4.0 RADIOLOGICAL DOSE ASSESSMENT

4.1 Methodology

The potential radiological impacts resulting from the release of radioactivity during 1984 have been estimated by calculating radiation doses received by the maximally exposed off-site individual and the population within an 80 km radius of the WVDP facility. The potential pathways of exposure to the general public from radioactive effluents released by the WVDP operations are shown in Figure 4-1. The exposure modes considered in the dose calculations are:

- Direct exposure from immersion in air containing radionuclides,
- Direct radiation from ground surfaces contaminated by deposited radionuclides,
- Immersion in contaminated water,
- Inhalation of airborne radionuclides, and
- Ingestion of contaminated water and food produced from the land and surface waters in the area.

Because the ridges and hills in the vicinity of the WVDP frequently channel the winds, strong systematic deviations from straight-line air flow over long distance are expected. To realistically account for the terrain effects on wind flow, a fine grid, two-dimensional wind field was developed using the WNDSRF3 code and meteorological data measured hourly at seven stations around the WVDP and the three nearest National Weather Service stations. The wind field data were then input to the EPM3 code, a variable-trajectory Gaussian puff dispersion code for calculating the radionuclide concentrations from routine operational releases. The EPM3 code is formulated according to the guidelines described by NRC in Regulatory Guide 1.111. The assumption

underlying the code is that a number of discrete puffs are serially released from the source to simulate a continuous plume. Each puff is assumed to have a Gaussian concentration distribution in three dimensions. Puffs expand in size as they move downwind from the source in response to spatial and temporal wind and stability conditions. Each puff is transported independently by the nonuniform wind field and is tracked until it leaves the grid region. Concentration and deposition are computed at each grid receptor location.

A detailed discussion of the computer codes WNDSRF3 and EPM3 is given in the WVDP Safety Analysis Report, Supplements Volume.

This 1984 Environmental Monitoring Report is based on analyses that use relative concentration values calculated for gaseous effluents released from the WVDP plant at a height of 60 metres and at ground level. Twelve-month meteorological data (August 1983 through July 1984) are used as a basis for the dispersion calculations.

The calculated annual average relative concentration values for 60 metre and ground level releases are given in Tables 4-1 and 4-2 for each of the sixteen 22.5 degree wind sectors in an 80 km radius circle centered at the WVDP plant. The maximum mean annual relative concentration values at the point of an actual residence in the vicinity of the site are 1.4×10^{-7} sec/m^3 (at 2.3 km SW) and 1.4×10^{-6} sec/m^3 (at 1.4 km NW) for stack and ground level releases.
To calculate the radiation doses to the maximally exposed individual and the population within 80 km from the plant, relative concentration values are used as input to the AIRDOS-EPA code (Moore et al., 1979). The radiation dose commitment to the maximally exposed individual and the collective dose to the population within 80 km from the WVDP from the water pathway were calculated using the computer code LADTAP II (Simpton and McGill, n.d.). Both LADTAP II and AIRDOS-EPA implement the NRC Regulatory Guide 1.109 recommendations for terrestrial food chains.

The dose estimates were made by calculating radionuclide concentrations in air, rates of deposition on ground surfaces, ground surface concentrations, intake rates via inhalation, and ingestion of meat, milk, and fresh vegetables. Site specific data on production and consumption of milk, meat, and agricultural products were used in computing the collective population dose.

The area surrounding the facilities is shown in Figure 1-1. It was overlaid with an 80 km radius grid system with the facility at its center. The grid system was further divided into 10 concentric regions and 16 compass directions. For each sector formed by the grid system, the specific human populations, beef and dairy cattle populations, and agricultural areas were assumed to be as described in Figures 4-2 through 4-9.

For each radionuclide of concern, the inhalation dose conversion factors used are for an activity median aerodynamic diameter (AMAD) of 0.3 micrometer. For alpha emitters, the dose conversion factors are derived by using a quality factor of 20 as per ICRP recommendation (Dunning, n.d.). All of the doses from internal exposure are 50-year committed dose equivalents and are calculated for the 50-year period following inhalation or ingestion. The internal dose conversion factors used in this report are from Dunning.

In this report, the effective dose equivalent, as well as the dose equivalent to the thyroid, lungs, bone, liver, kidneys, and gastrointestinal tract were considered to determine the critical organs for various potential pathways of exposure. These estimates were based on parameters applicable to an average adult. The collective population dose estimate in person-rem is the effective dose equivalent commitment to the whole body as calculated in accord with the recommendations of the ICRP (ICRP, 1977).

In addition to these estimates of dose commitments based on dispersion modeling, the dose to a hypothetical maximally exposed individual who consumed locally produced milk, fish, and venison (deer) was predicted. Measured radionuclide concentrations from samples of milk, fish, and venison were used in these calculations. Many of the nuclides which may be present in these samples are often below the detectable limit. In such cases, the radionuclide concentration was assumed to be the limit of detection.

4.2 Source Term Estimates

4.2.1 Airborne Radioactive Effluents

There are three points on the plant site from which ventilation systems release low concentrations of airborne radioactivity. These three locations are:

1. Main plant process stack,

2. Laundry exhaust vent, and

3. LLWT ventilation exhaust.

The air released from these vents is sampled continuously and the collected particulates are periodically analyzed. The results of measurements during 1984 are summarized in Table 4-3. A total of 1.1×10^{-5} Ci of gross alpha activity and 8.1×10^{-4} Ci of gross beta/gamma was released from these three vents during the year. More than 99 percent of the activity was discharged through the main plant stack.

4.2.2 Liquid Radioactive Effluents

There were three sources of liquid effluents from WVDP operations in 1984:

1. Lagoon No. 3 discharges (six planned releases),

2. Sewage treatment outfall, and

3. Ground water releases from the swamp drain and french drain.

The volumes of the liquid effluents and the radioactivity they contained (reported in WVDP 1984 Effluent and On-Site Discharge Report, March, 1985) are summarized in Table 4.4. All liquids were discharged via Buttermilk Creek. For conservative radiological dose calculations, americium-241 was assumed to represent all gross alpha activity in both gaseous and liquid effluents. The gross beta activity was assumed to be represented by Sr-90. Although Sr-90 and Am-241 were actually not present in as high a concentration as assumed, they would be the most limiting isotopes in any mixture of radionuclides found in Project effluents. (See Appendix B.)

4.3 Potential Radiation Doses to the Public

4.3.1 Maximum Hypothetical Individual Radiation Exposure

The point of maximum potential radiation exposure in the vicinity of the site from airborne radioactivity is located about 2.3 km SW of the WVDP plant. A hypothetical maximum effective dose equivalent of 0.0025 mrem was calculated as a result of WVDP airborne releases during 1984 when all possible pathways were considered. The calculated dose commitment to bone surface (the critical organ) at this location was 0.02 mrem. The maximum hypothetical exposures are less than 0.002 percent of the allowable standard promulgated in DOE Order 5480.1.

An important potential contributor to the dose commitment from radioactivity in the terrestrial food-chain is the airborne pathway to the pasture and then to cow and to milk. Measurements of radioactivity in the milk produced at the nearest dairy farm to the WVDP facility indicated that no I-129, Cs-134, or Cs-137 was present in concentrations above the limits of detection. The maximum dose to an individual from ingestion of about 1 litre of this milk per day was estimated by assuming that the nuclides were present in amounts equal to the detection limits. This conservative calculation predicts a dose commitment of 15 mrem to the thyroid and an effective dose equivalent commitment of 1.0 mrem. Despite their extreme conservatism, these calculated maximum potential doses are less than 1 percent of the allowable standards. Further improvement in the detection limit will permit more realistic estimates of the dose commitment due to consumption of milk produced in the vicinity of the WVDP. These more realistic estimates are expected to be substantially lower than the small maximum values quoted above.

Estimates were made of the hypothetical maximum dose commitments to an adult from consumption of 21 kg per year of fish (the maximum value recommended in NRC Regulatory Guide 1.109) caught in Cattaraugus Creek. From the measured concentrations of radionuclides in the edible parts of the fish (see Table C-3.4), the maximum organ dose commitment to an individual was estimated to be 0.5 mrem to bone surfaces. The maximum effective dose equivalent commitment to an individual was calculated to be 0.28 mrem from consumption of 21 kg of fish.

The hypothetical dose commitment also was estimated for an individual who consumed 45 kg of venison. The measured radionuclide concentrations (Table C-3.2) in the flesh of a deer taken about a kilometre away from the WVDP in the fourth quarter of 1984 was used as the basis for this estimate. The dose commitment was calculated to be 0.25 mrem to the bone surface and 0.33 mrem for an effective dose equivalent commitment. Table 4-3 summarizes the potential radiation doses to

individual adult members of the general public at the points of highest potential exposure from gaseous and liquid effluents from the WVDP facility operations during 1984. Although no direct pathway to drinking water from airborne or liquid effluents was found or evaluated for exposure, drinking well water data are presented in Appendix C.

4.3.2 Collective Dose to the Population

The collective effective dose equivalent commitment to the population within an 80 km radius of the WVDP from operations during 1984 was estimated to be 0.02 person-rem from gaseous effluents and 0.13 person-rem from liquid effluents. These estimates are based on the releases summarized in Tables 4-3 and 4-4 and the use of the AIRDOS-EPA and LADTAP II codes as described in Section 4.1.

These collective doses may be compared to an estimated annual 170,000 person-rem to the same population resulting from natural background radiation. Based on the collective dose given above and a total population of 1.7 million in the region, the average effective dose equivalent to an individual residing within 80 km of the WVDP was about 8.8×10^{-5} mrem during 1984--insignificant when compared to the average dose to each individual of approximately 100 mrem per year from natural sources.

TABLE 4 - 1

Relative Concentration Values (sec/m^3) by Sector From 60 Metre Stack Release

RECEPTOR AZIMUTH (DEGREES)	Distance (metres) 805.0	2414.0	4023.0	5633.0	7242.0
22.50	1.34865E-08	1.71927E-08	1.53659E-08	1.16008E-08	1.00686E-08
45.00	3.03278E-08	6.62833E-08	1.19462E-07	2.28011E-08	1.79982E-08
67.50	3.64481E-08	7.69928E-08	1.02821E-07	9.41885E-08	5.77431E-08
90.00	3.74919E-08	6.31151E-08	5.99791E-08	5.94198E-08	3.82357E-08
112.50	5.66527E-08	6.61298E-08	1.00890E-07	6.25578E-08	5.45213E-08
135.00	6.47129E-08	4.14320E-08	4.15299E-08	5.34836E-08	5.67103E-08
157.50	3.90271E-08	4.06824E-08	6.03020E-08	4.09102E-08	2.77476E-08
180.00	3.81781E-08	1.22124E-07	5.71550E-08	3.28513E-08	1.65135E-08
202.50	3.39626E-08	1.18178E-07	3.81683E-08	2.06887E-08	1.37497E-08
225.00	2.65459E-08	1.33789E-07	1.40559E-08	1.47592E-08	2.14601E-08
247.50	2.28710E-08	1.40234E-07	9.92964E-09	9.23873E-09	1.20779E-08
270.00	1.89206E-08	5.87795E-08	8.15801E-09	4.43197E-09	3.40148E-09
292.50	1.80572E-08	2.08576E-08	7.37967E-09	7.54285E-09	6.41255E-09
315.00	1.64857E-08	1.12181E-08	5.58730E-09	3.48013E-09	4.18897E-09
337.50	1.37407E-08	8.56651E-09	6.98284E-09	6.43618E-09	1.03046E-08
360.00	1.63022E-08	1.86618E-08	1.33696E-08	1.43328E-08	1.57260E-08

RECEPTOR AZIMUTH (DEGREES)	12070.0	24140.0	40234.0	56327.0	72420.0
22.50	3.76277E-08	4.60131E-09	1.47900E-09	4.16372E-10	2.13197E-10
45.00	1.14274E-08	1.28140E-08	3.44087E-09	8.05384E-10	3.94584E-10
67.50	1.83720E-08	9.47802E-09	2.61500E-09	8.27191E-10	4.15068E-10
90.00	1.31074E-08	4.10035E-09	1.79761E-09	9.47011E-10	5.42868E-10
112.50	1.79356E-08	3.37901E-09	1.27255E-09	7.68376E-10	4.88769E-10
135.00	2.17244E-08	4.63600E-09	1.59818E-09	9.12074E-10	6.59780E-10
157.50	1.22420E-08	3.63091E-09	1.25836E-09	7.58553E-10	3.65875E-10
180.00	5.12675E-09	1.39954E-09	7.05623E-10	3.11794E-10	1.85159E-10
202.50	4.33084E-09	1.20774E-09	4.64639E-10	3.76650E-10	2.20628E-10
225.00	4.05277E-09	9.84525E-10	3.82512E-10	2.98694E-10	2.65110E-10
247.50	5.01156E-09	8.45959E-10	3.46917E-10	2.67128E-10	1.88775E-10
270.00	2.40747E-09	1.31323E-09	4.71842E-10	2.33383E-10	1.46546E-10
292.50	3.13835E-09	8.59511E-10	3.11297E-10	1.78562E-10	1.59762E-10
315.00	3.96969E-09	8.39388E-10	3.62375E-10	1.98663E-10	1.45786E-10
337.50	3.50730E-08	1.98774E-09	5.06830E-10	2.95021E-10	2.01301E-10
360.00	1.08030E-08	3.06156E-09	8.97284E-10	4.01882E-10	2.13954E-10

TABLE 4 - 2

Relative Concentration Values (sec/m^3) by Sector From Ground Level Release

RECEPTOR AZIMUTH (DEGREES)	Distance (metres) 805.0	2414.0	4023.0	5633.0	7242.0
22.50	1.49512E-06	3.97532E-07	1.47083E-07	8.42645E-08	5.33960E-08
45.00	1.64903E-06	3.53979E-07	1.37949E-07	4.90462E-08	3.72500E-08
67.50	1.03133E-06	2.02443E-07	9.76274E-08	6.36793E-08	4.29648E-08
90.00	1.12677E-06	1.93299E-07	7.68176E-08	4.17450E-08	2.62357E-08
112.50	1.85268E-06	2.85787E-07	1.13283E-07	5.70845E-08	3.65770E-08
135.00	2.07273E-06	2.98862E-07	1.13469E-07	6.26892E-08	4.29658E-08
157.50	1.23256E-06	1.83867E-07	7.49610E-08	3.87072E-08	2.45899E-08
180.00	9.11350E-07	1.21526E-07	4.69202E-08	2.12329E-08	1.26233E-08
202.50	5.43176E-07	8.27004E-08	3.14103E-08	1.62575E-08	1.04974E-08
225.00	6.51885E-07	7.38846E-08	2.38500E-08	1.47004E-08	1.10149E-08
247.50	4.49106E-07	8.76961E-08	1.99028E-08	1.24286E-08	1.17705E-08
270.00	8.33984E-07	9.80329E-08	2.08584E-08	9.69459E-09	6.36376E-09
292.50	1.51654E-06	2.19763E-07	3.25829E-08	3.23126E-08	2.15832E-08
315.00	3.09325E-06	6.30377E-07	7.04640E-08	2.02217E-08	2.77029E-08
337.50	6.43818E-06	1.39608E-07	5.78384E-08	6.06062E-08	1.03569E-07
360.00	3.61907E-06	4.15637E-07	9.97603E-08	1.26180E-07	1.51884E-07

RECEPTOR AZIMUTH (DEGREES)	12070.0	24140.0	40234.0	56327.0	72420.0
22.50	3.04523E-08	2.98528E-09	8.55379E-10	3.03205E-10	1.46205E-10
45.00	2.15690E-08	5.14011E-09	1.73757E-09	6.37543E-10	3.64292E-10
67.50	1.54270E-08	5.34287E-09	1.92672E-09	8.74415E-10	5.08823E-10
90.00	9.70648E-09	3.01629E-09	1.45596E-09	8.22257E-10	4.93815E-10
112.50	1.29208E-08	3.20793E-09	1.16046E-09	7.54841E-10	4.73182E-10
135.00	1.64306E-08	3.86002E-09	1.31326E-09	7.71110E-10	5.18604E-10
157.50	1.02799E-08	2.75939E-09	9.61845E-10	5.49548E-10	2.85193E-10
180.00	4.31490E-09	1.06545E-09	4.04546E-10	1.98032E-10	1.31576E-10
202.50	3.84823E-09	9.15400E-10	3.95853E-10	2.51647E-10	1.43985E-10
225.00	3.37117E-09	8.69089E-10	3.30965E-10	2.44201E-10	1.30591E-10
247.50	3.00494E-09	7.52568E-10	3.28716E-10	2.37072E-10	1.50662E-10
270.00	2.83375E-09	1.13770E-09	4.49876E-10	2.28809E-10	1.51995E-10
292.50	7.62140E-09	1.26463E-09	3.63726E-10	1.88658E-10	1.46872E-10
315.00	2.43399E-08	8.55431E-10	4.37296E-10	2.11385E-10	1.16099E-10
337.50	2.36564E-08	1.78745E-09	5.95391E-10	3.21227E-10	2.20000E-10
360.00	2.55674E-08	3.41404E-09	9.24519E-10	3.80997E-10	1.83592E-10

TABLE 4-3

RADIOACTIVITY RELEASED TO THE ATMOSPHERE DURING 1984

Release Point	Total Curies Released			
	Gross Alpha	Gross Beta	Specific Nuclides	
Main Plant Stack	1.1-05	8.1-04	Sr-90	1.6-04
			Ru-106	1.5-05
			I-129	9.4-05
			Cs-134	2.6-06
			Cs-137	5.1-04
Laundry Vent	6.1-08	1.5-06	None Identified	
LLWT Vent	1.1-07	3.1-06	None Identified	

TABLE 4-4

RADIOACTIVITY RELEASED IN LIQUID

EFFLUENTS DURING 1984

Release Point	Volume Released (Litres)	Released Radioactivity (Ci)					
		Gross Alpha	Gross Beta	H-3	Sr-90	I-129	Cs-137
Lagoon 3	5.2+07	1.2-02	8.1-02	7.3	8.5-03	1.1-03	6.3-02
Sewage Treatment Outfall	6.1+06	9.8-06	3.1-04	1.4-03	1.3-04	9.3-06	------
Swamp Drain	6.1+07	------	------	1.3-01	------	------	------
French Drain	6.8+06	------	------	1.6-01	------	------	------
TOTAL	1.2+08	1.2-02	8.1-02	7.6	8.6-03	1.1-03	6.3-02

TABLE 4-5

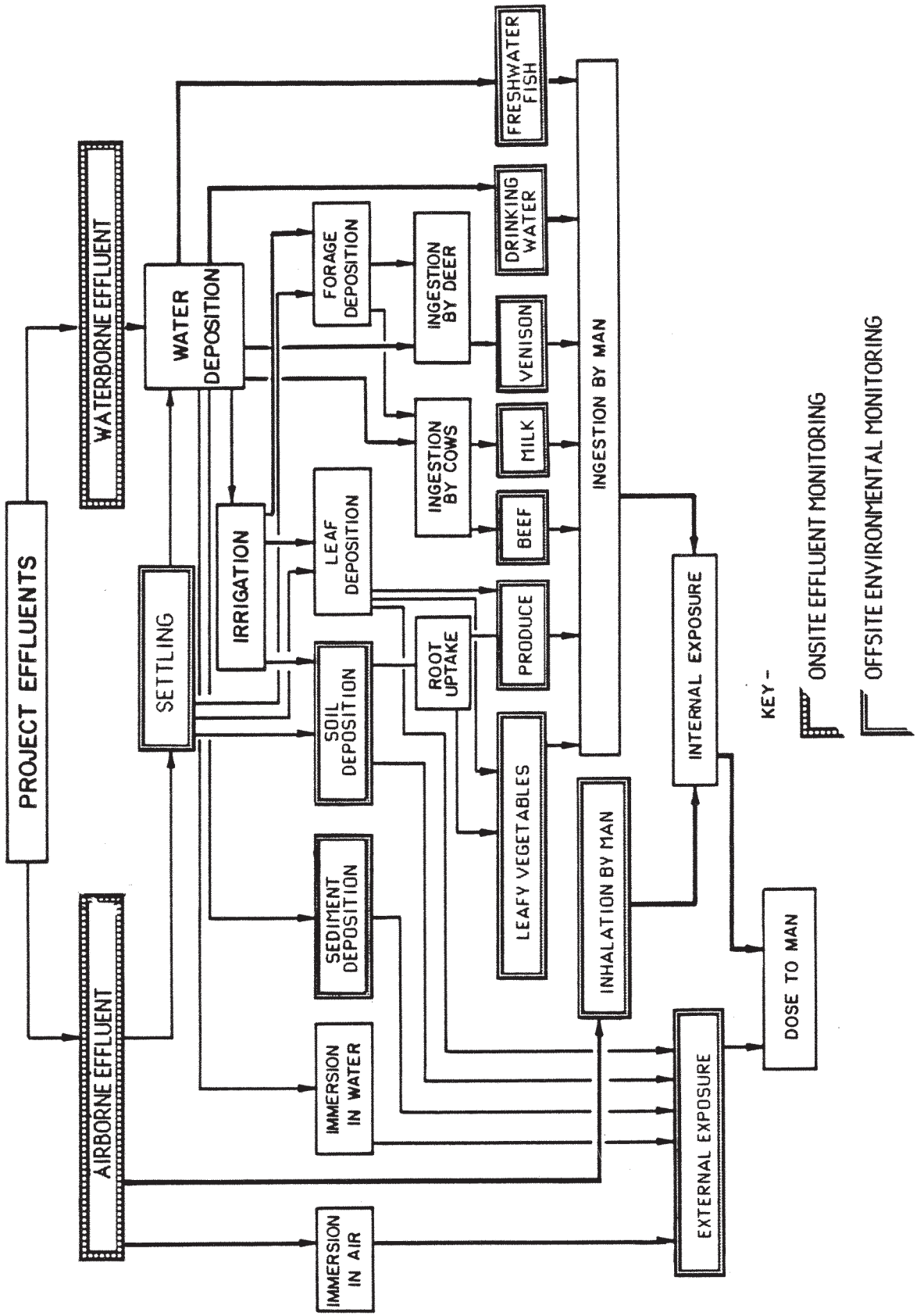
SUMMARY OF HYPOTHETICAL ESTIMATED DOSE COMMITMENTS

TO AN ADULT INDIVIDUAL AT LOCATIONS OF MAXIMUM EXPOSURE DURING 1984

Pathway	Location	50-Year Dose Commitment (mrem) Effective Whole Body Equivalent	Critical Organ
Gaseous Effluents			
All Pathways*	Nearest residence (2.3 km SW)	0.0025	0.02 Bone Surface
Milk	Produced 4 km NE	1.0	15 Thyroid
Venison	Deer taken within 1 km of WVDP	0.33	0.33 Whole Body
Liquid Effluents			
Fish	Collected in Cattaraugus Creek below WVDP	0.28	0.50 Bone Surface

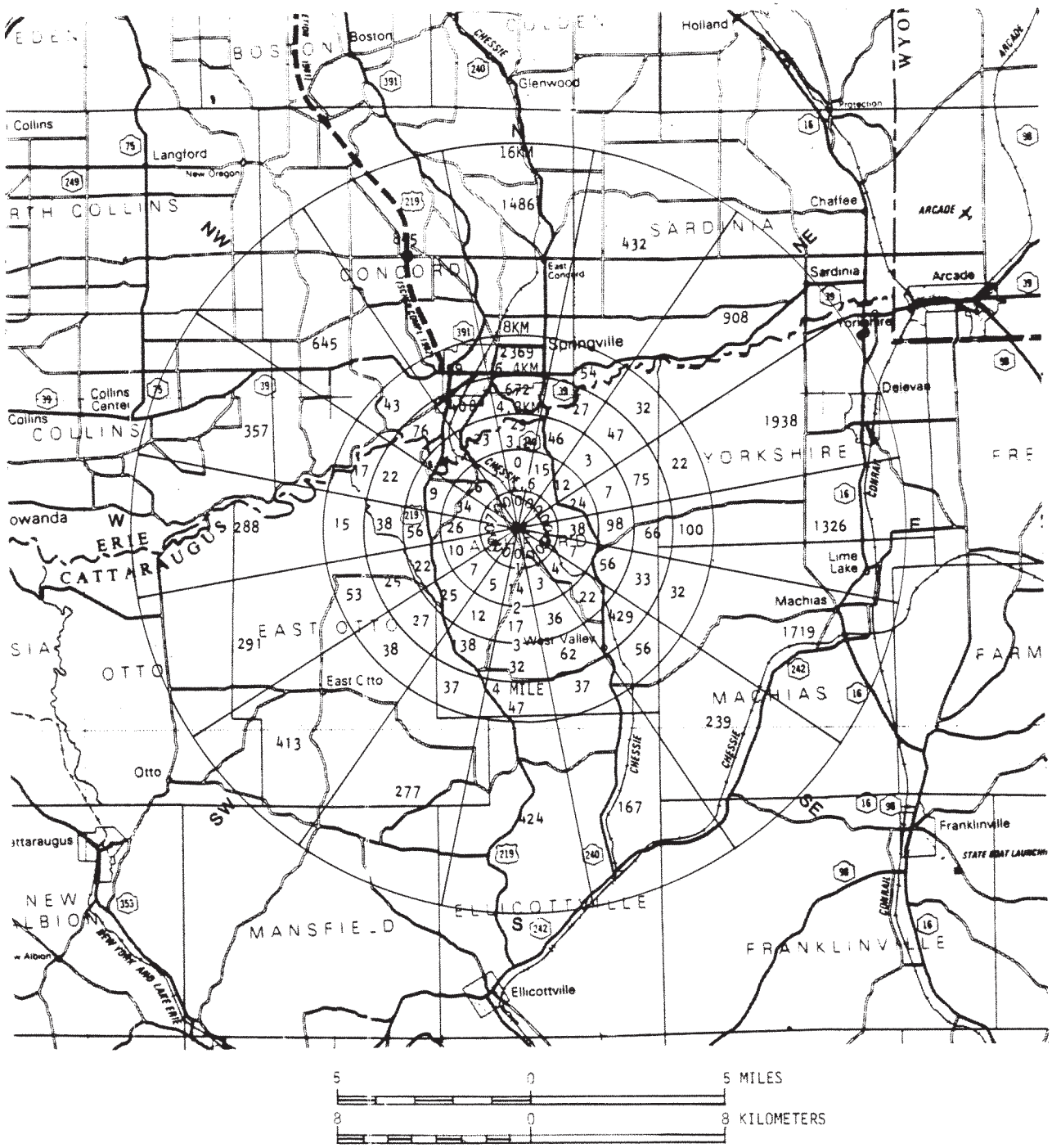
*Estimates based on measured radioactivity in airborne effluents (Table 4-3) and dispersion and radiological dose calculations described in Section 4.1. All other values based on measured concentrations in food and consumption rates for maximally exposed individuals recommended in U.S. NRC Regulatory Guide 1.109.

Note: Annual average whole body dose from natural background sources in the U.S. is about 100 mrem.



COMPARTMENT MODEL OF PATHWAYS AND MONITORING INTERCEPT POINTS

FIGURE 4-1



1990 POPULATION PROJECTIONS BY SECTOR

WITHIN 16 KILOMETERS (10 MILES) OF SITE

FIGURE 4-2

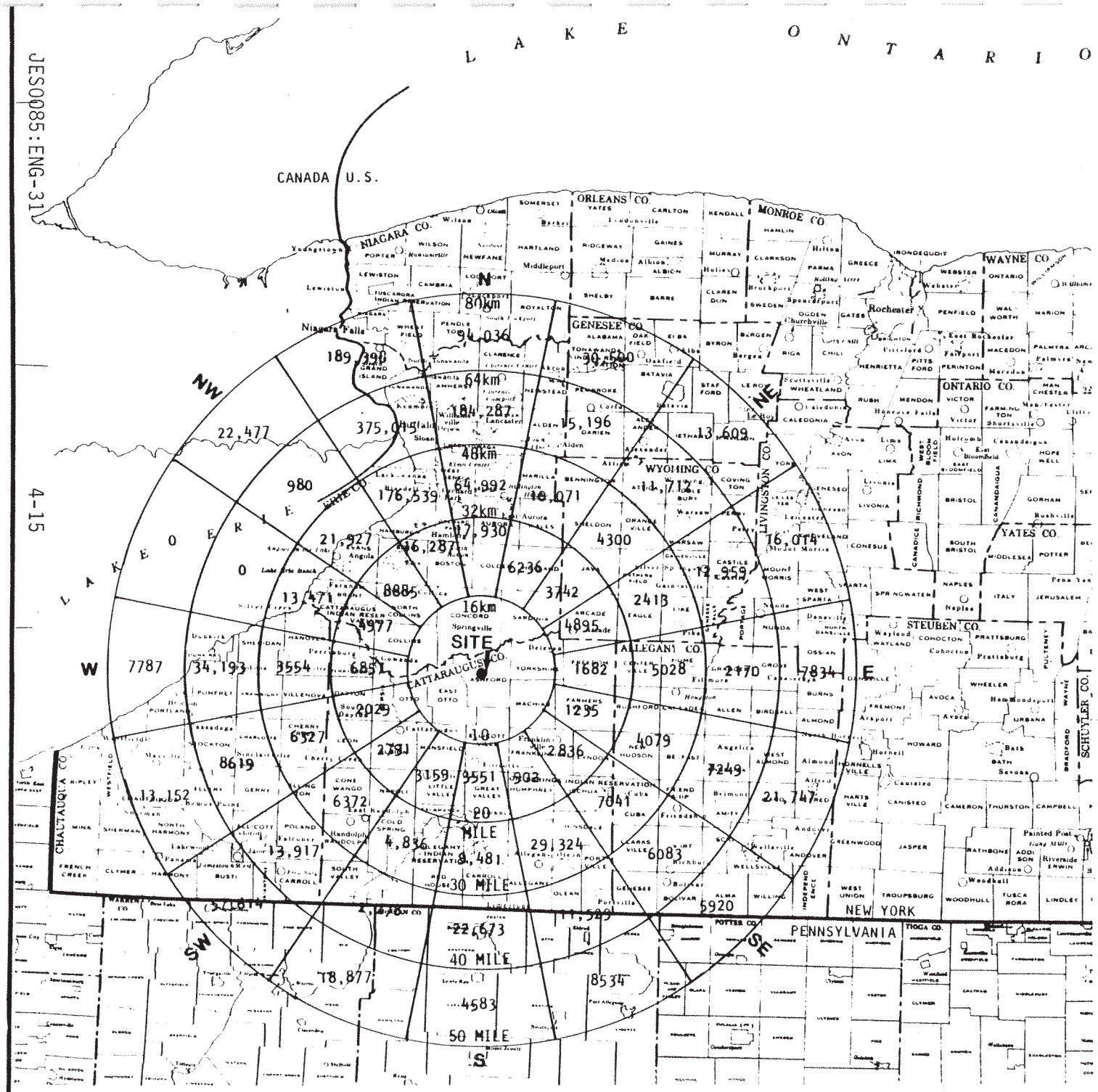
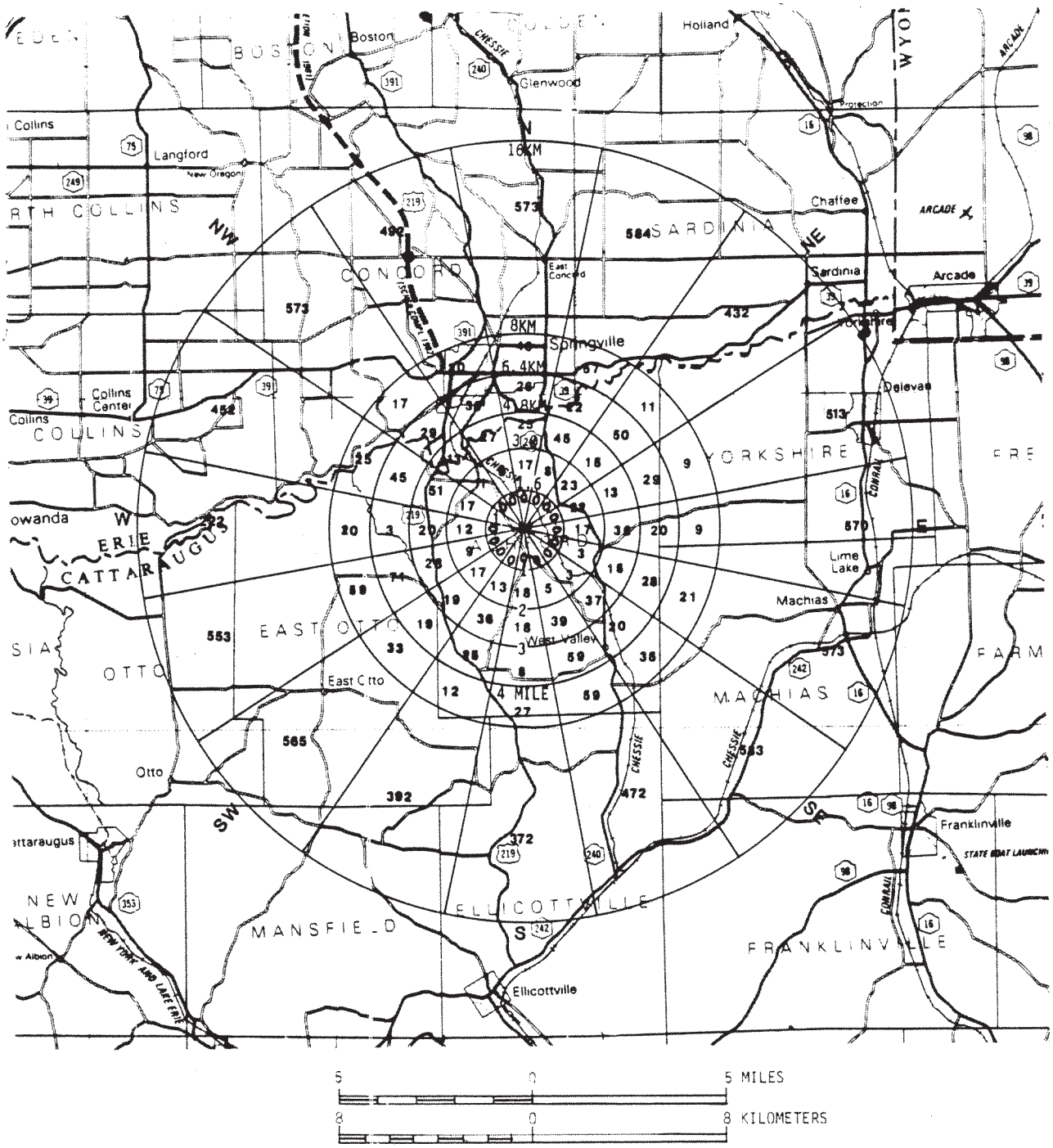


FIGURE 4-3

1990 POPULATION PROJECTIONS BY SECTOR

WITHIN 16-80 KILOMETERS (10-50 MILES) OF THE SITE

MAP REFERENCE: U.S. BUREAU OF THE CENSUS, 1970.



NUMBER OF DAIRY COWS BY SECTOR

WITHIN 16 KILOMETERS (10 MILES) OF SITE

FIGURE 4-4

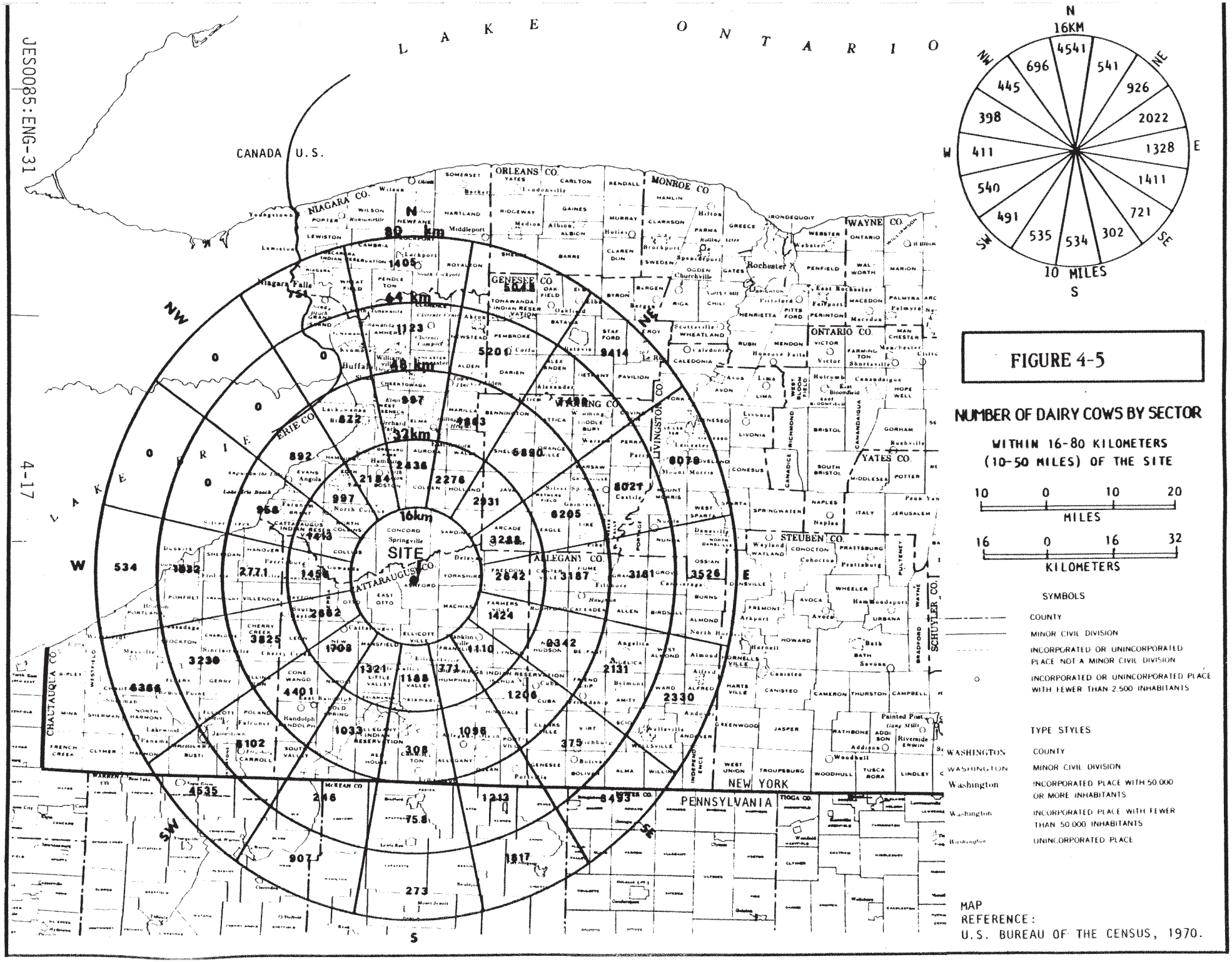


FIGURE 4-5

NUMBER OF DAIRY COWS BY SECTOR

WITHIN 16-80 KILOMETERS
(10-50 MILES) OF THE SITE

10 0 10 20
MILES

16 0 16 32
KILOMETERS

SYMBOLS

COUNTY

MINOR CIVIL DIVISION

INCORPORATED OR UNINCORPORATED PLACE NOT A MINOR CIVIL DIVISION

INCORPORATED OR UNINCORPORATED PLACE WITH FEWER THAN 2,500 INHABITANTS

TYPE STYLES

WASHINGTON — COUNTY

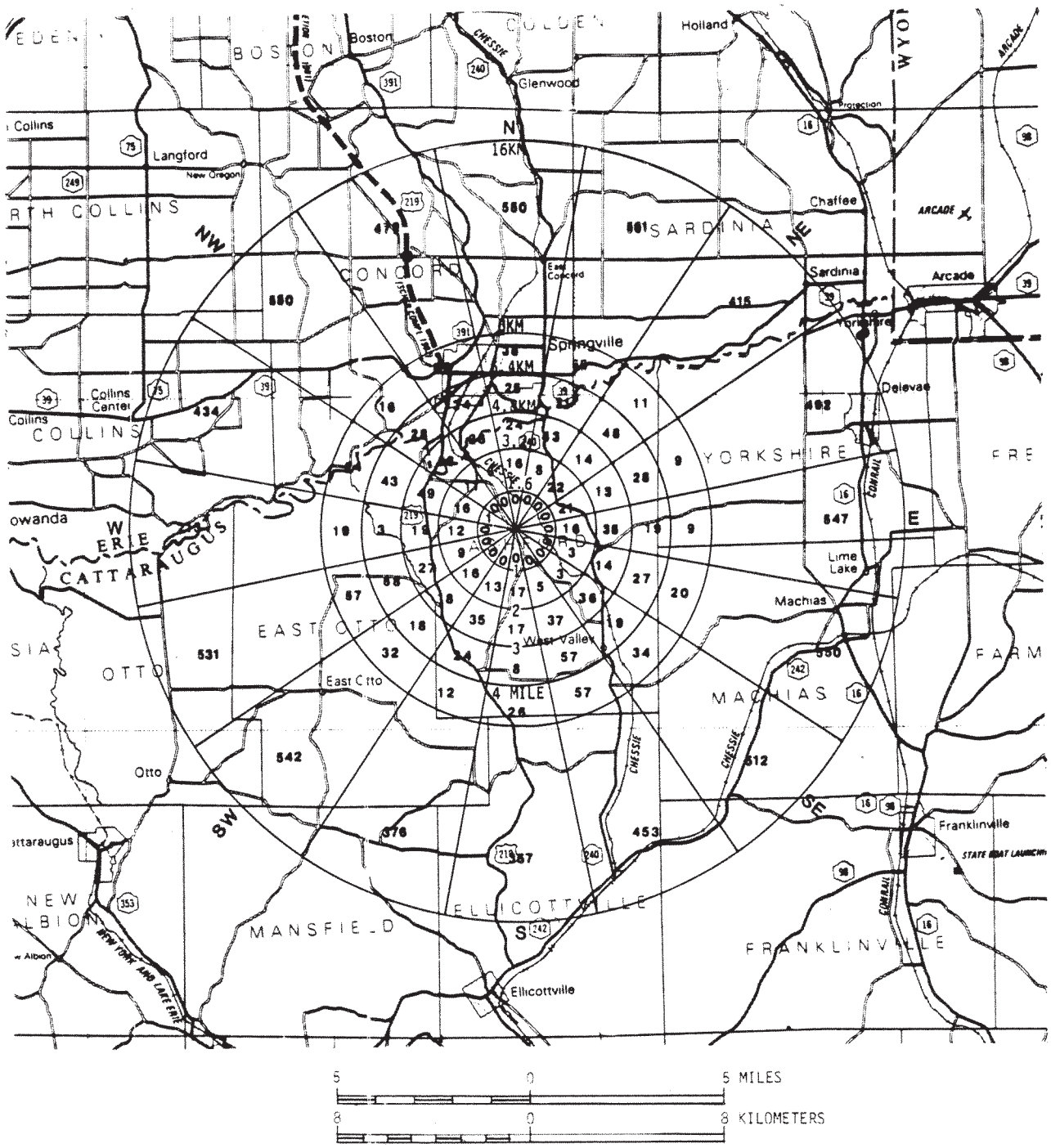
WASHINGTON — MINOR CIVIL DIVISION

Washington — INCORPORATED PLACE WITH 50,000 OR MORE INHABITANTS

Washington — INCORPORATED PLACE WITH FEWER THAN 50,000 INHABITANTS

Washington — UNINCORPORATED PLACE

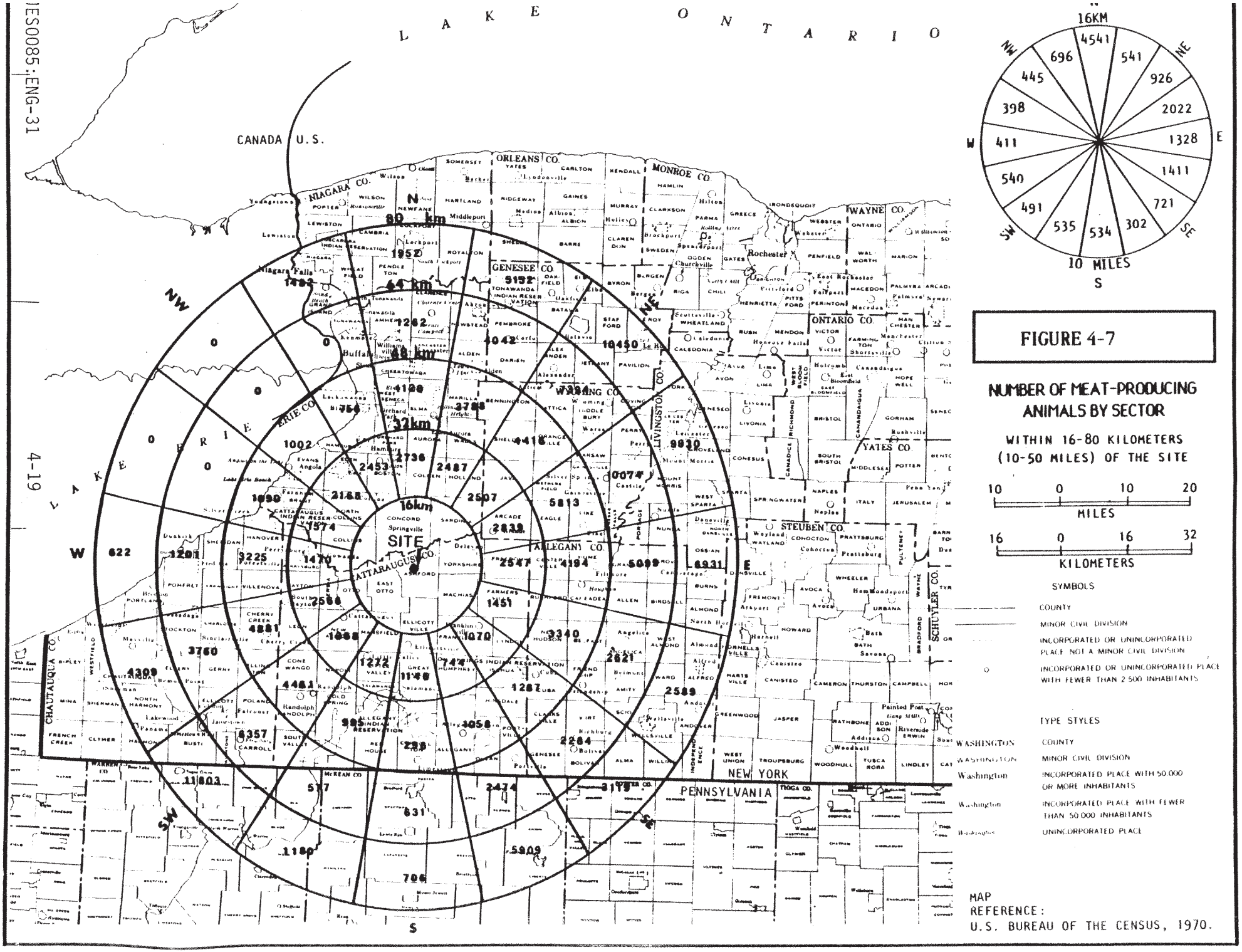
MAP
REFERENCE:
U.S. BUREAU OF THE CENSUS, 1970.

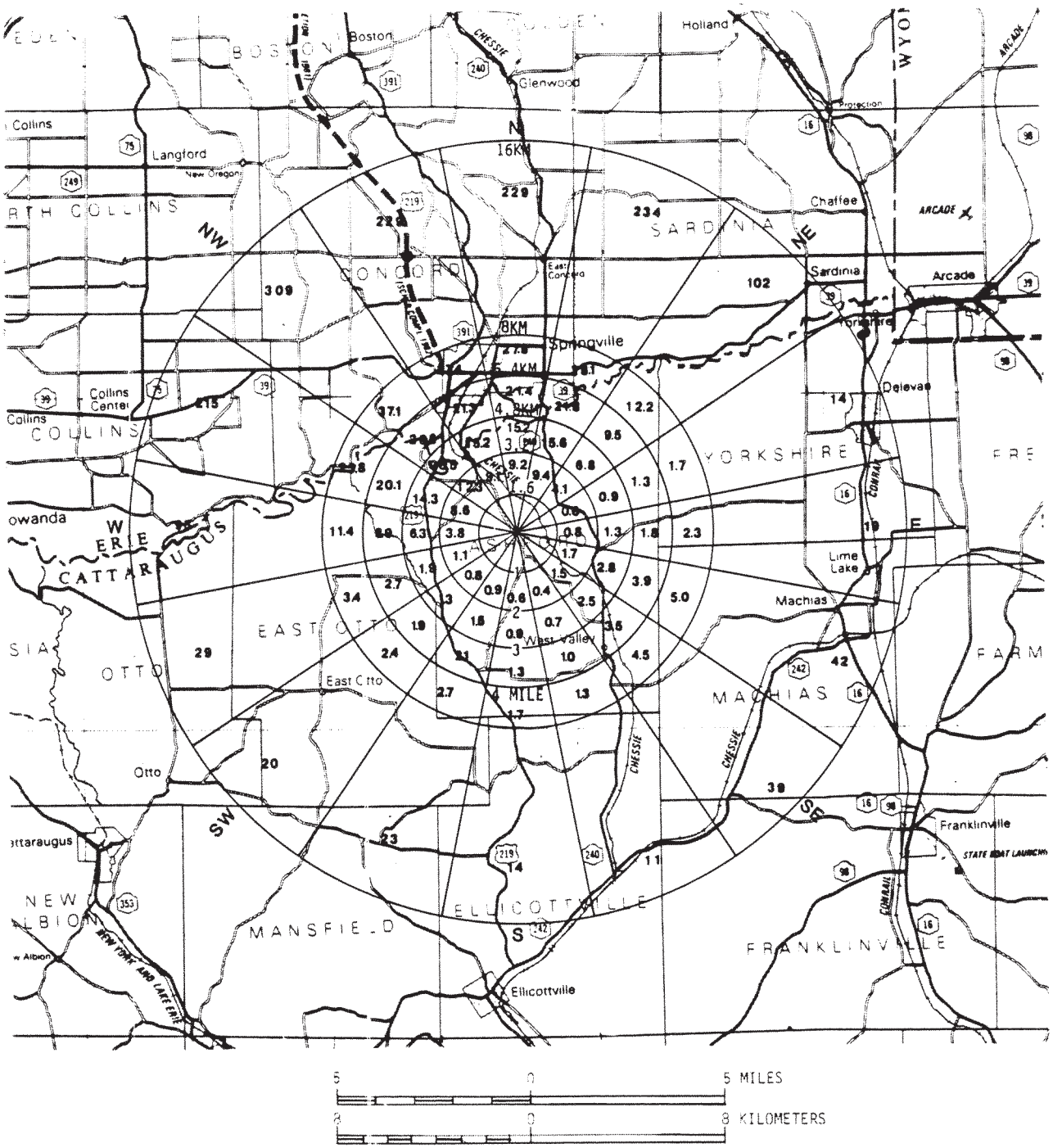


NUMBER OF MEAT-PRODUCING ANIMALS BY SECTOR

WITHIN 16 KILOMETERS (10 MILES) OF SITE

FIGURE 4-6


LAKE ONTARIO
CANADA
U.S.
LAKE ERIE
NIAGARA CO.
ORLEANS CO.
MONROE CO.
WAYNE CO.
GENESEE CO.
ONTARIO CO.
WYOMING CO.
LIVINGSTON CO.
YATES CO.
STEUBEN CO.
ALLEGANY CO.
CATTARAUGUS CO.
ERIE CO.
CHAUTAUQUA CO.
SCHUYLER CO.
NEW YORK
PENNSYLVANIA
SITE
16km
32km
48km
64km
80 km
N
NE
E
SE
S
SW
W
NW
16KM
10 MILES
4541
541
926
2022
1328
1411
721
302
534
535
491
540
411
398
445
696
FIGURE 4-7
NUMBER OF MEAT-PRODUCING ANIMALS BY SECTOR
WITHIN 16-80 KILOMETERS
(10-50 MILES) OF THE SITE
10 0 10 20
MILES
16 0 16 32
KILOMETERS
SYMBOLS
COUNTY
MINOR CIVIL DIVISION
INCORPORATED OR UNINCORPORATED PLACE NOT A MINOR CIVIL DIVISION
INCORPORATED OR UNINCORPORATED PLACE WITH FEWER THAN 2 500 INHABITANTS
TYPE STYLES
WASHINGTON COUNTY
WASHINGTON MINOR CIVIL DIVISION
Washington INCORPORATED PLACE WITH 50 000 OR MORE INHABITANTS
Washington INCORPORATED PLACE WITH FEWER THAN 50 000 INHABITANTS
Washington UNINCORPORATED PLACE
MAP
REFERENCE:
U.S. BUREAU OF THE CENSUS, 1970.



AGRICULTURAL PRODUCE LAND AREA (ha) BY SECTOR

WITHIN 16 KILOMETERS (10 MILES) OF SITE

FIGURE 4-8

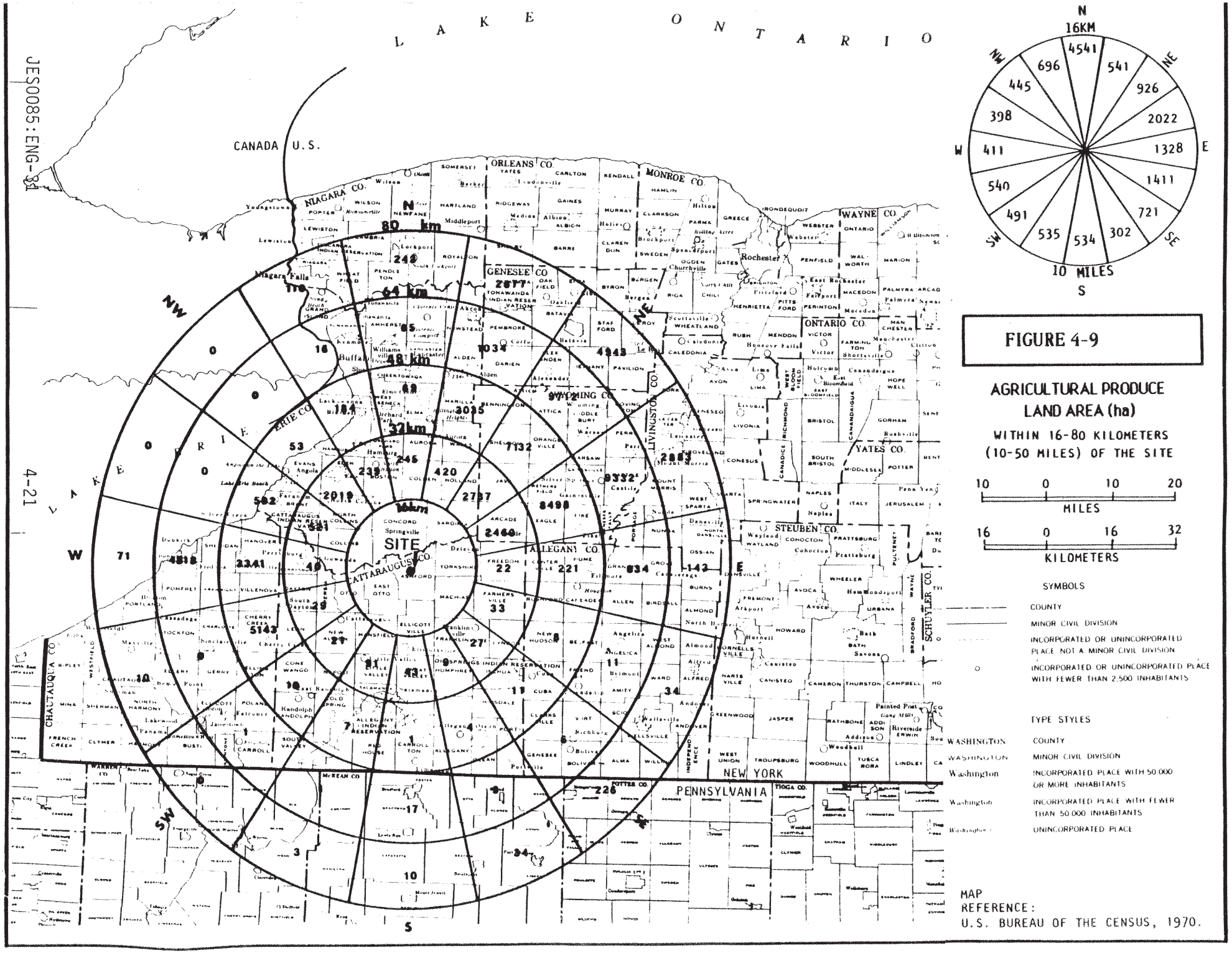


FIGURE 4-9

AGRICULTURAL PRODUCE LAND AREA (ha)

WITHIN 16-80 KILOMETERS (10-50 MILES) OF THE SITE

JES0085:ENG-81