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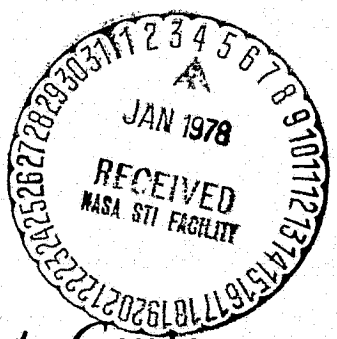
NASA TECHNICAL MEMORANDUM

NASA TM-78146

CANDIDATE LOCATIONS FOR SPS RECTIFYING ANTENNAS

By Anne W. Eberhardt
Preliminary Design Office

November 1977



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Marshall Space Flight Center, Alabama

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16. ABSTRACT

An investigation is made into the feasibility of placing 120 Satellite Power System (SPS) rectifying antenna (rectenna) sites across the U.S. In the investigation, an initial attempt is made to put two land sites in each state using several land site selection criteria. When only 69 land sites are located, it is decided to put the remaining sites in the sea and sea site selection criteria are identified. An estimated projection of electrical demand distribution for the year 2000 is then used to determine the distribution of these sites along the Pacific, Atlantic, and Gulf Coasts. A future study will also attempt to include the Great Lakes in this distribution.

As a result of this study, a methodology for distributing rectenna sites across the country and for fine-tuning exact locations is developed, and recommendations on rectenna design and operations are made. This developed methodology will be used in the reevaluation of the rectenna sites identified in this preliminary study. It is suggested that the design recommendations be considered in future rectenna design studies.

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I. INTRODUCTION

Due to the continuing search for new, renewable sources of electric energy to power our energy-intensive society, many groups across the country are considering the feasibility of Satellite Power Systems (SPS). Several alternate concepts for the SPS are being suggested, but most concepts involve generating electric energy at a station in geosynchronous Earth orbit and then beaming this energy to Earth in the form of microwaves. A rectifying antenna (rectenna) then collects this energy and rectifies it to dc power. Afterwards, it is converted to 60 cycle ac and enters the U.S. power grid.

For an ambitious SPS program with a buildup rate to 600 GW, 120 rectennas with 5 GW capacity are required [1]. For this analysis, the rectenna site, which contains the actual rectenna and a safety zone, is assumed to be a 15 mile diameter circle. In all cases, this is sufficient to contain the entire elliptical rectenna (which is somewhat longer at higher latitudes) and some safety zone. Figure 1 shows an artist's concept of a rectenna site.

An initial strategy of putting two sites in each state (except Alaska[1]) has been adopted. Notice that this strategy does not take the distribution of national electrical demand into account. However, after identifying 69 land sites, the remaining sites were placed in the oceans taking an estimated projection of demand into account. The following sections identify 120 preliminary rectenna sites. These sites are identified to illustrate the feasibility of locating 120 sites across the United States and are not suggested as actual locations for rectenna placement.

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1. No rectennas will be placed in Alaska due to its high latitude and low population. All statistics quoted in this report exclude Alaska.

II. LAND SURVEYS

A. Selection Criteria

Initially, all rectennas were to be located on land. Data indicate the percentage of total electric power used in a region [2] closely correlates to the percentage of the national population in that region [3]. Figure 2 shows a breakout of the nine regions in the U.S. and Figure 3 shows a correlation between electric power use and population in these regions. Further inspection indicates that regions with large percentages of the U.S. population often have little land available for rectenna placement, since 65 percent of the U.S. population lives east of the Mississippi River on 29 percent of the land [4] (and uses 65 percent of the total U.S. electrical power). Thus, rectenna density on land could not correspond to electrical energy usage without major disruptive impacts.

Seventy-one percent of the U.S. land is west of the Mississippi River with only 35 percent of the population occupying it. Thus, there is room for the majority of the 120 rectennas to be placed in the western U.S., especially in the Mountain, Western North Central, and Western South Central states. However, electrical demand in most areas of these regions is small, and the losses associated with power transmission over great distances is generally large enough to make it undesirable to put the majority of the rectennas in these sparsely populated areas.

Therefore, a compromise strategy which approaches uniform rectenna distribution was initiated. Under this strategy an attempt would be made to put two rectenna sites in each state (excepting Alaska) to identify a total of up to 98 sites. Then the remaining 22 or more sites would be located where possible on land or off-shore to achieve a better distribution with respect to demand.

Next, certain criteria had to be identified to quantify the meaning of a good potential land site. These criteria had to take into account such questions as where people live and how the land is used. The following criteria have been identified for site selection:

1. Minimum impact on land intensively used [5] (e.g., cropland, urban areas, etc.).

2. Minimum impact on population [6].

3. Minimum impact on transportation [7, 8, 9].

4. Minimum elevation variations [10].

5. Maximum Federal land use [11].

These criteria are evaluated to differing degrees of accuracy in this preliminary site selection survey due to the use of general reference material. For example, the readily available references in the area of transportation yield a good evaluation of these impacts. Similarly, the reference material on land usages and Federal land locations allows a fairly good evaluation. However, the references on elevation variation and population distributions only give an approximate evaluation of the impacts. Therefore, the following comments on rectenna locations give only average elevation variation ranges, and often these ranges are too broad to have much meaning. These numbers will be refined in the next phase of the study using topographical maps of the areas in which the rectennas are located. Similarly, the preliminary population displacement assessment uses average county population densities. However, since rectennas are usually located in areas of minimum county population density (away from cities and towns), the actual number of persons displaced should be much less than the estimate given. Better estimates of these displacements will be determined in the next phase of the study using actual county population distributions from state census data books.

B. Comments on Each Region

The following discussion is broken into nine parts based on the nine U.S. geographic regions identified in the Statistical Abstract of the United States (Fig. 2). Regional data along with statistics on the rectenna land sites are given in each part.

The Northeast region of the country includes Maine, New Hampshire, Vermont, Massachusetts, Rhode Island, and Connecticut. These states contain 6 percent of the U.S. population on 2 percent of the land. Furthermore, 80 percent of the region's population is concentrated in the tiny states of Massachusetts, Rhode Island, and Connecticut; consequently, no land rectennas could be located in these states, but there is potential for sea sites off their coastlines. The remaining states are fairly mountainous, but one rectenna site is identified in the state of Vermont and two each in the states of Maine and New Hampshire. However, one New Hampshire site covers two small towns. These five rectennas displace a maximum of 0.2 percent of the Northeast region's population or 27 000 persons and average 40 miles to an existing power tie. The average elevation range in the area covered by rectennas is 800 to 2200 ft with

a maximum of 3000 ft in New Hampshire and Vermont. Approximately 10 miles of road are covered by each site and the predominant type of land impacted is ungrazed forest land. Figures 4, 5, and 6 show rectenna locations in these states with respect to Standard Metropolitan Statistical Areas (SMSA) and county boundaries.

The Middle Atlantic states are New York, Pennsylvania, and New Jersey, which contain 18 percent of the U.S. population on only 3 percent of the land. These data indicate a need for many sites on little land, but there is again the possibility for sea sites. No rectenna sites could be identified in the mostly urban state of New Jersey, but two sites are identified in the densely populated state of New York. Two sites are also identified in Pennsylvania, but one site covers two small towns. These four rectennas displace a maximum of 0.1 percent of the region population or 48 000 persons and average 10 miles to an existing power tie. All of the sites are in mountainous areas and the average elevation range of the impacted areas is 700 to 1800 ft with a maximum of 3000 ft. An average of 10 miles of road is covered by each site, and the only type of land impacted is ungrazed forest land. Figures 7 and 8 show rectenna locations in these states.

Wisconsin, Illinois, Michigan, Indiana, and Ohio form the Eastern North Central region with 19 percent of the national population on 8 percent of the land. These states are densely populated and criss-crossed with many major highways so only four land sites are identified; however, there may be potential for water sites in the Great Lakes. Of the four sites selected, two are located in north Wisconsin, one is located in the northern peninsula of Michigan, and the other is located on the main part of Michigan. These four sites displace a maximum of 0.1 percent of the population or 21 000 persons and average 20 miles to the nearest power tie. The average elevation at each site is 200 to 500 ft with an absolute maximum of 1000 ft. An average of 20 miles of road is covered by each site, and the covered land is predominantly ungrazed forest land with some cropland and pasture. Figures 9 and 10 show rectenna locations in these states.

The Western North Central region includes North Dakota, South Dakota, Minnesota, Nebraska, Iowa, Kansas, and Missouri. They contribute only 8 percent of the national population on 17 percent of the land and contain 13 rectenna sites. Only one site is identified in Iowa due to its density of small towns and major highways, and the two sites identified in Missouri are questionable because they cover small towns. However, the one missing site and the two questionable sites could be placed in more sparsely populated areas of this relatively flat region. The 13 presently identified rectennas displace a maximum of 0.3 percent of the population or 46 000 persons and average 35 miles to a

power tie. The average elevation range at these sites is 100 to 300 ft with a maximum of 500 ft. The average road coverage is 25 miles, and land at the sites is mainly used for crops with some grazing, marsh, grass, and forest land. Figures 11 through 17 show rectenna locations in these states.

The South Atlantic states are Delaware, Maryland, West Virginia, Virginia, North Carolina, South Carolina, Georgia, and Florida. They contain 16 percent of the U.S. population on 9 percent of the land and are quite densely populated. However, these states have excellent possibility for off-shore rectenna placement, and even some of the identified land sites may be moved off-shore. No rectennas could be located in the tiny states of Delaware and Maryland, but two locations are identified in North Carolina (one covers 15 miles of a U.S. highway) and two are identified in Florida. The other South Atlantic states each contain only one rectenna site due to population and transportation constraints, and the Virginia site covers two small towns. The eight rectenna sites identified displace a maximum of 0.2 percent of the region's population or 70 000 persons and average 25 miles to the nearest existing power tie. The average elevation at these sites is 150 to 500 ft, but these averages would be lower if the site in West Virginia, which has an elevation variation of 1000 to 3000 ft, was not included. Each rectenna covers an average of 20 miles of road and the majority of impacted land is marsh and forest with some cropland and grazing land. Figures 18 through 23 show rectenna locations in these states.

Kentucky, Tennessee, Alabama, and Mississippi comprise the Eastern South Central states and contain 6 percent of the U.S. population on 6 percent of the land. Two rectennas are placed in Mississippi and two in Tennessee, but one of the Tennessee sites covers three small towns. The density of small towns and transportation networks allowed only one site in Alabama, and none in Kentucky. Thus, the region contains only five rectennas, but there is some potential for sea sites. These five sites displace a maximum of 0.4 percent of the population or 54 000 persons and average 10 miles to a power tie. The average elevation variation is 300 to 700 ft, and one site in Tennessee has a maximum elevation change of 3000 ft. Each rectenna covers an average of 25 miles of road and the type of land impacted includes forest, grazing land, and cropland with some marsh. Figures 24, 25, and 26 show rectenna locations in these states.

The Western South Central states are Oklahoma, Arkansas, Texas, and Louisiana. These states contain 10 percent of the population on 15 percent of the land, which indicates that the region has some sparsely populated areas. Two sites are identified in each state with a maximum of 0.2 percent of the population or 34 000 persons displaced, but the two sites in Arkansas are

questionable because they each cover small towns. However, alternate sites could probably be identified in this region with further analysis. The eight identified rectennas average 25 miles to a power tie, and the average elevation change is 200 to 500 ft with a maximum of 3000 ft at the Arkansas sites. Therefore, if the Arkansas sites were changed, both the population impact and elevation variation statistics would improve. Approximately 15 miles of road are covered by each site, and the predominant type of land under the rectennas is grazing land with cropland, forest, and swamp. Figures 27 through 30 show rectenna locations in these states.

The Mountain states include Montana, Idaho, Wyoming, Nevada, Utah, Colorado, Arizona, and New Mexico. They contain only 4 percent of the U.S. population on 29 percent of the land and form the most sparsely populated region in the country. Although the extremely mountainous areas of the region must be avoided, there is little problem in placing 2 rectennas in each state which means that there are more land rectennas in the Mountain states than in any other region. These 16 rectennas displace a maximum of 0.6 percent of the region's population or 60 000 persons and average 40 miles to a power tie. The average elevation change at the sites is 400 to 950 ft with a maximum height of 3000 ft at the Arizona and Nevada sites. An average of 5 miles of road is covered by each rectenna and the land types covered are grazing land, desert, and grass lands with some cropland and forest. Figures 31 through 38 show rectenna locations in these states.

For this analysis, the Pacific states include only Washington, Oregon, and California. (No rectenna sites are identified in Alaska or Hawaii.) These states contribute 13 percent of the national population on 11 percent of the land. Two rectennas could be identified in each state displacing a maximum of 0.2 percent of the regional population or 47 000 persons, but one Washington site covers a small town. These rectennas average 15 miles to the nearest existing power tie and the average elevation change is 550 to 1250 ft with a maximum elevation change of 3000 ft. Approximately 15 miles of road are covered by each rectenna and the main types of land impacted are desert and grazing land with some forest, cropland, and grass land. Figures 39, 40, and 41 show rectenna locations in these states.

More specific descriptions of rectenna sites in each state can be found in the appendix, Table A-1. This table lists the states in alphabetical order and gives the following rectenna information:

1. Candidate rectenna site location number (e.g., in Alabama locations 1 and 2 were rejected and location 3 accepted).

2. Name of counties impacted.

3. Average population density of each county.

4. Elevation characteristics and land use at each rectenna site.

5. Road, railroad, and river impacts.

6. Distance from each rectenna to a utility tie.

7. Pertinent comments.

Elevation characteristics [10] and land use [5] keys (Tables A-2 and A-3) are given in the appendix. Figure 42 shows an overview of the distribution of the 120 rectennas through the 9 regions of the country, and statistics on the number of land rectenna sites in each region and the percent of the national population, electrical use, and land area in that region are given in Table 1.

C. Summary of Results

The preliminary population density survey yields an overly pessimistic population displacement profile due to the use of average county population densities. However, even using these averages, only 0.19 percent of the population of the U.S. or 407 000 persons would be displaced by the 69 land rectennas.

The national power grid survey yields an average distance of 30 miles from the rectenna to an existing major power network tie. This result is illustrated in Figures 43 through 49 where rectenna locations are overlayed on charts of the national power grid [12].

The preliminary elevation characteristics survey indicates that elevation variations of at least 1000 ft and possibly up to 3000 ft can be expected. As previously stated, more work must be done to avoid these large elevation variations where possible and to quantify more precisely those variations which still exist.

The transportation analysis shows that the average rectenna covers 16 miles of secondary roads (with one exception where a primary road is covered) and no major rivers or railroads. This indicates that rectenna impact on existing ground transportation networks is minimal. (However, if the microwave beam interferes with air traffic, the impact on air transportation is substantial.)

TABLE 1. THE NUMBER OF LAND AND SEA RECTENNA SITES AND THE PERCENTAGE OF THE NATIONAL POPULATION, ELECTRICAL USE, AND LAND AREA IN EACH REGION OF THE COUNTRY.

Region	Number of Land Rectennas	Number of Sea Rectennas	Percentage of National Population	Percentage of National Electrical Use	Percentage of National Land Area
Northeast	5	6	5.75	4.12	3.40
Middle Atlantic	4	4	17.63	13.63	3.40
East North Central	4	0	19.33	20.26	8.22
West North Central	13	0	7.89	6.58	17.11
South Atlantic	8	18	15.71	17.04	9.22
East South Central	5	1	6.33	9.98	6.02
West South Central	8	9	9.74	9.45	14.52
Mountain	16	0	4.45	5.00	28.58
Pacific	6	13	13.17	13.94	10.72

The land use analysis shows a major use of forested land along with a significant use of crop, desert, marsh, and grazing lands. It also shows that 22 percent of the 69 rectennas are at least partially on Federal land.

III. SEA SURVEYS

A. Selection Criteria

Based on 1976 population distribution [3] and 1974 electrical demand distribution data [2], all remaining rectennas should be placed east of the Mississippi River. However, the steady westward and southward shift in the center of population (125 miles west and 40 miles south in the period from 1940 to 1970 [13]) indicates a need for reevaluation. If these data are extrapolated to the year 2000, the center of population will be at approximately 92° W longitude and 38°N latitude or 40 miles south of Jefferson City, Missouri. Assuming that electrical energy demand is indeed proportional to population distribution (Fig. 3) and denoting the future center of population as the origin of a coordinate system, then 15 more rectennas are required in the Northeast quadrant and 16 more in the Southeast quadrant. Also, four more are required in the Northwest and 16 more in the Southwest quadrants.

This information does not indicate where the population will aggregate in these quadrants, but data over the years from 1940 to 1973 [14] indicate that approximately 50 percent of the U.S. population has consistently lived within 50 miles of a coastline — either the Atlantic Ocean, Gulf of Mexico, Great Lakes, or Pacific Ocean. Because of this and the fact that the off-shore platform industry is continually making advancements which will be directly applicable to rectenna design, an attempt was made to put the remaining rectennas in the sea. The selection criteria for the sea sitings include minimization of rectenna impact on shipping channels and minimization of water depth impact on rectenna design [15].

B. Comments on Each Quadrant

As stated earlier, no rectennas will be located off the coast of Alaska. However, electrical demand in the state of Hawaii could reach a point where rectenna placement there would be desirable. A survey of the Hawaiian coastline, however, indicates that only a floating rectenna would be practical there due to the extreme water depth even right off of the shorelines. Because of this, no sites are identified in Hawaii.

A similar problem exists on the west coast of the continental U.S. The sea depths there increase at the lower latitudes making rectenna placement difficult. However, 10 sites are identified north of the 38° latitude axis (which is just north of San Francisco) with a maximum depth coverage of 400 ft. Only 3 sites could be identified south of this line with a maximum depth coverage of 550 ft. These sites account for 13 of the 20 sites desired in the western states. The remaining 7 sites are located in the western Gulf of Mexico with a maximum depth coverage of 125 ft. Figures 39, 40, and 41 show sea rectenna locations in the Pacific Ocean and Figures 29 and 30 show Gulf of Mexico locations.

As stated earlier, 31 additional sites are desired east of 92°W longitude and 15 of these should be in the northeast quadrant. It is believed that of these at least 8 should be located in the Great Lakes for access by the heavily populated East North Central states. However, limited resources require that the identification of Great Lakes sites be postponed until the next phase of this study. To compensate for the possibility that no sites can be identified in the Great Lakes, locations for all 31 eastern sites have been identified in the Atlantic and eastern Gulf of Mexico. This is possible partly because the coastal depths of the Atlantic are considerably less severe than in the Pacific. However, ocean depths increase at higher latitudes and the 6 rectenna sites identified off the coasts of Massachusetts and Maine cover depths to 300 ft. The maximum depth of the 6 sites from New York through Maryland is 130 ft, and the maximum depth of the 11 sites from Virginia through Georgia is only 100 ft. No rectennas are located on the Atlantic coast of Florida to avoid impact on the rectennas by the space program launch activity from Cape Canaveral required to support the SPS program. But, even without this consideration, the Florida rectennas would be placed in the Gulf because it offers a calmer environment for rectenna placement. Therefore, 9 rectennas are located in the eastern Gulf (east of 92°W) with a maximum depth coverage of 138 ft. Figures 4, 7, 19, 20, 21, 22, 50, 51, 52, and 53 show rectenna locations in the Atlantic Ocean and Figures 23, 26, and 30 show rectenna locations in the eastern Gulf of Mexico.

More specific descriptions of rectenna sites off the coast of each state can be found in the appendix in Tables A-4 through A-7. These tables give the sea site location number, coordinates in longitude and latitude, and ocean floor depth ranges. An overall view of sea sites can also be found in Figure 42, and regional statistics on these sites can be found in Table 1.

C. Summary of Results

In summary, no major shipping channels are impacted by rectenna placement. Even minor impacts could be reduced in some cases if further investigation shows that rectennas could be moved to areas labeled "danger zone," "dumping grounds," [15] etc., or are used to cover groups of hazards since such areas are already avoided by mariners. However, sea depth impacts on rectenna sites may require the use of floating rectennas or the relocation of some sites.

IV. CONCLUSIONS

Both land and sea sites have advantages and disadvantages. One advantage on the land is the ease of power transmission from a land rectenna into the national power grid (Figs. 43 through 49). Also, land rectennas may encounter less rust and collision problems than sea rectennas. Furthermore, the slight temperature increase under the rectenna could provide longer growing seasons for any crops planted there. Some disadvantages to land sites include the facts that they force people (although relatively few) to give up their homes and property and may require the costly rerouting of roads. In addition, land sites often must deal with greater elevation (depth) changes than sea sites and could be damaged by hurricanes, earthquakes, tornadoes, floods, etc.

Sea sites have many advantages and may even produce benefits. Sea rectennas could aid mariners by providing navigation assistance and by covering submerged hazards. They could be beneficial to fishermen by providing artificial reefs where fish could live and breed in water slightly warmer than the surrounding sea. Also, sea rectennas do not affect private property or require the building of new roads. However, the effects of saltwater, hurricanes, rough seas, ships in a fog, seaquakes, etc., could provide a more hostile environment for rectennas in the sea than on land.

Many of the problems mentioned can be circumvented through planning and design. The land site selection criteria already attempts to minimize population, intensive land use, and transportation impacts along with elevation variations. Future work will use topographical maps and census data on actual population distribution in counties to fine-tune locations. Furthermore, rectenna design and operations schemes can help to minimize problems. For example, rectennas should be designed to avoid the clear cutting of land, and a rectenna

operations scheme should be developed to allow intermittent periods of nonpower site activity such as the harvesting of trees, crops, and fish. During these periods the microwave antenna may be switched to an alternate rectenna built for this purpose or turned off for scheduled maintenance. Rectenna design will also have to deal with bad weather and large elevation variations. However, these elevation variations could possibly be taken advantage of to orient the rectenna perpendicular to the beam and thus reduce the site area.

A similar situation is encountered in sea settings. Planning can reduce the number of collisions of ships with rectennas by placing rectennas away from shipping lanes. Extremely tall platforms can be avoided either by careful placement or the design of floating rectennas (an option not available to land sites). Other areas of concern such as power transmission, rust, and weather must be handled by rectenna design.

Planning must also include a careful mix of land and sea locations. It is evident that electrical energy demand in the Western States will increase at a high rate and will probably be concentrated near the Pacific coast. However, the extreme ocean depths encountered in the Pacific, if not handled by floating rectennas, may require the movement of some sea rectenna sites to sparsely populated areas of the Mountain, Western North Central, and Western South Central States. The Eastern States, however, will continue to be densely populated, and the electrical demand there will remain high. This could indicate the need for moving even more rectenna sites from this intensively used land into the shallow waters of the Atlantic Ocean, Gulf of Mexico, and, possibly, the Great Lakes. Thus, if rectenna placement is to correspond to electrical energy demand and if an ambitious SPS program such as described earlier is pursued, both land and sea rectenna sites will be required, and rectenna design studies should proceed accordingly.

V. WORK REMAINING

In the next phase of the rectenna location study, several improvements will be made to the present distribution and locations of the 120 rectennas. First, a section-by-section electrical demand projection for the year 2000 must be used to reevaluate the distribution of the rectennas. Most locations will probably remain unchanged by this exercise, but some off-shore sites may be moved inland and some inland sites may be moved off-shore. Also, some sites may be moved into the Great Lakes if the study indicates that this is feasible. After the redistribution is completed, new and old sites will be scrutinized.

The new sites will first be evaluated according to the criteria outlined in this preliminary study. All land sites will then be refined in the area or population impact using county population distribution data and in the area of elevation variation using topographic maps.

In general, a fine-tuning of present results should yield a good distribution of land and sea sites. These refined sites should ensure that electrical power will be available where needed and with only minimal impact on land and sea usage.

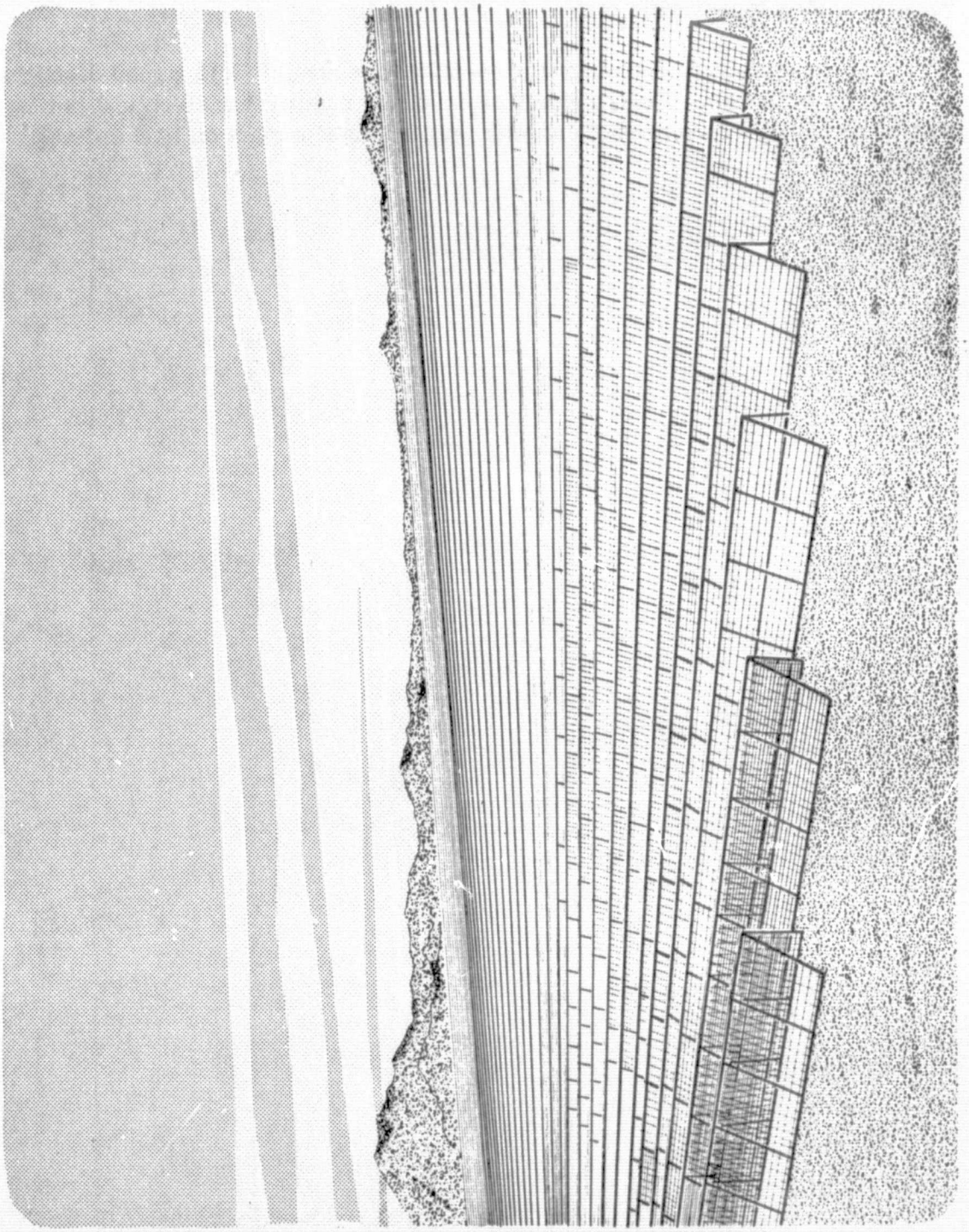

Figure 1. Artist's concept of rectenna site.

Figure 2. Regions of the U.S.

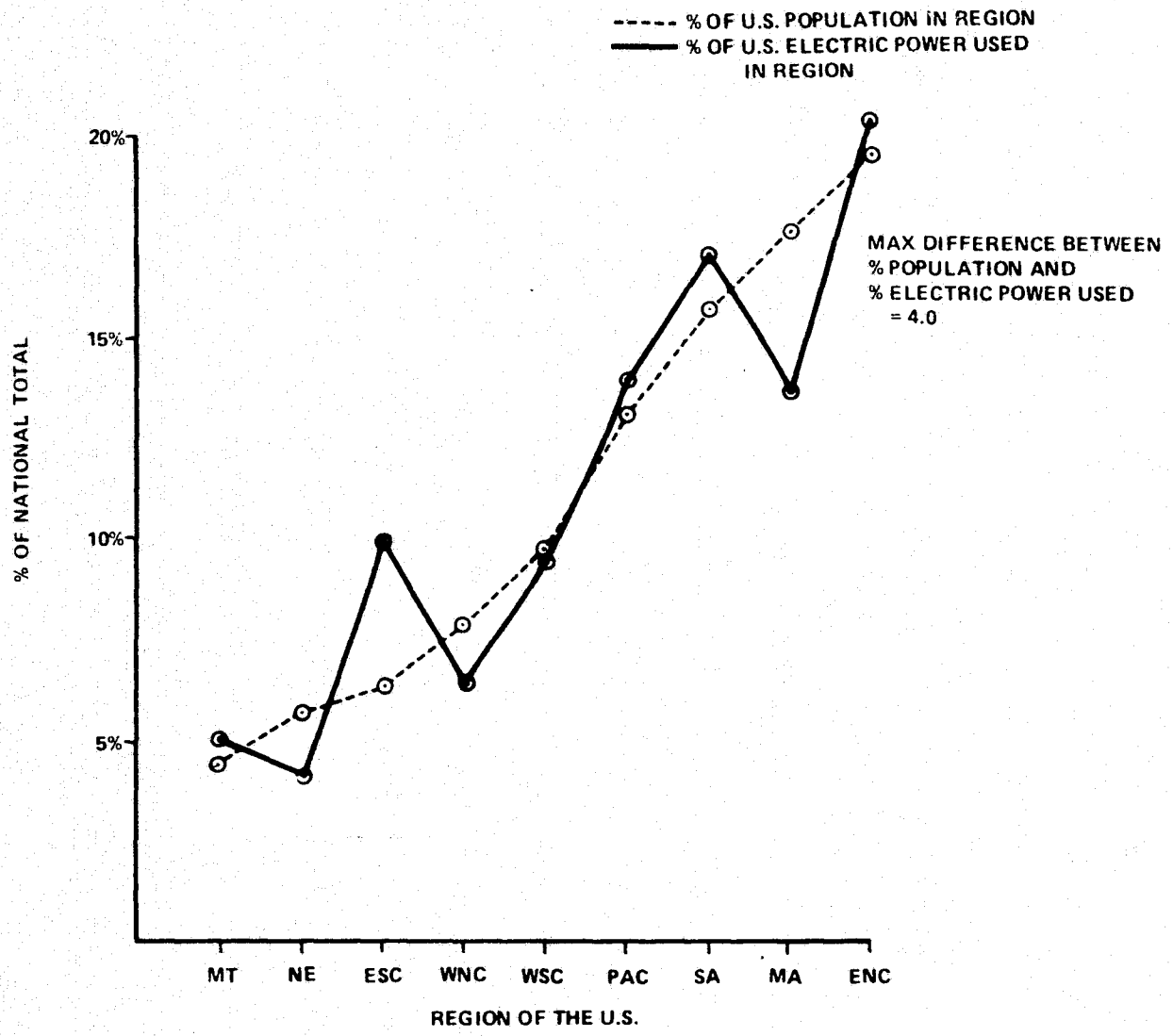

Figure 3. Correlation between percent of U.S. population in a region and percent of total electric power used in that region.

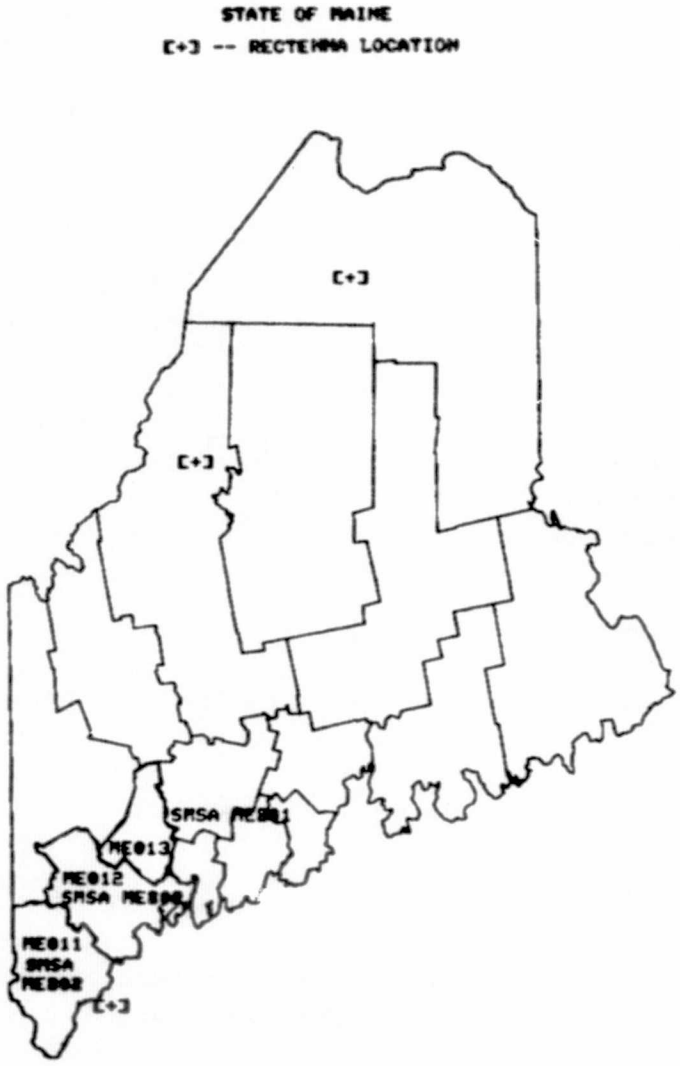

Figure 4. Rectenna locations in the state of Maine.

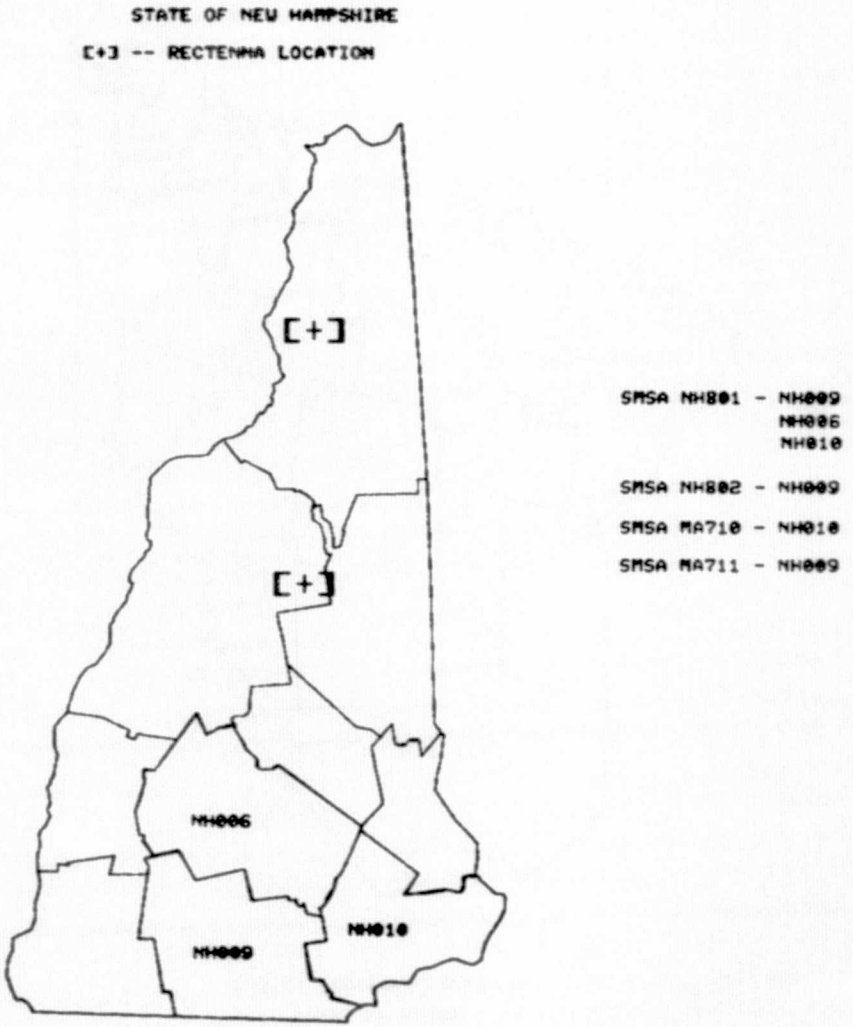

Figure 5. Rectenna locations in the state of New Hampshire.

Figure 6. Rectenna location in the state of Vermont.

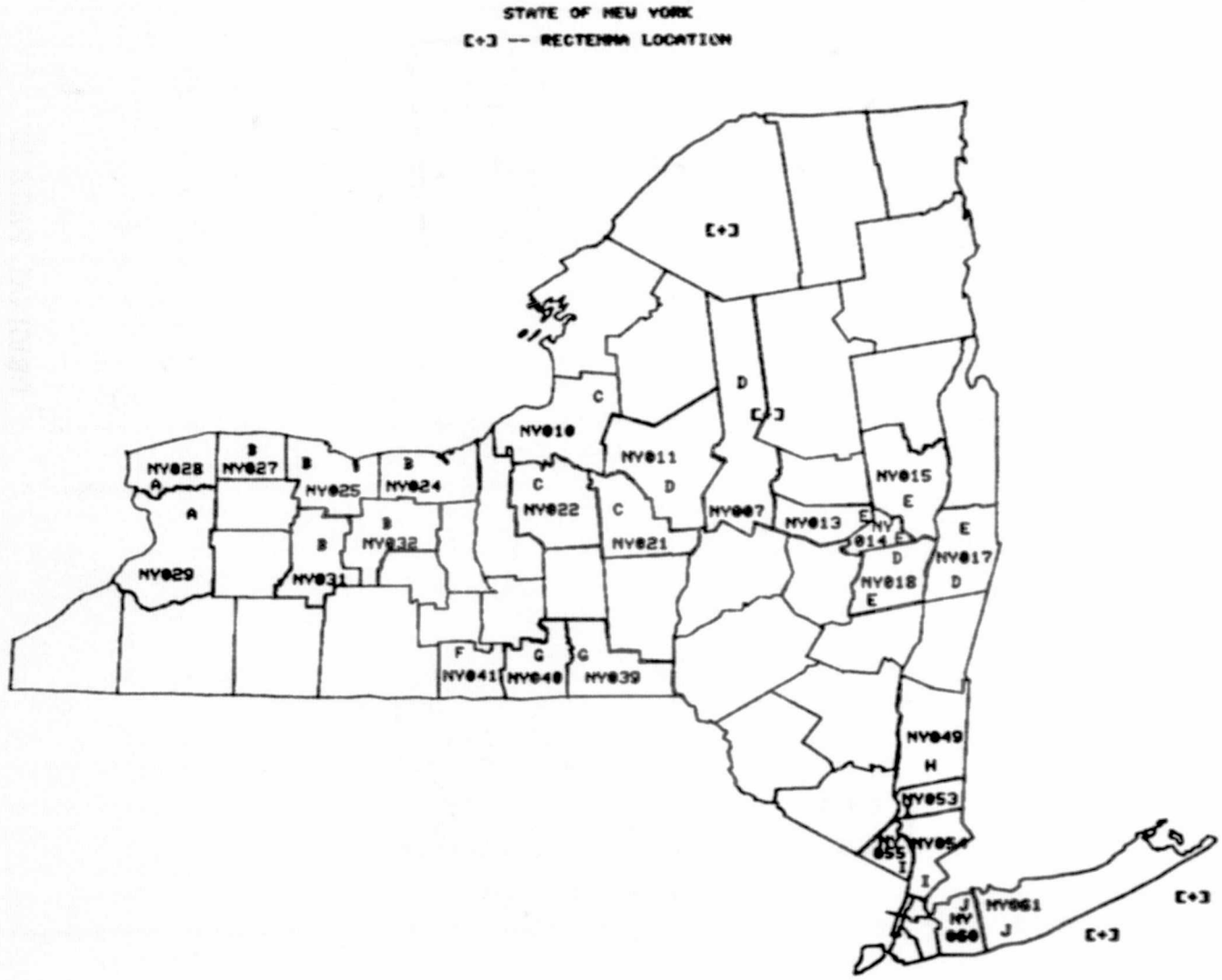

Figure 7. Rectenna locations in the state of New York.

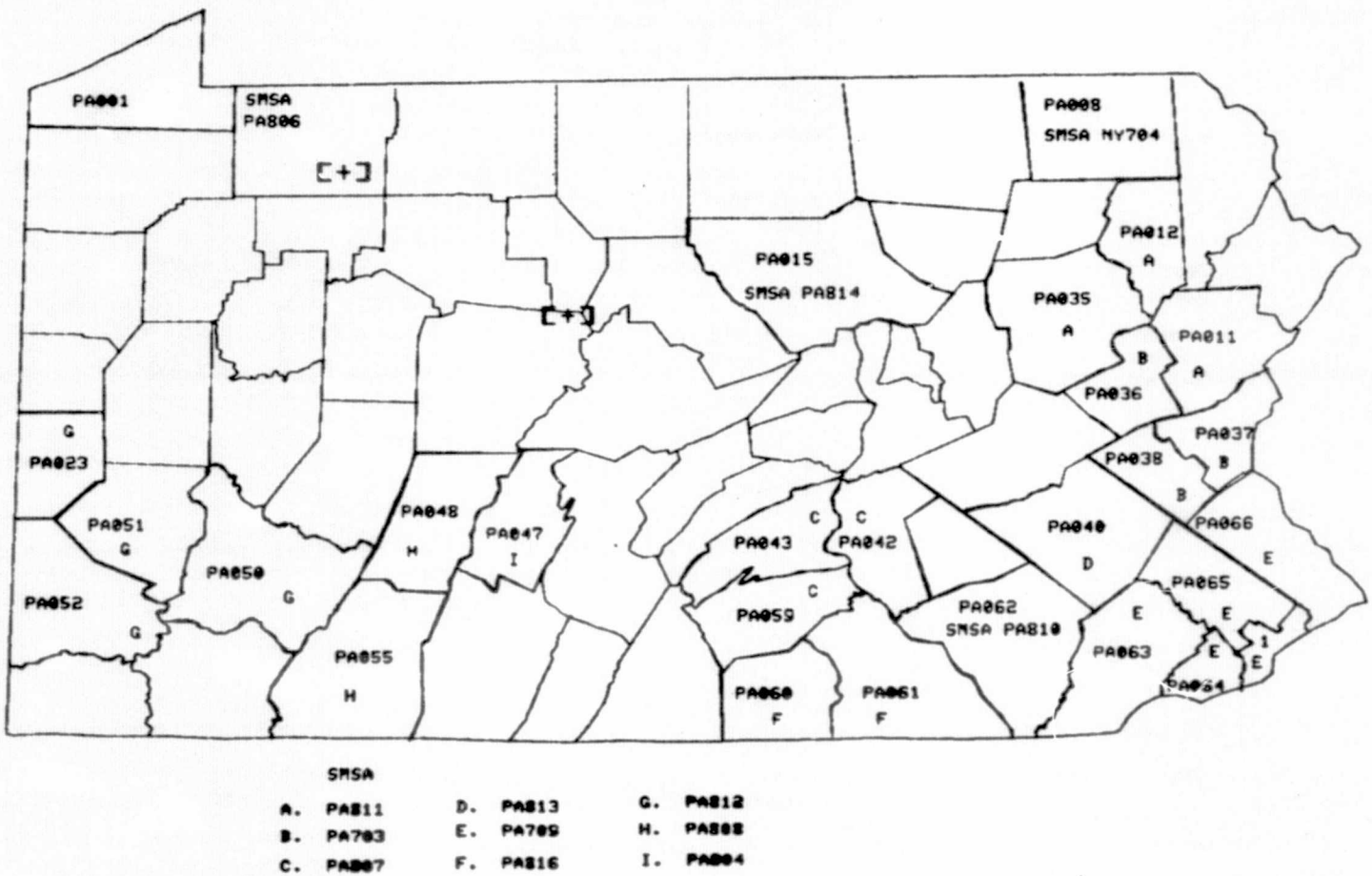

Figure 8. Rectenna locations in the state of Pennsylvania.

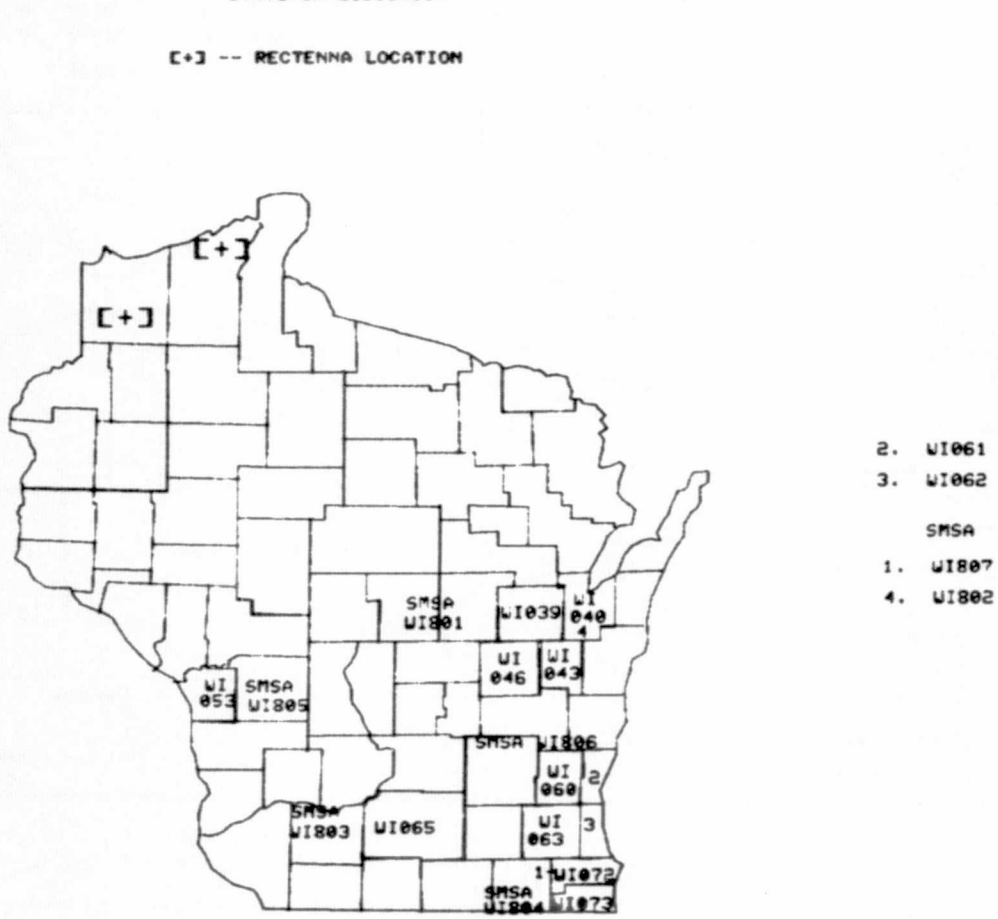

Figure 9. Rectenna locations in the state of Wisconsin.

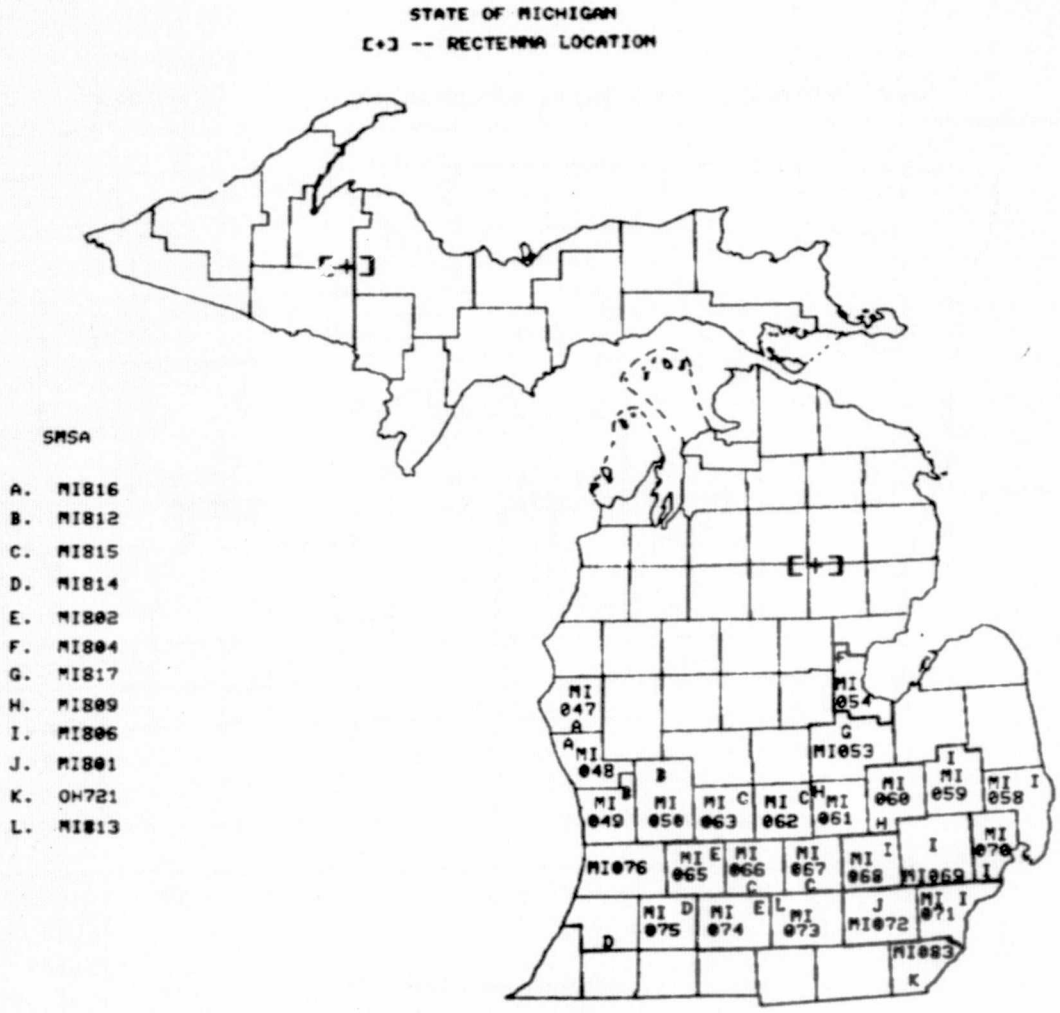

Figure 10. Rectenna locations in the state of Michigan.

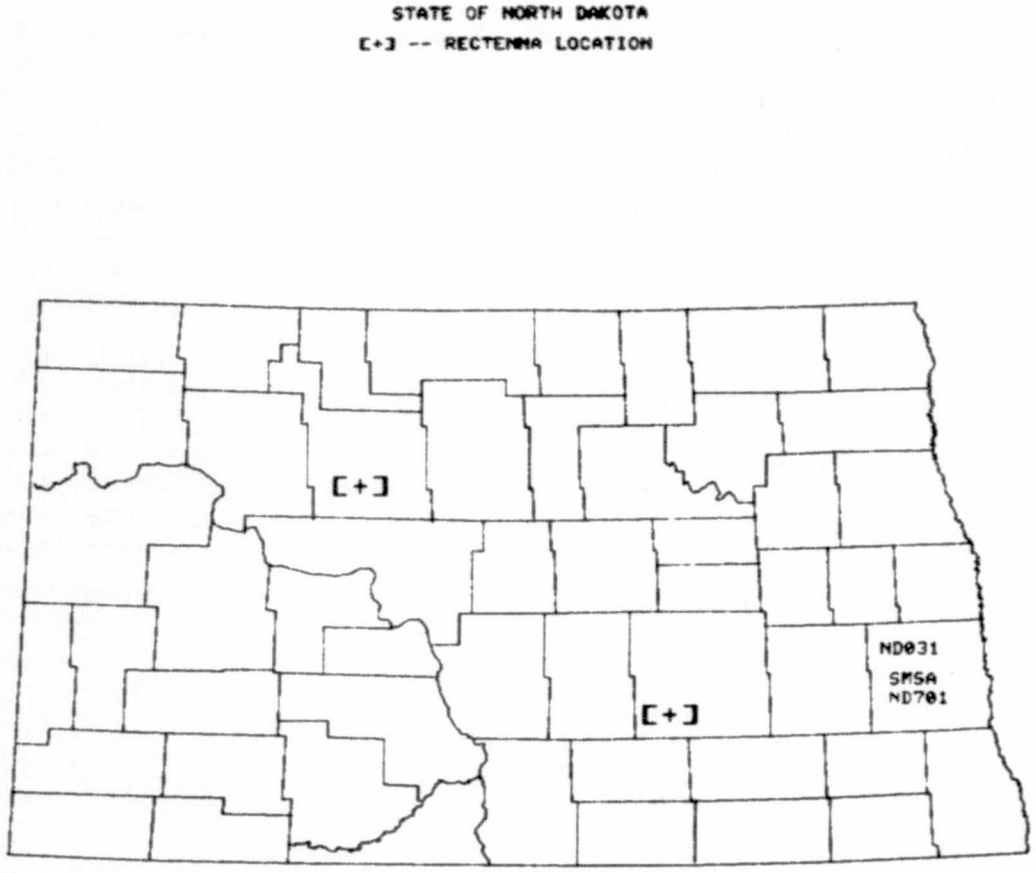

Figure 11. Rectenna locations in the state of North Dakota.

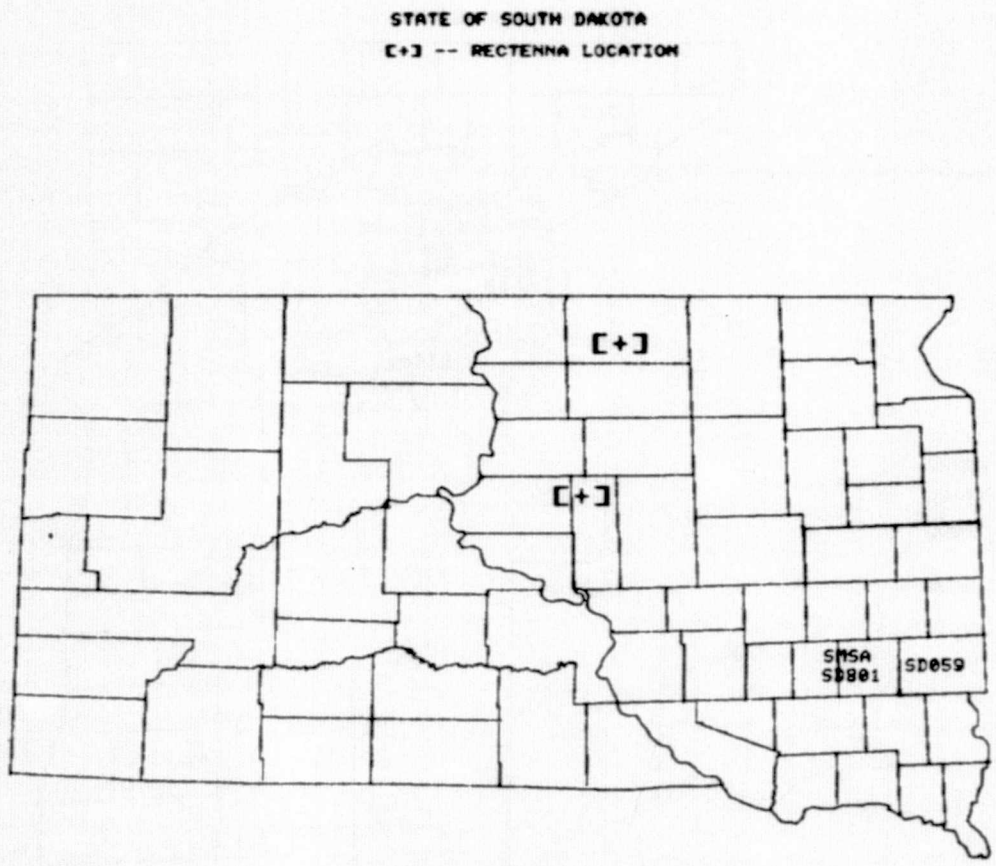

Figure 12. Rectenna locations in the state of South Dakota.

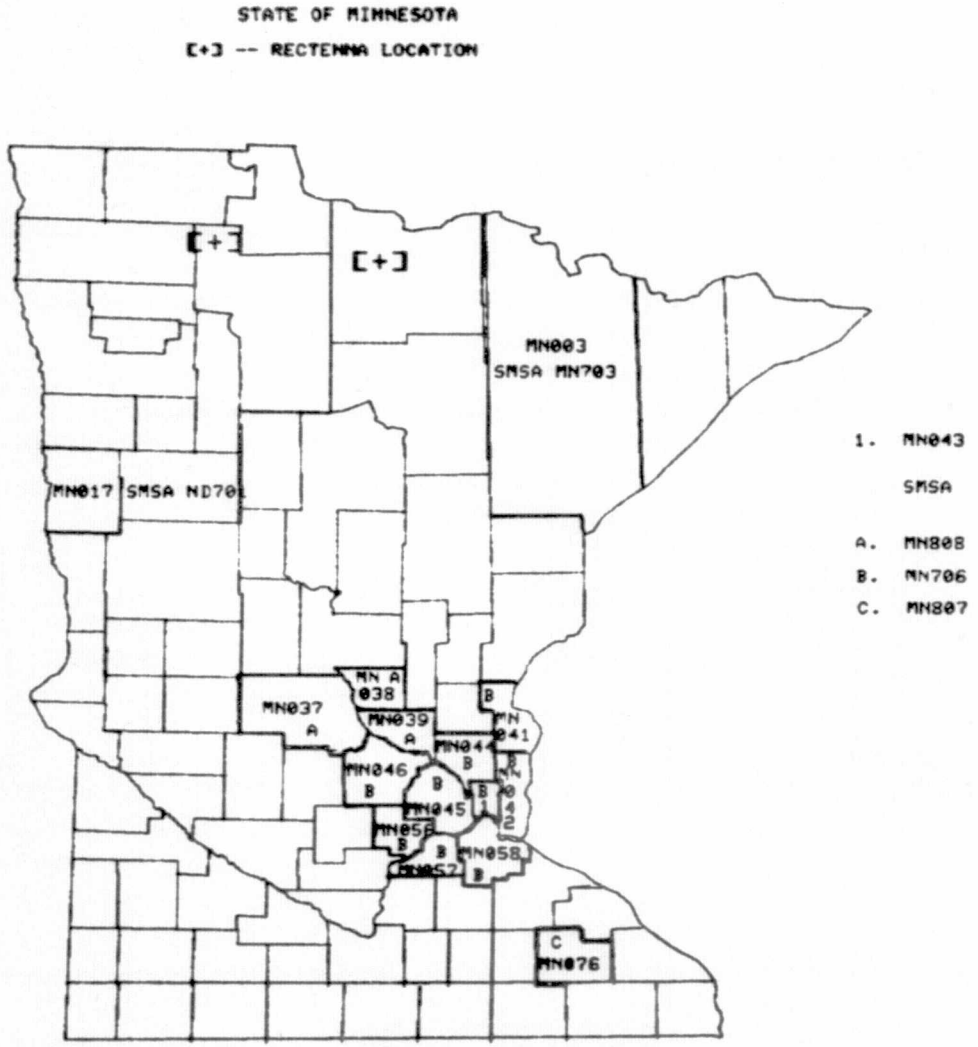

Figure 13. Rectenna locations in the state of Minnesota.

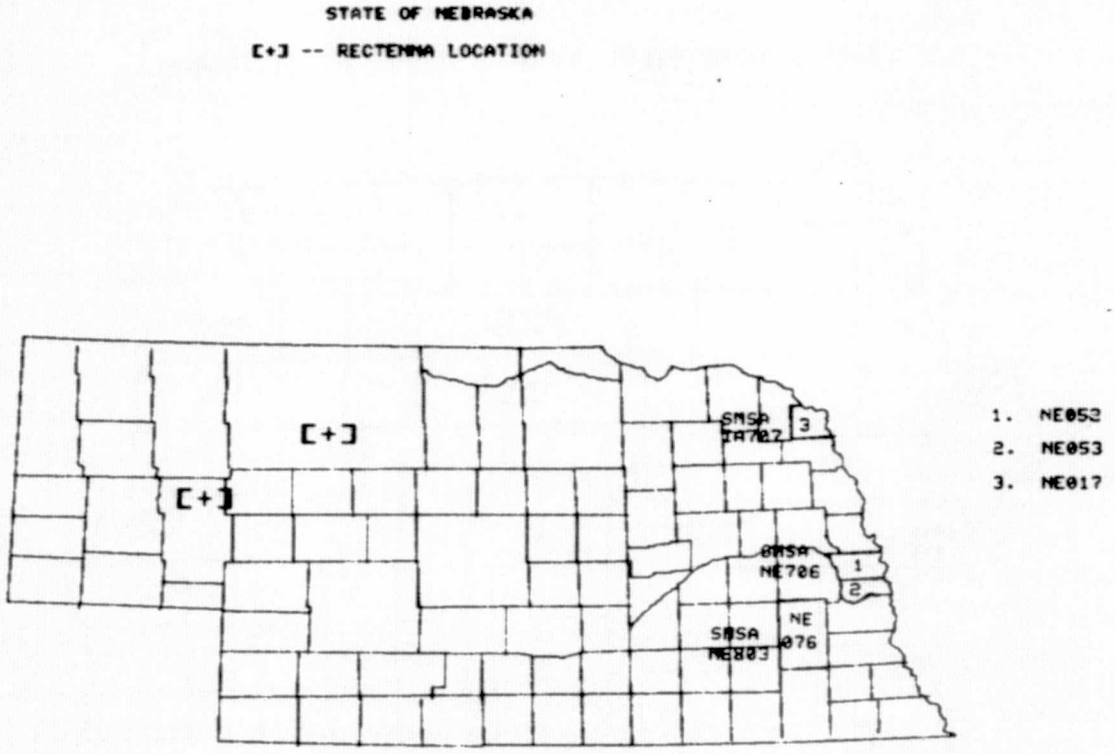

Figure 14. Rectenna locations in the state of Nebraska.

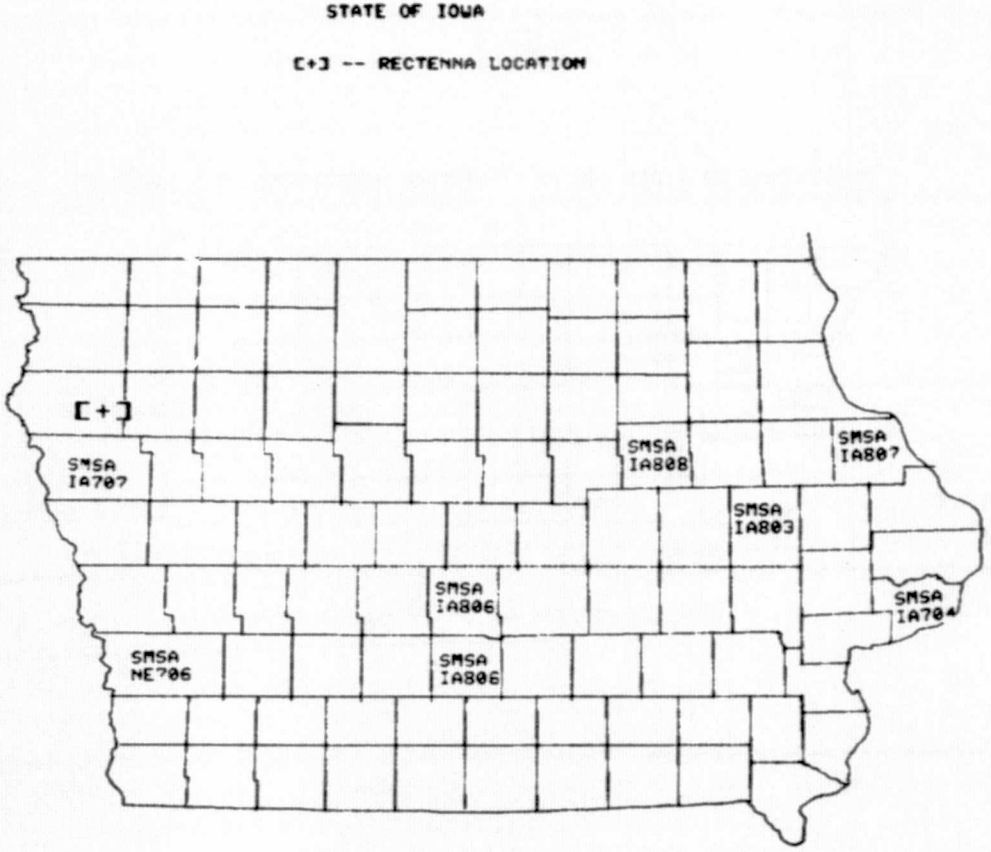

Figure 15. Rectenna location in the state of Iowa.

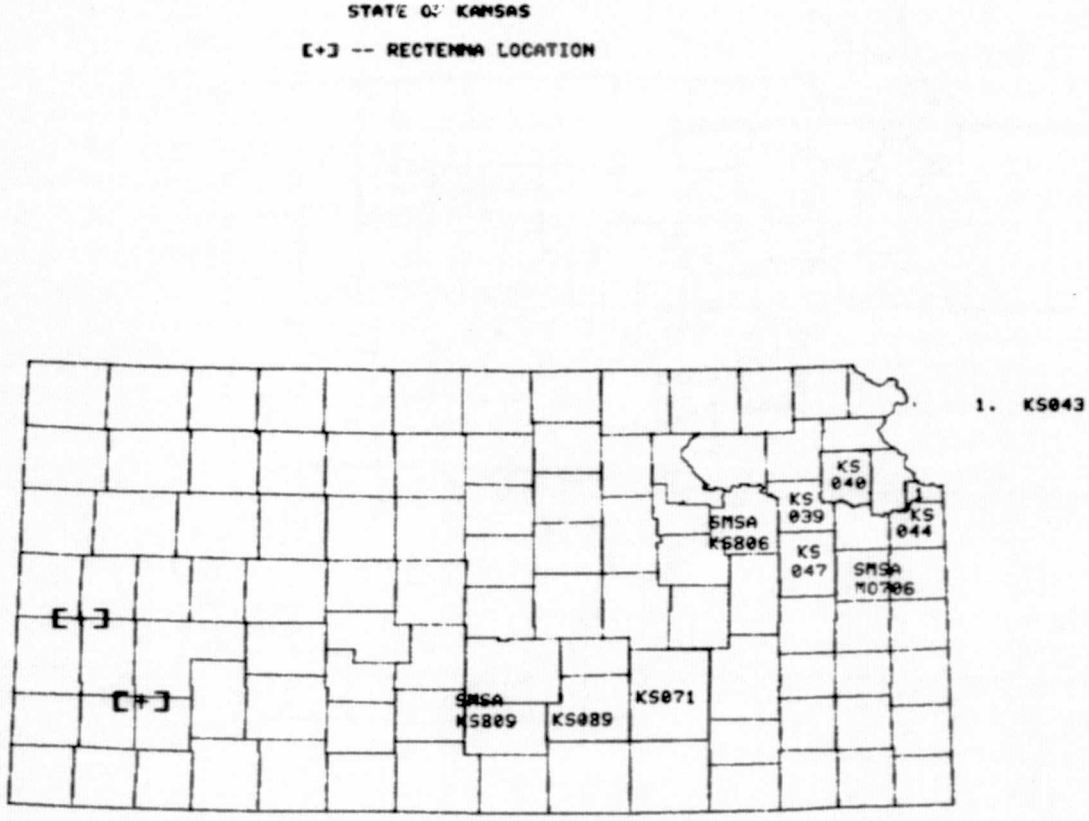

Figure 16. Rectenna locations in the state of Kansas.

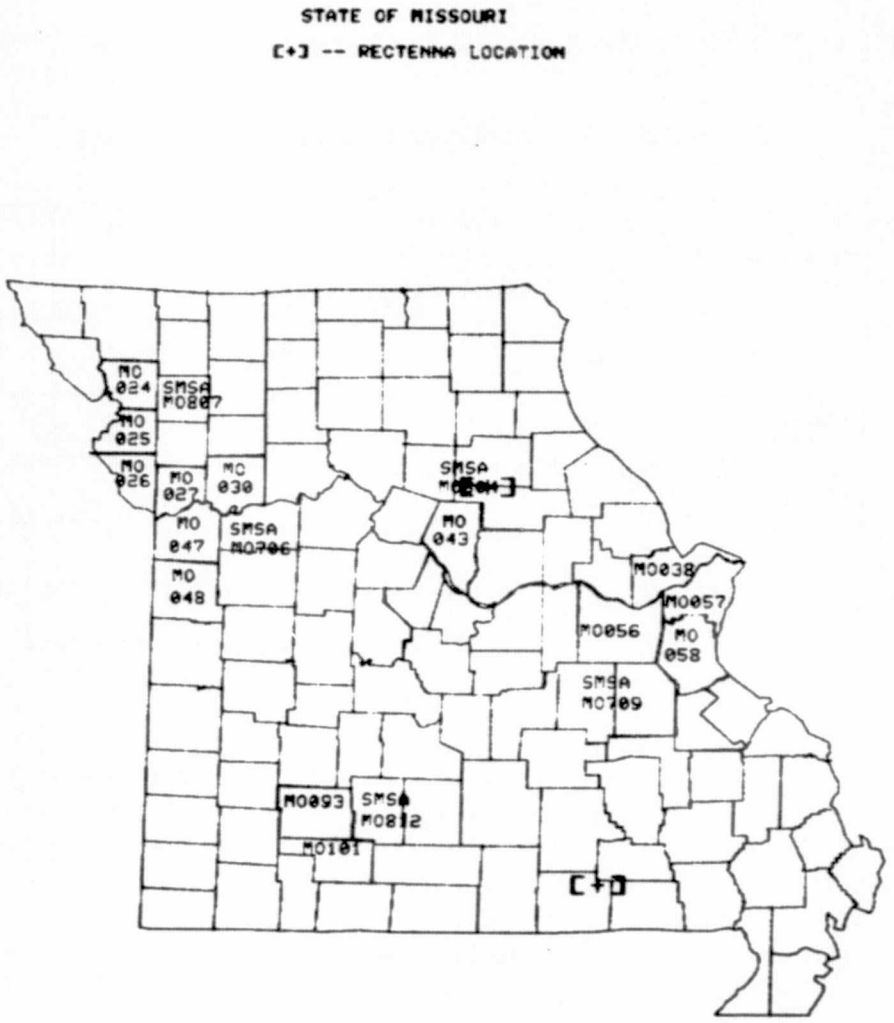

Figure 17. Rectenna locations in the state of Missouri.

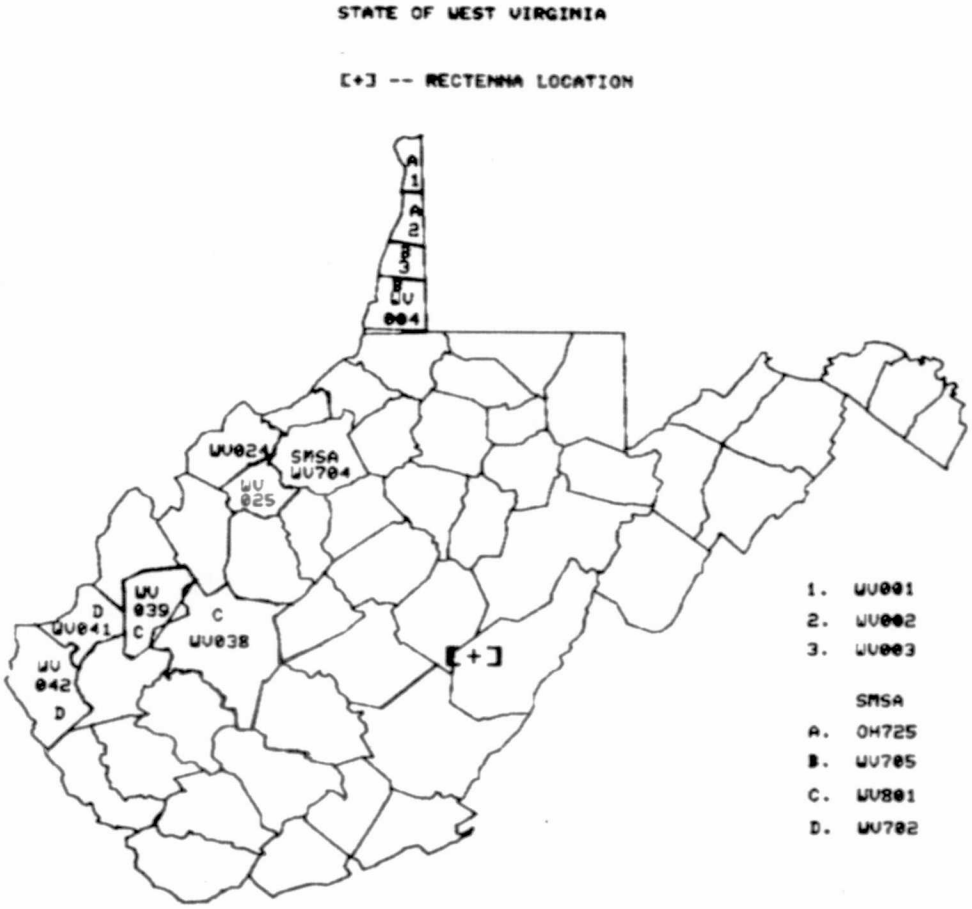

Figure 18. Rectenna location in the state of West Virginia.

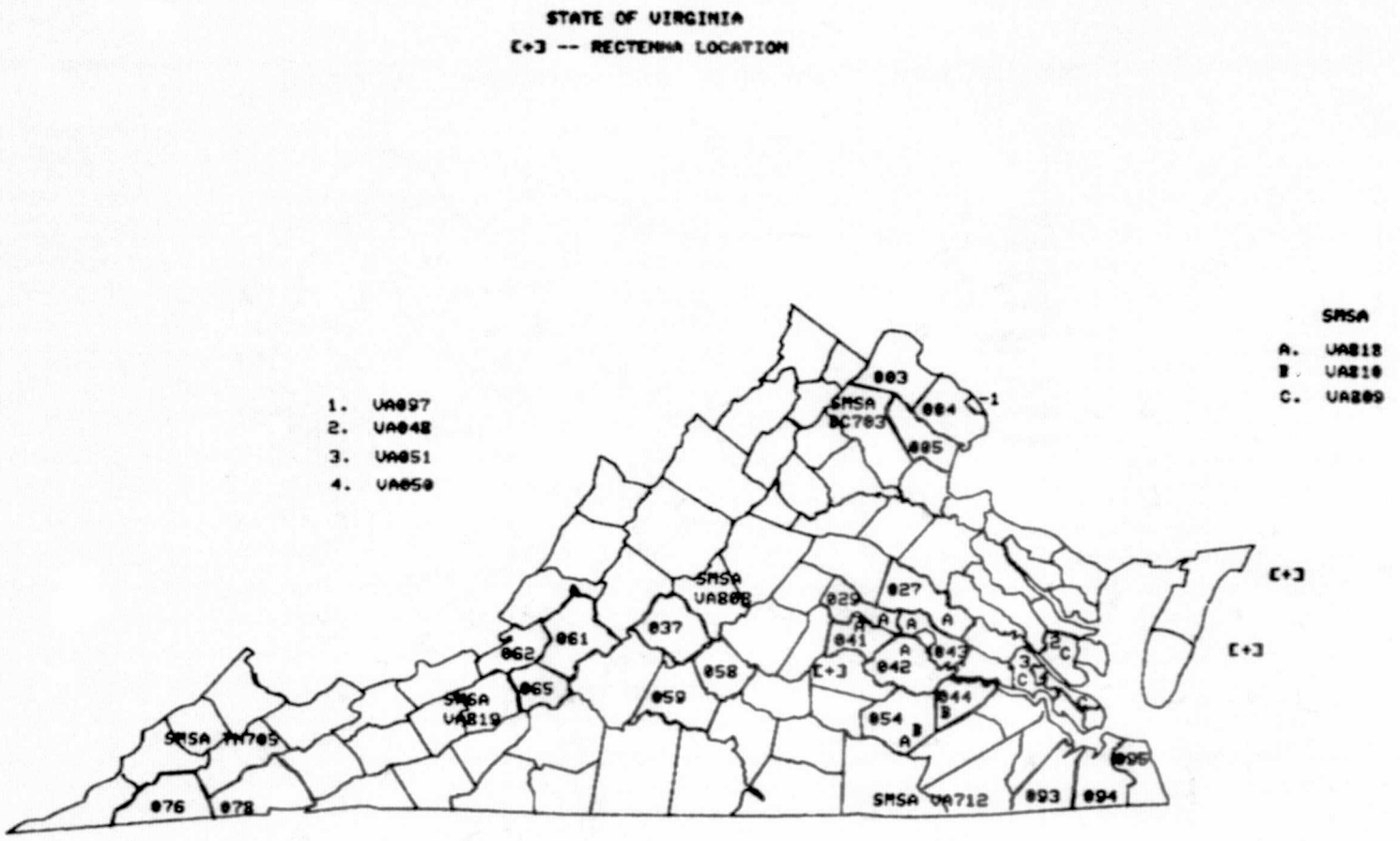

Figure 19. Rectenna locations in the state of Virginia.

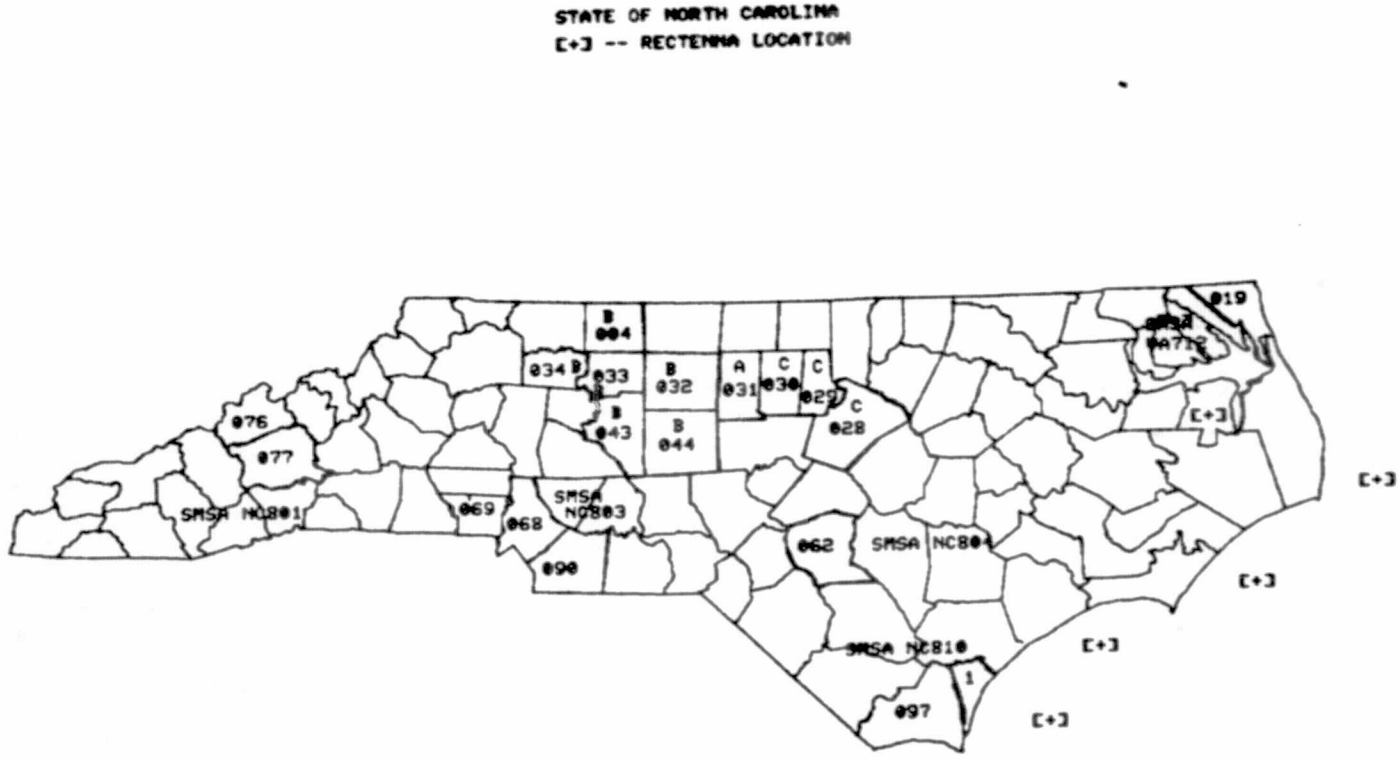

Figure 20. Rectenna locations in the state of North Carolina.

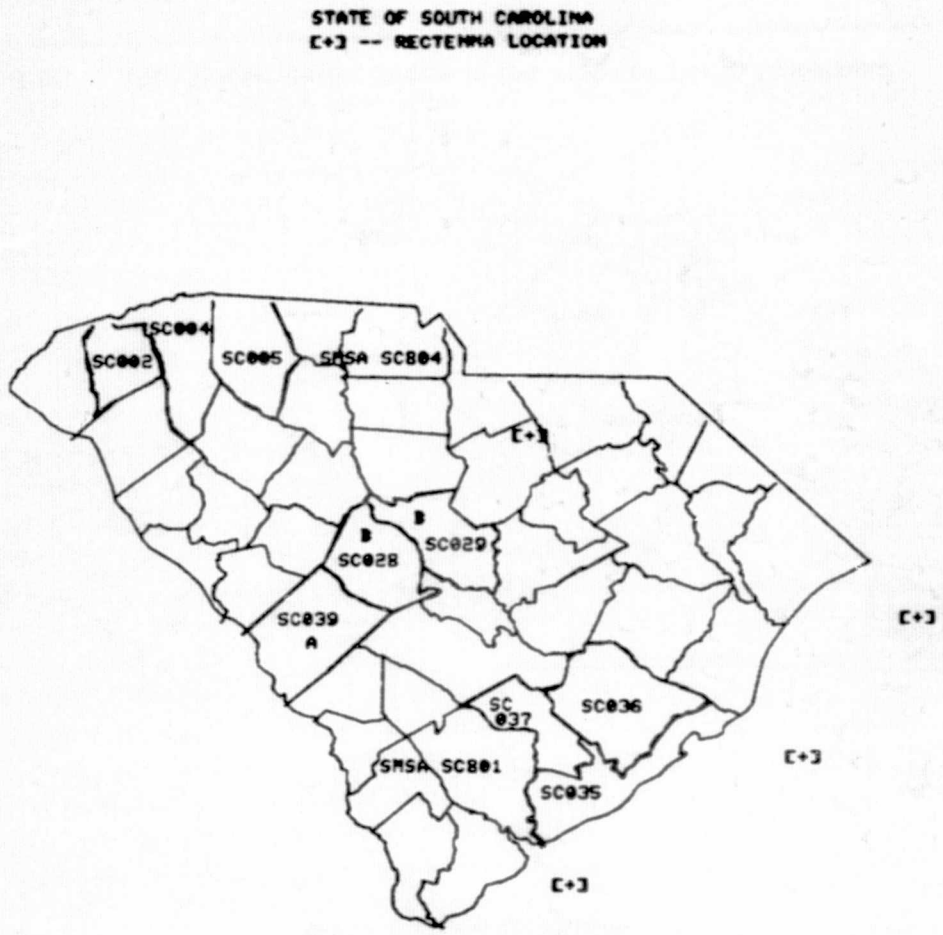

Figure 21. Rectenna locations in the state of South Carolina.

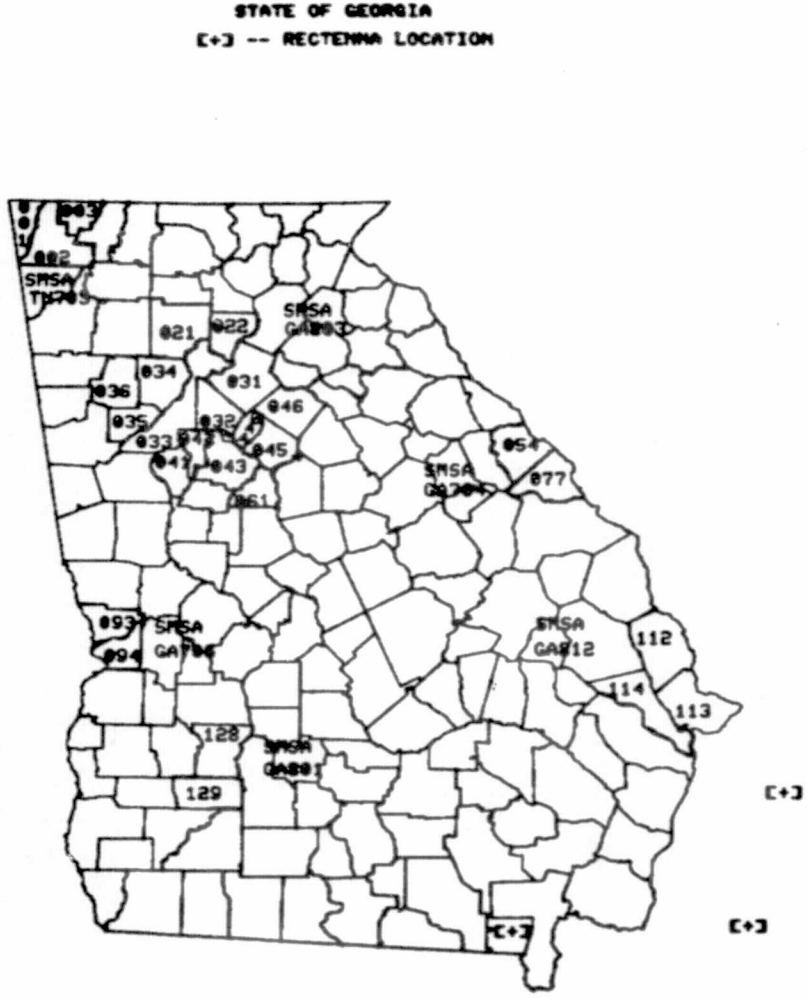

Figure 22. Rectenna locations in the state of Georgia.

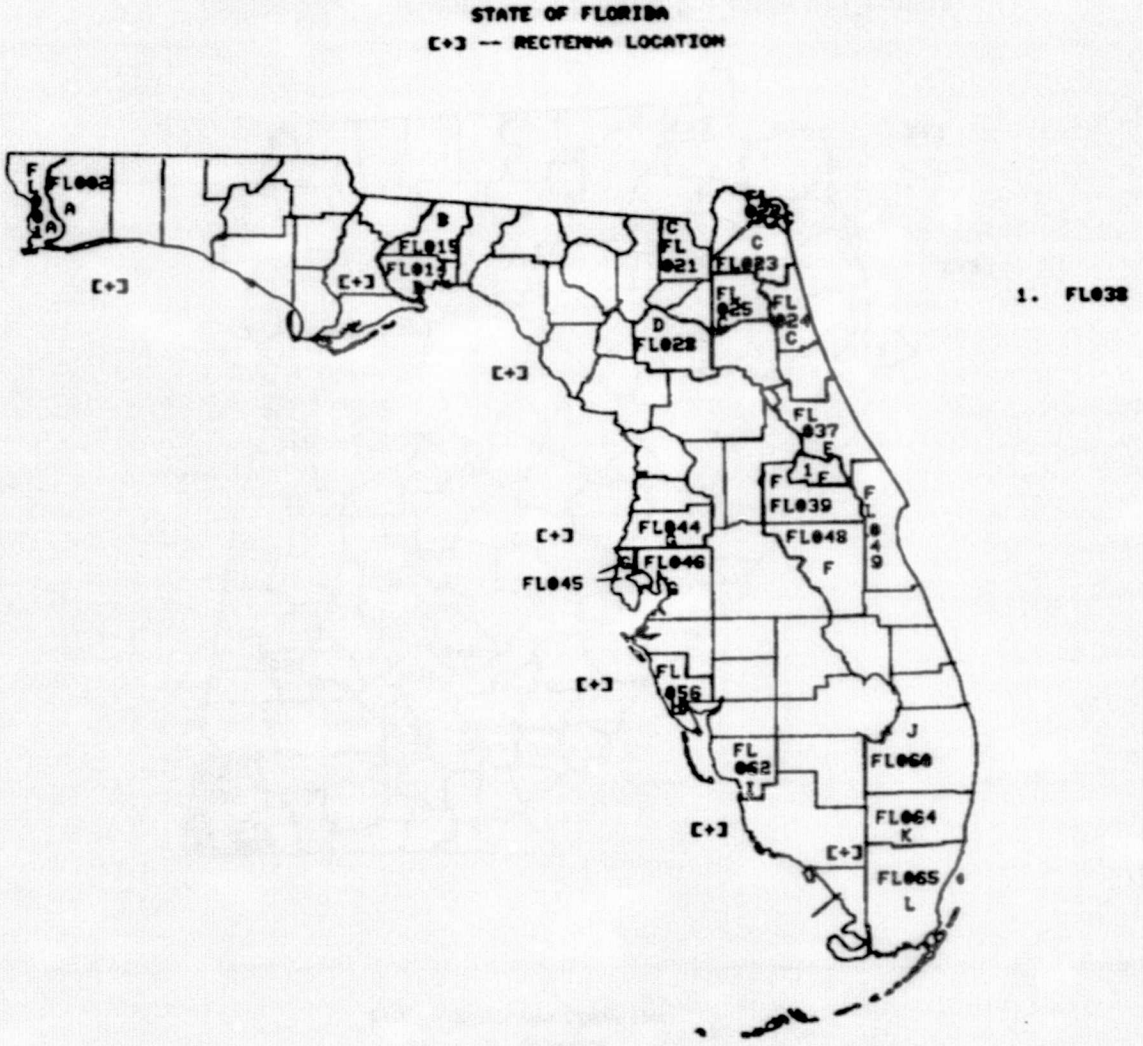

Figure 23. Rectenna locations in the state of Florida.

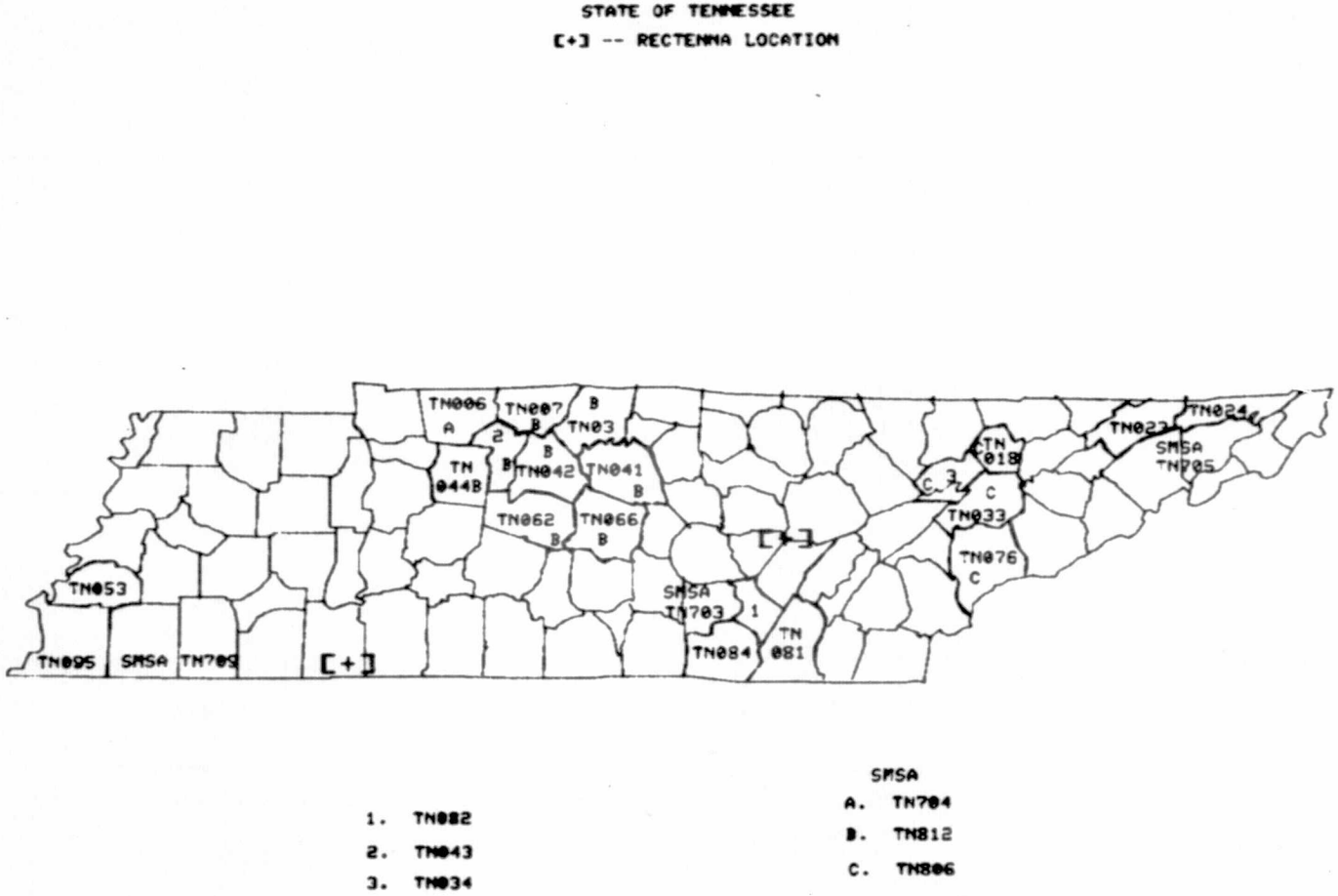

Figure 24. Rectenna locations in the state of Tennessee.

STATE OF ALABAMA

[+] -- RECTENNA LOCATION

SMSA

A. AL804
B. AL806
C. AL805
D. AL801
E. AL803
F. AL813
G. AL812
H. AL809

SMSA TN703
AL001,AL003,AL002

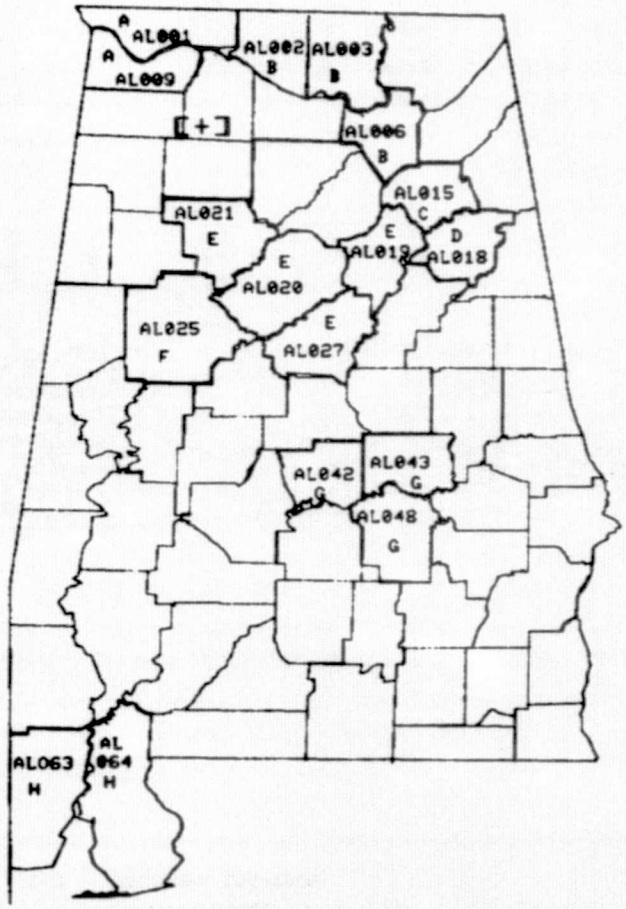

Figure 25. Rectenna location in the state of Alabama.

Figure 26. Rectenna locations in the state of Mississippi.

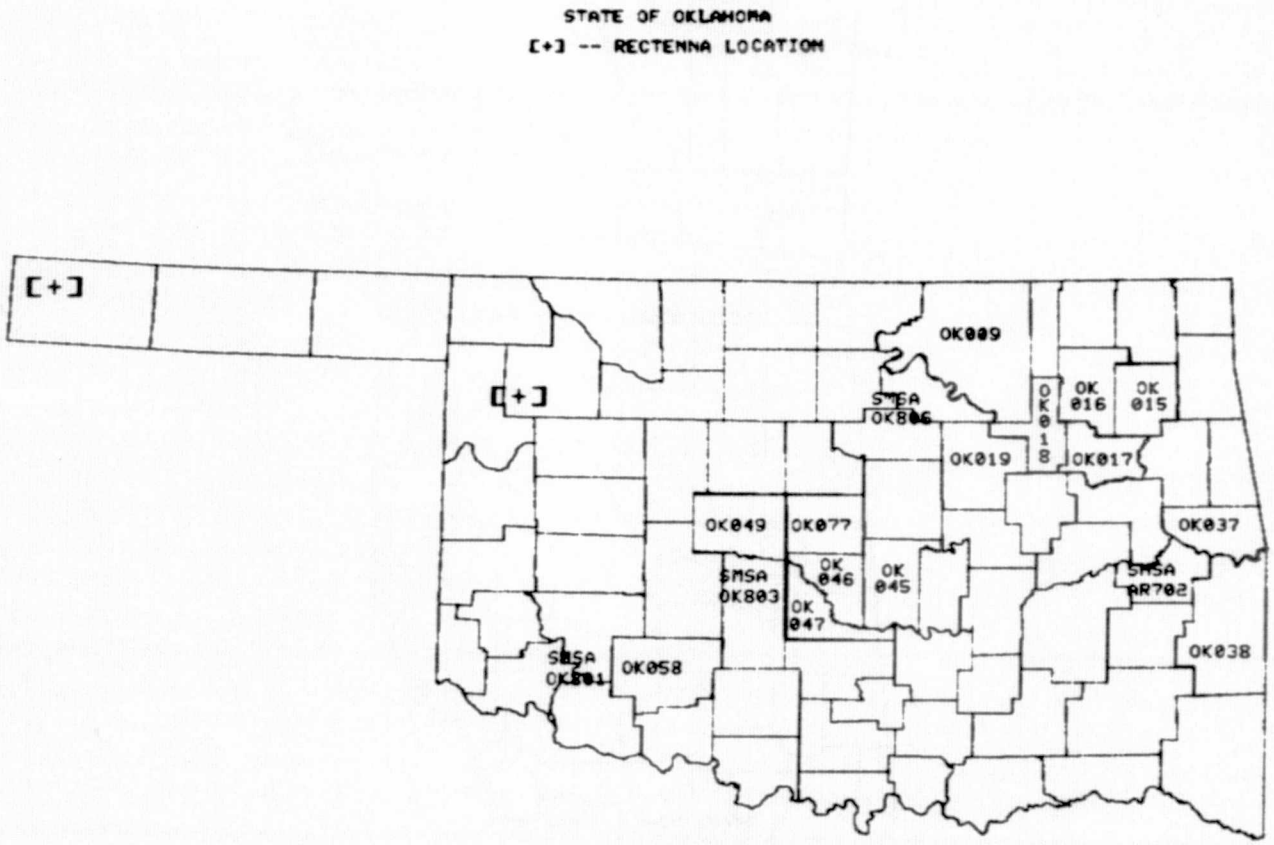

Figure 27. Rectenna locations in the state of Oklahoma.

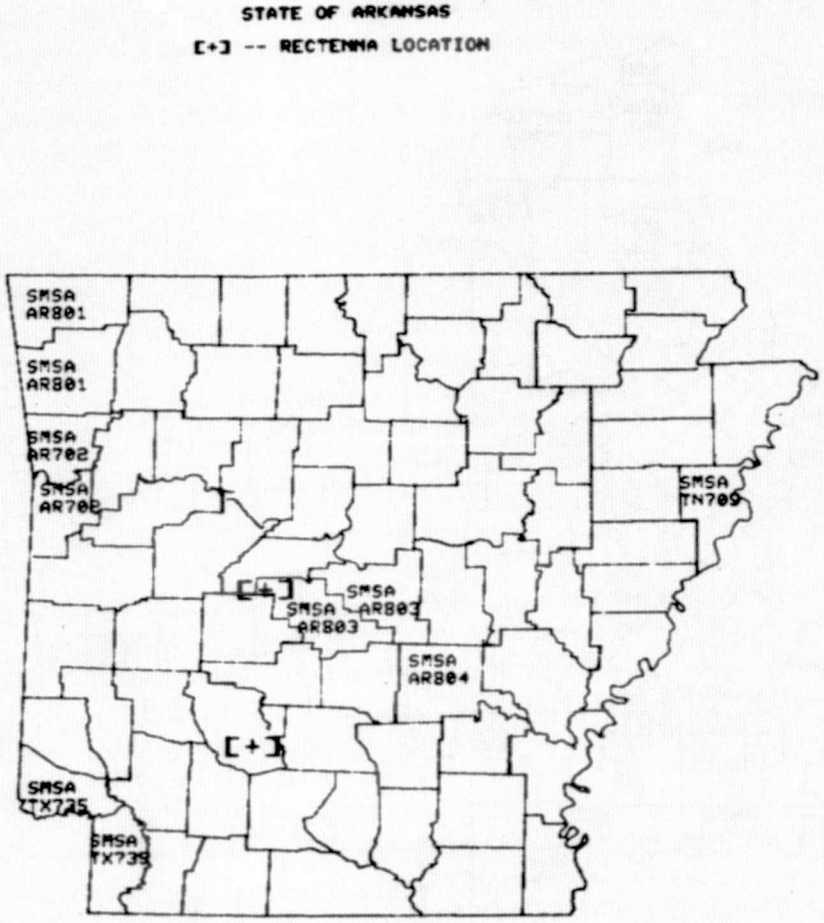

Figure 28. Rectenna locations in the state of Arkansas.

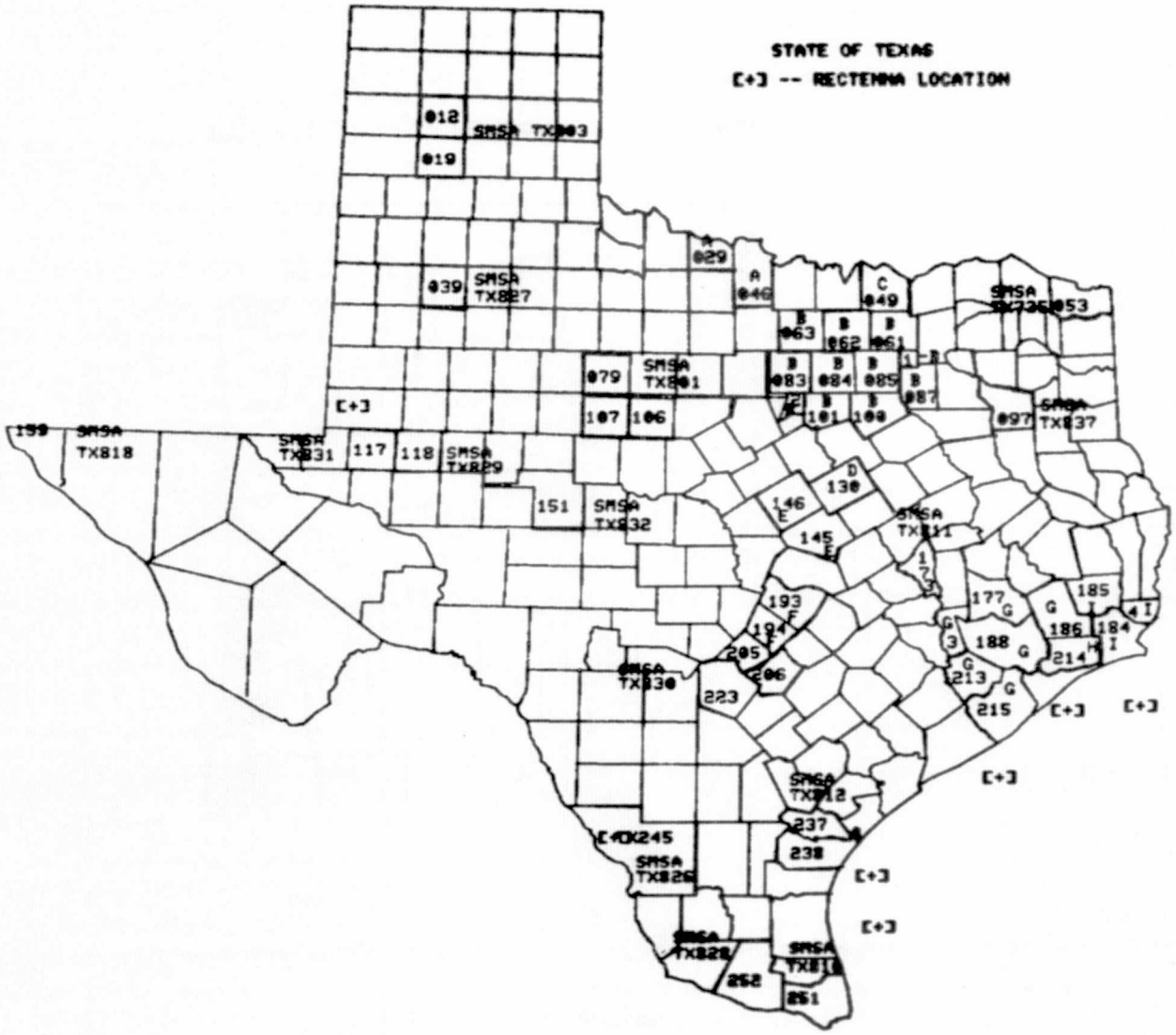

Figure 29. Rectenna locations in the state of Texas.

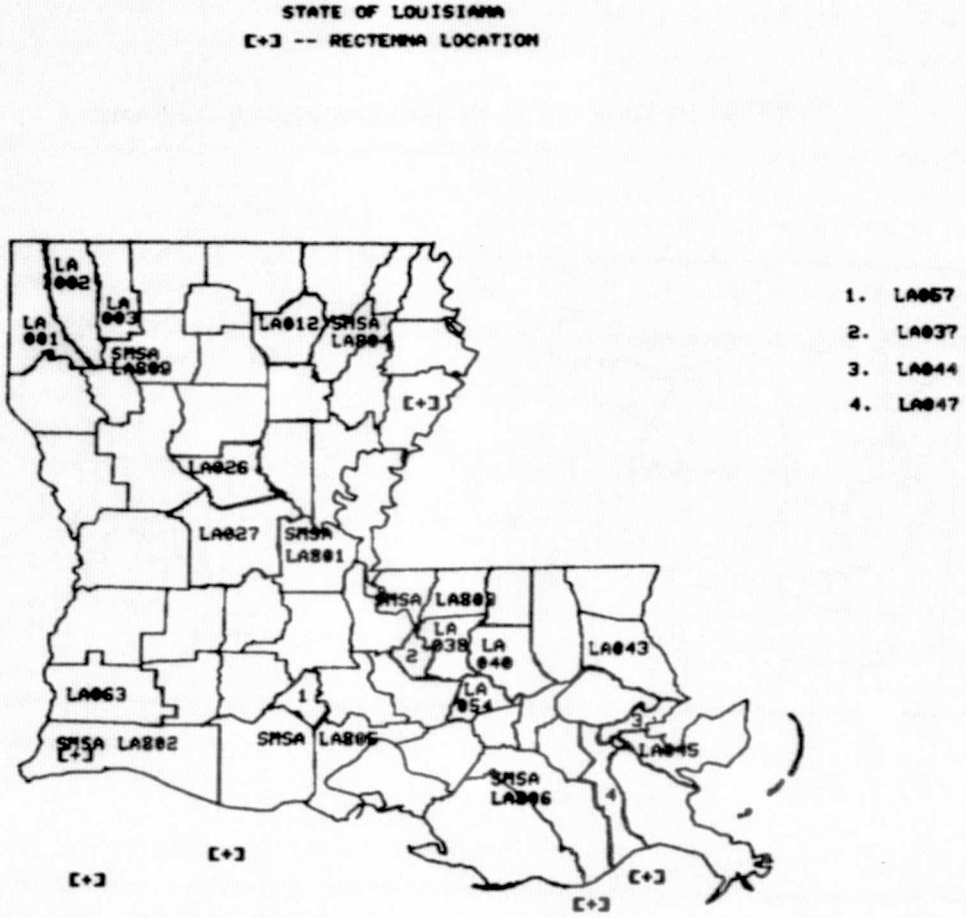

Figure 30. Rectenna locations in the state of Louisiana.

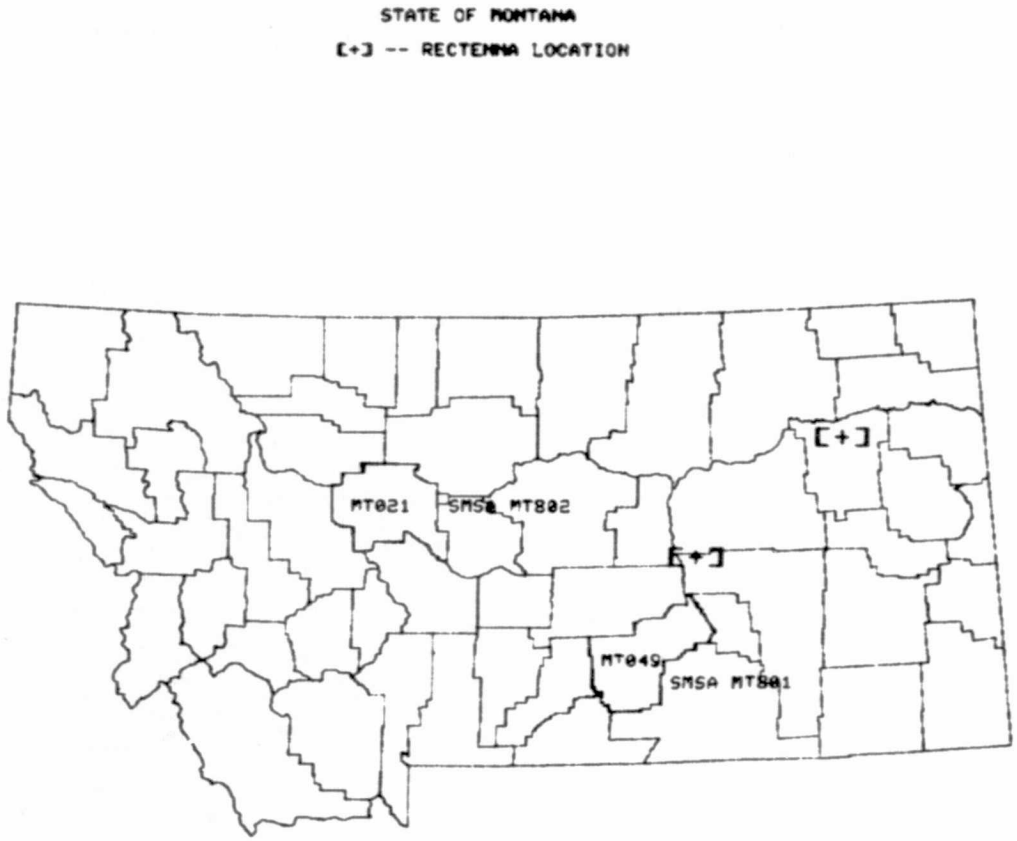

Figure 31. Rectenna locations in the state of Montana.

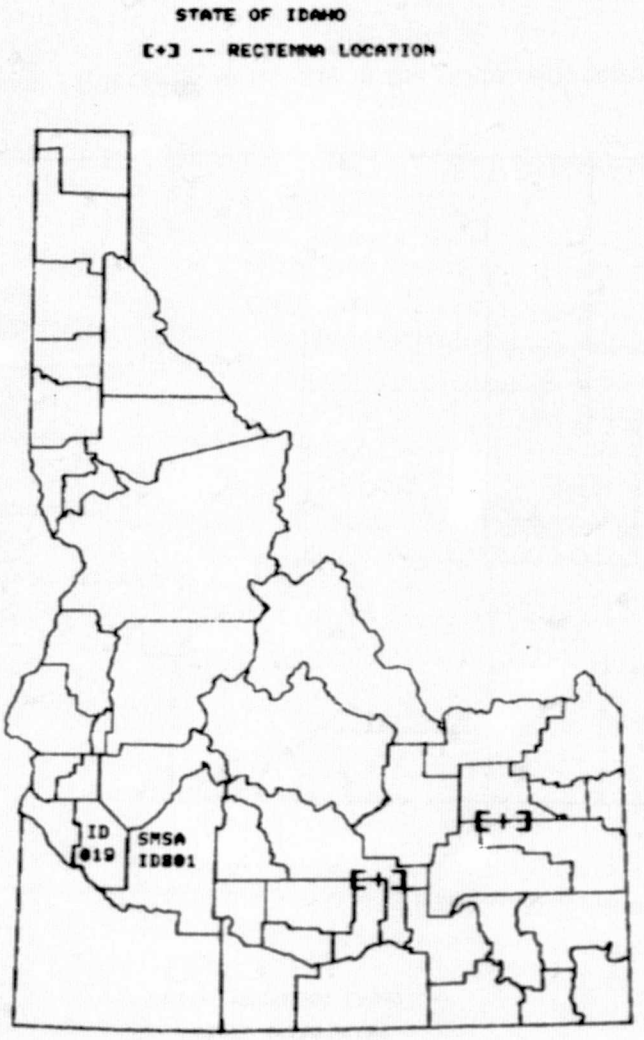

Figure 32. Rectenna locations in the state of Idaho.

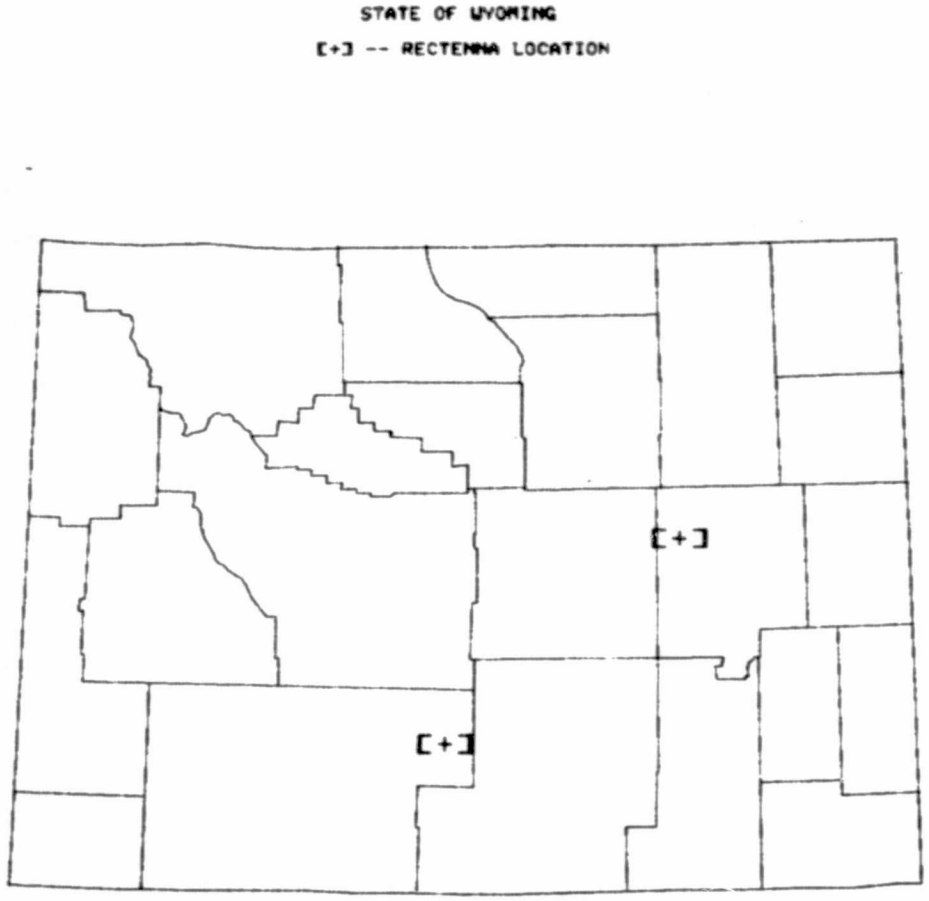

Figure 33. Rectenna locations in the state of Wyoming.

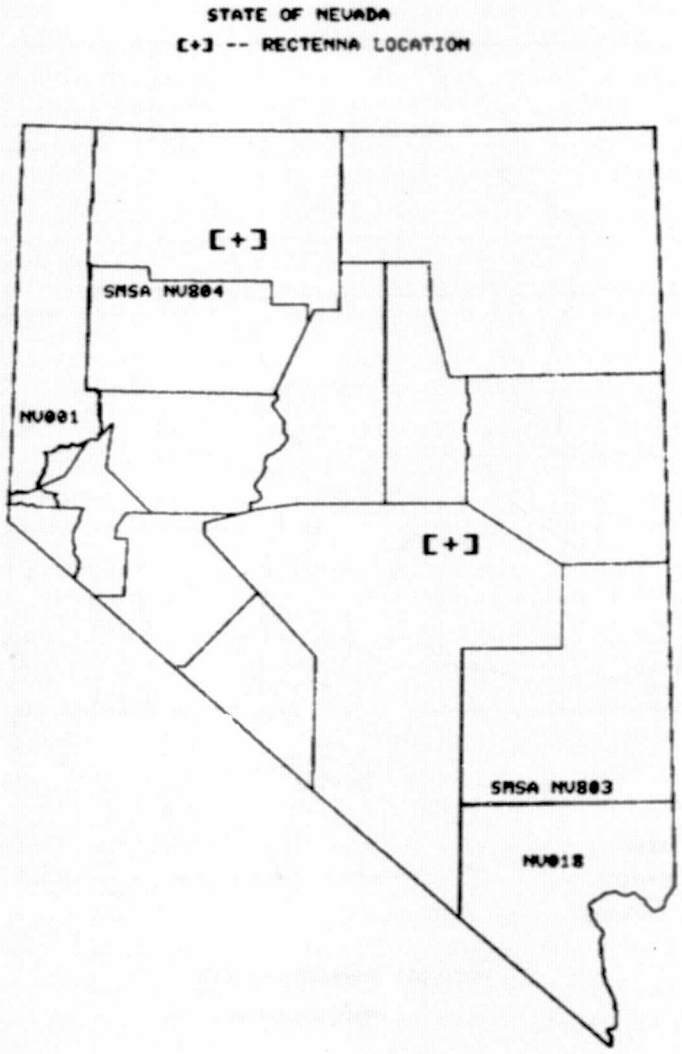

Figure 34. Rectenna locations in the state of Nevada.

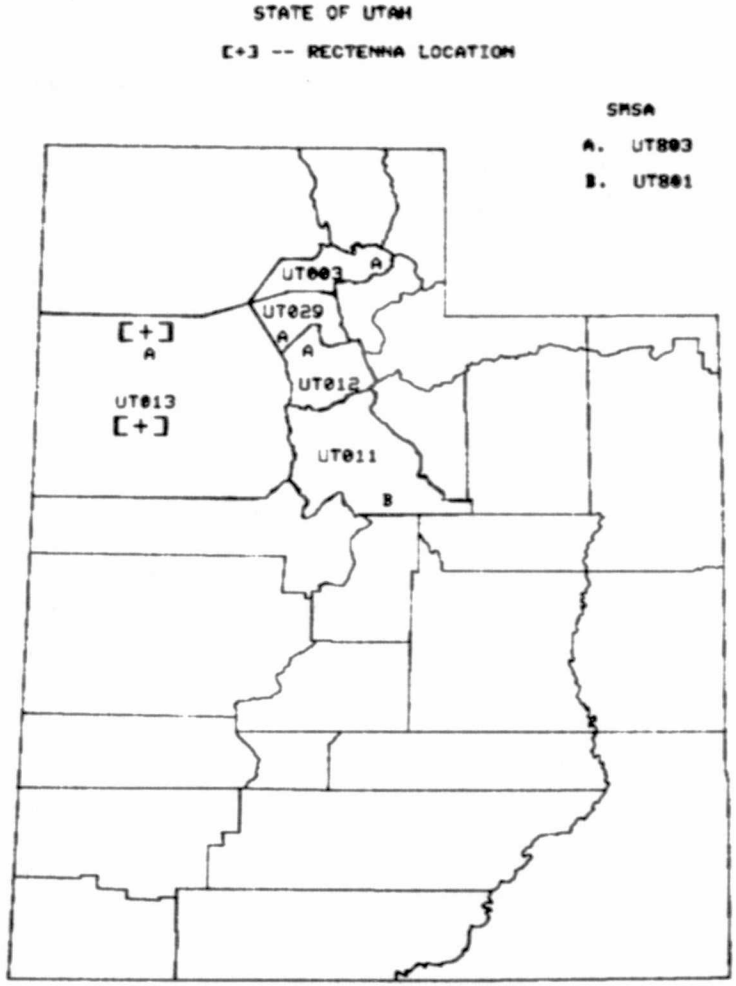

Figure 35. Rectenna locations in the state of Utah.

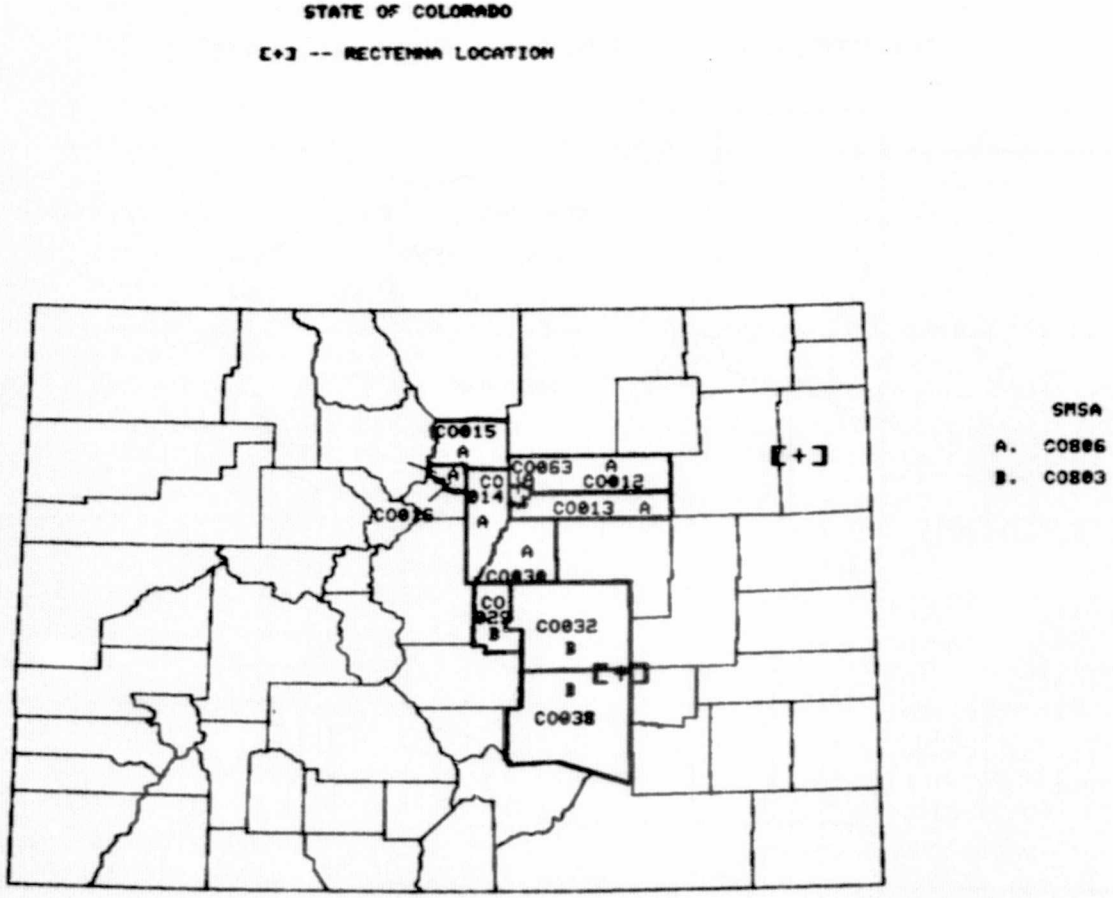

Figure 36. Rectenna locations in the state of Colorado.

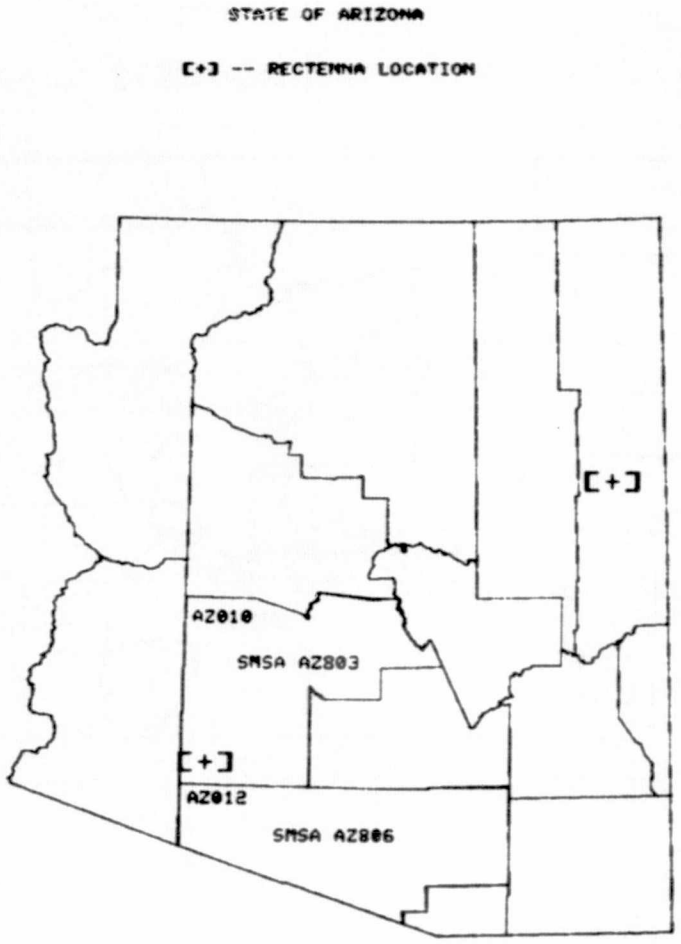

Figure 37. Rectenna locations in the state of Arizona.

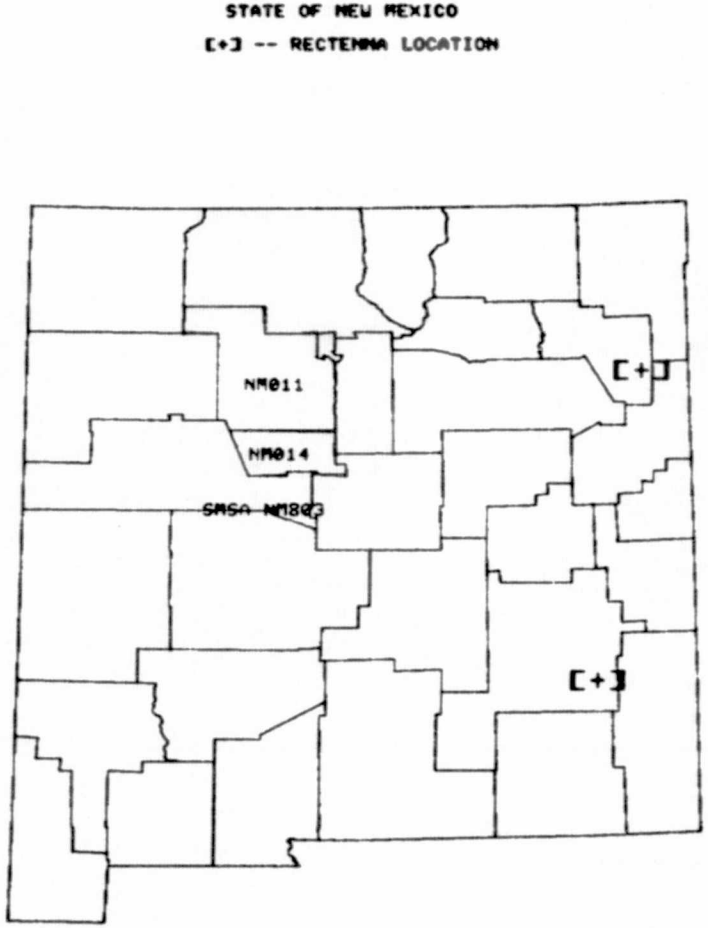

Figure 38. Rectenna locations in the state of New Mexico.

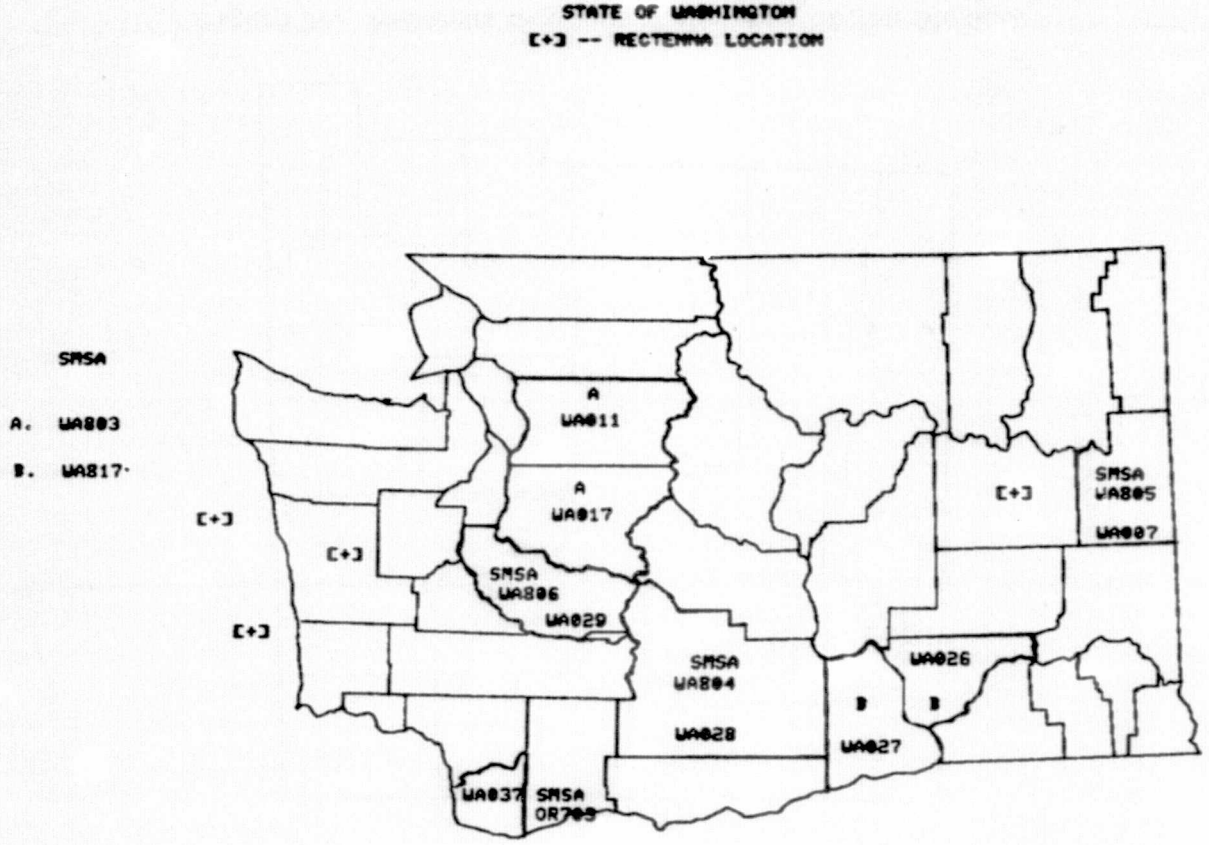

Figure 39. Rectenna locations in the state of Washington.

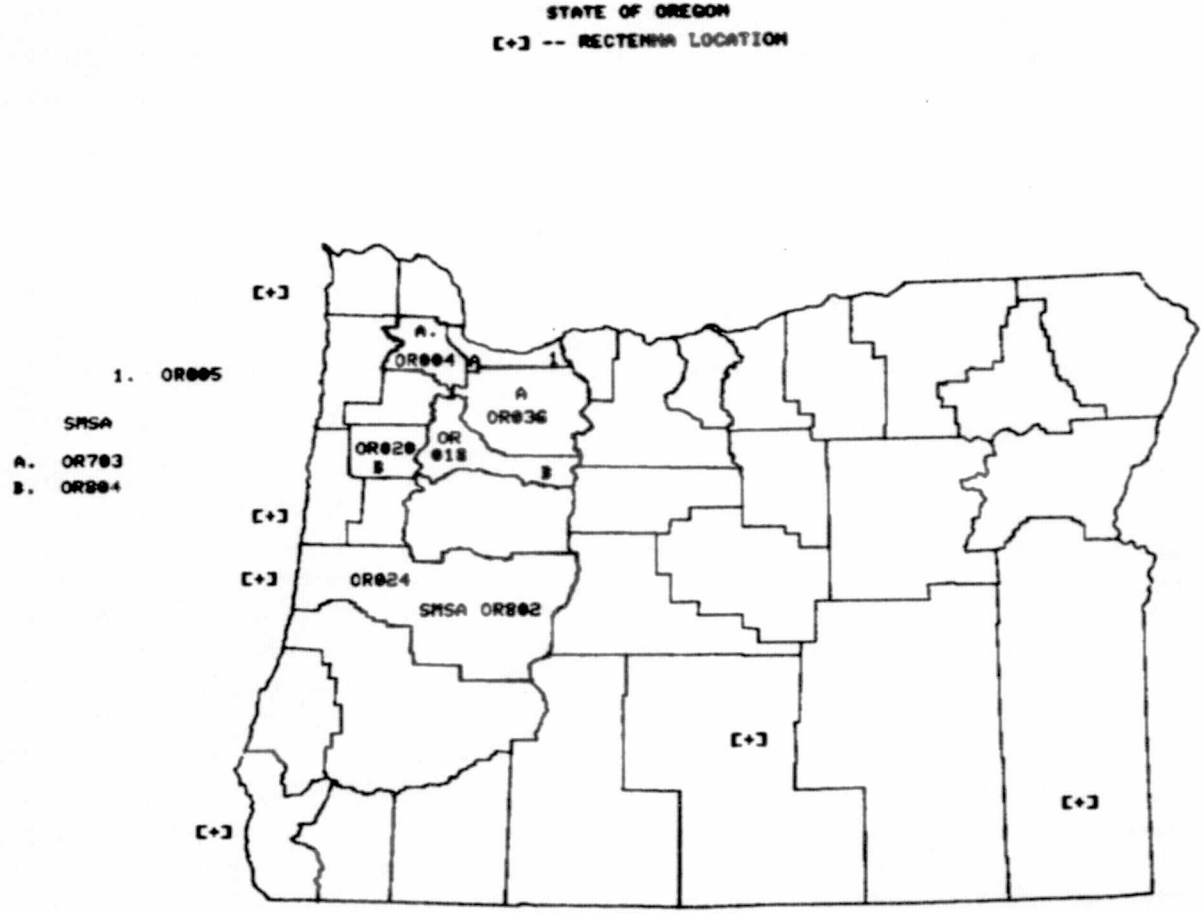

Figure 40. Rectenna locations in the state of Oregon.

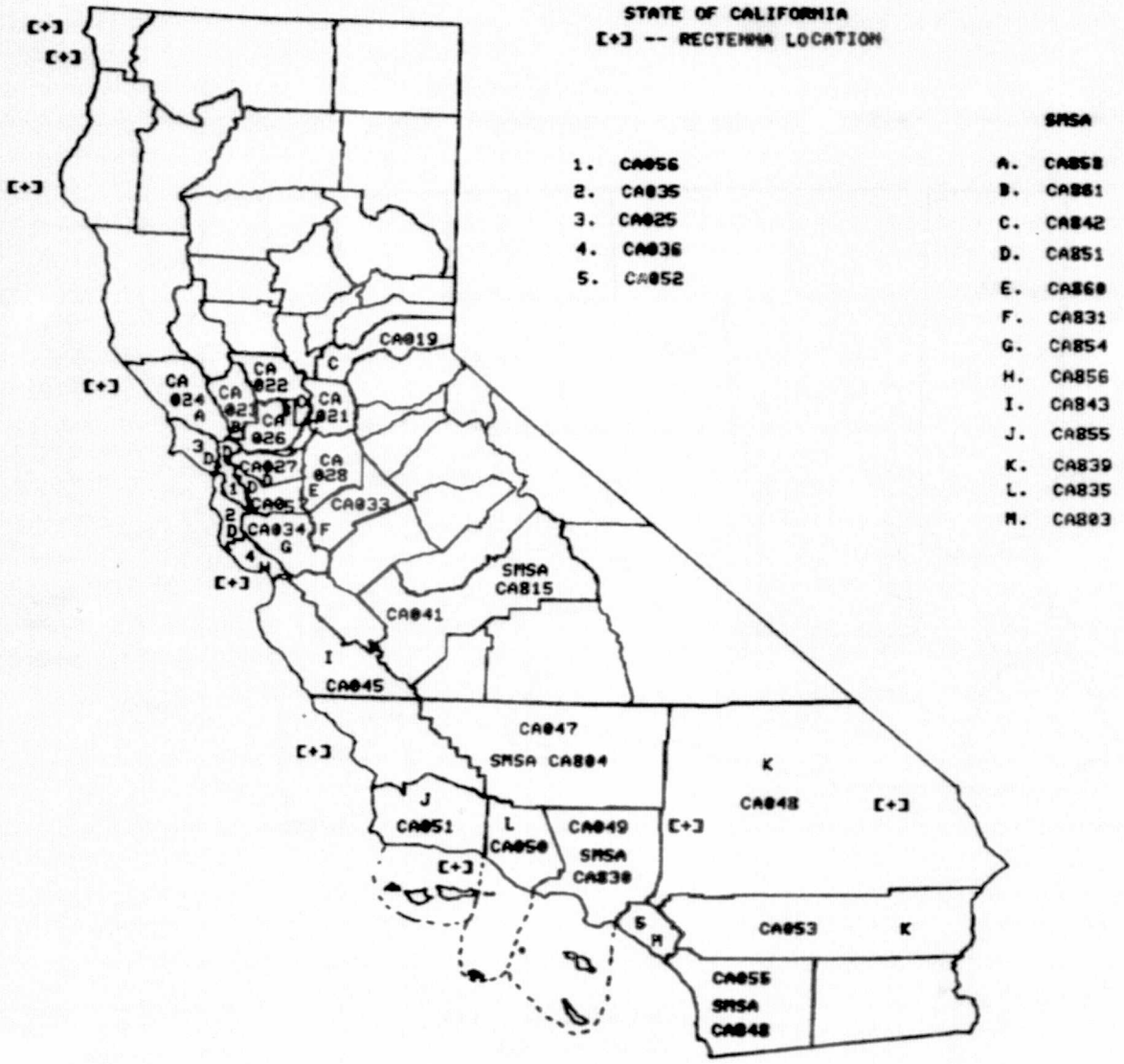

Figure 41. Rectenna locations in the state of California.

Figure 42. Rectenna distribution through the nine regions of the country. (Rectennas are not to scale.)

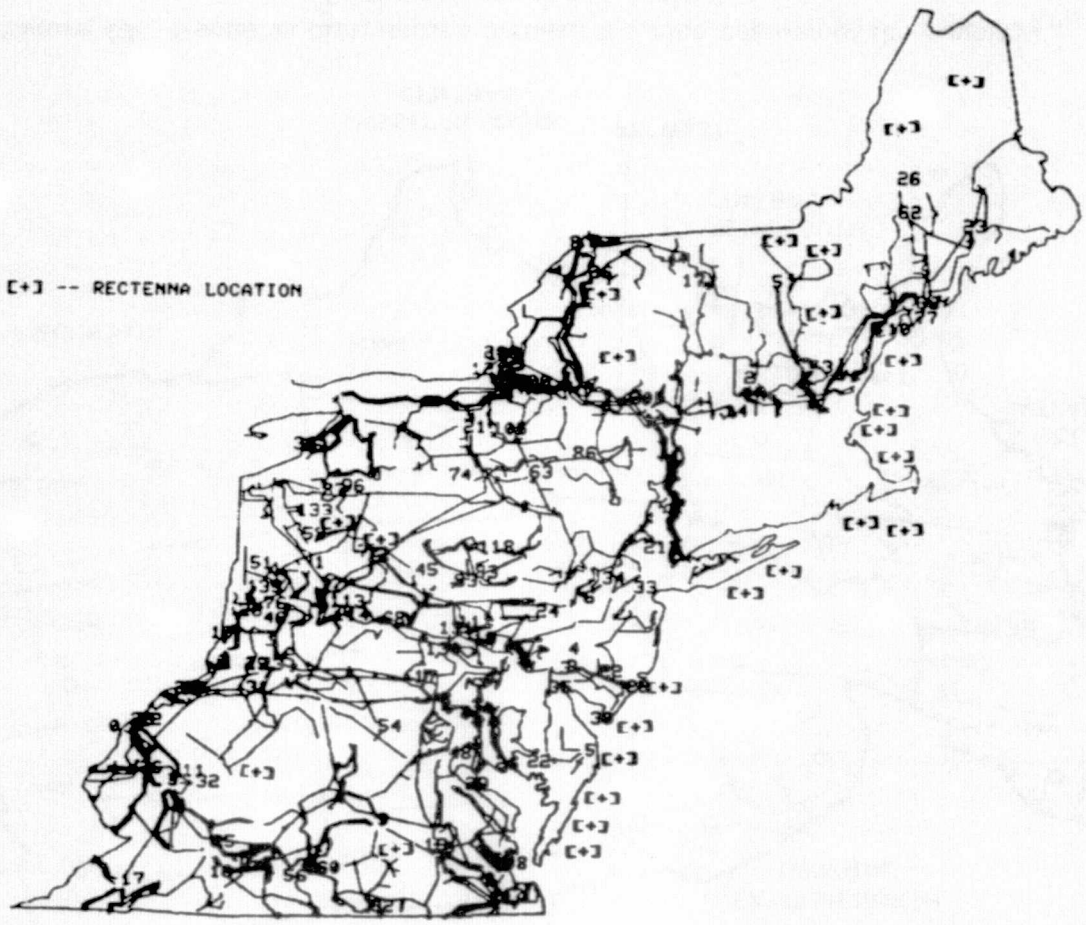

Figure 43. Rectenna locations overlayed on principal electric facilities in the Northeastern U.S.

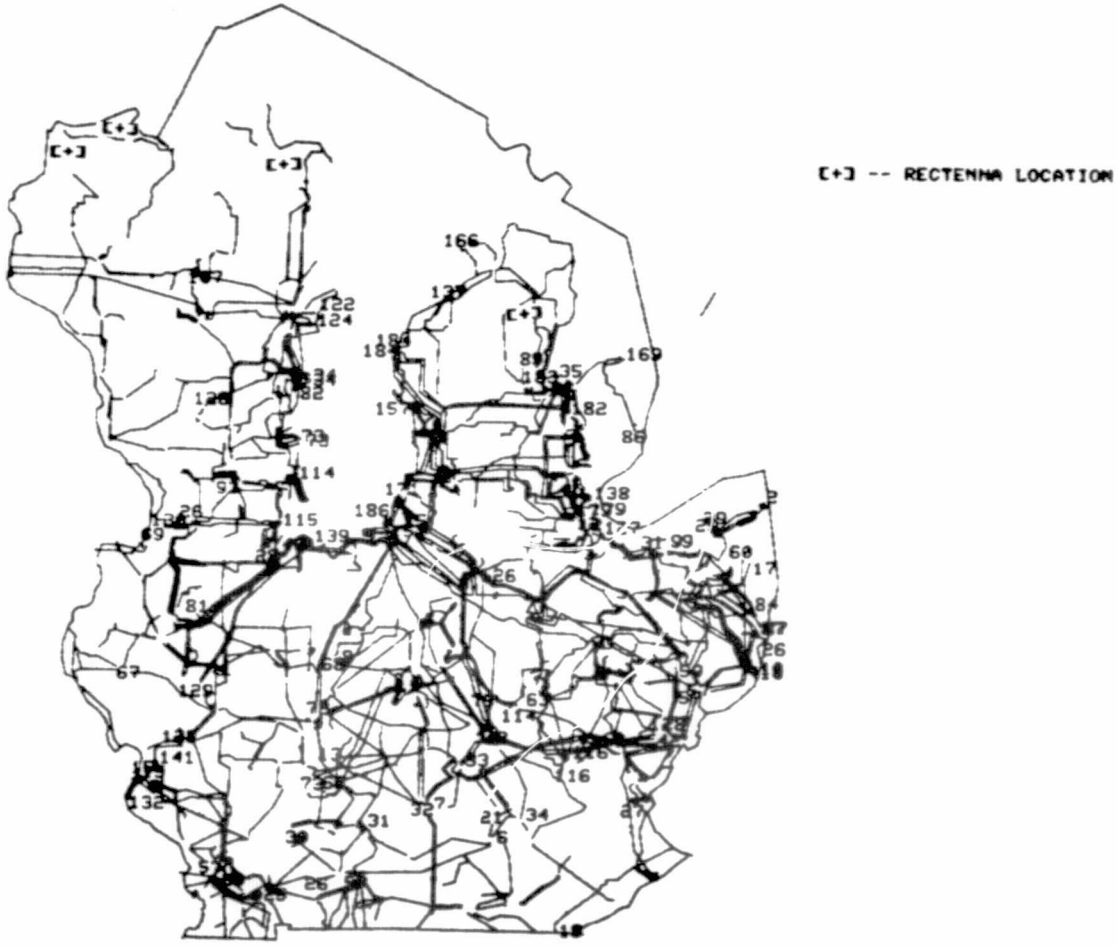

Figure 44. Rectenna locations overlayed on principal electric facilities in the Eastern North Central U.S.

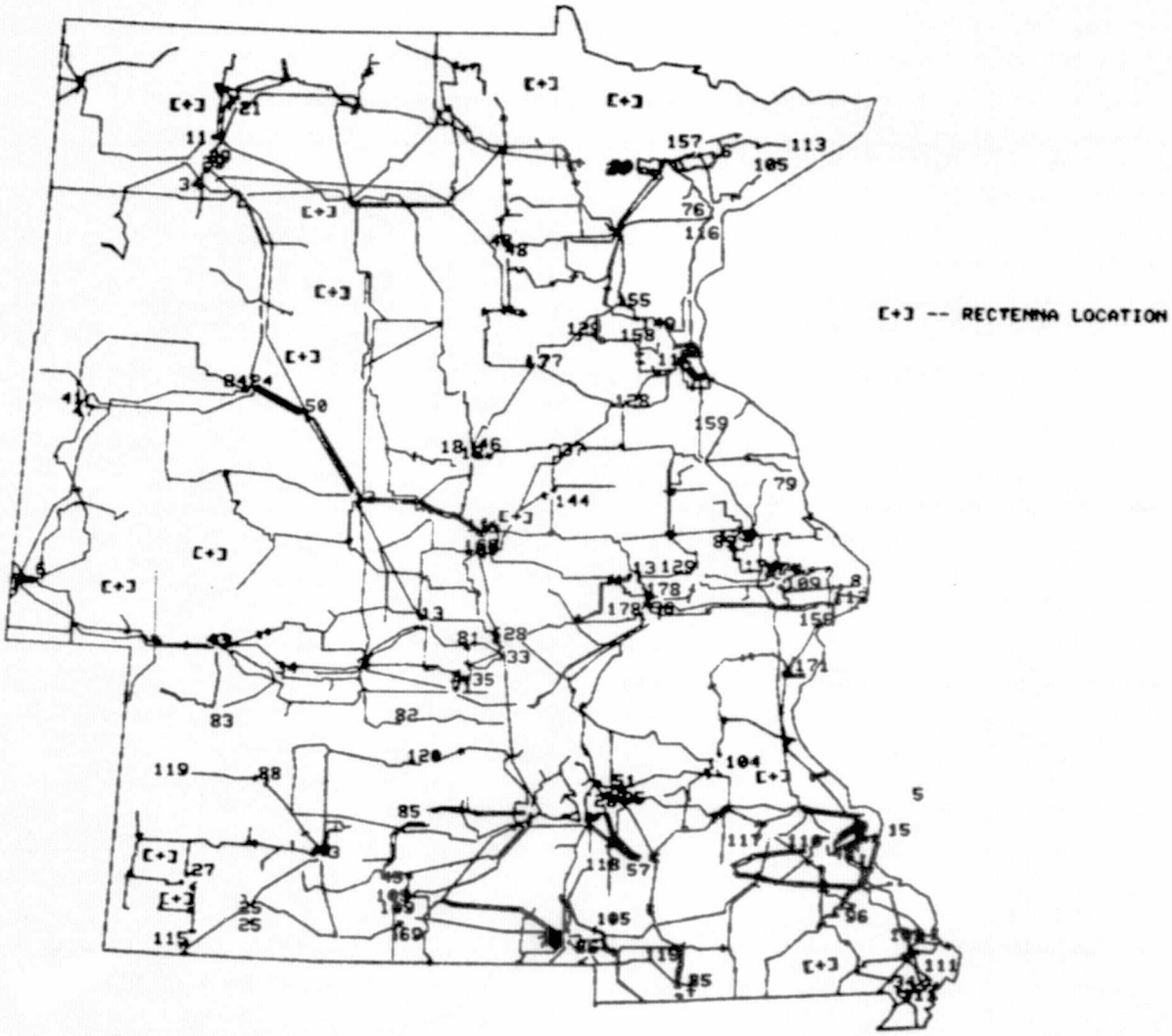

Figure 45. Rectenna locations overlayed on principal electric facilities in the Western North Central U.S.

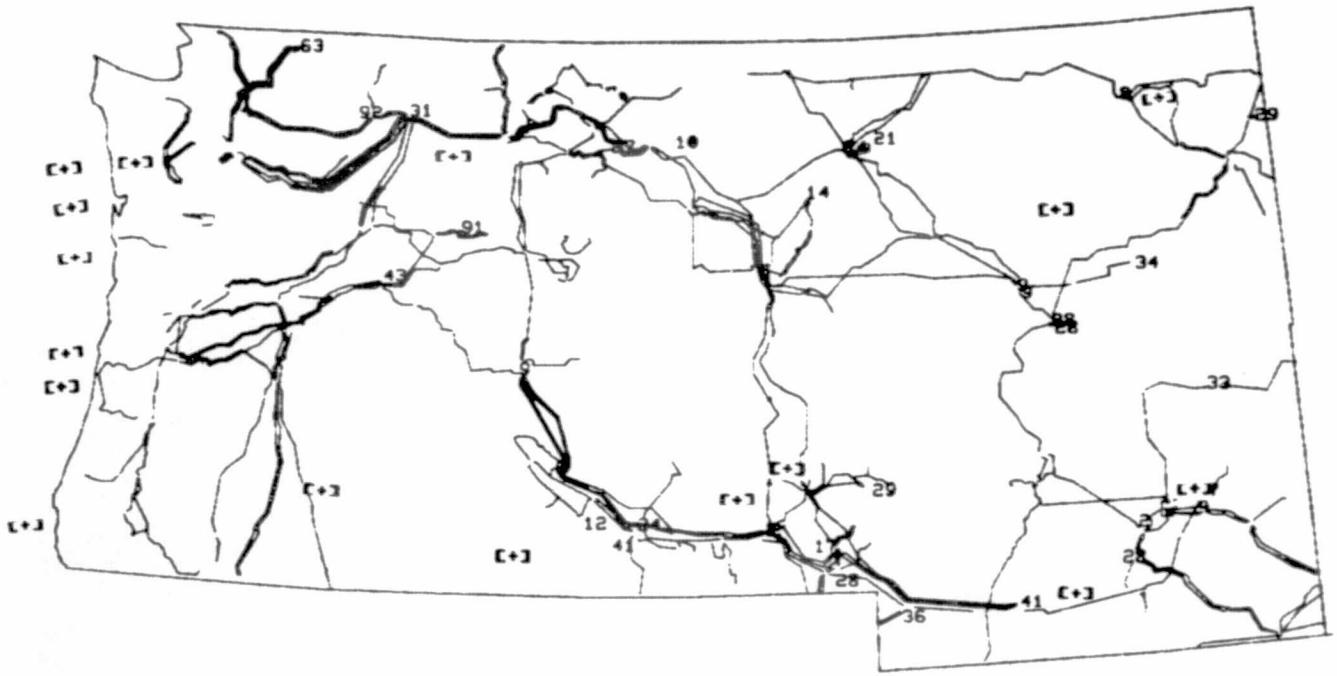

Figure 46. Rectenna locations overlayed on principal electric facilities in the Pacific Northwestern U.S.

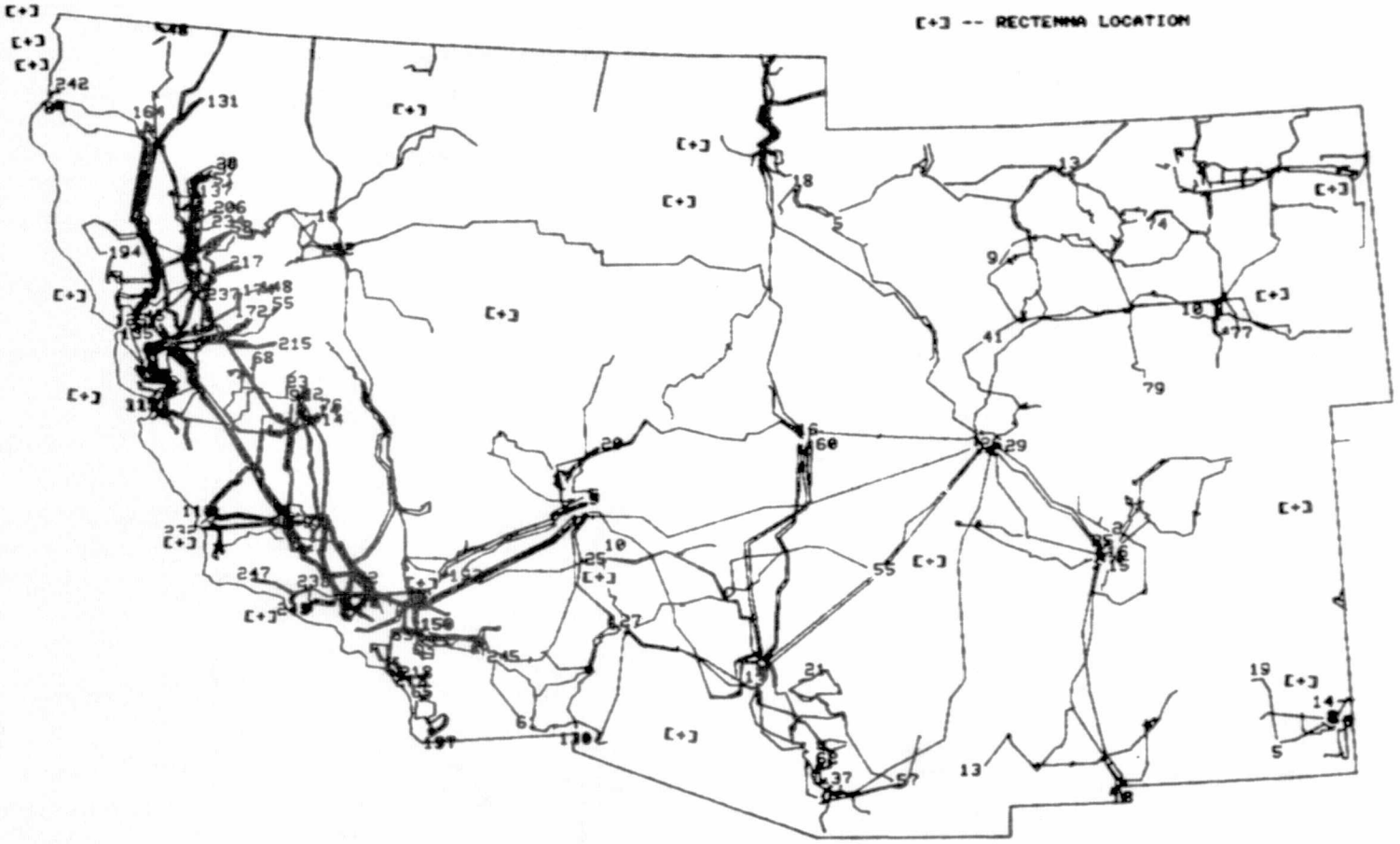

Figure 47. Rectenna locations overlayed on principal electric facilities in the Southwestern U.S.

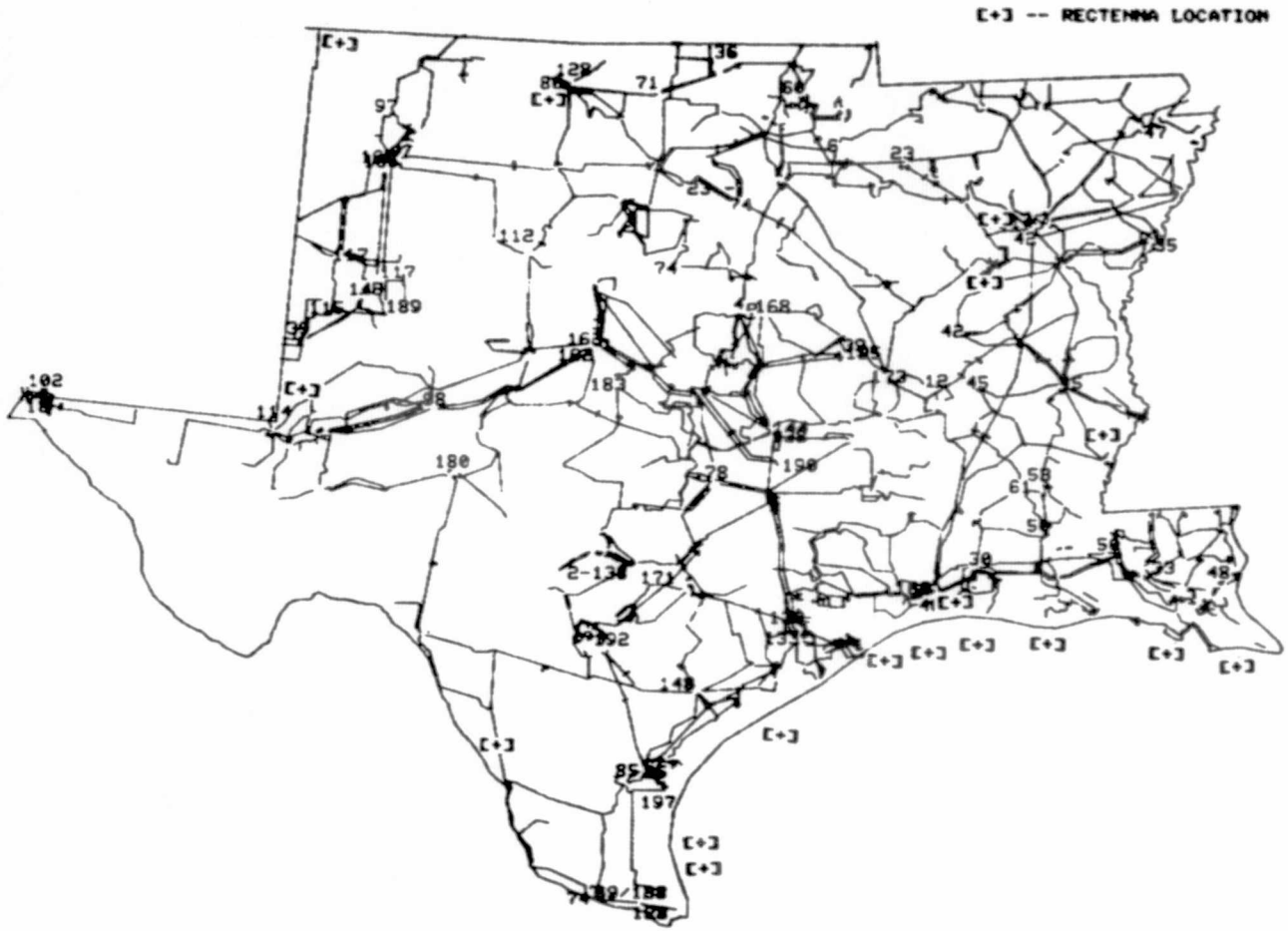

Figure 48. Rectenna locations overlayed on principal electric facilities in the South Central U.S.

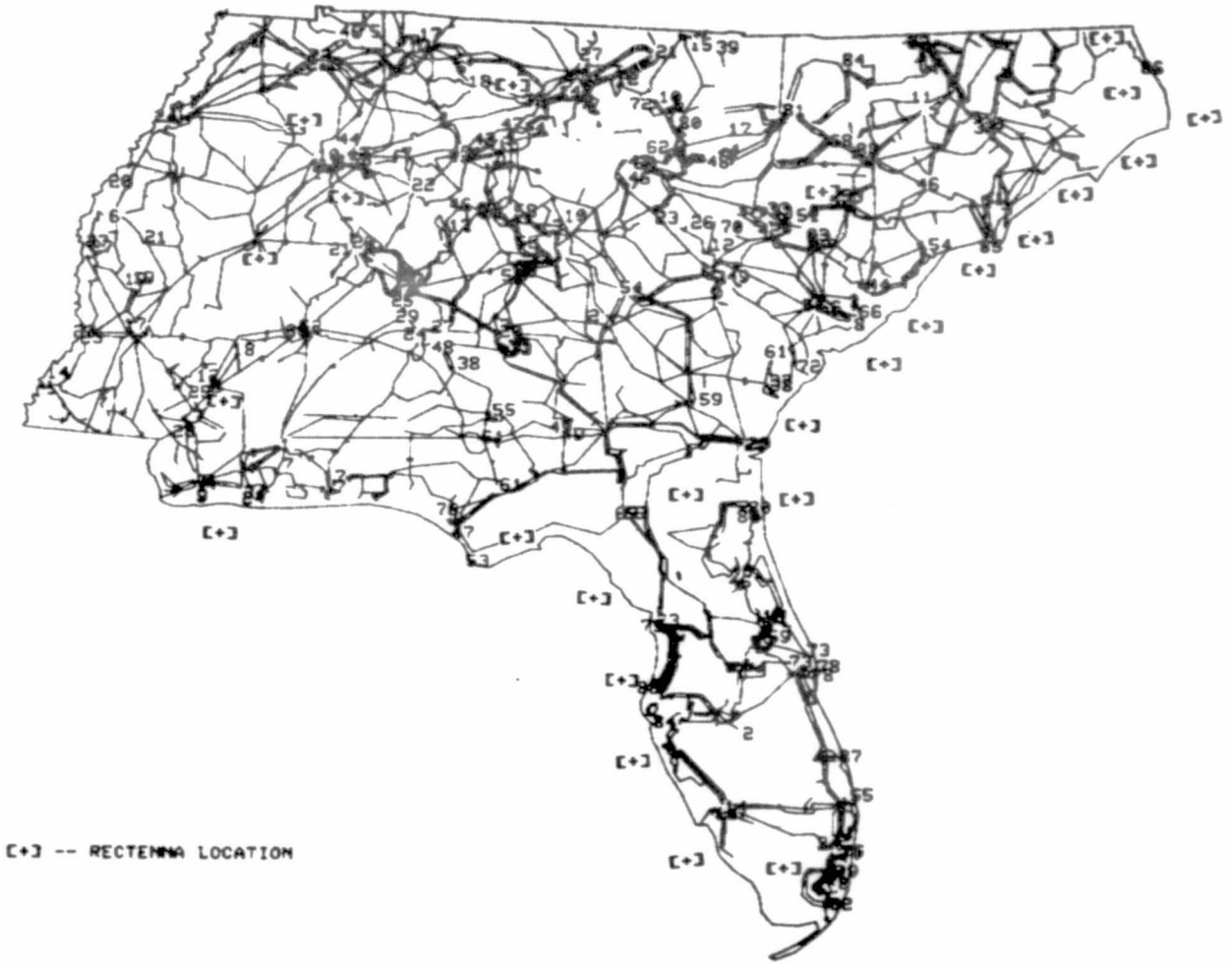

Figure 49. Rectenna locations overlayed on principal electric facilities in the Southeastern U.S.

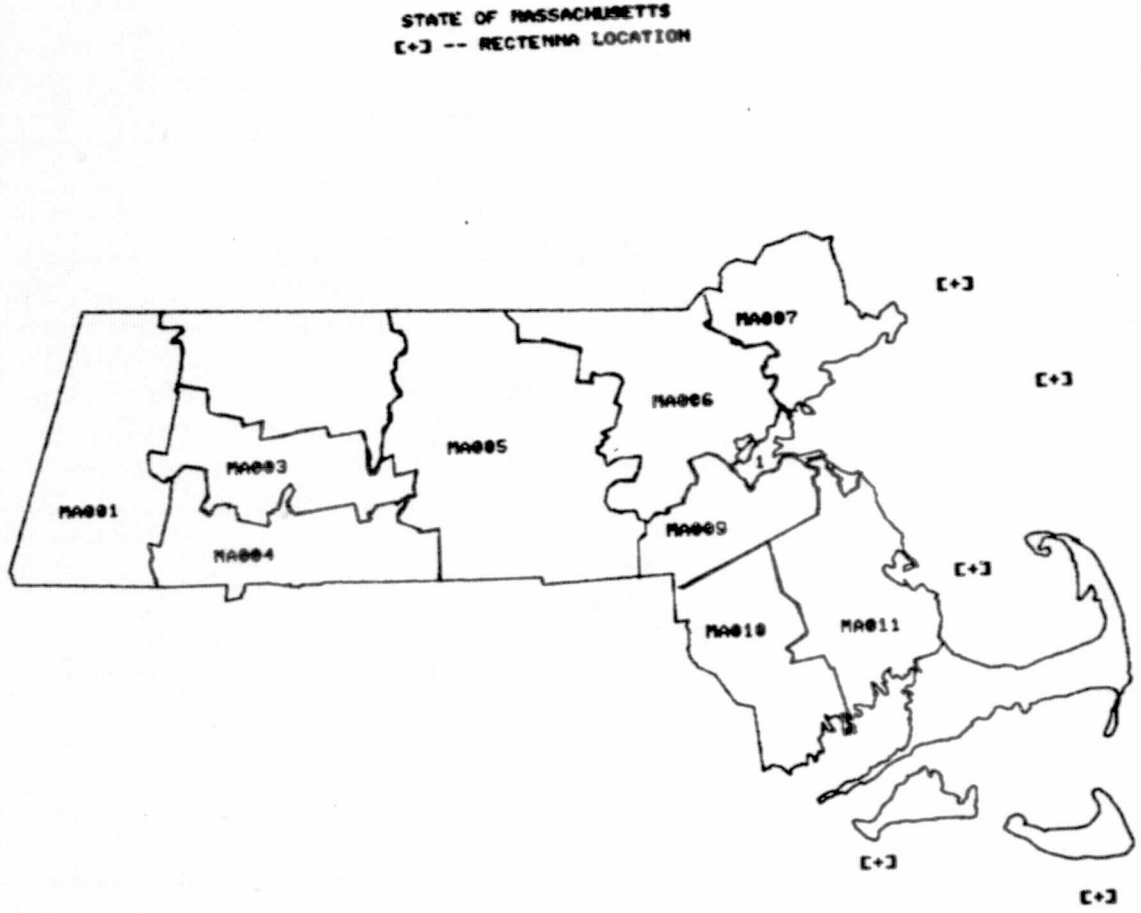

Figure 50. Rectenna locations in the state of Massachusetts.

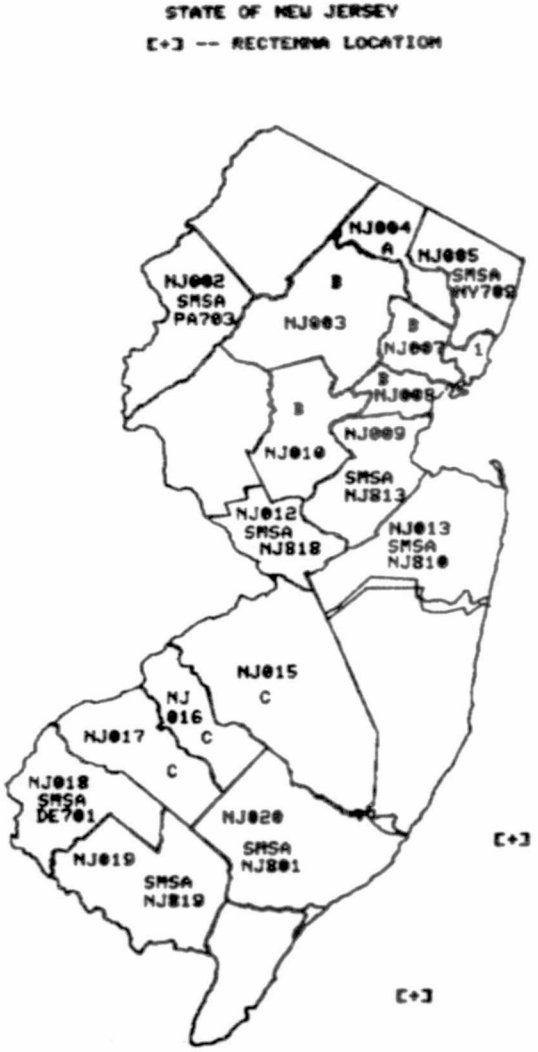

Figure 51. Rectenna locations in the state of New Jersey.

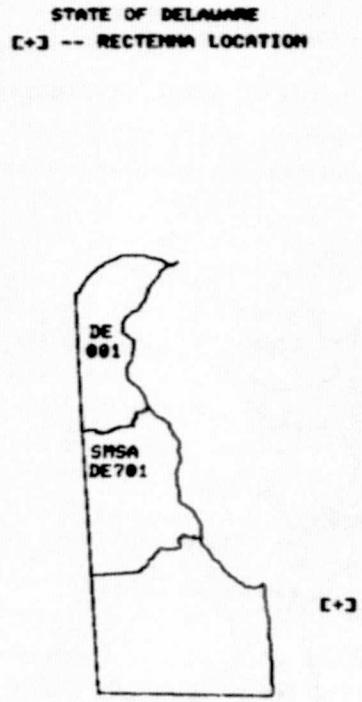

Figure 52. Rectenna location in the state of Delaware.

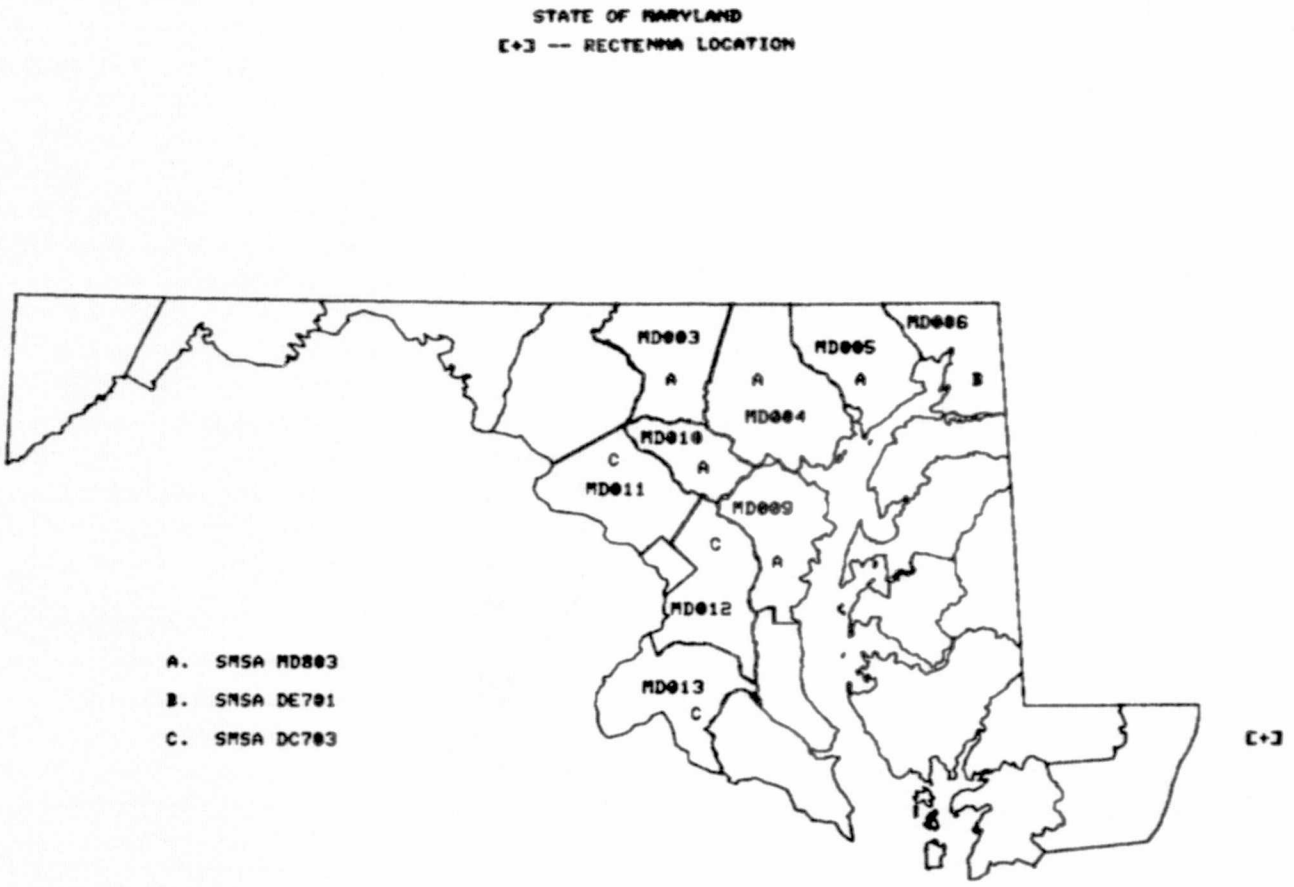

Figure 53. Rectenna location in the state of Maryland.

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3. U.S. Bureau of the Census, Statistical Abstract of the United States: 1976 (97th Edition), No. 10, Washington, D.C., 1976, p. 11.

4. U.S. Bureau of the Census, Statistical Abstract of the United States: 1976 (97th Edition), No. 303, Washington, D.C., 1976, p. 180.

5. The National Atlas of the United States of America, Land Usage Map, 1970, pp. 158-159.

6. The National Atlas of the United States of America, Population Density Map, 1970, p. 241.

7. The National Atlas of the United States of America, Air Flights and Facilities Map, 1970, pp. 232-233.

8. Rand McNally Standard State Maps.

9. Rand McNally's Road and Reference Atlas, State Highway Maps, 1970, pp. 4-91.

10. The National Atlas of the United States of America, Elevation Characteristics Map, 1970, pp. 62-63.

11. The National Atlas of the United States of America, Regional Maps, 1970, pp. 6-36.

12. Federal Power Commission Maps of Principal Electric Facilities.

13. U.S. Bureau of the Census, Statistical Abstract of the United States: 1976 (97th Edition), No. 6, Washington, D.C., 1976, p. 9.

14. U.S. Bureau of the Census, Statistical Abstract of the United States: 1976 (97th Edition), No. 7, Washington, D.C., 1976, p. 9.

15. NOAA Coastal Charts.

APPENDIX

TABLE A-1. ALPHABETICAL LISTING OF STATES DESCRIBING LAND RECTENNA LOCATIONS IN EACH STATE*

Location No.	Counties Impacted: Name	Persons/ Square Mile	Elevation Characteristics	Land Use	Transportation: Roads Type	Roads Miles	Railroads	River	Utility Ties Distance (~miles)	Comments
					ALABAMA					
3	Lawrence Winston Franklin	25 to 49.9 10 to 24.9 10 to 24.9	C3c	6,3	State 33 County	10 20	No	Creeks	10	Partially located in Bankhead Forest; escarpments and valley sides
					ALASKA					Mostly above 60°N latitude Practical cut-off point
					ARIZONA					
1	Maricopa	50 to 99.9	B5a	10	No	0	No	Creek	60	Same county as Phoenix.
2	Apache	<5	B2c, B4c	8,9	No	0	No	Creek	30	Not on reservation
					ARKANSAS					
1	Clark	10 to 24.9	B2b, C4a	3,6	State 26,8	25	No	Creek	10	Over one town
2	Saline Perry	25 to 49.9 5 to 9.9	C5a C4a	6	State 7 County	5 15	No	Creeks and lakes	25	Over Ouachita National Forest; Saline, next to Little Rock; over two towns.
					CALIFORNIA					
4	San Bernardino Los Angeles	25 to 50 250 or more	A3a	11,10	2 County	25	No	No	15	Not actually near Los Angeles
3	San Bernardino	25 to 50	B5a	11,10	No	—	No	No	10	Crests
					COLORADO					
1	El Paso Pueblo Lincoln Crowley	50 to 99.9 25 to 49.9 <5 5 to 9.9	B3c	8,2	County	15	No	No	5	El Paso county contains Colorado Springs; Pueblo county contains Pueblo; rectenna is not adjacent to either city
2	Yuma	<5	B2c, A2c	1,2,8	2 County	30	No	No	10	
					CONNECTICUT					
None Identified										Consider over Atlantic Ocean

*Elevations characteristics and land usage keys on pages 77 and 78.

TABLE A-1. (Continued)

Location No.	Counties Impacted: Name	Persons/Square Mile	Elevation Characteristics	Land Use	Transportation: Roads Type	Roads Miles	Railroads	River	Utility Ties Distance (~miles)	Comments
					DELAWARE					
None Identified										Consider over Atlantic Ocean
					FLORIDA					
1	Collier	3 to 9.9	A1	13,6,14	No	—	No	No	50	Everglades swamplands — >50 percent area covered by standing water
2	Liberty Franklin	<3 10 to 24.9	A1	6,13	Small State and County	20	No	No	0	Appalachicola National Forest — >50 percent area covered by standing water
					GEORGIA					
3	Ware Charlton	25 to 49.9 3 to 9.9	A1	13,6	No	—	No	Small	30	Okefenokee Swamp and National Wildlife Refuge — >50 percent covered by standing water
					HAWAII					
None Identified										Consider over Pacific Ocean
					IDAHO					
1	Jefferson Bonneville	10 to 24.9 25 to 49.9	B3b	10,4	No	—	No	No	0	Bonneville County contains Idaho Falls
2	Blaine Minidoka	<3 10 to 24.9	B3b	10	No	—	No	No	35	
					ILLINOIS					
None Identified										Consider over Lake Michigan
					INDIANA					
None Identified										Consider over Lake Michigan
					IOWA					
1	Plymouth	25 to 49.9	A2b, B2c	1	County	45	No	Creeks	20	

TABLE A-1. (Continued)

Location No.	Counties Impacted: Name	Persons/ Square Mile	Elevation Characteristics	Land Use	Transportation: Roads Type	Roads Miles	Railroads	River	Utility Ties Distance (~miles)	Comments
					KANSAS					
1	Greeley Hamilton Wichita Kearny	<5 <5 <5 <5	A2c	1	County	45	No	No	20	Site could be moved north so rectennas would not be so close together
2	Haskell Finney Grant Kearny	5 to 9.9 10 to 24.9 5 to 9.9 <5	A2c	1	County	35	No	No	20	>50 percent of area covered by sand
					KENTUCKY					
None Identified										
					LOUISIANA					
1	Cameron	<5	A1	14	No	—	No	Creeks	20	Sabine National Wildlife Reserve — >50 percent land covered by standing water
2	Tensas Franklin	10 to 24.9 25 to 49.9	A1	13,3	Small State 573	15	No	Tensas River Bayou	20	10 to 50 percent covered by standing water
					MAINE					
1	Somerset	10 to 24.9	C4a	7	No	—	No	Creeks and ponds	40	
2	Aroostook	10 to 24.9	C4a	7	No	—	No	Creek	80	
					MARYLAND					
None Identified										Consider over Atlantic Ocean
					MASSACHUSETTS					
None Identified										Consider over Atlantic Ocean
					MICHIGAN					
1	Iron Baraga Marquette	10 to 24.9 5 to 9.9 25 to 49.9	B2b	7	No	—	No	Small	30	10 to 50 percent of area covered by standing water
2	Oscoda Ogemaw Roscommon Crawford	5 to 9.9 10 to 24.9 10 to 24.9 5 to 9.9	A2b, B2b	7,5	County	40	No	Small	20	Partially in Huron National Forest — 10 to 50 percent of area covered by standing water

TABLE A-1. (Continued)

Location No.	Counties Impacted: Name	Persons/ Square Mile	Elevation Characteristics	Land Use	Transportation: Roads Type	Roads Miles	Railroads	River	Utility Ties Distance (~miles)	Comments
					MINNESOTA					
1	Beltrami	5 to 9.9	A1	13,5,14	No	—	No	No	40	10 to 50 percent of land covered by standing water
2	Koochiching	5 to 9.9	A1	14	County	10	No	Creeks	70	>50 percent of area covered by standing water
					MISSISSIPPI					
1	Wayne	10 to 24.9	B2b	6,13,5	Small State and County	30	No	Creeks	10	De Soto National Forest — Jones County contains Laurel
	Jones	50 to 99.9								
3	Oktibbeha	50 to 99.9	B2b	2,3	Small State and County	20	No	Creeks	25	Partially over Noxubee National Wildlife Refuge
	Winston	25 to 49.9								
	Noxubee	10 to 24.9								
					MISSOURI					
2	Monroe	10 to 24.9	A2d	1,3	State 15	15	No	Creeks	40	Over two towns
	Audrain	25 to 49.9			County	25				
3	Oregon	10 to 24.9	C3c, A1	6,3	County	40	No	Small	45	
	Carter	5 to 9.9								
	Ripley	10 to 24.9								Mark Twain National Forest — over three towns
	Shannon	5 to 9.9								
					MONTANA					
1	McCone	<5	B3c,C4c	8,2	County	15	No	No	25	Crests
2	Garfield	<5	B3c,C4c	8	No	—	No	Creek	50	Crests
	Rosebud	<5								
					NEBRASKA					
1	Garden	<5	C3c	8	No	—	No	No	30	Lakes in area; near National Wildlife Refuge — >50 percent covered by sand
2	Cherry	<5	C3c	8	County	30	No	No	60	>50 percent covered by sand
					NEVADA					
3	Nye	<5	B5a	10	No	—	No	No	90	Desert valley — crests
	Humboldt	<5	B5a	10	No	—	No	No	15	Near Indian Reservation — crests

TABLE A-1. (Continued)

Location No.	Counties Impacted: Name	Persons/ Square Mile	Elevation Characteristics	Land Use	Transportation: Roads Type	Roads Miles	Railroads	River	Utility Ties Distance (~miles)	Comments
					NEW HAMPSHIRE					
1	Coos	10 to 24.9	C5a	7	County	5	No	Several Streams	30	Crests
2	Grafton Carroll	25 to 49.9 10 to 24.9	D5	7,5	State and County	20 15	No	Several Streams	15	White Mountain National Forest — crests; covers two towns
					NEW JERSEY					
None Identified										Consider over Atlantic Ocean
					NEW MEXICO					
1	Chaves	5 to 9.9	A2b	10,8	No	—	No	No	30	
2	Harding	<5	B3c	8,9	No	—	No	No	90	
					NEW YORK					
1	St. Lawrence	25 to 49.9	B4b	7	Small State	5	No	Several small	5	Adirondack Forest Reserve
3	Hamilton Herkimer	<5 25 to 49.9	C5a	7	No	—	No	creeks	40	Crests
					NORTH CAROLINA					
1	Pasquotank Gates Perquimans	100 to 249.9 25 to 49.9 25 to 49.9	A1	3,13,5	US 158	15	No	No	5	>50 percent of land covered by standing water
2	Tyrrell	10 to 24.9	A1	13	State 94	15	No	No	50	>50 percent of land covered by standing water
					NORTH DAKOTA					
1	Ward	10 to 24.9	B2b, A2c	1,8	State 23 County	15 20	No	No	30	
2	Stutsman	10 to 24.9	B2b, A2c	1	County	30	No	No	25	
					OHIO					
None Identified										Consider over Lake Erie
					OKLAHOMA					
3	Cimarron	<5	A2c	8	County	20	No	Small	75	>50 percent of area covered by sand
4	Woodward Ellis	10 to 24.9 <5	B2b, B3c	1	County	35	No	No	15	

TABLE A-1. (Continued)

Location No.	Counties Impacted: Name	Persons/ Square Mile	Elevation Characteristics	Land Use	Transportation: Roads Type	Roads Miles	Railroads	River	Utility Ties Distance (~miles)	Comments
					OREGON					
1	Lake	<5	B4b, B5b	10	—	—	—	—	0	
2	Malheur	<5	B4c	10	—	—	—	Creek	35	
					PENNSYLVANIA					
2	Warren	50 to 99.9	C4d	7	State 666	15	—	Tionesta Creek	0	Allegheny National Forest — over two towns
	Forest	10 to 24.9			County	25				
3	Clearfield	50 to 99.9	C4d, D5	7	No	—	No	No	0	Escarpments and valley sides
	Cameron	10 to 24.9								
	Elk	25 to 49.9								
					RHODE ISLAND					
None Identified										Consider over Atlantic Ocean
					SOUTH CAROLINA					
1	Kershaw	25 to 49.9	B2c	3,5,6	State 5	50	—	Lynches	15	Slightly over Carolina Sand Hills National Wildlife Refuge
	Chesterfield	25 to 49.9								
	Lancaster	50 to 99.9								
					SOUTH DAKOTA					
1	Sully	<5	A2c	2	Small State and County	20	—	Creek	45	
	Hyde	<5								
2	McPherson	5 to 9.9	A2c, B2b	1,2,3	Local and State	25	—	Several small lakes	35	
					TENNESSEE					
3	Cumberland	25 to 49.9	C3a	6,3	State 101	15	No	Small creeks	0	
	Bledsoe	10 to 24.9	C5c							
	Van Buren	10 to 24.9								
	White	25 to 49.9								
1	Hardin	25 to 49.9	C3b	3,5,6	State 69	15	—	Horse Creek	10	Over three small towns
	Wayne	10 to 24.9			County	20				

TABLE A-1. (Concluded)

Location No.	Counties Impacted: Name	Person/ Square Mile	Elevation Characteristics	Land Use	Transportation: Roads Type	Roads Miles	Railroads	River	Utility Ties Distance (~ miles)	Comments
					TEXAS					
1	Andrews	5 to 9.9	A2c	8	—	—	—	—	20	
3	Webb	10 to 24.9	B2b	10	—	—	—	No	30	
					UTAH					
1	Tooele	<5	A2a	10,11	—	—	—	—	40	In Great Salt Lake Desert
2	Tooele	<5	A2a	11	—	—	—	—	80	In Great Salt Lake Desert
					VERMONT					
1	Essex	5 to 9.9	C5a	7	—	—	—	Small lakes and creeks	30	
					VIRGINIA					
1	Amelia Cumberland Prince Edward	10 to 24.9 10 to 24.9 25 to 49.9	B2c	3,5,7	County State 307	50 2	—	Appomattox River	15	Over two towns
					WASHINGTON					
1	Grays Harbor	25 to 49.9	C3b	7	—	—	—	Several small rivers	15	Borders Olympic National Forest — covers one town
2	Lincoln	<5	B3c	1,8	County	50	—	Small lakes	15	
					WEST VIRGINIA					
1	Pocahontas Webster	10 to 24.9 10 to 24.9	C5d D5	3,5,7	County	20	—	Cranberry River	20	Over Monogahela National Forest
					WISCONSIN					
1	Douglas	25 to 49.9	A2c,B4c	5,7	County	25	—	Creeks	20	
2	Bayfield	5 to 9.9	A2c,B4c	5,7	County	15	—	Creeks	15	In Chequamegon National Forest
					WYOMING					
1	Sweetwater	<5	B3b	10	—	—	—	No	15	
2	Converse	<5	B3c	8	County	10	—	Creeks	10	

TABLE A-2. ELEVATIONS CHARACTERISTICS KEY

Classes of Land Surface Form

Plains

- A1 — Flat plains
- A2 — Smooth plains
- B1 — Irregular plains, slight relief
- B2 — Irregular plains

Tablelands

- B3c,d — Tablelands, moderate relief
- B4c,d — Tablelands, considerable relief
- B4c,d — Tablelands, high relief
- B6c,d — Tablelands, very high relief

Plains with Hills or Mountains

- A, B3a, b — Plains with hills
- B4a, b — Plains with high hills
- B5a, b — Plains with low mountains
- B6a, b — Plains with high mountains

Open Hills and Mountains

- C2 — Open low hills
- C3 — Open hills
- C4 — Open high hills
- C5 — Open low mountains
- C6 — Open high mountains

Hills and Mountains

- D3 — Hills
- D4 — High hills
- D5 — Low mountains
- D6 — High mountains

Scheme of Classification

Slope (Capital Letters)

- A — More than 80 percent of area gently sloping
- B — 50 to 80 percent of area gently sloping
- C — 20 to 50 percent of area gently sloping
- D — Less than 20 percent of area gently sloping

Local Relief (Number)

- 1 — 0 to 100 ft
- 2 — 100 to 300 ft
- 3 — 300 to 500 ft
- 4 — 500 to 1000 ft
- 5 — 1000 to 3000 ft
- 6 — Over 3000 ft

Profile Type

- a — More than 75 percent of gently slope in lowland
- b — 50 to 75 percent of gentle slope in lowland
- c — 50 to 75 percent of gently slope in upland
- d — More than 75 percent of gently slope in upland

Other Classes (Noted in Work Sheet Comments)

- Greater than 50 percent of area covered by sand
- 10 to 50 percent of area covered by standing water
- Greater than 50 percent of area covered by standing water
- Irregular peaks and cones
- Crests
- Escarpments and valley sides

TABLE A-3. LAND USAGE KEY

1	Mostly cropland
2	Cropland and grazing land
3	Cropland with pasture, woodland, and forest
4	Irrigated land
5	Woodland and forest with some cropland and pasture
6	Forest and woodland; grazed
7	Forest and woodland; mostly ungrazed
8	Subhumid grassland and semiarid grazing land
9	Open woodland; grazed
10	Desert shrubland; grazed
11	Desert shrubland; mostly ungrazed
12	Alpine meadows, mountain peaks above timberline
13	Swamp
14	Marshland
15	Moist tundra and muskeg

TABLE A-4. LOCATIONS OF RECTENNAS IN THE PACIFIC

Location No.	Coordinates	Depth Range	Comments
	WASHINGTON		
			More sites could be located in "Warning Area"
1s	124°40' W, 47°15' N	186' to 348'	Located in a "Warning Area"
2s	124°25' W, 46°50' N	186' to 342'	Partially located in a "Restricted Dumping Ground"
	OREGON		
1s	124°10' W, 46°05' N	198' to 360'	
2s	124°10' W, 44°25' N	72' to 240'	
3s	124°15' W, 44°10' N	78' to 324'	
4s	124°30' W, 42°35' N	96' to 366'	
	CALIFORNIA		
1s	124°15' W, 42°N	66' to 312'	
2s	124°15' W, 41°40' N	66' to 294'	
3s	124°15' W, 41°20' N	72' to 372'	
6s	123°15' W, 38°15' N	252' to 402'	
7s	122°30' W, 37°10' N	78' to 390'	
8s	120°45' W, 35°05' N	66' to 552'	
9s	119°35' W, 35°15' N	90' to 534'	Covers a "Caution Area"

TABLE A-5. LOCATIONS OF RECTENNAS IN THE NORTH ATLANTIC

Location No.	Coordinates	Depth Range	Comments
	MAINE		
1s	70°25' W, 43°15' N	72' to 240'	Southern tip of Maine
	MASSACHUSETTS		
1s	70°25' W, 42°40' N	114' to 258'	
2s	70°10' W, 42°25' N	156' to 294'	
3s	70°25' W, 42°05' N	126' to 198'	
4s	70°10' W, 41°N	72' to 108'	
5s	70°45' W, 41°10' N	93' to 144'	
	NEW YORK		
1s	72°W, 40°50' N	72' to 132'	
2s	72°35'W, 40°40' N	78' to 126'	
	NEW JERSEY		
1s	74°20' W, 39°05' N	48' to 96'	
2s	74°W, 39°30' N	66' to 84'	Over a "Danger Area"
	DELAWARE		
1s	74°45' W, 38°45' N	30' to 102'	Between main shipping channels
	MARYLAND		
1s	74°45' W, 38°15' N		

TABLE A-6. LOCATIONS OF RECTENNAS IN THE SOUTH ATLANTIC

Location No.	Coordinates	Depth Range	Comments
	VIRGINIA		
1s	75°W, 37°55' N	60' to 108'	One alternate location also identified in Virginia
2s	75°15' W, 37°25' N	60' to 102'	
	NORTH CAROLINA		
3s	75°10' W, 35°25' N	54' to 102'	Two alternate sites also identified in North Carolina
4s	75°55' W, 34°55' N	66' to 84'	Could be moved to a "Danger Area"
5s	76° 50' W, 34°25' N	66' to 90'	Could be moved to a "Danger Area"
6s	77°25' W, 34°05' N	66' to 96'	
	SOUTH CAROLINA		
1s	78°20' W, 33°30' N	66' to 78'	Could be moved to a "Prohibited Dumping Area"
2s	79°W, 32°50' N	66' to 84'	Could be moved to a "Dumping Ground"
3s	80°10' W, 32°15' N	42' to 66'	
	GEORGIA		
1s	80°50' W, 31°30' N	48' to 66'	Could be moved to a "Danger Area"
2s	81°W, 30°40' N	48' to 66'	Partially off Florida coast

TABLE A-7. LOCATIONS OF RECTENNAS IN THE GULF OF MEXICO

Location No.	Coordinates	Depth Range	Comments
	FLORIDA		
1s	87°05' W, 30°05' N	72' to 126'	All Florida sea rectennas located in Gulf to avoid impact by space program launch activity from Cape Canaveral and because water is shallower
2s	83°40' W, 29°30' N	33' to 54'	
3s	83°10' W, 28°15' N	33' to 66'	
4s	82°50' W, 27°05' N	66' to 96'	
5s	82°25' W, 26°10' N	63' to 84'	
	MISSISSIPPI		
1s	88°30' W, 30°N	66' to 96'	
	LOUISIANA		
1s	93°20' W, 29°N	63' to 78'	
2s	92°40' W, 29°10' N	66' to 84'	
3s	89°50' W, 29°N	66' to 138'	
4s	90°15' W, 28°50' N	66' to 96'	
	TEXAS		
1s	94°05' W, 28°50' N	66' to 84'	
2s	94°50' W, 28°50' N	63' to 90'	
3s	95°45' W, 28°20' N	84' to 126'	
4s	97°05' W, 27°25' N	66' to 102'	
5s	97°10' W, 26°50' N	66' to 114'	

APPROVAL

CANDIDATE LOCATIONS FOR SPS RECTIFYING ANTENNAS

By Anne W. Eberhardt

The information in this report has been reviewed for security classification. Review of any information concerning Department of Defense or Atomic Energy programs or activities has been made by the MSFC Security Classification Officer. This report, in its entirety, has been determined to be unclassified.

This document has also been reviewed and approved for technical accuracy.

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