APPENDIX J
Nebraska Forest Service Wood Waste Supply & Utilization Assessment

Nebraska Forest Service
Wood Waste
Supply & Utilization
Assessment

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December 2008

1.0 Executive Summary

Woody biomass utilization offers opportunities to produce renewable energy, develop bio-based businesses, generate energy cost savings and create new markets for low value and waste wood resources. A state-wide examination of wood waste supply sources and potential bio-energy opportunities is an important first step necessary to increase utilization of woody biomass as a feedstock for bio-energy production. The Nebraska Forest Service received a USDA Forest Service "Wood-to-Energy Jumpstart" federal grant to conduct a wood waste supply assessment for the entire state and to perform a geo-spatial analysis that identified potentially optimal wood-to-energy market locations. In Nebraska, a state often characterized by its extensive food-crop production and prolific grasslands rather than by its forests, all three major sources of existing and potentially-available wood waste supply were studied, which included:

- **Forest biomass** generated as a result of commercial timber harvest, forest fuels reduction and range improvement activities.
- **Residual by-products** from primary and secondary wood products manufacturing operations.
- Sources of **Urban Wood Waste**, which includes tree debris separated from the municipal solid waste stream, public & private tree care service providers and utility line construction & maintenance activities.

Wood-Waste Supply – 766 wood waste supply locations were identified using information provided by the Nebraska Forest Service and on-line search methods. All listings were categorized by Standard Industrial Classification (SIC) codes. A survey form was mailed to all wood waste supply locations. Responses to the survey provided sufficient information to characterize wood waste supply types and helped to quantify wood waste amounts by category and location. The survey data was augmented with information obtained from the USDA-Forest Service and the Nebraska Forest Service to determine the estimated amounts of forest and primary wood processing wood waste. There is an estimated 172,395 tons of all types of wood waste currently produced annually in Nebraska. An additional 98,128 tons of forest biomass wood waste could become available for wood-to-energy utilization**.** If this additional forest biomass was processed, the total supply of wood waste in Nebraska would increase to 270,523 tons.

Wood-Waste Utilization - Existing institutions, organizations and businesses that could potentially utilize wood waste as a feedstock to produce energy were identified in order to define the potential demand for woody biomass in Nebraska. A subset of the 10,000 plus licensed boilers on the Nebraska Department of Labor list was selected in consultation with the Nebraska Forest Service. The wood-waste utilization analysis was focused upon the 422 boilers located in public institutions (hospitals, jails, schools & colleges) across the state of Nebraska that are 40 years of age or older. The optimal locations for replacement of aged boilers, based on the proximity of wood waste supply to potential demand sites, exist in eastern Nebraska, particularly in the Omaha and Lincoln metropolitan areas. Other potential locations for wood energy production exist in rural counties. This wood waste supply and demand infrastructure assessment serves an important function in the development of wood-to-energy opportunities. Additional in-depth feasibility analyses are necessary to implement site-specific investments.

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2.0 Introduction & Objectives

Increased utilization of wood waste can help decrease our Nation's dependence on foreign energy purchases, generate energy cost-savings, enhance the efficiencies of forest and range management efforts, reduce the amount of wood waste disposed of in landfills and stimulate local economic development. In 2006 a Rand Corporation analysis found that 25% of the Nation's energy could be competitively produced from ethanol, wind power and other forms of renewable energy such as woody biomass. A national alliance, known as the Energy Future Coalition, has subsequently advanced the "25 x 25 Initiative". (www.25x25.org) The Coalition's vision, now endorsed by the National Association of State Foresters, states: "By 2025, America's farms, forests and ranches will provide 25 percent of the total energy consumed in the United States, while continuing to produce safe, abundant and affordable food, feed and fiber."

In order to help produce renewable energy and create new markets for low value waste wood resources, the Nebraska Forest Service (NFS) is investigating the potential to increase the State's utilization of wood-waste biomass to produce bio-energy and bio-fuels. NFS received a USDA Forest Service "Wood-to-Energy Jumpstart" grant to conduct a wood waste supply assessment for the entire state and to provide a geo-spatial analysis that identified potentially optimal wood-to-energy market locations.

Wood waste can be an appropriate material to heat and cool building complexes such as college campuses, schools, hospitals and correctional facilities. For instance, Chadron State College in northwestern Nebraska installed wood fuel boilers to heat and cool its 1.1 million square feet of buildings. Wood waste, in the form of wood chips produced from logging slash, has replaced natural gas as the primary fuel in that location. The Lied Lodge and Conference Center in Nebraska City also utilizes wood waste as the feedstock for its Fuelwood Energy Plant. Five alfalfa hay de-hydration plants in Nebraska are using wood waste as a source of heat energy. Additionally, since the early 1980's, Northwest Missouri State University in Maryville, Missouri has used waste paper and sawdust to fuel its wood-fired boiler. In other states, such as Montana and Idaho, the use of wood waste (sawdust, bark and processed logging slash generated as a result of lumber production and timber processing) to heat public schools has increased in recent years

The heat and steam produced as a result of burning wood waste (instead of coal, propane or natural gas) can also be used to generate electricity and power industrial processes. Utilization of wood waste biomass to generate bio-energy has the potential to improve the net energy balance of producing ethanol. Appropriate types of wood waste can also be transformed into wood pellets and other value-added products. In North America, there are now more than 60 wood pellet manufacturers with a total annual production of 2 million tons – it is estimated that 7 million cubic yards of wood waste biomass are annually diverted from landfills and converted to wood pellet home heat sources.

Nebraska is historically known for its extensive corn crops (1.2 billion bushels produced from 8.1 million acres), and also now as the nation's third largest producer of ethanol. The State's existing 20 corn ethanol plants produce 1.3 billion gallons of ethanol annually, with 20 more ethanol plants on the drawing board. The State also supports a $76 billon manufacturing sector

and many other institutions or businesses that consume large amounts of energy in industrial process and to heat and cool their buildings. Of the 652 trillion BTUs of energy consumed in the State, 19.5 trillion BTUs (3%) originate from non-fossil fuel sources, including biomass, hydroelectric power, geothermal, wind and solar power. Biomass, including wood waste and ethanol, accounts for about 1.4% of Nebraska's total energy consumption.

The assessment of current and potential sources of wood waste supplies is an important first step to achieve the goal of increasing the utilization of woody biomass as a feedstock for bio-energy production. This project is designed to assess and characterize existing and potential supply sources of wood waste and to analyze potential wood-to-energy consumers through a geospatial database system that links the supply of wood waste biomass with institutions that have the potential to convert boilers to wood energy.

There are three major sources of wood waste supply. Forest biomass is generated as a result of commercial timber harvest and also from forest fuels reduction and range improvement activities. The State of Nebraska has 2.5 million acres of land where trees are the predominant vegetation. These lands include 1.245 million acres classified as forest land (including the 142,000 acre Nebraska National Forest) and 1.25 million acres of wooded riparian areas, shelterbelts and Christmas tree plantations. Eastern red cedar encroachment into native prairies and other agricultural lands also affects an extensive area. There are numerous businesses in Nebraska (such as commercial logging, tree thinning and brush removal contractors) that provide timber harvest and other tree removal and transportation services.

These forests and woodlands also help support many primary and secondary wood products manufacturing operations throughout Nebraska. The by-products (such as chips, sawdust, shavings and bark) generated by these businesses represent a traditional source of biomass supply.

Urban wood waste can be an important component of wood waste supply sources. Nebraska, birthplace of the Arbor Day Foundation, has over 150 communities and many are enhanced by the presence of urban forests where tree species such as cottonwood, bur oak, maple, linden, ponderosa pine and Colorado blue spruce thrive. Tree debris created from the maintenance and removal of these trees can often represent an important component of the urban wood waste supply stream. Tree care service companies or city governments are normally responsible for the disposal of this material.

Nebraska is home to over 1.8 million residents – wood waste studies performed in other states indicate that significant amounts of wood waste usually exist in the municipal waste stream. In many states, up to 90% of that material is typically burned or buried in landfills.

Maintenance and construction of utility line corridors requires management of the vegetation that can affect the transmission of electricity and fuels such as natural gas. The tree debris removed from utility line corridors can represent another potential source of urban wood waste supply.

The presence and potential availability of these various types of wood waste resources, combined with a heightened interest in increased production of bio-energy products, provided the impetus

for the Nebraska Forest Service to assist with efforts that can lead to implementation of wood-to-energy opportunities. Camas Creek (www.CamasCreek.biz), as prime contractor, was responsible for accomplishing the project objectives, and, with its strategic business partner Geodata Services (www.geodataservicesinc.com) provided established deliverables. Camas Creek's president Rich Lane has 25 years of experience managing raw material supply systems for the forest products industry in the western and southern United States. Geodata Service's president Ken Wall has provided geo-spatial analysis services for multiple forest management and bio-energy projects for two decades.

The two major objectives of the Nebraska Wood Waste Supply and Utilization state-wide project were to:

1. Quantify the amount and character of the Woody Biomass Resource in the State of Nebraska, and,
2. Develop criteria to prioritize and rate the feasibility for institutions in the State of Nebraska to produce wood energy.

3.0 Wood Waste Supply Findings

3.1 Supply Assessment Methodology

A replicable wood waste supply assessment system was established. All types and sources of wood waste were organized within three major categories:

- Forest Biomass
- Wood Processing Residual By-Products
- Urban Wood Waste

Within these three major categories, the following eight supply sources were identified:

- Forest Biomass
    1. Commercial Logging & Forest Fuels Management Contractors
    2. Range Improvement Contractors
- Wood Processing Residual By-Products
    3. Primary Wood Products Manufacturing Businesses
    4. Secondary Wood Products Manufacturing Businesses
- Urban Wood Waste
    5. Municipal Waste Disposal Facilities
    6. Tree Care – Private Businesses
    7. Tree Care – City Governments
    8. Utility Companies

3.2 Data Collection - Supplier Survey

Written questionnaires were the primary data collection tool. An appropriate questionnaire for each of the eight groups was developed by Camas Creek and endorsed by the NFS. The eight survey forms and their cover letters are provided in Appendix One.

Supplier contact information for individual entities was acquired using partial lists provided by the Nebraska Forest Service and other on-line data base searches conducted by Camas Creek. To compile the complete list of contacts, ESRI Business Analyst software was used to access InfoUSA data bases for targeted business types, which were sorted by standard industrial classification (SIC) codes. The SIC codes included relevant Major Groups within Division A "Agriculture, Forestry and Fishing" and Division D "Manufacturing", as classified within the SIC system by the U.S. Department of Labor. 766 potential supply sources were obtained for the census survey. The contact information for these potential suppliers is included in the Supply Master List (Appendix Two). All address locations were geo-coded with Business Analyst Online to facilitate geo-spatial analysis.

The Dillman written questionnaire method was employed. A post card announcement was mailed to each contact two weeks before the first survey was distributed. One week after the initially requested response date a second questionnaire was mailed to all non-respondents. In certain cases, delivery of the surveys was not possible due to non-forward able changes of address or business terminations. Information was also obtained directly via phone

conversations. A wood waste supply database was tabulated by business type, business name, physical location, county, type and amount of waste produced annually. The database is in GIS format and was provided to NFS in digital format.

The survey response rates for each supply source category are shown below:

Group	Source	Surveys Mailed	Valid Population	Surveys Returned	Percent Returned
1	Logging & Fuels Reduction	55	54	12	22%
2	Range Improvement	49	43	11	26%
3	Municipal Waste	78	77	30	39%
4	Private Tree Care	197	188	55	29%
5	Gov. Tree Care	114	114	67	59%
6	Utility Company	39	39	28	72%
7	Primary Processors	57	56	16	29%
8	Secondary Processors	177	171	58	34%
	Totals	766	742	277	37%

The data collection process via written survey responses was actually a census rather than a sample or sub-set of the entire population, therefore data reported by survey responders should not be extrapolated to derive data from non-responders.

3.3 Data Collection - Supplemental Sources

Forest Biomass – Timber Harvest: The slash produced as a result of commercial timber harvest can be an important source of Forest Biomass supply. In addition to information provided via the surveys, data pertaining to this biomass supply category was obtained from the USDA Forest Service Timber Products Output (TPO) report. This 2006 report, which was compiled for the state of Nebraska by the Northern Research Station of the USDA Forest Service in St. Paul, MN, reported county-level timber harvest levels in Nebraska**.** Figure 1 illustrates these commercial timber harvest levels. Figure 2 illustrates the amounts of the logging slash or forest residue produced as a result of those timber harvest levels.

Forest Biomass – Fuels Reduction & Range Improvement: NFS Foresters Richard Woollen and Doak Nickerson provided county-level data regarding the extent of forest fuels reduction (tree thinning) and range improvement (brush removal) activities on private lands. These materials represent a potentially available supply source if they are mechanically processed into bio-energy feedstock material.

Wood Processing Residual By-Products – To supplement the survey data, the above referenced USFS Timber Products Output report provided additional state-wide data regarding the amount of wood residue produced from primary manufacturing operations.

3.4 Supply Characteristics

The below analysis characterizes each of the eight major supply groups based on the survey responses and supplemental data sources. The physical locations of Wood Waste Supply Sources are illustrated in map format.

3.4.1 Forest Biomass

Commercial Logging Contractors
Logging contractors are companies that provide commercial timber harvesting services for private landowners and governmental agencies responsible for forest management. As noted in the introduction to this report, forest biomass generated by commercial timber harvest can represent a significant source of wood-waste supply. The available amounts of this type of wood waste are ultimately dependent upon timber harvest levels and a multitude of other factors discussed below. In 2005, for a wood biomass feasibility study in Montana, Camas Creek developed a method to estimate harvest and transportation costs for small-diameter trees.

The four phases of timber harvest include:

- Tree felling,
- Log processing
- Loading
- Hauling

The log processing phase involves (1) cutting the tree into appropriate sizes for loading and hauling, and, (2) the removal of the limbs, tops and other un-merchantable portions of the tree. The wood waste generated as a result of log processing is commonly known as logging slash or forest residue. Logging slash must be mechanically processed in order to produce usable bio-energy feedstock material. The processing of logging slash into usable wood waste in a forest setting requires the use of a portable chipper or a grinder, suitable transportation systems must be in-place and hauling equipment must be available.

Results of the Nebraska logging contractor survey indicated that half of the respondents processed logs in the woods and half processed logs at a log landing. The location of the log processing phase is critical if logging slash is to be further processed into usable wood waste. It is common for felled trees to be processed at a log landing – the whole tree, with limbs and tops attached, is skidded to a location where trees are processed and then loaded/hauled. This method is known as whole-tree skidding. The logging slash accumulated at a log landing (as a result of whole-tree skidding) can be readily accessible for further processing into usable wood waste. In most cases, if log processing occurs “in the woods” and not at the log landing, then typically logging slash is not readily available for chipping or grinding into bio-energy products. However, specialized mobile equipment has been developed to bale logging slash “in the woods” and carry it to a log landing for further transport.

The surveys indicate that a relatively small number of contractors currently process logging slash into bio-energy feedstock. However, numerous logging contractors indicated a moderate to high level of interest regarding the production of bio-energy products as part of their businesses.

It should be noted that, when combined with commercial timber harvesting projects, certain conditions must exist for the successful production and delivery of bio-energy feedstock. Road systems and conditions must be suitable in order for hauling equipment to access log landings. Bio-energy products, when produced commercially, are commonly hauled to market in chip trailers or vans. The turning radius for most chip trailers is greater than needed for conventional log hauling equipment. Inclement weather affecting road conditions can often cause disruptions in hauling schedules. Because costly mechanical processing and transportation steps are needed to convert otherwise un-merchantable stems and limbs into delivered bio-energy feedstock material, the marketplace must be willing to compensate accordingly.

Fuels Management Contractors

In Nebraska, softwood trees species such as Ponderosa pine and Eastern red cedar are managed in certain forest settings in order to reduce forest fuels. Management activities to achieve fuels reduction are conducted by independent contractors on private lands and on property administered by government agencies. In some situations, commercial logging contractors are also equipped to perform these fuels reduction services.

At present, these management activities do not result in the generation of significant amounts of utilized commercial products (such as commercial timber or bio-energy material) even though tree density and the associated amounts of wood waste are often very high. Thus, at present, no or very little net revenue is generated as a result of fuels management activities. Most often, these land stewardship efforts are accomplished only if the property owner or a governmental agency is willing to financially subsidize the activity by paying for all or a significant portion of the costs.

The economic and operational challenges involved in fuels reduction practices in Nebraska are nearly identical to the challenges that other states in the western United States are working to resolve. The challenges associated with access, road conditions and suitable hauling equipment are similar to those associated with producing bio-energy products from commercial timber harvest. Because costly mechanical processing and transportation steps are needed to convert stems and limbs into delivered bio-energy feedstock material, the marketplace must be willing to compensate accordingly.

As noted above, because fuels management practices do not typically generate immediate financial revenues, it is necessary for private landowners or governmental agencies to pay contractors to perform the desired work. Government cost-share assistance is available through the Nebraska Forest Service, which administers a “Fuels Management Program” to reduce forest fuels. This state program is active in the Pine Ridge area and in the Niobrara River Valley – typically pine is thinned to a designated spacing and in most instances all eastern red cedar is removed.

The physical locations of the Commercial Logging and Fuels Management Contractors in Nebraska are illustrated in Figure 3.

Range Improvement Contractors

In Nebraska, Eastern red cedar encroachment has negatively affected forage conditions for livestock and wildlife. Management activities to improve range conditions, such as tree thinning and tree removal, are conducted by independent contractors on private lands and on property administered by government agencies. At present, these management activities do not result in the generation of significant amounts of utilized commercial products (such as commercial timber or bio-energy material) even though tree density and the associated amounts of wood waste are often very high. Thus, at present, no revenue is generated as a result of range improvement activities. Most often, these land stewardship efforts are accomplished only if the property owner or a governmental agency is willing to financially subsidize the activity by paying for all or a significant portion of the costs.

The economic and operational challenges involved in range improvement practices in Nebraska are nearly identical to the challenges that other states in the western United States are working to resolve. The challenges associated with access, road conditions and suitable hauling equipment are similar to those associated with producing bio-energy products from commercial timber harvest. Because costly mechanical processing and transportation steps are needed to convert stems and limbs into delivered bio-energy feedstock material, the marketplace must be willing to compensate accordingly.

As noted above, because range improvement practices do not typically generate immediate financial revenues, it is necessary for private landowners or governmental agencies to pay contractors to perform the desired work. Government cost-share assistance is available through two programs:

- The USDA Natural Resource and Conservation Service (NRCS) administers a "Brush Management" federal cost-share program to aid the removal of eastern red cedar that has encroached into range areas. Over the last three fiscal years (2006- 2008), this program has resulted in the removal of eastern red cedar on 8,349 acres.
- The Nebraska Game & Parks Commission administers Landowner Incentive Program grant funds provided by the U.S. Fish & Wildlife Service to assist with tree removal that will protect, enhance or restore habitat for at-risk species on private land.

Other government range improvement efforts in Nebraska include:

- State-owned lands administered by the Nebraska Game & Parks Commission, such as State Parks.
- School trust land management administered by their trustee (the Nebraska Board of Educational Lands and Funds)
- Windbreak renovation administered by the NRCS. Over the last three years, windbreak renovation has been conducted on about 83 acres.

Continued and/or increased management of these vegetation types represent a potential future supply of bio-energy products. Figure 4 illustrates the physical location of businesses currently engaged in range improvement. Figure 5 depicts the various levels of Range Improvement activities in Nebraska.

3.4.2 Wood Manufacturing By-Products

Primary Processors
Primary wood processors are businesses that manufacture wood products using logs or other roundwood as raw material. In Nebraska, manufactured wood products include lumber, veneer, house logs, firewood, shavings, stairway spindles and wooden fencing materials (posts, poles & rails).

The by-products of primary wood processing (see below discussion) are a common raw material feedstock for pulp & paper manufacturing and large-scale bio-energy production facilities (including wood pellets) in areas of the U.S. and Canada where forests and solid-wood product manufacturing businesses (sawmills and plywood plants) are more prevalent.

A major advantage of this type of wood waste is that, unlike Forest Biomass, additional materials-processing steps are minimal or not required. For instance, sawdust produced as a result of sawing lumber can be utilized without additional processing. However, value-added utilization of wood waste is a market-driven phenomenon. Since many of the primary wood processors in Nebraska now burn or otherwise dispose of wood waste to reduce costs, or utilize it for landscaping mulch, an efficient bio-energy market could provide a suitable incentive for these suppliers to sell their wood waste as bio-energy feedstock material.

Typically, four types of wood waste are generated as a result of manufacturing solid wood products from logs. These are bark, sawdust, chips and shavings. The survey results indicated that landscape mulch is also a common log processing by-product. In many situations tree bark is removed prior to initial processing, which results in the generation of bark as a by-product. The wood products manufacturing by-product "sawdust" is produced during the initial log break-down phase and as lumber is edged and trimmed. Slabs produced during the initial log break-down phase can be further processed into chips and/or wood mulch, or can be pulled off the production line and later burned or used as firewood. Shavings are produced by planning lumber to produce a smooth surface – sometimes green lumber is surfaced and other times only dried lumber is surfaced, which affects the moisture content of that by-product.

There are a total of 56 primary processors in Nebraska. Forty-nine (49) of these primary processors are sawmills that produce lumber. The other five (5) plants produce wood veneer, shavings, cabin logs, posts, etc. Five sawmills produce in excess of one million board feet per year (1MMBF/yr.) - only two sawmills produce more than 5 MMBF/yr. Figure 6 illustrates the locations of the primary processors in Nebraska.

Secondary Processors
Secondary wood processors are defined as businesses that manufacture wood products from lumber, partially manufactured logs, or residue from primary wood products manufacturing or logging operations. These businesses are one step removed from the primary processing of logs or other roundwood. For instance, shipping pallet manufacturers use lumber (that they produce internally at a company sawmill or buy from another sawmill or lumber broker) to build pallets. In Nebraska, secondary products include cabinets, shipping pallets, construction stakes, roof &

floor trusses, interior doors, window jambs, utility transmission arms & braces, picture frames, hardwood molding and trophy plaques.

Secondary processors primarily produce sawdust and shavings – chips and bark are not a common by-product of secondary processing. These wood waste products (sawdust and shavings) are currently utilized as animal bedding, landscape products or are burned or land-filled. Like the by-products produced by primary processors, the by-products associated with secondary processing are also suitable for bio-energy production. Figure 7 depicts the locations of secondary wood manufacturing businesses.

3.4.3 Urban Wood Waste

Municipal Waste Disposal Facilities

The category known as "municipal waste" consists of everyday household and business garbage, construction & demolition waste and also includes other wood waste generated as a result of lawn maintenance and urban forest management activities. The suitable wood waste segment (see below explanation of suitable vs. unsuitable) of municipal waste represents a potential supply of bio-energy feedstock in Nebraska. By way of example, the city of St. Paul, Minnesota is currently utilizing municipal wood waste (including a significant amount of tree waste) to fuel a 25 MW combined heat and power (CHP) plant.

All permitted waste disposal facilities in Nebraska were contacted to evaluate current wood waste disposal and utilization practices. These facilities included landfills, transfer stations, tree debris drop-off sites and Construction & Demolition (C&D) sites. Several types of facilities (landfills and transfer stations) currently separate tree debris and other wood waste at the site – this material is often disposed of by burning or burial rather than being further processed into usable wood waste products.

This study defined "suitable urban wood waste" as the portion of the municipal waste stream that includes pruned branches, stumps, and whole trees from street and park maintenance, wooden shipping pallets and woody material from land clearing activities. For purposes of this wood waste supply study, we specifically excluded "unsuitable urban wood waste" materials, which are those wood waste products not considered suitable for bio-energy utilization. "Unsuitable urban wood waste" is generated from construction & demolition activities and commonly contains wood preservation chemicals, paint and adhesives. Sixty percent of the survey respondents provided data on the amount of suitable urban wood waste received annually. Figure 8 shows the locations of all municipal waste disposal operations in Nebraska.

Tree Care Service Companies

The disposal of whole trees, tree branches and other wood waste generated as a result of urban forest management represents a potential future supply of bio-energy feedstock. Tree care companies directly provide urban tree maintenance and tree removal services for individual private property owners and often provide similar services for city governments responsible for urban forests. Figure 9 illustrates the locations of tree care service companies in Nebraska.

City Government Tree Care

The disposal of whole trees, tree branches and other wood waste generated as a result of urban forest management represents a potential future supply of bio-energy feedstock. City governments sometimes provide tree/tree debris pick-up and disposal services for individual private property owners and are usually responsible for urban forest management in city parks and other public settings. Oftentimes, all or some of a city's tree removal/tree maintenance activities are out-sourced to private tree care service companies (see above). City governments in towns with populations exceeding 1,000 residents were contacted to evaluate current tree wood waste disposal practices. Figure 10 illustrates the locations of the surveyed cities.

Utility Companies

The disposal of whole trees, tree branches and other wood waste generated as a result of utility distribution line activities represents a potential future supply of bio-energy feedstock. These companies provide urban and rural utility distribution such as residential and industrial electrical and natural gas services. The construction and annual maintenance of above and below-ground utility distribution corridors requires an active vegetation management program. In total, the companies that responded to the survey are responsible for line maintenance on over 43,500 miles of utility right of way – based on a 20 foot average corridor width there is over 105,000 acres potentially available as a bio-energy land base, if access and operational issues are resolved. Figure 11 depicts the geographic locations of major utility lines in Nebraska.

3.5 Supply Summary

Currently Processed Wood Waste: The following table illustrates the amounts of currently processed wood waste in Nebraska, by Major Category:

Table 1: Currently Processed Wood Waste Supply by Major Category

Major Category	Green Tons	Percent of Total
Forest Biomass	11,900	6.9 %
Residual By-Products	83,357	48.4 %
Urban Wood Waste	77,138	44.7%
Total	172,395	100%

The below table illustrates the individual sources of currently processed wood waste

Table 2: Currently Processed Wood Waste Supply by Group

Group	Green Tons	Percent of Total
Commercial Logging & Fuels Management Contractors	11,500	6.7 %
Range Improvement Contractors	400	0.2 %
Primary Wood Products	71,972	41.7 %
Secondary Wood Products	11,385	6.6 %
Municipal Waste Disposal Facilities	22,854	13.3 %
Tree Care Service	32,236	18.7 %
City Governments	12,542	7.3 %
Utility Companies	9,506	5.5 %
Total	172,395	100%

Unprocessed Forest Biomass Supply: There is documented potential to increase the amount of Forest Biomass supply by 98,128 tons annually if all wood waste associated with ongoing commercial timber harvest (forest residue), Fuels Reduction and Range Improvement activities were utilized. According to the USFS Timber Outputs report, there is an additional 54,023 tons of un-utilized wood waste associated with annual commercial timber harvest. Fuels reduction operations could potentially annually generate an additional 16,210 tons of wood waste generated from tree thinning designed to reduce forest fuel levels. Range improvement activities are sufficient to generate up to 27,895 tons annually, based on the number of acres where Eastern

red cedar is removed. With the addition of these amounts, the total annual supply of wood waste in Nebraska would increase to 270,523 tons, as shown in Table 3.

Table 3: Processed & Unprocessed Wood Waste Supply by Major Category

Major Category	Green Tons	Percent of Total
Forest Biomass	110,028	40.7 %
Residual By-Products	83,357	30.8 %
Urban Wood Waste	77,138	28.5 %
Total	270,523	100%

3.6 County-level Supply Ranking

The county level was the smallest geographic unit available to geo-spatially analyze a combination of all categories of wood waste supply data. The location of the majority (84%) of the 270, 523 tons of currently processed and potentially-processed wood waste supply was identified at the county level, a key metric that identifies the geographic sources of bio-energy feedstock supply. County level data was available for all wood residue produced by primary processors that responded to the survey – the additional wood residue produced by primary processors not responding to the survey is included in the above totals for the Residual By-Products category but was not available for geo-spatial analysis at the county level.

Forty-two of Nebraska's ninety-three counties have wood waste supply that exceeds 1,000 tons annually. Of this group, wood waste supply in 7 counties exceeded 10,000 tons annually. These are Dawes, Lincoln and Dundy in western Nebraska and Butler, Lancaster, Douglas and Sarpy counties in eastern Nebraska. Figure 12 illustrates the county level geographic distribution of wood waste supply amounts. Figure 13 provides a summary of wood waste supply amounts for each county in bar chart format.

3.7 Supply Suitability Assessment

Raw material feedstock supply suitability is a major factor affecting bio-energy projects. Bio-energy project proponents must recognize that numerous economic and operational factors need to be resolved in order to increase the utilization of wood waste in Nebraska. The following discussion provides insight into each of these challenges. It is also important that each potential wood energy producer assess the regional and global competitive advantages/disadvantages associated with wood waste supply and utilization for their individual product and location.

In 2006, Camas Creek developed a "Preferred Supplier Matrix" format to rank suppliers of various types of small-diameter roundwood, based on each potential supplier's raw material

supply system, plant production capabilities, customer relations, technology, production equipment, marketing system and location. A systematic assessment of wood waste supply should be performed for individual suppliers of bio-energy feedstock in relation to each contemplated wood-to-energy project, to include the following topics:

Seasonality – Seasonality pertains to the timely availability of wood waste supply. Irregular availability will influence delivered raw material cost structures, working capital requirements and inventory space requirements. A variety of factors affect the seasonality of each type of wood waste. For instance, municipal waste facilities experience variations in the delivery of tree debris over the course of a normal year, as tree debris delivery normally is less in the winter than during the spring/fall period. Private and government tree maintenance activities do not generally occur year-round. Severe storms may result in irregular periodic increases of tree debris. Secondary processors are normally not affected by weather conditions, but may be affected by seasonal market demand for their products. Large primary wood processing companies usually operate year-round, but many smaller sawmills in Nebraska do not operate on a consistent basis. Weather conditions often affect field operations associated with utility line maintenance, commercial logging, fuels reduction and range improvement projects.

Reliable Access – Access to supply sources is affected by weather that affects roads needed to transport products generated by utility line maintenance, commercial logging, forest fuels reduction and range improvement projects. Truck access to secondary wood processors may be affected by available space needed to load wood waste products, especially in situations where wood waste loading was not anticipated.

Processing – Wood waste generated by secondary processing is typically in a form that does not require further mechanical processing. In general, primary wood processors have equipment in-place to chip or grind slabs, and the sawdust and shavings they produce are already in suitable form. Many tree service and utility companies already mechanically process tree debris using chippers. However, to generate suitable wood waste at municipal waste facilities, mechanical processing must occur, just as it must occur for commercial logging, fuels reduction and range improvement projects.

Freight – Resolution of freight challenges is critical for utility companies, commercial logging, fuels reduction and range improvement contractors. Typically, it is difficult to maximize legal net weights when hauling wood waste due to its low density/high bulk characteristics. Specialized equipment, such as chip vans, is needed to transport processed wood waste from forested settings to market locations. This type of equipment is also needed to efficiently haul material generated at locations such as sawmills, which are sometimes many miles from market.

Quality Conformity – Product quality is often overlooked in the initial stages of procuring raw material feedstock. Product quality, which is specified by the purchaser and dependent on the technology platform used to produce bio-energy, refers to moisture content, size distribution, presence of undesirable material such as tree needles, leaves, bark content, over-sized or un-chipped material and contaminants, such as metal or plastic.

Materials Separation – Wood waste is often co-mingled with other non-combustible or unsuitable material. The processes necessary to segregate suitable wood waste from typical house-hold trash, and their associated costs, are a primary reason why landfills do not readily embrace wood recycling unless landfill space is limited or an economical incentive or legislative mandate exists. Proper materials separation is also required for other sources of wood waste generated during urban tree maintenance, utility line maintenance and for operations occurring in the forest or resulting from range improvement projects. Primary and secondary wood processing operations generally require a lower degree of material separation if sawdust can be mixed with other residual wood products.

Sustainability – The issues of sustainability pertain to ecological factors and long-term supply availability. The amount of wood waste generated directly from trees in the forest or an urban setting is a function of biological growth rates and the level of management intensity required to obtain desired conditions. Municipal wood waste supply is unlikely to be affected by sustainability issues. Many secondary wood processors obtain raw material from sources outside Nebraska – this wood waste supply category is unlikely to be affected by sustainability issues.

Competition – Current and planned future uses of wood waste supply must be considered for all site-specific wood energy analyses. Multiple wood-fired boilers already exist in or near Nebraska and additional projects are underway. The wood waste already used or expected to be consumed by those operations and the undocumented amounts consumed by other known users in Nebraska should be factored into every analysis exploring increased wood waste utilization. It is also known that significant amounts of wood waste in Nebraska are currently processed into landscape mulch for use at college campuses and by city governments

3.8 Supply Diversity Analysis

Supply diversity pertains to the variety of different types of supply sources within a county. A high level of supply diversity adds to the complexity of a wood waste procurement strategy and the associated transportation and delivered product un-loading systems. A high level of supply diversity may also mitigate issues such as seasonality, access sustainability and competition. However, many wood waste utilization businesses have operated successfully for many years by depending upon a single source of wood waste supply. Determining the optimal level of supply diversity is a decision left to the individual operation.

Figure 14 depicts the county-level percentages of each major supply category in pie chart format overlaid on wood waste supply amounts for each county. In general, western Nebraska tends to have less diversity of supply sources, with most counties having one source, although several had up to three supply sources, primarily from forest harvest or fuels reduction. The lower populations in the western counties constricted the landfill and urban tree residue amounts, though some tree care companies and landfills reported significant amounts of wood waste residue in counties such as Kimball, Keith, Box Butte and Cherry counties. The lack of supply diversity in western Nebraska, however, may cause long term supply sustainability considerations.

In eastern Nebraska there is a broader mix and diversity of supply sources, though 20 of the rural eastern counties still would entirely rely on commercial timber harvest residue and wood manufacturing by-products as sources of wood waste supply. The current market for wood products and other nation-wide forest industry trends are a cause for some wood waste supply concerns.

The three large urban counties (Douglas and Sarpy within the greater Omaha area and Lancaster with the city of Lincoln) have the most wood waste supply and a good mix of supply sources. There are significant differences in the supply sources for the urban counties, with Lancaster primarily having municipal waste sources and fewer resource based sources, and the Omaha counties having a larger industrial component.

4.0 Wood Waste Utilization Findings

4.1 Existing Wood Waste Utilization

Wood-fired Boilers –There are currently eight commercial scale wood-fired boilers located in Nebraska. They are Chadron State College in Chadron, Lied Lodge & Conference Center in Nebraska City, American Wood Fibers in Clarks, Consolidated Blenders in Hastings, Hillside Dehy in Uhling, Dehy Alfalfa Mills in Arlington, Gothenburg Feed Products in Gothenburg and Island Dehy Company in Cozad. These existing wood energy producers consume a minimum of 17,900 tons of wood waste. Their feedstock requirements should be carefully considered as new wood energy producers are contemplated.

Additionally, there are several boiler conversion projects currently under consideration in Nebraska, which if implemented would consume 31,390 tons of wood waste. These are the Chadron Community Hospital in Chadron (400 tons/year), Crow Butte Resources in Crawford (350 tons per year), Nebraska College of Technical Agriculture in Curtis (1,040 tons/year), Peru State College in Peru (3,200 tons/year), and the University of Nebraska – East Campus in Lincoln (26,400 tons/year). Their locations, a wood waste consumer in Missouri (Northwest Missouri State University) and a waste wood consumer in Council Bluffs, Iowa (American Walnut) are depicted in Figure 15.

Other businesses and public institutions in Nebraska are currently conducting feasibility studies or are reportedly interested in the utilizing wood waste to produce heat and/or steam.

Other Current Uses of Wood Waste
In Nebraska, processed wood waste is commonly utilized as landscape mulch by homeowners or at city parks, universities, plant nurseries and animal feedlots.

Emerging Opportunities for Wood Energy
In addition to wood-fired boiler conversion projects, other potential opportunities exist to utilize wood waste to produce bio-energy products. Direct combustion and gasification technology platforms are available that use waste wood to produce steam to generate electricity. Wood waste can be utilized as the sole feedstock to generate electricity or can be used to co-fire facilities that produce electricity from coal. Except in cases where there are other primary uses

of steam (such as the Eagle Studs sawmill and lumber dry kiln in Hall Montana that uses exhaust steam to power piston generators that produce 700 KW of internally-used electricity) investments in wood-fired boiler facilities that generate less than 1MW of electricity are usually not economical. A 1MW wood waste electrical generation plant was recently built in Carson City Nevada, which will consume 12,000 to 15,000 tons of wood waste annually. A 5MW electrical generation plant will require up to 75,000 tons of wood waste annually. Given the available wood waste supply in Nebraska, the only area where electrical generation would be potentially feasible is in the general area surrounding the three urban counties. A complete site-specific supply analysis should be conducted if this use of wood waste is contemplated.

Thermo-chemical processes have been developed that use wood to produce bio-fuels such as cellulosic ethanol and bio-diesel. Other energy intensive facilities represent waste-wood energy potential, such as using wood waste to produce heat and steam for the corn ethanol production process. Such private business wood-to-energy investments will be internally driven based on alternative energy costs and a multitude of other factors.

4.2 Boiler Conversion Analysis

In Nebraska, there are 10,421 existing licensed boilers used to produce heat and power, as determined by the Nebraska Department of Labor (DOL) records. Potential future consumers of wood waste often include public institutions or business operations that are considering replacement of an existing boiler that currently uses natural gas, propane or electricity as its fuel source. With direction provided by the Nebraska Forest Service, an initial target candidate list of 2,325 existing boilers was selected from the DOL boiler list to include boilers at the following public institutions:

- Nebraska State University system campuses
- Community, tribal & other private college campuses
- Primary and secondary schools,
- Hospitals
- Correctional institutions

The age distribution of these boilers is presented below:

Table 4: Selected Boiler Age

YEAR BUILT	AGE	Hospitals	Jails	Schools	Colleges	TOTAL	PERCENT
1988-present	0-20 years old	121	43	961	271	1396	60%
1968-1987	21-40 years old	65	12	315	108	500	22%
1945-1967	41-63 years old	42	4	285	67	398	17%
1944 and earlier	64 years and older	0	0	20	4	24	1%
NO DATE		0	0	0	7	7	0%
TOTAL		228	59	1581	457	2325	100%

Note that there are multiple boilers at many of public institution locations.

Wood-waste boiler conversion studies indicate that boilers older than 40 years of age are more likely to be replaced than newer boilers. As a group, boilers that exceed 40 years of age are the prime candidates for bio-energy conversion. These boilers comprise the demand side of the following proximity analysis – their locations at the county level are depicted in Figure 16. Note that there are 17 counties with no boilers older than 40 years, 67 counties with 1-7 boilers older than 40 years, and 9 counties with 10 – 82 boilers older than 40 years. Figure 17 illustrates the county level distribution of boilers older than 40 years in bar chart format.

4.3 Proximity Analyses

Wood waste supply and potential demand (represented by existing public institution boilers older than 40 years) were compared geographically to examine their geographic and quantitative relationships. Two ranking systems (4.3.1 and 4.3.2) were developed to identify the optimal counties for site-specific feasibility studies.

4.3.1 Optimal Locations for Boiler Conversion based on Supply Amounts

This analysis method is based upon the amount of wood waste supply in each county compared to the number of boilers older than 40 years. It identifies the seven counties with the highest theoretical potential for boiler conversions. The results of this analysis are depicted on Figure 18.

Four of the seven counties with more than 10,000 green tons per year of supply had a limited number of selected boilers over 40 years old, and possibly had greater supply than demand. Dawes and Lincoln counties had 5 and 4 older boilers respectively, Dundy County had 2 and Butler had 1 older boiler. Seventeen counties had no boilers over 40. Figure 18 also shows a total of 12 counties in the state with one boiler over 40 and less than 1,000 green tons per year of supply, likely an inadequate amount to sustain a single boiler. An additional 16 counties had 2 older boilers and less than 2,000 green tons per year of supply, indicating a marginal theoretical sustainable supply/demand ratio. All together, this indicates that boiler conversion to utilize wood waste biomass supply may be a viable alternative in approximately half of the counties in Nebraska.

4.3.2 Optimal Locations for Boiler Conversion based on Number of Supply Sources

This analysis method is solely based upon the number of identified wood waste supply sources (independent of reported wood waste supply amounts) in each county compared to the number of boilers older than 40 years. The county level supplier counts are illustrated on Figure 19. The results of this proximity analysis are shown on Figure 20 and demonstrate a strong correlation with the results obtained in 4.3.1 above.

4.3.3 Metropolitan Area Analysis

The two above analysis techniques indicate wood-to-energy opportunities in or near the two large metropolitan areas of Nebraska. Figures 21 and 22 illustrate supply sources and boiler locations in the Lincoln and Omaha metropolitan area.

4.3.4 Rural Area Analysis

The wood waste supply analysis revealed that forty-two of Nebraska's ninety-three counties have wood waste supply that exceeds 1,000 tons annually. These counties are depicted in Figures 12 and 13, and should be considered as potential locations for small-scale wood-to-energy production. Information obtained via personal communication with David Atkins (USDA-Forest Service Wood Biomass Coordinator – Region One) confirmed that feedstock requirements for small scale wood boilers varies from 800 – 1,200 tons per year depending on boiler type, the amount of heat or steam required, and the number of calendar days each year that heat was required. This calculation, based on actual amounts of biomass feedstock required for various successful "Fuels for Schools" projects in Montana, assumes that between 5,000 – 5,400 BTUs are produced from each pound of biomass feedstock. For example, the Darby Montana 3.3 MMBTU wood biomass boiler when operated about 200 days per year consumes between 800 to 1,000 tons of biomass feedstock annually.

4.4 Project Level Analysis

The primary objectives of this project were to provide a state-level analysis of wood waste supply and to identify potentially optimal geographic areas for wood-to-energy projects. The above analyses provide a state-wide and county-level view of wood waste supply and boiler conversion opportunities. Additional in-depth analysis regarding the state's two major metropolitan areas (Omaha and Lincoln) is provided. Opportunities for wood-to-energy production in rural area are also depicted.

The supply and demand data sets, as provided, are also suitable for project level analysis for site-specific feasibility analyses in other areas of Nebraska. County-level summaries of wood waste supplies are attached to this report. The individual survey responses (provided under separate copy) are also an important source of supply information for project level analyses.

However, the survey respondents and other potential wood-waste suppliers listed in the Master Supply List should be personally contacted by the project investigator to provide additional insight regarding supply amounts, cost estimates, presence of existing competition and other factors regarding supply availability. The Master Supply List also provides contact information for each non-responding business potentially producing wood waste. These non-respondents should also be contacted by the project investigator to determine supply availability. New or revised data can be added to the data base for further analysis.

Forest Biomass amounts are available in this report at the county-level. Data regarding forest thinning for fuels reduction and brush removal for range improvement was provided by NFS at county levels. A site-specific feasibility analysis will require additional geographic information regarding Forest Biomass supplies in order to achieve an acceptable degree of accuracy.

The locations of the 2,325 boilers examined in this report are geo-coded and available in the county-level shape files provided. Our analyses demonstrated that there are many opportunities for bio-energy production in the two major metropolitan areas of Omaha and Lincoln, based on

the amounts and diversity of supply and ages of existing boilers. The geographic locations of new boilers should also be geo-coded if further analysis is desired.

To examine new site-specific boiler locations in relationship to existing and/or potential wood waste supply, or to identify waste wood supply amounts in relationship to a contemplated boiler conversion project, two processes, outside the scope of this project, are available. Further GIS analyses may be desired but is likely not necessary and would require purchase of a subscription to Business Analyst On-line (approximately $995/year). In contrast to investing the time and money needed to obtain technical support and to perform detailed GIS analysis for each contemplated boiler conversion project, we recommend a more practical approach once a site-specific boiler conversion location is considered. A thorough site-specific feasibility study would require NFS personnel to conduct complete verification of the wood waste supply data provided via the surveys. Non-respondents should also be queried. Supply-source suitability should be examined and it is recommended that supplier selection criteria also be developed. The complete supply chain should be analyzed to include a competitive analysis, transportation costs, transportation equipment availability, feedstock processing costs and feedstock quality standards for each site-specific project. Distance and transportation costs for each potential wood waste supplier can be estimated using MapQuest or a similar distance and/or drive-time model.

5.0 Conclusions

Overall

1. Based on the data collected from survey respondents and obtained from other documented sources, processed wood waste supplies currently existing at various points throughout Nebraska represent an immediate opportunity to further pursue wood-to-energy production at site-specific locations. There is currently at least 172,395 green tons of processed wood waste generated annually in Nebraska.
2. Forest biomass supplies, generated by processing logging slash and non-commercial trees from commercial timber harvest, fuels reduction and range improvement activities in Nebraska currently represent an important but minor component of the state's bio-energy feedstock supply. Much (9,000 tons per year) of the currently processed forest biomass is produced to provide feedstock for Chadron State College.
3. There is potential to increase the amount of processed forest biomass supply by at least 98,128 green tons of wood waste per year based on current levels of commercial timber harvest, forest fuels reduction and range improvement activities.
4. The wood waste by-products generated from primary and secondary wood products manufacturing in Nebraska represent an important bio-energy feedstock source. A significant amount of this processed wood waste is currently used for landscape mulch and major amounts are burned or disposed of in landfills.
5. Urban wood waste, generated by segregating suitable wood waste from non-suitable waste of various types at municipal waste disposal locations, represents an important potential bio-energy feedstock source in Nebraska. Further mechanical processing of a significant portion of this supply type would be necessary.

6. Tree debris that is currently chipped or ground by private or public tree care organizations and utility line maintenance companies prior to delivery to a municipal waste site could be utilized for wood-to-energy production at the present time.
7. In Nebraska there are 422 existing boilers over 40 years old at selected public institutions – this group of boilers represent the most likely retrofit candidates. Potential demand for wood waste feedstock (based on the number of existing boilers in Nebraska that exceed 40 years of age) exceeds existing and potential future wood waste supply. Nonetheless, there are numerous site-specific woody biomass retrofit opportunities that should be explored in areas where feedstock supply amounts are adequate and available.
8. The state-wide geospatial supply/demand analysis demonstrated that the greatest concentrations of wood waste supply exists in the same general areas where boiler conversion potential is highest, based on boiler age.
9. Overall, the greatest potential for wood-to-energy projects is in the Omaha and Lincoln metropolitan areas, based on wood waste supply amounts and the number of boilers older than 40 years.
10. There are also numerous potential wood-to-energy opportunities in many other rural counties, where wood waste supply exceeds 1,000 tons annually. Boiler conversion to utilize wood waste biomass supply may be a viable alternative in approximately half of the counties in Nebraska.

Project Level Analysis

1. The data accumulated for this project is geo-coded and formatted in a manner to facilitate project- level analysis. The master supplier list provides a complete set of contact information for each identified wood-waste source. Additional supply information should be accumulated by NFS for site-specific potential wood energy producers. For each project-level analysis, supply-source suitability should be examined and it is recommended that supplier selection criteria also be developed.

Further Research Needs

1. The amounts and locations of other sources of biomass, including agricultural by-products such as wheat straw, corn stover (stalk, leaf, cob & husk), shells, pits, orchard prunings and orchard removals, should be researched to supplement wood waste feedstock supplies for certain biomass energy facilities
2. Development of technology used to convert wood waste to bio-energy products (such as cellulosic ethanol and syn-gas) should be monitored.
3. Funding opportunities for development of the bio-fuels industry (via the National Bio-fuels Action Plan) should also be monitored. Loan guarantees for renewable energy production are reportedly available through the 2007 Energy Independence & Security Act and the Food, Conservation and Energy Act of 2008.

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Emergent Solutions, Christopher Allen and Associates, CTA Architects and Engineers and Geodata Services Inc, **Assessment: Potential for Expanding the Fuels for Schools Concept to other Institutions and Industries**. December 2004.

Nebraska Forest Service. **Woody Biomass Energy: Nebraska's Untapped Resource.** 2008

Figure 1: Commercial Timber Harvest Levels

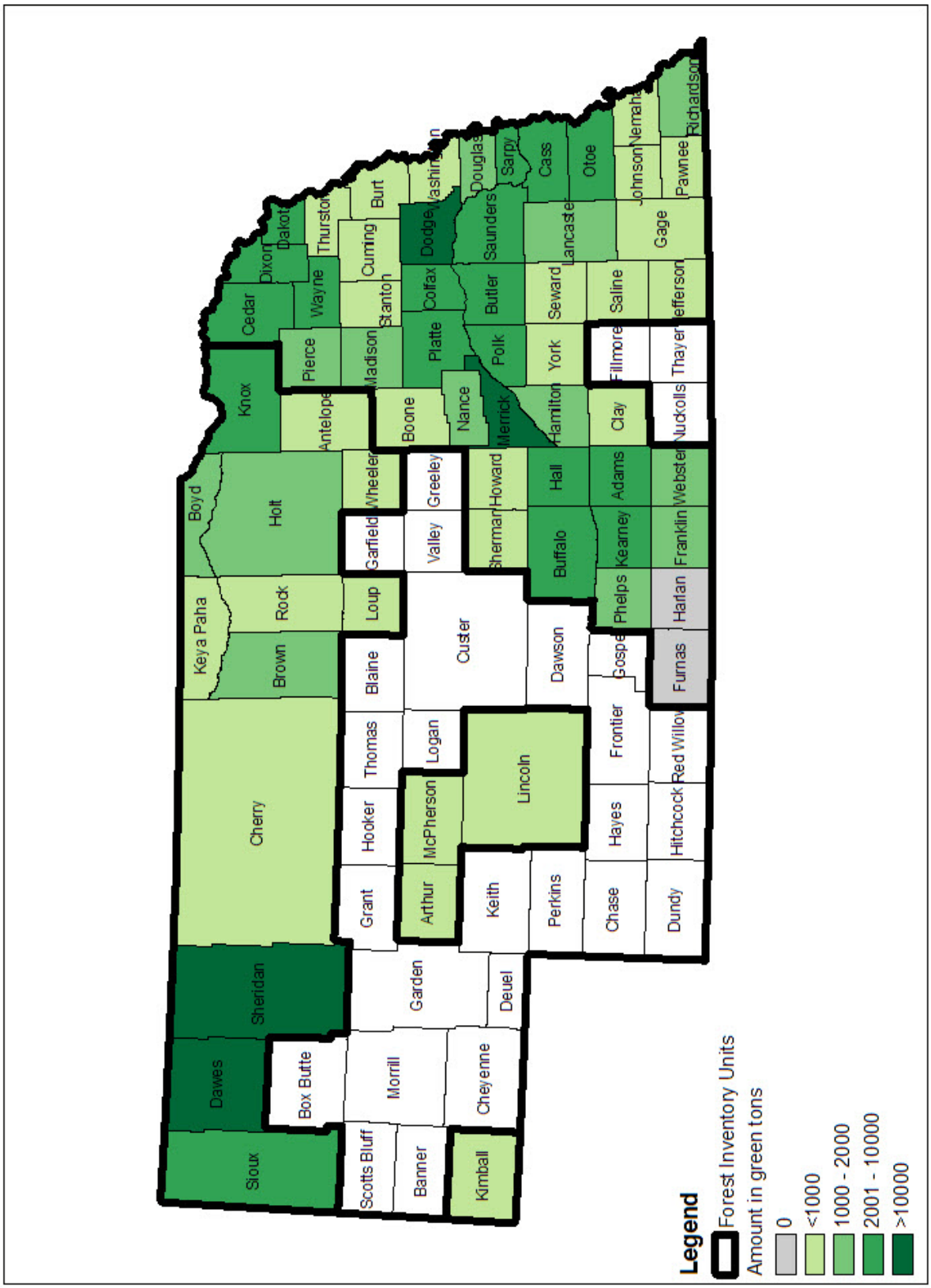

Figure 2: Forest Residue Amounts

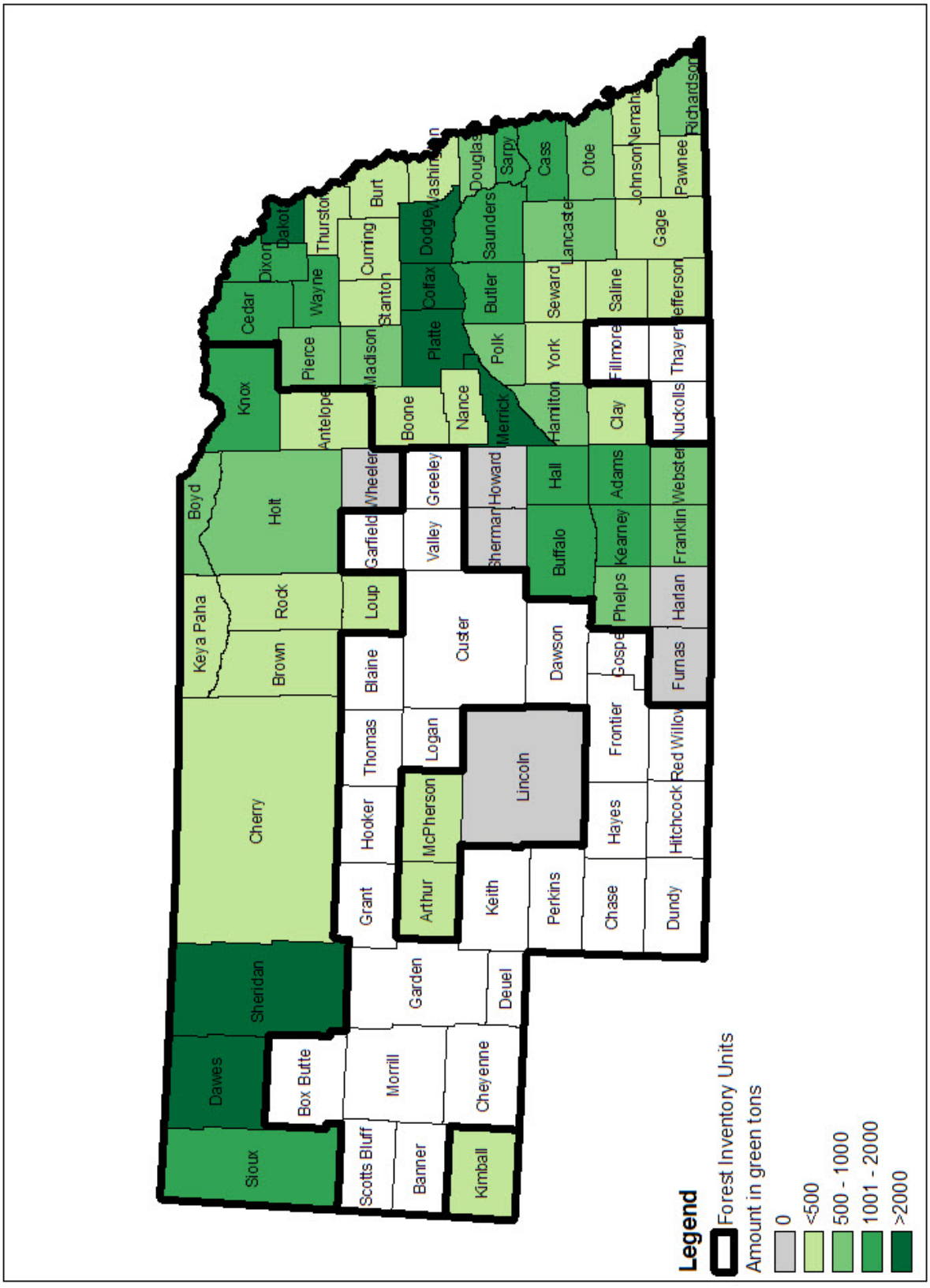

Figure 3: Locations of Logging & Fuels Reduction Contractors

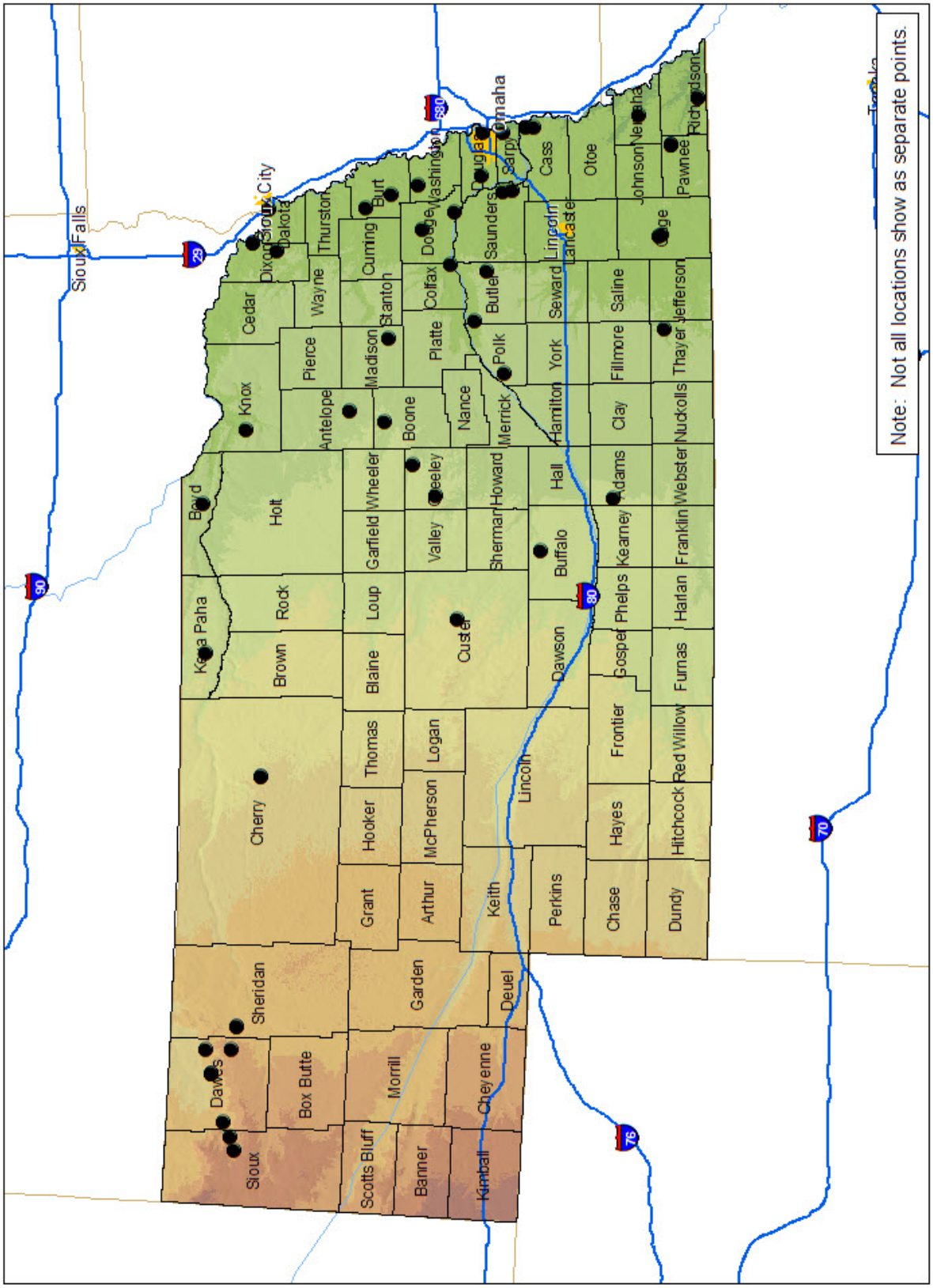

Figure 4: Locations of Range Improvement Contractors

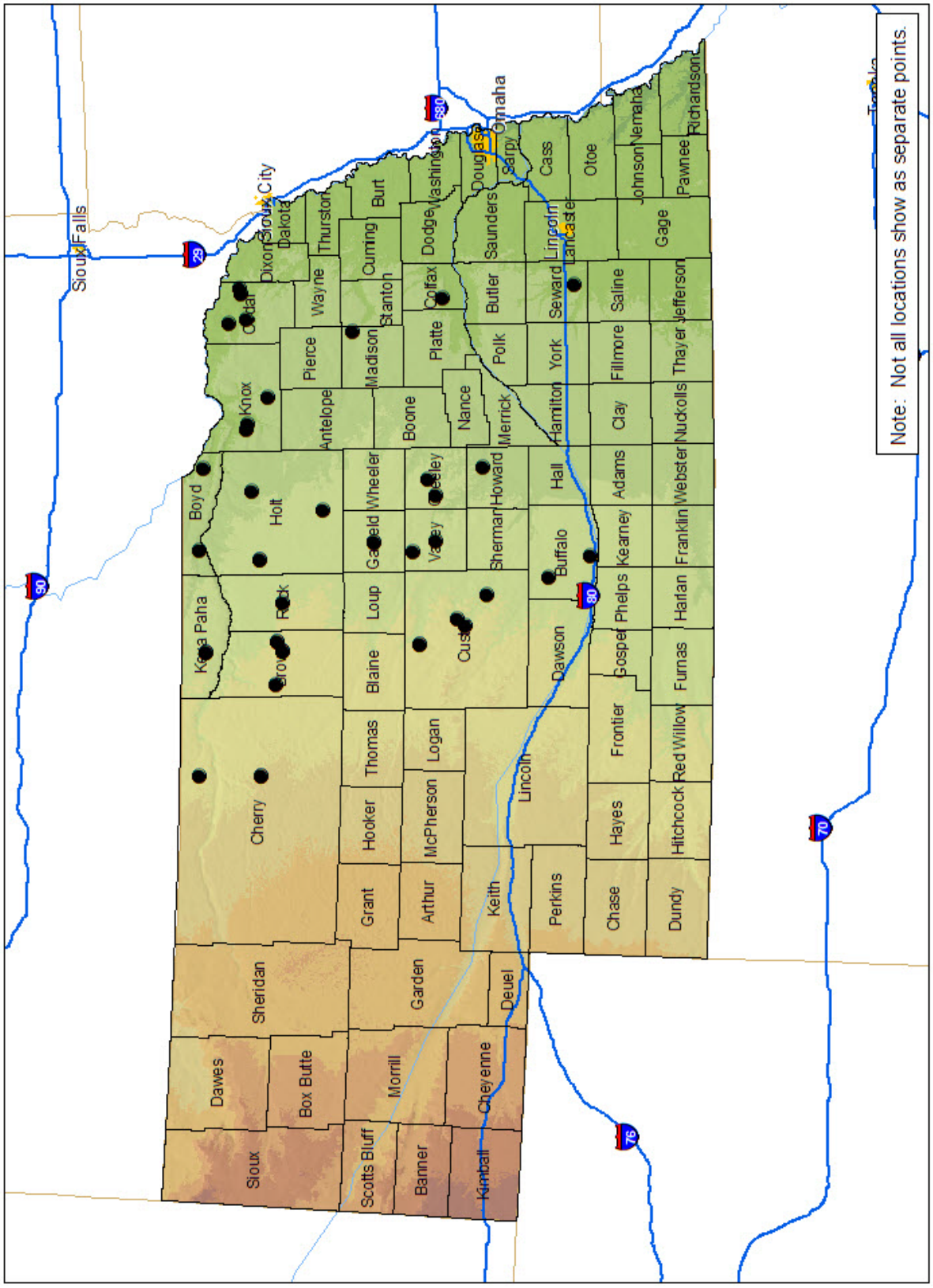

Figure 5: Range Improvement Levels

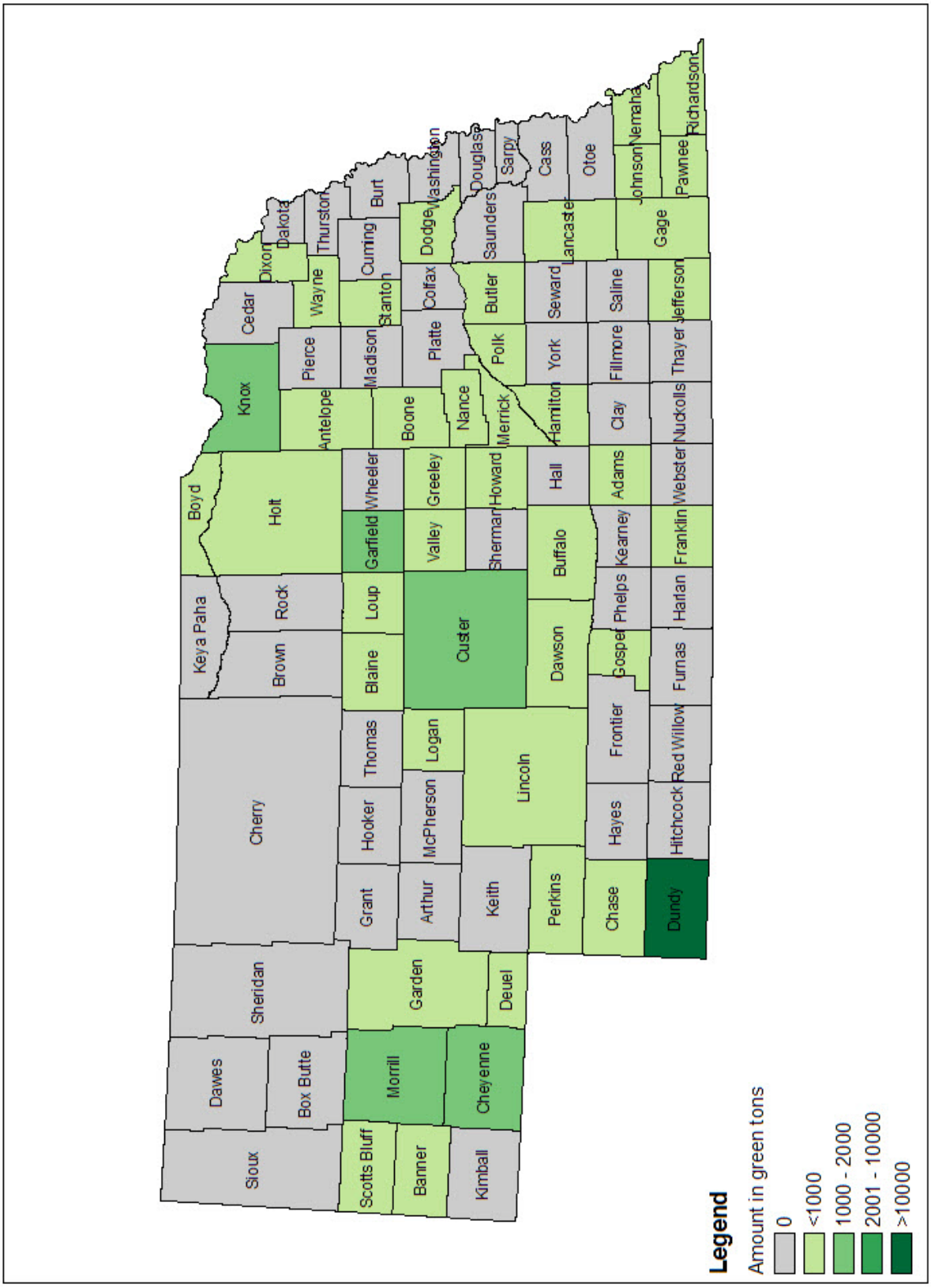

Figure 6: Locations of Primary Processors

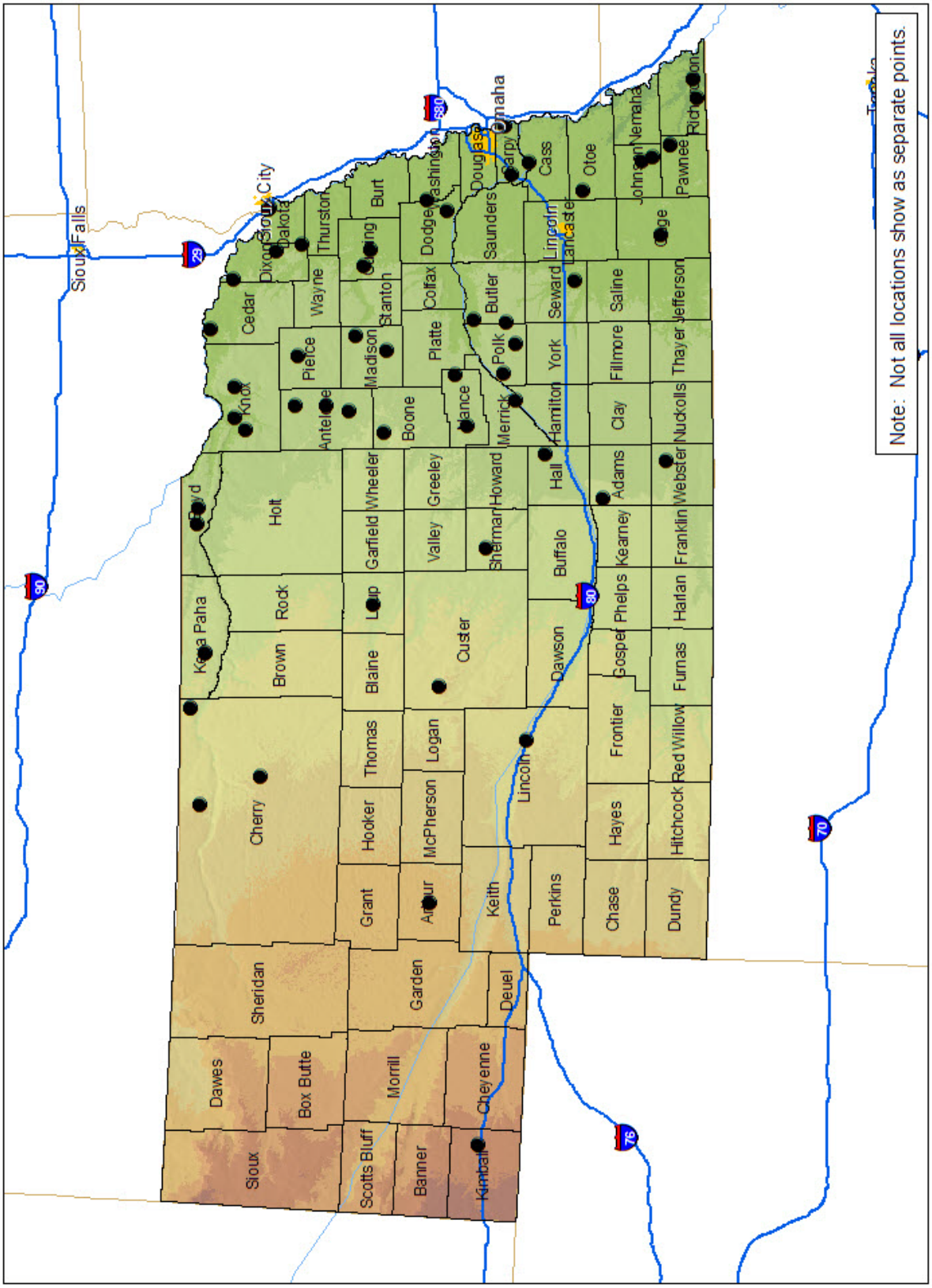

Figure 7: Locations of Secondary Processors

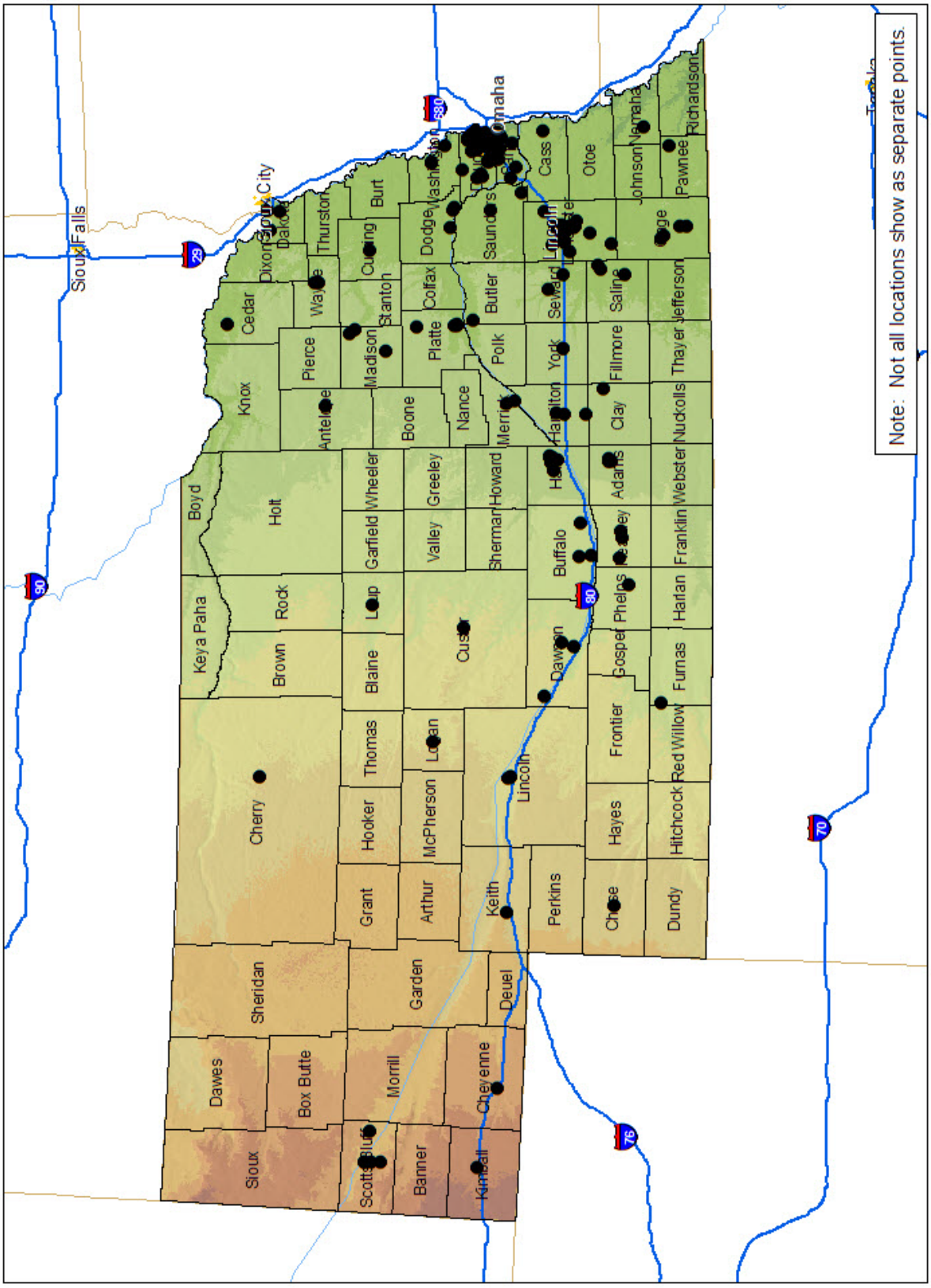

Figure 8: Locations of Municipal Waste Disposal Facilities

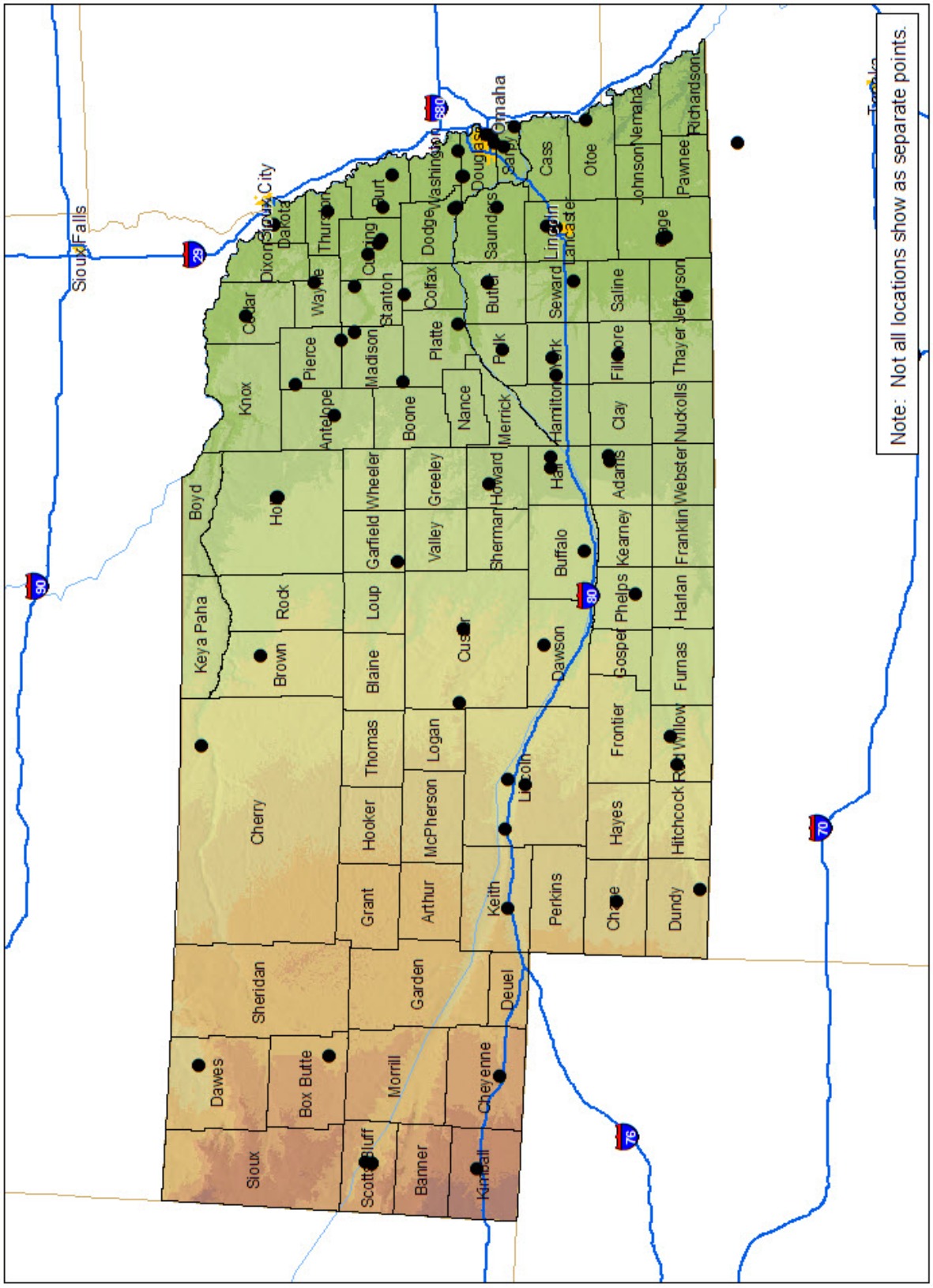

Figure 9: Locations of Tree Care Service Firms

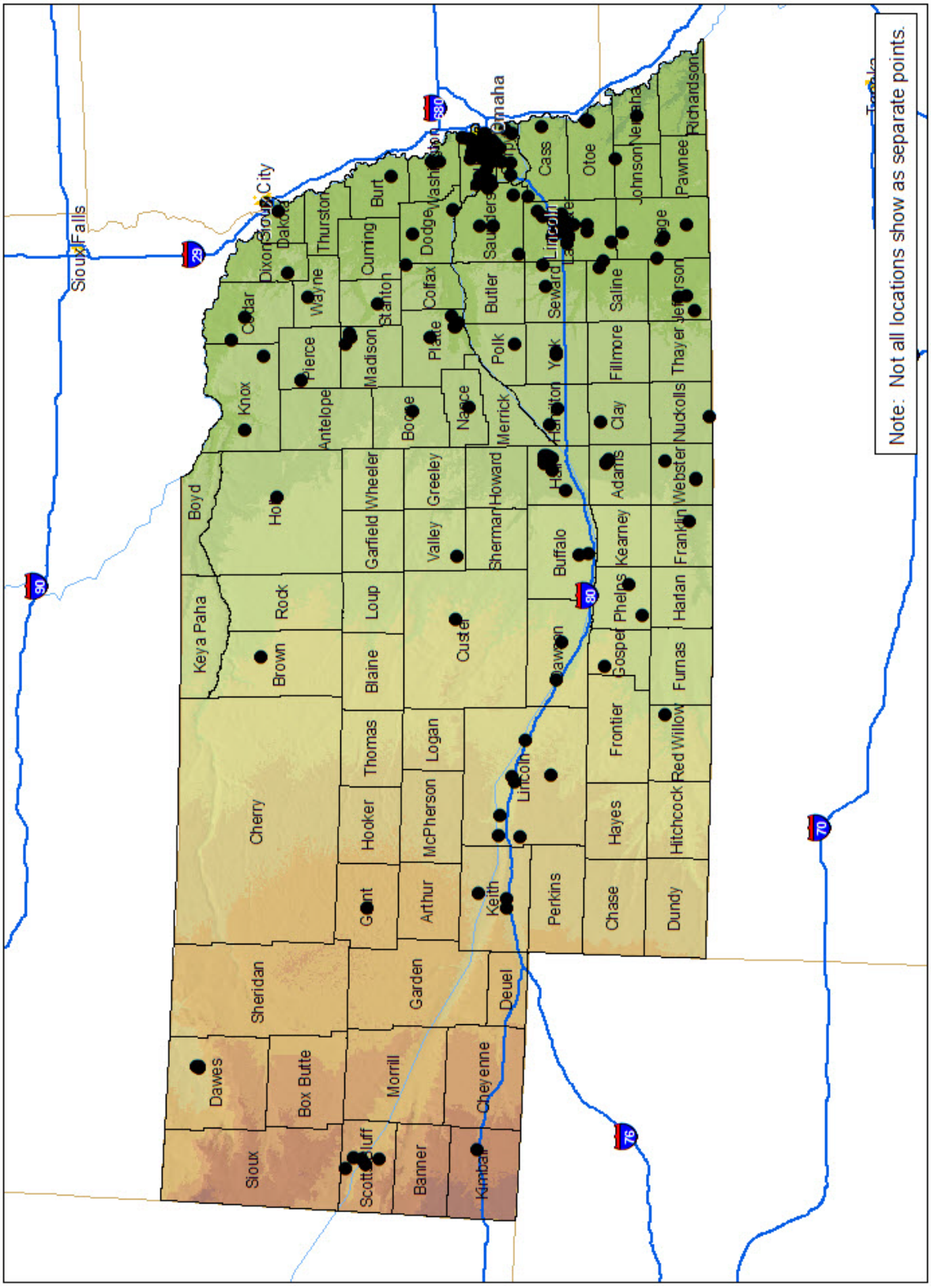

Figure 10: Nebraska Cities + 1,000 population

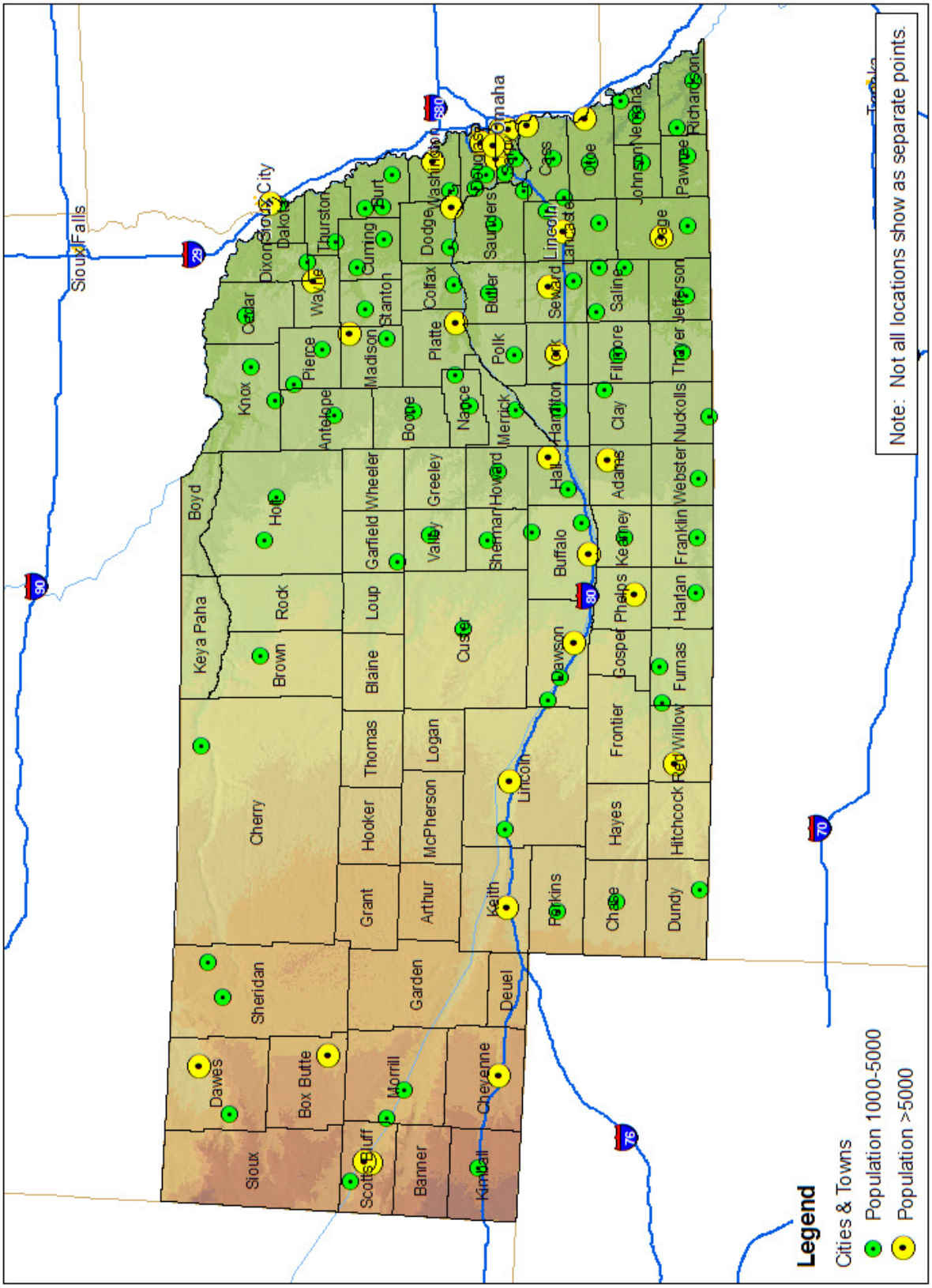

Figure 11: Locations of Utility Lines

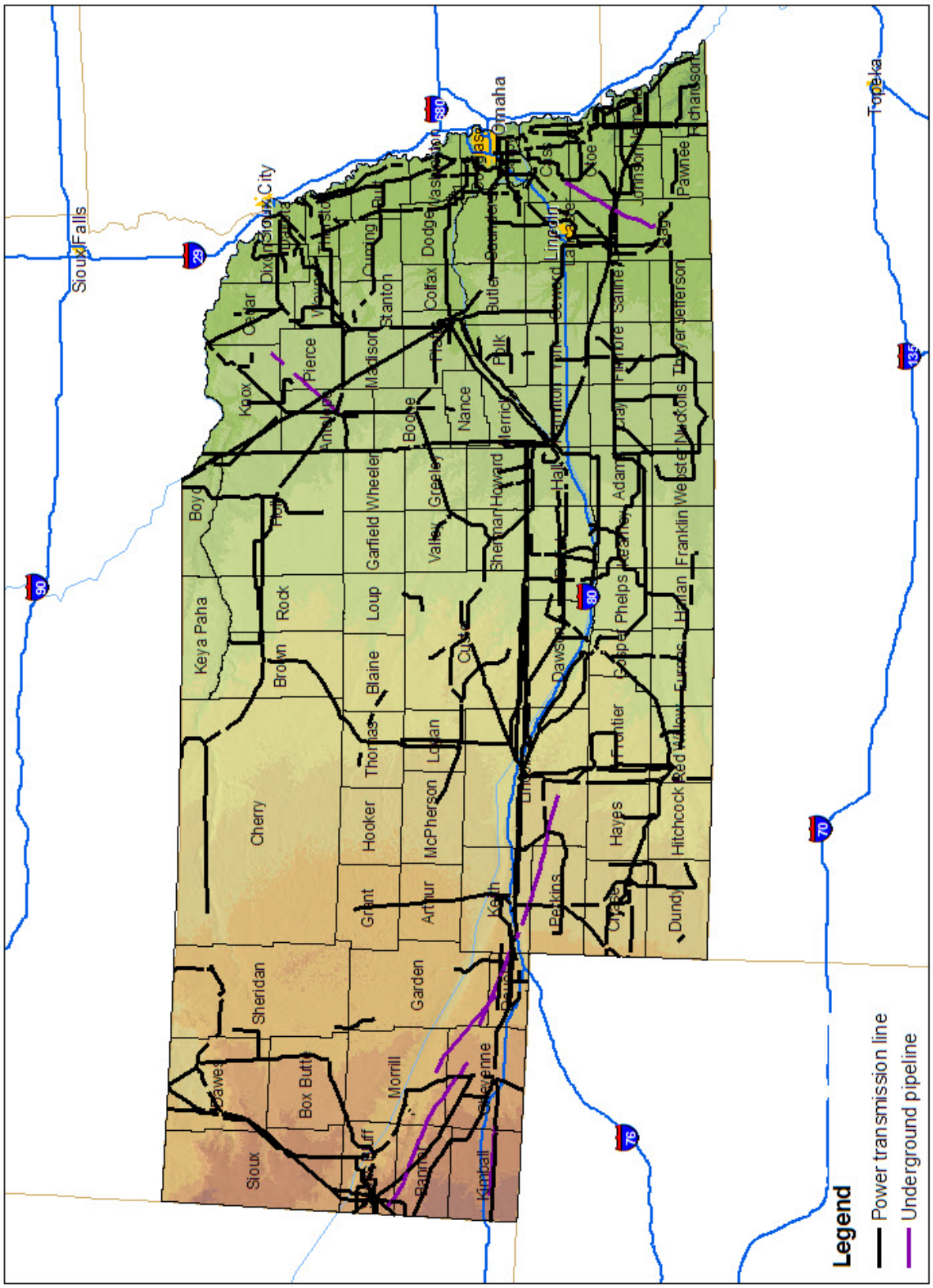

Figure 12: County-level Wood Waste Supply

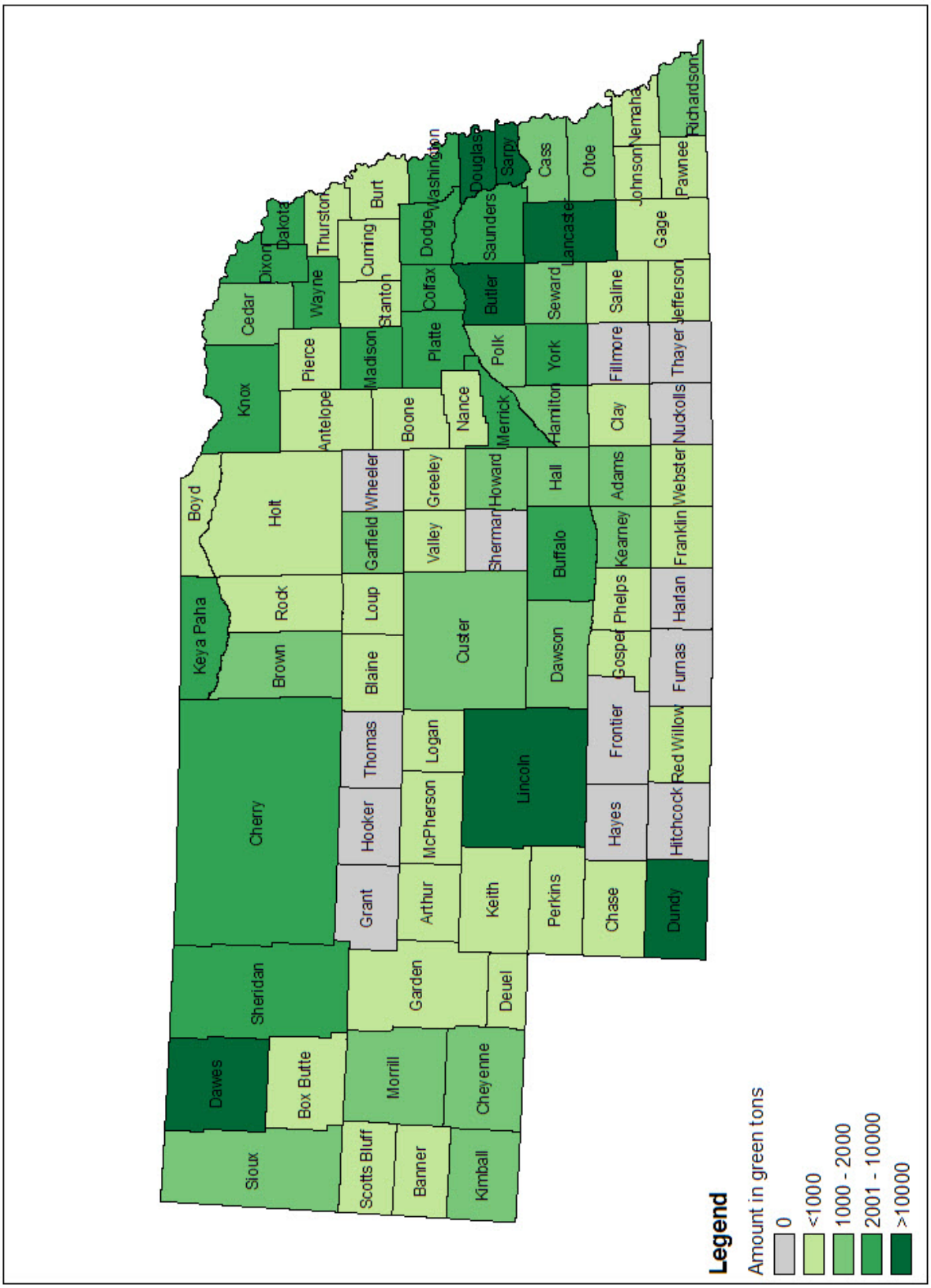

Figure 13: Wood Waste Supply Amounts by County

COUNTY	SupplyTot		COUNTY	SupplyTot
Sarpy	27,519		Perkins	965
Lancaster	23,856		Franklin	818
Butler	19,420		Holt	759
Dawes	18,984		Pawnee	752
Douglas	17,514		Boyd	749
Lincoln	12,805		Webster	637
Dundy	11,010		Phelps	612
Sheridan	6,906		Box Butte	589
Washington	6,049		Jefferson	560
Buffalo	5,100		Pierce	514
Cherry	4,420		Red Willow	433
Dodge	4,053		Nemaha	425
Dakota	4,024		Rock	422
Madison	3,820		Johnson	414
Wayne	3,547		Nance	400
Keya Paha	2,756		Garden	395
Platte	2,754		Gage	377
Knox	2,666		Valley	340
York	2,554		Saline	322
Colfax	2,180		Scotts Bluff	290
Merrick	2,169		Stanton	288
Dixon	2,114		Boone	260
Saunders	2,070		Antelope	241
Sioux	1,880		Blaine	200
Cass	1,868		Logan	155
Cedar	1,788		Burt	136
Seward	1,745		Cuming	98
Hall	1,730		Keith	75
Otoe	1,580		Thurston	74
Custer	1,545		Loup	74
Adams	1,499		Clay	74
Dawson	1,435		Arthur	49
Kearney	1,279		Greeley	40
Hamilton	1,252		McPherson	24
Kimball	1,194		Deuel	20
Howard	1,170		Gosper	15
Polk	1,134		Chase	15
Brown	1,124		Banner	5
Garfield	1,110		Wheeler	0
Cheyenne	1,065		Thomas	0
Morrill	1,045		Thayer	0
Richardson	1,040		Sherman	0
			Nuckolls	0
			Hooker	0
			Hitchcock	0
			Hayes	0
			Harlan	0
			Grant	0
			Furnas	0
			Frontier	0
			Fillmore	0

Figure 14: County-level Wood Waste Supply Diversity

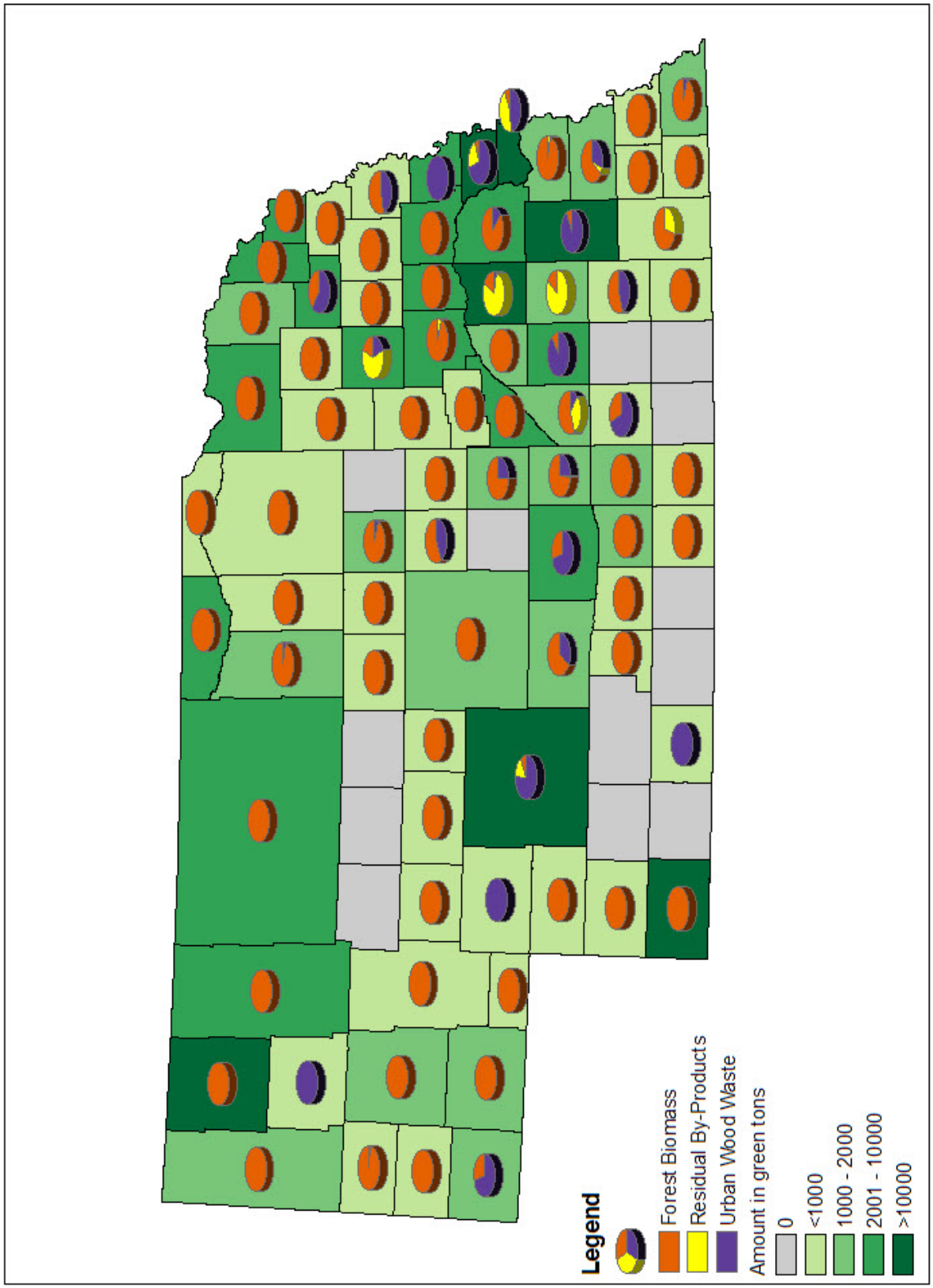

Figure 15: Locations of Wood Waste Boilers

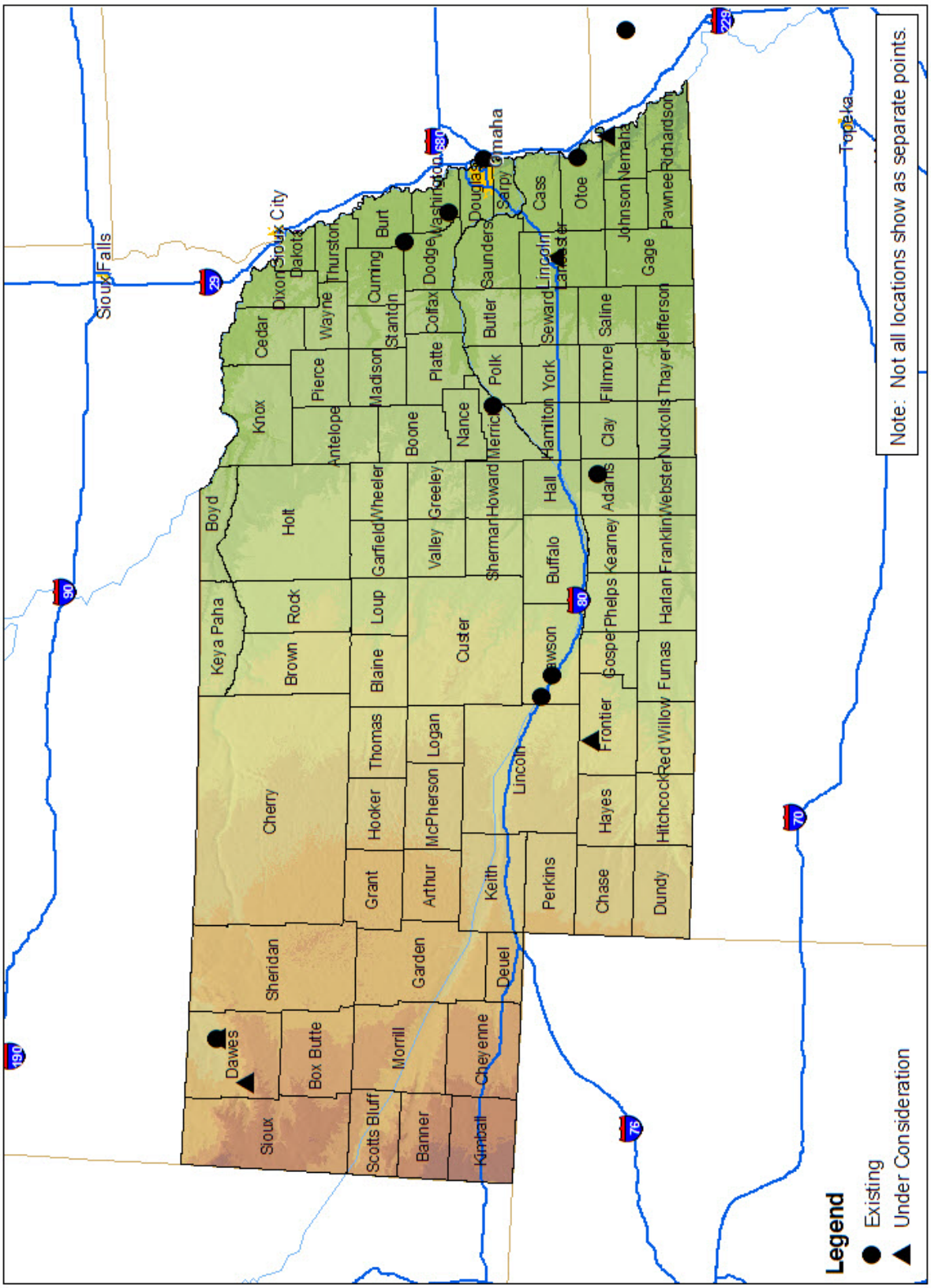

Figure 16: Locations of Selected Public Institution Boilers + 40 years

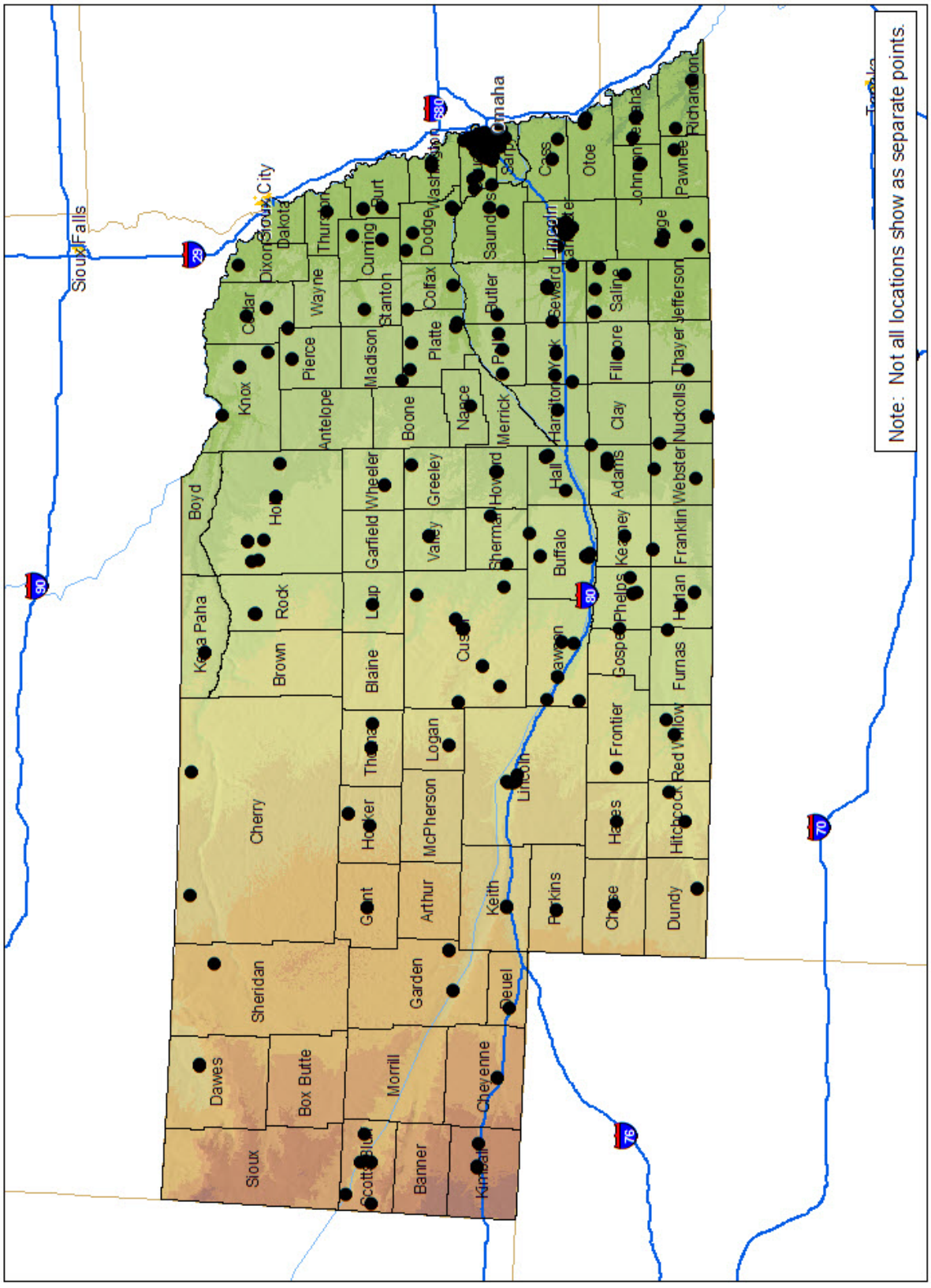

Figure 17: Selected Public Institution Boilers Older Than 40 Years

COUNTY	BAgeGt40		COUNTY	BAgeGt40
Douglas	82		Wheeler	2
Lancaster	37		Webster	2
Seward	21		Sherman	2
Sarpy	17		Richardson	2
Adams	16		Red Willow	2
Holt	15		Pierce	2
Custer	14		Logan	2
Dodge	12		Keith	2
Buffalo	10		Kearney	2
York	7		Hitchcock	2
Washington	7		Hamilton	2
Scotts Bluff	7		Grant	2
Saline	7		Franklin	2
Dawson	7		Fillmore	2
Otoe	6		Dundy	2
Hall	6		Colfax	2
Cedar	6		Cheyenne	2
Platte	5		Cherry	2
Phelps	5		Chase	2
Nuckolls	5		Thurston	1
Lincoln	5		Thayer	1
Kimball	5		Stanton	1
Garden	5		Sheridan	1
Thomas	4		Pawnee	1
Nemaha	4		Nance	1
Knox	4		Madison	1
Keya Paha	4		Loup	1
Gage	4		Hayes	1
Dawes	4		Greeley	1
Burt	4		Furnas	1
Valley	3		Frontier	1
Saunders	3		Dixon	1
Rock	3		Deuel	1
Polk	3		Clay	1
Perkins	3		Butler	1
Johnson	3		Wayne	0
Howard	3		Sioux	0
Hooker	3		Morrill	0
Harlan	3		Merrick	0
Cuming	3		McPherson	0
Cass	3		Jefferson	0
			Gosper	0
			Garfield	0
			Dakota	0
			Brown	0
			Boyd	0
			Box Butte	0
			Boone	0
			Blaine	0
			Banner	0
			Arthur	0
			Antelope	0

Figure 18: Optimal Locations – Supply Amounts

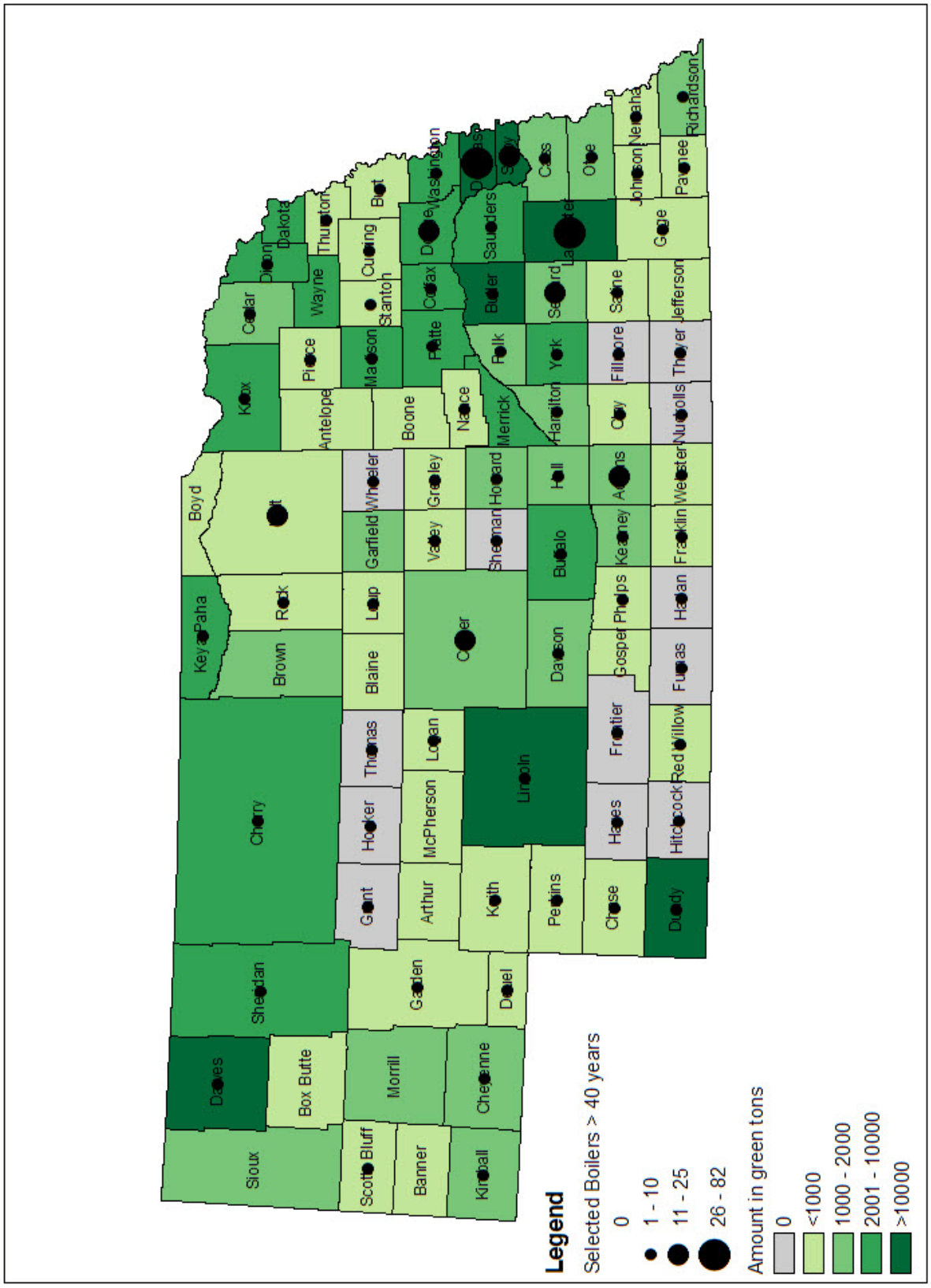

Figure 19: Supplier Count by County

COUNTY	Supply_CNT		COUNTY	Supply_CNT
Douglas	92		Valley	3
Lancaster	53		Red Willow	3
Sarpy	25		Nemaha	3
Hall	24		Nance	3
Madison	15		Merrick	3
Lincoln	15		Kearney	3
Gage	15		Johnson	3
Scotts Bluff	14		Garfield	3
Adams	13		Colfax	3
Platte	12		Boone	3
Dodge	12		Stanton	2
Dakota	12		Sioux	2
Dawes	11		Sheridan	2
Cherry	11		Loup	2
Saunders	10		Howard	2
Custer	10		Clay	2
Washington	9		Cheyenne	2
Knox	9		Chase	2
Cedar	9		Thurston	1
Buffalo	9		Thayer	1
Butler	8		Sherman	1
Brown	8		Rock	1
Seward	7		Nuckolls	1
Pawnee	7		Logan	1
Holt	7		Grant	1
Dixon	7		Gosper	1
York	6		Furnas	1
Keya Paha	6		Franklin	1
Dawson	6		Fillmore	1
Cuming	6		Dundy	1
Cass	6		Box Butte	1
Antelope	6		Arthur	1
Polk	5		Wheeler	0
Otoe	5		Thomas	0
Keith	5		Perkins	0
Hamilton	5		Morrill	0
Burt	5		McPherson	0
Boyd	5		Hooker	0
Webster	4		Hitchcock	0
Wayne	4		Hayes	0
Saline	4		Harlan	0
Richardson	4		Garden	0
Pierce	4		Frontier	0
Phelps	4		Deuel	0
Kimball	4		Blaine	0
Jefferson	4		Banner	0
Greeley	4			

Figure 20: Optimal Locations – Supplier Count

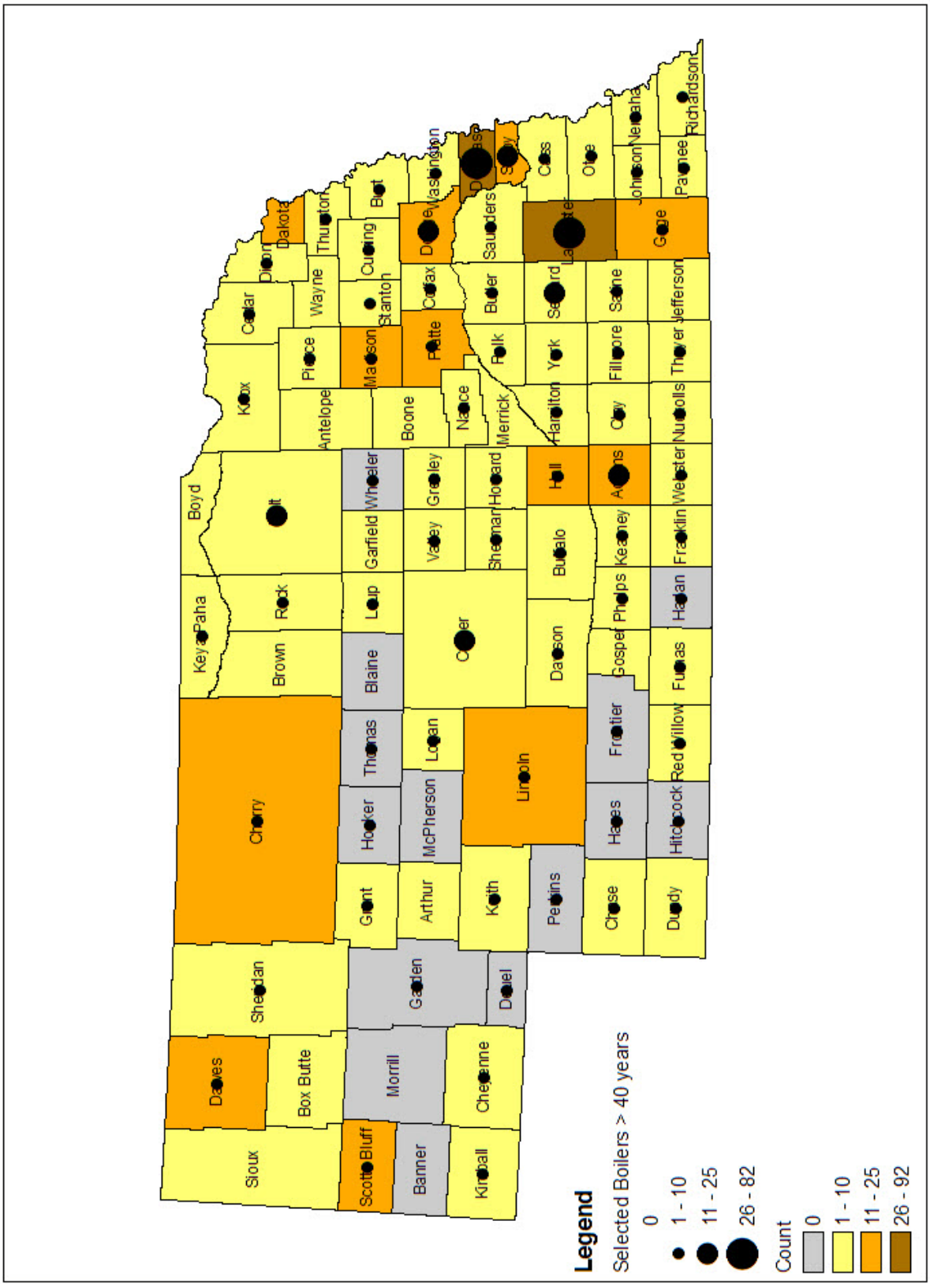

Figure 21: Lincoln Metro Area

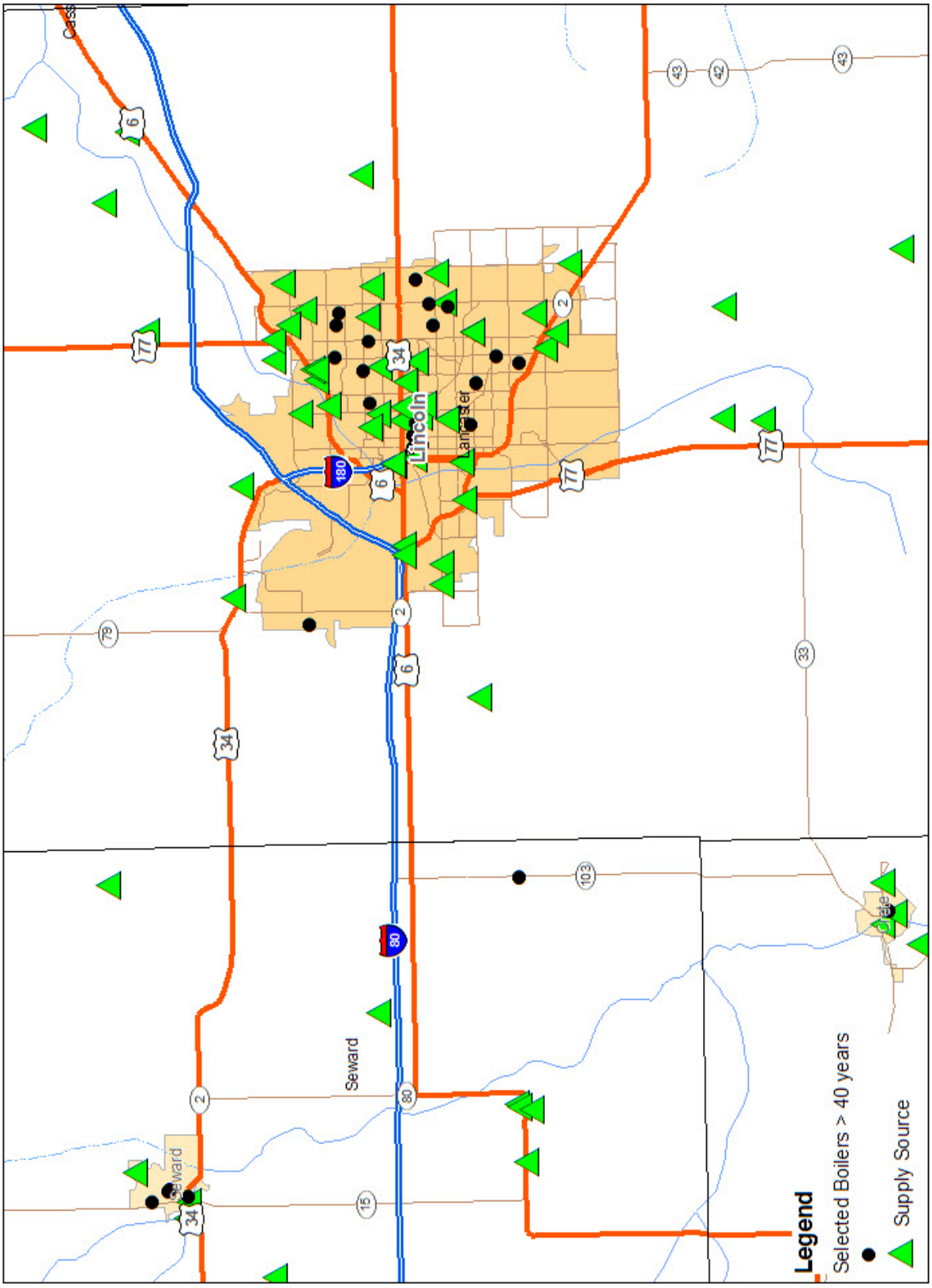

Figure 22: Omaha Metro Area