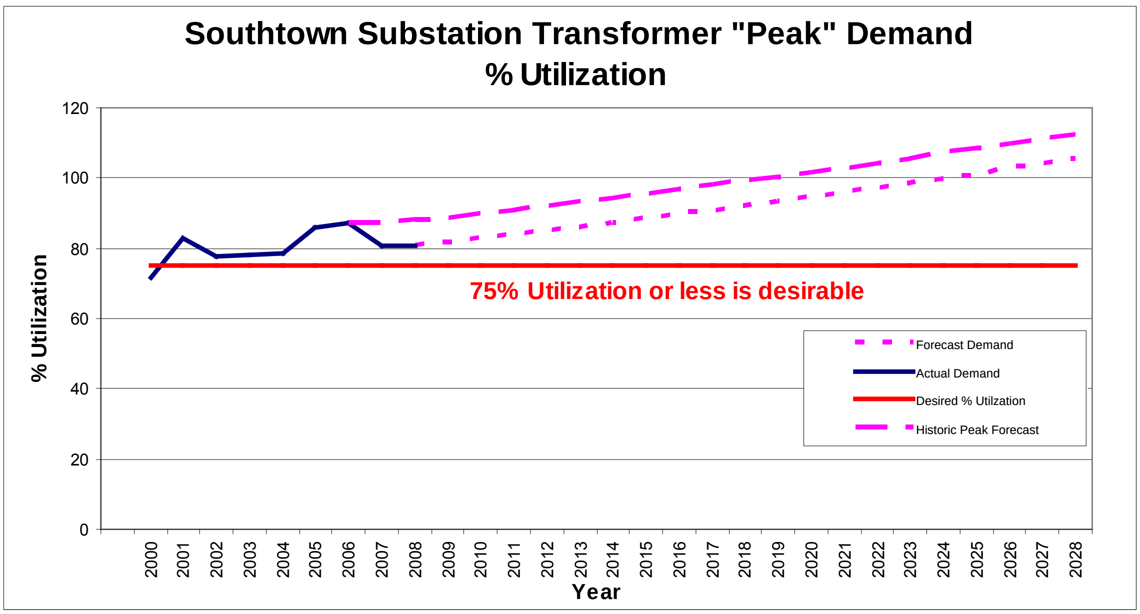


Figure 4.13 provides the historical and anticipated utilization percentages and overloads for the transformers at the Southtown Substation, which is the only substation within and completely dedicated to serving load in the Focused Study Area, for various years between 2000 and 2028.

Figure 4.13: Summary of Southtown Substation Transformer Utilization and Overloads

Southtown – One (1) Substation View Substation Transformer Utilization and Overloads									
	2000	**2004**	**2006**	**2008**	**2009**	**2013**	**2018**	**2023**	**2028**
# of Transformers	3	3	3	3	3	3	3	3	3
MW Normal Capacity	214.1	214.1	214.1	214.1	214.1	214.1	214.1	214.1	214.1
Actual Loads			**Peak Year**						
% Growth	1.5% Average Annual Growth Rate 8 years from 2000 to 2006								
% Utilization	72%	78%	87%	81%					
# Transformers	3	3	3	3					
N-1 MW Overload	9.9	24.1	42.4	28.5					
Historic Trend Forecast Overloads									
% Growth					1.4% Average Annual forecast Rate -2009 to 2028				
% Utilization					82%	86%	92%	99%	105%
# Transformers N-1					3	3	3	3	3
N-1 MW Overload					30.6	40.1	52.7	66.2	80.6
0.5% Growth Forecast Overloads			**Peak Year**						
% Utilization					81%	83%	85%	87%	89%
# Transformers N-1					3	3	3	3	3
N-1 MW Overload					29.4	32.8	37.2	41.7	46.3

The table entries were calculated using the Southtown Substation transformer forecasts included in Appendix D.

Southtown Substation transformer utilization percentage was 87% in historic peak year 2006 and 81% in the cooler temperature year 2008. Both load levels surpass the 75% utilization planning criteria for substation transformer loading levels. Southtown Substation is presently at its maximum design capacity. These high utilization rates and forecast increasing peak transformer loads indicate longer peak periods of transformer N-1 overloads. Based on this analysis, Distribution Planning concluded that Southtown transformers are not capable of serving more customer load.

5.0 ANALYSIS OF THE GREATER SOUTH MINNEAPOLIS ELECTRIC DISTRIBUTION DELIVERY SYSTEM

After determining that the south Minneapolis electric distribution delivery system in the Focused Study Area has an existing feeder circuit capacity deficit of 55 MW and that this deficit is only expected to increase in future years, Distribution Planning examined the Southtown Substation transformer capacity.

In 2006, Southtown transformer utilization was at 87% with N-1 overloads of more than 43 MW. Southtown transformer 10 year load forecasts are for 92% utilization with N-1 forecast overloads of more than 50 MW by 2018. Based on these load levels and the fact that Southtown Substation is already at its ultimate design capacity, Planning Engineers broadened the scope of their analysis to include the Greater Study Area in order to determine, in part, the availability of additional capacity near the Focused Study Area.

5.1 HISTORICAL LOAD AND LOAD FORECASTS

Historic substation transformer demands (2000 through 2008) were used as a basis to forecast each of the 15 substation transformer loads in the Greater Study Area. Distribution Planning Engineers used DAA, which supports multi-year analyses, to forecast distribution substation transformer loads from 2009 to 2028, using historical growth rates and knowledge of anticipated future load levels.

The Greater Study Area includes the 15 substation transformers comprising the five (5) Metro West substations that ring the Focused Study Area (Aldrich, Elliot Park, St Louis Park, Wilson, Southtown). Similar to feeder circuit peak loads in the Focused Study Area, transformer peak loads in the Greater Study Area occurred in 2001 and again in the 2005/2006 timeframe.

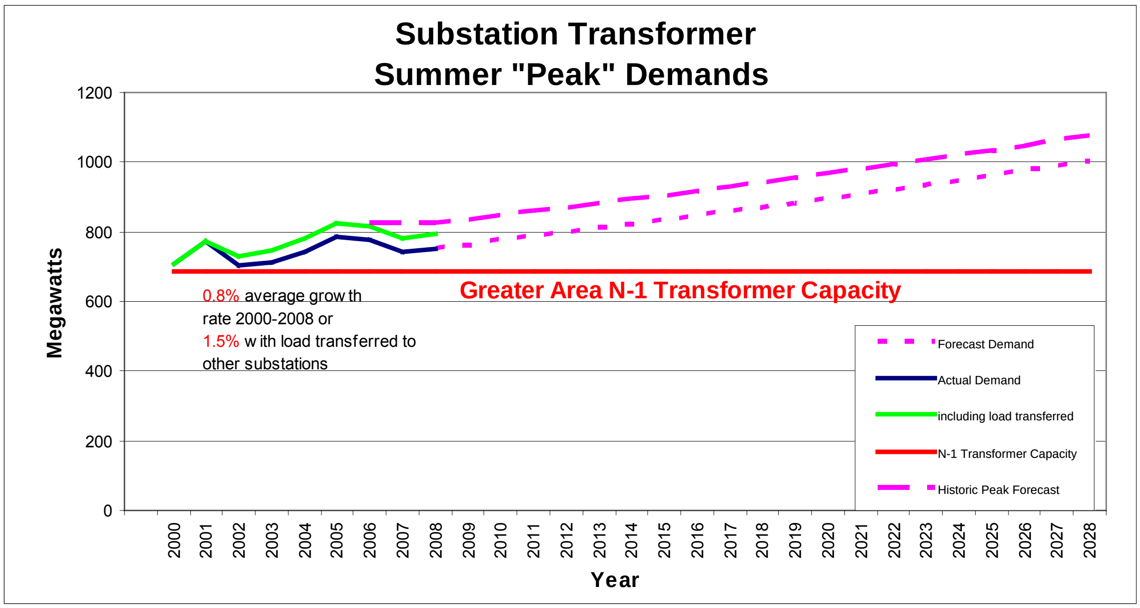
Each distribution substation in the Greater Study Area has a demand meter for each transformer located in the substation, which is read monthly, and the data is recorded in Passport. These meters record the monthly peak for the substation transformer. All affected distribution substation transformers also have a SCADA system connection that monitors the real time load on the transformer. Similar to the distribution feeders, this system feeds a SCADA data warehouse and the DAA warehouse where hourly data is stored so Electric Capacity Planning and Field Operations can view the substation transformer's load history. Each transformer's peak in a multi-transformer substation is non coincident.

Each of the 15 distribution substation transformers in the five substations serve multiple feeder circuits. Substation transformer peak load is proportional but not equal to the sum of the feeder circuit peak loads served from that substation transformer. The detail of substation transformer loading is a larger granularity than feeder circuit loads with a corresponding greater impact on customer service.

Each distribution substation transformer in the Greater Study Area serves the aggregate load of the connected down-line feeder circuits of that transformer. While each of the feeder circuits has a non-coincident peak load that the feeder circuit must be capable of serving, the combination of multiple feeders serves the diversified load of the aggregated feeders. Since the substation transformers serve diversified feeder load, the non-coincident transformer load is less than the sum of the feeder peak loads.

The historical and forecasted loads for the 15 substation transformers serving the Greater Study Area from 2000 through 2028 are provided in Appendix D to this Study. Figure 5.1 is a linear depiction of the load growth on the 15 substation transformers in the Greater Study Area from 2000 through 2028.

Figure 5.1: Greater Study Area – Historical and Forecasted Loads



The lower dashed line shows the forecast peak load levels from 2008 peak loads that are also in Appendix D, while the upper dashed line shows loads forecast based on 2006 historic peak load levels. The actual demand peaks in Figure 5.1 are not adjusted for load originally served by the 15 transformers in 2000 and transferred away through 2008. The sum of these peaks increased an average of 0.8% annually.

The figure also includes calculations of the 15 transformer load adjusted to include the load that had to be transferred from Aldrich and St. Louis Park substations to new substations outside of the Greater Study Area. The adjusted sum of the measured peaks increase an average of 1.5% per year from 2000 through 2008.

Figure 5.2 summarizes the amount of Non-Coincident Substation Transformer Load that has been transferred since 2000.

Figure 5.2: Transformer Load Transferred from Greater Study Area Since 2000

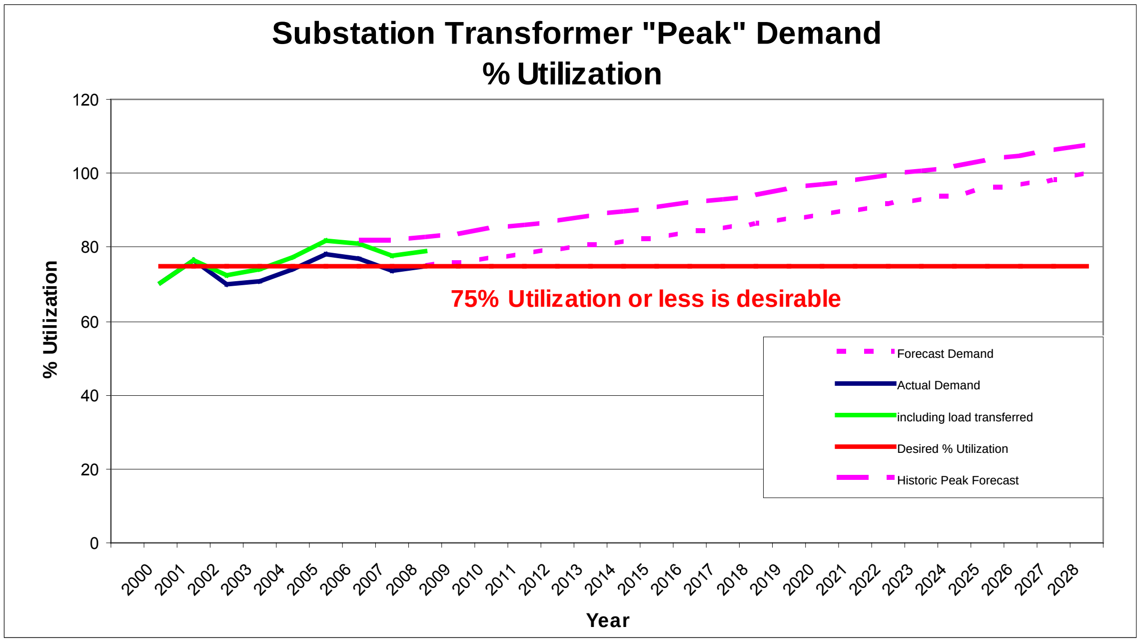
Load Adjustments due to Load Transfers to Adjacent Substations	Number of Feeder Circuits	Load (in kW) Transferred Away	Adjusted % Utilized of Transformer Normal Capacity
From Aldrich to West River Road – 2000 to 2008 Cedar Lake – 2001 to 2008	 4 1	 + >20,000 + > 6,000	
From St Louis Park to 35 kV – 2000 to 2005 Cedar Lake – 2001 to 2008	 3 3	 + >12,000 + >14,000	
Total Load Transferred Away	**11**	+ >52,000	
Impact on Greater Study Area without Transfers	**121**	Increase to >795,000	Increase to > 79%

Comparison of transformer load levels for the Greater Study Area to transformer load levels for the Southtown Substation, provided in Section 4.0, shows a similar load growth pattern from 2000 through 2008 with increasing peaks in 2001, and 2005/2006. The Southtown Substation load growth, at an average of 1.5% growth per year, mirrors the adjusted 15 transformer 1.5% per year growth and reflects a lower, more diversified growth rate than the 1.7% historical rate of non-coincident feeder circuits. Load diversity results in a transformer peak load that is slightly less than the sum of all of the feeder circuit peak loads fed from the substation transformer due to the feeder circuits reaching their individual peaks at different times.

5.2 TRANSFORMER OVERLOADS AND UTILIZATION

Planning Engineers compiled the transformer loading and utilization data for the 15 substation transformers in the Greater Study Area and found that utilization rates began exceeding 75% beginning in 2001 and have increased to 77% in 2006. Greater Study Area transformer N-1 overloads have increased both in number and duration since that time.

Figure 5.3: Greater Study Area – Substation Transformer Bank Utilization Percentage



As shown in Figure 5.3, the Greater Study Area substation transformer peak utilization percentage first exceeded 75% during 2001 peak loading. Despite load transfers of more than 52,000 MW from 2000 through 2008 to new West River Road and Cedar Lake substation transformers, average peak utilization percentage has exceeded 75% since 2004.

Substation transformer contingency overloads, which can be characterized by average feeder utilization percentage increasing above 75% and substation transformer utilization simultaneously more than 75%, typically occur in distribution areas where many and continued distribution fixes to widespread overloads use up existing feeder circuits and consume distribution substation transformer capacity. Distribution systems that experience feeder circuit N-1 and N-0 overloads soon measure substation transformer N-1 overloads of increasing amounts for longer durations. Southtown substation transformers, located in the only substation in the Focused Study Area, experienced 87% utilization in 2006 and 81% utilization in 2008 as a result of the cooler weather and reduced air conditioning usage.

Figure 5.4 summarizes the utilization percentages and anticipated overloads for the 15 substation transformers in the Greater Study Area for various years between 2000 and 2028.

Figure 5.4: Summary of Substation Transformer Utilization and Overloads of the Five Substations Serving Greater Study Area Load

Greater Study Area – Fifteen (15) Transformers Substation Transformer Utilization and Overloads									
	2000	**2004**	**2006**	**2008**	**2009**	**2013**	**2018**	**2023**	**2028**
# of Transformers	15	15	15	15	15	15	15	15	15
MW Normal Capacity	1,007.4	1,007.4	1,007.4	1,007.4	1,007.4	1,007.4	1,007.4	1,007.4	1,007.4
Actual Loads			**Peak Year**						
% Growth	1.5% Average Annual Growth Rate 8 years from 2000 to 2008 **								
% Utilization	70%	74%	77%	75%					
# of Transformers with N-1 Overloads	12	9	9	12					
N-1 MW Overload	46.5	82.7	102.9	71.7					
Historic Trend Forecast Overloads									
% Growth					1.4% Average Annual Forecast Growth Rate 2009 to 2028				
% Utilization					76%	80%	86%	93%	100%
# Transformers N-1					12	15	15	15	15
N-1 MW Overload					81.5	124.5	184.4	248.8	318.3
0.5% Growth Forecast Overloads			**Peak Year**						
% Utilization					75%	77%	79%	81%	83%
# Transformers N-1					9	12	12	15	15
N-1 MW Overload					71.0	87.2	103.2	126.6	147.1

Note ** The actual load growth shown in the table above does not account for load transfers of more than 42,000 kW from Aldrich and St Louis Park substations to the new West River Road and Cedar Lake Substations built in 2001 and 2003, respectively.

Southtown Substation transformer utilization in 2008 reached 81% (see Figure 4.13). Aldrich Substation capacity, at 62% utilization in 2008, cannot be further utilized due to full feeder circuit routes into the Greater Study Area. Peak transformer loading for the entire area above 75% utilization demonstrates that it is no longer feasible to transfer load away from the Southtown Substation transformers.

Planning Engineers generated graphics that illustrate the transformer overloads tabulated above and that provide a geographic based perspective of the present and forecast substation transformer utilization and overloads under single contingency (N-1) scenarios. These figures illustrate the geographic placement and loading level by color of substation transformers described in the table of Figure 5.4 in the Greater Study Area. Colors are used to represent substation transformer loading levels and identify overloads under N-1 first contingency operating conditions for load capacity limits in 2006 and future forecast years 2009 through 2028. The complete set of these graphics is provided in Appendix E.

Substation transformer N-1 loading levels for all distribution transformers of the same distribution voltage (13.8 kV) are addressed together because the means to transfer large amounts of load between substation transformers is built into the substation design. Substation transformer loading levels for a substation are planned for N-1 conditions resulting from the worst case possibility of one transformer (the largest transformer if the transformers are different capacities) out of service during peak loading. The maximum amount of transformer capacity that can be served from all transformers grouped together in a substation under N-1 conditions is also known as substation firm capacity. The N-1 data provided in this section of the Study for substation transformers in the Greater Study Area are based on the loss of the single transformer in a substation.

Two of the transformer overload graphics are depicted in Figures 5.5 and 5.6, respectively. The color codes in the graphics depict varying amounts of load described in the chart at Figure 5.3 and the table at the Figure 5.4 for the labeled years as follows:

> Not Overloaded - The feeder circuits emanating from the substation transformers that are not overloaded during N-1 conditions are shown in green. The quantity of substation transformers that are not overloaded is listed.
>
> < 10 MW Overloads in Yellow - The feeder circuits that are overloaded by 10 MW or less under N-1 conditions are yellow. The number of substation transformers that are overloaded by less that 10 MW are listed. 10 MW is the maximum amount of load that can be transferred by utilizing field switching in about 2 hours.
>
> 10 to 25 MW Overloads in Orange - The feeder circuits that are overloaded by less than 25 MW but more than 10 MW are orange. The quantity of substation transformers that are overloaded by 10 to 25 MW is listed. 25 MW is the typical amount of load that can be served by a mobile transformer installation. A mobile transformer can sometimes be installed as quickly as 24 hours under emergency conditions.
>
> Severe Overloads > 25 MW in Red - The feeder circuits that are overloaded by more than 25 MW are red. The quantity of substation transformers that are overloaded by more than 25 MW is listed. Typically, more than 25 MW of load cannot be restored in less than 24 hours if a large substation transformer fails and could result in extended customer outages.

Figure 5.5 shows first contingency N-1 substation transformer loading from 2006. Aldrich and Elliot Park substation transformers do not reflect first contingency overload. St. Louis

Park has N-1 overload of less than 10 MW. And both Wilson and Southtown substation transformers have N-1 overloads of more than 25 MW.

Figure 5.5: Greater Study Area 2006 N-1 Substation Transformer Risks – Single Contingency

Colored by Substation:		
0	6 Transformers	
0 to 10 MW	3 Transformers	
10 MW to 25 MW		
> 25 MW	6 Transformers	

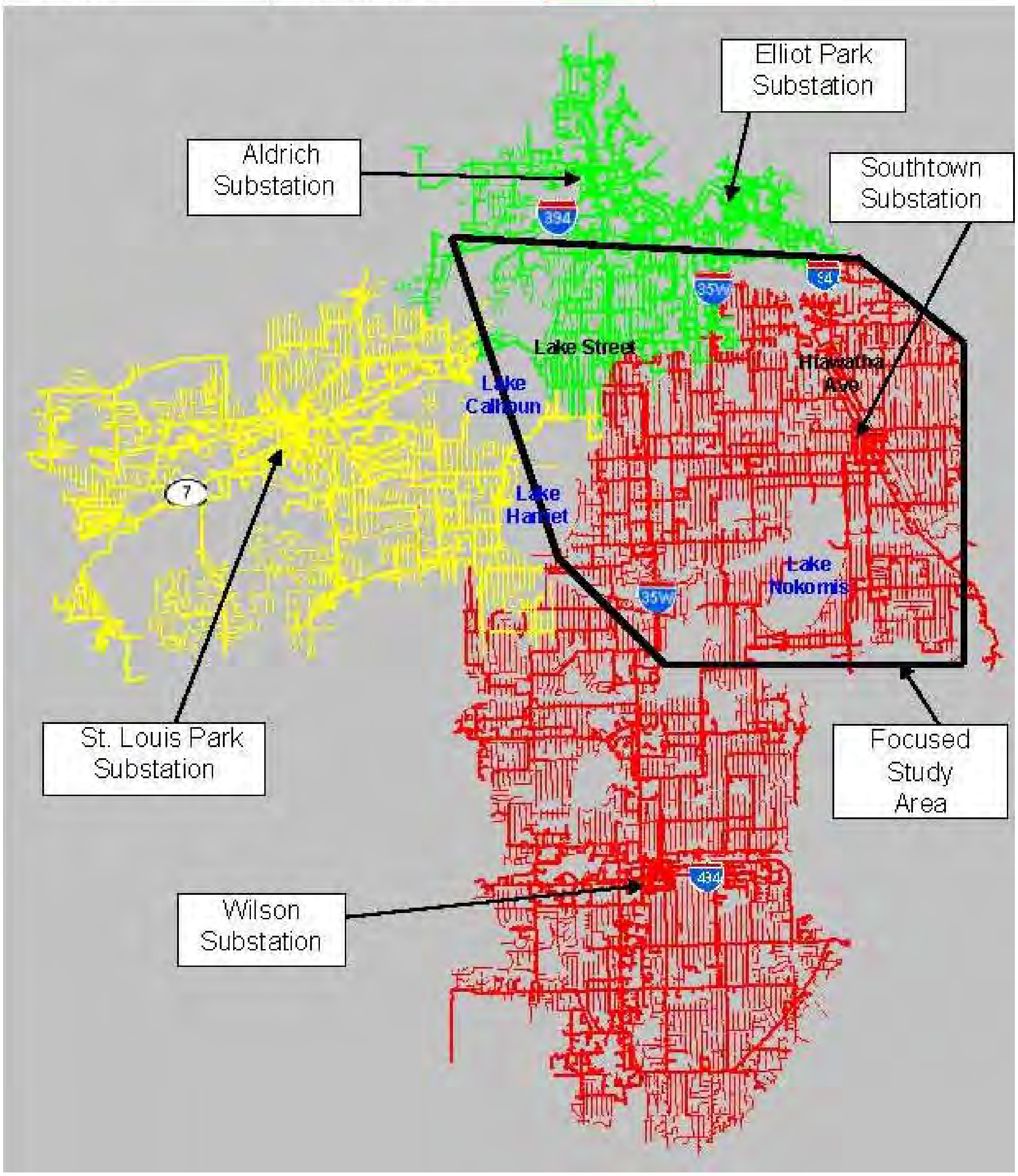


Figure 5.6 has increasing first contingency N-1 overloads in 2018 over 2006 levels. Within 10 years, Elliot Park Substation transformers have up to 10 MW overload, Aldrich Substation transformers have 10 MW to 25 MW overloads, and St. Louis Park have more than 25 MW overload while both Southtown and Wilson substation transformers have overloads that are greater than 25 MW each and are more severe than 2006 levels.

Figure 5.6: Greater Study Area 2018 N-1 Substation Transformer Risks – Single Contingency

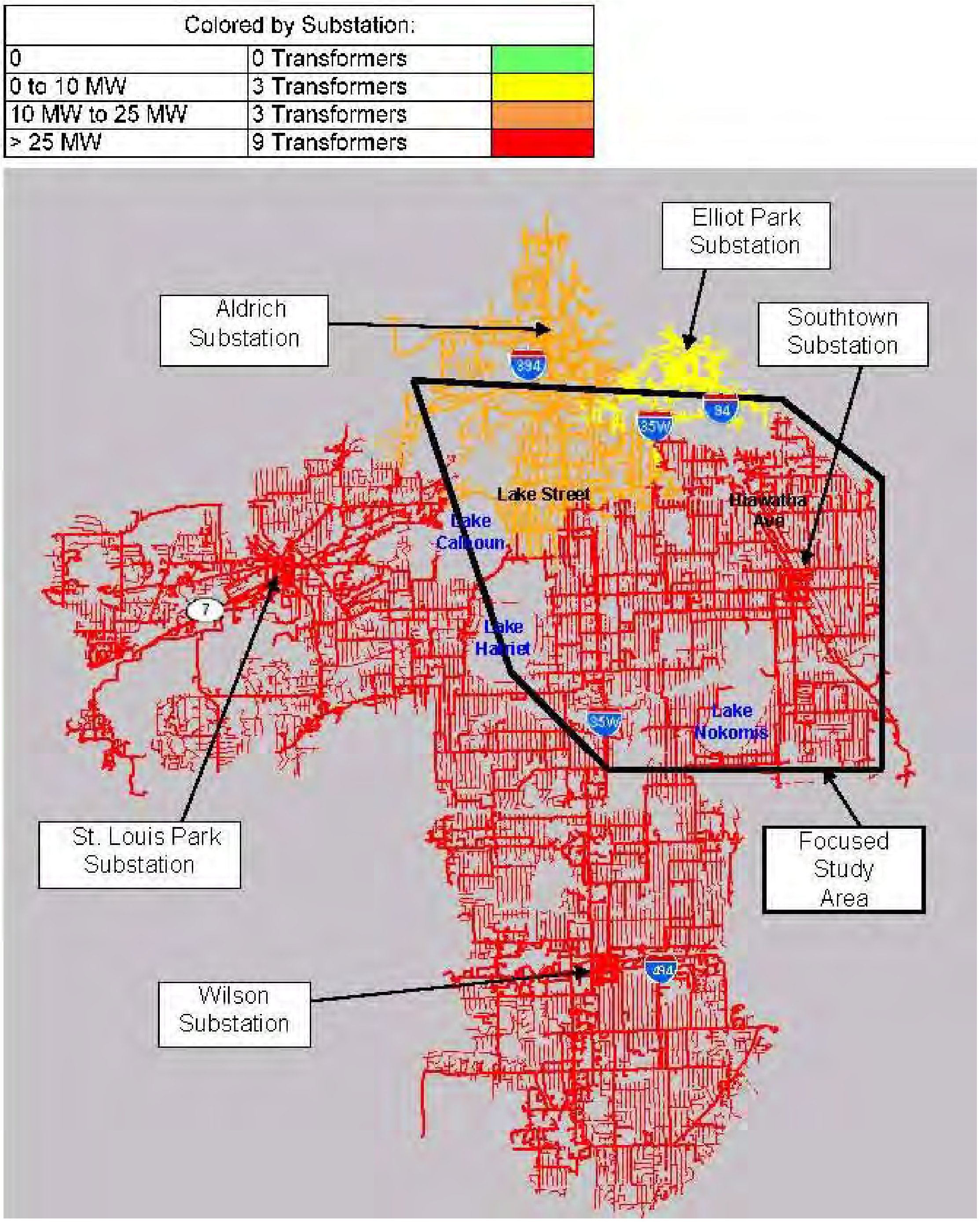


Figure 5.7 summarizes the additional substation transformer capacity (in MW) needed to mitigate the overloads detailed in Figure 5.4. A single new 50 MVA substation transformer will serve 36.75 MW of load at 75% utilization.

Figure 5.7: Summary of Substation Transformer Capacity Required to Mitigate Overloads

Minimum Number of Substation Transformers Required to Correct Southtown Transformer N-1 Overloads									
	2000	**2004**	**2006**	**2008**	**2009**	**2013**	**2018**	**2023**	**2028**
N-1 Deficiency (MW)	9.9	24.1	42.4	28.5	30.6	40.1	52.7	66.2	80.6
Minimum # of New Transformers* Needed	1	1	2	2	2	2	2	2	3

*Assumes 50 MVA transformers with 75% or less utilization.

Figure 5.7 shows that there is an existing need for two new transformers in the Focused Study Area since 2006. Even though conservative load forecasts are lower than 2006 levels, 2006 historic peak load levels remain as latent load that is likely to recur, and even exceed 2006 levels due to additional customer load, when future years reach temperature levels of the summer of 2006. As load grows, it is anticipated that additional transformers will be needed in future years. Figure 5.7 is based on forecasted load growth, and the timing of the need for additional transformers in the future is subject to change based on actual future load growth data. Any substations constructed to house the two currently needed transformers, however, should be designed to accommodate the likely future inclusion of additional transformers.

6.0 ANALYSIS OF ALTERNATIVES

After identifying system deficiencies, Planning Engineers identified potential solutions to provide necessary additional capacity to the Focused Study Area. Planning Engineers first considered distribution level alternatives including adding feeders, extending feeders and expanding existing substations. Planning Engineers concluded that these alternatives would not meet identified needs because these typical strategies had already been exhausted and were no longer sufficient to address these overloads. Planning Engineers then evaluated alternatives that would bring new distribution sources into the Focused Study Area.

6.1 DISTRIBUTION LEVEL ALTERNATIVES IMPLEMENTED IN THE FOCUSED STUDY AREA

Over the past decade, Distribution Planning Engineers implemented an array of distribution level alternatives in the Focused Study Area. Engineers applied these alternatives in proportion to the amount and frequency of overloads as identified by the annually measured feeder circuit and substation transformer overloads. Alternatives implemented in the last decade used feeder circuit and substation transformer capacity by fully utilizing ultimate substation design capacities in a way that did not require a new transmission line source to address the distribution delivery system needs.

Distribution capacity planning methods address and solve a continuum of distribution equipment overload problems, including isolated feeder overloads, widespread feeder overloads, and substation transformer contingency overloads associated with widespread feeder overloads. These were described in more detail in Sections 4.0 and 5.0.

Alternatives implemented in the last decade to address continuing overloads in the Focused Study Area are described briefly in the sections below and in more detail in Appendix A. Alternatives include reinforcing existing feeder circuits to address isolated feeder circuit overloads, adding or extending new feeder circuits and adding substation transformer capacity up to the ultimate substation design capacity to address more widespread overloads.

6.1.1 Reinforcing Existing Feeder Circuits

Feeder circuit improvements used to address isolated Focused Study Area feeder overloads included reinforcing at least seven (7) existing feeder circuits by increasing wire size or doubling-up wires, adding at least a dozen capacitor banks, converting three 4 kV substations to 13.8 kV, targeting overloaded customer transformer areas by adding or upsizing more than 150 customer serving transformers, and rearranging at least nine (9) feeder circuits by moving increased customer demand from an overloaded feeder to an adjacent feeder circuit with existing capacity. Alternatives implemented from 2001 to 2008 to reinforce existing feeder circuits in the Focused Study Area are detailed in Appendix A.

6.1.2 Adding New or Extending Feeder Circuits

Feeder circuit improvements used to address widespread Focused Study Area feeder overloads and some substation transformer contingency overloads included replacing at least six feeder circuits and more than 120 cables of existing overloaded and damaged feeder equipment with new equipment capable of delivering equal or higher capacity, and adding four (4) Southtown and two (2) Elliot Park feeder circuits from substation transformers that have more capacity in the Focused Study Area and longer feeder circuits from adjacent substations. Alternatives implemented from 2001 to 2008 to add and extend feeder circuits in the Focused Study Area are detailed in Appendix A.

Underground feeder circuits from Aldrich, Elliot Park, and Southtown substations now fill existing duct lines to their thermal capacity, and there is no more room in utility easement or street right-of-way routes for additional duct lines from these substations to the distribution load. See Section 2.3.2 for a detailed description of limits to concentrated feeder installations.

New feeder circuits from Southtown Substation in the Focused Study Area and substations in the Greater Study Area have consumed all available substation transformer capacity, or filled all feeder circuit routes or both. Planning Engineers have determined that all reinforcing and new feeder circuit improvement alternatives in and around the Focused Study Area are exhausted.

6.1.3 Expanding Existing Substations to Ultimate Design Capacity

As Planning Engineers fully utilize available feeder circuit capacity and then substation transformer capacity to serve customer load, the next logical step is to increase the number and size of substation transformers to the substation ultimate design capacity. In the five substations of the Greater Study Area, expansion beyond ultimate design capacity is limited by several factors, including:

- Substation expansion is physically limited,
- Substation equipment is electrically limited inside the substation and
- Physical distance from substations to customer load concentrations.

Distribution Planning Engineers examined each of the five substations in the Greater Study Area, evaluating each substation's capacity, utilization percentage and whether a substation could presently serve or be expanded to serve additional load in the Focused Study Area. The following is a summary of Distribution Planning's analysis for each of the five substations.[2]

[2] Again, Main Street Substation was not considered in the Greater Study Area as a source of load relief. The one feeder circuit from the Main Street substation presently serving customer load in the Focused Study Area, is not part of future plans to serve load in the Focused Study Area. The one (1) Main Street substation feeder circuit traverses several miles and crosses the Mississippi River to reach the study area. All Main Street feeder circuits crossing the Mississippi River were vulnerable and were damaged when the Interstate 35W bridge collapsed in 2007. There are no additional feeder circuit routes available in the congested duct lines between Main Street Substation and overloaded feeder circuits in the Focused Study Area.

The one feeder circuit emanating from Main Street substation that serves customer load in the Focused Study Area was at 86% utilization in 2008; the N-1 overload of 1,592 kW requires load relief. This Main Street feeder circuit presently passes other Main Street and Elliot Park feeder circuits that are overloaded on the route from the Main Street substation to the part of the study area where it serves customer load. The one Main Street

Aldrich Substation

Aldrich Substation presently has three (3) 115/13.8 kV 70 MVA substation transformers installed and is constructed to the ultimate design capacity. This substation overloaded in 1999, 2000 and 2001. In 2001, peak loads levels were more than 15,000 kW over the Aldrich Substation transformer N-1 capacity. Load relief from the new West River Road Substation[3] beginning in 2001 and the new Cedar Lake Substation[4] beginning in 2003 reduced utilization to 65% in 2008 which is 3,618 kW under the N-1 capacity. This capacity will be consumed in less than two years at the 1.3% forecast growth rate. Additional capacity or load relief is needed at Aldrich Substation after 2011.

Even if there were available Aldrich transformer capacity to serve load in the Focused Study Area, existing feeder circuit and duct line (required for concentrations of feeders) routes are full. Conventional methods for new duct line routes needed to cross over the Lowry Hill tunnel or be constructed through downtown Minneapolis and across bridges over interstates 94 and 35W are exhausted.

Elliot Park Substation

Elliot Park Substation presently has three (3) 115/13.8 kV 47 MVA substation transformers installed. Elliot Park Substation transformers utilization of 77% in 2007, are within 3,168 kW of the substation N-1 limit. Some load relief of about 12,000 kW will occur in 2009 due to feeder circuit repairs to damage from the Interstate 35W bridge collapse in 2007. The capacity made available from repairs is already designated to relieve existing overloaded Elliot Park feeder circuits outside the Focused Study Area and future downtown Minneapolis load growth to the west of the substation location.

Even if there were available capacity to serve load in the Focused Study Area, new feeder circuit and duct line (required for concentrations of feeders) routes that need to cross

feeder circuit in the Focused Study Area has feeder circuit ties to Southtown and Elliot Park feeder circuits that are presently overloaded and require load relief.

[3] West River Road substation is located north of Aldrich substation near the intersection of Plymouth Ave and West River Road northeast of downtown Minneapolis. The substation was constructed to provide load relief primarily to Aldrich and Fifth Street substations and help provide future electrical energy to the growing customer demand north of Minneapolis and in downtown Minneapolis. The two West River Road substation transformers, which were added in 2001, delivered 42,115 kVA of electrical power in 2008 at peak loading; More than 20,000 kW of peak load has been transferred from overloaded Aldrich substation feeder circuits and substation transformers beginning in 2001.

[4] Cedar Lake substation is located north of St Louis Park substation near the intersection of Cedar Lake Road and Edgewood Ave in St Louis Park. The substation was constructed to provide load relief primarily to St Louis Park, Medicine Lake, and Aldrich substations and help provide future electrical energy to growing customer demand along Interstate 394 west of Penn Ave. The first Cedar Lake substation transformer, added in 2003, and the second substation transformer, added in 2008, delivered 30,510 kW of electrical power in 2008 at peak loading; more than 20,000 kW of peak load has been transferred from Aldrich (6000 kW), and St Louis Park (14,000 kW) substation feeder circuits and substation transformers beginning in 2003.

through downtown Minneapolis and across bridges over the interstates 94 and 35W commons are not possible because existing duct lines and duct line routes are physically full.

Southtown Substation

Southtown Substation presently has three (3) 115/13.8 kV substation transformers (2-70 MVA, 1-62.5 MVA) installed and is constructed to ultimate design capacity. The substation transformers reached 83% utilization in 2001, exceeding substation N-1 capacity by more than 33,000 kW. The 23 feeder circuits emanating from this substation increased substation transformer utilization to 87% in 2006, remaining at 81%, 29,102 kW above substation transformer N-1 limits in 2008. These overloads continue, despite feeder circuit load transfers to Aldrich and Elliot Park substations and cooler temperatures in 2008 when compared to 2005 and 2006.

The three (3) Southtown Substation transformers have 2008 N-1 overloads of more than 29,000 kW. In 2006 Southtown Substation transformers experienced a higher peak load year due to higher temperatures and correspondingly higher air conditioning loads with N-1 overloads of more than 43,000 kW. Southtown Substation transformers are expected to experience peak loading at or above 2006 levels when economic conditions improve and future year temperatures reach 2006 levels.

Southtown Substation capacity can be increased by about 4,000 kW by replacing the smallest substation transformer with the maximum size that can be installed in the substation. This capacity increase, which would reduce N-1 transformer overloads to about 39,000 kW and costing more than $1.5 million, is not cost effective. Even if the substation transformer capacity upgrade were funded, 2008 feeder circuit N-0 overloads totaling more than 7,500 kW and N-1 overloads totaling more than 38,700 kW in the Focused Study Area are not reduced.

St. Louis Park Substation

The St. Louis Park Substation currently serves less than 500 kW, a statistically insignificant amount of customer load in the Focused Study Area. The substation presently has three (3) 115/13.8 kV 70 MVA substation transformers installed and is constructed to the ultimate design capacity for substation transformers. This substation overloaded in 1999, and at 71% utilization in 2001 was more than 12,000 kW over the substation transformer N-1 capacity.

Peak loading has declined from 75% in 2005, with N-1 overloads of 22,445 kW to 66% (N-1 overload of 1,632 kW) in 2008 due to load relief from new circuits built to the west of the substation beginning in 1995 and the new Cedar Lake Substation feeders beginning in 2003, cooler weather than 2005 / 2006, and a slower economy. Plans are to continue to use Cedar Lake Substation transformers and feeder circuits to relieve some of the St Louis Park Substation transformer and feeder circuit overloads.

Even if there were available capacity to serve load in the Focused Study Area, new feeder circuit and duct line (required for concentrations of feeders) routes would need to cross through more than four miles of suburban St. Louis Park and Minneapolis, which would increase line losses. Duct line routes are full close to the St Louis Park Substation. Feeder concentrations in duct lines would need to be constructed crossing Highway 100 by modifying existing highway bridges or installing duct line casings underneath Highway 100. Duct routes would cross though congested or full routes along streets both north and south of Lake Calhoun.

Wilson Substation

The Wilson Substation serves less than 1,200 kW, a statistically insignificant amount of customer load in the Study Area. The substation presently has three (3) 115/13.8 kV 70 MVA substation transformers installed and is constructed to the ultimate design capacity for substation transformers. A substation project started in 2006, which completed feeder circuit reconfigurations in 2007, replaced obsolete substation equipment and resulted in the present substation configuration.

This substation overloaded prior to 1999, and at 87% utilization in 2001, saw N-1 substation transformer overloads of more than 42,000 kW. Despite the Wilson Substation improvement project in 2005 through 2007, 2008 transformer utilization reached 86% with N-1 substation transformer overloads of more than 39,000 kW. Wilson Substation transformers have no capacity presently available to relieve the Focused Study Area.

Even if there were available capacity to serve load in the Focused Study Area, new feeder circuit and duct line (required for concentrations of feeders) routes would need to cross bridges over or boring under Interstate 494 and Crosstown freeway (county road 62), and be installed through suburban Richfield and Minneapolis to reach the Focused Study Area.

After considering whether the Focused Study Area load could be served from existing substations in or adjacent to the Focused Study Area, Planning Engineers determined that these substations were either already at capacity or had capacity that was already designated to serve load in other areas.

6.1.4 Feeder and Substation Transformer Additions, Expansions Are Exhausted

The ability to serve the increasing load in the Focused Study Area with additional feeder circuits from the Greater Study Area are exhausted. Existing substation transformer capacity and existing substations in the Greater Study Area cannot be expanded with additional transformers. As discussed in Sections 4.0 and 5.0, peak feeder and transformer loads for the Focused Study Area will likely reach levels in the range between the conservative forecast and historic peak forecast lines.

Measured 2007 and 2008 peak loads are lower, in part, due to cooler summer temperatures than 2005 or 2006. Impacts of the economy are factored into load forecasts that do not reach 2006 levels until about 2012 or 2013. Unpredictable and cyclic conditions such as a multiple day or week long period of high temperatures and high humidity similar to 2001/2002 and 2006 could result in load levels that exceed forecasted and 2006 actual peak load levels.

Feeder circuits 2008 peak loads in the Study Area average 76% utilization, with 24 of 39 circuits overloaded by more than 38 MW during N-0 or N-1 conditions. Measured loads that are down by 16 MW from the historic, weather related peak of 2006, are expected to meet and exceed 2006 peak load levels when summer temperature patterns again occur at 2006 levels.

Three (3) Southtown Substation transformer (the only transformers in the Study Area) 2008 peak loads average 81%, with the substation overloaded by more than 29 MW during N-1 conditions. Fifteen (15) substation transformer 2008 peak loads average 75%, with the five substations overloaded by more than 71 MW during N-1 conditions.

6.2 NEW SUBSTATION ALTERNATIVES

After concluding that distribution level additions and improvements would not meet the identified need for the Focused Study Area, Planning Engineers considered the addition of new distribution sources (*i.e.*, substation transformers with associated feeder circuits) to meet the electricity demands of the Focused Study Area. Ideally, new distribution sources should be located as close as possible to the "center-of-mass" for the electric load that they will serve. Installing substation transformers close to the load "center-of-mass" minimizes line losses, reduces system intact voltage problems, and reduces exposure of longer feeder circuits and outages associated with more feeder circuit exposure.

Planning Engineers considered four alternatives for bringing new distribution sources into the Focused Study Area and increase the capacity of the system to address system deficiencies and provide additional capacity for future growth. Each alternative consists of incremental installation plans from initial installation through the alternative's full design capacity. Identified final improvements for each alternative in 2023 are expected to provide the necessary capacity to the year 2028. The Planning Engineers compared the alternatives at their full design capacity. The four alternatives are as follows:

- New Source Alternative-1 ("A1"): Hiawatha and Midtown 115/13.8 kV distribution substations and two looped 115 kV transmission lines
- New Source Alternative -2 ("A2"): Hiawatha Substation and West Midtown Substation 115/13.8 kV distribution substations and two looped 115 kV transmission lines
- New Source Alternative -3 ("A3"): Hiawatha Substation 13.8 kV distribution substation
- New Source Alternative -4 ("A4"): Hiawatha 13.8 kV distribution and 34.5 kV sub-transmission with three substations in Midtown for 13.8 kV distribution

A1 and A2 are considered standard installation. A3 and A4 are considered non-standard installation because they involve using multiple distribution voltage express feeder circuits at 13.8 kV or 34.5 kV to move power from a distant substation transformer location instead of using a 115 kV transmission line to transmit power.

6.2.1 Criteria Used to Develop and Compare Alternatives

Distribution Planning Engineers evaluated and compared the effectiveness of each of the four alternatives to address the identified system deficiencies according to the following objective criteria: System Performance, Operability, Future Growth, Cost, and Electrical Losses, which are described in more detail below.

All four alternatives have the ability to meet existing and forecast capacity requirements. To facilitate a comparison of the alternatives, A1, A2, A3, and A4 were developed to equally fix N-0 and N-1 overloaded feeder circuits and N-1 substation transformer overloads in the Focused Study Area and install additional infrastructure in the year needed to fix forecast overloads.

6.2.1.1 System Performance

System performance is how the physical infrastructure addition of an alternative impacts energy delivery to distribution customers. Frequency of outages has been found to correlate to circuit length with longer feeders experiencing more outages than shorter feeders. Each unit of length of a feeder circuit generally has comparable exposure due to common outage causes, including underground circuit outages caused by public damage (*e.g.*, customer dig-ins to cable), equipment failure; and overhead circuit outages caused by acts of nature (*e.g.*, lightning).

SynerGEE system models of 13.8 kV feeder circuits indicate that fully loaded 12,000 kW circuits more than approximately four miles long with the load at the end of the feeder cannot maintain nominal voltage within required +/-5% limits. Experience with Elliot Park, Southtown, and Aldrich substation feeder circuits since reaching 2005/2006 loading levels on the existing distribution system demonstrated that required minimum voltage levels cannot be maintained under first contingency N-1 conditions. A large hospital and other voltage sensitive customers in the vicinity of Chicago Avenue and Lake Street load corridors have experienced unacceptably low voltages under first contingency conditions.

Accordingly, for purposes of this Study, performance is based on the equipment and control systems required to maintain customer nominal voltage, and customer exposure to outages as differentiated by the length of the feeder circuit from the substation transformer to the customer.

6.2.1.2 Operability

Operability is how the alternative impacts Xcel Energy distribution equipment, operating crews and construction crews operating the distribution system during normal and contingency operations. Operability is evaluated based on system planning criteria that represent the robust capability of the distribution response as described by feeder circuit and substation transformer N-0 and N-1 percent utilization and ease of operation as impacted by integration with the installed distribution delivery system. Integration of non-standard equipment using new and untested technology in the first several generations of implementation are often complicated to operate, or have unanticipated difficulties that require additional engineering to solve problems, additional expenditures, additional equipment, new operating techniques and crew training. New technologies often require several generations of changes to reach simplicity of operation required to maintain present levels of customer service and reliability.

6.2.1.3 Future Growth

Future growth is how the alternative facilitates and enables future infrastructure additions required to serve future customer demand. Possibility for future growth is enhanced by an alternative that addresses future customer demand with the least cost amount of additional distribution infrastructure.

For example, when considering a standard solution, an alternative that locates a substation nearest the load center and has room to add feeder circuits and substation transformers has better future growth possibilities than an alternative that requires adding another substation with an additional transmission line into the Focused Study Area.

6.2.1.4 Cost

Cost is the total cost of the proposed alternative based on indicative estimates and may change with estimate refinement. Cost is the present value of all anticipated expenditures required for an alternative to serve the forecast customer loads through 2028.

6.2.1.5 Electrical Losses

Electrical losses are most often discussed in reference to the additional amount of generation required to make up for the incremental line losses. Increased efficiency in the electrical delivery system reduces the amount of generation needed to serve load. Electrical losses also impact the amount of distribution system equipment by requiring incrementally increased amounts of electrical feeder circuits and substation transformers to make up for electrical energy lost by transporting electrical energy at distribution voltages when compared to using transmission line voltages.

6.2.2 Standard Alternatives

6.2.2.1 A1: Hiawatha and Midtown 115/13.8 kV Distribution Substations and Looped 115 kV Transmission Lines

This option initially included a standard installation with an ultimate design capacity of six (6) distribution substation transformers with a total of 30 feeder circuits located at two new substation locations. As initially designed, each substation location would have included a standard installation of three (3) substation transformers and up to fifteen (15) feeder circuits. Subsequently, this option was modified to include an ultimate design capacity of five distribution substation transformers with a total of 30 feeder circuits located at two new substation locations.

One substation would be located near the existing site of the former Hiawatha Substation which requires a short 115 kV transmission line extension to tap the existing Elliot Park – Southtown 115 kV transmission line into the substation site. This substation would have an ultimate design capacity for a total of three 50 MVA substation transformers and up to 15 feeder circuits.

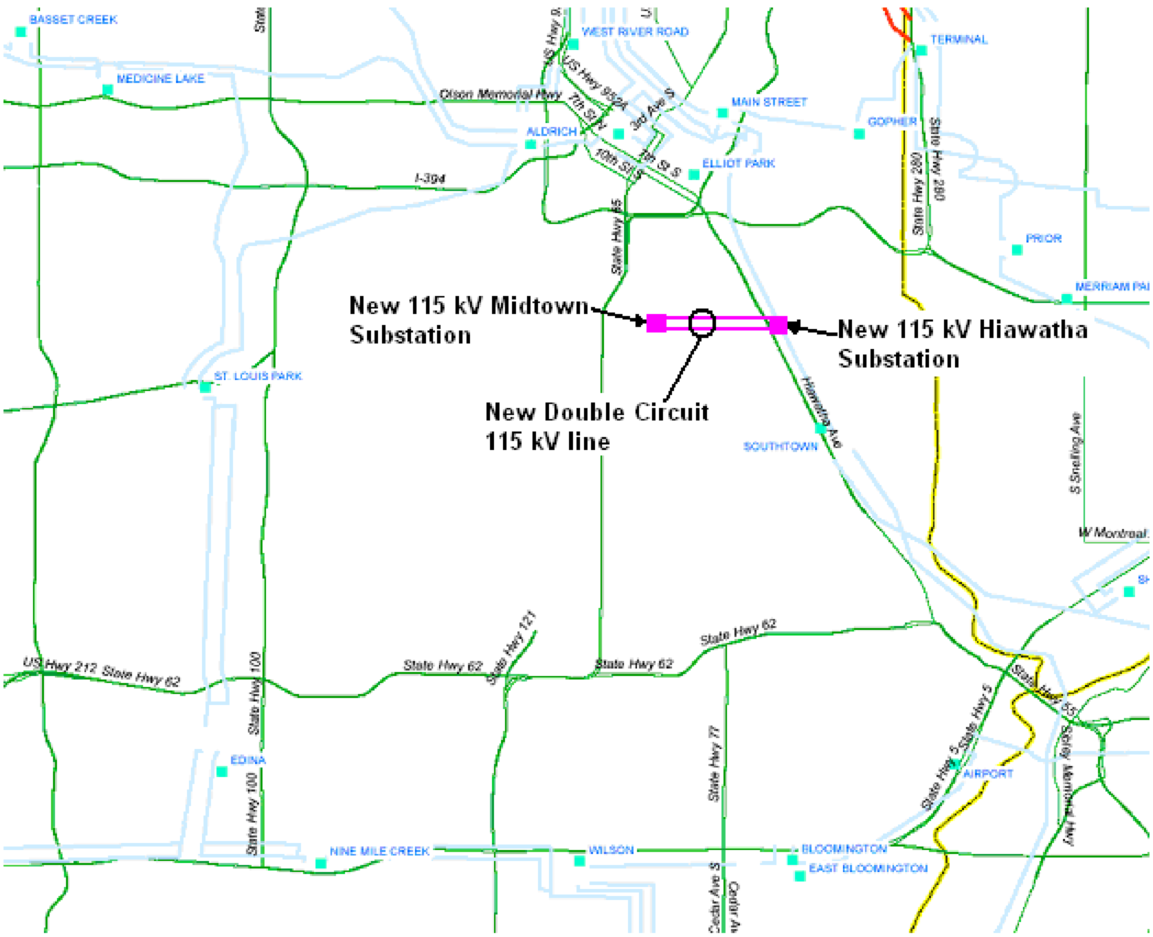
The second new substation would be located close to the identified load center and nexus of feeder circuits that need additional capacity, which is west of Chicago Avenue and east of I-

35W in the Midtown area. This proposed substation would have an ultimate design capacity of two 70 MVA substation transformers, instead of the standard three 50 MVA substation transformers, and up to 15 feeder circuits. The Midtown substation taps the existing Elliot Park – Southtown 115 kV transmission line. Two additional transmission lines would be located between the Hiawatha Avenue and the new Midtown area substations.

The initial installation includes a single substation transformer and five (5) associated feeder circuits installed at each of two substation locations.

Figure 6.1 illustrates the A1 configuration.

Figure 6.1: A1 – Hiawatha and Midtown 115/13.8 kV Distribution Substations and Looped Transmission Lines



A1 best satisfies the Planning Engineers' criteria. With respect to System Performance, A1 installs additional substation transformer capacity at two new substations at or near the identified load center in the Focused Study Area. As a result, A1 requires shorter feeder circuits to serve load from these two new substations. Shorter feeder circuits consist of less equipment, have fewer elements that can fail, and have less exposure to external factors that increase the chance of feeder outages. A1 is capable of maintaining adequate voltage on feeder circuits. A1 also has the best operability over the other alternatives. A1 is an extension of the existing simple distribution system and provides for a large number of standard options that could be quickly implemented under contingency conditions. With respect to Future Growth, A1 provides possibilities for future capacity additions in an area expected to experience significant growth in electricity demand. A1 addresses future load serving needs.

A1, at ultimate design capacity, is estimated to cost approximately $55.9 million and is the lowest cost alternative. Staging costs include the following:

- 2010
  - Hiawatha 115 kV substation - $14,300,000
  - Midtown 115 kV substation - $11,120,000
  - Double circuit 115 kV line between Hiawatha-Midtown - $3,310,000
  - Distribution duct and feeder circuits - $4,650,000
  - Total Distribution Costs - $33,380,000
- 2016
  - 2nd substation transformer added at Midtown - $6,570,000
  - Distribution duct and feeder circuits - $1,950,000
  - Total Distribution Costs - $8,520,000
- 2017
  - 2nd substation transformer added at Hiawatha - $5,175,000
  - Distribution duct and feeder circuits - $3,150,000
  - Total Distribution Costs - $8,325,000
- 2023
  - 3rd substation transformer added at Hiawatha - $3,930,000
  - Distribution duct and feeder circuits - $1,700,000
  - Total Distribution Costs - $5,630,000

Cost information for A1 is provided in Appendix G.

With respect to electrical losses, A1 has the lowest line losses because it utilizes 115 kV transmission lines to transmit power from Hiawatha Avenue to the load center. A1 is the lowest loss and A3 the highest loss alternative of A1 through A4. By using SynerGEE and performing a load flow the loss difference between A1 and A3 at peak was determined and found to be around 1 MW. This 1 MW is the same as the MW $\text{reduction}_{\text{PEAK}}$ value that is discussed in Appendix F. Over the 20-year view of this Study there would be approximately 42,000 MWh in savings, which correlates to 40,000 tons of CO_2 in savings and $3.8 million saved.

6.2.2.2 A2: Hiawatha and West Midtown 115/13.8 kV Distribution Substations and Looped 115 kV Transmission Lines

This option includes an ultimate design capacity of six (6) distribution substation transformers with a total of 30 feeder circuits located at two new substation locations. Each substation location includes three (3) substation transformers and up to fifteen (15) feeder circuits.

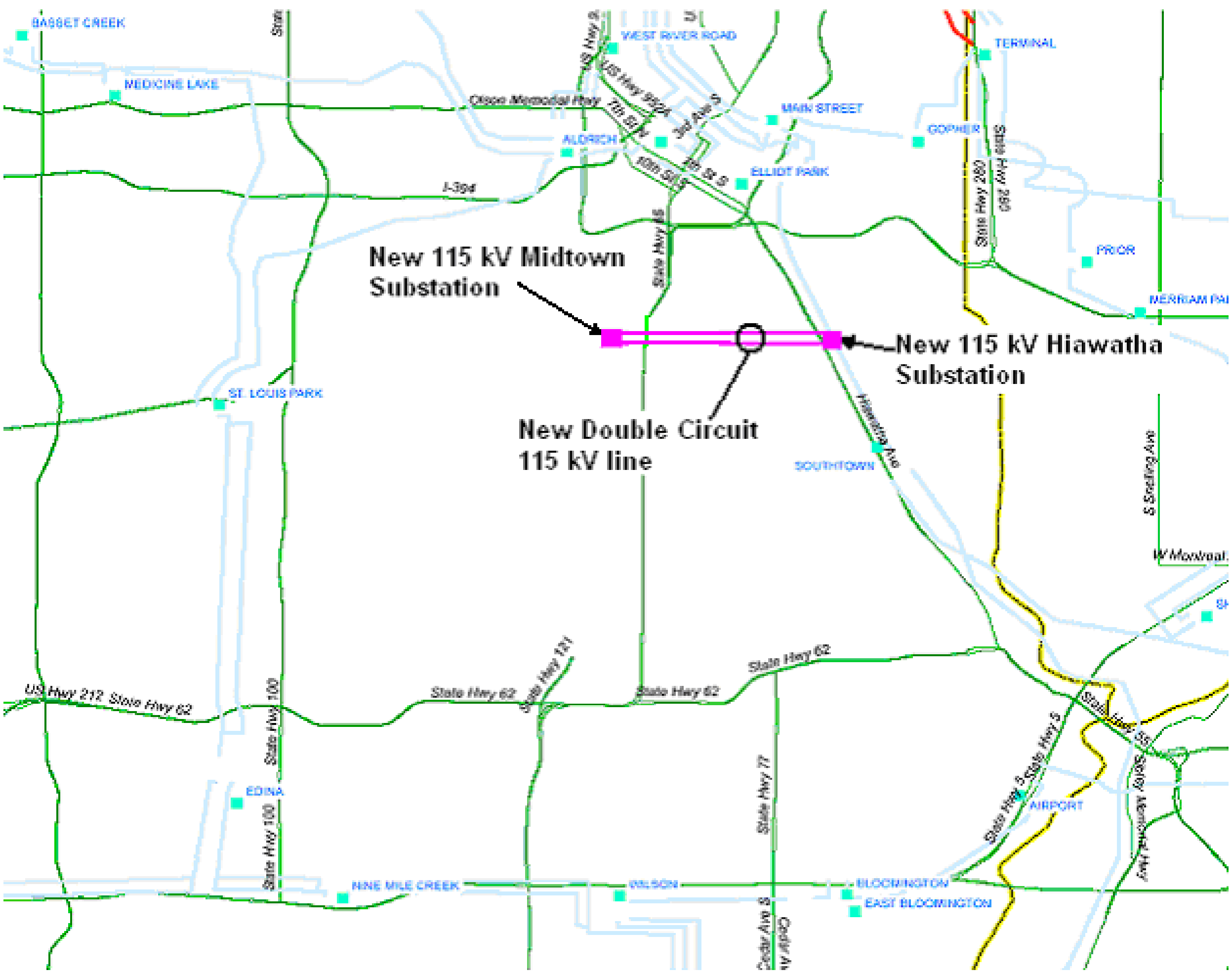
One substation would be located near the existing site of the former Hiawatha Substation which requires a short 115 kV transmission line extension to tap the existing Elliot Park – Southtown 115 kV transmission line into the substation site.

The second new substation would be located west of the Interstate 35W in the Midtown area. The Midtown substation taps the existing Elliot Park – Southtown 115 kV transmission line. Two additional transmission lines would be located between the Hiawatha Avenue and the new Midtown area substations.

The initial installation includes a single substation transformer and five (5) associated feeder circuits installed at two substation locations.

Figure 6.2 illustrates the A2 configuration.

Figure 6.2: A2 – Hiawatha and West Midtown 115/13.8 kV Distribution Substations and Looped 115 kV Transmission Lines



A2 meets the various criteria by which Planning Engineers compared each alternative. With respect to System Performance, A2 installs additional substation transformer capacity at two new substations, one of which would be located west of Interstate 35W in the Midtown area, a greater distance than the substations under A1 from the identified load center in the Focused Study Area. As a result, A2 requires slightly longer feeder circuits than A1 to serve load, and therefore, is subject to slightly greater exposure to conditions that could lead to line failures. With respect to Operability, similar to A1, A2 is an extension of the existing distribution system and provides for a large number of standard options that could be quickly implemented under contingency conditions. With respect to Future Growth, A2 provides possibilities for future capacity additions in an area expected to experience significant growth in electricity demand, but requires more infrastructure than A1. A2 addresses future load serving needs.

A2 is estimated to cost approximately $60.6 million. Staging costs include the following:

- 2010
    - Hiawatha 115 kV substation - $14,300,000
    - Midtown 115 kV Substation - $17,130,000
    - Double Circuit 115 kV line between Hiawatha-Midtown - $6,320,000
    - Distribution duct and feeder circuits - $4,650,000
    - Total Distribution Costs - $42,400,000
- 2016
    - 2nd substation transformer added at Midtown - $2,000,000
    - Distribution duct and feeder circuits - $2,250,000
    - Total Distribution Costs - $4,250,000
- 2017
    - 2nd substation transformer added at Hiawatha - $5,175,000
    - Distribution duct and feeder circuits - $3,150,000
    - Total Distribution Costs - $8,325,000
- 2023
    - 3rd substation transformer added at Hiawatha - $3,930,000
    - Distribution duct and feeder circuits - $1,700,000
    - Total Distribution Costs - $5,630,000

A2 costs more than A1 due to a higher transmission line cost for a longer 115 kV line, higher site development costs, and higher feeder circuit costs. Cost information for A2 is provided in Appendix G.

With respect to electrical losses, A2 has the second lowest line losses of the four alternatives because it utilizes 115 kV transmission lines to transmit power from Hiawatha Avenue to the west of the load center.

6.2.3 Non-Standard Alternatives – Use Distribution Voltages Instead of Transmission Voltages to Transmit Power to the Midtown Area

6.2.3.1 <u>A3: Hiawatha 13.8 kV Distribution and Express 13.8 kV Feeders to the Load Center</u>

This option includes an ultimate design capacity of six (6) distribution substation transformers with a total of thirty (30) feeder circuits located at one new substation location.

Three of the substation transformers at 115/13.8 kV serve fifteen (15) 13.8 kV feeder circuits that serve customer loads directly from the substation location.

Three of the substation transformers serve fifteen (15) feeder circuits that are express circuits installed in duct banks from the Hiawatha Substation site to the nexus of the 13.8 kV feeder circuits located near the existing former Oakland Substation in the Midtown area.

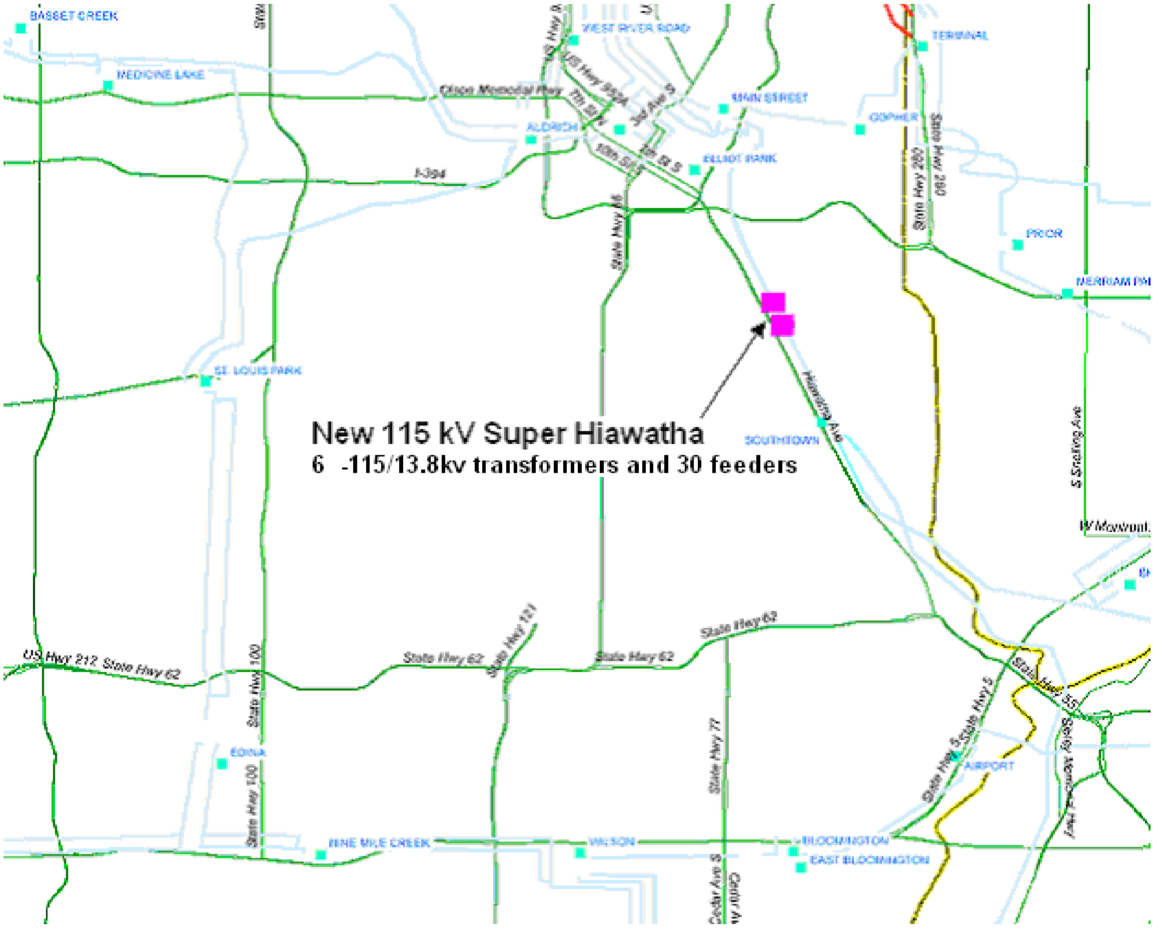
A distribution substation with an ultimate capacity of six (6) distribution transformers and 30 feeder circuits with 15 express feeder circuits instead of a 115 kV transmission line is a non-standard installation.

One substation would be located near the existing site of the former Hiawatha Substation which requires a short transmission line extension to tap the existing Elliot Park – Southtown 115 kV transmission line into the substation site and more extensive 115 kV equipment installation in the substation to enable the installation of six (6) substation transformers. The proposed site requires a larger physical size than the substation considered in A1 or A2.

The initial installation includes two substation transformers and ten associated feeder circuits at one substation site. The first 115/13.8 kV transformer with 5 associated feeder circuits would serve distribution customer load directly from the substation location. The second 115/13.8 kV transformer, also installed in the same substation site has five (5) 13.8 kV express feeders installed in at least 12,000 feet long manhole and duct bank(s) installed from Hiawatha Substation site to the nexus of feeder circuits at the existing former Oakland Substation site near Oakland Avenue and 29th Street in the Midtown area. The length of the duct line and express feeders will be determined by the exact location of the Hiawatha Substation. The five 13.8 kV feeder circuits are connected to existing feeders at the former Oakland Substation site.

Figure 6.3 illustrates the A3 configuration.

Figure 6.3: A3 – Large Hiawatha 115/13.8 kV Distribution Substation and 13.8 kV Express Feeders



With respect to System Performance, A3 does not meet voltage requirements. A load flow run on the system model configured for A3 indicated system-intact N-0 voltage problems on two of the express feeders constructed to serve customer load west of the load center. These heavily loaded feeders would serve loads as far as four miles from the distribution substation, and the feeders do not maintain voltages that comply with the tolerances for voltage at the customer meter (±5% of 120 volt nominal) as stated in American National Standards Institute ("ANSI") Standard C84.1 entitled Electric Power Systems and Equipment – Voltage Ratings (60 Hertz). A3 feeder circuits also do not meet minimum voltage requirements under N-1, first contingency conditions. A3 has the longest feeder circuits of the four alternatives. Longer feeder circuits consist of more equipment, have more elements that can fail, and have more exposure to external factors that increase the chance of feeder outages. A3 is the worst alternative with respect to System Performance.

With respect to Operability, A3 uses standard distribution delivery components in a non-standard way, making A3 more vulnerable during overload and outage conditions. A3 also uses long express feeder circuits that require many more components to keep in running order and fully operational during all possible conditions.

With respect to Future Growth, A3 provides roughly equal possibilities for future capacity additions as do A1 and A2 in an area expected to experience significant growth in electricity demand. A3 addresses future load serving needs.

A3 is estimated to cost approximately $60 million and is the third most expensive alternative. Staging costs include the following:

- 2010
    - Hiawatha 115 kV substation - $15,160,000
    - Distribution duct and feeder circuits - $6,650,000
    - Total Distribution Costs - $21,810,000
- 2016
    - 3rd substation transformer added at Hiawatha - $5,210,000
    - Distribution duct and feeder circuits - $8,000,000
    - Total Distribution Costs - $13,210,000
- 2017
    - 4th substation transformer added at Hiawatha - $4,530,000
    - Distribution duct and feeder circuits - $10,400,000
    - Total Distribution Costs - $14,930,000
- 2023
    - 5th substation transformer added at Hiawatha - $7,900,000
    - Distribution duct and feeder circuits - $2,200,000
    - Total Distribution Costs - $10,100,000

Cost information for A3 is provided in Appendix G.

With respect to electrical losses, A3 results in more electrical losses than either A1 or A2 because it requires one substation and utilizes 13.8 kV feeder circuits instead of 115 kV transmission lines to transmit power from Hiawatha substation to the load center near the existing former Oakland substation. By using SynerGEE and performing a load flow the loss difference between A3 and A1 peak was determined to be around 1 MW. This 1 MW is the same as the MW reduction_{PEAK} value that was discussed in Appendix F describing electric losses. Over the 20-year view of this Study there would be approximately 42,000 MWh in additional cost to A3 above A1, which correlates to 40,000 tons of CO_2 in cost and $3.8 million higher cost.

6.2.3.2 A4: Hiawatha 13.8 kV Distribution and 34.5 kV Sub-Transmission with Three Substations in Midtown for 13.8 kV Distribution

This option includes an ultimate design capacity of 14 distribution substation transformers with a total of 37 feeder circuits located at four new substation locations.

The first substation location contains six substation transformers. Three of the substation transformers at 115/13.8 kV serve fifteen (15) 13.8 kV feeder circuits that serve customer loads directly from the substation location. Three of the substation transformers at 115/34.5 kV serve six (6) 34.5 kV feeder circuits that are express circuits installed in duct banks from the Hiawatha Substation site to the three 34.5/13.8 kV substations.

The second substation location contains four substation transformers. The third and fourth substation locations each contain two substation transformers. The three 34.5/13.8 kV substations each are distribution substations fed from 34.5 kV sub-transmission voltage lines. The six (6) 34.5 kV express feeders are installed along an approximately six mile route instead of installing 115 kV transmission lines and a second new transformer located in the Midtown area.

Substation one would be located near the existing site of the former Hiawatha Substation which requires a short transmission line extension to tap the existing Elliot Park – Southtown 115 kV transmission line into the substation site and a more extensive 115 kV equipment installation in the substation to enable the installation of six (6) substation transformers. This substation has an ultimate substation capacity of six (6) substation transformers with three (3) 115/13.8 kV and three (3) 115/34.5 kV. The proposed site requires a larger physical size than the substation considered in A1 or A2.

Substation two, located near the existing site of the former Oakland Substation, has an ultimate capacity of four (4) 34.5/13.8 kV distribution substation transformers which feed eight (8) 13.8 kV feeder circuits. 34.5 kV feeder circuits will be installed in a duct bank about 18,000 feet long from the Hiawatha Substation site to the existing former Oakland Substation site near Oakland Ave and 29th Street. The Oakland Substation site is at the nexus of 13.8 kV feeder circuits nearest the load center in Midtown.

Substation three, located near the existing site of the former Garfield Substation, has an ultimate capacity of two (2) 34.5/13.8 kV distribution substation transformers which feed four (4) 13.8 kV feeder circuits. Two 34.5 kV feeder circuits will be installed in a duct bank about 24,000 feet from the Hiawatha Substation site to the existing former Garfield Substation site west of Interstate 35W near Garfield Ave and 33rd St in the south Minneapolis area.

Substation four, located near the existing site of the former Nicollet Substation, has an ultimate capacity of two (2) 34.5/13.8 kV distribution substation transformers which feed four (4) 13.8 kV feeder circuits. Two 34.5/13.8 kV feeder circuits will be installed in a duct bank about 36,000 feet from the Hiawatha Substation site to the existing former Nicollet Substation site west of Interstate 35W near Nicollet Ave and 47th Street in the south Minneapolis area.

A distribution substation with an ultimate capacity of six distribution transformers and 37 feeder circuits with six (6) 34.5 kV express feeder circuits instead of a 115 kV transmission line is a non-standard installation.

The initial installation requires five substation transformers and fourteen associated feeder circuits; ten (10) feeder circuits at 13.8 kV and four (4) feeder circuits at 34.5 kV at two of the four new substation sites.

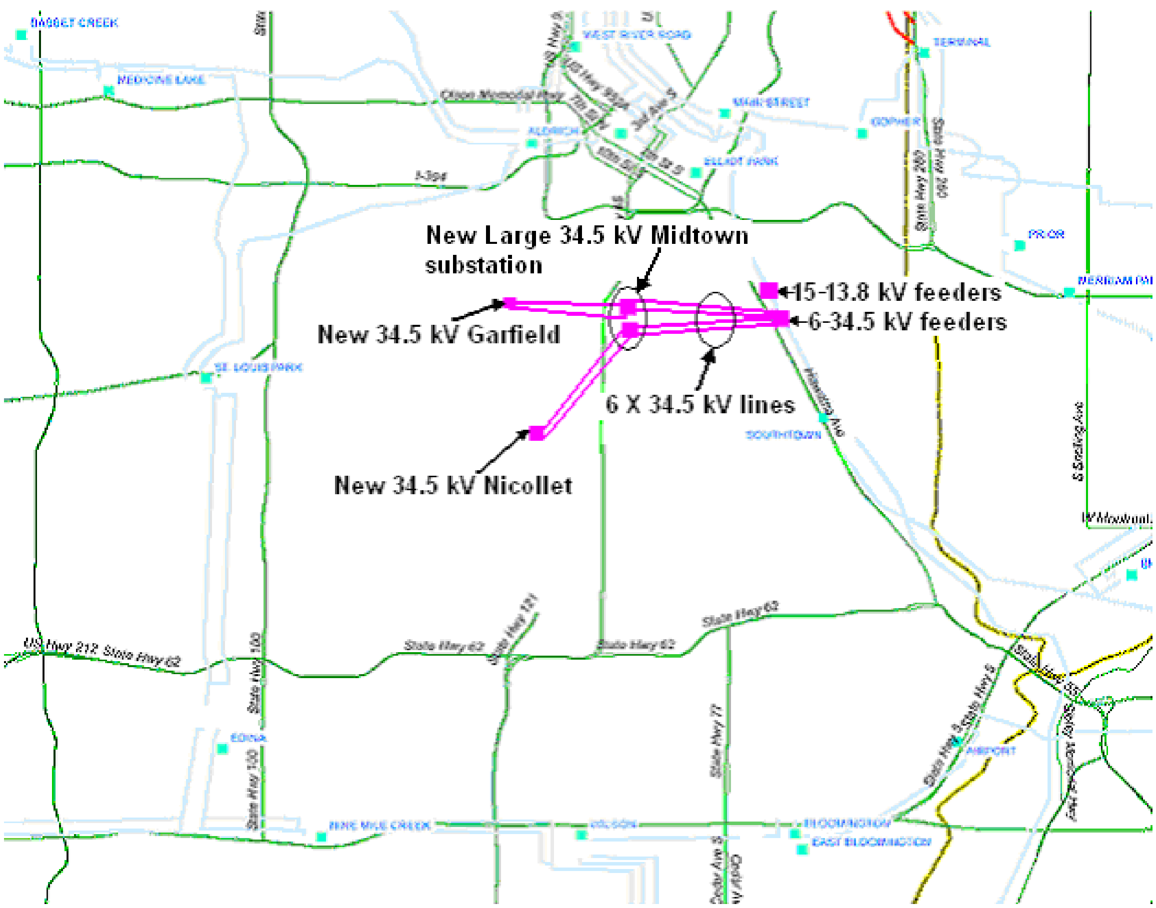
The first 115/13.8 kV transformer is installed at Hiawatha Substation site with five associated feeder circuits that serve distribution customer load directly from the substation location. The second and third 115/34.5 kV transformers are also installed at the Hiawatha substation site with four (4) 34.5 kV express feeders installed in multi-feeder express duct bank(s).

Two 34.5 kV feeder circuits will be installed in a duct bank from the Hiawatha Substation site to the Oakland Substation site. Two 34.5 kV feeder circuits will be installed in a duct bank from the Hiawatha Substation site to the existing former Garfield Substation site west of Interstate 35W.

The fourth and fifth 34.5/13.8 kV transformers are installed near the existing Oakland Substation site and the existing Garfield Substation site, respectively. Each substation transformer is installed in a distribution substation that is fed by a primary and a backup 34.5 kV circuit. The Oakland Substation site will initially serve three (3) 13.8 kV feeder circuits and the Garfield Substation site will initially serve two (2) 13.8 kV feeder circuits.

Figure 6.4 illustrates the configuration of A4.

Figure 6.4: A4 – Large Hiawatha 115/13.8 kV Distribution Substation with 34.5 kV Sub-transmission and Three 13.8 kV Distribution Substations



With respect to System Performance, A4, which installs four substations and uses 34.5 kV as sub-transmission to transmit power, has more exposure to line failures than A1 or A2 due to adding 34.5 kV circuits between the substation and the customer. A4 is capable of maintaining adequate voltage on feeder circuits but is the most complex of the alternatives and requires the most equipment. With respect to Operability, A4 is the worst alternative based on this criterion because it introduces a new distribution voltage and adds another level of transformation at additional 34.5/13.8 kV substations, making operations more difficult and complex.

With respect to Future Growth, A4 is difficult to integrate into the existing distribution delivery system and so would require additional 34.5 kV infrastructure to assist in serving future load, which is possible, but not as easily done as by A1 and A2.

A4 is estimated to cost approximately $122 million. Staging costs include the following:

- 2010
  - Hiawatha 115 kV substation - $25,125,000
  - Oakland 34.5 kV substation - $13,490,000
  - Distribution duct and feeder circuits - $22,500,000
  - Total Distribution Costs - $61,115,000
- 2016
  - 4th substation transformer added at Hiawatha - $9,250,000
  - Garfield 34.5 kV substation - $7,965,000
  - Distribution duct and feeder circuits - $4,950,000
  - Total Distribution Costs - $22,165,000
- 2017
  - 5th substation transformer added at Hiawatha - $7,470,000
  - Nicollet 34.5 kV substation - $11,435,000
  - Distribution duct and feeder circuits - $8,400,000
  - Total Distribution Costs - $27,305,000
- 2023
  - 6th substation transformer added at Hiawatha - $9,715,000
  - Distribution duct and feeder circuits – $1,700,000
  - Total Distribution Costs - $11,415,000

A4 is the highest cost alternative. Cost information for A4 is provided in Appendix G.

With respect to Electrical Losses, A4 has the third highest losses of the four alternatives. A4, which uses 34.5 kV circuits instead of 115 kV transmission lines to transmit power has lower losses than using 13.8 kV, but adds the cost of losses of a second voltage transformation.

6.2.4 Preferred New Distribution Source Alternative

Distribution Planning compared each new source alternative relative to all new source alternatives with respect to each evaluation criteria. The results of the comparison are summarized in the decision matrix in Figure 6.5. Note that A1 has the highest total score using all the criteria and is the preferred alternative.

Figure 6.5: Alternatives Comparison Matrix

ALTERNATIVES COMPARISON CRITERIA	Alternative 1- 2-13.8 kV subs	Alternative 2- 2 subs, 1 west	Alternative 3- 1 sub-13.8 transmit	Alternative 4- 4 subs-34.5 transmit
1-Distribution System Performance	4	3	0	2
2-Operability	3	3	2	1
3- Future Growth	4	3	2	1
4- Cost	4	2	3	1
5-Electrical Losses	4	3	1	2
TOTAL	19	15	7	6
			Not Feasible	

Note: Higher number ranking is a better alternative (*i.e.*, 4 is best). A zero score indicates the alternative is not feasible due to not meeting minimum required standards.

Based on the above analysis, Planning Engineers determined that A1 is the preferred new source alternative because it best satisfies the five established distribution planning criteria. A1 locates a new distribution substation closest to the greatest amount of customer load. A1 has the shortest feeder circuits, resulting in the least amount of customer exposure to outages and the best system performance. It uses the smallest addition of proven reliable elements to relieve existing overloads, resulting in the highest operability of the alternatives considered. The Midtown Substation location proposed in A1 is closest to planned future load growth, so it has the best potential to adapt to future growth. A1 is the least expensive to construct and has the lowest electrical losses, making it the most cost effective and efficient option of the four alternatives that are capable of meeting south Minneapolis customer load requirements.

Transmission Planning Engineers also evaluated the alternatives and determined that double-circuiting the two 115 kV transmission lines connecting the two substations in A1 would not impair the performance of the facilities with respect to the distribution capacity need.

7.0 RECOMMENDATION

Distribution Planning recommends A1 to meet the identified capacity needs on the south Minneapolis electrical distribution delivery system in the Focused Study Area. To confirm that A1 will mitigate the feeder overloads in the Focused Study Area, Distribution Planning Engineers analyzed how the distribution system would function after construction of the first phase of A1.

Figure 7.1 displays the area of load served by the two new substation transformers in the context of the Greater Study Area

Figure 7.1: Post-Proposed Project Installation: Load Served by New Hiawatha and Midtown Substations

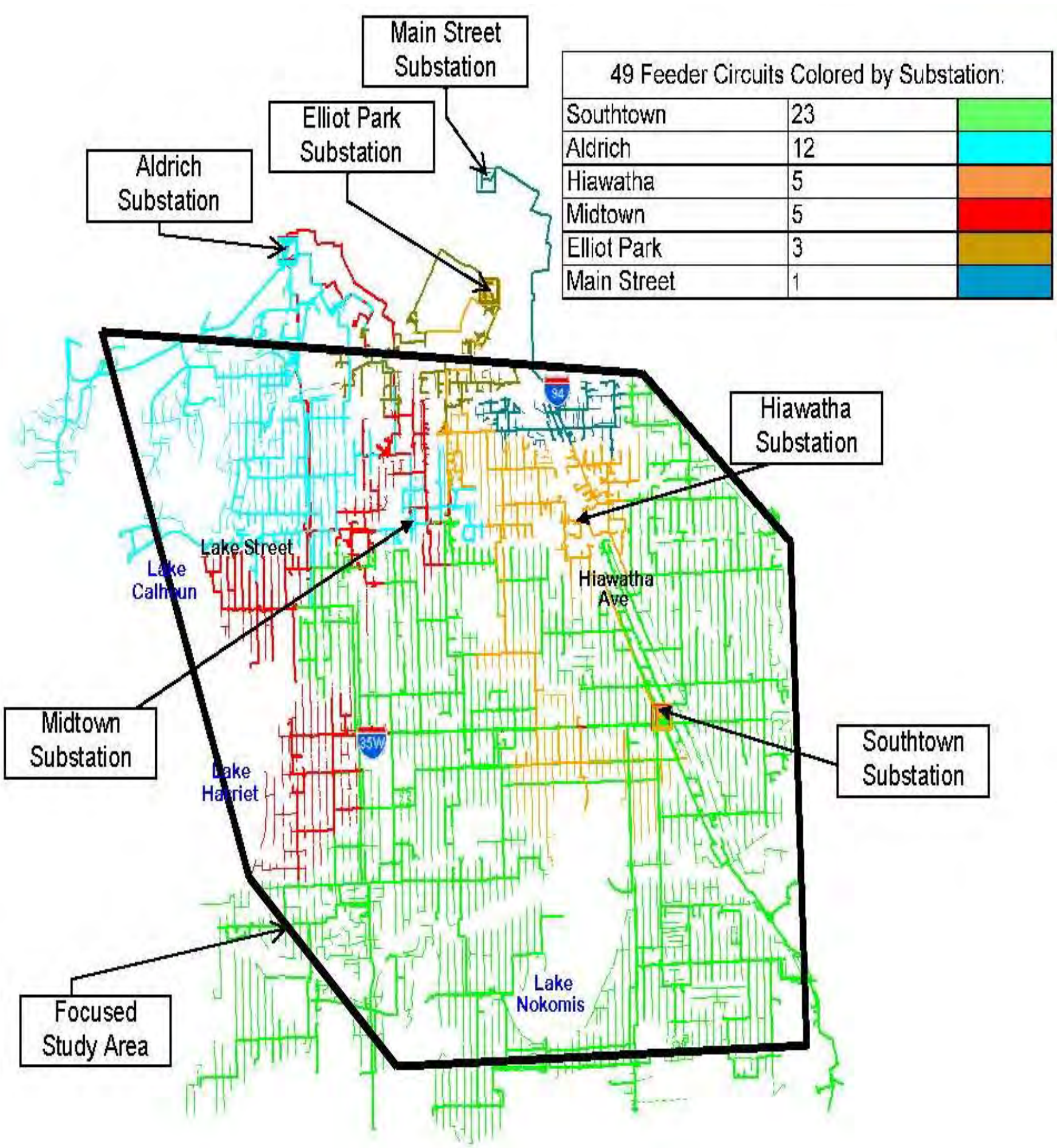
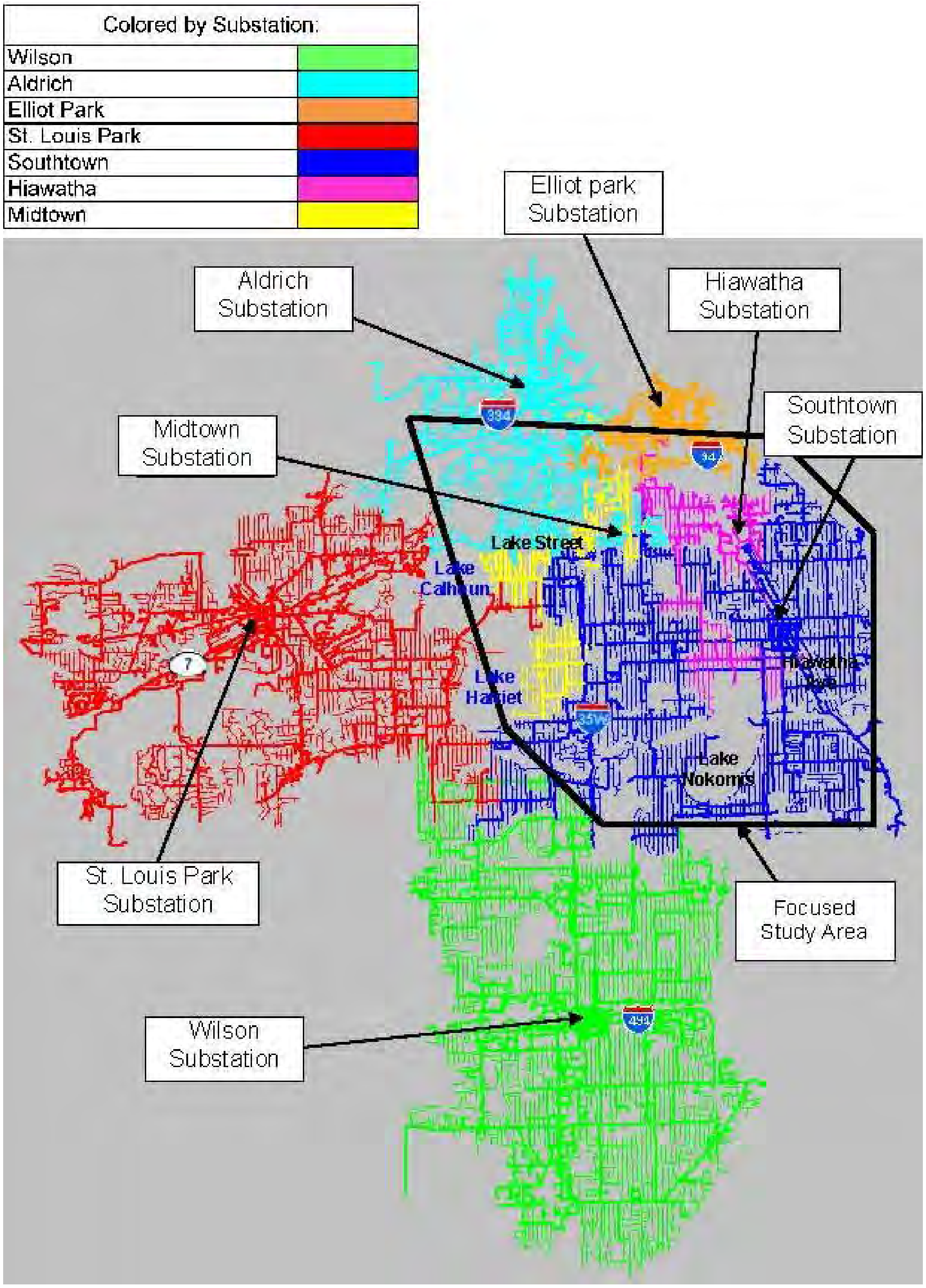


Figure 7.2 displays the area of load served by the ten (10) new feeder circuits from two (2) new substation transformers at two new substations that comprise A1 in the context of the Focused Study Area

Figure 7.2: Post-Proposed Project Installation: Load Served by 49 Feeder Circuits in Focused Study Area

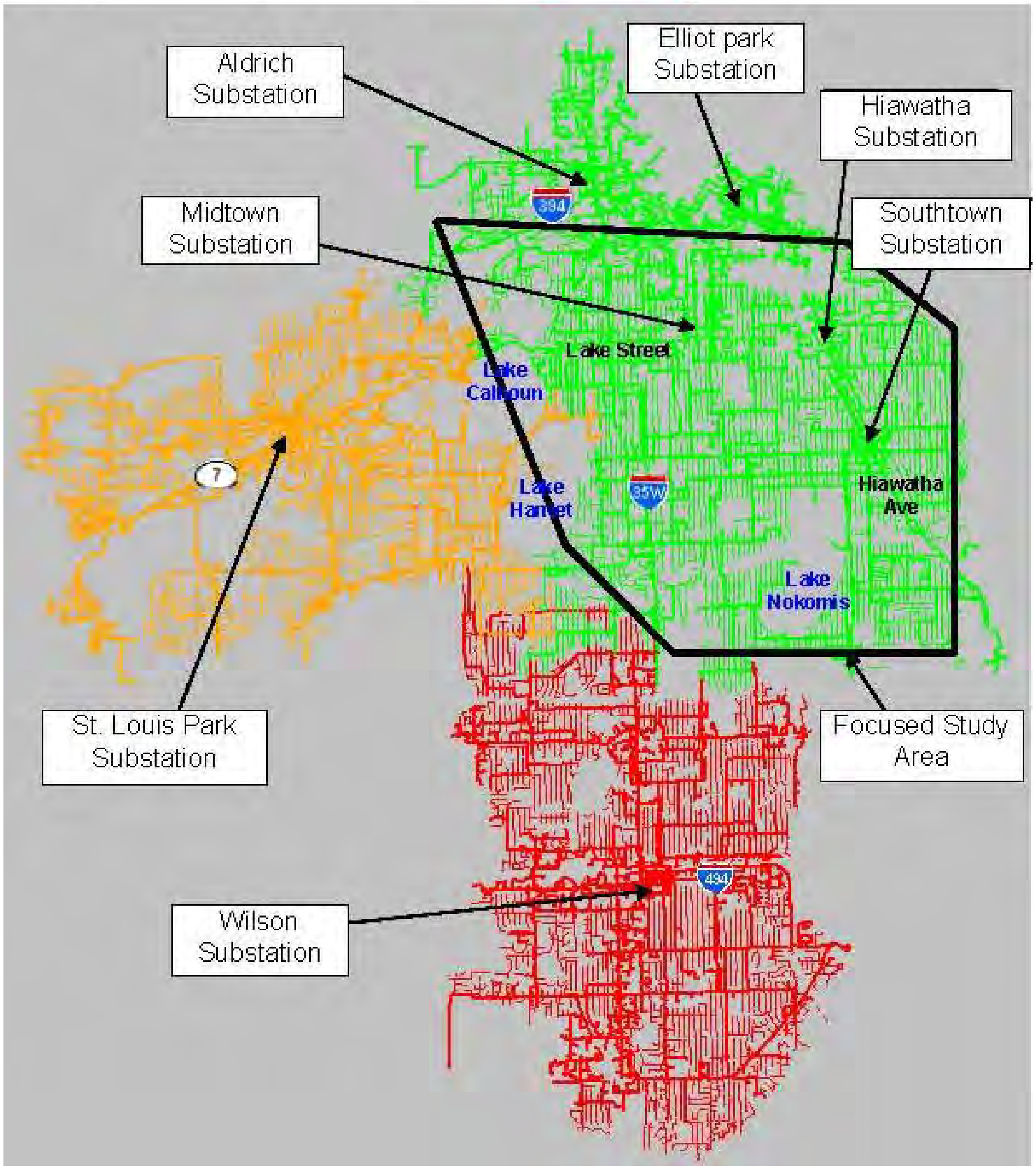


Contingency overloads of Southtown and Aldrich substation transformers are solved by the addition of the two new substation transformers. The overloaded transformers at St Louis Park and Wilson substations are beyond the range of feeder circuits from the new substations and are not impacted by the new substations in the Midtown area. Forecast substation overloads for the duration of the study period can be solved by adding substation transformers to the recommended substations within the initial fenced limits of the new substations.

Figure 7.3 displays the overloaded transformers in the Greater Study Area after the two new substation transformers and ten new feeder circuits are installed.

Figure 7.3: Post-Proposed Project Installation: 2010 N-1 Contingency Substation Transformer Risks

Colored by Substation:		
0	11 Transformers	(green)
0 to 10 MW		(yellow)
10 MW to 25 MW	3 Transformers	(orange)
> 25 MW	3 Transformers	(red)

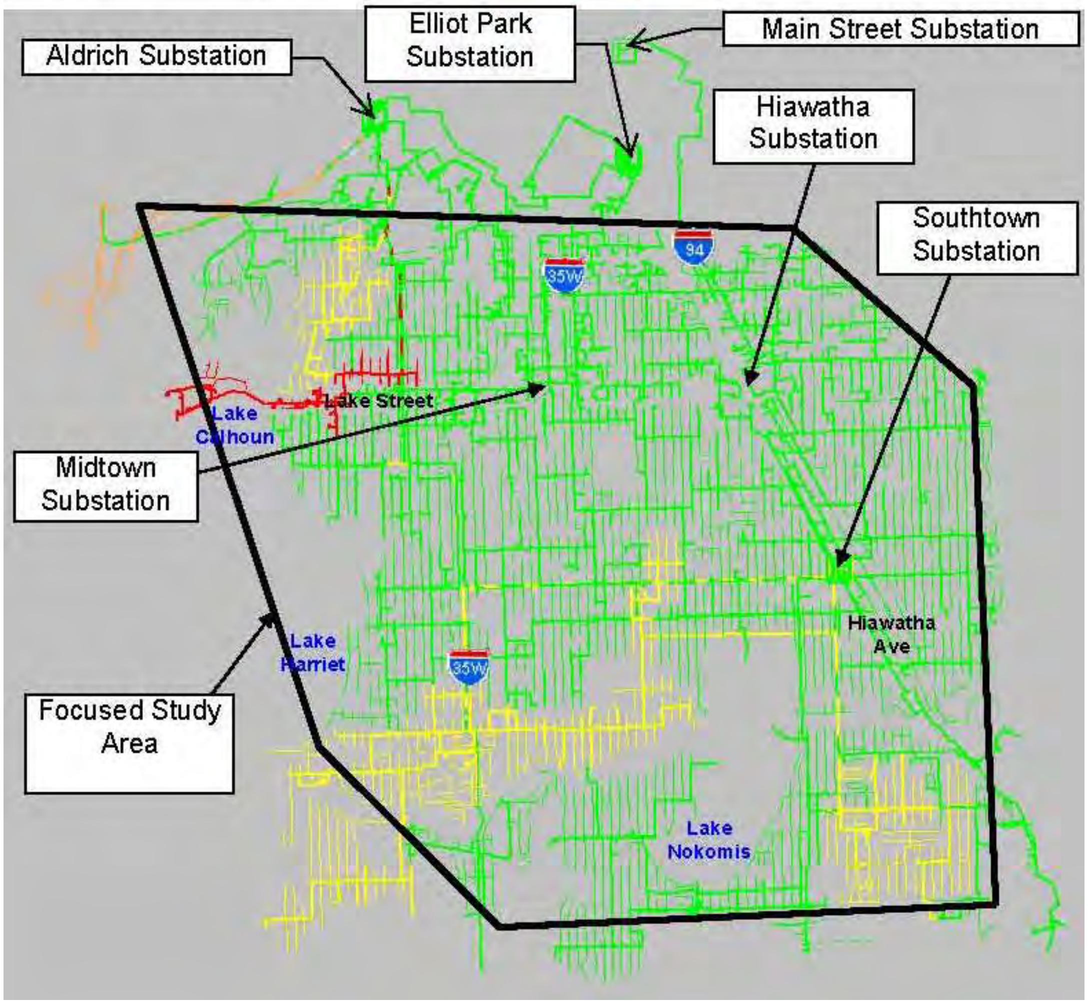


All N-0 system intact overloads in the Focused Study Area can be solved by the addition of the ten new feeder circuits. There are no system intact overloads on 43 of 49 feeder circuits due to the additional circuits. The six (6) remaining overloads shown from Aldrich and Southtown substations will be solved by a cascaded sequence of rerouting and reconfiguring feeder circuits that are directly relieved by the new feeder circuits.

Figure 7.4 shows the N-0 feeder circuit overloads solved directly by the ten new feeder circuits of the recommended alternative.

Figure 7.4: Post-Proposed Project Installation: 2010 N-0 Feeder Circuit Risks

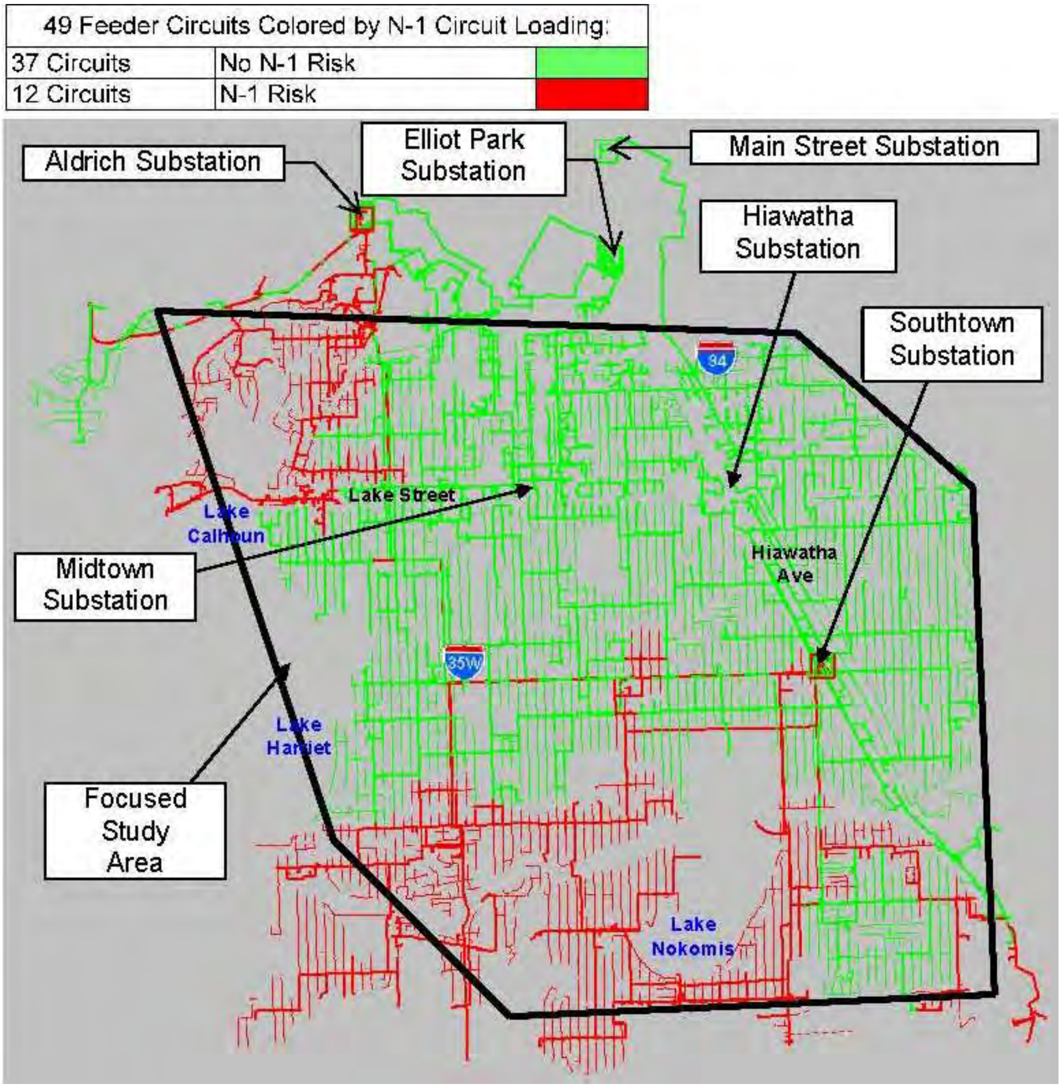
49 Feeder Circuits Colored by N-0 Circuit Loading:		
43 Circuits	<75%	
4 Circuits	75%-100%	
1 Circuit	100%-115%	
1 Circuit	>115%	



The majority of the N-1 first contingency overloads can be solved by the addition of the ten new feeder circuits. Thirty seven (37) of the 49 feeder circuits have no N-1 overload after the addition of 10 new feeder circuits. Rerouting and reconfiguring feeder circuits solves 7 more N-1 overloads that are closest to Southtown and Aldrich substations. Remaining N-1 feeder circuit overloads are beyond the reach of the new and existing substation and feeder circuit additions in the Study Area.

Figure 7.5 shows that the ten new feeder circuits of A1 directly solve the N-1 first contingency feeder circuit overloads.

Figure 7.5: Post-Proposed Project Installation: 2010 N-1 Feeder Circuit Risks



Distribution Planning recommends that the first phase of A1 be constructed to be in-service by 2010/2011.

Appendix A: History of Feeder Circuit Improvements to South Minneapolis Distribution Delivery System to Serve Focused Study Area

To address the increasing demand in the south Minneapolis area, in particular the Focused Study Area, Distribution Planning Engineers have implemented substantial improvements to correct existing feeder circuit overloads, including those listed below:

Reinforced Existing Feeder Circuits to Serve Increasing Customer Load

Feeder circuit reinforcements in the Focused Study Area from 2002 through 2005 include:

Installed larger overhead wire on feeder circuits along 21st Street east of Chicago Avenue and underground on Chicago Avenue south of 19th Street (ELP62).

Installed double underground cable circuits on 42nd Street to west and north (SOU83, SOU86).

Installed double overhead wire on 10th Avenue and Elliot north of 42nd to Lake Street (SOU84, ALD81).

Installed double underground cable and double deck overhead circuits south (SOU61, SOU64).

Rearranged Feeder Circuits to Get Capacity to Overloads

Feeder circuit rearrangements in the Focused Study Area from 2002 through 2007 in specific areas in response to specific load additions include:

Chicago Ave (SOU66, ELP84)

New Southtown Circuit east (SOU69)

Uptown, Lake St (ALD72, ALD92)

Veterans Administration Hospital, Hiawatha Ave (SOU65, SOU76)

Abbott Hospital (SOU84, ALD81)

Midtown Exchange (SOU81)

Feeder Circuit Solutions to Address Widespread Feeder Circuit Overloads

Feeder circuit condition based equipment replacement for feeder circuits located in the Focused Study Area from 2001 through 2006 include:

2001 to 2004 – Identified and aggressively replaced more than 120 damaged feeder circuit cables in the south Minneapolis Study Area.

Replaced overhead feeder wire south (SOU79)

Replaced feeder cable north (SOU66, SOU68)

Replaced feeder cable south (SOU65, SOU76)

Replaced overhead feeder wire north (SOU60)

Other Improvements to the Electrical System

Distribution system improvements from 2001 to 2008 in the Focused Study Area include:

Addition of capacitor banks to maintain voltage on deficient feeder circuits

Annual Feeder Circuit Reliability Reviews included multiple circuits in the study area

Line clearance (tree trimming) of multiple overhead feeder circuits selected based on a combination of time since last line clearance and feeder circuit performance

Converted 4 kV substations to standard system voltage (Garfield – 2003, Oakland - 2005, Nicollet – 2006)

Targeted distribution transformer overloads (on the pole in the alley) caused by MAC sound reduction air conditioner additions, and

Reduced peak related outages (due to bigger transformers and more transformers on poles and on pads serving each block).

New Feeder Circuits

Feeder circuit additions and adding new feeder breakers equipment to re-commission previously decommissioned substation feeders in the Focused Study Area from 2002 through 2006 include:

New Elliot Park Circuit south (ELP81)

New Elliot Park Circuit south (ELP84)

New Southtown Circuit east (SOU69)

New Southtown Circuit west (SOU78)

New Southtown Circuit north (SOU79)

New Southtown Circuit north (SOU88)

Appendix B: Feeder Circuit Forecasts for Focused Study Area

Feeder Circuit Load (kVA) History and Forecast

Appendix B, Table 1

Historical Peak Loads

Forecast Peak Loads

Feeder	00 Cap	04 Cap	2008 Capacity	2000 Peak	2001 Peak	2002 Peak	2003 Peak	2004 Peak	2005 Peak	2006 Peak	2007 Peak	2008 Peak	2009 Fcst	2010	2011	2012	2013	2018	2023	2028	% Growth		SOU	ALD	ELP	MST
ALD071	7600	7600	7600	10135	10100	10800	9900	8100	8330	8550	8560	6191	7284	7393	7504	7617	7731	8328	8971	9664	1.077222			1		
ALD072	7600	7600	7600	9514	9600	10900	9600	10700	10910	7930	7730	7770	8048	8128	8209	8292	8374	9246	10209	11272	1.104132			1		
ALD073	7600	7600	7600	8697	9600	12900	12600	10100	5490	6050	5660	5690	5947	6006	6066	6127	6188	6504	6836	7185	1.051067			1		
ALD074	7600	7600	7600	7513	1950	2000	2600	6700	7730	6710	5950	5720	6527	6592	6658	6725	6792	7139	7504	7887	1.05109			1		
ALD081	7800	7800	7800	8412	5300	6700	8300	6700	6960	10940	10220	10630	10736	10844	10952	11062	11172	11742	12341	12971	1.05102			1		
ALD083	9600	9600	9600	7799	6700	9500	3700	4800	4970	5280	5180	4980	5230	5282	5335	5388	5442	5720	6012	6319	1.051084			1		
ALD085	9894	9894	9894	9800	9800	11000	10200	6100	6100	9070	8380	7770	8148	8229	8311	8395	8479	8911	9365	9842	1.050949			1		
ALD088	10100	10100	10100	5798	4600	4600	9200	5100	7700	6140	6190	6050	6110	6172	6233	6296	6359	6683	7024	7381	1.050951			1		
ALD091	7700	7700	7700	8493	6700	6700	8800	9300	9450	9120	8520	7490	7565	7641	7717	7794	7872	8442	9053	9709	1.072409			1		
ALD092	10100	10100	10100	8657	9000	9000	9200	12500	12930	10480	10370	12480	13105	13236	13368	13502	13637	14333	15065	15833	1.051038			1		
ALD093	7700	7700	7700	6942	7800	9000	1200	2000	2490	5510	3950	8220	8302	8385	8469	8554	8639	9080	9544	10031	1.051048			1		
ALD095	10690	10690	10690	12413	14000	15900	14000	13100	14420	9940	11800	9285	9424	9566	9709	9855	10003	10663	11367	12117	1.06598			1		
ELP071	7700	7700	7700	9800	10500	11500	10200	7100	6960	10320	9430	8733	8818	8906	8996	9085	9176	9644	10136	10653	1.051003				1	
ELP081		10197	10197	0	0	0	0	7600	11700	8860	8360	7620	7696	7773	7851	7929	8009	8417	8846	9296	1.050943				1	
ELP084		10575	10575	0	0	0	3000	6500	7200	6620	7180	7070	7176	7284	7393	7504	7616	8282	9006	9794	1.087447				1	
MST074	10600	10600	10600	8167	10800	8000	8000	9400	10190	10574	9670	9117	9208	9300	9393	9487	9582	10071	10585	11125	1.051033					1
SOU060	10200	10200	10200	5880	6600	6900	7500	8200	6220	6807	6220	4890	4939	4988	5038	5089	5139	5402	5678	5969	1.051177		1			
SOU061		14300	14300	1225	3200	0	5100	5100	11930	13109	11497	8950	8995	9040	9085	9130	9176	9408	9646	9890	1.025283		1			
SOU063	12500	12500	12500	8412	8800	10700	12500	9600	12630	10050	8463	10167	10269	10371	10475	10580	10686	11231	11804	12406	1.051001		1			
SOU064	13900	13900	13900	10628	12600	16900	16900	14000	12430	13990	8870	8521	7189	7333	7483	7633	7782	8592	9486	10474	1.104086		1			
SOU065	9600	9600	9600	4982	6800	9500	6100	6100	6710	7059	6205	6341	6404	6468	6533	6598	6664	7004	7361	7737	1.05102		1			
SOU066	9400	9400	9400	2695	5000	7700	5100	5100	5700	6933	5040	6394	7322	7468	7618	7770	7925	8750	9661	10667	1.104101		1			
SOU068	10000	10000	10000	8657	10300	10700	10400	10800	9450	9642	9691	9584	9680	9777	9874	9973	10073	10587	11127	11695	1.051027		1			
SOU069	13900	13900	13900	8085	8500	8500	7000	4600	5970	5146	4544	3981	4319	4363	4406	4450	4495	4724	4965	5218	1.050945		1			
SOU072	10200	10200	10200	8085	8100	8100	10500	10300	7460	7240	8090	8001	8081	8162	8243	8326	8409	8838	9289	9763	1.051017		1			
SOU073	11400	11400	11400	7187	7600	7700	7500	7500	12430	12500	11882	12196	12436	12686	12945	13204	13463	14857	16395	18093	1.103543		1			
SOU075	9300	9300	9300	10372	10800	12500	13000	10900	8500	9231	9156	9011	9591	9783	9979	10178	10382	11462	12654	13971	1.104026		1			
SOU076	8600	8600	8600	8657	11100	12200	10500	7400	8450	10196	8603	7778	8334	8500	8670	8844	9021	9959	10995	12138	1.10398		1			
SOU077	13600	13600	13600	7758	8700	9200	9200	11400	10940	10837	10429	10914	11023	11133	11245	11357	11471	12056	12671	13317	1.050998		1			
SOU078			13900	2450	3700	0	0	0	4970	5205	5620	5884	6002	6122	6244	6369	6496	7173	7921	8746	1.104218		1			
SOU079			13500	2450	5100	1300	0	0	7460	7778	7793	7152	7674	7750	7828	7906	7985	8392	8820	9269	1.050971		1			
SOU081	8600	8600	8600	9188	10000	10700	11200	6800	6710	7933	7186	7860	8017	8178	8341	8508	8678	9581	10578	11679	1.104056		1			
SOU082	8000	8000	8000	11678	11800	12900	10200	10200	6710	5554	5487	5690	5804	5920	6038	6159	6282	6936	7658	8455	1.104107		1			
SOU083	14000	14000	14000	6043	6200	6700	7600	8800	12780	14662	12186	12779	12907	13036	13166	13298	13431	14116	14836	15593	1.051001		1			
SOU084	12500	12500	12500	8330	9900	9500	10000	7700	8950	8205	7822	7472	7547	7622	7698	7775	7853	8254	8675	9118	1.051063		1			
SOU085	13900	13900	13900	8032	9100	9000	9400	6200	7060	7110	7584	8545	8630	8717	8804	8892	8981	9439	9920	10426	1.050997		1			
SOU086	12500	12500	12500	5553	11500	11500	7500	7300	9940	10662	10766	12104	12225	12347	12471	12595	12721	13370	14052	14769	1.051018		1			
SOU087	9200	9200	9200	7105	7600	9500	8300	8100	9450	9341	9176	8040	8201	8365	8532	8703	8877	9801	10821	11948	1.104089		1			
SOU088			13900	0	0	0	0	0	0	6510	6220	5928	5987	6047	6108	6169	6230	6419	6614	6814	1.030337		1			
Capacity	333584	368656	409956	33	36	34	35	36	38	39	39	39	39									39	23	12	3	1
# Fdrs	33	36	39																							

Feeder	00 Cap	04 Cap	2008 Capacity	2000	2001	2002	2003	2004 peak	2005 Peak	2006 Peak	2007 Peak	2008 Peak	2009 Fcst	2010	2011	2012	2013	2018	2023	2028			SOU	ALD	ELP	MST
MVA	333584	368656	409956	275592	299450	320200	306000	291900	326380	337794	315680	312998	320939	326923	330999	335130	339304	361574	385513	411260		312998	188182	92276	23423	9117
MW	326912	361283	401757	270080	293461	313796	299880	286062	319852	331038	309366	306738	314520	320385	324379	328427	332518	354343	377803	403035		306738	184418	90430	22955	8935
kVA/ Feeder		39		8351	8318	9418	8743	8108	8589	8661	8094	8026	8229	8383	8487	8593	8700	9271	9885	10545		308538	59.8%	29.3%	7.4%	2.9%
		8yr % Growth										1.7%														
		annual % Growth																				Totals				
	DAA kVA Annual Growth			-14708	23858	20750	-14200	-14100	34480	11414	-22114	-2682	7941	5984	4076	4131	4174	22270	23939	25748						
	DAA % Annual Growth Rate			-4.0%	6.4%	5.6%	-4.1%	-4.0%	9.4%	2.9%	-5.4%	-0.7%	1.9%	1.9%	1.2%	1.2%	1.2%	1.2%	1.2%	1.2%						
	DAA % Utilization			83%	80%	93%	86%	79%	83%	83%	77%	76%	78%	80%	81%	82%	83%	88%	94%	100%						
DAA	kVA Over 75%			-3926	19933	61833	39101	17354	31284	32273	8213	5531	13472	19456	23532	27663	31837	54107	78046	103793						
MW				-3847	19534	60596	38319	17006	30658	31627	8049	5420	13203	19067	23061	27110	31200	53025	76485	101718						
	Demand for 1/2% Annual Grow											312998	314563	316136	317716	319305	320902	329005	337313	345830						
	1/2% Growth Rate % Utilizatio											76%	77%	77%	78%	78%	78%	80%	82%	84%						
Peak	Difference (In kVA) from DAA t											0	6376	10787	13283	15825	18402	32569	48200	65430						
Grows																										
1/2%	kVA Over 75%											5531	7096	8669	10249	11838	13435	21538	29846	38363						
MW												5420	6954	8495	10044	11601	13166	21107	29249	37596						

South Minneapolis STUDY

Feeder Circuit Loads - Historic Based Forecast : N-0, N-1 Analysis

Appendix B, Table 2

2009

Feeder	00 Cap	04 Cap	2008 Capacity	2008 % Load	N-0 % Load	kVA >100%	kVA >75%	R >= 115	O	A	G	N-1 R	kVA over
ALD071	7600	7600	7600	81%	96%		1584			1		1	6393
ALD072	7600	7600	7600	102%	106%	448	2348		1			1	2068
ALD073	7600	7600	7600	75%	78%		247			1		1	4195
ALD074	7600	7600	7600	75%	86%		827			1		1	5267
ALD081	7800	7800	7800	136%	138%	2936	4886	1				1	6092
ALD083	9600	9600	9600	52%	54%						1	1	1258
ALD085	9894	9894	9894	79%	82%		728			1		1	2923
ALD088	10100	10100	10100	60%	60%						1	1	1134
ALD091	7700	7700	7700	97%	98%		1790			1		1	1347
ALD092	10100	10100	10100	124%	130%	3005	5530	1				1	5586
ALD093	7700	7700	7700	107%	108%	602	2527		1				
ALD095	10690	10690	10690	87%	88%		1407			1		1	5660
ELP071	7700	7700	7700	113%	115%	1118	3043	1				1	791
ELP081		10197	10197	75%	75%		48			1		1	2477
ELP084		10575	10575	67%	68%						1	1	3101
MST074	10600	10600	10600	86%	87%		1258			1		1	1592
SOU060	10200	10200	10200	48%	48%						1		
SOU061		14300	14300	63%	63%						1	1	2418
SOU063	12500	12500	12500	81%	82%		894			1		1	6887
SOU064	13900	13900	13900	61%	52%						1	1	3734
SOU065	9600	9600	9600	66%	67%						1	1	2015
SOU066	9400	9400	9400	68%	78%		272			1		1	3516
SOU068	10000	10000	10000	96%	97%		2180			1		1	400
SOU069	13900	13900	13900	29%	31%						1		
SOU072	10200	10200	10200	78%	79%		431			1		1	2744
SOU073	11400	11400	11400	107%	109%	1036	3886	1				1	2613
SOU075	9300	9300	9300	97%	103%	291	2616		1			1	879
SOU076	8600	8600	8600	90%	97%		1884			1		1	533
SOU077	13600	13600	13600	80%	81%		823			1		1	810
SOU078			13900	42%	43%						1		
SOU079			13500	53%	57%						1		
SOU081	8600	8600	8600	91%	93%		1567			1		1	2579
SOU082	8000	8000	8000	71%	73%						1	1	2818
SOU083	14000	14000	14000	91%	92%		2407			1		1	6644
SOU084	12500	12500	12500	60%	60%						1	1	4859
SOU085	13900	13900	13900	61%	62%						1		
SOU086	12500	12500	12500	97%	98%		2850			1		1	8126
SOU087	9200	9200	9200	87%	89%		1301			1		1	4132
SOU088			13900	43%	43%						1		
Capacity	333584	368656	409956										
# Fdrs	33	36	39										
Feeder	00 Cap	04 Cap	2008 Capacity	2008 % Load	% Load	kVA >100%	kVA >75%	R >= 115	O	A	G	R	kVA over
MVA	333584	368656	409956	76%	78%	9436	47333	4	3	18	14	32	105591
MW	326912	361283	401757			9247	46387				39		103479
kVA/ Feeder		39				3	21						
		8yr % Growth											
		annual % Growth											
DAA kVA Annual Growth						4	4						
DAA % Annual Growth Rate						7	25						
DAA % Utilization						3145	2254						
DAA kVA Over 75%													
MW						3082	2209						
Demand for 1/2% Annual Growth Rate						1348	1893						
1/2% Growth Rate % Utilization													
Peak Grows 1/2% Difference (in kVA) from DAA to 1/2%													
kVA Over 75%													
MW						1321	1855						

2013

Feeder	N-0 % Load	kVA >100%	kVA >75%	R >= 115	O	A	G	N-1 R	kVA over
ALD071	102%	131	2031		1			1	9153
ALD072	110%	774	2674		1			1	3842
ALD073	81%		488			1		1	4698
ALD074	89%		1092			1		1	5796
ALD081	143%	3372	5322	1				1	6918
ALD083	57%						1	1	3020
ALD085	86%		1059			1		1	5198
ALD088	63%						1	1	2031
ALD091	102%	172	2097		1			1	3587
ALD092	135%	3537	6062	1				1	8023
ALD093	112%	939	2864		1			1	3079
ALD095	94%		1986			1		1	7149
ELP071	119%	1476	3401	1				1	2346
ELP081	79%		361			1		1	6470
ELP084	72%						1	1	3803
MST074	90%		1632			1		1	2989
SOU060	50%						1		
SOU061	64%						1	1	2923
SOU063	85%		1311			1		1	7977
SOU064	56%					1		1	4042
SOU065	69%						1	1	3315
SOU066	84%		875			1		1	5036
SOU068	101%	73	2573		1			1	940
SOU069	32%						1		
SOU072	82%		759			1		1	3836
SOU073	118%	2063	4913	1				1	4750
SOU075	112%	1082	3407		1			1	2729
SOU076	105%	421	2571		1			1	3124
SOU077	84%		1271			1		1	1123
SOU078	47%						1		
SOU079	59%						1		
SOU081	101%	78	2228		1			1	2012
SOU082	79%		282			1		1	3410
SOU083	96%		2931			1		1	8437
SOU084	63%						1	1	8741
SOU085	65%						1		
SOU086	102%	221	3346		1			1	9443
SOU087	96%		1977			1		1	4770
SOU088							1		
Feeder	% Load	kVA >100%	kVA >75%	R >= 115	O	A	G	R	kVA over
MVA	83%	14339	59512	4	9	14	12	33	154710
MW		14052	58322				39		151616
kVA/ Feeder		13	23						
DAA kVA Annual Growth		4	4						
DAA % Annual Growth Rate		17	27						
DAA % Utilization		1103	2587						
DAA kVA Over 75%									
MW		1081	2536						
Demand for 1/2% Annual Growth Rate		843	2204						
MW		827	2160						

2018

Feeder	N-0 % Load	kVA >100%	kVA >75%	R >= 115	O	A	G	N-1 R	kVA over
ALD071	110%	728	2628		1			1	9492
ALD072	122%	1646	3546	1				1	6307
ALD073	86%		804			1		1	6449
ALD074	94%		1439			1		1	6346
ALD081	151%	3942	5892	1				1	8150
ALD083	60%						1	1	4319
ALD085	90%					1		1	7748
ALD088	66%						1	1	3257
ALD091	110%	742	2667		1			1	4608
ALD092	142%	4233	6758	1				1	11297
ALD093	118%	1380	3305	1				1	3392
ALD095	100%		2646		1			1	9158
ELP071	125%	1944	3869	1				1	3808
ELP081	83%		769			1		1	7486
ELP084	78%		351			1		1	4400
MST074	95%		2121			1		1	3514
SOU060	53%						1		
SOU061	66%						1	1	3730
SOU063	90%		1856			1		1	8384
SOU064	62%						1	1	4463
SOU065	73%						1	1	3392
SOU066	93%		1700			1		1	5170
SOU068	106%	587	3087		1			1	1656
SOU069	34%						1		
SOU072	87%		1188			1		1	5425
SOU073	130%	3457	6307	1				1	5484
SOU075	123%	2162	4487	1				1	2559
SOU076	116%	1359	3509	1				1	3383
SOU077	89%		1856			1		1	2760
SOU078	52%						1		
SOU079	62%						1		
SOU081	111%	981	3131		1			1	2552
SOU082	87%		936			1		1	3584
SOU083	101%	116	3616		1			1	9574
SOU084	66%						1	1	9573
SOU085	68%						1		
SOU086	107%	870	3995		1			1	11178
SOU087	107%	601	2901		1			1	5185
SOU088	46%						1		
Feeder	% Load	kVA >100%	kVA >75%	R >= 115	O	A	G	R	kVA over
MVA	88%	24748	75364	8	8	11	12	33	####
MW		24253	73856				39		####
kVA/ Feeder		8	19						
DAA kVA Annual Growth		8	8						
DAA % Annual Growth Rate		16	27						
DAA % Utilization		3094	3967						
DAA kVA Over 75%									
MW		3032	3887						
Demand for 1/2% Annual Growth Rate		1547	2791						
MW		1516	2735						

2023 / 2028

Feeder	2023 N-0 % Load	kVA >100 %	kVA >75%	R >= 115	O	A	G	2028 N-0 % Load	kVA >100 %	kVA >75%	R >= 115	O	A	G
ALD071	118%	1371	3271	1				127%	2064	3964	1			
ALD072	134%	2609	4509	1				148%	3672	5572	1			
ALD073	90%		1136			1		95%	-415	1485		1		
ALD074	99%		1804			1		104%	287	2187		1		
ALD081	158%	4541	6491	1				166%	5171	7121	1			
ALD083	63%						1	66%						1
ALD085	95%		1945			1		99%		2422			1	
ALD088	70%						1	73%						1
ALD091	118%	1353	3278	1				126%	2009	3934	1			
ALD092	149%	4965	7490	1				157%	5733	8258	1			
ALD093	124%	1844	3769	1				130%	2331	4256	1			
ALD095	106%	677	3349		1			113%	1427	4099		1		
ELP071	132%	2436	4361	1				138%	2953	4878	1			
ELP081	87%		1198			1		91%		1649			1	
ELP084	85%		1075			1		93%		1863			1	
MST074	100%		2635		1			105%	525	3175		1		
SOU060	56%						1	59%						1
SOU061	67%						1	69%		-835			1	
SOU063	94%		2429			1		99%	-94	3031		1		
SOU064	68%						1	75%		49			1	
SOU065	77%		161			1		81%		537			1	
SOU066	103%	261	2611		1			113%	1267	3617		1		
SOU068	111%	1127	3627		1			117%	1695	4195	1			
SOU069	36%						1	38%						1
SOU072	91%		1639			1		96%		2113			1	
SOU073	144%	4995	7845	1				159%	6693	9543	1			
SOU075	136%	3354	5679	1				150%	4671	6996	1			
SOU076	128%	2395	4545	1				141%	3538	5688	1			
SOU077	93%		2471			1		98%		3117			1	
SOU078	57%						1	63%						1
SOU079	65%						1	69%						1
SOU081	123%	1978	4128	1				136%	3079	5229	1			
SOU082	96%		1658			1		106%	455	2455		1		
SOU083	106%	836	4336		1			111%	1593	5093	1			
SOU084	69%						1	73%						1
SOU085	71%						1	75%		1			1	
SOU086	112%	1552	4677		1			118%	2269	5394	1			
SOU087	118%	1621	3921	1				130%	2748	5048	1			
SOU088	48%						1	49%						1
Feeder	% Load	kVA >100 %	kVA >75%	R >= 115	O	A	G	% Load	kVA >100 %	kVA >75%	R >= 115	O	A	G
MVA	94%	37914	96037	12	6	10	11	100%	53668	116130	15	7	9	8
MW		37156	94116				39		52595	113807				39
kVA/ Feeder		6	16						7	16				
DAA kVA Annual Growth		12	12						15	15				
DAA % Annual Growth Rate		18	28						22	31				
DAA % Utilization		6319	6002						7667	7258				
DAA kVA Over 75%														
MW		6193	5882						7514	7113				
Demand for 1/2% Annual Growth Rate		2106	3430						2439	3746				
MW		2064	3361						2391	3671				

Feeder Circuit Loads - Historical Analysis

Appendix A, Table 3

				2000 N-0							2004 N-0							2006 N-0							2006 N-1		2008-DAA N-0						
Feeder	00 Cap	04 Cap	2008 Capacity	% Load	kVA >100%	kVA >75%	R>= 115	O	A	G	% Load	kVA >100%	kVA >75%	R>= 115	O	A	G	% Load	kVA >100%	kVA >75%	R>= 115	O	A	G	R	kVA over	% Load	kVA >100%	kVA >75%	R>= 115	O	A	G
ALD071	7600	7600	7600	133%	2535	4435	1				107%	500	2400		1			113%	950	2850		1			1	12567	81%		491			1	
ALD072	7600	7600	7600	125%	1914	3814	1				141%	3100	5000	1				104%	330	2230		1			1	5587	102%	170	2070		1		
ALD073	7600	7600	7600	114%	1097	2997			1		133%	2500	4400			1		80%		350			1		1	7896	75%					1	
ALD074	7600	7600	7600	99%		1813			1		88%		1000			1		88%		1010			1		1	6023	75%		20			1	
ALD081	7800	7800	7800	108%	612	2562		1			86%		850			1		140%	3140	5090	1				1	6587	136%	2830	4780	1			
ALD083	9600	9600	9600	81%		599			1		50%						1	55%						1	1	981	52%						1
ALD085	9894	9894	9894	99%		2380			1		62%						1	92%		1650			1		1	4153	79%		350			1	
ALD088	10100	10100	10100	57%						1	50%						1	61%						1	1	2543	60%						1
ALD091	7700	7700	7700	110%	793	2718		1			121%	1600	3525	1				118%	1420	3345	1				1	2046	97%		1715			1	
ALD092	10100	10100	10100	86%		1082			1		124%	2400	4925	1				104%	380	2905		1			1	7183	124%	2380	4905	1			
ALD093	7700	7700	7700	90%		1167			1		26%						1	72%						1	1	697	107%	520	2445		1		
ALD095	10690	10690	10690	116%	1723	4396	1				123%	2410	5083	1				93%		1923			1		1	6104	87%		1268			1	
ELP071	7700	7700	7700	127%	2100	4025	1				92%		1325			1		134%	2620	4545	1				1	1645	113%	1033	2958		1		
ELP081		10197	10197	0%							75%					1		87%		1212			1		1	737	75%					1	
ELP084		10575	10575	0%							61%						1	63%						1	1	957	67%						1
MST074	10600	10600	10600	77%		217			1		89%		1450			1		100%				1			1	6702	86%					1	
SOU060	10200	10200	10200	58%						1	80%		550				1	67%						1			48%						1
SOU061		14300	14300	9%							36%						1	92%		2384			1		1	9989	63%						1
SOU063	12500	12500	12500	67%						1	77%		225			1		80%		675			1		1	5661	81%		792			1	
SOU064	13900	13900	13900	76%		203			1		101%	100	3575		1			101%	90	3565		1			1	8760	61%						1
SOU065	9600	9600	9600	52%						1	64%						1	74%						1	1	6902	66%						1
SOU066	9400	9400	9400	29%						1	54%						1	74%						1	1	4367	68%						1
SOU068	10000	10000	10000	87%		1157			1		108%	800	3300		1			96%		2142			1		1	2562	96%		2084			1	
SOU069	13900	13900	13900	58%						1	33%						1	37%						1			29%						1
SOU072	10200	10200	10200	79%		435			1		101%	100	2650		1			71%						1	1	6420	78%		351			1	
SOU073	11400	11400	11400	63%						1	66%						1	110%	1100	3950		1					107%	796	3646		1		
SOU075	9300	9300	9300	112%	1072	3397		1			117%	1600	3925	1				99%		2256			1		1	5128	97%		2036			1	
SOU076	8600	8600	8600	101%	57	2207		1			86%		950			1		119%	1596	3746	1				1	8356	90%		1328			1	
SOU077	13600	13600	13600	57%						1	84%		1200			1		80%		637			1		1	2760	80%		714			1	
SOU078			13900	18%							0%						1	37%						1			42%						1
SOU079			13500	18%							0%						1	58%						1			53%						1
SOU081	8600	8600	8600	107%	588	2738		1			79%		350			1		92%		1483			1		1	3368	91%		1410			1	
SOU082	8000	8000	8000	146%	3678	5678	1				128%	2200	4200	1				69%						1	1	4442	71%						1
SOU083	14000	14000	14000	43%						1	63%						1	105%	662	4162		1			1	8020	91%		2279			1	
SOU084	12500	12500	12500	67%						1	62%						1	66%						1	1	9335	60%						1
SOU085	13900	13900	13900	58%						1	45%						1	51%						1			61%						1
SOU086	12500	12500	12500	44%						1	58%						1	85%		1287			1		1	9922	97%		2729			1	
SOU087	9200	9200	9200	77%		205			1		88%		1200			1		102%	141	2441		1			1	4533	87%		1140			1	
SOU088			13900	0%							0%						1	47%						1	1	787	43%						1
Capacity	333584	368656	409956																														
# Fdrs	33	36	39																						R	kVA over							
Feeder	00 Cap	04 Cap	2008 Capacity	% Load	kVA >100%	kVA >75%	>= 115	R	A	G	% Load	kVA >100%	kVA >75%	>= 115	R	A	G	% Load	kVA >100%	kVA >75%	>= 115	R	A	G			% Load	kVA >100%	kVA >75%	>= 115	R	A	G
																									33	173720							
MVA	333584	368656	409956	83%	16169	48224	5	5	11	12	79%	17310	52083	6	4	11	18	82%	12429	55837	4	8	12	15		170246	76%	7729	39510	2	4	18	15
MW	326912	361283	401757		15846	47260				33		16964	51041				39		12180	54721				39				7574	38720				39
kVA/ Feeder		39																															
		8yr % Growth																															
		annual % Growth																															
	DAA kVA Annual Growth																																
	DAA % Annual Growth Rate																																
	DAA % Utilization																																
DAA	kVA Over 75%																																
MW																																	
	Demand for 1/2% Annual Grow																																
	1/2% Growth Rate % Utilizatio																																
Peak	Difference (in kVA) from DAA t																																
Grows																																	
1/2%	kVA Over 75%																																
MW																																	

South Minneapolis STUDY

Feeder Circuit Load - 1/2% Growth Scenario Forecast : N-0, N-1 Analysis

Appendix B, Table 4

2008 N-0 / 2009-1/2% N-0

Feeder	00 Cap	04 Cap	2008 Capacity	2008 Load	% Load	kVA >100%	kVA >75%	R>= 115	O	A	G	2009 Load	% Load	kVA >100%	kVA >75%	R>= 115	O	A	G
ALD071	7600	7600	7600	6191	81%		491			1		6222	82%		522			1	
ALD072	7600	7600	7600	7770	102%	170	2070		1			7809	103%	209	2109		1		
ALD073	7600	7600	7600	5690	75%					1		5718	75%		18			1	
ALD074	7600	7600	7600	5720	75%		20			1		5749	76%		49			1	
ALD081	7800	7800	7800	10630	136%	2830	4780	1				10683	137%	2883	4833	1			
ALD083	9600	9600	9600	4980	52%						1	5005	52%						1
ALD085	9894	9894	9894	7770	79%		350			1		7809	79%		388			1	
ALD088	10100	10100	10100	6050	60%						1	6080	60%						1
ALD091	7700	7700	7700	7490	97%		1715			1		7527	98%		1752			1	
ALD092	10100	10100	10100	12480	124%	2380	4905	1				12542	124%	2442	4967	1			
ALD093	7700	7700	7700	8220	107%	520	2445		1			8261	107%	561	2486		1		
ALD095	10690	10690	10690	9285	87%		1268			1		9331	87%		1314			1	
ELP071	7700	7700	7700	8733	113%	1033	2958		1			8777	114%	1077	3002		1		
ELP081		10197	10197	7620	75%					1		7658	75%		10			1	
ELP084		10575	10575	7070	67%						1	7105	67%						1
MST074	10600	10600	10600	9117	86%		1167			1		9163	86%		1213			1	
SOU060	10200	10200	10200	4890	48%						1	4914	48%						1
SOU061		14300	14300	8950	63%						1	8995	63%						1
SOU063	12500	12500	12500	10167	81%		792			1		10218	82%		843			1	
SOU064	13900	13900	13900	8521	61%						1	8564	62%						1
SOU065	9600	9600	9600	6341	66%						1	6373	66%						1
SOU066	9400	9400	9400	6394	68%						1	6426	68%						1
SOU068	10000	10000	10000	9584	96%		2084			1		9632	96%		2132			1	
SOU069	13900	13900	13900	3981	29%						1	4001	29%						1
SOU072	10200	10200	10200	8001	78%		351			1		8041	79%		391			1	
SOU073	11400	11400	11400	12196	107%	796	3646		1			12257	108%	857	3707		1		
SOU075	9300	9300	9300	9011	97%		2036			1		9056	97%		2081			1	
SOU076	8600	8600	8600	7778	90%		1328			1		7817	91%		1367			1	
SOU077	13600	13600	13600	10914	80%		714			1		10969	81%		769			1	
SOU078			13900	5884	42%						1	5913	43%						1
SOU079			13500	7152	53%						1	7188	53%						1
SOU081	8600	8600	8600	7860	91%		1410			1		7899	92%		1449			1	
SOU082	8000	8000	8000	5690	71%						1	5718	71%						1
SOU083	14000	14000	14000	12779	91%		2279			1		12843	92%		2343			1	
SOU084	12500	12500	12500	7472	60%						1	7509	60%						1
SOU085	13900	13900	13900	8545	61%						1	8588	62%						1
SOU086	12500	12500	12500	12104	97%		2729			1		12165	97%		2790			1	
SOU087	9200	9200	9200	8040	87%		1140			1		8080	88%		1180			1	
SOU088			13900	5928	43%						1	5958	43%						1
Capacity	333584	368656	409956																
# Fdrs	33	36	39																

2013-1/2% N-0 / 2018-1/2% N-0

Feeder	2013 Load	% Load	kVA >100%	kVA >75%	R>= 115	O	A	G	2018 Load	% Load	kVA >100%	kVA >75%	R>= 115	O	A	G
ALD071	6379	84%		679			1		6540	86%		840			1	
ALD072	8006	105%	406	2306		1			8208	108%	608	2508		1		
ALD073	5863	77%		163			1		6011	79%		311			1	
ALD074	5894	78%		194			1		6043	80%		343			1	
ALD081	10953	140%	3153	5103	1				11229	144%	3429	5379	1			
ALD083	5131	53%						1	5261	55%						1
ALD085	8006	81%		586			1		8208	83%		788			1	
ALD088	6234	62%						1	6391	63%						1
ALD091	7718	100%	18	1943		1			7912	103%	212	2137		1		
ALD092	12859	127%	2759	5284	1				13184	131%	3084	5609	1			
ALD093	8470	110%	770	2695		1			8684	113%	984	2909		1		
ALD095	9567	89%		1550			1		9809	92%		1791			1	
ELP071	8998	117%	1298	3223	1				9226	120%	1526	3451	1			
ELP081	7851	77%		204			1		8050	79%		402			1	
ELP084	7285	69%						1	7469	71%						1
MST074	9394	89%		1444			1		9631	91%		1681			1	
SOU060	5039	49%						1	5166	51%						1
SOU061	9222	64%						1	9455	66%						1
SOU063	10476	84%		1101			1		10740	86%		1365			1	
SOU064	8780	63%						1	9002	65%						1
SOU065	6534	68%						1	6699	70%						1
SOU066	6588	70%						1	6755	72%						1
SOU068	9875	99%		2375			1		10124	101%	124	2624		1		
SOU069	4102	30%						1	4206	30%						1
SOU072	8244	81%		594			1		8452	83%		802			1	
SOU073	12566	110%	1166	4016		1			12884	113%	1484	4334		1		
SOU075	9285	100%		2310		1			9519	102%	219	2544		1		
SOU076	8014	93%		1564			1		8217	96%		1767			1	
SOU077	11246	83%		1046			1		11530	85%		1330			1	
SOU078	6063	44%						1	6216	45%						1
SOU079	7369	55%						1	7555	56%						1
SOU081	8099	94%		1649			1		8303	97%		1853			1	
SOU082	5863	73%						1	6011	75%		11			1	
SOU083	13167	94%		2667			1		13500	96%		3000			1	
SOU084	7699	62%						1	7893	63%						1
SOU085	8805	63%						1	9027	65%						1
SOU086	12472	100%		3097		1			12787	102%	287	3412		1		
SOU087	8284	90%	-916	1384			1		8493	92%		1593			1	
SOU088	6108	44%						1	6262	45%						1

2023-1/2% N-0 / 2028-1/2% N-0

Feeder	2023 Load	% Load	kVA >100%	kVA >75%	R>= 115	O	A	G	2028 Load	% Load	kVA >100%	kVA >75%	R>= 115	O	A	G
ALD071	6705	88%		1005			1		6875	90%		1175			1	
ALD072	8415	111%	815	2715		1			8628	114%	1028	2928	1			
ALD073	6163	81%		463			1		6318	83%		618			1	
ALD074	6195	82%		495			1		6352	84%		652			1	
ALD081	11513	148%	3713	5663	1				11804	151%	4004	5954	1			
ALD083	5394	56%						1	5530	58%						1
ALD085	8415	85%		995			1		8628	87%		1207			1	
ALD088	6553	65%						1	6718	67%						1
ALD091	8112	105%	412	2337		1			8317	108%	617	2542		1		
ALD092	13517	134%	3417	5942	1				13858	137%	3758	6283	1			
ALD093	8903	116%	1203	3128	1				9128	119%	1428	3353	1			
ALD095	10056	94%		2039			1		10310	96%		2293			1	
ELP071	9458	123%	1758	3683	1				9697	126%	1997	3922	1			
ELP081	8253	81%		605			1		8461	83%		814			1	
ELP084	7657	72%						1	7851	74%						1
MST074	9874	93%		1924			1		10124	96%		2174			1	
SOU060	5296	52%						1	5430	53%						1
SOU061	9693	68%						1	9938	69%						1
SOU063	11012	88%		1637			1		11290	90%		1915			1	
SOU064	9229	66%						1	9462	68%						1
SOU065	6868	72%						1	7041	73%						1
SOU066	6925	74%						1	7100	76%		50			1	
SOU068	10380	104%	380	2880		1			10642	106%	642	3142		1		
SOU069	4312	31%						1	4421	32%						1
SOU072	8666	85%		1016			1		8884	87%		1234			1	
SOU073	13209	116%	1809	4659	1				13543	119%	2143	4993	1			
SOU075	9760	105%	460	2785		1			10006	108%	706	3031		1		
SOU076	8424	98%		1974			1		8637	100%	37	2187		1		
SOU077	11821	87%		1621			1		12119	89%		1919			1	
SOU078	6373	46%						1	6534	47%						1
SOU079	7746	57%						1	7942	59%						1
SOU081	8513	99%		2063			1		8728	101%	128	2278		1		
SOU082	6163	77%		163			1		6318	79%		318			1	
SOU083	13841	99%		3341			1		14190	101%	190	3690		1		
SOU084	8093	65%						1	8297	66%						1
SOU085	9255	67%						1	9489	68%						1
SOU086	13109	105%	609	3734		1			13441	108%	941	4066		1		
SOU087	8708	95%		1808			1		8928	97%		2028			1	
SOU088	6420	46%						1	6583	47%						1

Summary (2008, 2009-1/2%, 2013-1/2%)

Feeder	00 Cap	04 Cap	2008 Capacity	2008	% Load	kVA >100%	kVA >75%	>= 115	R	A	G	2009	% Load	kVA >100%	kVA >75%	>= 115	R	A	G	2013	% Load	kVA >100%	kVA >75%	>= 115	R	A	G
MVA	333584	368656	409956	312998	76%	7729	40677	2	4	18	15	314563	77%	8029	41715	2	4	18	15	322506	79%	8654	47175	3	6	15	15
MW	326912	361283	401757	306738		7574	39863				39	308272		7869	40881				39	316056		8481	46231				39
kVA/ Feeder		39																									
		8yr % Growth																									
		annual % Growth																									
	DAA kVA Annual Growth																										
	DAA % Annual Growth Rate																										
	DAA % Utilization																										
DAA	kVA Over 75%																										
MW																											
	Demand for 1/2% Annual Grow																										
	1/2% Growth Rate % Utilizatio																										
Peak	Difference (In kVA) from DAA t																										
Grows																											
1/2%	kVA Over 75%																										
MW																											

Summary (2018-1/2%, 2023-1/2%, 2028-1/2%)

Feeder	2018	% Load	kVA >100%	kVA >75%	>= 115	R	A	G	2023	% Load	kVA >100%	kVA >75%	>= 115	R	A	G	2028	% Load	kVA >100%	kVA >75%	>= 115	R	A	G
MVA	330650	81%	11957	52784	3	7	15	14	338999	83%	14577	58675	5	5	15	14	347559	85%	17618	64764	6	7	13	13
MW	324037		11718	51728				39	332219		14286	57501				39	340608		17266	63469				39

Appendix C: Distribution System Maps of 39 Feeder Circuits Serving the Focused Study Area

Figure C.1: Focused Study Area 2006 N-0 Feeder Circuit Risks – System Intact

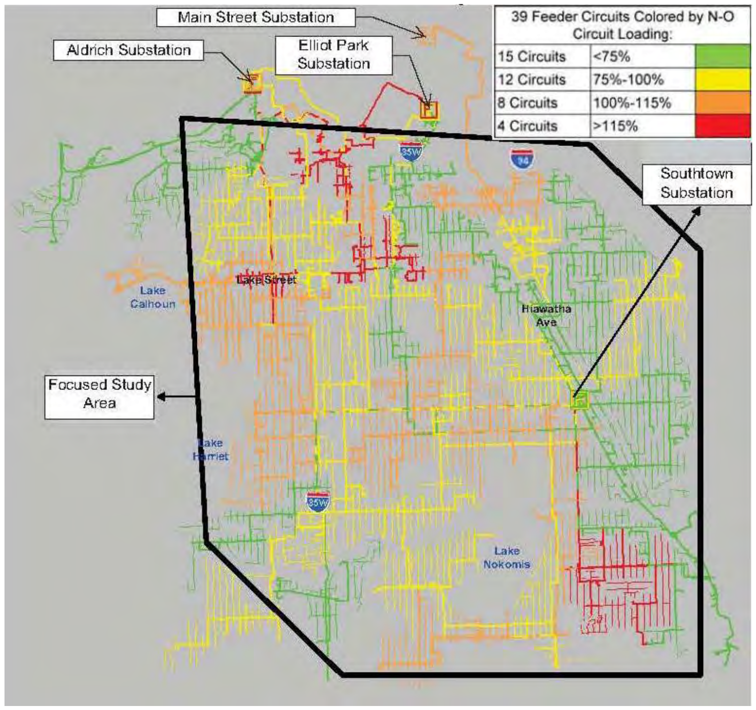


Figure C.2: Focused Study Area 2009 N-0 Feeder Circuit Risks – System Intact

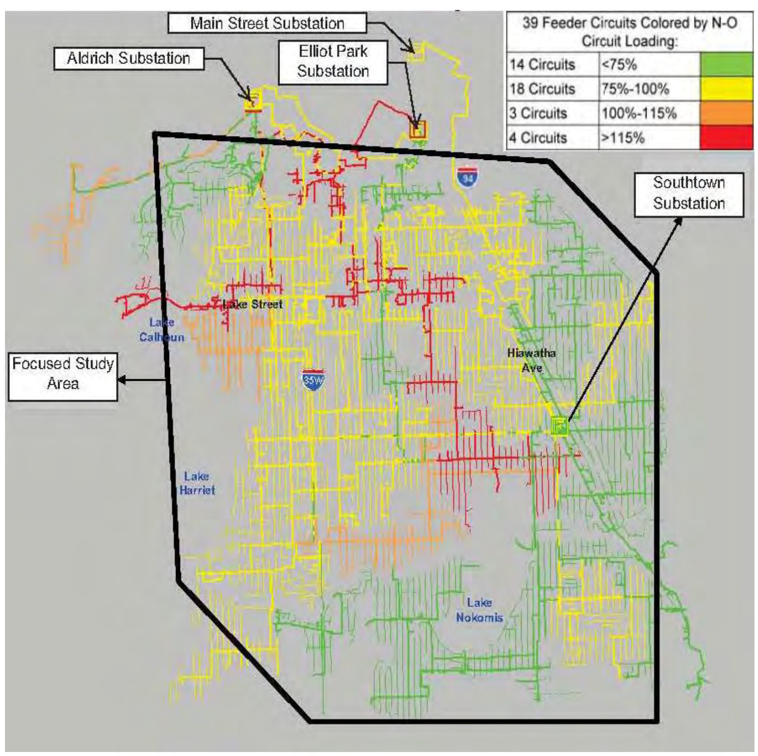


Figure C.3: Focused Study Area 2013 N-0 Feeder Circuit Risks – System Intact

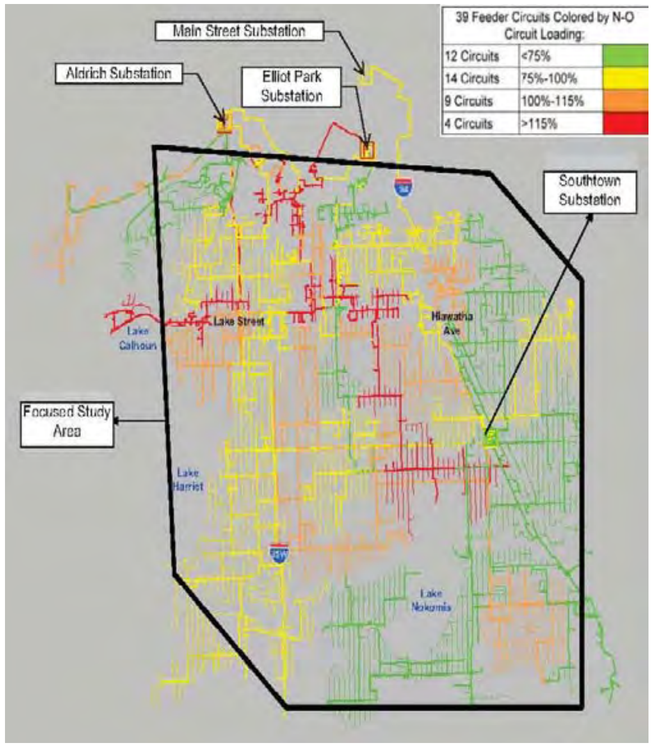


Figure C.4: Focused Study Area 2018 N-0 Feeder Circuit Risks – System Intact

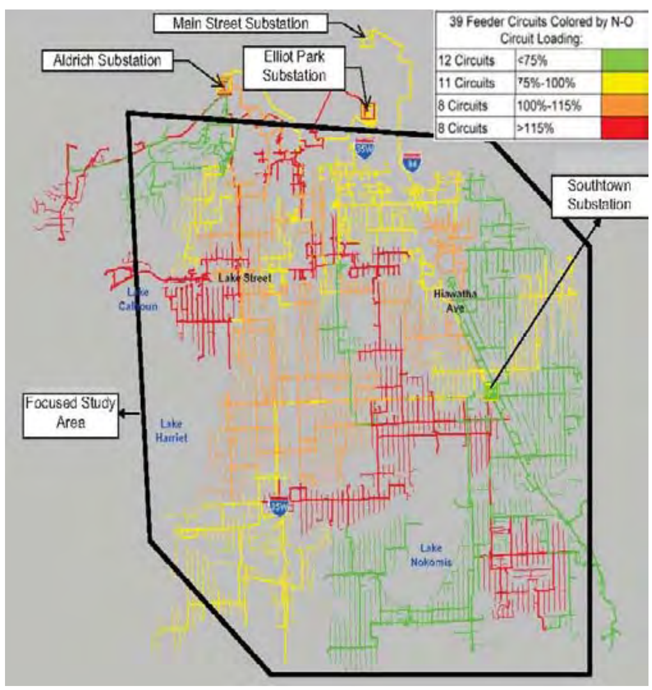


Figure C.5: Focused Study Area 2023 N-0 Feeder Circuit Risks – System Intact

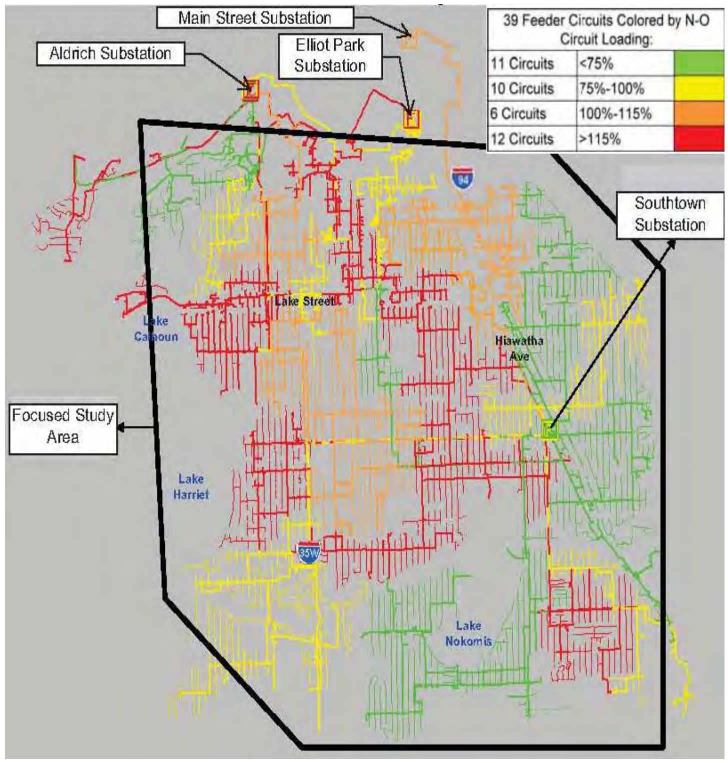


Figure C.6: Focused Study Area 2028 N-0 Feeder Circuit Risks – System Intact

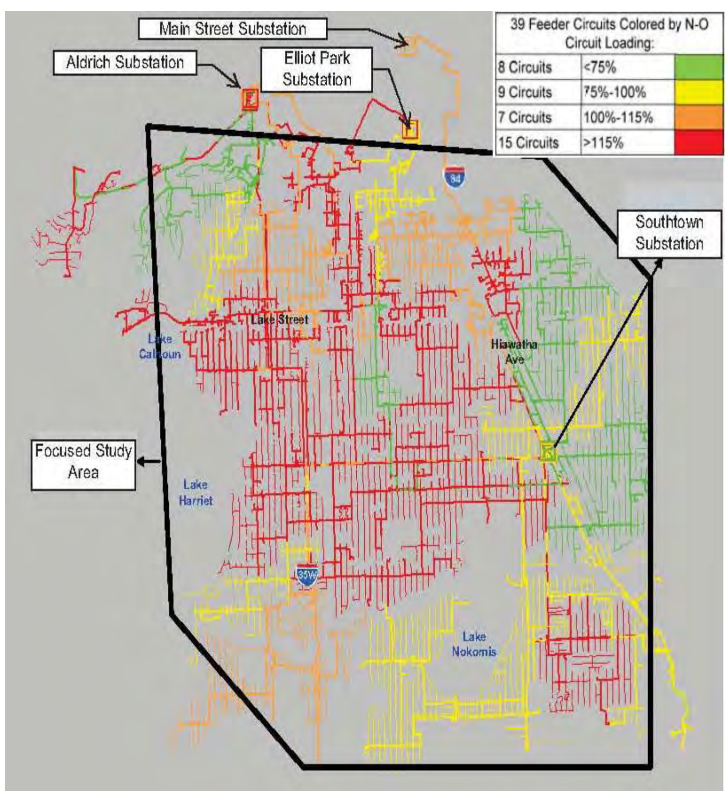


Figure C.7: Focused Study Area 2006 N-1 Feeder Circuit Risks – Single Contingency

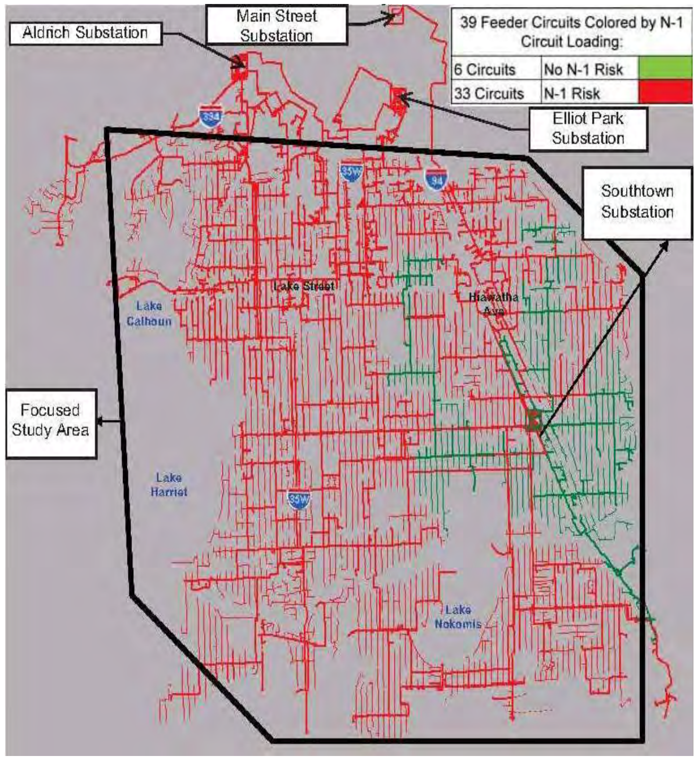


Figure C.8: Focused Study Area 2009 N-1 Feeder Circuit Risks – Single Contingency

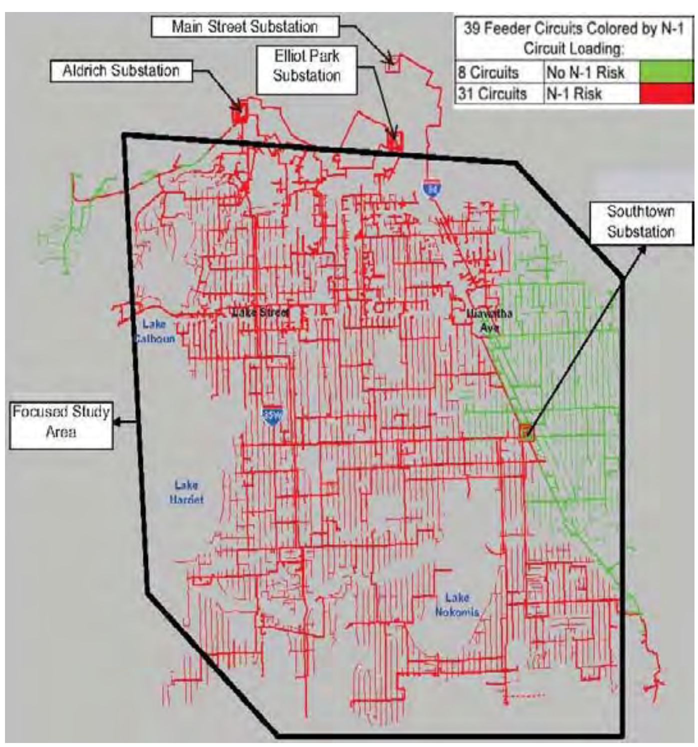
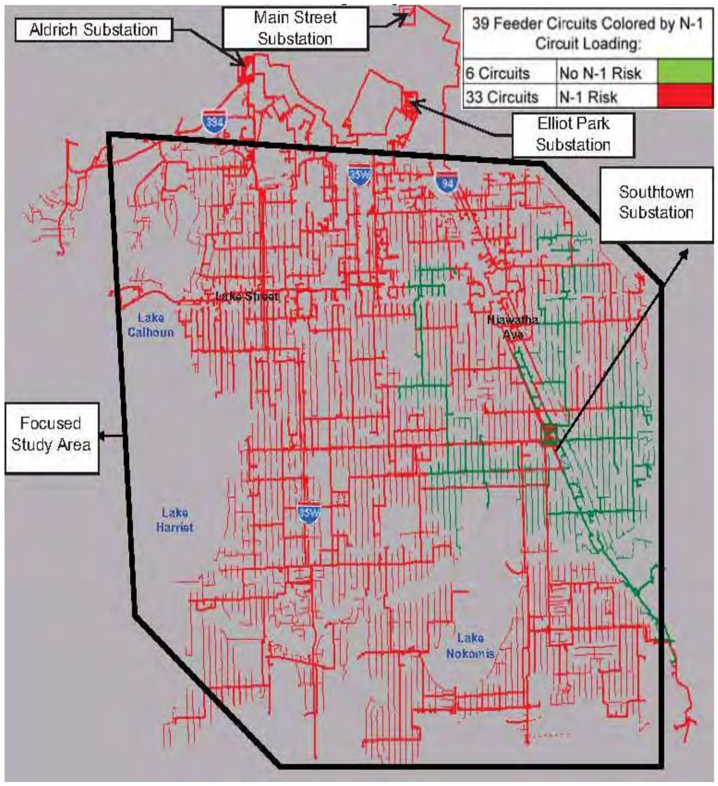


Figure C.9: Focused Study Area 2018 N-1 Feeder Circuit Risks – Single Contingency



Appendix D: Substation Transformer Forecasts for Greater Study Area

Greater Area - Substation Transformer Load History, Forecast

Appendix D, Table 1

	# of feeders	Nameplate	Normal	2000 Peak	2001 Peak	2002 Peak	2003 Peak	2004 peak	2005 Peak	2006 Peak	2007 Peak	2008 Peak	2009 Fcst	2010	2011	2012	2013	2018	2023	2028	
SOUTR1			71709	44100	59600	59100	65800	63000	64000	66260	56100	54400	54683	55323	55974	56632	57295	60770	64456	68365	1.060651
SOUTR2			74099	49000	53900	48000	46300	55000	57500	55490	54714	55270	56195	57081	57987	58904	59832	64737	70044	75786	1.08198
SOUTR3			68327	60400	63700	59000	55000	50000	62146	62970	61910	62850	63773	64613	65466	66331	67209	71683	76455	81544	1.066568
ALDTR2	5	70000	71709	32200	32000	38000	36700	38200	34603	28970	29690	27730	30192	30576	30965	31360	31760	34256	36948	39852	1.078589
ALDTR3	8	70000	71709	55600	55500	50400	51000	40300	43000	47260	52960	49220	52218	52736	53264	54180	54731	57500	60409	63465	1.050593
ALDTR4	8	70000	71709	66400	71300	50300	46300	57000	58268	56870	55430	62880	62217	64739	65479	66213	66956	70799	74863	79159	1.057396
ELPTR1	6	47000	51054	31900	34300	34300	30200	34000	37785	33730	34420	38140	34951	35396	35845	36302	36766	39186	41765	44514	1.065822
ELPTR2	6	47000	51870	30600	32700	31400	29000	32900	33000	32520	36210	37910	34307	34649	34995	35345	35699	37520	39434	41445	1.05101
ELPTR3	7	47000	51054	29800	32100	28000	26000	33000	42632	47180	37031	42910	41372	43655	44282	44920	45568	49030	52755	56763	1.075974
SOUTR1	8	70000	71709	44100	59600	59100	65800	63000	64000	66880	56100	54400	54683	55323	55974	56632	57295	60770	64456	68365	1.060651
SOUTR2	7	70000	74099	49000	53900	48000	46300	55000	57500	56600	54714	55270	56195	57081	57987	58904	59832	64737	70044	75786	1.08198
SOUTR3	8	62500	68327	60400	63700	59000	55000	50000	62146	63230	61910	62850	63773	64613	65466	66331	67209	71683	76455	81544	1.066568
SLPTR4	7	70000	76527	51400	44000	49000	53000	54800	62146	57430	53340	53840	56759	57768	58808	59872	60951	66629	72836	79621	1.093157
SLPTR5	7	70000	71709	52300	54700	48700	53500	56300	54000	45940	53360	51790	54009	55013	56036	57079	58142	63773	69949	76724	1.096849
SLPTR6	7	70000	71709	45700	57200	43900	46500	46600	49717	49710	41030	39420	40818	41578	42349	43138	43939	48177	52824	57919	1.096452
WILTR1	1	42000	42183	37600	42500	38100	40200	34800	42350	0	0	0	0								
WILTR2	1	42000	42183	24000	27000	22600	29700	42000	31270	0	0	0	0								
WILTR3	9	70000	71709	63000	68600	65800	65100	67000	75440	74810	63260	65450	68576	69633	70707	71799	72909	78741	85040	91842	1.07999
WILTR4	9	70000	76527	49000	57200	51300	52500	54700	55540	68190	69636	70690	71900	73044	74208	75394	76602	82987	89904	97398	1.083353
WILTR5	8	70000	76527					0	0	62070	57214	56052	55015	55687	56368	57057	57756	61394	65261	69372	1.062989
Big Box Total			1112314	723000	786300	717900	726800	759600	803397	791390	756305	768552	776985	791491	802733	814526	826115	887182	952943	1023771	
1/2% Growth											795347	799324	803320	807337	811374	815430	819508	840201	861417	883169	
ALD	21	210000	215127	154200	158800	138700	134000	135500	135871	133100	138080	139830	144627	148051	149708	151753	153447	162555	172220	182477	
ELP	19	141000	153978	92300	99100	93700	85200	99900	113417	113430	107661	118960	110630	113700	115122	116567	118033	125736	133954	142723	
SOU	23	202500	214135	153500	177200	166100	167100	168000	183646	186710	172724	172520	174651	177017	179427	181867	184336	197190	210955	225696	
SLP	21	210000	219945	149400	155900	141600	153000	157700	165863	153080	147730	145050	151586	154359	157193	160089	163032	178579	195609	214264	
WIL	26	210000	224763	173600	195300	177800	187500	198500	204600	205070	190110	192192	195491	198364	201283	204250	207267	223122	240205	258612	
Big Totals	110	973500	1027948	723000	786300	717900	726800	759600	803397	791390	756305	768552	776985	791491	802733	814526	826115	887182	952943	1023771	
SOU Tota	23	210000	214135	153500	177200	166100	167100	168000	183646	186710	172724	172520	174651	177017	179427	181867	184336	197190	210955	225696	
Big MW		954030	1007389	708540	770574	703542	712264	744408	787329	775562	741179	753181	761445	775661	786678	798235	809593	869438	933884	1003295	
SOU MW		205800	209852	150430	173656	162778	163758	164640	179973	182976	169270	169070	171158	173477	175838	178230	180649	193246	206736	221182	
% Utilization-big box				70%	76%	70%	71%	74%	78%	77%	74%	75%	76%	77%	78%	79%	80%	86%	93%	100%	
No 35kV																					
1/2% SOU Growth													173383	174250	175121	175996	176876	181343	185922	190617	
1/2% Big Box Growth													772395	776257	780138	784039	787959	807856	828255	849170	
1/2%SOU MW													169915	170765	171618	172476	173339	177716	182203	186804	
1/2%Big MW													756947	760732	764535	768358	772200	791699	811690	832186	
% Utilization-big box 1/2 % growth				70%	76%	70%	71%	74%	78%	77%	74%	75%	75%	76%	76%	76%	77%	79%	81%	83%	

Loads converted to MW

	2008	2009	2013	2018	2023	2028
ALD	137033	141734	145090	146714	148718	150378
ELP	116581	108417	111426	112820	114236	115672
SOU	169070	171158	173477	175838	178230	180649
SLP	142149	148554	151272	154049	156887	159771
WIL	188348	191581	194397	197257	200165	203122
Big Totals	753181	761445	775661	786678	798235	809593

Greater Area - Substation Transformer Load Analysis

Appendix D, Table 2

		Nameplate	Normal	2000 Peak	2001 Peak	2002 Peak	2003 Peak	2004 peak	2005 Peak	2006 Peak	2007 Peak	2008 Peak	2009 Fcst	2010	2011	2012	2013	2018	2023	2028
Nameplate	ALD			210000	210000	210000	210000	210000	210000	210000	210000	210000	210000	210000	210000	210000	210000	210000	210000	210000
	ELP			141000	141000	141000	141000	141000	141000	141000	141000	141000	141000	141000	141000	141000	141000	141000	141000	141000
	SOU			202500	202500	202500	202500	202500	202500	202500	202500	202500	202500	202500	202500	202500	202500	202500	202500	202500
	SLP			210000	210000	210000	210000	210000	210000	210000	210000	210000	210000	210000	210000	210000	210000	210000	210000	210000
	WIL			210000	210000	210000	210000	210000	210000	210000	210000	210000	210000	210000	210000	210000	210000	210000	210000	210000
Total										973500	973500	973500	973500							
Normal	ALD			215127	215127	215127	215127	215127	215127	215127	215127	215127	215127	215127	215127	215127	215127	215127	215127	215127
	ELP			153978	153978	153978	153978	153978	153978	153978	153978	153978	153978	153978	153978	153978	153978	153978	153978	153978
	SOU			214135	214135	214135	214135	214135	214135	214135	214135	214135	214135	214135	214135	214135	214135	214135	214135	214135
	SLP			219945	219945	219945	219945	219945	219945	219945	219945	219945	219945	219945	219945	219945	219945	219945	219945	219945
	WIL			224763	224763	224763	224763	224763	224763	224763	224763	224763	224763	224763	224763	224763	224763	224763	224763	224763
Total				1027948	1027948	1027948	1027948	1027948	1027948	1027948	1027948	1027948	1027948	1027948	1027948	1027948	1027948	1027948	1027948	1027948
1 Cycle	ALD			215127	215127	215127	215127	215127	215127	215127	215127	215127	215127	215127	215127	215127	215127	215127	215127	215127
	ELP			174537	174537	174537	174537	174537	174537	174537	174537	174537	174537	174537	174537	174537	174537	174537	174537	174537
	SOU			217517	217517	217517	217517	217517	217517	217517	217517	217517	217517	217517	217517	217517	217517	217517	217517	217517
	SLP			224688	224688	224688	224688	224688	224688	224688	224688	224688	224688	224688	224688	224688	224688	224688	224688	224688
	WIL			239761	239761	239761	239761	239761	239761	239761	239761	239761	239761	239761	239761	239761	239761	239761	239761	239761
Total										1071630	1071630	1071630	1071630							
N-1 Capacity	ALD			143418	143418	143418	143418	143418	143418	143418	143418	143418	143418	143418	143418	143418	143418	143418	143418	143418
	ELP			115792	115792	115792	115792	115792	115792	115792	115792	115792	115792	115792	115792	115792	115792	115792	115792	115792
	SOU			143418	143418	143418	143418	143418	143418	143418	143418	143418	143418	143418	143418	143418	143418	143418	143418	143418
	SLP			143418	143418	143418	143418	143418	143418	143418	143418	143418	143418	143418	143418	143418	143418	143418	143418	143418
	WIL			152979	152979	152979	152979	152979	152979	152979	152979	152979	152979	152979	152979	152979	152979	152979	152979	152979
Total										699025	699025	699025	699025							
% Utilization	ALD			72%	74%	64%	62%	63%	63%	62%	64%	65%	67%	69%	70%	71%	71%	76%	80%	85%
	ELP			60%	64%	61%	55%	65%	74%	74%	70%	77%	72%	74%	75%	76%	77%	82%	87%	93%
	SOU			72%	83%	78%	78%	78%	86%	87%	81%	81%	82%	83%	84%	85%	86%	92%	99%	105%
	SLP			68%	71%	64%	70%	72%	75%	70%	67%	66%	69%	70%	71%	73%	74%	81%	89%	97%
	WIL			77%	87%	79%	83%	88%	91%	91%	85%	86%	87%	88%	90%	91%	92%	99%	107%	115%
Total				70%	76%	70%	71%	74%	78%	77%	74%	75%	76%	77%	78%	79%	80%	86%	93%	100%
% Growth	ALD			-5.7%	3.0%	-12.7%	-3.4%	1.1%	0.3%	-2.0%	3.7%	1.3%	3.4%	2.4%	1.1%	1.4%	1.1%	1.2%	1.2%	1.2%
	ELP			0.5%	7.4%	-5.4%	-9.1%	17.3%	13.5%	0.0%	-5.1%	10.5%	-7.0%	2.8%	1.3%	1.3%	1.3%	1.3%	1.3%	1.3%
	SOU			0.4%	15.4%	-6.3%	0.6%	0.5%	9.3%	1.7%	-7.5%	-0.1%	1.2%	1.4%	1.4%	1.4%	1.4%	1.4%	1.4%	1.4%
	SLP			-10.3%	4.4%	-9.2%	8.1%	3.1%	5.2%	-7.7%	-3.5%	-1.8%	4.5%	1.8%	1.8%	1.8%	1.8%	1.9%	1.9%	1.9%
	WIL			-1.8%	12.5%	-9.0%	5.5%	5.9%	3.1%	0.2%	-7.3%	1.1%	1.7%	1.5%	1.5%	1.5%	1.5%	1.5%	1.5%	1.5%
Total				-3.8%	8.8%	-8.7%	1.2%	4.5%	5.8%	-1.5%	-4.4%	1.6%	1.1%	1.9%	1.4%	1.5%	1.4%	1.5%	1.5%	1.5%
N-0 Overload	ALD					2.9%	2.3%	2.0%	3.4%	3.2%	2.2%	1.4%								
	ELP					-1.5%	-0.8%	0.2%	1.2%	0.8%	0.7%	0.3%								
	SOU																			11561
	SLP																			
	WIL																		15442	33849
Total				0	0	0	0	0	0	0	0	0							15442	45409
N-1 Overload	ALD			10782	15382								1209	4633	6290	8335	10029	19137	28802	39059
	ELP											3168			-670	775	2241	9944	18162	26931
	SOU			10082	33782	22682	23682	24582	40228	43292	29306	29102	31233	33599	36009	38449	40918	53772	67537	82278
	SLP			5982	12482		9582	14282	22445	9662	4312	1632	8168	10941	13775	16671	19614	35161	52191	70846
	WIL			20621	42321	24821	34521	45521	51621	52091	37131	39213	42512	45385	48304	51271	54288	70143	87226	105633
Total				47467	103967	47503	67785	84385	114294	105045	70749	73115	83122	94558	103708	115501	127090	188157	253918	324746
N-1 Overload MW	ALD			10566	15074	0	0	0	0	0	0	0	1185	4540	6164	8168	9828	18754	28226	38277
	ELP			0	0	0	0	0	0	0	0	3105	0	0	-657	760	2196	9745	17799	26392
	SOU			9880	33106	22228	23208	24090	39423	42426	28720	28520	30608	32927	35289	37680	40100	52697	66186	80632
	SLP			5862	12232	0	9390	13996	21996	9469	4226	1599	8005	10722	13500	16338	19222	34458	51147	69429
	WIL			20209	41475	24325	33831	44611	50589	51049	36388	38429	41662	44477	47338	50246	53202	68740	85481	103520
Total MW				46518	101888	46553	66429	82697	112008	102944	69334	71653	81460	92667	101634	113191	124548	184394	248839	318251
Feeder	Big Box	Sm box	Capacity	2000	2001	2002	2003	2004 peak	2005 Peak	2006 Peak	2007 Peak	2008 Peak	2009 Fcst	2010	2011	2012	2013	2018	2023	2028

ALD ELP MST

Greater Area - Substation Transformer Loads - 1/2% Growth Forecast

Appendix D, Table 3

	# of feeders	Nameplate	Normal	1 Cycle	2006 Peak	2007	2008		2009 1/2% Fcst	2010 1/2% Fcst	2011 1/2% Fcst	2012 1/2% Fcst	2013 1/2% Fcst	2018 1/2% Fcst	2023 1/2% Fcst	2028 1/2% Fcst
SOUTR1			71709	76%	66260	56100	54400		54672	54945	55220	55496	55774	57182	58626	60106
SOUTR2			74099	75%	55490	54714	55270		55546	55824	56103	56384	56666	58097	59564	61068
SOUTR3			68327	92%	62970	61910	62850		63164	63480	63797	64116	64437	66064	67732	69443
													0	0	0	0
ALDTR2	5	70000	71709	71709	28970	29690	27730		27869	28008	28148	28289	28430	29148	29884	30639
ALDTR3	8	70000	71709	71709	47260	52960	49220		49466	49713	49962	50212	50463	51737	53044	54383
ALDTR4	8	70000	71709	71709	56870	55430	62880		63194	63510	63828	64147	64468	66096	67765	69476
ELPTR1	6	47000	51054	57896	33730	34420	38140		38331	38522	38715	38909	39103	40090	41103	42141
ELPTR2	6	47000	51870	58745	32520	36210	37910		38100	38290	38481	38674	38867	39849	40855	41887
ELPTR3	7	47000	51054	57896	47180	37031	42910		43125	43340	43557	43775	43994	45104	46243	47411
SOUTR1	8	70000	71709	71709	66880	56100	54400		54672	54945	55220	55496	55774	57182	58626	60106
SOUTR2	7	70000	74099	74099	56600	54714	55270		55546	55824	56103	56384	56666	58097	59564	61068
SOUTR3	8	62500	68327	71709	63230	61910	62850		63164	63480	63797	64116	64437	66064	67732	69443
SLPTR4	7	70000	76527	81270	57430	53340	53840		54109	54380	54652	54925	55200	56593	58022	59488
SLPTR5	7	70000	71709	71709	45940	53360	51790		52049	52309	52571	52834	53098	54439	55813	57223
SLPTR6	7	70000	71709	71709	49710	41030	39420		39617	39815	40014	40214	40415	41436	42482	43555
WILTR1	1	42000	42183	45658	0	0	0		0	0	0	0	0	0	0	0
WILTR2	1	42000	42183	45658	0	0	0		0	0	0	0	0	0	0	0
WILTR3	9	70000	71709	71709	74810	63260	65450		65777	66106	66437	66769	67103	68797	70534	72315
WILTR4	9	70000	76527	86782	68190	69636	70690		71043	71399	71756	72114	72475	74305	76181	78105
WILTR5	8	70000	76527	81270	62070	57214	56052		56332	56614	56897	57181	57467	58919	60406	61932
Big Box Total			1112314	1	791390	756305	768552		772395	776257	780138	784039	787959	807856	828255	849170
1/2% Growth																
ALD	21	210000	215127	215127	133100	138080	139830	18%	140529	141232	141938	142648	143361	146981	150692	154498
ELP	19	141000	153978	174537	113430	107661	118960	15%	119555	120153	120753	121357	121964	125044	128201	131438
SOU	23	202500	214135	217517	186710	172724	172520	22%	173383	174250	175121	175996	176876	181343	185922	190617
SLP	21	210000	219945	224688	153080	147730	145050	19%	145775	146504	147237	147973	148713	152468	156318	160265
WIL	26	210000	224763	239761	205070	190110	192192	25%	193153	194119	195089	196065	197045	202021	207122	212352
Big Total	110	973500	1027948	75%	791390	756305	768552	100%	772395	776257	780138	784039	787959	807856	828255	849170
SOU Tota	23	210000	214135	81%	153080	147730	145050		145775	146504	147237	147973	148713	152468	156318	160265
Big MW		954030	1007389		775562	741179	753181		756947	760732	764535	768358	772200	791699	811690	832186
SOU MW		205800	209852		150018	144775	142149		142860	143574	144292	145013	145738	149419	153192	157060
% Utilization-big box						ALD MW	137033									
No 35kV						ELP MW	116581									
1/2% SOU Growth						SOU MW	169070									
1/2% Big Box Growth						SLP MW	142149									
1/2%SOU MW						WIL MW	188348									
1/2%Big MW							753181									
% Utilization-big box 1/2 % growth					77%	74%	75%									

South Minneapolis STUDY

Greater Area - Substation Transformer Loads - 1/2% Growth Analysis

Appendix D, Table 4

		Nameplate	Normal	1 Cycle	2006 Peak	2007 1/2% Fcst	2008 1/2% Fcst	2009 1/2% Fcst	2010	2011	2012	2013	2018	2023	2028
Nameplate	ALD				210000	210000	210000	210000	210000	210000	210000	210000	210000	210000	210000
	ELP				141000	141000	141000	141000	141000	141000	141000	141000	141000	141000	141000
	SOU				202500	202500	202500	202500	202500	202500	202500	202500	202500	202500	202500
	SLP				210000	210000	210000	210000	210000	210000	210000	210000	210000	210000	210000
	WIL				210000	210000	210000	210000	210000	210000	210000	210000	210000	210000	210000
Total					973500	973500	973500	973500	973500	973500	973500	973500	973500	973500	973500
Normal	ALD				215127	215127	215127	215127	215127	215127	215127	215127	215127	215127	215127
	ELP				153978	153978	153978	153978	153978	153978	153978	153978	153978	153978	153978
	SOU				214135	214135	214135	214135	214135	214135	214135	214135	214135	214135	214135
	SLP				219945	219945	219945	219945	219945	219945	219945	219945	219945	219945	219945
	WIL				224763	224763	224763	224763	224763	224763	224763	224763	224763	224763	224763
Total					1027948	1027948	1027948	1027948	1027948	1027948	1027948	1027948	1027948	1027948	1027948
1 Cycle	ALD				215127	215127	215127	215127	215127	215127	215127	215127	215127	215127	215127
	ELP				174537	174537	174537	174537	174537	174537	174537	174537	174537	174537	174537
	SOU				217517	217517	217517	217517	217517	217517	217517	217517	217517	217517	217517
	SLP				224688	224688	224688	224688	224688	224688	224688	224688	224688	224688	224688
	WIL				239761	239761	239761	239761	239761	239761	239761	239761	239761	239761	239761
Total					1071630	1071630	1071630	1071630	1071630	1071630	1071630	1071630	1071630	1071630	1071630
N-1 Capacity	ALD				143418	143418	143418	143418	143418	143418	143418	143418	143418	143418	143418
	ELP				115792	115792	115792	115792	115792	115792	115792	115792	115792	115792	115792
	SOU				143418	143418	143418	143418	143418	143418	143418	143418	143418	143418	143418
	SLP				143418	143418	143418	143418	143418	143418	143418	143418	143418	143418	143418
	WIL				152979	152979	152979	152979	152979	152979	152979	152979	152979	152979	152979
Total					699025	699025	699025	699025	699025	699025	699025	699025	699025	699025	699025
% Utilization	ALD				62%	64%	65%	65%	66%	66%	66%	67%	68%	70%	72%
	ELP				74%	70%	77%	78%	78%	78%	79%	79%	81%	83%	85%
	SOU				87%	81%	81%	81%	81%	82%	82%	83%	85%	87%	89%
	SLP				70%	67%	66%	66%	67%	67%	67%	68%	69%	71%	73%
	WIL				91%	85%	86%	86%	86%	87%	87%	88%	90%	92%	94%
Total					77%	74%	75%	75%	76%	76%	76%	77%	79%	81%	83%
% Growth	ALD					3.7%	1.3%	0.5%	0.5%	0.5%	0.5%	0.5%	0.5%	0.5%	0.5%
	ELP					-5.1%	10.5%	0.5%	0.5%	0.5%	0.5%	0.5%	0.5%	0.5%	0.5%
	SOU					-7.5%	-0.1%	0.5%	0.5%	0.5%	0.5%	0.5%	0.5%	0.5%	0.5%
	SLP					-3.5%	-1.8%	0.5%	0.5%	0.5%	0.5%	0.5%	0.5%	0.5%	0.5%
	WIL					-7.3%	1.1%	0.5%	0.5%	0.5%	0.5%	0.5%	0.5%	0.5%	0.5%
Total															
N-0 Overload	ALD														
	ELP														
	SOU														
	SLP														
	WIL														
Total															
N-1 Overload	ALD													7274	11080
	ELP									4961	5565	6172	9252	12409	15646
	SOU				43292	29306	29102	29965	30832	31703	32578	33458	37925	42504	47199
	SLP				9662	4312	1632	2357	3086	3819	4555	5295	9050	12900	16847
	WIL				52091	37131	39213	40174	41140	42110	43086	44066	49042	54143	59373
Total					105045	70749	69947	72496	75057	82593	85784	88991	105268	129230	150145
N-1 Overload MW	ALD				0	0	0	0	0	0	0	0	0	7129	10858
	ELP				0	0	0	0	0	4862	5454	6048	9067	12161	15333
	SOU				42426	28720	28520	29365	30215	31069	31927	32789	37166	41654	46255
	SLP				9469	4226	1599	2310	3024	3742	4464	5189	8869	12642	16510
	WIL				51049	36388	38429	39370	40317	41268	42224	43185	48061	53060	58186
Total MW					102944	69334	68548	71046	73556	80941	84068	87211	103163	126646	147142
Feeder	Big Box	Sm box	Capacity	2008 % Load	2006 Peak	2007 1/2% Fcst	2008 1/2% Fcst	2009 1/2% Fcst	2010	2011	2012	2013	2018	2023	2028

>= 115	R	A	G	R	kVA over	% Load	kVA >100 %	kVA >75%	>= 115	R	A	G	% Load	kVA >100 %	kVA >75%	>= 115	R	A	G

Appendix E: Distribution System Graphics of 15 Transformers and Associated Feeder Circuits Serving the Greater Study Area

Figure E.1: Greater Study Area 2006 N-1 Substation Transformer Risks – Single Contingency

Colored by Substation:		
0	6 Transformers	(green)
0 to 10 MW	3 Transformers	(yellow)
10 MW to 25 MW		(orange)
> 25 MW	6 Transformers	(red)

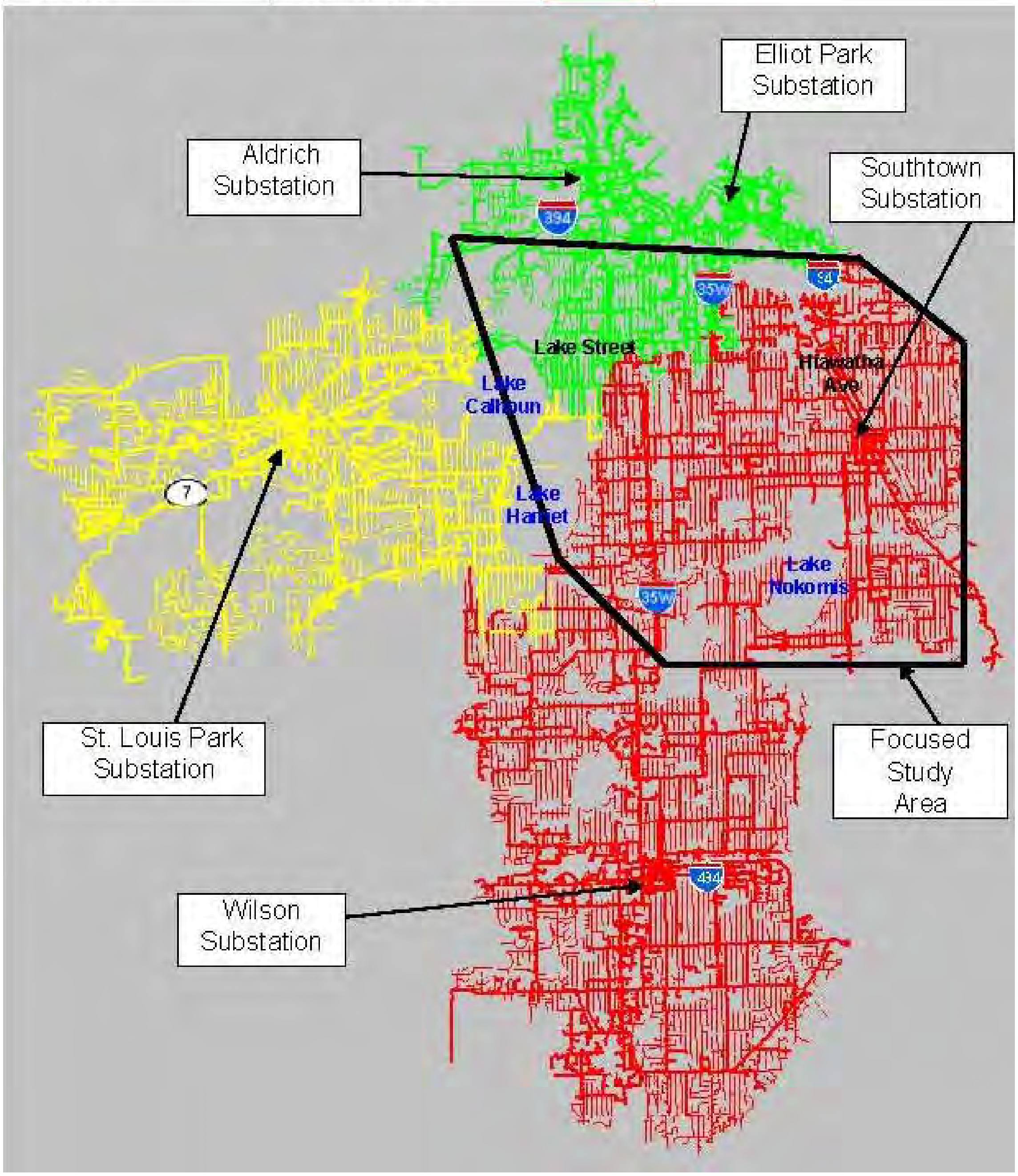


Figure E.2: Greater Study Area 2009 N-1 Substation Transformer Risks – Single Contingency

Colored by Substation:		
0	3 Transformers	(green)
0 to 10 MW	6 Transformers	(yellow)
10 MW to 25 MW	0 Transformers	(orange)
> 25 MW	6 Transformers	(red)

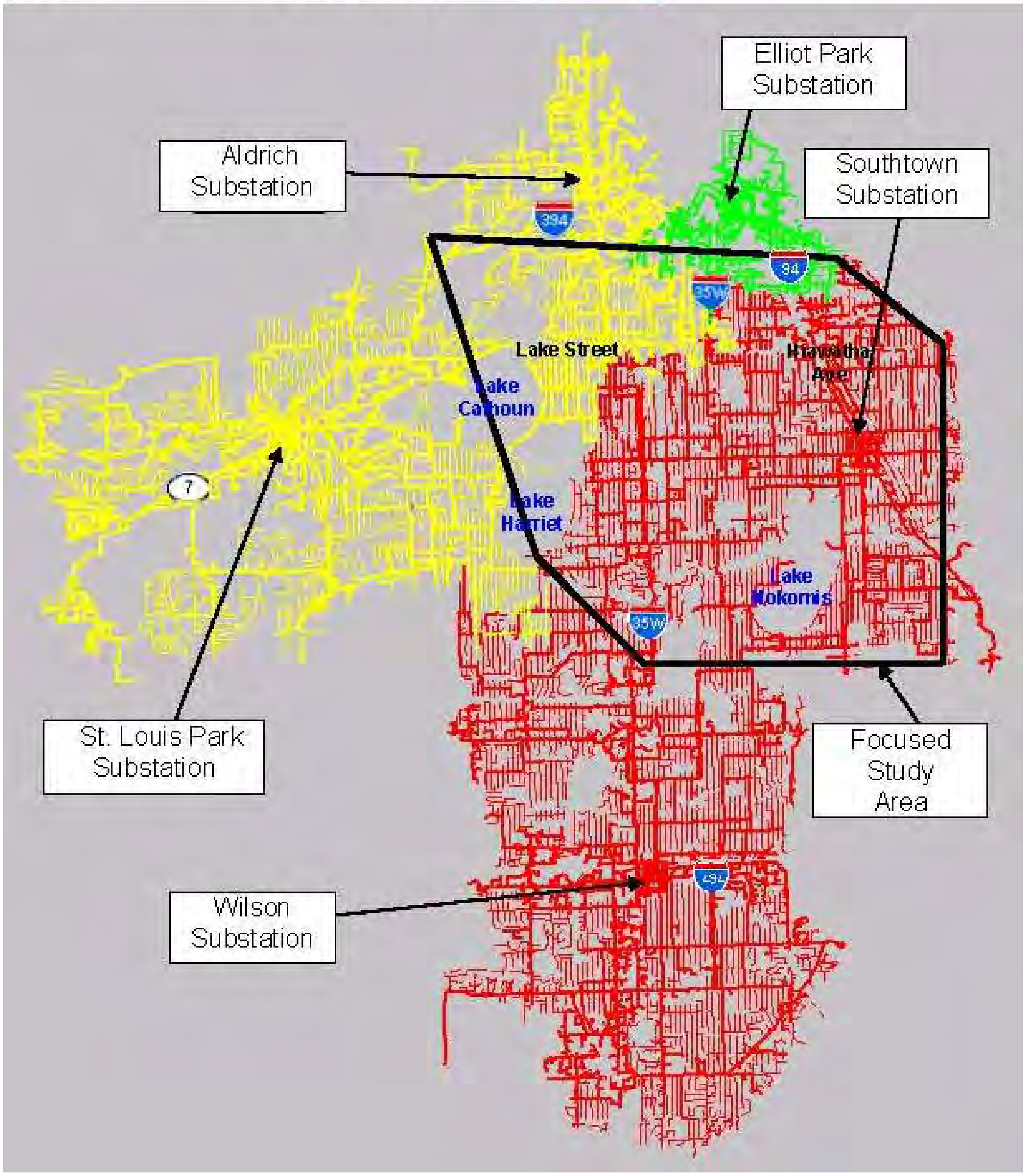


Figure E.3: Greater Study Area 2013 N-1 Substation Transformer Risks – Single Contingency

Colored by Substation:		
0	0 Transformers	
0 to 10 MW	3 Transformers	
10 MW to 25 MW	6 Transformers	
> 25 MW	6 Transformers	

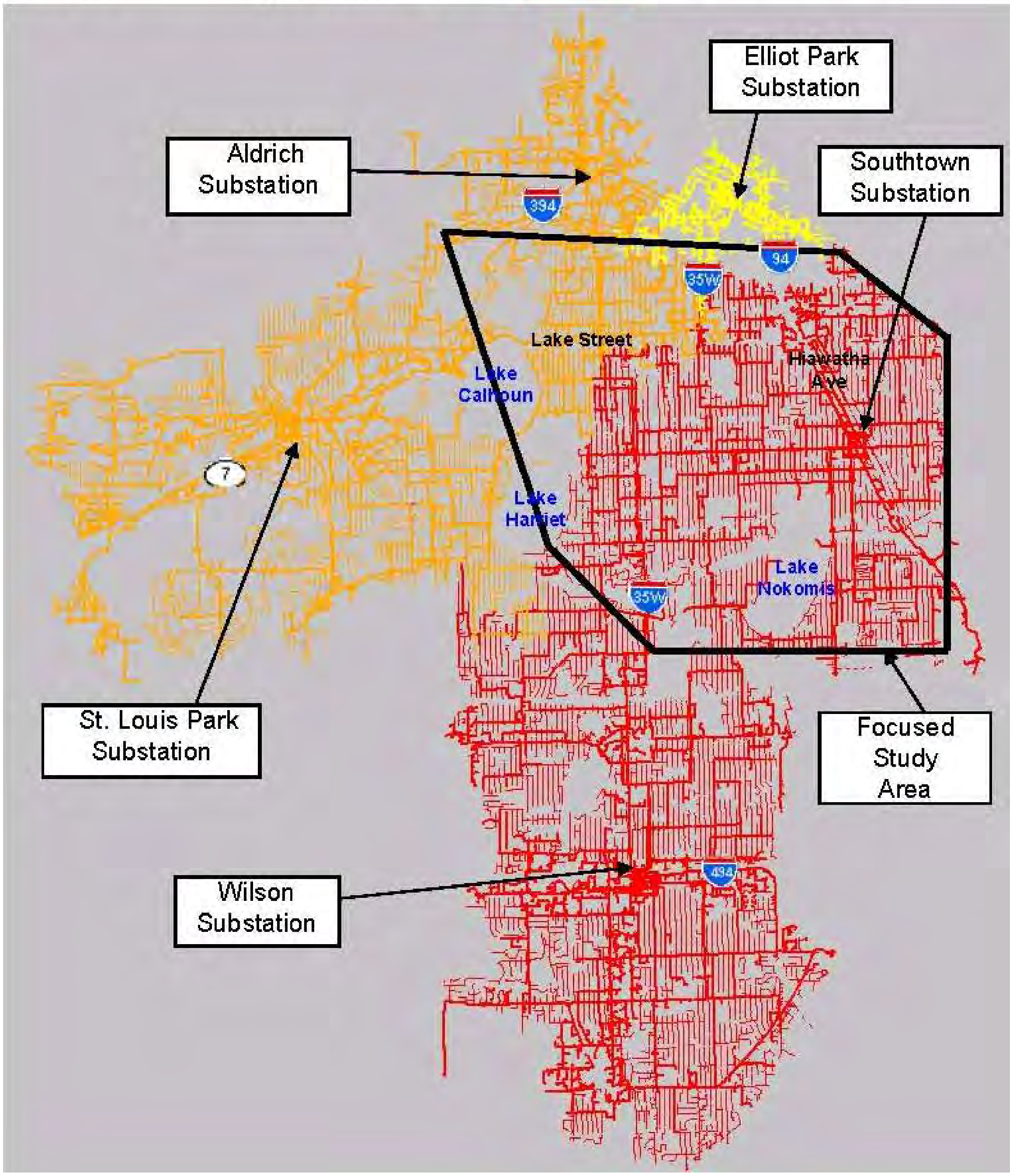


Figure E.4: Greater Study Area 2018 N-1 Substation Transformer Risks – Single Contingency

Colored by Substation:		
0	0 Transformers	green
0 to 10 MW	3 Transformers	yellow
10 MW to 25 MW	3 Transformers	orange
> 25 MW	9 Transformers	red

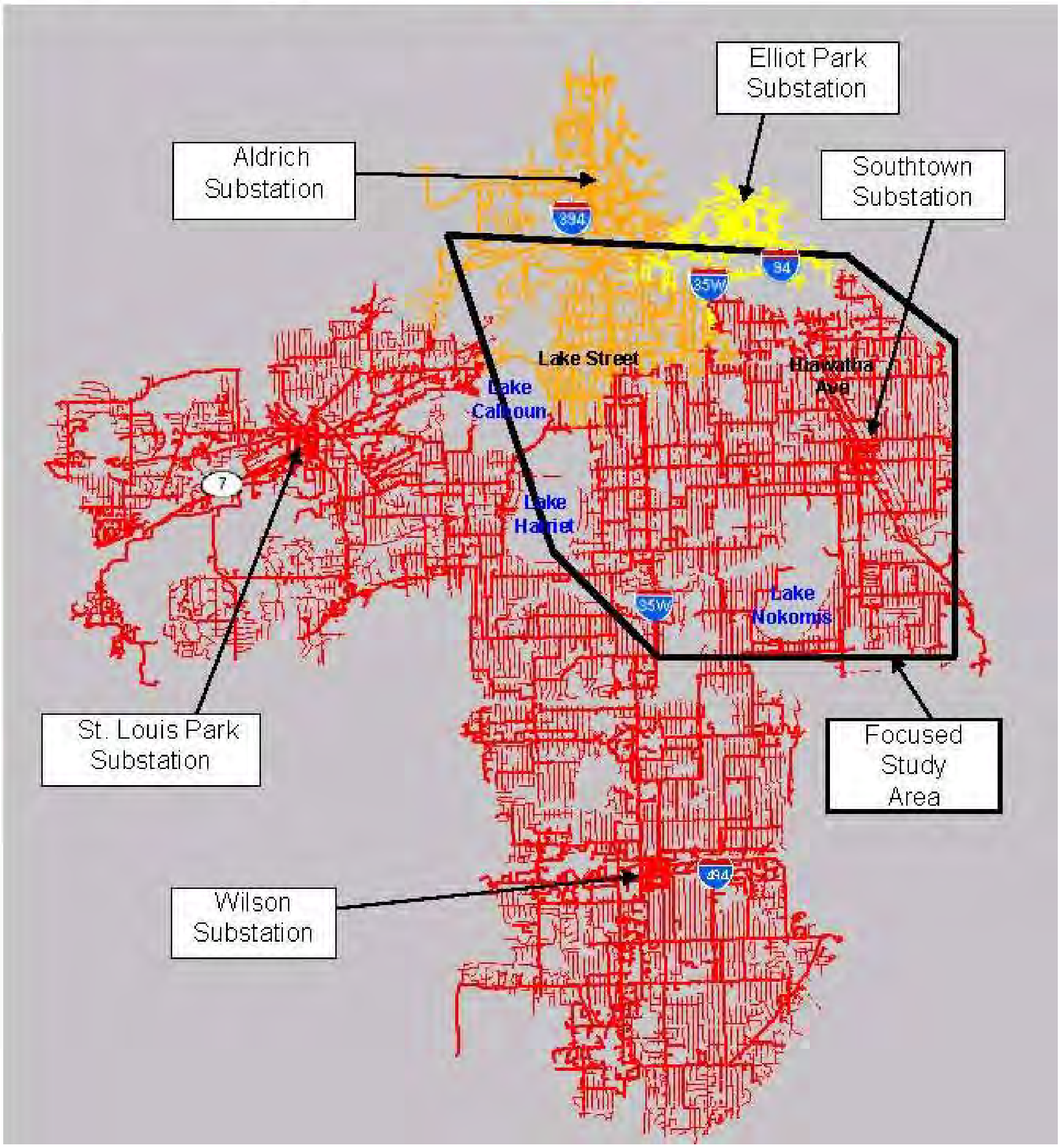


Figure E.5: Greater Study Area 2023 N-1 Substation Transformer Risks – Single Contingency

Colored by Substation:		
0	0 Transformers	
0 to 10 MW	0 Transformers	
10 MW to 25 MW	3 Transformers	
> 25 MW	12 Transformers	

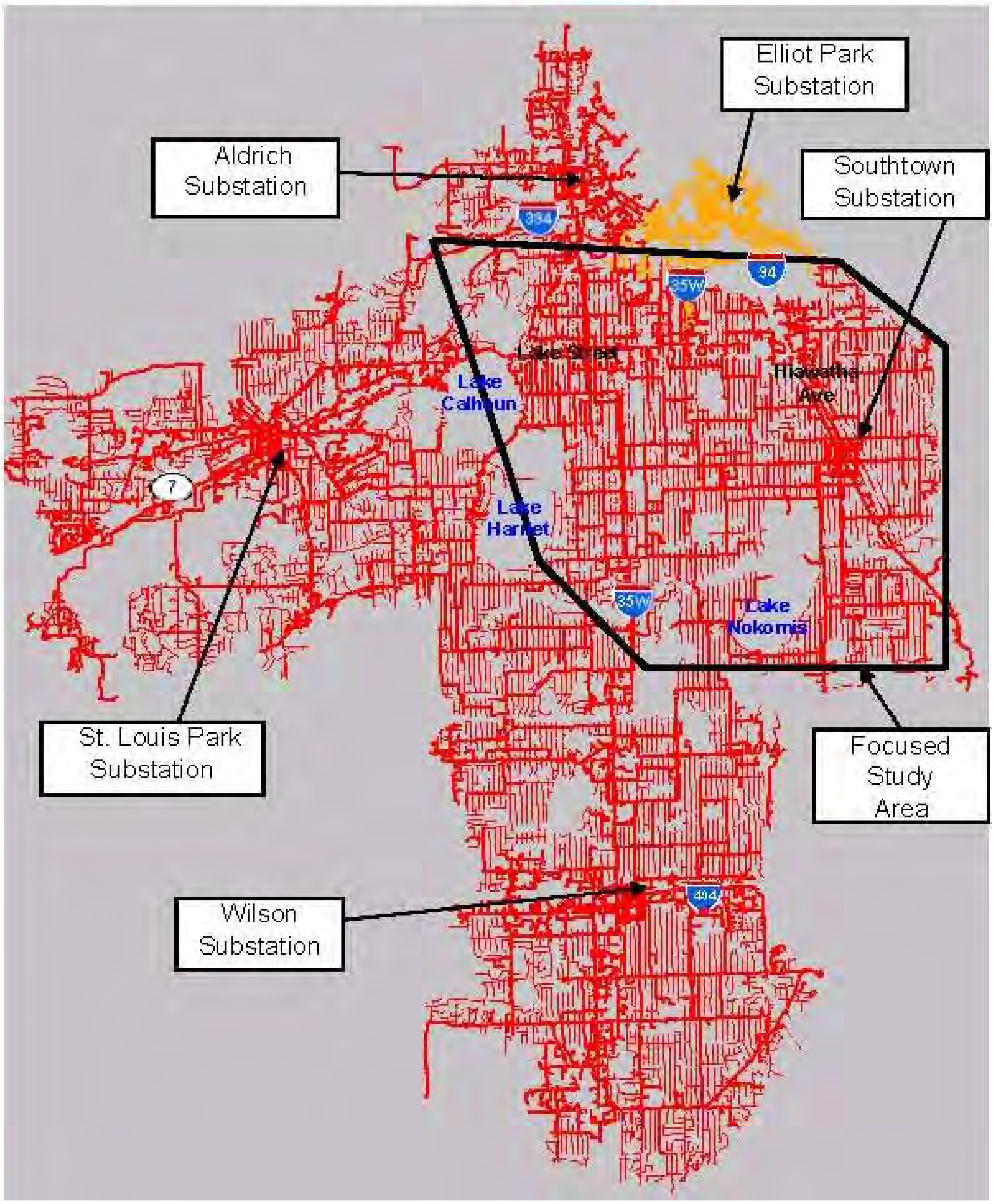
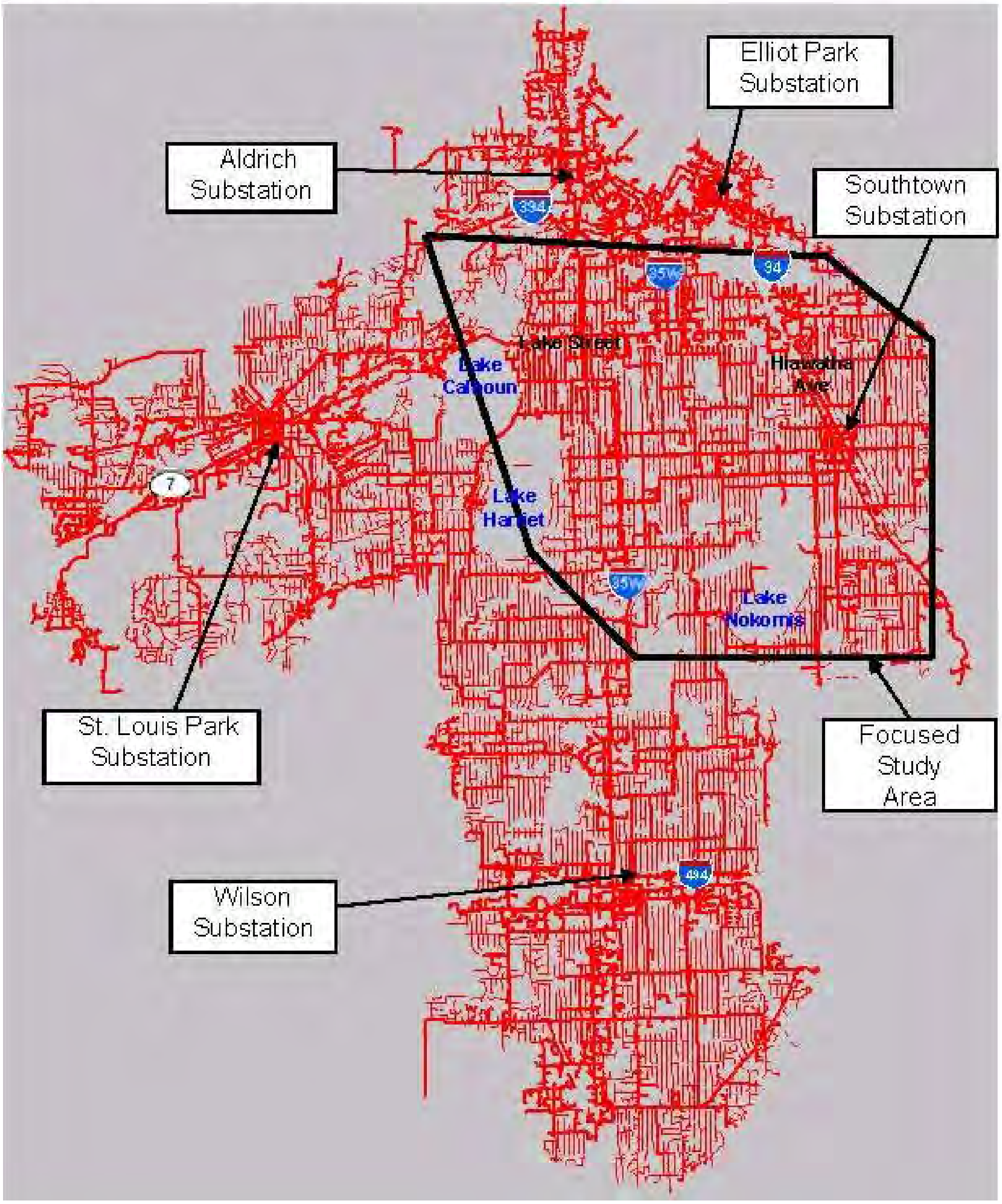


Figure E.6: Greater Study Area 2028 N-1 Substation Transformer Risks – Single Contingency

Colored by Substation:		
0		
0 to 10 MW	0 Transformers	
10 MW to 25 MW	0 Transformers	
> 25 MW	15 Transformers	



Appendix F: Explanation of Loss Analysis:

Losses are power that dissipates in electric conductors due to a materials resistance. The amount of loss is greatly reduced by lowering the current flowing through a line and shortening the length of a line. For the South Minneapolis 20 Year plan losses were evaluated for different mitigations to risks in the area. The cost of purchasing generation at marginal prices for capacity and energy were evaluated. These savings were factored into the economic analysis.

To develop the savings associated with reducing losses, an evaluation technique was developed. Load duration curves for residential areas, commercial and residential areas, commercial and industrial areas, and industrial areas were considered. The different load duration curves lead to different load factors, which represent the comparison of average demand of a transformer or feeder to its peak demand. The formula for this is shown below in Equation 1.

$$LoadFactor = \frac{Demand_{AVG}}{Demand_{PEAK}}$$

Equation 1: Load Factor Development

From the load factor, the loss factor can then be calculated. The loss factor relates the amount of losses in the peak case to the expected amount of losses at an average level throughout the year. Equations 2 thru 4 below detail the calculation of the loss factor. Equation 3 demonstrates the correlation between load and current. As the load increases the loading on the distribution lines will increase in equal proportions. Due to this relationship Equation 4 can be applied to get the loss factor. This development comes from the standard loss formula in Equation 2.

$$Losses = I^2 R$$

Equation 2: Power Loss Formula

$$Load \propto I$$

Equation 3: Correlation between load and current

$$LossFactor = LoadFactor^2$$

Equation 4: Loss Factor Development

The loss factor is then used to calculate energy use. The total yearly savings can then be calculated by using Equation 5. This equation includes the cost of energy and capacity, which were supplied by Xcel Energy's resource planning department. For the economic analysis, this formula was applied each year.

$$\$Savings / Year = [MWreduction_{PEAK} * LossFactor * 8760 * (\$ / MWH)] + [MWreduction_{PEAK} * \$20,000]$$

Equation 5: Savings Calculation

From this data one could also calculate the MWH Loss Savings annually as well as the tons of CO_2 saved. Equations 6 and 7 below show these calculations.

$$MWHSavings / Year = MWreduction_{PEAK} * LossFactor * 8760$$

Equation 6: Annual MWH Loss Savings

$$CO_2 Savings / Year = \frac{(MWHSavings / Year)}{(2MWH / TonCoal)} * \frac{(1.86tonCO_2)}{TonCoal}$$

Equation 7: Annual CO_2 Savings in Tons

There are essentially two different types of alternatives being considered to address the risks on the distribution system in South Minneapolis:

- Build Two Substations: Build a Hiawatha Substation and a Midtown Substation with five feeders at each substation.

- Build One Substation: Build only a Hiawatha Substation. This single Hiawatha Substation would have ten feeders total. There will be five feeders to address the same areas as the Hiawatha Substation in the first option and five feeders to address the same areas as the Midtown Substation in the first option. The feeders addressing the Midtown area would be pulled in duct lines using 1000Al-paralleled cable for 15,000 feet.

The second alternative will introduce more losses than the first option because of the longer length of the feeders. Using this assertion the loss analysis done bases its evaluations on the difference in losses between the plans or the loss savings by going with the two-substation option.

By using SynerGEE and performing a load flow the loss difference between the two alternatives at peak was determined and found to be around 1 MW. This 1 MW is the same as the MW $reduction_{PEAK}$ value that was discussed in the previous section. With this value and considering several different loss factors based on the type of load on a circuit, i.e. residential, commercial, industrial, the Figure F.1 was developed.

Figure F.1: Loss Savings

South Minneapolis Loss Study						
Feeder Load Composition	**Type of Loss Savings**	**2010**	**Thru 2013**	**Thru 2018**	**Thru 2023**	**Thru 2028**
Residential	MWH Savings	350	1160	3864	6867	10701
	Total Dollars Savings	$47,920	$203,005	$494,438	$881,284	$1,407,212
	CO_2 Savings Tons	326	1079	3594	6386	9952
	MWH Savings	788	2610	8693	15452	24077
	Total Dollars Savings	$82,820	$349,008	$836,820	$1,492,924	$2,402,752
	CO_2 Savings Tons	733	2427	8084	14370	22392
Commercial/Residential Mix						
	MWH Savings	1402	4639	15455	27469	42803
	Total Dollars Savings	$131,679	$553,412	$1,316,156	$2,349,219	$3,796,509
	CO_2 Savings Tons	1304	4314	14373	25546	39807
	MWH Savings	2190	7249	24148	42921	66880
	Total Dollars Savings	$194,499	$816,218	$1,932,445	$3,450,170	$5,588,481
Commercial/Industrial Mix	CO_2 Savings Tons	2037	6742	22458	39917	62198
	MWH Savings	3154	10439	34773	61806	96308
	Total Dollars Savings	$271,279	$1,137,424	$2,685,688	$4,795,777	$7,778,669
	CO_2 Savings Tons	2933	9708	32339	57480	89566
	MWH Savings	4292	14208	47330	84125	131086
	Total Dollars Savings	$362,018	$1,517,032	$3,575,883	$6,386,040	$10,367,074
Industrial	CO_2 Savings Tons	3992	13213	44017	78236	121910

Since the load in the Focused Study Area is neither purely residential, nor purely commercial, nor purely industrial, a matrix was created to illustrate the ranges of loss savings that could be expected depending on the type of load. The best generalization for the type of load in this area would be a commercial and residential mix with very little industrial load and thus correspond to the yellow highlighted section of Figure F.1.

From Figure F.1, one can see that by going with the two-substation plan described in alternative 1 as opposed to the single substation described in alternative 3 there are significant loss savings to be had. Over the 20-year view of this study there would be approximately 42,000 MWH in savings, which correlates to 40,000 tons of CO2 in savings and $3.8 million saved.

Appendix G: Cost Information (cost reflects millions (+,000)) for South Minneapolis Alternatives 1-4

YEAR	Feeder Load (MVA)	Alternative 1 -A1 Hiawatha and Midtown 115/13.8 kV with two looped 115 kV transmission lines	Alternative 2 -A2 Hiawatha and west Midtown 115/13.8 kV with two looped 115 kV transmission lines	Alternative 3 -A3 Hiawatha 115/13.8 kV and express 13.8 kV Feeders to the Load Center (nonstandard)	Alternative 4 -A4 Hiawatha 115/13.8 kV and 115/34.5 kV, 34.5 kV sub-transmission with three midtown substations for 13.8 kV distribution (non-standard)
2000	275592				
2001	299450				
2002	320200				
2003	306000				
2004	291900				
2005	326380				
2006	337794				
2007	315680				
2008	312998				
2009	320939				
* 2010	326923	$33,380	$42,400	$21,810	$61,115
2011	330999				
2012	335130				
2013	339304				
2014	343600				
2015	348000				
* 2016	352500	$8,520	$4,250	$13,210	$22,165
* 2017	357000	$8,325	$8,325	$14,930	$27,305
2018	361574				
2019	366200				
2020	371000				
2021	375700				
2022	380600				
* 2023	385513	$5,630	$5,630	$10,100	$11,415
2024	390500				
2025	395600				
2026	400700				
2027	406000				
2028	411300				
		$55,855	$60,605	$60,050	$122,000

Note: Cost is shown in the year that the peak load forecast requires capacity addition.
Costs are based on indicative estimates which may change due to estimate refinement.