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HEALTH RESOURCE ALLOCATION RURAL COLOMBIA

by

Bryan Hamon

Special Project Report

HEALTH RESOURCE ALLOCATION IN RURAL COLOMBIA

APPENDIX B TO FINAL REPORT TO AID, CONTRACT AID/TA-C-1363

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HEALTH RESOURCE ALLOCATION IN RURAL COLOMBIA

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HEALTH RESOURCE ALLOCATION

RURAL COLOMBIA

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EXECUTIVE SUMMARY

This report is an effort to develop two systematic approaches - computer mapping techniques and location analysis - as tools to assist Colombian health officials in planning for the allocation, deployment, and use of rural health resources.

Colombia is in the midst of a demographic and developmental transition from a rural to a predominately urban nation. Morbidity and mortality patterns characteristic of less developed countries are gradually being replaced with patterns similar to those of developed nations. Benefits from improved health have not been distributed equitably to all segments of the Colombian population. Pockets of extreme poverty and poor health continue to exist, particularly in the rural areas of the country.

In response to these problems, the Colombian government has recognized the importance of improving and expanding health services. The Colombian public health system is based on the regionalized and hierarchical delivery of appropriate levels of care. Minimally trained indigenous health care workers (promotoras), and local and regional hospitals are the foundations of this system.

The limited resources of the Colombian public health system dictate an incremental approach to extending rural health care services. Present allocation methods are described in the text.

The view is developed that planners may wish to extend health service to those rural areas that evidence the greatest "need" for those services. The study attempts to operationalize "need" by determining: (a) what data should be used to describe rural health conditions; (b) how this information can best be portrayed; and (c) how comparisons of different areas can be made.

Computer mapping is one method for displaying and comparing health characteristics of different rural areas. Health and demographic information is presented and analyzed for 14 health indicators in the Colombian state of Valle del Cauca. A health status index, used in conjunction with computer mapping, is also presented as a method for comparing various combinations of health and demographic factors.

In order for the regionalized rural health care program to function effectively, a system of logistical support is necessary. A rural medical vehicle system provides the coordination between rural health workers and the hospitals. This medical vehicle system performs tasks that include: (a) the transport of medical manpower (doctors and nurses) from hospitals to consult with patients and supervise the rural primary health care workers; (b) the

transport of basic medical supplies and educational materials used by the promotora in her work; and (c) the transport of emergency and referral patients from the rural areas into medical institutions.

Planning for rural medical transportation is complicated by the multiple and often competing roles of the rural medical vehicles. Present planning efforts are limited to determining manpower requirements for the rural ambulance drivers using a work-norm approach. The problem with this "work-norm" approach is that it does not take into consideration demands for (a) rural emergency patient transportation; (b) emergency transport of supplies; or (c) transfer of referral patients up and down the various levels of the regional health system. This study considers the potential for possible improvements in the rural medical vehicle system through the use of a systematic planning technique called location analysis.

The material and transport goals are currently considered to be the most important activities of the ambulances. This study confirms that the current sites of vehicles are the locations that minimize average or maximal travel time for the performance of these functions.

If the rural medical vehicle system is modified to improve emergency service care, health care planners will face the issue of determining where to locate ambulance bases. The current Colombian perspective is that deploy-

ment should maximize the accessability of resources to potential demands for services. When formulated in optimization terms, the problem of siting rural ambulances is found to be a variant of the maximal covering location problem. This study uses a heuristic to obtain good solutions to this problem that can be tested for optimality by linear programming.

Maximal covering is used to assess three issues related to deployment of ambulances: (a) would sites that are optimal in reference to patient transport goals be significantly more accessable to the rural population than current ambulance sites?; (b) would the performance of the ambulance system be affected by alternative administrative arrangements?; and (c) what are the best potential sites for extending rural ambulances into rural areas that are medically underserved?

Information is presented on village population, travel times and distances between villages, and the status of existing health services in Zarzal, a five county region in the state of Valle del Cauca, Colombia. Maps are developed to illustrate how medical vehicles cover the rural population. Trade-off curves are also generated to show the relation between the intensity of health resources and the percent of the rural population with access to the ambulance system.

CHAPTER ONE

GENERAL CHARACTERISTICS OF THE COLOMBIAN HEALTH SECTOR

Within the past 40 years Colombia has evolved from a rural to a predominately urban nation. The process of urbanization and development has brought about a number of changes in the health characteristics of the Colombian population. Morbidity and mortality patterns characteristic of less developed countries are gradually being replaced with health patterns similar to those of developed nations. The benefits from improved health have not been distributed equitably to all segments of the Colombian population. Pockets of extreme poverty, illness, and underdevelopment still exist in the country. This chapter will explore some of the changes in the health status of the Colombian population. It will also examine the Colombian health delivery system and recent efforts of the Colombian government to extend health services into unserved areas of the country.

EVOLUTION OF COLOMBIAN HEALTH PATTERNS

Colombia is becoming an urban nation. In 1938, about 29 percent of the Colombian population lived within

urban areas (1). By the early 1960's, half the population could be classified as urban. It has been projected that by 1980, urban dwellers will make up approximately 75 percent of the total population (2).

This transition is due in large part to an out-migration from the rural to the urban areas. This migration has been precipitated by perceptions of greater economic opportunity in the urban areas. An examination of the distribution of income in Colombia illustrates the economic disparity that exists between the urban and rural areas. While 27.7 percent of the urban population earned less than 500 pesos* in 1970, 59.7 percent of the rural population earned less than this amount. In the urban areas, 40.8 percent of the population earned more than 1,000 pesos monthly; the corresponding fraction of the rural population was only 10.5 percent (3).

Another way to view urban/rural differences is to examine the incomes of various sectors of the economy. Rural sectors such as agriculture, hunting, and fishing receive only 20 percent of the national income yet employ 34.4 percent of all working people. Urban sectors such as manufacturing, construction, commerce, tourism, transportation, and banking, generate more than 50 percent of the national income and employ 43.6 percent of Colombia's workforce (4).

---

*In 1970, one U.S. dollar was equal to 18 Colombian pesos.

Urban and rural birth and fertility rates show a similar pattern with respect to rural/urban differences. From 1938 to 1951, the Colombian population grew by 2.2 persons per hundred population per year (5). The national rate increased to 3.2 during 1951-1954, but fell back somewhat to 2.95 persons per hundred population during 1964-1973. The rural birth rate is substantially higher (4.4 to 4.7 per hundred) than the urban birth rate (2.5 to 2.8 per hundred) (6). According to the 1973 Colombian census, the total fertility rate for women living in urban areas was 3.06 per thousand women. The corresponding rate for women residing in rural areas was 6.3 per thousand women--more than twice the urban rate (7).

Developments in the health status of the Colombian population are illustrated by time trends over the past 40 years. Crude mortality rates have dropped. The rate during the 1938-1951 period was 22.4 deaths per 1,000 population. Due in large part to the introduction of vaccination procedures, water and sewage treatment, and environmental sanitation programs, the crude mortality rate declined to 17.4 during the 1951-1954 period. By 1970, it had been reduced further to 8.8 deaths per 1,000 population (8). Although total death rates have declined, the infant mortality rate is still extremely high, at 70 deaths per 1,000 live births (9).

The increase in average life expectancy of Colombians reflects the reduction in general mortality. Life expectancy for both male and female nearly doubled between 1930 and 1965, as illustrated in table 1-1. The life expectancy at

TABLE 1-1:
LIFE EXPECTANCY AT BIRTH IN COLOMBIA, BY SEX, 1930-1965

Year	Male Life Expectancy (years)	Female Life Expectancy (years)
1930	33.6	34.8
1940	37.1	39.0
1950	47.3	49.0
1957	55.0	59.0
1965	59.0	62.0

Source: Agency for International Development, *AID Health Sector Analysis*, Bogota, Colombia: U.S.A.I.D., 1974, p. 7.

birth for males increased from 33.6 years (in 1930) to 59 years (in 1965). Female life expectancy has increased from 34.8 years (in 1930) to 62 years (in 1965). Comparative rates between urban and rural areas are not available.

The causes of death have changed over the last 30 years. Death from communicable diseases have decreased while trauma and degenerative diseases have increased (10). These mortality patterns are similar to those of developed countries. Each of the ten leading causes of death during the 1940's were related to environmental and vector causes. In 1969, one-half of the ten leading causes were of a

TABLE 1-2: TEN PRIMARY CAUSES OF DEATH IN COLOMBIA IN 1969

Order	Cause	Number of deaths	Percent of Total
1	Gastroenteritis, diarrheas	19,807	11.2
2	Pneumonias (non-viral)	12,992	7.2
3	Heart disease, other	10,221	5.8
4	Bronchitis, asthma	9,317	5.3
5	Ischemic heart disease	7,637	4.2
6	Cerebrovascular disease	6,957	3.9
7	Avitaminosis, nutritional deficiencies	5,960	3.3
8	Anoxia-hypoxia, non-specific	4,040	2.3
9	Malignant tumors, other	3,746	2.1
10	Tuberculosis of respiratory tract	3,277	1.8
11	Other causes	95,625	53.2

Source: Ministry of Public Health, *XIX Conferencia Sanitaria Panamericana*, Bogota, Colombia, Minsalud, Oct. 1974, p. 13.

degenerative origin as illustrated in table 1-2. Although gastroenteritis and diarrheas are the leading causes of death, disease related to the environment and degenerative diseases cause roughly an equal fraction of total deaths.

Further evidence of the transition in cause specific mortality is shown in the ten leading causes of death in 1971.* This is illustrated in table 1-3. Chronic diseases and trauma account for seven of the top ten causes of death in Colombia in 1971. Deaths related to gastroenteritis and diarrheas dropped from 11.2 percent (in 1969) to 9.2 percent

*The reason for using this limited time series information is its availability and consistency. Clearly one cannot draw inferences from only two years data.

TABLE 1-3: TEN PRIMARY CAUSES OF DEATH IN COLOMBIA IN 1971

Order	Cause	Number of Deaths	Percent of Total
1	Gastroenteritis, diarrheas	13,357	9.2
2	Pneumonias (non viral)	10,655	7.3
3	Heart Disease, other	9,292	6.4
4	Bronchitis, asthma	7,374	5.0
5	Ischemic heart disease	7,176	4.9
6	Cerebrovascular disease	6,093	4.2
7	Avitaminosis, nutritional deficiencies	5,425	3.7
8	Trauma related	3,348	2.3
9	Anoxia-hypoxia, non-specific	3,211	2.2
10	Malignant tumors, other	3,158	2.2

Source: Ministry of Public Health, *XIX Conferencia Sanitaria Panamericana*, Bogota, Colombia, Minsalud, Oct. 1974, p. 22.

of total deaths (in 1971), while deaths from malignant tumors, cerebrovascular disease, and heart disease increased. Of particular interest of this study is the rapid increase in death related to trauma. In 1969, trauma was not listed among the ten leading causes of death. By 1971, it was considered the eighth leading cause of death.

The distribution of cause specific mortality is highly skewed with respect to various age cohorts. Gastroenteritis, diarrheas, bronchitis, avitaminosis, and other diseases related to nutrition account for the large majority of deaths of children less than five years of age. The major causes of death of persons 15-45 are trauma, accidents,

homicides, and suicides. Degenerative diseases such as heart disease and cancer account for most of the deaths among people 45 years and older (11).

The patterns of ill health parallel the mortality patterns. Intestinal, respiratory, and anemia ailments cause the most ill health among children. In the 15-44 age group, birth complications, abortions, and accidental injuries account for a high percentage of ill health. The 45 and over age group suffers primarily from circulatory, respiratory, digestive, and genitourinary problems (12).

THE OTHER COLOMBIA

Although Colombia appears to have made significant strides to transform health conditions, there are still many people who live in poverty and ill health. Infant and child mortality rates are still unacceptably high. Forty-three percent of all deaths occurred among children younger than five years of age. Infants* comprise four percent of the population yet account for approximately one-fourth of all deaths (13).

A large fraction of the deaths and disease in Colombia is considered preventable, and related to environmental and infectious diseases. The five most severe environmental health problems by incidence rates are listed in

---

*Infants are children younger than one year of age.

TABLE 1-4:
MORBIDITY RATES OF HEALTH PROBLEMS RELATED TO THE ENVIRONMENT

Problem	rate (per 1,000 pop.)
Infectious and parasitic diseases	302
Anemia	129
Dysentery	51
Bronchitis	33
Enteritis, colitis	19

Source: Agency for International Development, *AID Health Sector Analysis*, Bogota, Colombia: U.S.A.I.D., 1974, p. 21.

table 1-4. The morbidity rates listed in table 1-4 were derived from a national study on morbidity. The study revealed that 79 percent of all Colombians had some form of health problem (14). Many of these problems are directly related to the poor quality of the living environment. One source estimates that 50 percent of communicable diseases are transmitted by water, and that 14 percent of all deaths are caused by water-born diseases (15). The quality of drinking water and sanitation facilities varies greatly between the urban and rural areas. In 1972, 30 percent of the rural population had access to potable drinking water, and 34 percent had sewage disposal service. Seventy-five percent of urban dwellers had access to potable water, and approximately 60 percent had sewage disposal services (16).

Malnutrition is a major problem in Colombian rural areas. Statistics from the Colombian Health Ministry show

that 66 percent of lower income children in Colombia suffer from some form of malnutrition (17) and that more than 65 percent of all rural pre-school children suffer from chronic malnutrition (18).

ACCESS TO THE COLOMBIAN MEDICAL SYSTEM

While most of the demographic and health indicators have shown improvement, the accessibility of the Colombian population to medical services is far from adequate. The Colombian medical system is composed of three parts: the private, social security, and the public health system. The private system, where a fee is paid for the service, is utilized by approximately 15 percent of the total population, or 3.5 million persons. A government sponsored social security system covers those who are insured workers and their beneficiaries, or approximately nine percent of the total population. The public health system, operated by the federal and state governments, is the largest component in the health system. In theory public health services cover the 76 percent of the Colombian population that are not able to use the private or social security systems. However due to resource limitations, approximately four million Colombians, or 26 percent of the total population, do not have access to the public health system. Consequently this 26 percent have access to no medical services at all (19).

A document from the Ministry of Public Health reports that the great majority of these four million persons outside the health system reside "in the rural zones of the country" (20).

The distribution of medical personnel reflects the urban/rural split. In aggregate terms, the Colombian physician/population ratio (5.4 doctors per 10,000 population) seems well above the minimum World Health Organization (WHO) standards of one physician per 10,000 population. However, 74.2 percent of the available physicians practice in state capitals, leaving the rest of the country with only one physician per 6,384 inhabitants (21).

Of the estimated 10,000 physicians in Colombia, only 2,300 work for the public health system. If these doctors could provide services to the three-fourths of the total population they are supposed to serve, the 1.6 physicians to 10,000 population ratio is barely above WHO standards. In contrast, the private sector ratio of 13.6 doctors per 10,000 persons approaches the levels of the U.S. and other industrialized countries.* Most public health physicians also work in metropolitan areas. Forty-six percent of all public doctors (1.074 physicians) are affiliated with university hospitals. Thirty-four percent (784 doctors) work

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*The physician/population ratio in the United States is 15 doctors per 10,000 population.

at the regional level and only 20 percent (451) serve the local population (22).

THE COLOMBIAN RURAL HEALTH MODEL

The government of Colombia has recognized that its primary task is to coordinate existing health services and to extend medical resources into the rural areas that are without medical services (23). In response to this need, the Ministry of Health has developed a national health plan to implement a regionalized and hierarchical model for the extension of health services. The program aims to allocate medical resources to selected levels of the health system and to integrate those levels through a transportation and communication network. The principle of this system is that people should receive the appropriate level of care.

National health policy in Colombia is the responsibility of the Ministry of Public Health. Although the Ministry does directly deliver certain health services, its main role is to plan and advise and provide financial support to the states. Implementation of health services is the responsibility of the Servicio Seccionales (state health departments) located in the various departmental (state) capitals. Line responsibility is either handled directly at this level or delegated to regional and local health

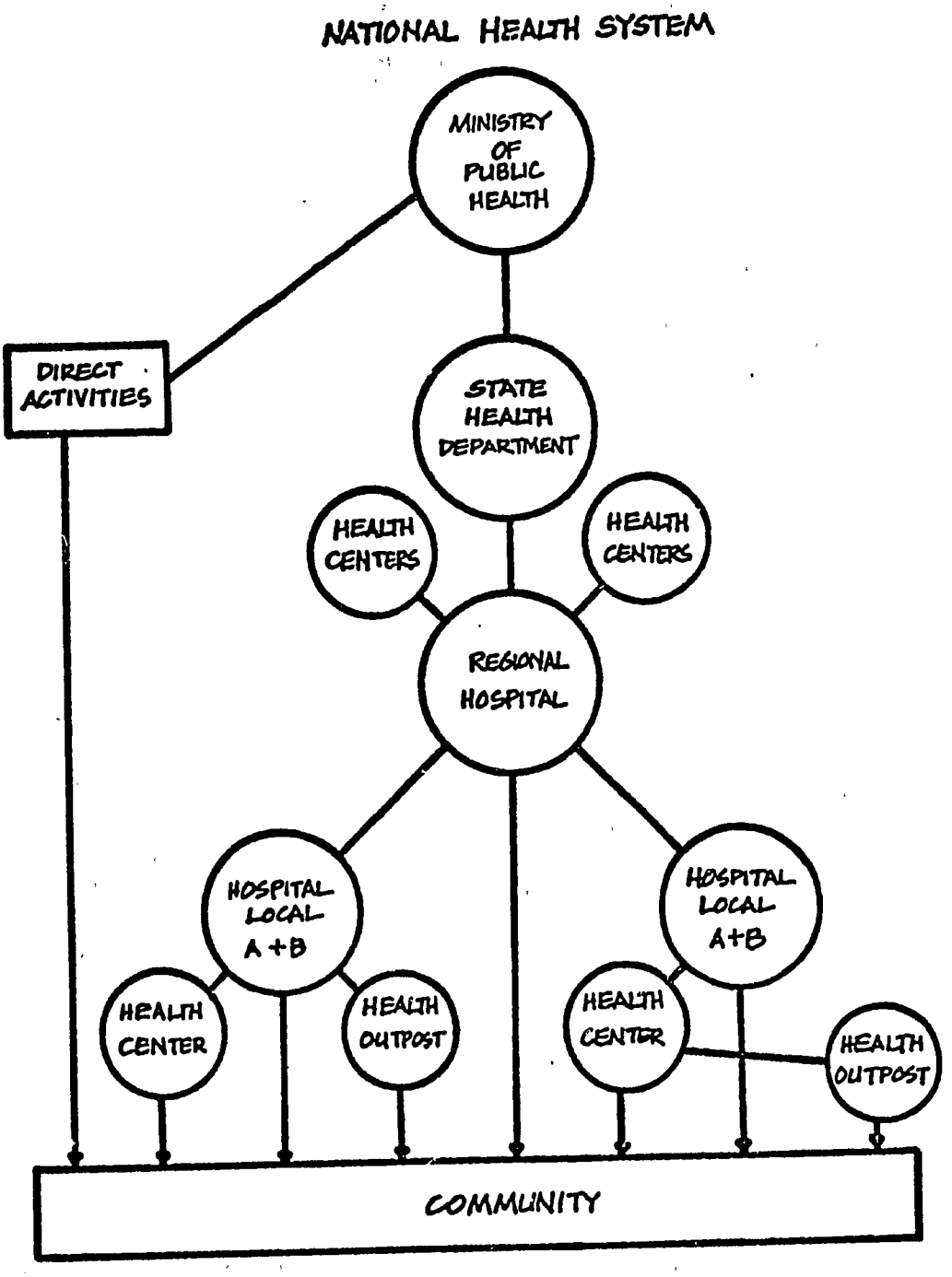
departments within each state. Figure 1-1 is a diagram of the public health institutional infrastructure.

Although figure 1-1 does reflect the Colombian Ministry of Public Health's conception of their rural health service at one point in time (1975), that system is in a state of constant change. The description of staffing policies and inter-relationships between levels in 1975 was but may not now be precisely correct. However, the hierarchical and regional organization of the system is correct.

The building block of the national health plan is an indigenous paramedical worker who can provide basic primary health care to the rural population. The paramedic, or promotora de salud (health promoter), serves the rural community as a "change agent" (24) to improve community health standards. A promotora is trained to educate the population regarding preventative health concepts and to provide limited medical services. The promotora is also the initial contact point for rural patients needing referral to other parts of the medical system for more extensive diagnosis and/or treatment.

In some cases, a promotora will work out of her home or a health outpost (puesto de salud). In other areas of Colombia, a health outpost employs auxilliary nurses and visiting physicians to support and supervise the promotora. Health outposts, the first fixed installation in the rural

FIGURE 1-1: NATIONAL PUBLIC HEALTH SYSTEM



Source: Modified from a widely used diagram of the Colombian Ministry of Public Health.

health plan, may also provide limited diagnostic and treatment services.

Health centers (centros de salud) support and supervise the health outposts and promotoras. Health centers offer a range of medical treatment in both urban and rural areas. These facilities are designed to be staffed by a full-time physician and support personnel. When situations arise at the local level that are beyond the limited capacity of the health center, the patient is referred into the next level of care in the regionalized system, the county hospital. Two classes of county hospitals exist, A and B. Class A hospitals practice family medicine, specializing in obstetrics, pediatrics, and internal medicine. Class B hospitals provide those services and offer in addition limited surgical procedures.

Regional hospitals, which supervise between five to seven county hospitals, provide more extensive diagnostic and treatment facilities. Regional hospitals often employ medical specialists and include pathology departments to do laboratory examinations. While outpatient care is still of primary importance, regional hospitals also provide post-operative and inpatient care.

Those medical cases that demand a higher level of sophisticated diagnosis and treatment are referred to the university hospitals. University facilities provide the

full range of diagnostic and treatment services, including radiology, respiratory therapy, and pathology laboratories.

A transportation and communications network integrates the levels of the hierarchy. Vehicles transport manpower and supplies between hospitals and rural health centers and outposts. They also function as a patient transport system to move patients from the rural areas to local hospitals or to more intensive care available at higher levels in the regional system. Telephone, radiophone, or telex systems in theory provide for communication between the various parts of the regional system.

The primary purpose of the regional model is to extend services into the rural areas that are not served by the existing medical system. The Ministry's goal is to first expand the public health system to all areas and to provide a minimum level of health services. As stated in the national health plan, "when all are at a minimum level, we will be able to continue advancing toward the ideal" (25). Given the limited resources of the Colombian government, this minimum level of care cannot instantly be established, but must be programmed incrementally over time in line with budget allocations. While the Colombian government is committed to extending medical services into the rural areas, current resources are scarce. The incremental decisions on expanding the system will determine how well the public

health system provides or fails to provide medical services to the rural population.

MAJOR RURAL HEALTH ISSUES

Plans to extend the rural health system typically address a number of issues. These include:

- WHAT IS THE PROPER DEPLOYMENT OF MEDICAL RESOURCES IN RURAL AREAS? Do all rural areas need services equally or should the health status of each rural area determine the allocation of health resources? If so, how can these conditions and needs be determined? What methods might be used to facilitate allocation decisions?

- WHAT NORMS SHOULD GOVERN THE ALLOCATION AND USE OF RURAL HEALTH RESOURCES? The explicit goal of the rural health system is to provide services to all unserved rural residents. What standards should be met by different rural health services?

- WHAT PROCEDURES EXTEND HEALTH SERVICES IN THE MOST EFFECTIVE MANNER? Are some problems too complex for intuition and common sense alone? If so, are there health planning methods that can be adapted to Colombian rural health needs and requirements?

These three issues will be considered in the following chapters. Chapter two addresses the question of determining the health conditions in rural Colombia. The difficulties associated with both defining health status and using health data are presented. An indexing method is developed to illustrate how health planners can array health related information. Chapter two also discusses how

to use rural health characteristics as a basis for determining extensions of rural health services.

Chapter three analyzes the planning procedures used in one particular component of rural health, the rural medical vehicle system. The multiple goals of the medical vehicle system are discussed. The chapter describes how present planning methods fail to accommodate one of the three goals, emergency patient transportation.

Chapters four through nine develop and apply location techniques to rural medical vehicle deployment. Chapter four reviews the development and use of location planning methods. One particular method that developed from the Maximal Covering Problem is discussed in detail. Chapter five presents a formulation of this problem along with additional requirements that better adapt the model to the Colombian rural health situation. Chapter six describes the project area, a five county region in Valle del Cauca, Colombia, and the data used in solving the Maximal Covering Problem. Chapter seven analyzes the present operating performance of the rural medical vehicle system. The system's performance is evaluated with respect to each of its three goals. Chapter eight and nine discuss the merits of restructuring and/or extending the rural medical vehicle system in the Zarzal region. Chapter ten presents the conclusions and recommendations of this study.

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(12) Ibid., p. 16.

(13) Colombian Ministry of Public Health, op. cit., p. 22.

(14) U.S. Agency For International Development, op. cit., p. 20.

(15) Ibid., p. 22.

(16) Colombian Ministry of Public Health, op. cit., p. 23.

(17) Ibid.

(18) Ibid.

(19) U.S. Agency For International Development, op. cit., p. 22.

(20) Colombian Ministry of Public Health, op. cit., p. 12.

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(22) Ibid., p. 159.

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(24) Penn, Bob Un Punto Clave En El Sistema De Salud Colombiano: La Promotora, Bogota, Colombia: The Fulbright Commission of Colombia, unpublished report, June, 1977, p. 8.

(25) Colombian Ministry of Public Health, op. cit., p. 17.

CHAPTER TWO

EXTENDING RURAL HEALTH CARE SERVICES

This chapter explores some issues of rural health service extension. Chapter one examined the Colombian government's commitment to deploy health services to residents of those areas without current access to the health care system. The size of the unserved population is large, approximately four million, and health care resources are limited (1). How can planning make the most effective use of available rural health resources? One initial question in planning a rural health system is, "to which area should medical services be extended first?" Many economic or political considerations ultimately may influence deployment decisions for rural health services (2). From a medical standpoint, Colombian health planners might wish to extend health services to those rural areas that evidence the greatest "need" for those services. In this chapter we try to operationalize the word "need" by asking three questions: (a) what data should be used to describe rural health conditions? (b) how should this information be portrayed?; and (c) how can comparisons of different areas be made?

RURAL HEALTH DATA

How can the health of a population be measured? Health status is a complex phenomenon involving the interrelationships between numerous social, demographic, economic and disease factors. No single measure, such as infant mortality, is universally accepted as a surrogate for health status. While health status may be indicated by a large number of statistics, it is measured by none of them. Although no volume of information is sufficient to adequately describe population health characteristics, the planner is often forced by circumstances to make allocation decisions.

The problem is not only whether data exists. The information that exists may or may not be reliable or accurate. Data may be misleading due to many reasons, including (a) poor sampling, (b) bias in collecting, (c) inaccuracies in diagnosis, (d) errors in compilation and analysis, or (e) inadequate compilation, storage, and retrieval of health data (3).

Colombian Health Data

Colombian health information is generally derived from the decennial census and general health records of birth, death and sickness. The national census bureau, Departamento Administrativo Nacional de Estadística (DANE) is the major

source of Colombian demographic and health information. DANE compiles a national census about every ten years which includes information on Colombian population, housing, education, employment, and health. The most recent census was undertaken in 1973, and the previous census was taken in 1964. One problem with DANE information is its timeliness. Census results often take four to five years to reach publication form; as of 1977, only a portion of the 1973 census had been released.

Census demographic information may, even when published, be inaccurate and unreliable. One source estimated that DANE undercounted the population in certain areas by as much as 27 percent (4). A graphic demonstration of the inadequacies of DANE's data is that DANE in 1973 counted only 70 villages in the Zarzal planning region. The Valle del Cauca state health department is aware of 74 villages that exist in Zarzal (5).

There are also a number of problems associated wit the collection of vital statistics. This information generally is collected by local and state health departments and forwarded to DANE for compilation. Morbidity, mortality, and birth statistics are taken from patient hospital records and from civil registration certificates. In any country, problems exist with respect to completeness and accuracy of diagnosis. How accurate can this information in Colombia

be when 36 percent of the Colombian population has no access to the health system and about one of two Colombians do not die in a hospital (6).

The reliability of data varies substantially through different states in Colombia (7). In some areas the efforts of DANE are enhanced by the state health departments. This paper did benefit from data collected by recent sanitary surveys of the health department in Valle del Cauca (8).

Twelve categories of demographic and vital statistics were readily available in Colombia. This information, which may be used to discuss rural health expansion, is presented in table 2-1.

TABLE 2-1: HEALTH INFORMATION IN VALLE DEL CAUCA, COLOMBIA

1. Total Births
2. Total Deaths
3. Infant Deaths
4. Hospital Beds
5. Tuberculosis Related Deaths
6. Measles Related Death
7. Respitatory Related Death
8. Malignent Tumor Related Death
9. Circulatory Related Death
10. Population
11. Rural Health Promotoras
12. Truama Related Death
13. Avitaminosis Related Death

The raw data for each of these factors is listed in Appendix A. Due to the small number of cases, and/or significant

variations between observed years, annual information for many of the factors was collected for a three year period.

The number of births and deaths do not describe adequately the health characteristics of a population. Birth and death rates, which are derived from the gross figures, allow comparisons between regions and periods. Rates for these 12 factors were calculated through equations which are listed in Appendix A. An illustration is the rate of infant mortality during the period 1972-1973-1974. Figure 2-1 shows how this rate was derived.

FIGURE 2-1: INFANT MORTALITY RATE

$$\text{Rate} = \sum_{i=1972}^{1974} \left(\frac{D_i}{B_i}\right) \times 1{,}000$$

Where B_i = Number of live births in year i, i = 1972, 1973, 1974

D_i = Number of infant (less than 1 yr.) deaths in year i, i = 1972, 1973, 1974

PRESENTATION OF HEALTH INFORMATION

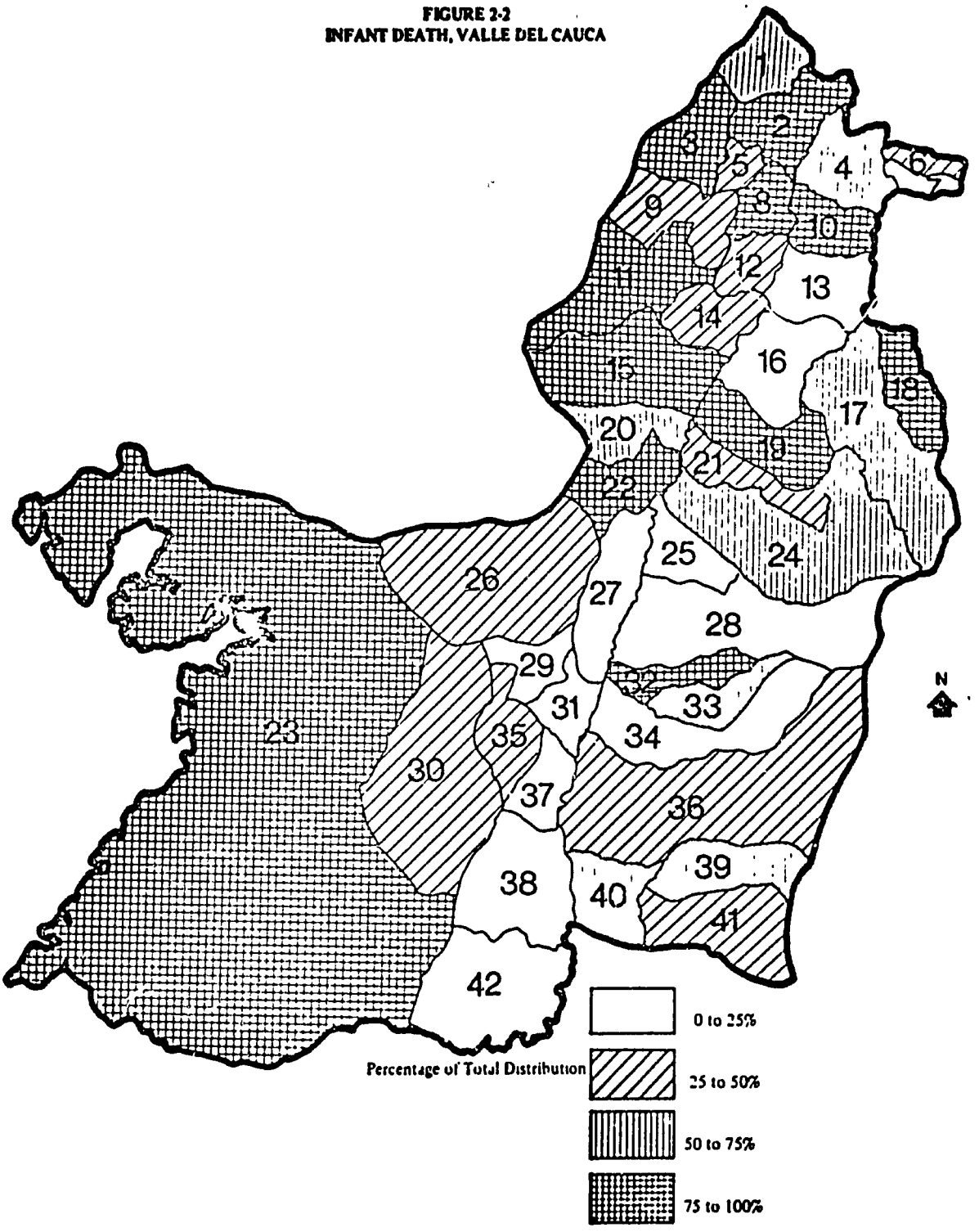
How can an analyst portray information to enhance the decision process? Trends over time or relationships between geographical areas may not be evident when data is represented in tabular or matrix form. Cartographic

(mapping) analysis offers another route to present geographic and time series information.

Mapping analysis in some form or another is centuries old. However, due to both time and human labor necessary for map production, map analysis has been utilized rarely outside of military planning operations. With the advent of computers, map production is no longer limited by time and labor factors. Commercial graphics programs are available that interface with standard computers (9). Computer mapping displays information over a geographic field divided along predetermined lines. The cartographic packages allow for the manipulation, weighting, aggregation, and display of data, subject only to the user's needs and computer budget. Appendix B offers a more extensive explanation of the computer mapping program used in this paper.

An example of computer mapping will better illustrate this point. Four requirements are necessary in order to construct a computer map. These are: (a) a source map of the area to be displayed; (b) a variable which is distributed within each subdivision of the map; (c) value ranges for the distribution of the variable; and (d) a shading pattern to be associated with each value range. Figure 2-2 represents a computer map showing infant mortality in the state of Valle del Cauca, Colombia. Due to difficulty in reducing and printing the actual computer map used in this paper, an

FIGURE 2-2
INFANT DEATH, VALLE DEL CAUCA



artist's reproduction is presented here.

The source map is constructed by transferring the boundaries of mapped areas to (x,y) coordinate points in a punch card format. The variable to be shown for each subdivision of the map (in this case infant mortality) is also represented in punch card format. The particular values for infant mortality in the Valle del Cauca are listed in table 2-2. Some ranges of values representing different outcomes or categories need to be defined by the user. In this example, infant mortality rates were divided into quartiles to show higher or lower infant death rates. The user can select a shading pattern to be associated with the value ranges.

COMPARISON OF HEALTH CHARACTERISTICS

How can health planners compare the relative health status between various jurisdictions? Tabular representation of information provides the planner with an understanding of health conditions of a population. Mapping analysis aids the planner to compare relationships between measures of health or ill health in different areas or in one area at several points in time. The meaning of these geographical or temporal differences--and how they should affect the allocation of health resources -- is not easy to determine. At present, no consistent set of criteria exists to guide

TABLE 2-2: INFANT DEATHS AND DEATH RATE*
VALLE DEL CAUCA, COLOMBIA (1972, 1973, 1974)

	1972	1973	1974	Rate		1972	1973	1974	Rate
1. El Agulia	57	38	35	102.7	22. Riofrío	59	44	46	269.4
2. Anserma Nueva	97	71	75	280.8	23. Buenaventura	335	326	332	132.7
3. El Cario	45	53	50	151.5	24. Tulua	281	224	197	92.6
4. Cartago	260	220	250	106.5	25. San Pedro	15	10	10	57.6
5. Argelia	42	25	31	69.1	26. Darien	23	18	25	65.1
6. Ulloa	7	5	7	67.1	27. Yotoco	24	19	17	43.5
7. Alcalá	39	16	42	97.8	28. Buga	212	177	150	55.4
8. Toro	41	36	45	119.7	29. Restrepo	34	18	19	56.7
9. Versalles	39	30	34	73.7	30. Dagua	64	73	44	58.0
10. Obando	51	28	52	158.5	31. Vijes	9	10	5	62.7
11. El Dovio	53	23	29	165.8	32. Guacari	52	30	28	98.8
12. La Unión	39	44	38	81.3	33. Ginebra	32	19	20	129.8
13. La Victoria	29	28	26	56.4	34. El Corrito	76	65	47	96.7
14. Roldonillo	42	38	44	64.2	35. La Cumbre	14	12	13	51.
15. Bolívar	45	40	33	126.1	36. Palmira	329	380	328	65.3
16. Zarzal	94	74	79	55.6	37. Yumbo	77	49	79	72.6
17. Sevilla	152	126	148	98.5	38. Cali	1,513	1,248	1,276	59.9
18. Caicedonia	113	105	83	118.1	39. Pradera	68	39	62	54.0
19. Bugalagrande	50	38	41	134.3	40. Candelaria	73	59	47	101.0
20. Trujillo	54	45	41	96.2	41. Florida	94	66	81	94.3
21. Andalucía	30	24	21	91.5	42. Jamundí	98	92	98	75.1

*Infant death rate calculated as

$$\text{Rate} = \sum_{i=1972}^{1974} \left(\frac{D_i}{B_i}\right) \times 1{,}000$$

Where D_i = Number of deaths of population in year i

B_i = Number of live births in year i

i = 1972, 1973, 1974

Source: Servicio Seccional de Valle

Colombian planners in extending the health care system. Currently the Ministry of Health assigns a general number of new rural facilities to each state. The state health departments, each in its own way, determine the actual deployment and staffing of new rural health facilities.

A "geographical equity" approach for determining areas for rural health intervention would be to locate facilities without regard to health conditions. Using this approach, the planner would view the rural areas as equally deserving of health facilities and siting could occur through a process of random selection, based perhaps on population density.

An alternate "health equity" approach would recognize that rural areas are not identical. A review of the health and demographic data presented in Appendix A finds that a substantial variation exists between rural areas that is not explained by urban/rural factors alone. For example, two counties in Valle del Cauca, El Dovio and San Pedro, both have similar percentages of rural inhabitants (between 70 and 80 percent). El Dovio has an infant mortality rate of 165 infant deaths per 1,000 live births while San Pedro's infant death rate is 57 deaths per 1,000 live births--a difference of nearly 200 percent.

A health equity approach would allocate rural health resources and extend care to those areas that evidence the

strongest "need" for the particular type of service. An example is the decision of where to site a tuberculosis sanitorium. One logical way would be to locate the facility close to an area with high levels of tuberculosis, other factors being equal.

Promotora extension is another area where planning the basis of "need" may be warranted. Health services are delivered by an indigenous promotora through community outreach. The promotora is the initial contact point for the health system and teaches preventative health practices. Her mode of operation is personal outreach to local households within her jurisdiction and through the use of community presentations (charlas) to selected groups, such as pregnant mothers, and school children.

Other factors being equal, promotora extension makes sense in those areas that could receive the most benefit from these skills. One way to determine these areas would be to establish an indicator or set of indicators that could serve as a surrogate for "promotora need." For example, infant mortality is generally held to be an indicator of poor environmental and nutritional condition. Many of the promotora's assigned tasks aim to improve the environment and infant nutrition. Using infant mortality as a surrogate for promotora need, health planners might consider those areas with high infant mortality rates as choice areas for

extending promotora health services. An example would be those areas in figure 2-2 with dark shading, which have the highest infant mortality rate.

Infant mortality might not be the only indicator that Colombian health planners would wish to use as a basis for promotora need. Promotoras are also trained in pre-natal care, mid-wifery, and nutrition, among other things. A number of indicators taken together might better represent the need for promotora skills.

A number of questions immediately arise concerning how to compare and combine health and demographic information. There is no universally valid way to select, weigh, and index different combinations of factors. Indexing is a problem of many refined value judgments. Some professionals support the idea of using certain "sentinel" health factors (related to preventable and/or controllable diseases) to signal a need for health care intervention (10). Various forms of health indices are used by the U.S. Department of Health, Education, and Welfare to designate "health underserved areas" for intervention by the Public Health Service and other federal programs. An index is simply a formal method of adding a number of factors together which is intended to form a composite figure reflecting all factors. An index can be constructed in many ways. An example of one type of index that Colombian planners might consider would be one

using the factors of infant death, avitaminosis related death, and intestinally related death. The selection of these particular factors are not the only factors relevant to a promotora's skills; however, they do reflect the type of problems a promotora is trained to handle.

The formulation for the index developed for this example is given in Appendix C. It is based upon the division of each factor into quartiles, as illustrated in table 2-3. Each quartile is assigned a ranking of one to four corresponding to the increasing level of incidence for each factor. The three factors are all weighted equally. After each of the three factors is divided and ranked, the index program then sums the three rankings assigned to each county in Valle. This composite distribution is again divided into quartiles and assigned a ranking from one to four corresponding to the severity. If we assumed that these three factors collectively indicated "need for promotora services," then the index can provide a method for distinguishing one county from another. An inspection of figure 2-3 identifies those areas such as the darker shaded northern part of Valle, that may be of interest to Valle health planners.

The disadvantages of an index are that it reduces information and can obscure differences. With the quartile index illustrated above, there are two steps of information reduction. First, the measures of some real event, such as

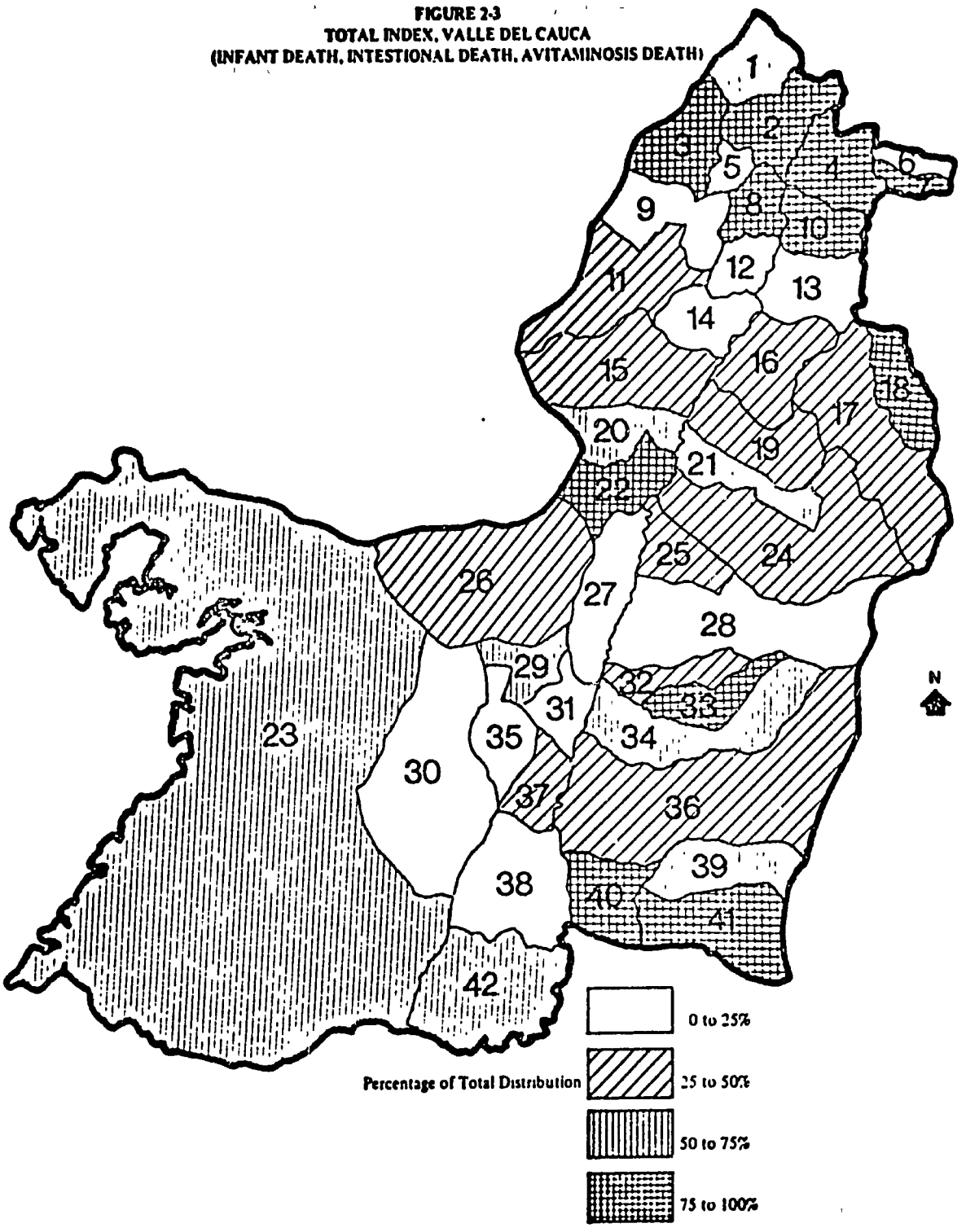
TABLE 2-3:
HEALTH STATUS INDEX, VALLE DEL CAUCA, COLOMBIA, 1972-1974

County	Infant Mortality*	Quartile Rank	Intestional Mortality**	Quartile Rank	Avitaminosis Mortality**	Quartile Rank	Index Rank
1. El Agulia	102.7	3	101.1	3	60.1	2	3
2. Anserma Nueva	280.8	4	224.5	4	147.1	4	4
3. El Cario	151.5	4	97.7	3	91.7	4	4
4. Cartago	106.5	3	148.8	4	71.9	3	4
5. Angelia	69.1	2	82.7	2	94.2	4	3
6. Ulloa	67.1	2	35.4	1	53.1	2	1
7. Acalá	97.8	3	150.1	4	120.0	4	4
8. Toro	119.7	4	123.8	3	64.9	3	4
9. Versalles	73.7	2	25.3	1	42.2	2	1
10. Obando	158.5	4	136.4	4	165.7	4	4
11. El Dovio	165.8	4	61.9	1	27.5	1	2
12. La Unión	81.3	2	133.8	4	60.2	2	3
13. La Victoria	56.4	1	90.4	2	34.8	1	1
14. Roldonillo	64.2	2	32.2	1	58.1	2	1
15. Bolívar	126.1	4	68.3	1	51.2	2	2
16. Zarzal	55.6	1	122.3	3	50.7	2	2
17. Sevilla	98.5	3	66.2	1	62.1	3	2
18. Caicedonia	118.1	4	129.9	4	139.0	4	4
19. Bugalagrande	134.3	4	78.4	2	34.3	1	2
20. Trujillo	96.2	3	80.1	2	66.7	3	3
21. Andalucía	91.5	2	88.4	2	147.4	4	3
22. Riofrío	269.4	4	157.1	4	61.5	3	4
23. Buenaventura	132.7	4	103.7	3	35.3	1	3
24. Tulua	92.6	3	93.1	2	66.6	3	2
25. San Pedro	57.6	1	86.7	2	67.5	3	2
26. Darien	65.1	2	81.3	2	104.6	4	2
27. Yotoco	43.5	1	111.1	3	20.2	1	1
28. Buga	55.4	1	52.4	1	44.7	2	1
29. Restrepo	56.7	1	135.1	4	124.8	4	3
30. Dagua	58.0	1	81.8	2	57.3	2	1
31. Vijes	62.7	2	43.1	1	10.8	1	1
32. Guacari	98.8	3	110.3	3	26.3	1	2
33. Ginebra	129.8	4	71.5	2	63.6	3	4
34. El Cerrito	96.7	3	110.3	3	38.9	2	3
35. La Cumbre	51.0	1	40.6	1	16.3	1	1
36. Palmira	65.3	2	80.9	2	37.2	2	2
37. Yumbo	72.6	2	127.6	4	34.6	1	2
38. Cali	59.9	1	61.9	1	14.9	1	1
39. Pradera	54.0	1	131.9	4	63.7	3	3
40. Candelaria	101.0	3	97.1	3	75.5	4	4
41. Florida	94.3	3	128.0	4	61.1	3	4
42. Jamundí	75.1	2	122.0	3	81.3	4	3

*Deaths per 1,000 live births

**Deaths per 100,000 population

FIGURE 2-3
TOTAL INDEX, VALLE DEL CAUCA
(INFANT DEATH, INTESTIONAL DEATH, AVITAMINOSIS DEATH)



infant death, are replaced by a quartile rank. Thus it is possible that a wide variation may exist within the individual quartiles. Then the quartile ranks for several variables are aggregated. A region with below average health indicators for two factors might appear to have average health status if it scores high on a third factor. The value of this approach is that it does combine several noncommensurate measures into a single number that may simplify comparison and still reasonably reflect health status. The quartile index used here is developed purely for illustrative purposes and the author has no intention of suggesting this particular index for use in planning.

CLOSING COMMENTS

How should Colombian health planners extend health services into rural areas? To deal with this extension issue this chapter has posed three questions relating to planning the extension of health services into the rural areas; how to collect, present, and analyze information. While this chapter has illustrated the methods of computer mapping and health indices, the determination of operating norms for Colombia is best left to the Colombian health planners. Given the scarcity of available resources, the decision of where to site health facilities deserves increased attention. The following chapter will examine the use of the present

Colombian health planning methods relating to one service component of the rural health system--the siting of medical vehicles.

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CHAPTER THREE

THE MULTIPLE GOAL MEDICAL VEHICLE SYSTEM

This chapter examines how the Colombian Ministry of Health plans for the use of rural medical vehicles. We enumerate the three goals that govern vehicle deployment and operation and the current work-norm approach to planning. We also discuss how to integrate patient transport into the rural health system.

THE THREE ROLES OF RURAL MEDICAL VEHICLES

The Colombian health system includes primary health promotoras, local and regional hospitals, and urban university medical schools.

Coordination and movement of personnel and materials between institutions is necessary in this type of system. Transportation is especially important for rural facilities that depend upon urban institutions for supplies and supervision.

The Colombian regionalized rural health system moves three commodities--personnel, materials, and patients. Rural medical vehicles move health manpower and medical supplies

between hospitals and rural health outposts. These vehicles also function as ambulances moving those patients requiring emergency and diagnostic treatment to appropriate levels of the regional system.

Physicians, dentists, and registered nurses travel between local hospitals and the rural health outposts. Such professional personnel do not work full-time in the rural areas but rather travel to supervise health personnel or to offer medical outreach services to villagers. These professionals are transported in health system vehicles since public transportation does not reach into most rural areas. Doctors and dentists may post schedules for travel so that rural villagers can travel by foot or burro from other communities for medical services. While travel patterns vary, the usual pattern is for the physician to travel at regular intervals from the local hospital to give medical services (consultas) in the rural villages.

Supervisory nurses travel regularly to villages, rural health outposts, or homes of promotoras to educate rural health workers and evaluate their skills. Skill evaluation is the second component of the promotora supervision program (1). When an auxiliary nurse makes an evaluation she may talk with community leaders about the promotora's performance, check required forms for completeness and accuracy, and accompany the promotora on domestic visits to

evaluate technical skills. Such supervision by hospital personnel is a key ingredient in assuring effective performance because each promotora receives only three months of training (2). According to a recent examination of the promotora role, three months is not sufficient to inculcate skills and a professional attitude:

> ... the training is not adequate without continuing education...without continuing education the promotora feels left out of the health system and usually the ability and dedication begin to drop (3).

The eighty percent annual attrition rate within the promotora workforce may reflect the present lack of continued supervision (4).

The second role of the rural medical vehicles is to move medical supplies from hospitals to the promotoras and the rural health outposts. The drugs and equipment include standard medicines, syringes, thermometers, tape, birth and death record forms, other simple medical instruments, and educational literature promoting sanitation, proper nutrition, family planning, and prenatal care. Because local markets are isolated and sell only essentials, the local and regional hospitals provide the only source for medical supplies.

The third purpose of medical vehicles is to transport patients back and forth from primary care facilities to local and regional hospitals. A patient requiring stitching for a machete wound may enter the health system by visiting the rural promotora. To receive care beyond first aid, the

patient may require transport to a hospital. This referral system can be activated by the decision of either the physician or the promotora. Buses and private vehicles may be used to transport referral cases (5). Since there are few public or private vehicles in rural areas, medical transportation becomes important. This subject of patient transport will be discussed in more detail later in this chapter.

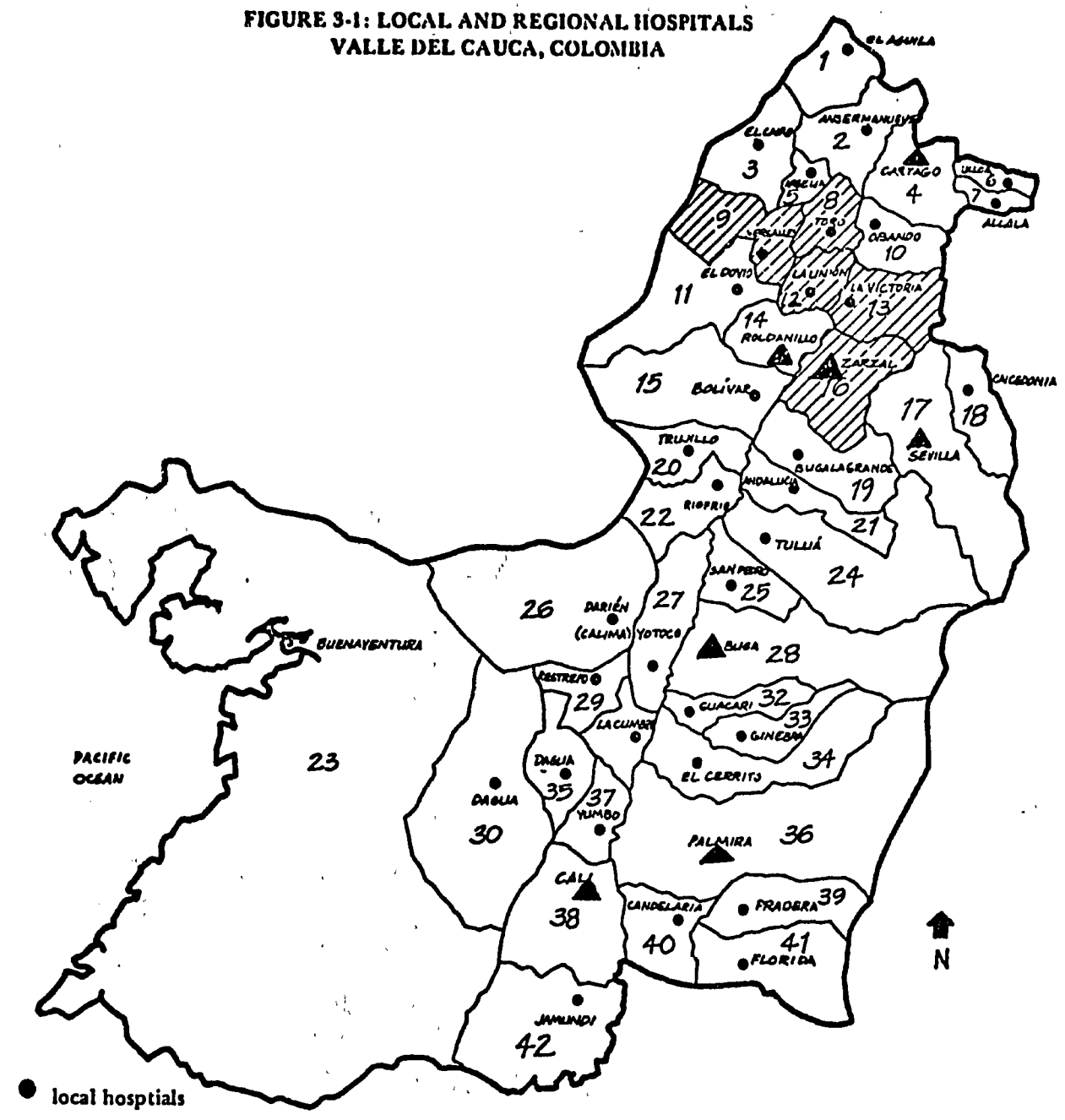
THE VALLE RURAL AMBULANCE NETWORK

The three roles of rural medical vehicles are integrated in the medical vehicle network. A good example of how these roles are reflected in the state and regional level ambulance system planning is the process in the state of Valle del Cauca.

Vehicles in Valle are sited only at local and regional hospitals. According to departmental health planner Dr. Francisco Perez, "We could never consider the possibility of locating them elsewhere" (6). All but one local and regional hospital in Valle has at least one vehicle; the exception is San Pedro (a small county close to the site of regional hospital at Buga). The sites of local and regional county hospitals in Valle del Cauca are illustrated in figure 3-1. Each regional hospital serves between two to seven local hospitals.

All nine regional hospitals have at least one ambulance (7). Five of the 33 local hospitals have ambulances.

FIGURE 3-1: LOCAL AND REGIONAL HOSPITALS VALLE DEL CAUCA, COLOMBIA



The remaining 27 local hospitals use either jeeps or trucks (8). At any given time, about one in eight vehicles is under repair in Cali, the state capital (9). If a hospital's vehicle is out of commission, there is no back-up system to allocate spare vehicles.

The Valle state health service purchases all vehicles and ambulances for the hospitals. There is a two year wait from the time of order of a new vehicle to delivery. The health service takes approximately one year to process a request and another year to fill the request (19). Some vehicles have been financed by the U.S. Agency for International Development (11) and some by the Colombian Health Ministry. Other vehicles are bought by the community directly by funds raised through events such as lotteries or fiestas (12). Such money is donated to the state health department for purchase of a new vehicle for the community.

A patient obtains the use of either an ambulance or a jeep by referral. In theory:

> If someone is sick, he/she goes to the promotora. The promotora decides that the person needs to go to the local hospital. She calls the hospital to request a vehicle. If the vehicle is available, it is sent right away. If not, the patient's family tries to figure out a way to send the patient to the hospital. If the local hospital cannot treat the person, the person is sent directly on to the regional hospital in the same vehicle. The person is automatically accepted at the regional hospital, where an evaluation is made. The vehicle is returned to the local hospital. If the regional hospital can do nothing, the person is sent on to the university hospital in the vehicle belonging to the regional hospital (13).

Hospitals have a driver on duty at all times. However, few drivers have any medical training. When a sick person is transported from the health outpost to the hospital, she or he may be accompanied by the promotora and usually a member of the patient's family. If the patient is referred on to the regional hospital, he or she is accompanied by either a nurse or an auxiliary nurse.

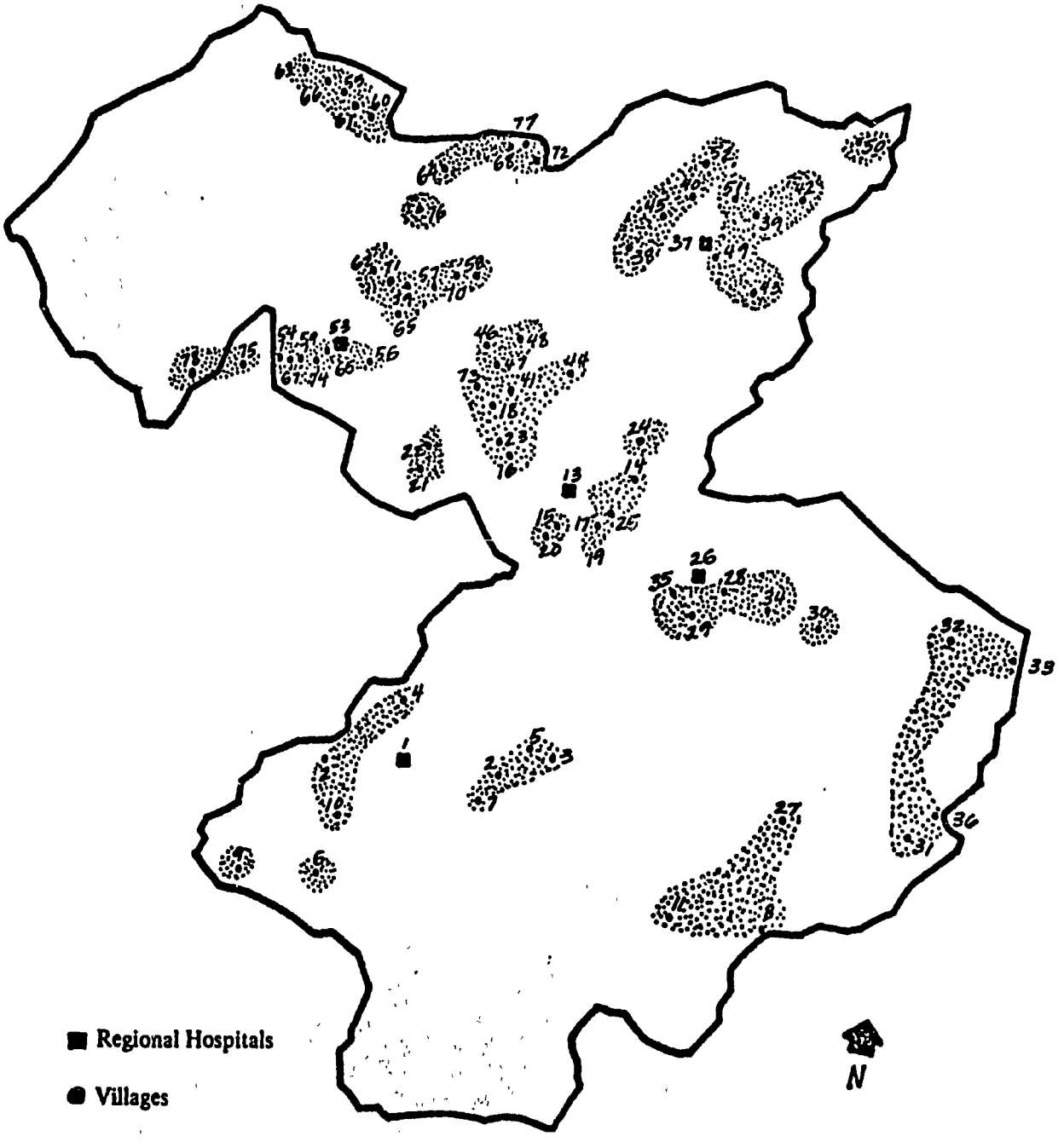
NORMS FOR AND PERFORMANCE OF VEHICLES

Colombian health planners have to date designed the medical vehicle system solely on the basis of two work norms. Sites are determined by a norm that all hospitals have at least one vehicle and that only hospitals can have vehicles. Staffing patterns and the number of drivers are derived from the "ambulance driver hours" necessary to complete specific tasks for a period of one year. This figure is divided by the hours a driver can work. The result is the number of ambulance drivers necessary to meet the project needs for ambulance use in that year.

The planning task of calculating the number of vehicle drivers can be illustrated with data from Zarzal, a five county health planning region north of Valle. Zarzal is subdivided into 23 planning units called "primary health zones" as illustrated in figure 3-2. Each zone contains between one and seven rural villages. The time to travel by car between the hospital and each health zone is known (14).

FIGURE 3-2

PRIMARY HEALTH CARE ZONES, ZARZAL, VALLE DEL CAUCA, COLOMBIA



To calculate the driver hours for one normal visit, the round trip travel time from the hospital to the health zone is added to a one hour vehicle preparation time. This service time for one visit is multiplied by 52 visits per year because each health zone is to be visited weekly. The total vehicle driver hours for the Zarzal region is the sum of the annual service travel times for all health zones. For example, health zone number one contains the villages of Una de Gato, Zambrano, and El Vergel. The estimated round trip travel time from the hospital to the zone is one hour. This hour is added to the one hour preparation time and then multiplied by fifty-two annual visits. The resulting figure, 104 hours, is the estimated number of ambulance driver hours needed to provide the projected level of service to the health zone. This can be calculated for each of the 23 health zones, as illustrated in figure 3-3.

How well does the medical vehicle system achieve its goals? The present method of estimating required ambulance driver hours does calculate the "expected" travel needs to maintain rural health supplies and supervision. The method does not take into consideration emergency shipment of goods or unscheduled supervision visits. Emergency situations arise when sufficient drivers are unavailable both for shipment of goods and transport of personnel. Such a "system overload" is one of the risks that Colombian health planners appear to be willing to assume.

FIGURE 3-3
ZARZAL AMBULANCE PLANNING

PRIMARY CARE LEVEL	VILLAGE	SERVICE TIME (hours)	PREPARATION TIME (hours)	ACTIVITY LEVEL	TOTAL TIME (hours)
1	UÑA DE GATO ZAMBRANO EL VERGEL	1.00 Hr.	1 Hr.	52	104
2	LA PAILA	.5 Hr.	1 Hr.	52	78
3	RIO PAILA	.66 Hr.	1 Hr.	52	86
.					.
.					.
.					.
23	SAN FRANCISCO	1.00 Hr.	1 Hr.	52	104
			TOTAL ANNUAL DRIVER TIME		2,545

Source: Servicio Seccional de Valle, *Censo y Diagnostico Sanitario de Salud de Zarzal*, Cali, Colombia: Colombian Ministry of Public Health, December 1977.

If vehicle deployment is evaluated solely in terms of personnel and supply transportation, then the location of vehicles at hospitals is quite efficient. Both medical supplies and medical personnel are stationed in hospitals. A medical vehicle site located outside of a hospital would have to first travel to the hospital to pick up supplies and personnel before servicing the rural villages. The medical vehicle would then be required to return medical personnel to the hospital before it could return to its dispatching site. The addition of two non-negative numbers to the round trip hospital-village travel time must exceed that travel time. Thus, the movement of goods or personnel by vehicles located at hospitals must be the sites that minimize total travel time.

The present system is convenient for the medical personnel and is optimal for moving medical personnel and supplies. But does it also move patients adequately? The planning basis of vehicle deployment does not take patient transportation into consideration. As illustrated in figure 3-3, staffing is based only on personnel and supply considerations. Indeed, if ambulance drivers worked according to schedules, there would not be time available for patient transportation. Why are these elements of workload not included in planning, even though vehicles do transport patients? Perhaps it is because, as with peak demand, patient transportation is hard to forecast. This lack of planning

can affect the outcome of emergency cases requiring immediate attention. Some patients may wait for hours by a road until a passing truck or car can transport the patient to the local hospital (15). Hospital sites may not be ideal vehicle sites if fast patient conveyance for a large portion of the rural population is important.

Present Colombian planning methods fail to adequately account for emergency ambulance services in two ways. The present framework fails to consider unanticipated emergency use of vehicles for movement of materials and medical personnel. Current methods also may not provide the best locations for emergency services.

INTEGRATING PATIENT TRANSPORTATION INTO AMBULANCE PLANNING

Present Colombian planners do coordinate and distribute manpower and supplies through the use of medical vehicles. Although patient transportation is an explicit goal of the system, vehicles are deployed in Colombia without consideration of vehicle demands for patient referral, accidents, or emergencies. As sanitation and preventative health campaigns improve health in rural Colombia, trauma and chronic diseases will become of increasing relative importance versus environmental and vector borne diseases. These chronic diseases will place increasing demands for a system of patient transportation.

If the medical vehicle system evolves from logistics support to patient transport, it will parallel the patient-oriented ambulance system that has become dominant in other nations. In some developed countries the primary function of medical vehicles has become intervention in trauma cases to bring a patient into the medical system in the shortest possible time. As patient transportation becomes more important, the role of "time" as a measure of value will increase.

"Time" is the one variable that relates to each of the multiple goals of the rural medical vehicle system. Even non-emergency uses employ "time of travel" in planning; deployment patterns reflect the driver hours required to provide a fixed amount of supervision and quantity of equipment to the rural health care facilities. Patient transportation is directly related to the concept of "critical time", defined as the maximum time from event occurrence to irreversible patient damage. Poisonings, machete wounds, or caesarean deliveries do not wait for medical intervention.

Present Colombian planning procedures do not explicitly consider (a) the number of vehicles; (b) the maximum time for travel; (c) the population covered; and (d) minimizing costs. Response times* or service times** are not

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* Response time is time elapsed from the dispatch of an ambulance and the arrival of an emergency vehicle at the emergency scene.

** Service time is the time from the dispatch of the ambulance to the arrival of a patient at a hospital.

integrated in ambulance planning. An accident victim in the rural Zarzal village of El Cedral is considered by health planners to be adequately served by the medical vehicle system even though it will take an ambulance at least four hours to travel from the hospital to the village and back.

An alternative paradigm is the United States' method of planning emergency medical services. Operational norms using population coverage and travel time for this type of ambulance system are established by law. The emergency medical systems are mandated to provide ambulance coverage to 95 percent of urban service demand within 10 minutes and within 30 minutes to rural areas (16).

Suppose that Colombian health planners wanted to incorporate maximum travel time into planning for emergency medical vehicles. How well does the present system perform in these terms? How would explicit inclusion of patient transportation affect manpower and equipment transportation goals? Later chapters in this study will describe how Colombian health planners might construct a planning system based on maximum service times. Because such planning may involve computer analysis it may be useful to review previous work as a basis for developing an approach appropriate to the needs of emergency vehicles in rural Colombia.

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CHAPTER FOUR

REVIEW OF EMERGENCY MEDICAL SERVICE LOCATION METHODS

This chapter reviews the development and use of location planning methods to site emergency medical services (EMS) vehicles. Methods of planned EMS vehicle deployment have been developed over the past fifteen years in response to the increasing geographical, social, and economic complexities involved with planning public services (1). It is beyond the scope of this study to describe all the literature on facility location. Indeed, such a review is unnecessary since excellent reviews of the general location literature (2) and the EMS literature (3) already exist.

This review will focus on public, as opposed to private sector location problems. ReVelle, Marks, and Liebman note that while private and public problems are similar in many respects and build upon a common conceptual foundation, there are distinct differences between private and public objectives (4). Private sector analyses tend to stress "profit maximization " or "cost minimization" goals, based upon monetary quantification of costs or profits. The difficulty of assigning monetary value to public goals is explored

by Rivlin (5). While budgetary funds are clearly public sector constraints, public sector location requires the determination of some quantifiable surrogate for public welfare other than financial goals.

One approach is to use average travel time or distance as surrogates for public welfare (6). The statement of this so-called P-median problem is:

> Locate p facilities on a network of demands so that the average travel time/distance of all users is a minimum.

In other words, facilities should be sited at that point which minimizes the average travel time or distance of either consumers or providers of a public service. By assumption, the smaller this travel time or distance is, the greater the public accessibility and utilization of the service. This problem was translated by ReVelle and Swain (7) into:

> Minimize the total weighted travel distance associated with a network of demand nodes by locating p-facility location points on the network (on arcs or at nodes) where each demand is served by its closest facility.

Certain public services, such as libraries, schools, and day-care centers, are classified by ReVelle, Marks, and Liebman as "ordinary public services," and are appropriate for the p-median model (8). The objective is to minimize the average travel time of all the demand points to the sites of services or vice-versa. The budget constraint is reflected by a limitation on the number of facilities that can be established.

Mean travel time is an appropriate welfare surrogate for ordinary public services. In other classes of public services, notably fire, police and ambulance services, "mean travel time" does not deal directly with individual travel time, and thus suffers as a welfare surrogate. An alternative measure of benefit, a maximum service time or distance that an individual would have to travel in order to consume a service, was developed by Toregas and others (9).

Maximum service distance or time is a better parameter for siting emergency-related services because it establishes an upper limit on the response time to all individuals who use the service. The original "set covering" problem that used maximal service time/distance can be stated as:

> Find the minimum number of facilities and their locations such that each point of demand has a facility within S time or distance units.

Toregas, et. al. solved this set covering problem on a hypothetical 30 node network with mixed integer programming. The authors also demonstrated the applicability of set covering to a modified form of the p-median problem. This notion of "worst case time" is further explored in Toregas and ReVelle (10). They point out that maximum service or critical time can be utilized as a surrogate for the level of facility utilization.

Users of emergency facilities also conceptualize their problem in terms of maximum time. As the National

Board of Fire Underwriters state in their standards:

> To accomplish quick response of the first due company, no point in any high value district shall be more than three-fourths mile travel distance from an engine company--or more than one mile from a company providing adequate ladder service; in residential areas the requirements are respectively one and one-half miles and two miles for closely built sections and up to three miles for each class where buildings are scattered (11).

Further examples of policy objectives are given in relation to emergency health services by Huntly (12):

> How many ambulances? Are they enough? What is an acceptable response time? Usually in a metropolitan area it is 15 minutes. Certainly this response time cannot be expected in rural areas. If a 15 minutes response time is demanded, where must they (the ambulances) be positioned to provide reasonable assurance that this criteria is met?

In short, maximum time to service is a meaningful measure for decision makers and individual consumers. There is an explicit trade-off between the number of facilities and the maximum time to service. Toregas and ReVelle suggest that the trade-off can be made explicit as in a cost effectiveness curve that would show how maximum travel time or distance decreases as the number of facilities increase to provide a service.*

The problem is termed "set covering" because a set of facilities can provide coverage for each point of demand within a maximum travel time. This problem is a special form of

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*The cost of a facility is assumed to be constant.

the integer-programming problem investigated by Toregas et.al. (13). Toregas and ReVelle show that reduction techniques can solve some problems (14).

Church and ReVelle developed a new objective, population coverage, to use along with maximal service time (15). They found that for any number of facilities there may exist a number of alternative optimum location configurations that meet the same maximum service time. Also, for some the number of facilities, total coverage at some maximum service time might not be possible. Church and ReVelle were interested in how to provide service for the largest segment of population possible, subject to budget constraints and maximum service times. Recall that the p-median problem utilizes the concept of total population and set covering does not deal with population at all. Church and ReVelle use the fraction of covered population served within the established service time as the surrogate for public welfare. As in the set covering problem, a trade-off curve can be developed examining the relationship between expenditures (facilities) and the population covered under an established service time. Their problem, called the "Maximal Covering Location Problem" (MCLP) is stated as:

> Maximize coverage (population covered) within a desired service distance S by locating a fixed number of facilities.

Realities of scarce resources combined with the dynamics of critical time in emergency services provide situations in which fulfillment of complete population coverage may be limited by financial and political constraints. The public statements of policy makers recognize goals stated in terms of both maximum service time and population coverage. One example, cited earlier in this chapter, is the Emergency Medical Services Act of 1973, Public Law 93-154. Another example is the Carnegie Commission on Higher Education proposal for national health centers located across the nation so that 95 percent of the population would be within one hour's travel from hospital services (16).

Church and ReVelle extend maximum covering to include the problem of covering all demand for a specified service time S., while maximizing coverage of demand for a shorter secondary service time T (where $T > S$). For example, a legal standard EMS response time might be set at 10 minutes for all the population ($S=10$). The problem of improving critical life support performance might be to cover as many persons as possible in less than four minutes ($T=4$). Maximal covering can find the location configurations that cover the largest percentage of population receiving services under T while meeting the legal standard of S. Church and ReVelle describe this "maximal covering

location with mandatory closeness constraints" problem as:

> Locate a fixed number of facilities in order to maximize the population covered within a service distance T, while maintaining mandatory coverage within distance S (T > S).

Church solved the maximal covering location problem with either two heuristics or mixed integer programming (17). One heuristic, called "Greedy Adding" (GA), finds sites that maximize the total coverage of each increamental facility. GA begins with an empty solution set and adds a facility if it proves to cover the most population. While the first facility will be optimal, by definition, the later solutions are not guaranteed to be optimal.

A second heuristic, called "Greedy Adding with Substitution" (GAS), is similar to GA but adds a substitution process. After each new location selection, GAS also seeks improvement (more population coverage) by testing whether substitution of any single facility in place of those selected in previous iterations would improve the solution. In a testing on a 55 node network, both of these heuristics obtained optimal coverage (as verified through mixed integer programming) more than 90 percent of the time.

One of the limitations of the so called context free approaches, p-median, set covering, and maximal covering, is that they do not allocate staff to vehicles or determine the number of vehicles at a particular facility site. The issue of "which drivers will use what vehicles, deployed

from which facilities?" is not addressed. A facility is cast in a role of an infinite supplier of services. One ambulance cannot provide services to two emergencies at the same time. Toregas and ReVelle propose a combination of context-free location and simulation queueing methods to simultaneously solve the staffing, deployment and location problems (18). Daberknow and King (19) and Berlin and Liebman (20) use these suggestions in their work of locating emergency medical facilities in rural California and Maryland respectively.

Berlin, ReVelle and Elzinga (21) extend these approaches to include response patterns other than one-way travel time. Return link times are developed between (a) point of rescue to point of ultimate service and (b) point of patient release to point of vehicle dispatch.

The problem of multi-objectives in location of emergency facilities (fire stations) is developed at length by Schilling (22). Working specifically with the siting of fire stations in Baltimore, Maryland, Schilling is faced with the problem of siting multiple services (fire engine pumpers and ladder crews) to serve multiple demands based on: (a) fire hazard to property; (b) fire hazard to population; (c) property value hazard; and (d) fire frequency. Schilling solves this multi-objective problem using variations of a dynamic maximal covering model. The use of this type of model allows for incremental changes in supply and demand. The relevancy of planning for a changing supply and demand is

explained by Schilling:

> The public budget is rarely large enough to construct an entire system at once. The construction must be spaced out over several years within an overall planning horizon. This extended development process may also occur when sufficient demand does not exist at present to justify building the entire system. This is particularly true in developing countries or regions where substantial growth is expected (and being planned for). The current population, while requiring service, would not utilize the entire capacity of the total system.

This review has illustrated how the maximal covering approach allows health planners the means to site facilities so as to maximize population coverage, minimize service time, and minimize facilities. Given the resource constraints and growing demands for emergency services, countries such as Colombia might benefit greatly from location analysis techniques.

NEW DEVELOPMENT IN THE MAXIMAL COVERING MODEL

One of the goals of this study is to develop a procedure to site medical vehicles in rural Colombia. This study represents an attempt to apply a number of the ideas discussed in the preceding section in the context of delivering emergency services. It also develops questions that have yet to be resolved in a maximal covering context.

For instance, this study formulates and analyzes emergency services using both "response time" and "service time" measures. This is similar to various "impedance measures" used by Berlin, ReVelle, and Elzinga. While they

formulated this problem in a verbal and mathematical form, it has yet to be applied to a field problem.

The standard approach used in solving the maximal covering problem is to begin with an empty solution set. Facilities are added via an assumption of a null set of existing facilities. Also, facility sites are selected usually without restrictions--any demand site can serve as a facility site. In contrast, the problem addressed within this study is how to evaluate the performance of the present facilities and to extend an existing system. This problem of location and/or analysis and extension of a system is addressed by Schilling; however, his results have yet to appear in the literature. This study also follows Schilling in the use of multiple objectives. However, Schilling is concerned with emergency fire services and this study is concerned with emergency medical vehicles.

This study also represents a first attempt to apply maximal covering to the problems of a developing country. The need for this kind of planning procedure for allocating resources in developing countries is explored in Eaton, et. al. (23).

As previously noted, the procedures to site facilities in Colombia are firmly established. If Colombian health planners incorporate additional norms such as "maximal travel times" in ambulance planning, they may find that

the present medical vehicle sites cannot adequately service the total population. Improvement in population may result only through adding new facilities. Is any site acceptable for a facility? If not, what criteria must be established for tending ambulance sites? Such criteria have not been developed prior to this study.

Finally, the "multiple goals"--above and beyond the use of multiple objectives of the medical vehicle system--provide unique circumstances for application of maximal covering. How will the goals of medical personnel and supply transfers relate to patient transport? The following chapters will attempt to answer these questions posed here by developing and applying a maximal covering approach to site medical vehicles in the Zarzal health region in Colombia.

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CHAPTER FIVE

LOCATING AMBULANCE FACILITIES THROUGH MAXIMAL COVERING

Present Colombian health policy restricts the location of ambulance facilities to local and regional hospitals. Vehicles are designated to cover every village in a political jurisdiction, without regard to the amount of time it might take to travel there. If patient transport would become important, maximum travel time could be used as a measure of the performance of the present medical vehicles. This chapter develops a maximal covering formulation to evaluate (a) the present rural ambulance system in the Zarzal region of Colombia and (b) to find sites for possible new vehicles. The formulation must account for present and potential restrictions that might be placed on the location of additional sites for medical vehicles. This formulation represents a special case of the formulation of Church and ReVelle (1).

POTENTIAL FACILITY SITES

Let each of m rural villages in the Zarzal region be considered a point of ambulance demand i, i=1,2,...,m. Let I be the set of all rural villages. Let j be any potential facility site for a rural medical vehicles, where there are n possible vehicle sites,

$j=1,2,\ldots,n$. Let J be the set of all possible ambulance sites.

Time of Travel

When an ambulance based in site j is called by a patient from village i, four activities must take place prior to receipt of treatment by the patient. First, there is an initial delay from the time of the call for service to the dispatch of the medical vehicle. Next the vehicle must travel from dispatch site j to village i. Third, after the ambulance arrives at village i, time is taken to find and load the patient. Additional time may be taken at village i to obtain gasoline or take care of other essential tasks. The final step is transporting the patient from village i to the nearest hospital. This service time can be expressed as:

$$v_{jih} = t_j + d_{ji} + t_i + d_{ih} \tag{5-1}$$

where v_{jih} = time for a patient from village i to receive service at a hospital h after transport by an ambulance dispatched from site j

t_j = time to prepare at dispatch site j

d_{ji} = time of travel from dispatch site j to village i

t_i = time to prepare for exit from village

d_{ih} = time of travel from village i to hospital h

h = an index of hospitals, $h=1,2,\ldots l$, $h \varepsilon H$

In order to forestall some unpleasant patient outcomes, planners may wish to limit the amount of time the patient must wait prior to service. Suppose that S minutes is the maximum time that a patient should wait prior to the

treatment. The task of a medical vehicle now becomes to complete the service trip from dispatch site j to village i to hospital h within S minutes. In order for an ambulance depot to be able to serve village i, it is necessary for the service time to be below S minutes, or

$$v_{jih} \leq S \tag{5-2}$$

In gathering information on ambulance siting in Zarzal, it was not possible to obtain all the data required by equation (5-1). In particular, it was not possible to obtain (a) t_j, the time to prepare for an ambulance to leave its station after a call for service and (b) t_i, the time to find the patient after arriving at village i, load the patient, and buy gasoline or accomplish other tasks before leaving village i. Assume that t_j and t_i are constants, say 5 and 10 minutes respectively in a hypothetical case. Let a constant k be defined as as their sum, or 15 minutes in this illustration. Then equation (5-1) can be re-written as

$$v_{jih} = d_{ji} + d_{ih} + k \tag{5-3}$$

$$\bar{v}_{jih} = d_{ji} + d_{ih} \tag{5-4}$$

where $\bar{v}_{jih}$ is equal to v_{jih} minus the constant k, which is equivalent to $t_i + t_j$. Then equation (5-2) would be

$$d_{ji} + d_{ih} \leq (S-k) \tag{5-5}$$

If hospitals are perceived as the only possible sites for

medical vehicles, then travel will be only from hospitals to villages and return to hospitals. The response time standard for patient transport would become:

$$d_{hi} + d_{ih} \leq (S-k) \quad \text{or} \quad \bar{v}_{hih} \leq S \tag{5-6}$$

Let $\bar{S}$ represent (S-k). If the travel time from hospital h to village i is the same as return travel time, then

$$d_{ih} + d_{ih} \leq \bar{S} \tag{5-7}$$

or

$$d_{ih} \leq \tfrac{1}{2}\bar{S} \tag{5-8}$$

If sites other than hospitals are allowed to serve as potential bases for medical vehicles, they would be selected only if the time of travel from village j to village i to the nearest hospital h is less than the time of travel from any hospital h to village i back to nearest hospital h, or

$$d_{ji} + d_{ih} < d_{hi} + d_{ih} \tag{5-9}$$

or

$$d_{ji} + d_{ih} \leq 2d_{ih} \leq \bar{S} \tag{5-10}$$

when the travel time matrix is symmetric. If symmetry exists, then we can write equation (5-10) as:

$$d_{ji} + d_{hi} \leq 2d_{ih} \leq \bar{S} \tag{5-11}$$

There is no reason to select an alternate site j unless $d_{ji} \leq d_{hi}$. Thus:

$$d_{ji} + d_{ji} \leq 2d_{ih} \leq \bar{S} \tag{5-12}$$

It must always hold that

$$2d_{ji} \leq \bar{S} \tag{5-13}$$

or

$$d_{ji} \leq \bar{S}/2 \tag{5-14}$$

Therefore site j will be considered as a potential ambulance base to cover area i if and only if

$$d_{ji} \leq d_{hi} \leq \bar{S}/2 \tag{5-15}$$

To summarize, a potential facility site j is one from which a vehicle can reach village i in less than $\bar{S}/2$ minutes. The set of potential facility sites can be defined as:

$$D_i = \{j | d_{ji} \leq \tfrac{1}{2}\bar{S}\} \tag{5-16}$$

where D_i is the set of potential sites. The assumptions regarding travel and the rationales for their use are listed in table 5-1. It is true that these assumptions will be used in later analyses and should be made explicit here. However, the methods for ambulance deployment

and extension can accommodate each of the alternate assumptions listed in table 5-1.

Restrictions on Potential Medical Vehicle Sites

One restriction on the set of potential medical vehicle sites is that each site must be able to serve an associated village in less than some maximal service time (equation 5-16). Present Colombian health policy further restricts medical vehicles to local and regional hospitals. This restriction is stated as

$$H = \{j \mid j \text{ is a hospital}\} \tag{5-17}$$

If N_i is the set of potential facility sites that meet both travel time and hospital restriction, then

$$N_i = D \cap H \tag{5-18}$$

Restricting vehicle sites to hospitals, and defining coverage via travel time may create a situation in which fewer than 100 percent of the population can be covered. Imagine that health planners wish to extend the ambulance system beyond the confines of hospitals in order to cover a larger fraction of the population within some time standard. Further suppose that only some villages are suitable sites for a vehicle depot. A suitable site might require the existence of services, such as electricity, gasoline and oil, auto repair, and living facilities for a crew. Zarzal health planners might consider population size of a village as a useful surrogate for these factors,

TABLE 5-1
LIST OF ASSUMPTIONS REGARDING TRAVEL TIME

Item	*Definition*	*Rational*	*Possible Alternate Assumptions*
t_j = constant	preparation time at dispatch site j	information unavailable	$t_j \neq$ constant
t_i = constant	preparation time for exit at demand site i	information unavailable	$t_i \neq$ constant
use $[d_{ij}]$ matrix rather than $[d_{ih}]$ matrix	non-hospitals will be used as facility sites only when they reduce time of travel from the facility site to the site of the emergency. Hence $d_{ji} + d_{ij}$ understates $d_{hi} + d_{ih}$	computational convenience	use d_{ih} rather than d_{ij}
$d_{ij} = d_{ji}$	symetrical travel times	computational	$d_{ij} \neq d_{ji}$

whatever they may be. For example, planners may find that only villages with more than 900 inhabitants are likely to meet the requirements for a vehicle facility site and that additional vehicles should be located in only those villages with more than 900 population. This restriction is written as

$$P = \{j \mid \text{the village } j \text{ has a population that exceeds 900 inhabitants}\} \tag{5-19}$$

The set of facility sites that meet both travel time and village size restrictions in serving village i can be defined as

$$N_i = D_i \cap P \tag{5-20}$$

Population size might not be the only factor that health planners would wish to consider in extension. Another limitation on medical vehicle facilities might be the presence of a rural health care facility. The rationales behind this restriction could be (a) the existence of persons with medical skills at a rural health care facility and (b) the existence of some demand for patient referral function from the rural health post. This restriction may be written as

$$M = \{j \mid \text{the village } j \text{ has an existing rural health facility and/or personnel}\} \tag{5-21}$$

The set of potential facility sites that meet travel time, village size and existing health facilities/personnel restrictions in serving village i can be defined as:

$$N_i = D_i \cap P \cap M \tag{5-22}$$

In summary, the formulation must account for (a) present restrictions on sites and (b) potential restrictions that might be placed on the location sites for medical vehicles. These restrictions are shown in table 5-2. The list of potential restrictions is not all inclusive. Colombian health planners might select other restrictions that better reflect the special characteristics of the Zarzal region and/or the rural ambulance system. Potential restrictions may be added to the maximal covering formulation to enhance its use in locating vehicle sites. Restrictions may be used singularly or in combination with other restrictions. The effect of a restriction is to reduce the set of potential facility sites to only those sites that meet all the requirements of health planners. Multiple restrictions limit facility sites to that subset derived from the intersection of the sets of each restriction. The use of restrictions will be discussed in greater detail in subsequent chapters.

THE CONSTRAINT SET AND OBJECTIVE FUNCTION

Consider the following variable definitions*:

$$x_j = \begin{cases} 1 \text{ if an ambulance is located at site } j \\ 0 \text{ if otherwise} \end{cases} \qquad j=1,2,\ldots,n \tag{5-23}$$

---

*See Church and ReVelle (1).

TABLE 5-2
FORMULATION OF PRESENT AND POTENTIAL
VEHICLE LOCATION RESTRICTIONS

Restriction	*Status*	*Formulation*
travel time	potential	$D_i = \{ j \mid d_{ij} \leq \frac{1}{2}\bar{S} \}$
hospital location	used in present planning	$H = \{ j \mid j \text{ is a hospital} \}$
village population	potential	$P = \{ j \mid \text{village } j \text{ has a population that exceeds 900 inhabitants} \}$
health facilities and/ or personnel	potential	$M = \{ j \mid \text{village } j \text{ has an existing rural health facility or health personnel} \}$

The decision as to whether a village i is "covered" or not can be stated as

$$y_i = \begin{cases} 1 \text{ when village } i \text{ is covered} \\ 0 \text{ if otherwise} \end{cases} \qquad i=1,2,\ldots,m \qquad (5\text{-}24)$$

In order for a village to receive ambulance services (to be covered), at least one ambulance facility must be located at a site that will cover it. This constraint can be stated as*:

$$\sum_{j \in N_i} x_j \geq y_i \qquad i=1,2,\ldots,n \qquad (5\text{-}25)$$

where N_i is the set of sites that are eligible to serve.

In most developing country contexts, some limit will exist on the budget for constructing facilities. Assume that all vehicle sites are similar and thus a health planner can calculate a cost per vehicle site. If these costs are added together, there will be some limit P on the number of sites that can be built.

$$\sum_{j=1}^{n} x_j = P \qquad (5\text{-}26)$$

Placing an upper limit on the number of ambulance facilities creates the possibility that it may not be possible to provide 100

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*See Church and ReVelle (1).

percent coverage to all points of demand. Consequently, specific villages (and more importantly the population a_i associated with each village i) may not receive the benefits of coverage from the emergency ambulance system. The consistent objective of the Colombian government has been to enhance the access of the rural population to health care (2). No systematic information is currently available regarding the "demand" for emergency patient transport. If a planner can assume that "population size" is a good surrogate for "emergency demand," the way to provide the best access is to maximize the sum of the covered populations of villages. This objective can be written as

$$\text{Maximize } Z = \sum_{i=1}^{m} a_i * y_i \tag{5-27}$$

where a_i represents village population as measured by census. As more villages are covered, the value of Z will increase.

Table 5-3 illustrates the complete formulation used in this study to site medical vehicles in Zarzal. This formulation is a special case of the maximal covering location problem developed by Church and ReVelle (3), as shown in table 5-4. The difference is that the set N_i has been defined in terms of the Colombian rural medical vehicle problem.

CONCLUDING STATEMENT

This chapter has developed a specific form of the maximal covering location problem for evaluation of emergency medical vehicles

TABLE 5-3
COLOMBIAN MEDICAL VEHICLE PROBLEM

$$\max Z = \sum_{i=I} a_i * y_i$$

subject to:

$$(1) \quad \sum_{j \in N_i} x_j = P$$

$$(2) \quad \sum_{j \in N_i} x_j \geq y_i$$

$$(3) \quad x_j = \begin{cases} 1 \text{ if an ambulance facility is located at } j \\ 0 \text{ otherwise} \end{cases}$$

$$(4) \quad y_i = \begin{cases} 1 \text{ if demand node is served by an ambulance} \\ 0 \text{ if otherwise} \end{cases}$$

Definitions

I = denotes the set of demand nodes
J = denotes the set of facility sites
a_i = population of node i
P = number of ambulance facilities to be located
N_i = set of potential ambulance sites that can serve village i
N_i = $D_i \cap$ (some subset of H and/or P and/or M)
d_{ij} = the shortest distance from node i to node j
$\bar{S}$ = maximum service distance or time
H = $\{ j \mid j \text{ is a hospital} \}$
P = $\{ j \mid \text{the village } j \text{ has a population that exceeds 900 inhabitants} \}$
M = $\{ j \mid \text{the village } j \text{ has an existing rural health facility and/or personnel} \}$
D_i = $\{ j \mid d_{ji} \leq \frac{1}{2} \bar{S} \}$

TABLE 5-4
THE MAXIMAL COVERING FORMULATION

$$\text{Max } Z = \sum_{i \in I} a_i y_i$$

$$\text{s.t.} \quad \sum_{j \in N_i} x_j \geq y_i \qquad \text{for all } i \in I$$

$$\sum_{j \in J} x_j = P$$

$$x_j = (0,1) \qquad \text{for all } j \in J$$

$$y_i = (0,1) \qquad \text{for all } i \in I$$

where,

- I = denotes the set of demand notes;
- J = denotes the set of facility sites;
- S = the distance beyond which a demand point is considered "uncovered" (the value of S can be chosen differently for each demand point if desired);
- d_{ij} = the shortest facility distance from node i to node j
- x_j = $\begin{cases} 1 \text{ if a facility is allocated to site } j \\ 0 \text{ otherwise;} \end{cases}$
- N_i = $\{ j \in J \mid d_{ij} \leq S \}$;
- a_i = population to be served at demand node i;
- P = the number of facilities to be located.

policies in Colombia. The use of maximum service time allows Colombian health planners to better evaluate the present coverage of their medical vehicle system. Quantifying the extent of population covered by emergency ambulance services also allows health policy makers to better evaluate the need for expanding the present medical vehicle network. This chapter has shown how the maximal covering approach of Church and ReVelle can be used to determine rural medical vehicle locations. The following chapters apply this maximal covering approach to the evaluation of the current system and to the location of possible extensions in the Zarzal region of Valle del Cauca, Colombia.

REFERENCES FOR CHAPTER FIVE

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"The Maximal Covering Location Problem," Papers of the Regional Science Association, 32:101, Fall 1974.

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Plan Nacional de Salud: Primera Fase -- Nivel Local, Bogota: Ministerio de la Salud Publica, November 3, 1975, p. 1.

(3) Church, R., and C. ReVelle, op. cit.

CHAPTER SIX

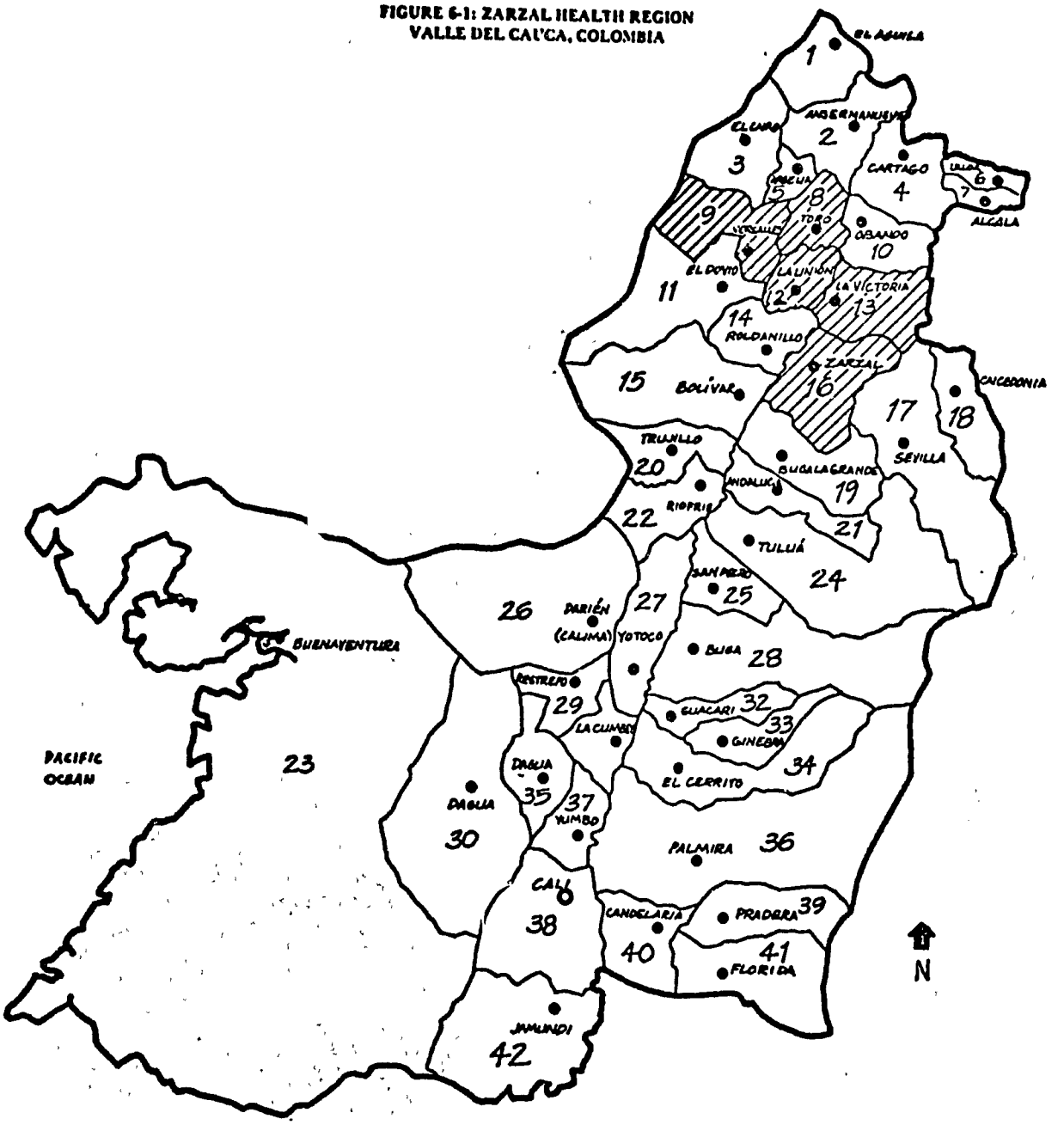
RURAL MEDICAL VEHICLE LOCATION IN ZARZAL

One purpose of this study is to explore alternatives for the allocation of scarce medical vehicles in a way that will best integrate patient transport into health planning. As a basis for that analysis, one section of this chapter describes the area used to illustrate these methods, the Zarzal health planning region. A second section presents the sources and limitations of data used to site rural medical vehicles.

THE ZARZAL PLANNING REGION

The Zarzal health planning region is a region in the north of the state of Valle del Cauca, consisting of five counties: Zarzal, La Union, La Victoria, Toro, and Versalles. The combined size of these five counties is 1,281 square kilometers, or about two-thirds the size of Rhode Island. The region is bordered on the east and the west by ranges of Andes Mountains, the Occidental and Central Cordillera. The region is illustrated in figure 6-1. The Cauca river, running from north to south, divides the region almost

FIGURE 6-1: ZARZAL HEALTH REGION
VALLE DEL CAUCA, COLOMBIA



in half. Many of the regional citizenry earn their living through agriculture, producing a variety of crops that include cane sugar, soya, sorghum, grapes, and corn in the central valley, and Colombian coffee grows in the highland area of the Andes (1).

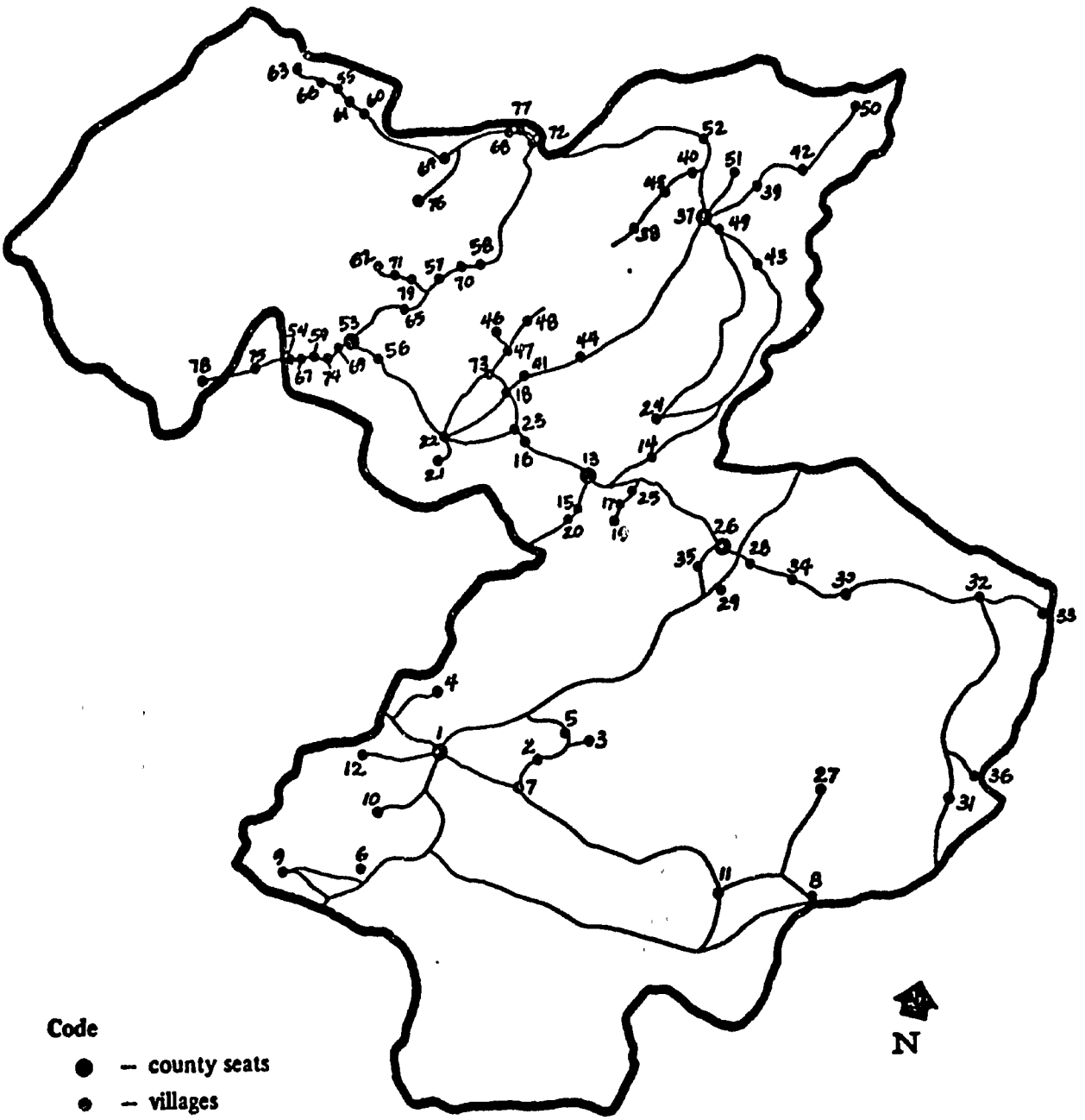
Approximately 25,000 of the Zarzal region's inhabitants live in areas that are classified as rural (2). These residents live in and around 74 villages illustrated in figure 6-2. A series of roads connect the villages and the county seats. The Pan American highway, a paved two-lane highway, extends the length of the region. The other roads in Zarzal are for the most part unpaved, but are passable by vehicles throughout the year. Public transportation (buses and taxis) provide service between the various county seats on a scheduled basis. However, public transportation between rural villages is almost non-existent.

The regional hospital is located in the city of Zarzal. It is a 47 bed facility and has both an ambulance and service vehicle. The remaining four counties each have a local hospital, ranging in size from La Union (11 beds) to Toro (16 beds) to La Victoria (17 beds) to Versalles (23 beds). Each local hospital owns some kind of medical vehicle.

The status of rural health in the Zarzal region has been described in chapter two and Appendix A. The area is consistently represented as having poor health as measured

FIGURE 6-2

VILLAGES, COUNTY SEATS, AND ROADS IN ZARZAL



Code

● – county seats

• – villages

Numbers represent village reference numbers

Lines between villages indicate roads

Source: Bennett , Vivienne, *The Use of Location Analysis for Siting Health Promotoras in Rural Colombia*, Austin, Texas: Lyndon B. Johnson School of Public Affairs, The University of Texas at Austin, 1978, p. 60.

by nearly every factor presented. The health status index developed in chapter two (using infant mortality, intestinal, and nutritional related mortality) shows a difference between the health status of the individual counties. The index, shown in figure 6-3, lists Toro in the "worst" category and La Victoria and Versalles in the "best" category.

DATA REQUIREMENTS

The maximal covering formulation used in siting rural medical vehicles for this project was developed in chapter five. Associated with this formulation are a specific number of data requirements. The formulation, along with the required data, is presented in table 6-1. Six distinct categories of information can be seen. These are: (a) population of each rural village, (b) the location of existing ambulance sites, (c) the distances/times between each village, (d) the identification of those villages with populations greater than 900 inhabitants, (e) the location of existing promotoras, and (f) a maximum allowable travel time. These information requirements can be divided into two primary types: census and transportation information.

Census Information

The census information came from two sources, the National Census Bureau (DANE), and a sanitary survey carried out by the State Health Department in Valle (3). The sites

FIGURE 6-3
TOTAL INDEX, VALLE DEL CAUCA
(INFANT DEATH, INTESTIONAL DEATH, AVITAMINOSIS DEATH)

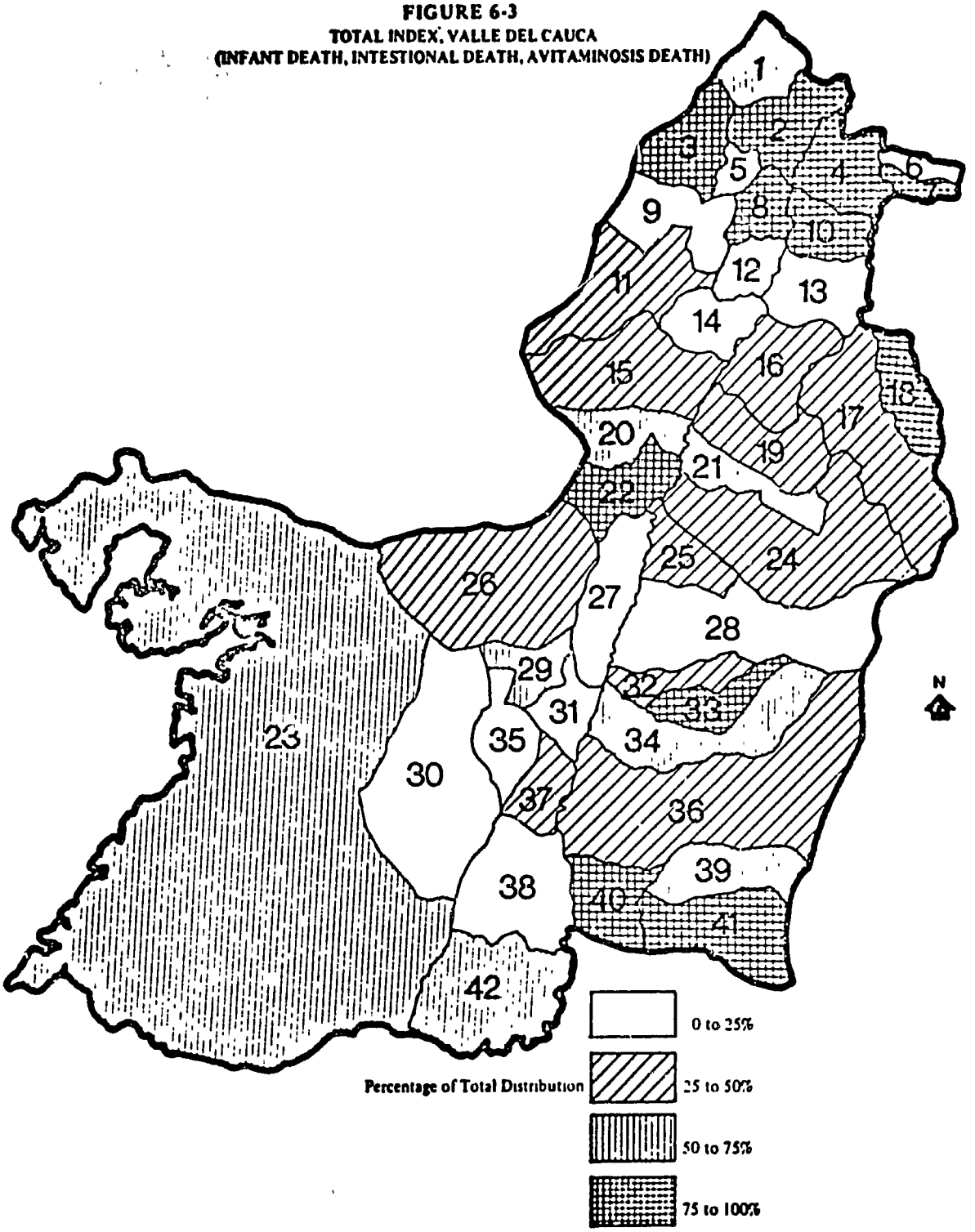


TABLE 6-1

FORMULATION OF MEDICAL VEHICLE LOCATION THROUGH MAXIMAL COVERING WITH DATA REQUIREMENTS

Formulation Statements Requiring Data	*Coefficient*	*Meaning*	*Data Required*
$\text{Max } Z = \sum_{i=1}^{m} a_i * y_i$	a_i	population needing coverage at village i	population of each village i Zarzal
$\text{S.T.} \quad \sum_{j=1}^{n} x_j = P$	P	number of facilities to be sited	location of existing facilities
Definitions			
$D_i = \{ j \mid d_{ij} \leq S \}$	d_{ij}	the shortest distance between village i and and site j	distance/ time travel between every village Zarzal
	S	maximum service distance/time between village i and site j	
$H = \{ j \mid j \text{ has no hospital} \}$			locations of hospitals in Zarzal
$P = \{ j \mid j \text{ has a population 900 inhabitants} \}$			villages with populations greater than 900
$M = \{ j \mid j \text{ has a rural health facility or personnel} \}$			villages with rural health facilities or personnel
$N_i = \{ j \mid \in D_i \cap H \cap P \cap M \}$	N_i	set of potential vehicle sites than can cover village i	

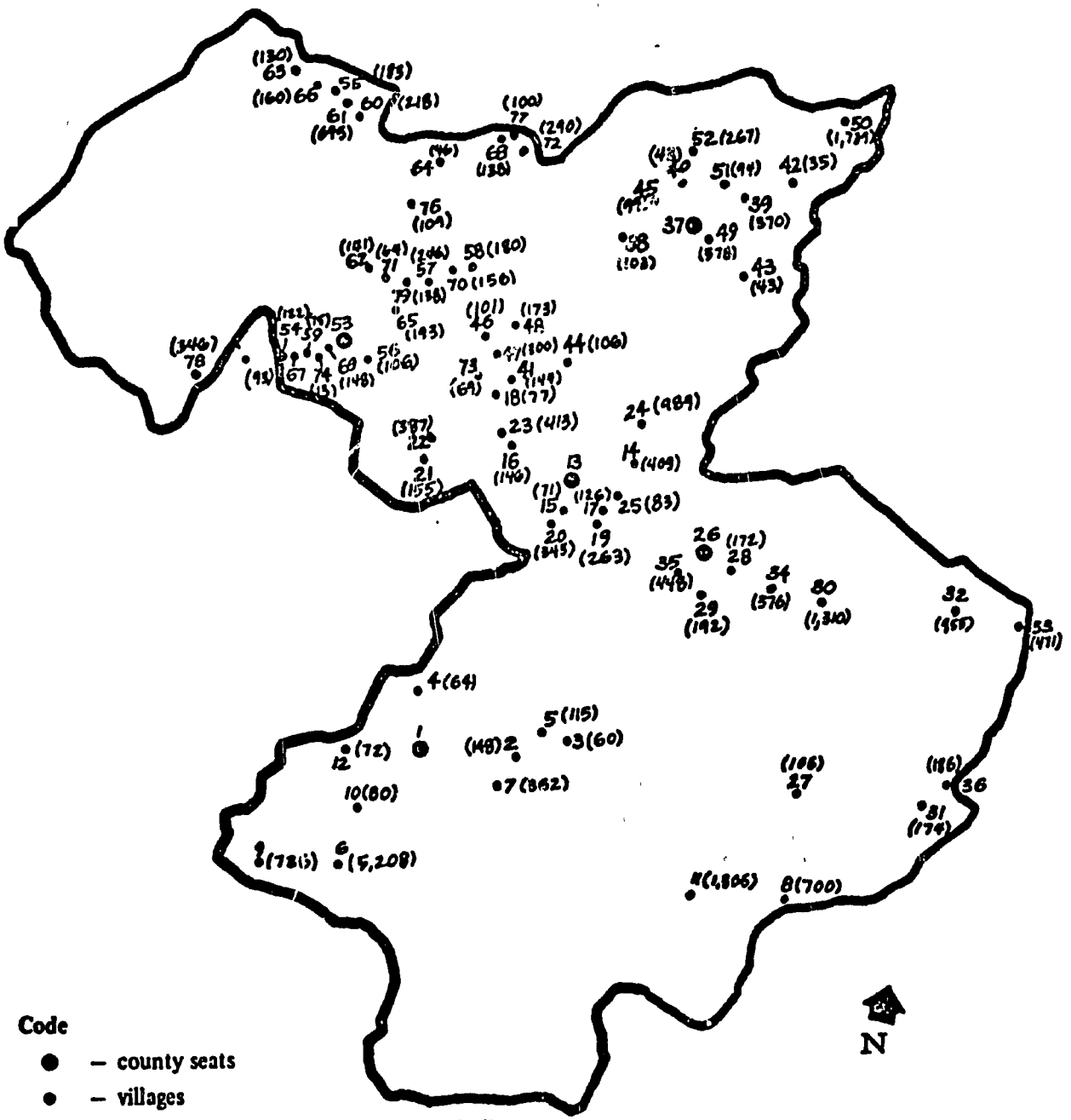
of villages and associated population figures were obtained directly from census material supplied by colleagues in the Valle Department of Health (4). Figure 6-4 shows the populations and locations of each of the 74 villages in Zarzal. Those villages with populations greater than 900 are denoted by stars. Figure 6-5 illustrates the sites of (a) existing medical vehicles (circles) and (b) existing rural promotoras. This variety of census data is listed in table 6-2. Some of the problems associated with the collection and interpretation of this data have been discussed in chapter two. A further discussion of strengths and weaknesses of Zarzal regional data can be found in Bennett (5).

Transportation Data Requirements

Some travel time information was available from maps and other data had to be estimated. Valle health department planning maps provided travel times between each of the 74 villages and their respective county seats. Travel times could be calculated between a village and its nearest neighbor on the same road leading to the county seat, as illustrated in figure 6-6. Miravalle is 25 minutes from the county seat of La Victoria. Holguin is fifteen minutes from the county seat of La Victoria. The travel time between Miravalle and Holguin is not given. This time was determined by subtracting the total time between Holguin and La Victoria (15 minutes) from Miravalle and La Victoria

FIGURE 6-4

ENUMERATED POPULATION BY VILLAGE FOR ZARZAL



Code

● – county seats

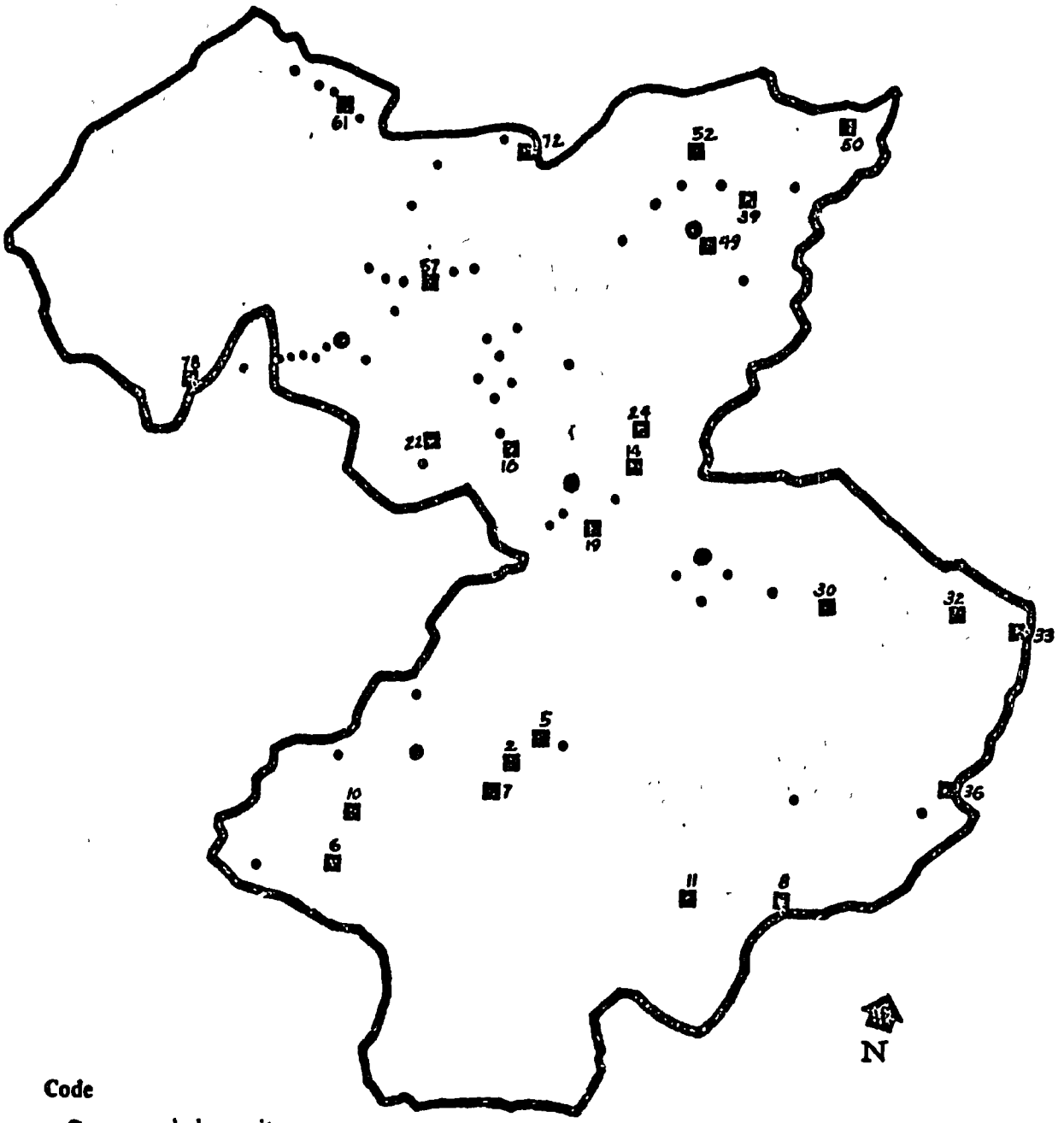
• – villages

Numbers in parentheses indicate population of village

Open numbers indicate village reference number

Source: Bennett , Vivienne, *The Use of Location Analysis for Siting Health Promoters in Rural Colombia*, Austin, Texas: The University of Texas at Austin, Masters Thesis, 1978, p. 63.

FIGURE 6-5:
LOCATION OF ZARZAL AMBULANCE SITES AND PROMOTORAS



Code

- ● — ambulance sites
- • — villages
- ■ — promotora

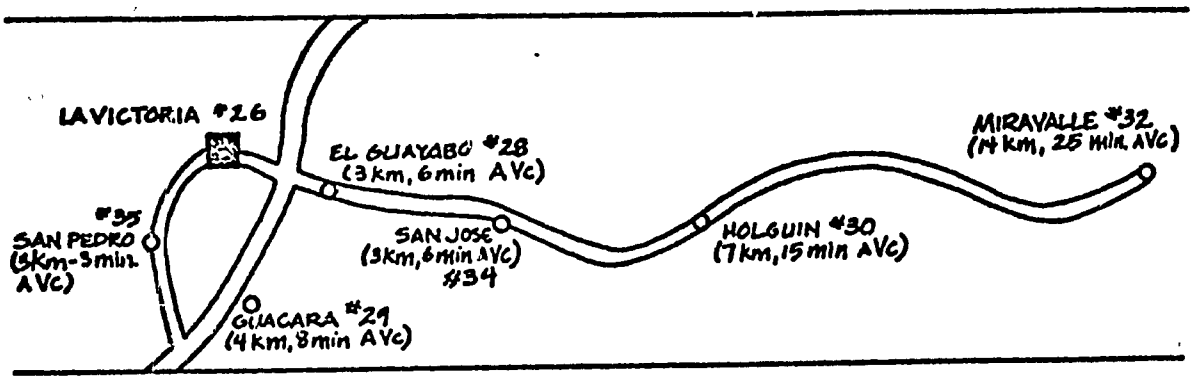
Numbers indicate village reference numbers

TABLE 6-2: AMBULANCE LOCATION INFORMATION ZARZAL HEALTH REGION

No.	Village	Population by Census	Hospital	Promotora	No.	Village	Population by Census	Hospital	Promotora
1	Zarzal (county seat)		Yes		41	El Cedro	144		
2	Alzal	148		Yes	42	Guachal	35		
3	Chaquiral	60			43	La Cayetana	43		
4	El Vergel	64			44	La Chica	106		
5	Guasimal	115		Yes	45	La Quiebra	99		
6	La Paila*	5208		Yes	46	La Robleda	101		
7	Limones	362		Yes	47	Patio Bonito	300		
8	Quebradanueva	700		Yes	48	Sabanazo	173		
9	Rio Paila	736			49	San Antonio	578		Yes
10	Uña de Gato	80		Yes	50	San Francisco*	1739		Yes
11	Vallejuelo*	1306		Yes	51	San José de Los Osos	94		
12	Zambrano	72			52	Ventaquemada	267		Yes
13	La Unión (county seat)		Yes		53	Versalles (county seat)		Yes	
14	Corcega	409		Yes	54	Altagracia	122		
15	El Guasimo	71			55	Arenillo	183		
16	El Rincón	146		Yes	56	Batambal	106		
17	La Isla	126			57	Campoalegre	246		Yes
18	Las Violetas	77			58	Coconuco	180		
19	Linderos	263		Yes	59	Dos Quebradas	75		
20	Lucero	343			60	El Arbolito	218		
21	Paramillo	155			61	El Balsal	645		Yes
22	Quebradagrande	387		Yes	62	El Bosque	141		
23	Sabanazo	413			63	El Cedral	130		
24	San Luis*	989		Yes	64	El Cedro	46		
25	San Rafael	83			65	El Diamante	193		
26	La Victoria (county seat)		Yes		66	El Embal	160		
27	Davila	106			67	El Rubí	93		
28	El Guayabo	172			68	El Silencio	158		
29	Guacará	192			69	El Tambo	148		
30	Holguin*	1310		Yes	70	Jigual	156		
31	La Holanda	174			71	La Arabia	64		
32	Mizaralle*	955		Yes	72	La Florida	290		Yes
33	Riveralta	471		Yes	73	La Sonora	69		
34	San José	376			74	Manzano	13		
35	San Pedro	448			75	Monte Azul	unknown		
36	Taguales	186		Yes	76	Morrañato	109		
37	Toro (county seat)		Yes		77	Murrapal	100		
38	Chontaduro	103			78	Peñones	346		Yes
39	El Bohio	370		Yes	79	Puente Tierra	138		
40	El Bosque	43							

*Villages with more than 900 inhabitants.

FIGURE 6-6: CALCULATION OF TRAVEL TIME, ZARZAL PLANNING REGION



(25 minutes); thus travel between Holguin and Miravalle was estimated at ten minutes.

From some villages it was possible to travel via two or more roads to other villages on the way to a county seat. The Valle planning maps listed only the distance from the village to the one village closest to the county seat. For example, in figure 6-6, the travel time between Guacara and La Victoria is eight minutes. The distance between San Pedro and La Victoria is three minutes. Because the road between Guacará and San Pedro is shorter than via La Victoria, the shorter path needed to be measured and the travel time estimated. Such estimated travel times between villages were later verified through field tests along those roads in the project area. Those estimations that proved to be inaccurate were changed. The complete travel time/distance information is presented in table 6-3.

Maximum Travel Times

The value of "time" is that it is the one variable that relates each of the multiple goals of the rural medical vehicle system. In non-emergency uses travel time is used to plan driver work patterns; the frequency of travel times and the total time of travel (including preparation) is the basis used to plan work loads to provide supervision and support to the rural health care facilities. For emergencies, the maximum patient transportation time is directly

TABLE 6-3: INFORMATION FROM THE ZARZAL CENSUS— DISTANCE/TRAVEL TIME BETWEEN VILLAGES

Arc. no.	From		To		DISTANCE/TIME kilometers	minutes
1	9	(Rio Paila)	6	(La Paila)	1.0	5
2	6	(La Paila)	10	(U'Ña de Gato)	10.0	15
3	9	(Rio Paila)	1	(Zarzal)	10.0	15
4	6	(La Paila)	1	(Zarzal)	9.0	12
5	10	(U'Ña de Gato)	1	(Zarzal)	4.0	5
6	12	(Zambrano)	1	(Zarzal)	12.3	25
7	4	(El Vergel)	1	(Zarzal)	1.2	5
8	7	(Limones)	1	(Zarzal)	1.2	5
9	2	(Alizal)	7	(Limones)	5.0	15
10	2	(Alizal)	3	(Chaparral)	5.8	10
11	2	(Alizal)	5	(Guasimal)	5.5	8
12	5	(Guasimal)	1	(Zarzal)	4.0	10
13	7	(Los Limones)	11	(Vallejuelo)	10.8	15
14	8	(Quebradanueva)	11	(Vallejuelo)	3.0	10
15	27	(Davila)	11	(Vallejuelo)	10.7	27
16	27	(Davila)	8	(Quebradanueva)	9.2	24
17	31	(La Holanda)	8	(Quebradanueva)	13.0	55
18	31	(La Holanda)	36	(Taguales)	5.0	21
19	31	(La Holanda)	32	(Miravalle)	13.0	55
20	36	(Taguales)	32	(Miravalle)	5.5	35
21	32	(Miravalle)	33	(Riveralta)	11.0	15
22	32	(Miravalle)	30	(Holguin)	7.0	10
23	30	(Holguin)	34	(San Jose)	2.0	5
24	34	(San Jose)	28	(El Guayabo)	2.0	4
25	28	(El Guayabo)	26	(La Victoria)	3.0	4
26	28	(El Guayabo)	29	(Guacara)	1.0	2
27	29	(Guacará)	35	(San Pedro)	4.0	8
28	35	(San Pedro)	26	(La Victoria)	3.0	6
29	25	(San Rafael)	17	(La Isla)	4.0	8
30	17	(La Isla)	19	(Tinderio)	2.0	4
31	25	(San Rafael)	15	(La Unión)	6.0	12
32	25	(San Rafael)	14	(Correga)	7.0	11
33	24	(San Luis)	15	(La Unión)	3.0	10
34	15	(La Union)	15	(Guasimo)	2.0	3
35	15	(Guasimo)	20	(Tuerto)	0.5	1
36	15	(La Union)	16	(El Rincon)	5.0	20
37	16	(El Rincon)	23	(Sabanazo)	6.2	10
38	23	(Sabanazo)	22	(Quebradagrande)	2.2	2
39	23	(Sabanazo)	18	(Las Violetas)	5.0	10
40	18	(Las Violetas)	41	(El Cedro)	2.0	5
41	18	(Las Violetas)	22	(Quebradagrande)	3.0	70
42	22	(Quebradagrande)	21	(Paramillo)	3.0	8
43	22	(Quebradagrande)	56	(Batambial)	7.0	12
44	22	(Quebradagrande)	73	(La Sonora)	3.0	8
45	41	(El Cedro)	44	(La Chica)	4.0	10
46	44	(La Chica)	37	(Toro)	6.5	10
47	18	(Las Violetas)	73	(La Sonora)	3.0	8
48	73	(La Sonora)	47	(Patio Bonito)	4.0	15
49	47	(Patio Bonito)	46	(La Robleda)	1.5	4
50	47	(Patio Bonito)	48	(Sabanazo)	2.0	5
51	48	(Sabanazo)	37	(Toro)	23.7	50
52	37	(Toro)	32	(Ventaquemada)	11.0	15
53	37	(Toro)	40	(El Bosque)	14.0	30
54	40	(El Bosque)	45	(La Quebra)	0.2	2
55	45	(La Quebra)	38	(Chontaduro)	0.3	3
56	37	(Toro)	51	(San José de Los Osos)	5.4	12
57	37	(Toro)	49	(San Antonio)	2.6	5
58	49	(San Antonio)	43	(La Cayetana)	1.4	5
59	37	(Toro)	39	(El Bohio)	2.0	5
60	39	(El Bohio)	42	(Guachal)	2.0	1
61	42	(Guachal)	50	(San Francisco)	7.0	24
62	56	(Batambal)	53	(Versalles)	5.0	10
63	73	(La Sonora)	53	(Versalles)	15.0	30
64	53	(Versalles)	69	(El Tambo)	1.6	5
65	69	(El Tambo)	74	(Manzano)	0.4	1
66	74	(Manzano)	59	(Dos Quebradas)	3.0	2
67	59	(Dos Quebradas)	62	(El Bosque)	2.0	2
68	62	(El Bosque)	54	(Altagracia)	0.6	2
69	54	(Altagracia)	75	(Monte Azul)	4.0	8
70	75	(Monte Azul)	78	(Peñones)	13.4	8
71	53	(Versalles)	65	(El Diamante)	7.6	10
72	71	(La Arabia)	67	(El Rulo)	0.8	20
73	71	(La Arabia)	79	(Puente Tierra)	1.2	10
74	79	(Puente Tierra)	65	(El Diamante)	3.9	20
75	65	(El Diamante)	57	(Campoalegre)	4.7	15
76	57	(Campoalegre)	70	(Jigual)	2.9	5
77	70	(Jigual)	58	(Coconuco)	1.5	4
78	58	(Coconuco)	72	(La Florida)	0.5	1
79	72	(La Florida)	77	(Murrajal)	3.7	5
80	72	(La Florida)	68	(El Silencio)	3.5	7
81	68	(El Silencio)	77	(Murrajal)	3.5	6
82	68	(El Silencio)	76	(Morroñato)	69.3	48
83	68	(El Silencio)	64	(El Cedro)	7.3	12
84	76	(Morroñato)	64	(El Cedro)	67.0	36
85	64	(El Cedro)	60	(El Arbolito)	2.0	6
86	60	(El Arbolito)	61	(El Balsal)	6.0	12
87	61	(El Balsal)	55	(Arenillo)	2.0	5
88	55	(Arenillo)	66	(El Embal)	5.0	8
89	66	(El Embal)	63	(El Cedral)	2.0	9
90	14	(Correga)	10	(La Cayetana)	11.0	25
91	40	(Guacara)	1	(Zarzal)	13.0	17
92	35	(San Pedro)	1	(Zarzal)	16.0	19
93	26	(La Victoria)	13	(La Unión)	15.0	31
94	26	(La Victoria)	25	(San Rafael)	10.0	20
95	24	(San Luis)	37	(Toro)	unknown	12
96	32	(Ventaquemada)	72	(La Florida)	unknown	19

related to health outcomes, some occurrence of irreversible patient harm. The reader may recall from chapters four and five that Colombian planners presently use county lines rather than maximum travel time to determine areas of ambulance service. Such planning ignores measures of access--it is assumed that a vehicle in the county seat serving the county will be sufficient. In order to begin to integrate time standards into ambulance planning, consultations were held with representatives in the Colombian Health Ministry to determine what maximum time limits might represent appropriate travel time norms for rural medical vehicles. A maximum one way travel time of one hour was designated as a norm for ambulance coverage (7).

A one hour travel time norm means different outcomes with respect to the three functions of the rural medical vehicle system. One hour as a maximum travel for movement of medical supplies and/or manpower means that the drivers never go too far from one base. One hour one way as a maximum travel time for reaching patients in an emergency is something else.

Is one hour one way fast enough to prevent unnecessary deaths? To receive treatment in Colombia, a patient must be first picked up and then delivered to a hospital. Emergency medical systems in the U.S. also operate under the constraints of maximum travel times. In the U.S. the

maximum travel time is based on the time of travel from the vehicle station to the point of patient pickup, e.g., one way response time. However, in the U.S. the existence of trained emergency medical personnel allows for medical intervention and stabilization of the patient in the vehicle. In Colombia, such para-professionals do not exist; some drivers may not even be trained in first aid. Stabilization of the patient can only take place at the hospital. Consequently, a one hour maximum service time, viewed as a response time, translates into at least a two hour time of waiting between the call for assistance and the time that a patient receives emergency services.

Given the lack of medical training of Colombian ambulance drivers, should emergency patient transportation planning be structured on the basis of response (one-way) time? If so, what should that specific time be? What is the effect of this time on emergency patient outcomes? What is the effect of the policy on providing coverage to the rural population? What are the implications of a specific travel time standard for rural population access to care and for Ministry budgets? These are some of the questions that are being addressed by Colombian health planners in their efforts to improve and expand rural medical vehicle services. It is not the intent of this study to define travel norms for the Colombian rural medical vehicles; such

decisions are better left with Colombian health planners. However, some uncertainty about the value of a travel time standard may be eliminated by illustrating the impact of proposed travel norms on access and budgets;* and the way to assess travel time standards is to examine several policy options. Chapters seven, eight, and nine will look at the implications of four alternative travel times or policies, 15 minutes, 30 minutes, 45 minutes, and 60 minutes of one way travel.

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*Such issues are investigated in the next chapter.

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Interview with Mr. Bryan Hamon, in Valle, Colombia, June 23, 1977.

(2) Ministerio de Salud de la Republica de Colombia, Servicio Seccional de Salud del Departamento de Valle del Cauca, and Universidad del Valle.
Censo Y Diagnostico Sanitario de la Unidad Regional de Salud de Zarzal. Cali, Colombia: Ministerio de Salud, 1977, p. 26.

(3) Ibid.

(4) Ibid.

(5) Bennett, Vivienne.
The Use of Location Analysis for Siting Health Promoters in Rural Colombia, Austin, Texas: The University of Texas at Austin, masters thesis, 1978.

CHAPTER SEVEN

AMBULANCE SITING THROUGH MAXIMAL COVERING

A vehicle system must be accessible to people in order to serve them. Since accessibility reflects location, vehicle deployment should be related to demands for service and the time to service. This chapter uses maximal covering to calculate the extent of coverage provided by the present ambulance system in Zarzal. Location analysis is then used to explore how much additional population could have access if the vehicles were shifted from their present locations to the sites that cover the largest fraction of the rural population. Areas of medical vehicle service are displayed through the use of maps.

This approach to ambulance planning is not a radical departure from accepted Colombian health planning methods. Similar access goals are used with siting rural health promotoras. The incorporation of population and service time measures in ambulance planning procedures would extend those policies.

PERFORMANCE OF THE PRESENT VEHICLE SYSTEM

Prior to considering other deployment patterns, it is useful to see how well the current location patterns of medical vehicles in Zarzal perform. To put it another way, given the number and location of the current facilities, how accessible (measured in terms of time) is patient transport to the rural residents (measured in terms of the fraction of the population covered)?

The reader will recall that the present planning procedures do not use time as a criteria for evaluating health services. County geographical boundaries -- not time of travel -- establish service regions. To assist us in this research effort, Colombian health planners established a time of one hour as the outside limit for the adequate delivery of services to the rural population (1).

Because Colombian medical vehicle drivers are not trained to initiate medical intervention for emergency patients, any patient stabilization and treatment efforts can occur only in the local and regional hospitals. Thus the one hour maximum service time (one-way) is really a round-trip time of at least two hours. Real service time is actually longer than two hours because a driver consumes time in vehicle preparation and patient pickup. Thus a response time of one hour implies a two hour-plus service time for emergency services.

Each of the five hospitals in the Zarzal health region currently provide independent medical vehicle services to rural residents. The Zarzal health planning areas are not integrated -- the areas of service for each vehicle are the geographical boundaries of its county. The county ambulance is responsible for providing service to all residents within its jurisdiction. This county system can provide emergency transportation services within two-plus hours to approximately 93 percent of the rural population in the Zarzal health region as illustrated in figure 7-1. The location of each medical site is denoted by the enclosing shape around the facility (those villages that are within a one hour's travel time from the facility).* Hospital-based vehicles can provide service to 66 of the 74 villages in the Zarzal health region within the two hour-plus service time.

State and national health plans call for an eventual integration of these five independent counties into a regional health care delivery system. An integrated ambulance system might be one element of such a regional system.

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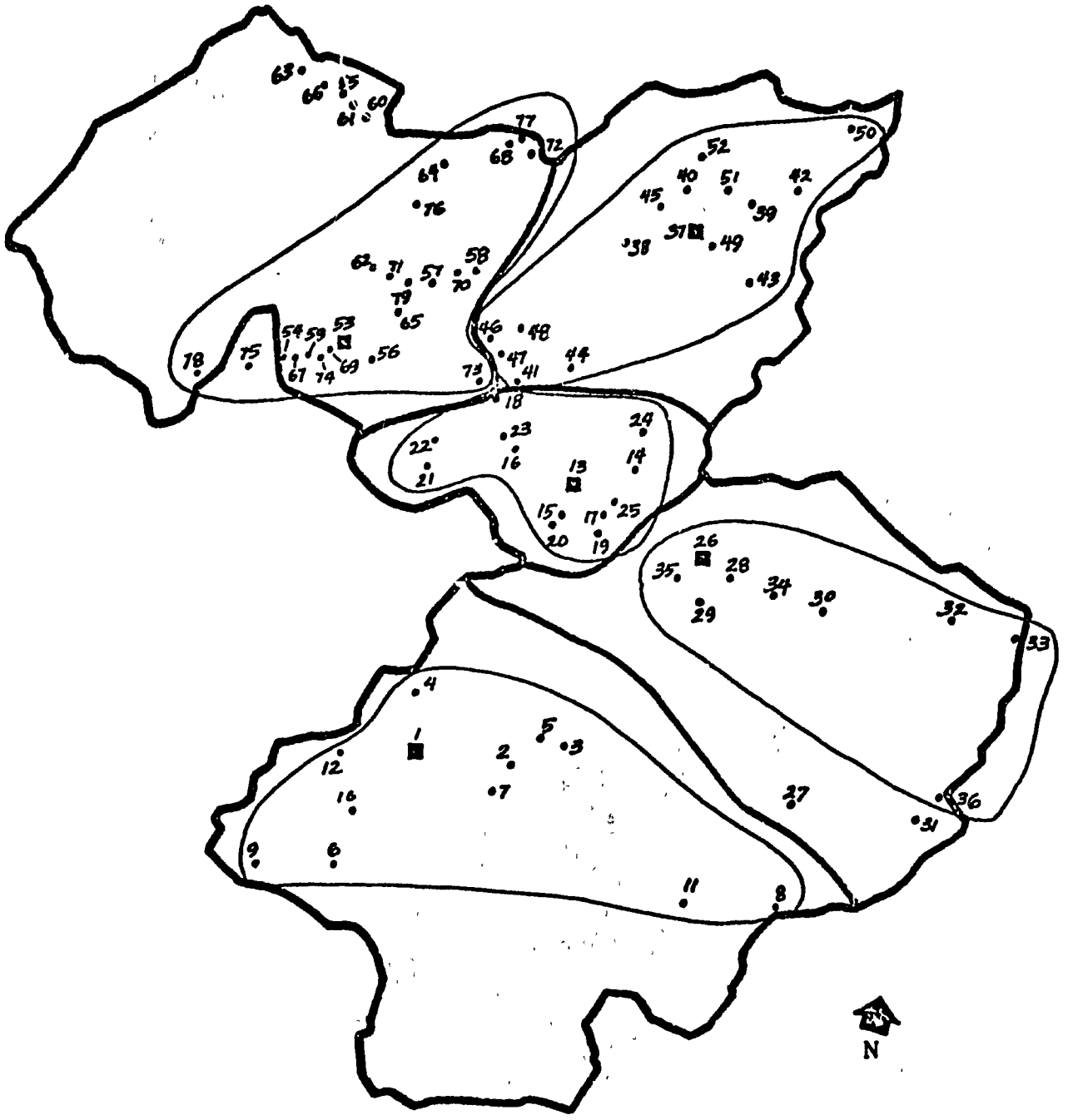
*The enclosing shape is misleading to the extent that it implies coverage of all areas within the enclosed shape. True coverage exists only for those points (villages) located on the roads and not for all the other remaining areas within the shapes. The enclosure is presented only to help the reader see the coverage provided by a facility at a given time.

FIGURE 7-1
RURAL MEDICAL VEHICLE COVERAGE
(two hour-plus service time)



■ vehicle sites

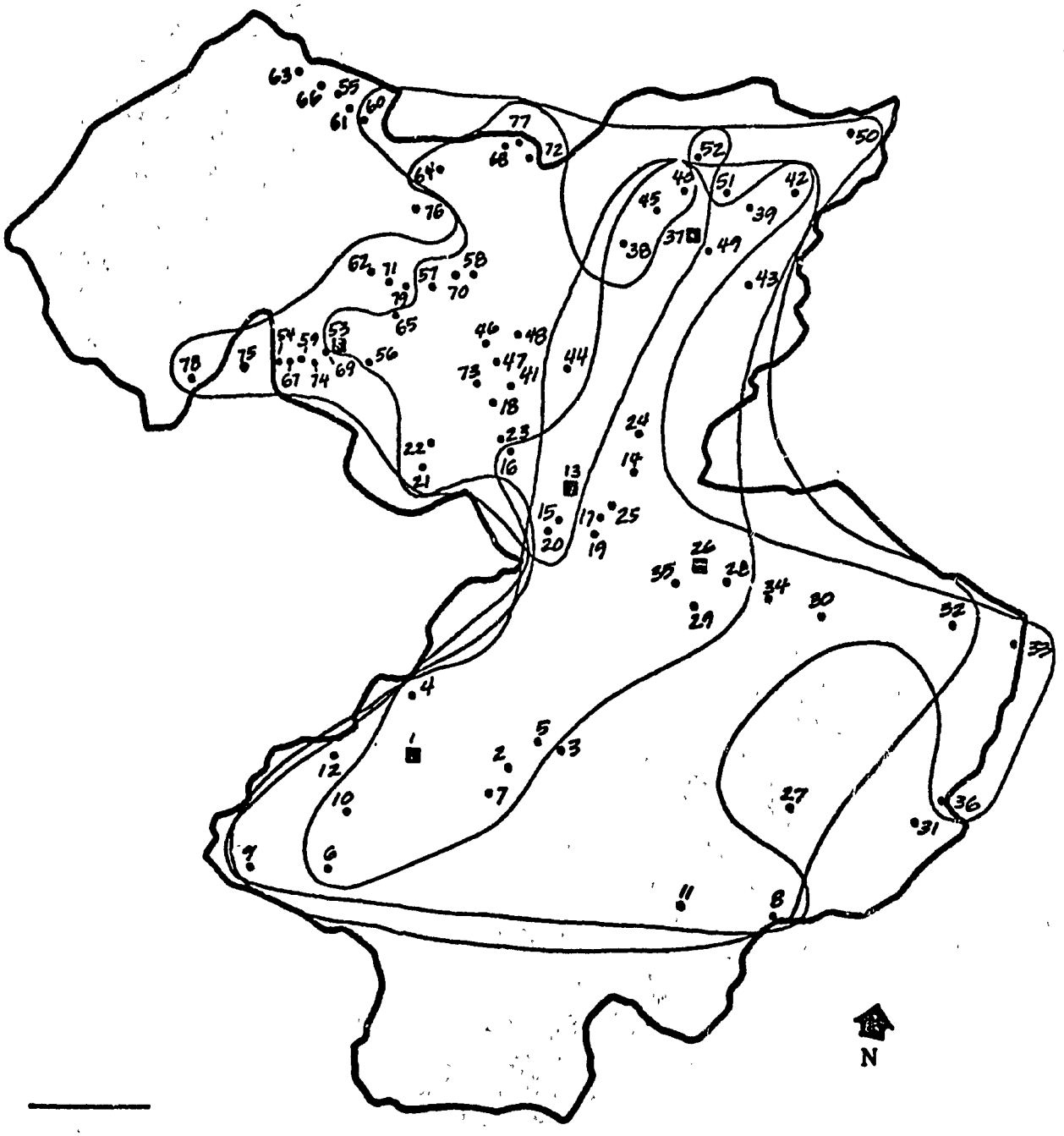
• villages

Under this concept an ambulance would be able to serve any rural village that lies within a maximum service time, whether the village is in the same county or not. What effects would a regionalized system have upon the delivery of emergency services to the rural residents?

Figure 7-2 shows the area of coverage provided under a regionalized system of care. Immediately apparent are wide areas of overlapping coverage. For example, the village of Lucerno (node 20) is situated such that it may be reached in one hour by any vehicle dispatched from sites 1, 13, 26, 37, and 53. Such patterns of double, triple or multiple coverage of a village imply greatly enhanced access to services for those villages. Rather than present the situation in which only one vehicle site (the hospital) can dispatch an ambulance, a village under a regional system could call upon any of the hospital-based vehicles.

If the five medical vehicles now operated from hospitals served the entire region, they could provide emergency services within two hours to over 94 percent of the rural population (68 of the 74 villages). This 94 percent coverage is a one percent (two additional villages) improvement in population coverage over the county (non-regional) system of Figure 7-1. Not only would a regional medical transportation system be more accessible, it would also utilize fewer vehicle stations. Vehicles based at four

FIGURE 7-2
RURAL MEDICAL VEHICLE SERVICE
(two hour-plus service time)



■ facility
• village

hospitals can reach 94 percent of the rural population within one hour's travel time. The fifth facility, in this case La Union (node 13), cannot improve upon the population already covered by the four other sites. While La Union still provides coverage to villages both inside and outside the county of La Union, all of these villages may already be reached by other medical vehicles within the two hour maximum service time. In other words, a regional transportation system in Zarzal would not only increase the rural population's access to emergency services, but also could provide these services with a smaller investment in vehicle facility sites.

How will a dispatcher of emergency vehicles decide upon which ambulance to call to provide service to a village that could be served by any of several hospital-based ambulances? While decision rules governing the specific allocation of vehicles to villages should be made by the local health planners, one principle might be "let that ambulance site closest to the village provide primary service." During a situation where that primary vehicle is busy, the village could be reached by other vehicles.

Although a regional system is an improvement over the current county system, it would still be six percent short of the public health system's goal of providing 100 percent coverage to the rural population within the two

hour-plus time limit. The only way for health planners to achieve 100 percent rural population coverage would be to add vehicles.

USE OF LOCATION ANALYSIS WITH NO RESTRICTIONS

We used GAS* to find the number of ambulance sites that can cover all the rural population within a two hour-plus maximum service time. These results are illustrated in figure 7-3. Five ambulance sites would be established and these could cover all (100 percent) of the rural population of Zarzal. By shifting the location of the present facilities, Colombian health planners could serve all the rural population with no more vehicle sites than presently used in Zarzal.

A closer inspection of figure 7-3 reveals that to achieve 100 percent of population coverage planners might not have to completely restructure the ambulance system. Three of the five locations (nodes 26, 13, and 53) selected as sites through maximal covering are the sites of existing local hospitals. By relocating two sites, medical vehicles could reach all rural villages within one hour of one-way travel.

While such relocation is suggested by this analysis of access, any final decision as to actual sites, staffing

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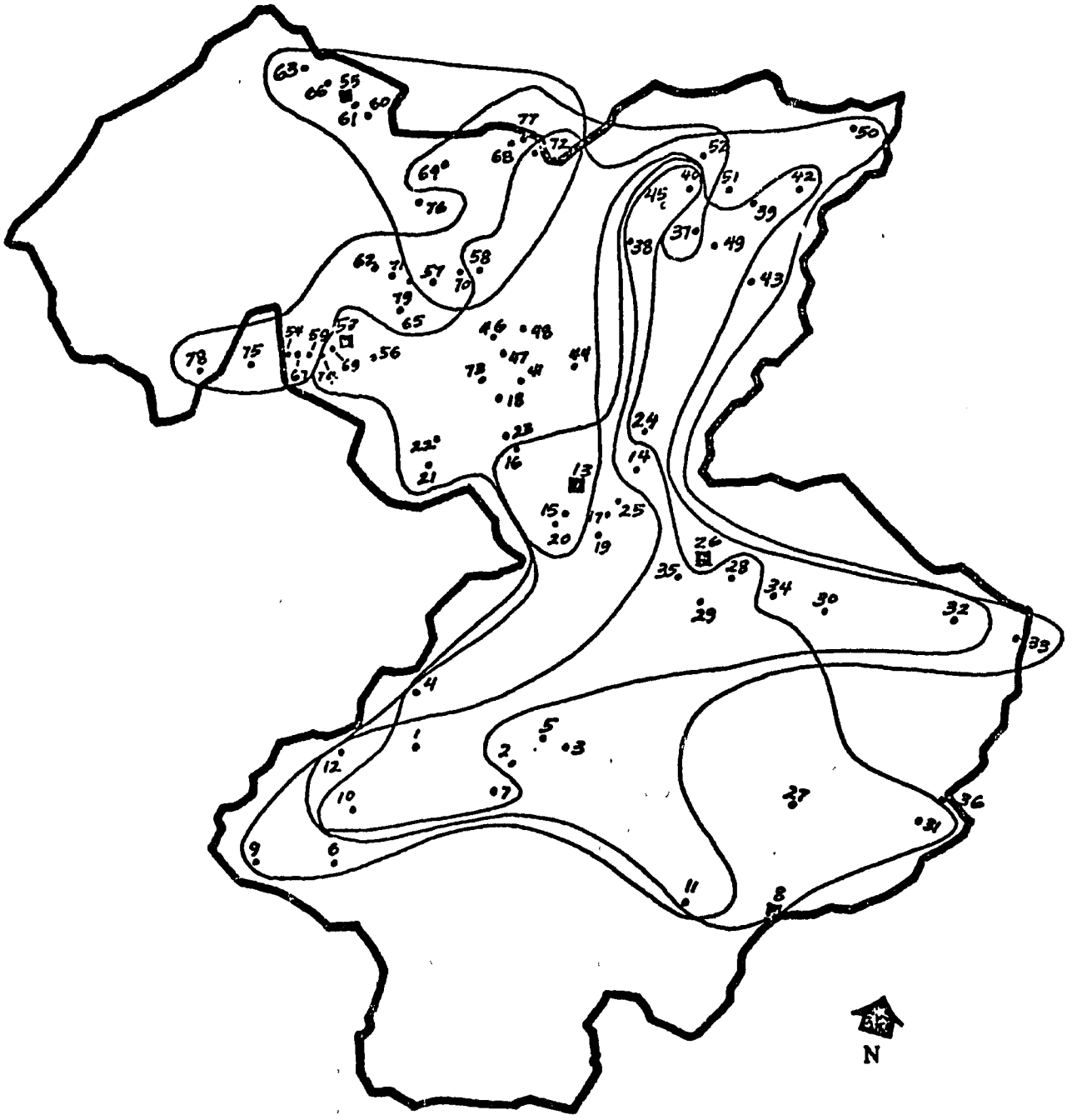
*Chapter 4 contains a description of GAS.

FIGURE 7-3
MEDICAL VEHICLE SERVICE–NO RESTRICTIONS
(two hour-plus service time)



■ vehicle site
• village

patterns, or primary service responsibilities should be left to local planners. Figure 7-3 is illustrative of this point. While five facilities provide service to 100 percent of the population, a vehicle from one site (node 14) could reach nearly 70 percent of the rural population within one hour of travel time. Two sites alone, villages 28 and 44, are accessible within the two hour-plus norm to more than 90 percent of the rural residents.* If four vehicle bases are established in villages 26, 13, 53, and 8, the fifth facility provides less than one incremental percent of population coverage. What do these results imply for Colombian health planners? Should several vehicles located at one or two central sites provide patient transportation to some large percentage of the total population? Should the added costs of additional facilities be incurred to cover all of the rural populations? These are some of the questions that will need to be addressed by Colombian health planners in their attempt to extend health services into the rural areas.

LOCATION ANALYSIS AND AMBULANCE PLANNING

If deployment of medical vehicles should reflect both the number of people receiving services and the amount of

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*The reader may notice that the configuration suggested for two vehicle bases does not include the best one site. These results are due to the substitution process provided in the GAS algorithm. A facility located in an iteration may be substituted by another village in a subsequent iteration.

travel time it takes to serve those people, then location analysis can be valuable to planners. In this chapter, analysis has demonstrated that:

(a) emergency transportation is not yet accessible to all of the rural population;

(b) more of the population can be served by implementing a fully integrated regional transportation network;

(c) the cost (figured in terms of facilities) of providing these services can be less under a regional framework; and

(d) a number of viable alternatives exist to the present delivery system that can either expand the number of people receiving services or reduce the number of facilities necessary to provide that service.

One question posed at the beginning of this chapter was "how well does the current system perform?" The system appears to perform well, providing services to over 93 percent of the rural population within the Colombians' established maximum service time. Further support for the effectiveness of the present locations is provided by the fact that even when any village (not only hospitals) can be an ambulance depot, three of the present hospital sites are re-selected as facilities. The accessibility of these seats does reflect the geography of the Zarzal region, a river valley bordered on two sides by ranges of the Andes. County seats are towns in the river valley. Villages have spread concentrically outward, and thus county seats remain centrally located with respect to the rural population.

Although the present system appears to provide a large degree of coverage to the rural population, how effective is this coverage in terms of providing emergency services? Is two hours a valid measure of emergency services? If not, then what is? In the United States, the Emergency Medical Services Act has established a norm for response times for rural residents at 30 minutes (2). One-half hour is substantially lower than the present two hour-plus service time standard for Zarzal. Since one of the goals of this study is to help Colombians plan for emergency-based transportation services, it may be useful to explore the implications of alternate time-to-service standards for the ambulance system.

REFERENCES TO CHAPTER SEVEN

(1) Valencia, Luis Guillermo, and Rodrigo Bustamonte. Interview with Mr. Bryan Hamon, in Bogota, Colombia, August 1, 1977.

(2) Emergency Medical Services Systems, Pub. L. No. 93-154, 87, Stat. p. 594 (codified at 42 USC 246).

CHAPTER EIGHT

PLANNING FOR AN EMERGENCY AMBULANCE SYSTEM IN ZARZAL

The last chapter examined the rural coverage of the present medical vehicle system within a two hour-plus service time. Because a standard of two hours-plus is too long a wait for stabilizing trauma, cardiac, or emergency cases, perhaps an alternative service time standard should be considered (1). This chapter explores the effects of a 30 minute maximum travel time (round-trip) upon the deployment of ambulance services in Zarzal.*

Location analysis is first used to examine the level of services that are available under present conditions. The "hospital only" siting rule for vehicles is then relaxed to allow for the selection of those sites that "best" cover the rural population. Illustrations are used to help make explicit the trade-offs between time, the number of vehicles, and population coverage associated with each location policy. Finally the chapter explores the possibility of extending the

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*A 15 minutes one-way response time implies a 30 minute-plus time to service.

hospital-based medical vehicle facilities to areas located outside of hospitals.

CURRENT MEDICAL SERVICE UNDER A THIRTY MINUTE SERVICE TIME

Present medical vehicles are based only in local and regional hospitals and can provide emergency service to approximately 51 percent of the rural population within a 30 minute maximum service time. These areas of service coverage are illustrated in figure 8-1. Present medical vehicle sites (hospitals) are designated by squares. Rural villages are represented as dots. Those rural villages that lie within a 15 minute one-way travel time from an ambulance site are said to be "covered" by that vehicle site and appear within a shape, representing the hospital's service district.* Certain villages, due to their proximity to two or more hospitals and a regional emergency model, can be covered by two hospitals.

The 51 percent coverage of the rural population within a 30 minute-plus service time is a substantial reduction from the 93 percent coverage provided under the two hour-

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*The enclosing shape is misleading to the extent that it implies coverage at all areas within the enclosed shape. True coverage exists only for those points (villages) located on the roads and not for all the other remaining areas within the shapes. The enclosure is presented to help the reader visualize the villages that are covered.

plus service time (see chapter seven). Of the 74 villages in Zarzal, the present system services only 29 villages, or less than 40 percent of the rural villages, within 30-plus minutes. To each enclosed shape corresponds a fraction of the population that can be served by the facility, as shown in table 8-1. Some hospitals are more accessible than others. For example, Versalles and La Union (nodes 53 and 13) provide together only five percent additional population coverage. Over 46 percent of the rural population can be served within 30 minutes using ambulances sited at only three towns.

TABLE 8-1

AMBULANCE LOCATION IN HOSPITALS
(30 minute service time)

Rank Order	*County Seat*	*Node Number*	*Population Covered (persons)*	*Percent of Total Population*
1	Zarzal	(1)	6,565	26.25
2	La Victoria	(26)	2,498	9.9
3	Toro	(37)	2,482	9.3
4	Versalles	(53)	798	3.19
5	La Union	(13)	497	1.99

FIGURE 8-1
AMBULANCE LOCATION IN HOSPITALS
(30 minute-plus service time)

■ vehicle sites

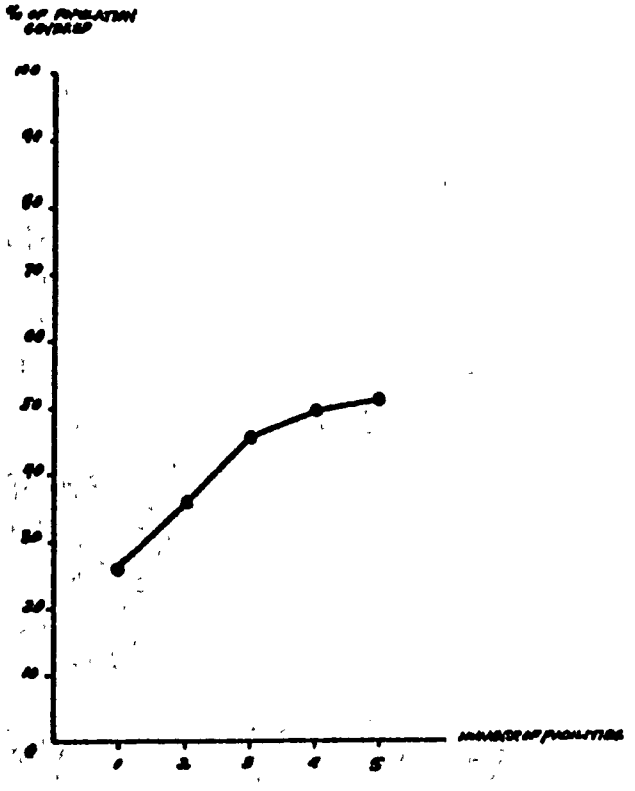
• rural villages

Another way to view coverage information is through a trade-off curve, a chart of how much incremental coverage each added vehicle provides. Figure 8-2 is a trade-off curve between population coverage (y-axis) and the number of sites (x-axis) for a 30 minute maximum service time. The only way to increase the percentage of population covered is to increase the number of facilities. It is interesting to note the diminishing marginal returns effect in figure 8-2. As the number of facilities increase, the percentage of accessible rural population also increases, but at a decreasing rate.

A trade-off curve shows the highest levels of coverage that can be achieved with given resources under certain conditions. Areas above and below the trade-off curve in figure 8-2 are considered either infeasible or inferior. For example, point A represents an infeasible point; the fraction of population covered at point A (50 percent) cannot be achieved with vehicles dispatched from the two sites. Point B below the trade-off curve is inferior to point C, since at point C more people are served with no change in the number of ambulance stations. In other words, to improve coverage (to move from C to D) a planner must add a new site.

These and other results based upon the GAS program are not optimal in a math programming sense because GAS

FIGURE 8-2
AMBULANCE LOCATION IN HOSPITALS:
30 MINUTE-PLUS SERVICE TIME–A TRADE-OFF CURVE

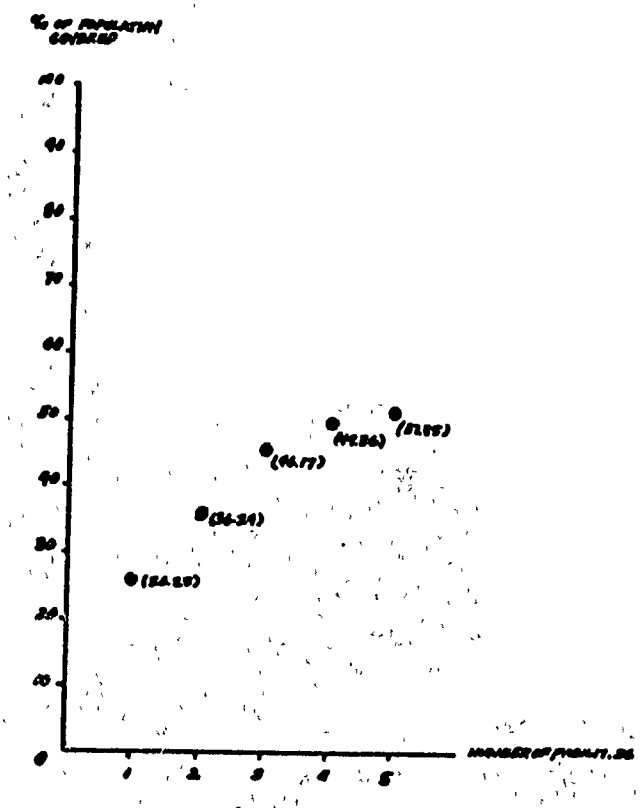


is a heuristic. While the first facility will be optimal (by definition), later solutions are not guaranteed to be optimal. Church compared results from integer programming and found that both GA and GAS heuristics terminated with optimal solutions over 80 percent of the time (2). Selected GAS generated results from this study (using a 79 node network) were later verified as optimal through comparisons with integer linear programming results.

The trade-off curve in figure 8-2 and other trade-off curves that are presented in this study appear to be continuous curves; an infinite number of (x,y) points representing service levels and vehicle sites. The "curve" is presented to enable the reader to visualize the relationship that exists between the two objectives, maximizing access and minimizing ambulance stations. These results are more correctly represented as in figure 8-3, as a series of step improvements. Vehicle siting in a village is a yes/no decision; it is impossible to allocate only half of a facility. A trade-off curve implies that non-integer solutions are possible, when in fact they are not.

How can a trade-off curve be useful to health planners developing patient transport services? The set of alternatives shown in figure 8-2 represents the highest level of possible access. This information allows a planner to weigh the value of a current facility in coverage terms.

FIGURE 8-3
AMBULANCE LOCATION IN HOSPITALS, 30 MINUTE-PLUS SERVICE TIME--TRADE-OFF POINTS



numbers in parentheses refer to the percentage of total population covered

For example, in figure 8-2, is the cost of maintaining the two last facilities, E and F, worth the added population coverage of approximately six percent? Such trade-offs have not previously been made explicit to Colombian health policy makers.

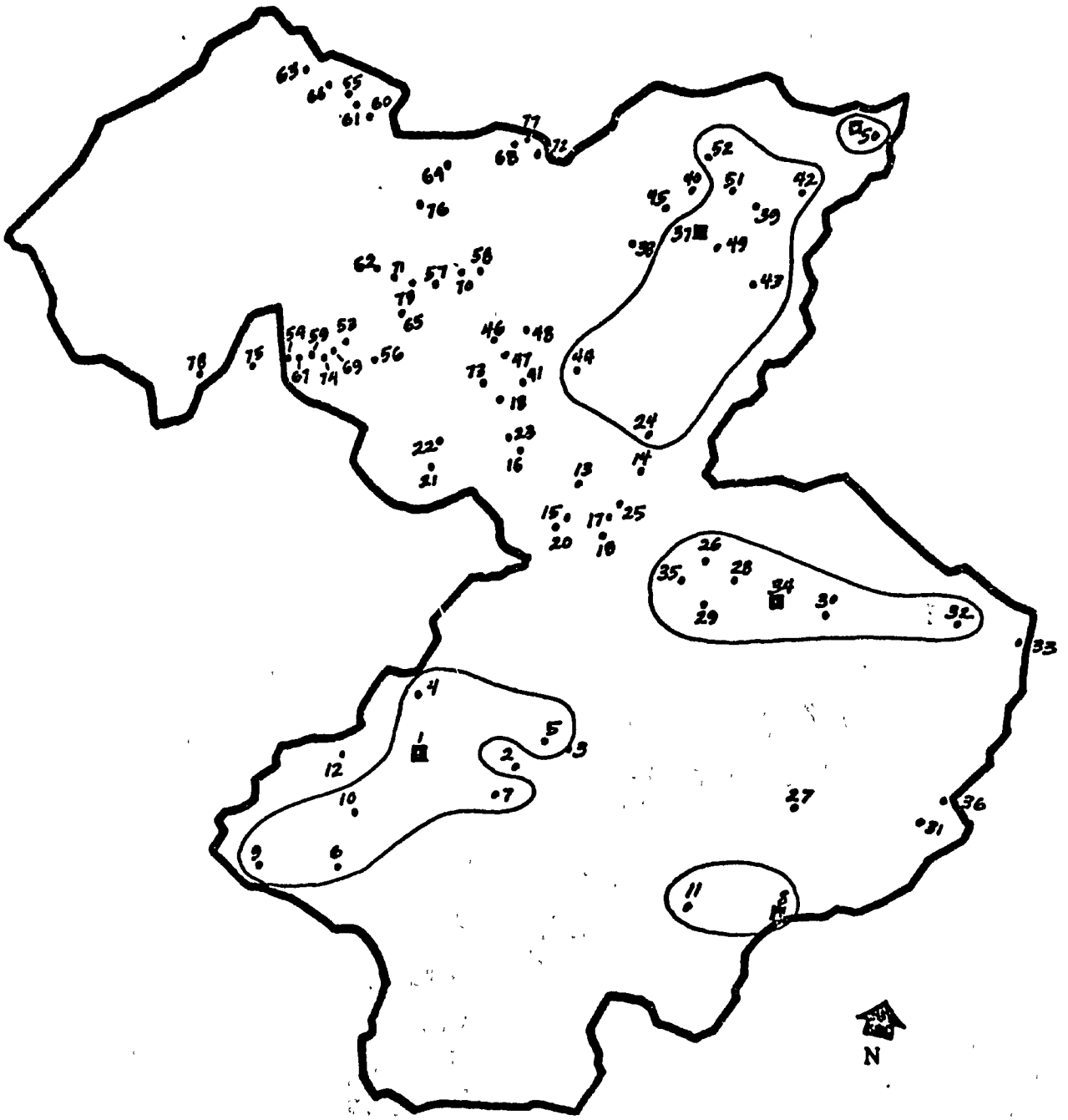
EMERGENCY AMBULANCE SITES WITH NO SITE RESTRICTIONS

When ambulances could be sited at any village under the two hour-plus standard, three of the five new sites selected as "best" by location analysis were hospitals (see chapter seven). Does the present system continue to perform well if the time standard (maximum service time) is reduced from two hours-plus to 30 minutes-plus?

Vehicles based at hospitals can cover 51 percent of the rural population within a 30 minute-plus service time. If any village can serve as a potential ambulance site, GAS location analysis would select a new configuration, figure 8-4, that increases population coverage to approximately 65 percent of the rural population. "No restriction" on sites thus leads to a 15 percent improvement over hospital-based ambulances.

Figure 8-5 provides another way to view the differences, a comparative trade-off curve. Note that under both policies, the first sited facility provides coverage to 26.25 percent of the rural population. This first "best" site is located in figure 8-4 and 8-1 at node number one

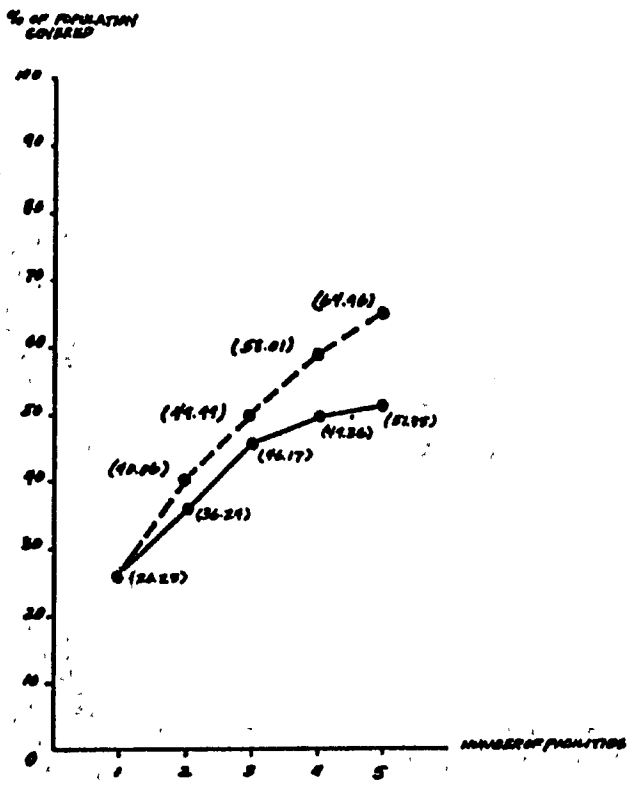
FIGURE 8-4
AMBULANCE LOCATION WITH NO RESTRICTION
(30 minute-plus service time)



■ vehicle site

• village

FIGURE 8-5
HOSPITAL LOCATION VS. NO RESTRICTION: A COMPARATIVE TRADE-OFF CURVE
(30 minute-plus service time)



---- no restriction location
—— hospital location

numbers in parentheses refer to the percentage of total population covered

(the county hospital at Zarzal). The optimal sites thereafter provide more access, with the difference widening for each incremental facility.

EXTENDING THE EMERGENCY VEHICLE SYSTEM

What other alternatives might Valle del Cauca public health planners consider in their efforts to increase the quality of emergency patient transport? One alternative might be to (a) let the hospital-based vehicles serve all three transportation goals, of moving supplies, personnel, and patients and (b) add additional ambulances for emergency transport. Maintaining hospital-based vehicles would assure that supply and personnel transport demands would be met. This system would, however, cover only 51 percent of patient emergency service demands. More complete emergency coverage could be achieved only by the addition of vehicles at other locations.

Unrestricted Ambulance Extension

Imagine that planners will seek the best sites without regard to existing village size or infrastructure. What amount of increased coverage can be provided by a nonrestricted extension of vehicles? Starting from the coverage base of 51.35 percent provided by the five hospital vehicle sites of table 8-2, the addition of eight new sites (12 total

TABLE 8-2
AMBULANCE SITE EXTENSION WITH NO RESTRICTIONS
(30 minute service time)

Rank Order	*Village*	*Node Number*	*Population Covered (persons)*	*Percent of Total Population*
	Base (5 vehicle sites)		12,840	51.35
1	Quebradanueva	8	2,006	59.37
2	San Francisco	50	1,738	66.32
3	Miravalle	32	1,426	72.02
4	Quebradagrande	22	1,396	77.59
5	El Basal	61	1,206	82.41
6	Coconuco	58	1,110	86.85
7	San Rafael	25	798	90.04
8	La Robleda	46	572	92.33
9	Monte Azul	75	348	93.72
10	Chontaduro	38	245	94.70

facilities) would increase total population coverage to over 90 percent.* Figure 8-6 illustrates how total coverage increases through the addition of each new ambulance site. The first new ambulance station would be established at Quebradanueva (node number eight) and would increase the covered population by eight percent. There is again a diminishing marginal return effect; the tenth facility, Chontaduro (node number 38) increases population coverage by less than one percent.

Restricted Ambulance Restriction

If the public health planners were to extend the ambulance system beyond the confines of hospitals, they may wish to limit vehicle extension to certain "suitable sites." Perhaps a vehicle is suitable only in villages with services such as electricity, communications, and living space for the drivers. Two previously developed surrogates for site suitability that Colombian health planners might consider are:

(a) that a potential facility site should have a village population of 900 or more inhabitants; and

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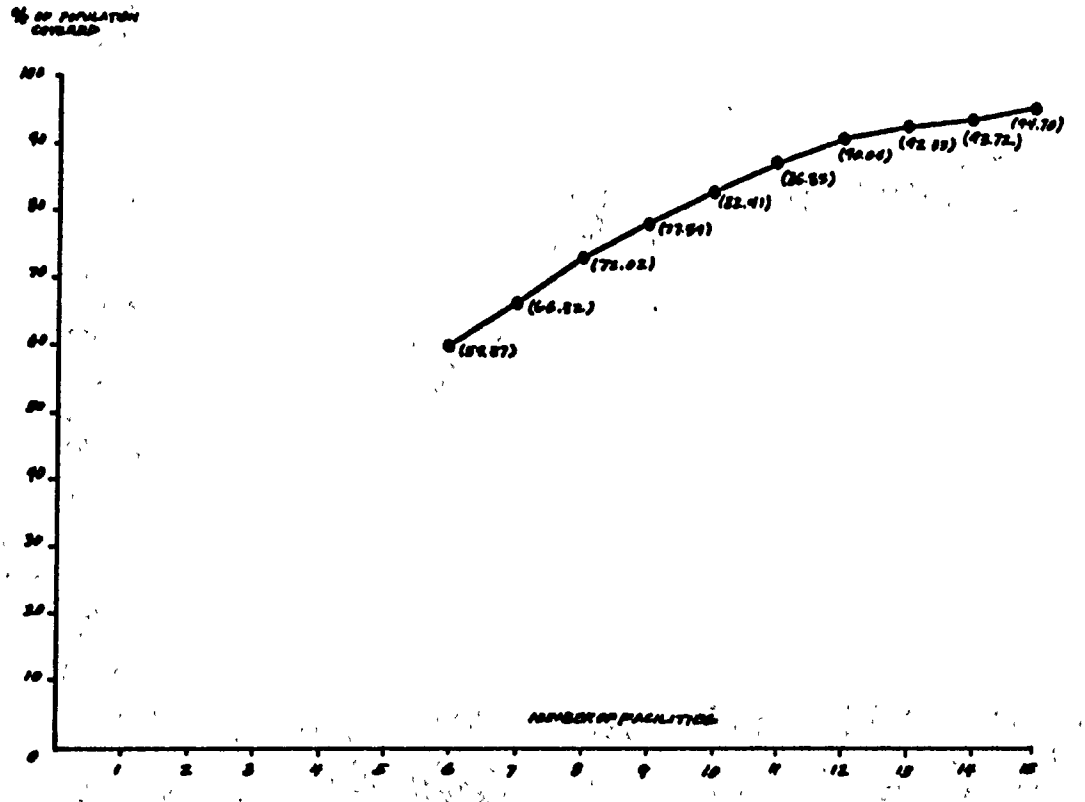
*Although it is possible to generate 100 percent population coverage with a "no restrictions" siting policy. In this example we limited the number of additional facilities to ten. This had the effect of limiting total population coverage to a level under 100 percent.

FIGURE 8-6
AMBULANCE EXTENSION WITH NO RESTRICTION: A TRADE-OFF CURVE
(30 minute service time)



numbers in parentheses refer to the percentage of total population covered

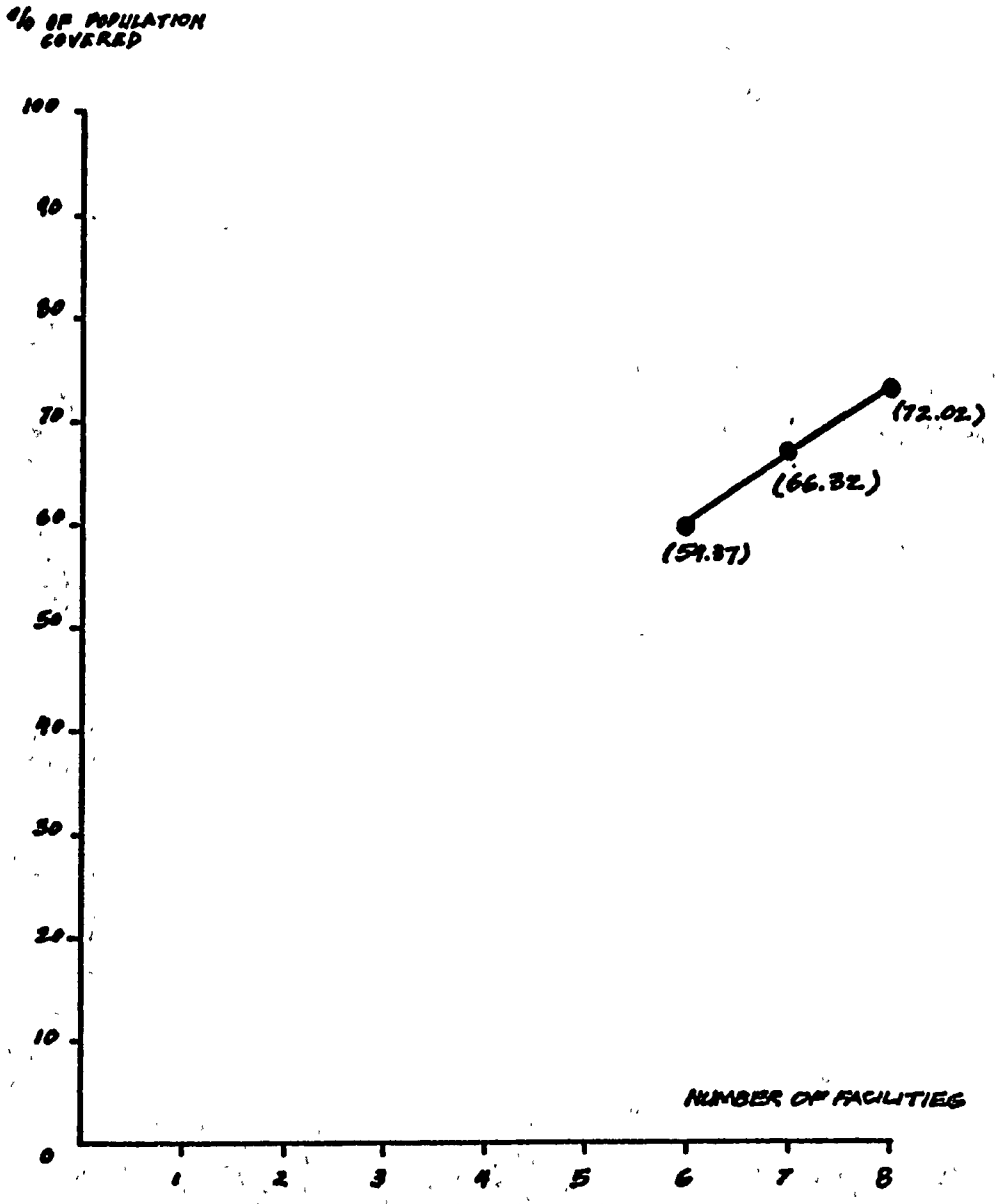
(b) that a potential site should have either an existing rural health facility (such as a health outpost), or a rural health worker (such as a promotora).

Other tests of suitability could easily be developed -- these two are only illustrative. Colombian health planners might select other restrictions that better reflect the special characteristics of the Zarzal region and/or the rural ambulance system.

If planners restrict vehicles to villages with greater than 900 inhabitants, only three facilities can be added (see figure 8-7). Six villages in Zarzal have a population greater than 900 inhabitants; however, only three could be selected as vehicle sites (Vallejuelo, San Francisco, and Miravalle). A vehicle sited at any of the other three would not increase the access of ambulances to the rural population.

It is surprising that an "unrestricted extension" and limiting new sites to villages with population exceeding 900 persons leads to identical coverage. Two of the first three sites selected in the unrestricted analysis (table 8-2) are also selected with 900-plus inhabitants analysis (table 8-3). While the population coverage for the first sited facility in table 8-2 and 8-3 are equal, the selected villages are different. The first facility sited in table 8-2 (Quebradanueva - node 8) and in table 8-3 (Vallejuelo - node 11) cover an equal number of additional rural residents. In

FIGURE 8-7
AMBULANCE SITE EXTENSION TO POPULATIONS GREATER THAN 900:
A TRADE-OFF CURVE
(30 minute service time)



numbers in parentheses refer to the percentage of total population covered

TABLE 8-3
AMBULANCE SITE EXTENSION–POPULATION GREATER THAN 900 RESTRICTION
(30 minute service time)

Rank Order	*Village*	*Node Number*	*Population Covered (persons)*	*Percent of Total Population*
	Base (5 vehicle sites)		12,840	51.35
1	Vallejuello	11	2,006	59.37
2	San Francisco	50	1,738	66.32
3	Miravalle	32	1,426	72.02

fact, a closer inspection of figure 8-4 reveals that a facility located at either site can cover the other. The decision rule for siting "alternative optima" used in the GAS program was to select the village with the lowest node number -- in the case of a "no restrictions" siting policy, node number eight, Quebradanueva. However, since node number eight does not have a population in excess of 900 inhabitants, node number 11, Vallejuello (population 1,306), was selected in table 8-3.

If ambulance sites are restricted to those villages with either an existing rural health outpost or a promotora, additional vehicles can be deployed at 11 sites illustrated in table 8-4. Rural population coverage can increase up to 93 percent. Figures 8-6 and 8-8 are identical up to the eight iteration with respect to (a) the sites chosen for vehicle facilities and (b) the percentage of population covered. A combination of the results from the three different extension policies is seen in table 8-5. All three ambulance extension policies lead to identical population coverage for the first three site selections.

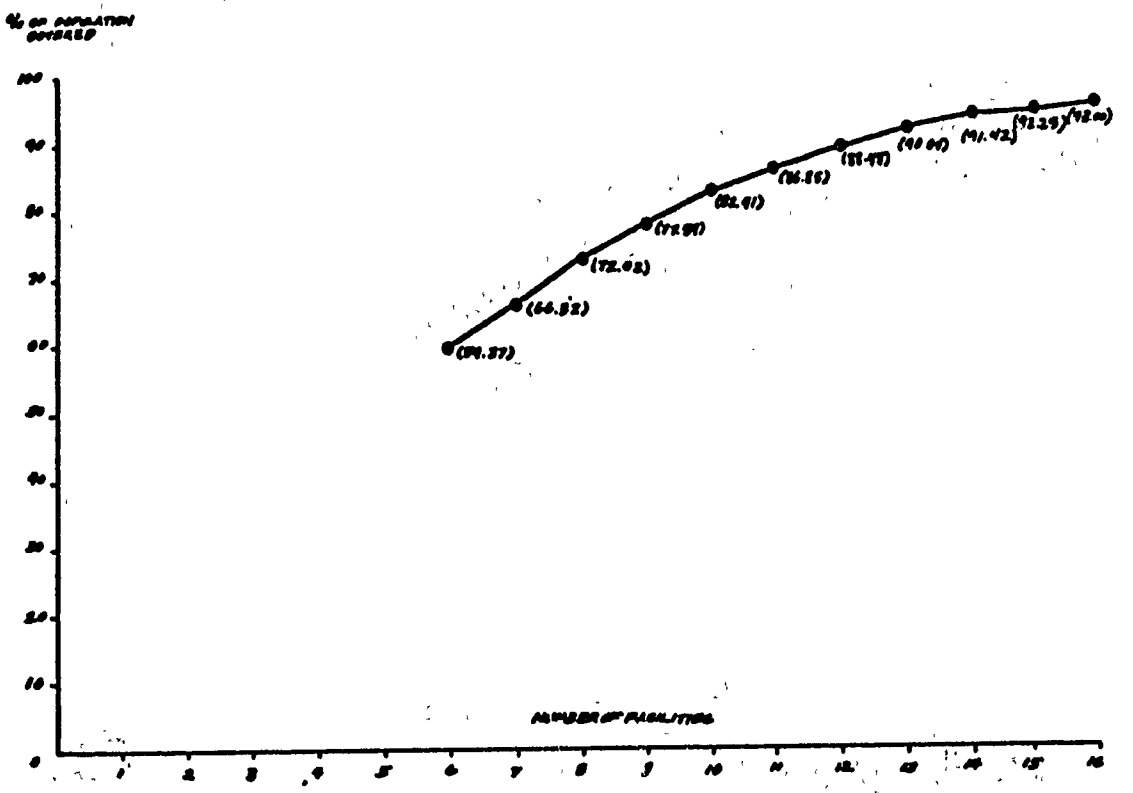
SUMMARY

The results of this analysis provide health policy makers several kinds of useful information. First, the analysis shows how costly, in terms of additional vehicle

TABLE 8-4
AMBULANCE SITE EXTENSION–PROMOTORA/HEALTH OUTPOST RESTRICTION
(30 minute service time)

Rank Order	*Village*	*Node Number*	*Population Covered (persons)*	*Percent of Total Population*
	Base (5 vehicle sites)		12,840	51.35
1	Quebradanueva	8	2,006	59.37
2	San Francisco	50	1,738	66.32
3	Miravalle	32	1,426	72.02
4	Quebradagrande	22	1,396	77.59
5	El Basal	61	1,206	82.41
6	La Florida	72	1,110	86.85
7	Corcega	14	407	88.48
8	Linderos	19	390	90.04
9	Penones	78	345	91.42
10	Chaquiral	3	207	92.25
11	Taquales	36	188	93.00

FIGURE 8-8
AMBULANCE EXTENSION TO HEALTH OUTPOSTS: A TRADE-OFF CURVE
(30 minute-plus service time)



numbers in parentheses refer to the percentage of total population covered

TABLE 8-5

COMPARISON OF AMBULANCE SITING PLANS
(30 minute service time)

Village	*Population Covered*	*Accumulated Percent of Total Population*
	Siting With No Restrictions	
Current Five County Seats	12,841	51.35
Quebradanueva	2,005	59.37
San Francisco	1,737	66.32
Miravalle	1,425	72.02
Quebradagrande	1,392	77.59
El Basal	1,205	82.41
Coconuco	1,110	86.85
San Rafael	797	90.04
La Robleda	572	92.33
Monte Azul	347	93.72
Chontaduro	222	94.70
	Siting Only in Villages With Existing Rural Health Facilities	
Current Five County Seats	12,841	51.35
Quebradanueva	2,005	59.37
San Francisco	1,737	66.32
Miravalle	1,425	72.02
Quebradagrande	1,392	77.59
El Basal	1,205	82.41
La Florida	1,110	86.85
Corcega	407	88.48
Linderos	390	90.04
Peñones	345	91.42
Chaquiral	207	92.25
	Siting Only in Villages with More Than 900 Inhabitants	
Current Five County Seats	12,841	51.35
Vallejuelo	2,005	59.37
San Francisco	1,737	66.32
Miravalle	1,425	72.02

sites, are the gains in population coverage. Second, location analysis provides the exact sites for each ambulance base under varying assumptions. Also, by comparing results from different policies, health planners may select sites that are good under all conditions.

In particular, if Zarzal health planners wish to provide additional rural population access to emergency services, Vallejuello is a good candidate site for an ambulance. Vallejuello has both a large population (1,306) and is already the site of rural health services. A vehicle operating out of Vallejuello would reach over eight percent of the rural population not presently covered by the hospital-based vehicles.

The intent of this study is to show what kinds of analysis can be used in emergency vehicle planning, not determine how an ambulance system in Zarzal should be built. This chapter has illustrated (a) the performance of the current system; (b) the potential benefits of reallocation/relocation of existing vehicle resources; and (c) coverage options for extending the present system to presently unserved areas.

This analysis has centered around a time concept for emergency services in a developed country. It is not clear what time standards for a developing country should be.

The next chapter looks at a range of time standards that Colombian health planners might consider.

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(2) Church, Richard.
Synthesis of a Class of Public Facilities Location Models, Baltimore, MD: The Johns Hopkins University, Ph.D. Dissertation, 1974.

CHAPTER NINE

ADDITIONAL TRAVEL TIME CONSIDERATIONS

Chapters seven and eight examined ambulance deployment in Zarzal under two alternate policies for extending emergency medical services into the unserved rural areas. One policy, a two hour-plus "maximum time to service" was suggested by Zarzal health planners. A second option, a 30 minute-plus maximum time to service for rural ambulances, reflects U.S. emergency medical service goals. The purpose of this chapter is to show how policies between these extremes affect the time standards of ambulance effectiveness, the number of vehicles, and the fraction of population that can be covered.

The five tables in this chapter illustrate the relationships between health resources and services. The performance of the present hospital-based ambulance system (table 9-1) can be compared to the service of a system where vehicles are sited to maximize accessability to rural residents in Zarzal (table 9-2). Both tables show how the number of ambulance bases determine the degree of coverage of the population.

Tables 9-3, 9-4, and 9-5 show the trade-offs of

time standards, vehicles, and coverage in terms of a potential extension of the present system -- how added vehicles would improve performance. They compare extensions where (a) any site is acceptable as a base for ambulances (9-3); (b) only villages with 900+ population are acceptable (9-4); and (c) where the set of potential ambulance sites is limited to those villages with existing rural health facilities and/or personnel (9-5).

THE CURRENT SYSTEM

The present hospital-based ambulance system, if operated on a regional basis, is accessable to 94.4 percent of the rural residents within two hours and to 51.3 percent of the population within 30 minutes round-trip service time. This table also shows coverage of the hospital-based system at 60 and 90 minute standards. Table 9-1 illustrates

TABLE 9-1
AMBULANCE SERVICE AT HOSPITAL FACILITIES
120–90–60–30 MINUTES

		PERCENTAGE OF TOTAL POPULATION SERVED			
Rank Order	*Service Time*	*120 Minutes* %	*90 Minutes* %	*60 Minutes* %	*30 Minutes* %
1		66.46	57.46	41.26	26.25
2		89.41	80.80	55.06	32.24
3		93.97	87.38	66.46	46.17
4		94.40	90.71	76.67	49.36
5		94.40	90.71	83.91	51.35

how service time standards can affect population coverage. If the number of vehicles is held constant, the more responsive the standard of service, the less comprehensive the service. As the upper bound on service time is reduced, the level of population coverage decreases. For example, compare the level of coverage provided by one facility at 30 and 60 minute standards. The vehicle covers a smaller fraction of the population under the more responsive 30 minute standard than the 60 minute standard. This effect is reduced as the upper bound on response time is relaxed. Coverage performance differences between 120 and 90 minute standards are less than between 60 and 30 minute maximum service time limits. Five facilities cover 32 percent more of Zarzal's rural residents within 60 minutes than they could in 30 minutes. Comparing 120 and 90 minute maximum service times, the difference between the coverage of these five hospital facilities is less than four percent.

This same conflict between responsiveness and comprehensiveness is evident for ambulance sites when locations are not constrained to existing hospitals. Table 9-2 shows similar results when ambulances are sited without restrictions. Five vehicles can reach all the rural population in 120 minutes; those same vehicles are only accessable to 65 percent of the rural population in 30 minutes. Table 9-2 also illustrates that hospitals do perform well as ambulance bases, even though other sites may be more accessable to

TABLE 9-2
AMBULANCE SERVICE WITH NO RESTRICTIONS
120–90–60–30 MINUTES

Rank Order	Service Time	PERCENTAGE OF TOTAL POPULATION SERVED 120 Minutes %	90 Minutes %	60 Minutes %	30 Minutes %
1		69.07	51.35	41.26	26.25
2		90.35	80.19	60.28	40.06
3		97.99	89.95	73.45	49.19
4		99.11	93.45	83.66	58.01
5		100.00	97.34	92.12	64.96

the rural population. In all but one case (five facilities at 30 minutes), vehicles based at hospitals can reach more than 90 percent of the maximum population that can be covered by the best sites. This difference in patient transport accessability may not be enough to justify shifting ambulances from hospital bases, since the hospitals are the optimal bases for vehicles that move equipment and medical personnel.

AMBULANCE EXTENSION

The basic message in table 9-3, which considers potential ambulance extensions, is that Colombian health planners must either (a) accept a long "time to service" standard or (b) construct more facilities to reach all the rural residents with ambulance service. With a two hour-plus time to service standard, a total of seven ambulance

(two additional vehicle sites) would completely cover the rural population. However, if the planners wish to achieve a time to service roughly similar to EMS systems in the U.S. (e.g., 30 minutes to service), even 15 facilities would provide only 92 percent coverage of the rural population.

TABLE 9-3
AMBULANCE FACILITY EXTENSION: NO RESTRICTION
120–90–60–30 MINUTES

		PERCENTAGE OF TOTAL POPULATION SERVED			
Rank Order	*Service Time*	*120 Minutes* %	*90 Minutes* %	*60 Minutes* %	*30 Minutes* %
Base Case		94.40	90.71	83.91	51.35
1		99.30	96.23	89.99	59.37
2		100.00	97.67	92.89	66.32
3			98.77	95.19	72.02
4			99.19	97.07	77.59
5				98.07	82.41
6				98.51	86.85
7				98.94	88.48
8					90.04
9					91.42
10					92.25

Not all sites may be suitable bases for a medical vehicle. Table 9-4 shows the best coverage possible if ambulance vehicles are restricted to sites where the population is greater than 900 residents. The impact of restricting sites to villages of more than 900 residents is great at service standards of 60, 90, and 120 minutes. For each of these norms, restricting the set of potential sites reduces total population coverage from four to seven percent versus the situation where all sites can be potential vehicle bases. There is no change in coverage at a 30-minute standard (compare tables 9-3 and 9-4). The same villages are selected as vehicle locations when (a) there are no restrictions and (b) sites are limited to those villages with populations exceeding 900 residents. These villages may be good potential sites.

TABLE 9-4
AMBULANCE FACILITY EXTENSION: + 900 POPULATION
120–90–60–30 MINUTES

		PERCENTAGE OF TOTAL POPULATION SERVED			
Rank Order	*Service Time*	*120 Minutes* %	*90 Minutes* %	*60 Minutes* %	*30 Minutes* %
Base Case		94.40	90.71	83.91	51.35
1		95.09	91.45	85.80	59.37
2			91.87	86.22	66.32
3					72.02

Indeed, table 9-3 is almost identical to table 9-5 (which shows the best ambulance locations when sites are restricted to those villages with existing rural health personnel). Changes in facility selection occur only within the last two added facilities at the 60 minute norm. The same villages are chosen in both analyses, an indication of strategic location relative to the other rural towns.

TABLE 9-5
AMBULANCE FACILITY EXTENSION: RURAL HEALTH OUTPOSTS
120–90–60–30 MINUTES

		PERCENTAGE OF TOTAL POPULATION SERVED			
Rank Order	*Service Time*	*120 Minutes* %	*90 Minutes* %	*60 Minutes* %	*30 Minutes* %
Base Case		94.40	90.71	83.91	51.35
1		99.30	96.23	89.99	59.37
2		100.00	97.67	92.89	66.32
3			98.77	95.19	72.02
4			99.19	97.07	77.59
5				98.51	82.41
6				98.94	86.85
7					88.48
8					90.04
9					91.42
10					92.25
11					93.00

SUMMARY

These tables allow the planner to compare different policies in terms of the trade-offs in goals -- accessability (the percentage of population covered), cost (the number of vehicles), and the quality (service time) for an emergency medical service. Ambulance deployment in Zarzal is as strongly influenced by geography as by policies by which planners might allocate vehicles to sites. This analysis also suggests that a great volume of descriptive data may not be needed by planners to find good ambulance sites. The computer runs associated with tables 9-3, 9-4, and 9-5 show that some of the same sites are selected under different "time to service" standards and location policies (what villages can be potential bases). The extent that this would be true under other geographical conditions is not known.

These service alternatives are just one source of information that may be used by Colombian health planners to determine those policies best suited for the rural health system. A medical system involves budgetary, accessability, and quality of service issues. For example, is it better to have two vehicles that can reach 90 percent of the rural residents within two-plus hours, or to have all five of the present hospital-based ambulances provide a higher quality of service (i.e., one hour-plus service time) to only 84 percent of the rural population? Location

analysis does provide some information upon which to base these decisions. However, the final decisions will reflect the values and judgement of the Colombian decision makers.

CHAPTER TEN

CONCLUSIONS AND RECOMMENDATIONS

The performance of certain health services is determined to some degree by the spatial distribution of facilities and resources that provide the services. This study has been motivated by three questions related to the deployment and performance of health resources. These questions are:

(a) How can proper deployment of medical resources in rural areas be determined?

(b) What norms should govern the allocation and use of rural health resources? and,

(c) What procedures extend health services in the most effective manner?

The approach of this study is to illustrate how the systematic use of computer mapping and location analysis can assist in answering these questions and planning for the deployment of health resources in rural areas.

COLOMBIAN RURAL HEALTH EFFORTS

The quality of health services in Colombia is improving but is still inadequate. Due to environmental health and sanitary compaigns in recent years, rates of

morbidity and mortality appear to have dropped. However, pockets of extreme poverty and poor health continue to exist, particularly in the rural areas of the country. For example, the Colombian government has estimated that approximately 36 percent of the total population (largely rural residents) have no access to public or private health services. The lack of health services in rural Colombia is one factor behind retarded rural development and out-migration from rural to urban areas.

In response to these problems, the Colombian government has recognized the importance of improving and expanding health services. Faced with a shortage of traditional medical resources (physicians and nurses), Colombian public health planners are developing a rural health care system around indigenous health workers and a system of local and regional hospitals.

Although Colombian health planners use strict guidelines to determine how various components of the rural health system are to be staffed and operated, they rarely develop criteria to allocate facilities in space. Deployment of resources is often determined by inspection and intuition. Although common sense is useful in many circumstances, the complexity of Colombia's rural health development program make it difficult for planners to balance all the factors to achieve the most effective and efficient location of services.

One alternative to inspection and intuition is the use of systematic analysis of health conditions in the rural areas as the basis for allocating rural health resources. Health services would be directed to those areas with the highest need for resources.

COMPUTER MAPPING ANALYSIS

The rationale for computer mapping is related to the proposition that health resources should be allocated to those areas where the need is greatest. Computer mapping is a means for arranging, analyzing, and displaying health information so that health planners can determine those areas of need. The potential and problems of mapping health information in Colombia were explored in chapter two. One inherent problem is the absence of an accurate and comprehensive health data base in Colombia. Serious efforts should be made by Colombian public health authorities to expand and standardize data collections.

Another impediment to using graphed measures of mortality and morbidity is the problem of developing a "health status index" of need (a basis for determining the areas that may best utilize additional rural health resources). There are numerous ways in which health related data may be combined to form an index of health status. To illustrate an approach, this study used quartile ranks of various health indicators. Quartile ranks were then com-

bined, by assigning equal weights to each indicator, to form an overall quartile-based index of health status. This particular index is only illustrative. Colombian health planners should consider developing some data-based rationale for evaluating competing claims of regions for health resources. Planners should recognize that the choice of either a geographical unit of observation or a measure of health status can influence the result of an indexing process.

Geographical aggregation to a county level may misrepresent rural health conditions. Health data at the national level in Colombia are available only on a county basis. Records of the variation between urban and rural health in the same county are not available.

A comparable loss of information occurs when individual measures of health or ill health are combined to form an index. A quartile obscures wide variations that may exist within and between individual quartiles. For example, a region with below average health indicators for two factors might appear to have average health status if it scored high on a third factor.

The value of a "health index" for some geographical area is that it can combine several incommensurate measures of health status into a single number that may simplify comparison and may reasonably reflect health status. If this information can be mapped and compared against other

counties, a planner has some basis for allocating health resources. The issue of "where to allocate additional health resources" deserves increased attention by Colombian health planners.

LOGISTICS AND EXTENDING HEALTH SERVICES

The Colombian Ministry of Health plans to extend primary health services to all rural areas presently without health services. The basic components of the rural health system are (a) the minimally trained primary health care worker and (b) the local and regional hospitals. The extension of these primary health services will need to be built around logistical support.

A rural medical vehicle system provides the coordination between rural health workers and the hospitals. This medical vehicle system performs tasks that include (a) the transport of medical manpower (doctors and nurses) from hospitals to rural villages for supervision of the rural primary health care workers or consulting visits; (b) the transport of medical supplies, such as basic medical supplies and educational materials used by the promotoras; and (c) the transport of emergency and referral patients from the rural areas into medical institutions. Planning for this rural medical transportation is complicated by the multiple and often competing roles of the rural medical vehicles.

Present planning efforts are limited to determining manpower requirements for the rural ambulance drivers, using a work-norm approach. Although present efforts do provide the manpower necessary to coordinate the rural health system, a work-norm approach does not accurately forecast the manpower levels necessary to provide coverage of emergencies and patient referral. "Expected work" norms do not take into consideration (a) the demand for rural emergency patient transportation; (b) the emergency transport of supplies; or (c) the transfer of referral patients both up and down the various levels of the regional health system.

Colombian health planners should consider restructuring the present transportation system into two separate systems -- one to move patients, and the other to transport supplies and medical personnel. Emergency patient transportation requires a vehicle that functions like an ambulance. Transportation of medical manpower and supplies could be accomplished with vehicles less sophisticated and less costly than those in current use. The differences between the emergency and non-emergency roles (measured in terms of equipment, manpower, and planning requirements) are sufficiently great to warrant a consideration of change.

Although patient transportation is an explicit goal of the system, vehicles are deployed in Colombia without consideration of vehicle demands for patient referral,

accidents, or emergencies. As long as the primary emphasis of the system is to move manpower and materials to support rural health facilities, Colombian planning efforts appear to be adequate. However, as sanitation and preventative health campaigns improve health in rural Colombia, trauma and chronic diseases will increase in importance relative to environmental and vector-borne diseases. These chronic diseases will place increasing demands for a system of patient transportation.

Presently, rural medical vehicle drivers do not receive any formal training in first aid or emergency care. Consequently, medical intervention can occur only after an emergency patient reaches the hospital. By implementing basic emergency medical training for rural ambulance drivers, Colombian health planners could reduce substantially the amount of time an emergency patient would have to wait to receive medical attention.

Health planners might also consider extending the concept of regionalized care to the medical vehicle system. Although most rural health services are provided by regional entity, each medical vehicle is currently confined to one county's geographical boundaries. Ambulances operate out of local hospitals in county seats and serve only the rural areas associated with that county. Regionalizing the medical vehicle system would increase the potential efficiency of the transportation system by (a) reducing

the travel time necessary to provide service; (b) reduce the total cost of transportation by reducing the number of facilities presently providing service; and (c) provide a transportation back-up capability for use in periods of peak demand through the potential "multiple coverage" of a regional system.

Colombian health policy makers should also reconsider their implicit assumption that rural medical vehicles must be based in local and regional hospitals. Hospital sites are ideal as bases for moving medical personnel and supplies. Other sites may be more accessable to the rural population to serve patients in emergencies. This study has shown optimal vehicle sites could cover 13 percent more of the rural population (assuming a 30-minute maximum time to service) than the current hospital bases.

Establishing some unit of time as a measure of system effectiveness would allow for more orderly health planning. Present Colombian planning procedures do not evaluate the quality of service being delivered by the rural ambulance system. In many other countries, "time to service" or "response time" has been accepted as a measure of performance in the delivery of medical transportation services. The current Colombian medical transportation system provides transportation to a specified area without regard to the amount of time necessary to provide that service.

If Colombian health planners decide at some future

time to plan more for ambulance or emergency transportation, they should consider each of these possible policy changes:

(a) Regionalizing vehicle services;

(b) Establishing time as a service indicator;

(c) Training ambulance drivers in medical care; and,

(d) Removing the location restriction on vehicle sites.

LOCATION ANALYSIS AND RURAL HEALTH PLANNING

If the rural medical vehicle system is modified to improve emergency service care, health planners will face the issue of determining where to locate ambulance sites. The complexities of these decisions will make it difficult for common sense alone to find the "best" locations. This study has illustrated how location analysis can be used in a systematic manner to assist with weighing the factors relating to ambulance deployment.

Location analysis can calculate how the present system performs. For example, Colombian planners indicated that one hour is a reasonable response time for medical vehicles. A one hour response time is equivalent to a limit of more than two hours on time of service. Under the present non-regionalized system, emergency transportation can be provided to approximately 93 percent of the rural population within two-plus hours.

Location analysis also allows Colombian health

planners to examine the effects that incremental policy changes would have upon the system's ability to provide emergency services. Such policies include:

(a) the effects that reduction in service has on population coverage;

(b) how location norms affect population coverage; and,

(c) the kinds and quantity of health planning data.

For example, a shift of the present county-vehicle system to a regional emergency transportation network would not only improve the accessability of ambulance vehicles to the rural population, but it also has a potential to reduce the number of needed vehicle sites. Ambulances based at only four regional sites cover a larger fraction of the rural population within a two-plus hour time to service than the five facilities presently used.

Location analysis was also shown in the study to be useful in examining the effects of changing location decision norms. Under the present hospital based system, approximately 94 percent of the rural population can receive emergency service within the maximum service time. By eliminating the hospital location rule, Colombian health planners could provide emergency services to 100 percent of the rural residents within the two-plus hour maximum service time with no change in the number of vehicle bases.

Location analysis can be used by health planners to examine the effects of policies to reduce the maximum

service time in patient transport service. A 30-minute response time is the standard for rural emergency services in the United States. If the Colombian public health system were to incorporate a similar time constraint, the current five hospital-based vehicles could reach only 51 percent of the rural residents in Zarzal. Even if vehicle policy selected the most accessable sites for facilities (not only hospitals), ambulances could serve only approximately 64 percent of Zarzal's rural residents within 30 minutes.

The only way Colombian health planners can increase the quality (reach more people in less time) of emergency services, would be to distribute a large number of ambulances around the Zarzal area. Location analysis can determine additional facility sites that provide the greatest degree of accessability to the rural population. Seven additional facilities would be needed in Zarzal to achieve a 90 percent coverage of the rural population at a standard of 30 minute maximum service time.

Location analysis can illustrate how changes in standards that restrict potential ambulance sites may or may not change the accessability of patient transport services. In this study the rural population in the Zarzal health region was concentrically dispersed around the county seats (location of the local hospitals). Thus, when current hospital location restrictions were changed, the

hospitals still proved to be very efficient sites for ambulance facilities. It is possible that hospital sites (county seats) are centrally located with respect to the rural villages in other parts of Colombia.

A final result of this deployment study is information regarding the necessary volume of data for site analysis. Different combinations of location factors were examined in an effort to determine those that yielded the best siting results. When no restrictions were used in locating additional facilities to the present county hospital/ambulance bases, the geography of the rural population sited ambulance bases at one set of locations. As restrictions upon potential sites were increased to include population limits and the existance of rural health facilities and promotoras, the sited facilities, for the most part, were the same as those sited using no restrictions.

The number of potential factors that may be used in considering potential ambulance bases are limited only by the imagination. However, in the case of Zarzal, the geography and distribution of the rural population are the most valuable factors for determining additional sites. However, it should be noted that the Zarzal planning region is an isolated example and that these results may not hold for all rural areas in Colombia.

SUMMARY AND RECOMMENDATIONS

Location and mapping analysis can display health information and assist in the allocation of health resources. These analytical methods provide a means for quantifying how the goals, standards, and restrictions of the Colombian public health system are interrelated. They can also be used to generate information regarding the trade-off's between policies. Used in conjunction with common sense, mapping and location analysis may assist Colombian public health officials to allocate, deploy, and extend rural health services in the most effective manner.

RECOMMENDATION ONE

DATA COLLECTION EFFORTS BY THE COLOMBIAN PUBLIC HEALTH SECTOR SHOULD BE EXPANDED AND STANDARDIZED

RECOMMENDATION TWO

COLOMBIAN PUBLIC HEALTH PLANNERS SHOULD CONSIDER DEVELPING DATA-BASED RATIONALES FOR EVALUATING COMPETING CLAIMS OF REGIONS FOR HEALTH RESOURCES

RECOMMENDATION THREE

THE ISSUE OF WHERE TO ALLOCATE ADDITIONAL HEALTH RESOURCES DESERVES INCREASED ATTENTION BY COLOMBIAN HEALTH PLANNERS

RECOMMENDATION FOUR

IN ORDER TO MEET THE DEMANDS OF EMERGENCY PATIENT TRANSPORTATION, THE COLOMBIAN PUBLIC HEALTH SYSTEM SHOULD IMPLEMENT THE FOLLOWING POLICIES

- -- REGIONALIZATION OF MEDICAL VEHICLE SERVICES
- -- ESTABLISHMENT OF TIME AS AN INDICATOR OF QUALITY OF MEDICAL VEHICLE SERVICE
- -- ESTABLISHMENT AND IMPLEMENTATION OF EMERGENCY MEDICAL TRAINING FOR MEDICAL VEHICLE DRIVERS

RECOMMENDATION FIVE

IN ORDER TO MEET THE DEMANDS OF EMERGENCY PATIENT TRANSPORTATION, THE COLOMBIAN PUBLIC HEALTH SYSTEM SHOULD CONSIDER

- -- REEVALUATING THE PRESENT DECISION RULES RESTRICTING MEDICAL VEHICLES TO HOSPITAL FACILITIES
- -- RESTRUCTURING THE PRESENT MEDICAL TRANSPORTATION SYSTEM INTO TWO SEPERATE SYSTEMS -- ONE TO MOVE PATIENTS, AND THE OTHER TO TRANSPORT SUPPLIES AND MEDICAL PERSONNEL.

APPENDICES

APPENDIX A

HEALTH RELATED DATA IN VALLE DEL CAUCA

The tables and figures in appendix A show the data and results that were used in the mapping analysis. As described in chapter two, there were 14 categories of data that were collected and analyzed.

TABLE A1: CIRCULATORY RELATED DEATHS* AND DEATH RATES**
VALLE DEL CAUCA, COLOMBIA (1973, 1974, 1975)

	1973	1974	1975	Rate		1973	1974	1975	Rate
1. El Agulia	11	14	15	130.13	22. Riofrío	10	14	13	81.98
2. Anserma Nueva	23	14	21	185.87	23. Buenaventura	133	224	218	132.75
3. El Cario	12	18	15	105.81	24. Tulua	208	257	244	209.47
4. Cartago	129	206	219	233.35	25. San Pedro	5	9	16	96.43
5. Argelia	6	9	6	94.22	26. Darien	15	9	15	151.16
6. Ulloa	5	5	7	88.52	27. Yotoco	11	16	12	131.32
7. Alcalá	9	17	17	140.8	28. Buga	195	271	246	278.94
8. Toro	17	19	13	94.38	29. Restrepo	11	23	31	228.84
9. Versalles	15	13	13	118.40	30. Dagua	25	29	35	122.8
10. Obando	4	15	7	87.73	31. Vijes	7	11	9	97.01
11. El Dovio	11	12	13	82.61	32. Guacari	18	48	44	194.51
12. La Unión	21	29	34	187.45	33. Ginebra	8	9	23	103.33
13. La Victoria	14	21	34	160.04	34. El Corrito	50	60	47	168.82
14. Roldonillo	44	60	53	201.48	35. La Cumbre	4	10	7	56.97
15. Bolívar	19	18	19	108.15	36. Palmira	324	427	476	220.79
16. Zarzal	50	69	69	188.04	37. Yumbo	35	62	62	140.98
17. Sevilla	61	85	90	109.03	38. Cali	1,666	1,803	1,885	186.87
18. Caicedonia	53	60	86	199.45	39. Pradera	28	40	56	186.55
19. Bugalagrande	33	26	30	147.13	40. Candelaria	28	48	36	133.08
20. Trujillo	11	19	21	75.65	41. Florida	45	47	49	136.74
21. Andalucía	12	22	27	66.34	42. Jamundí	29	62	52	150.17

*Included in the general category of circulatory deaths are the following causes of death:

(a) rheumatic disease of the heart
(b) hypertension
(c) isquemic heart disease
(d) other heart disease
(e) cerebrovascular disease
(f) disease of the arteries
(g) thrombosis and embolism
(h) other circulatory disease

Source: Servicio Seccional de Valle

**Circulatory death rate calculated as

$$\text{Rate} = \sum_{i=1973}^{1975} \left(\frac{D_i}{P_i}\right) \times 100{,}000$$

Where D_i = Number of circulatory related deaths in year i

P_i = Population in year i

i = 1973, 1974, 1975

FIGURE A-1
CIRCULATORY RELATED DEATHS IN VALLE DEL CAUCA, COLOMBIA (1973, 1974, 1975)

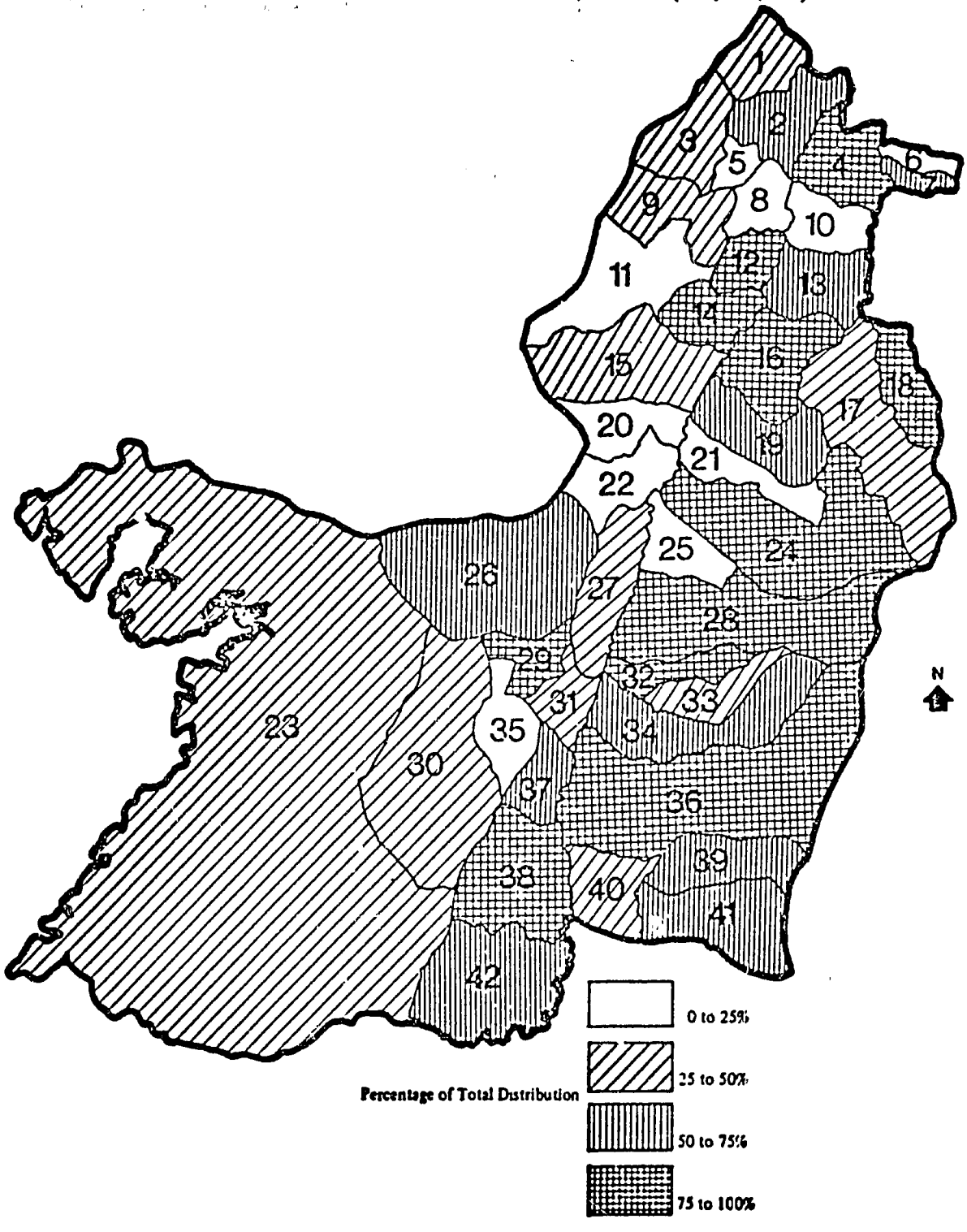


TABLE A2: POPULATION, VALLE DEL CAUCA, COLOMBIA (1973, 1974*, 1975)
(URBAN/RURAL PERCENTAGE FOR 1973)

	1973	1974	1975	% Rural (1973)		1973	1974	1975	% Rural (1973)
1. El Agulja	10,581	10,115	9,670	72.8	22. Riofrío	14,700	14,641	14,582	82.7
2. Anserma Nueva	13,522	11,036	12,566	52.5	23. Buenaventura	139,839	145,572	151,540	17.2
3. El Cario	14,459	14,199	13,943	74.1	24. Tulua	109,437	113,267	117,231	20.7
4. Cartago	77,890	79.448	81,036	11.2	25. San Pedro	10,238	10,381	10,526	78.6
5. Argelia	7,716	7,477	7,245	48.9	26. Darien	9,010	8,686	8,373	50.9
6. Ulloa	5,569	5,653	5,738	20.7	27. Yotoco	9,889	10.067	10,248	68.5
7. Alcalá	10,227	10,016	9,810	51.3	28. Buga	84.057	84,882	85,916	15.5
8. Toro	17,208	16,967	16,729	45.7	29. Restrepo	9,920	9,632	9,353	53.4
9. Versalles	11,995	11,827	11,661	63.8	30. Dagua	24,536	23,430	23,329	78.0
10. Obando	10,493	10,279	10,069	50.6	31. Vijes	7,160	7,167	7,246	64.4
11. El Dovio	14,457	14,529	14,602	72.7	32. Guacari	18,818	19,157	19,502	53.4
12. La Unión	15,001	14,941	14,881	33.9	33. Ginebra	12,315	12,610	12,913	66.7
13. La Victoria	14,292	14,363	14,435	47.4	34. El Cornito	29,804	30,996	32,236	41.8
14. Roldonillo	25,336	25,868	26,411	52.2	35. La Cumbre	12,127	12,297	12,469	85.2
15. Bolívar	17,903	17,598	17,299	82.8	36. Palmira	180,801	185,863	191,067	22.3
16. Zarzal	32,958	33,551	34,155	35.2	37. Yumbo	36,006	38,093	40,302	22.2
17. Sevilla	69,650	73,202	76,935	55.3	38. Cali	923,446	962,231	1,002,845	2.7
18. Caicedonia	32,593	33,147	33,710	27.7	39. Pradera	21,756	21,995	22,237	27.7
19. Bugalagrande	20,674	20,426	20,180	63.7	40. Candelaria	27,784	27,800	27,836	68.4
20. Trujillo	22,170	22,472	22,674	65.5	41. Florida	33,315	34,581	35,895	32.8
21. Andalucía	13,404	13,578	13,754	44.4	42. Jamundí	31,585	31,995	32,411	59.0

Source: Servicio Seccional de Valle

FIGURE A-2
RURAL POPULATION IN VALLE DEL CAUCA, COLOMBIA (1973, 1974, 1975)

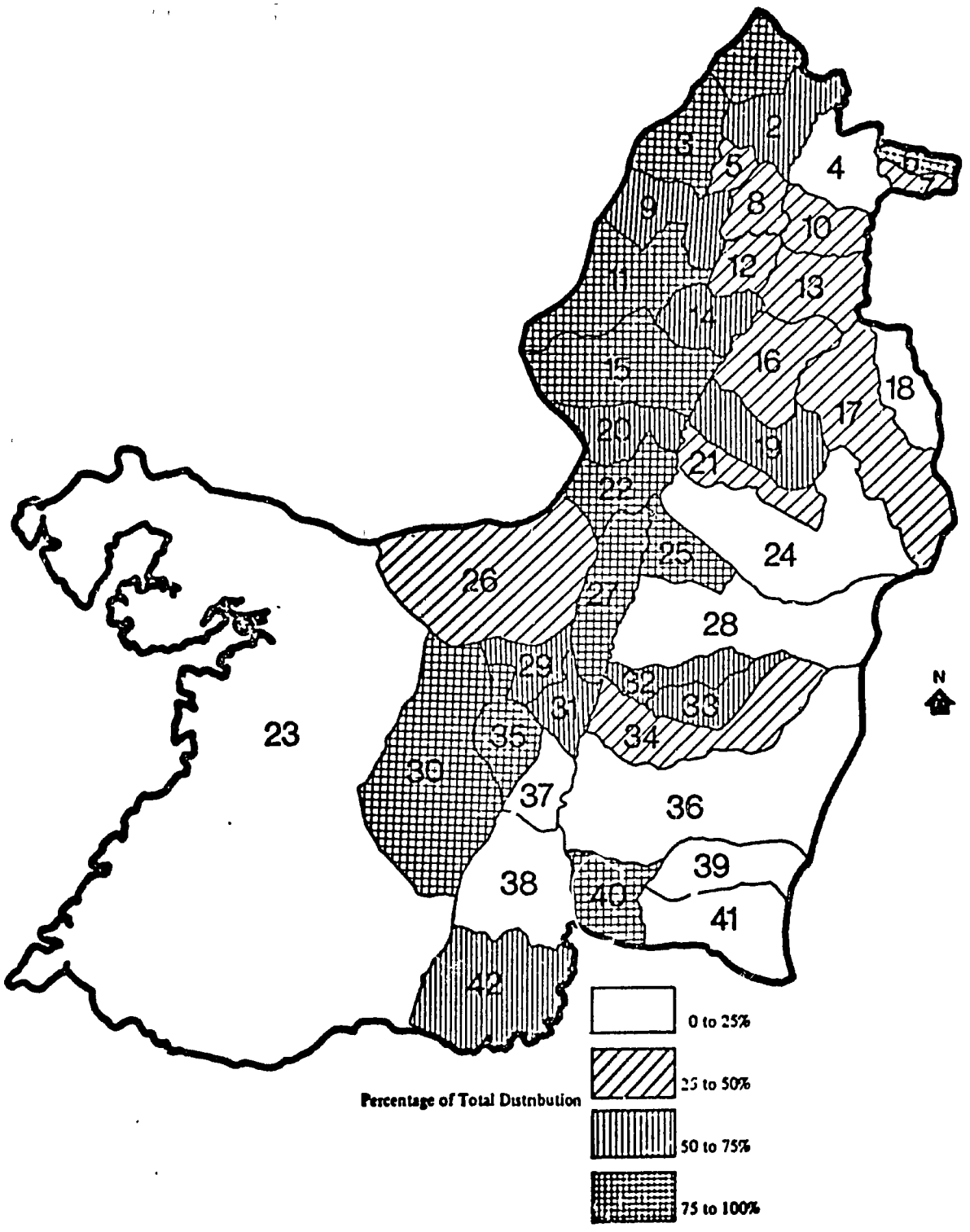


TABLE A3: TOTAL DEATHS AND DEATH RATE*
VALLE DEL CAUCA, COLOMBIA (1973, 1974, 1975)

	1973	1974	1975	Rate		1973	1974	1975	Rate
1. El Agulla	100	109	84	9.85	22. Riofrío	112	130	137	8.60
2. Anserma Nueva	182	185	140	13.08	23. Buenaventura	987	1,193	1,170	7.72
3. El Cario	132	101	95	7.47	24. Tulua	857	921	855	7.79
4. Cartago	798	946	899	10.07	25. San Pedro	42	60	76	5.11
5. Argelia	67	84	63	9.55	26. Darien	54	66	66	10.09
6. Ulloa	19	17	35	4.24	27. Yotoco	64	55	59	5.96
7. Alcalá	61	102	111	9.10	28. Buga	749	794	757	9.02
8. Toro	127	131	119	74.9	29. Restrepo	69	84	102	8.94
9. Versalles	99	108	104	6.28	30. Dagua	244	159	161	7.69
10. Obando	79	144	85	10.04	31. Vijes	23	28	38	3.23
11. El Dovio	85	71	112	6.12	32. Guacari	101	119	151	6.51
12. La Unión	134	132	156	9.43	33. Ginebra	61	84	76	5.88
13. La Victoria	107	91	117	7.30	34. El Corrito	210	204	194	6.59
14. Roldonillo	174	205	165	7.01	35. La Cumbre	39	45	84	3.41
15. Bolívar	134	99	120	6.71	36. Palmira	1,457	1,400	1,407	7.67
16. Zarzal	245	279	272	7.90	37. Yumbo	175	231	204	5.4
17. Sevilla	422	430	425	5.87	38. Cali	6,207	6,463	6,166	6.57
18. Caicedonia	325	305	344	9.79	39. Pradera	120	196	195	7.73
19. Bugalagrande	141	109	131	6.22	40. Candelaria	198	182	120	6.0
20. Trujillo	121	136	130	5.74	41. Florida	229	241	275	7.19
21. Andalucía	89	87	69	6.04	42. Jamundí	327	390	279	10.3

*Death rate calculated as

$$\text{Rate} = \sum_{i=1973}^{1975} \left(\frac{D_i}{P_i}\right) \times 1{,}000$$

Where D_i = Number of deaths in year i

P_i = Population in year i

i = 1973, 1974, 1975

Source: Servicio Seccional de Valle

FIGURE A-3
TOTAL DEATHS IN VALLE DEL CAUCA, COLOMBIA (1973, 1974, 1975)

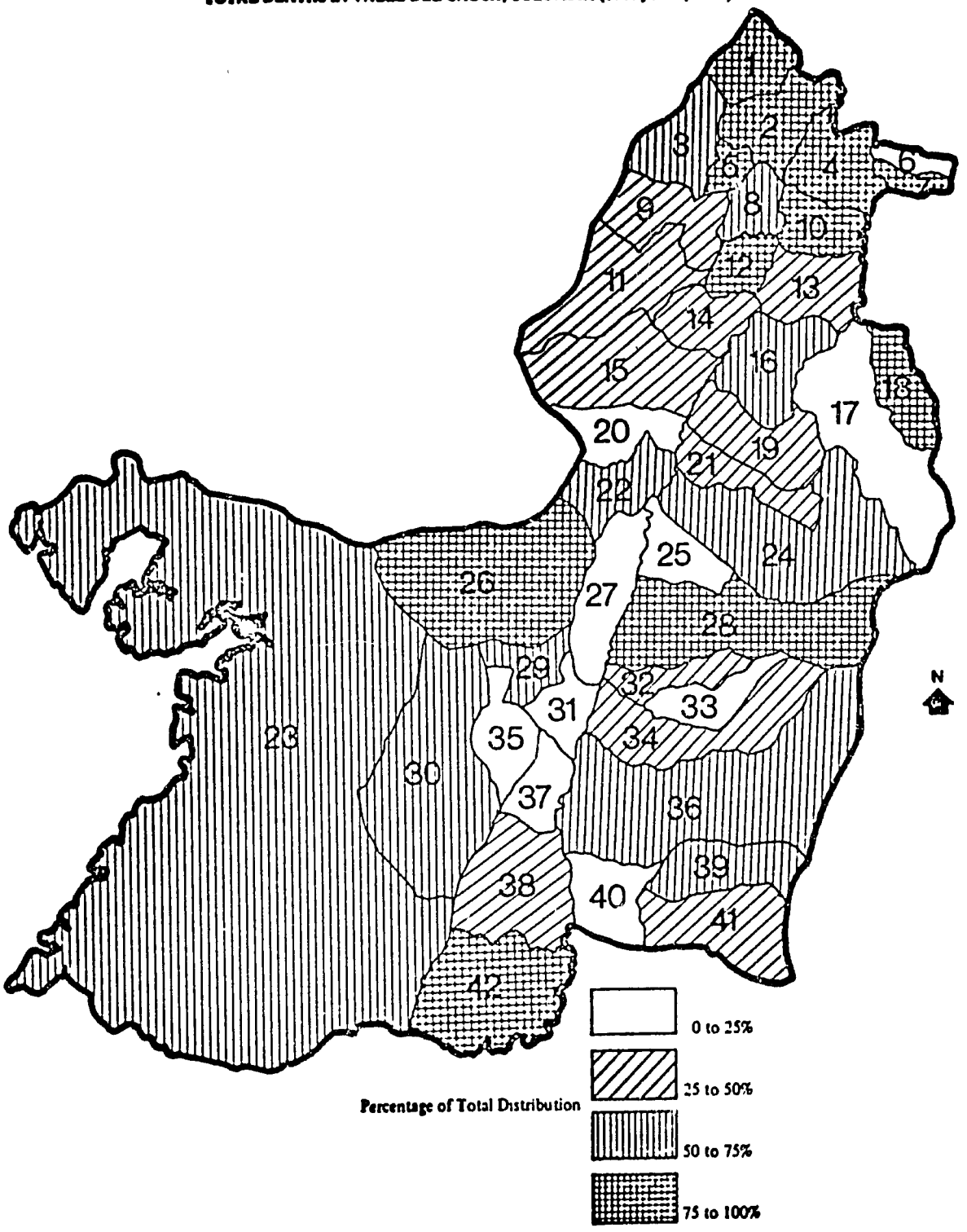


TABLE A4: BIRTHS AND BIRTH RATES*
VALLE DEL CAUCA, COLOMBIA (1972, 1973, 1974)

	1972	1973	1974	Rate		1972	1973	1974	Rate
1. El Agulla	464	469	333	39.8	22. Riofrío	225	224	104	12.53
2. Anserma Nueva	347	263	234	20.8	23. Buenaventura	3,282	3,372	2,802	15.62
3. El Cario	294	251	304	19.5	24. Tulua	2,674	2,567	2,337	23.1
4. Cartago	2,231	2,294	2,332	29.3	25. San Pedro	220	219	168	19.8
5. Argelia	622	411	386	48.7	26. Darien	306	287	420	37.5
6. Ulloa	103	100	80	16.9	27. Yotoco	298	607	473	46.4
7. Alcalá	405	274	312	32.3	28. Buga	1,772	3,698	4,242	38.5
8. Toro	435	316	268	19.7	29. Restrepo	484	412	355	42.0
9. Versalles	498	433	466	38.8	30. Dagua	1,102	1,099	920	42.4
10. Obando	302	295	229	26.2	31. Vijes	146	134	106	17.1
11. El Dovio	310	47	276	14.6	32. Guacari	219	617	277	19.7
12. La Unión	726	373	389	33.0	33. Ginebra	247	188	112	14.8
13. La Victoria	776	340	355	34.3	34. El Corrito	717	803	425	21.8
14. Roldonillo	666	686	578	25.4	35. La Cumbre	326	120	320	21.1
15. Bolívar	389	334	213	16.81	36. Palmira	5,332	5,453	5,096	29.3
16. Zarzal	1,076	2,493	876	44.9	37. Yumbo	914	1,101	809	25.1
17. Sevilla	1,607	1.449	1,268	20.7	38. Cali	24,074	20,870	22,464	24.3
18. Caicedonia	962	816	771	26.1	39. Pradera	966	1,142	1,017	47.8
19. Bugalagrande	569	272	115	15.4	40. Candelaria	982	1,112	569	21.3
20. Trujillo	337	970	147	21.8	41. Florida	1,136	663	757	25.6
21. Andalucía	337	295	187	20.4	42. Jamundí	1,317	1,419	1,100	40.5

*Birth rate calculated as

$$\text{Rate} = \sum_{i=1972}^{1974} \left(\frac{B_i}{P_i}\right) \times 1{,}000$$

Where B_i = Number of births in year i

P_i = Population in year i

i = 1972, 1973, 1974

Source: Servicio Seccional de Valle

FIGURE A-4
TOTAL BIRTHS IN VALLE DEL CAUCA, COLOMBIA (1972, 1973, 1974)

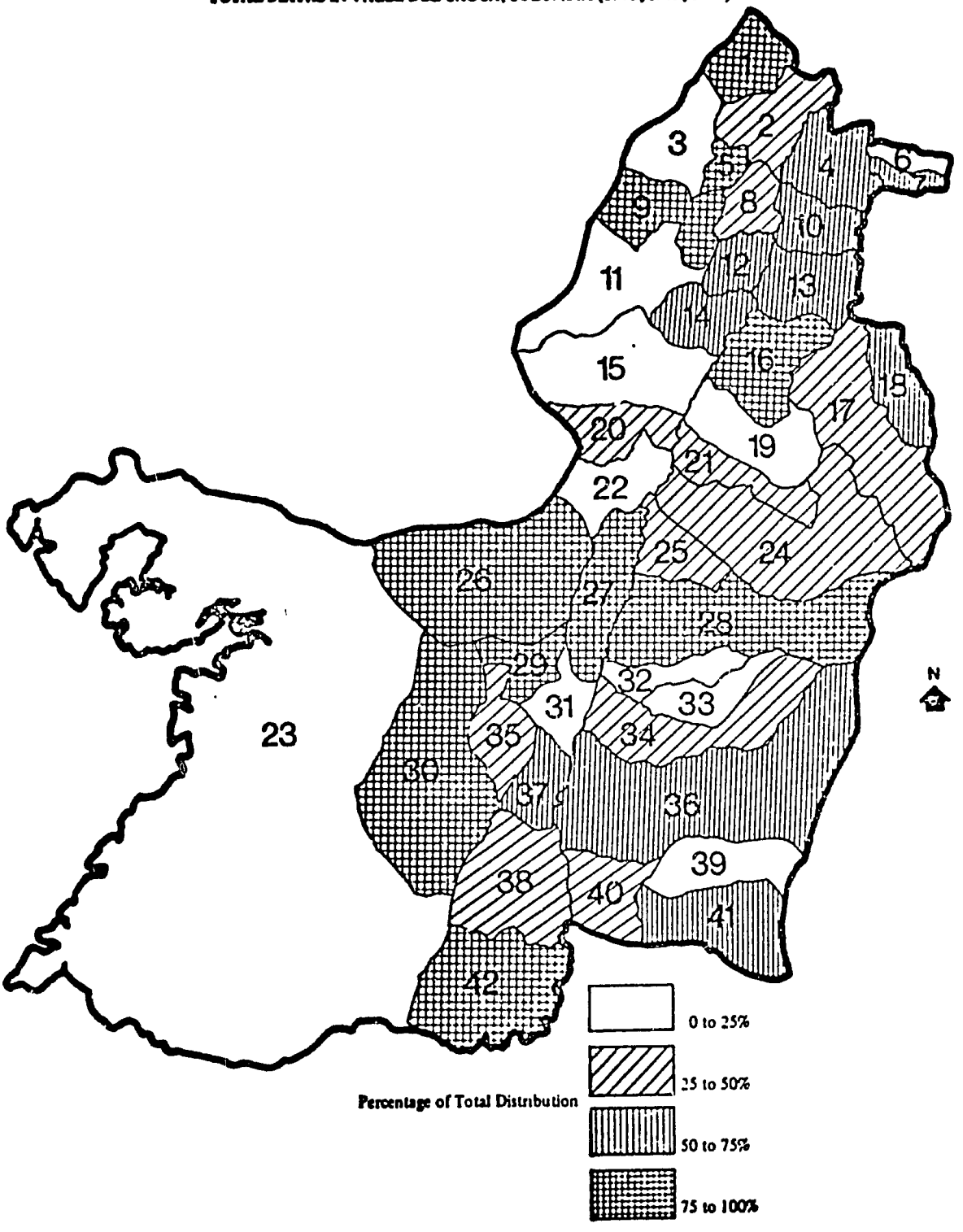


TABLE A5: INTESTINAL RELATED DEATHS* AND DEATH RATE**
VALLE DEL CAUCA, COLOMBIA (1973, 1974, 1975)

	1973	1974	1975	Rate		1973	1974	1975	Rate
1. El Agulia	15	13	6	110.1	22. Riofrío	24	18	27	157.1
2. Anserma Nueva	29	40	18	224.5	23. Buenaventura	142	143	164	103.7
3. El Cario	21	9	8	97.7	24. Tulua	111	101	104	93.1
4. Cartago	135	110	108	148.8	25. San Pedro	8	10	8	86.7
5. Argelia	3	9	5	82.7	26. Darien	3	13	5	81.3
6. Ulloa	1	4	4	35.4	27. Yotoco	9	11	12	111.1
7. Alcalá	12	22	10	150.1	28. Buga	52	51	42	52.4
8. Toro	23	25	14	123.8	29. Restrepo	9	13	17	135.1
9. Versalles	2	2	5	25.3	30. Dagua	26	14	21	81.8
10. Obando	11	22	9	136.4	31. Vijes	3	2	5	43.1
11. El Dovio	9	8	9	61.9	32. Guacari	24	14	24	110.3
12. La Unión	28	9	24	133.8	33. Ginebra	7	15	5	71.5
13. La Victoria	19	8	14	90.4	34. El Corrito	46	27	30	110.3
14. Roldonillo	14	18	11	52.2	35. La Cumbre	6	3	5	40.6
15. Bolívar	11	12	12	68.3	36. Palmira	171	134	146	80.9
16. Zarzal	32	50	41	122.3	37. Yumbo	41	56	48	127.6
17. Sevilla	53	47	44	66.2	38. Cali	661	617	500	61.9
18. Caicedonia	55	39	36	129.9	39. Pradera	22	28	38	131.9
19. Bugalagrande	10	22	15	78.4	40. Candelaria	35	28	19	97.1
20. Trujillo	15	20	18	80.1	41. Florida	41	46	45	128.
21. Andalucía	10	15	10	88.4	42. Jamundí	46	45	36	122.

*Included in the general category of intestinal disease are the following:

(a) typhoid fever
(b) paratyphoid fever and other salmonelosis
(c) bacillary dysentery and amoebic dysentery
(d) enteric and other diarrheas

**Intestinal related death rate calculated as

$$\text{Rate} = \sum_{i=1973}^{1975} \left(\frac{D_i}{P_i}\right) \times 100.000$$

Where D_i = Number of intestinal related deaths in year i

P_i = Population in year i

i = 1973, 1974, 1975

Source: Servicio Seccional de Valle

FIGURE A-5
INTESTIONAL RELATED DEATHS IN VALLE DEL CAUCA, COLOMBIA (1973, 1974, 1975)

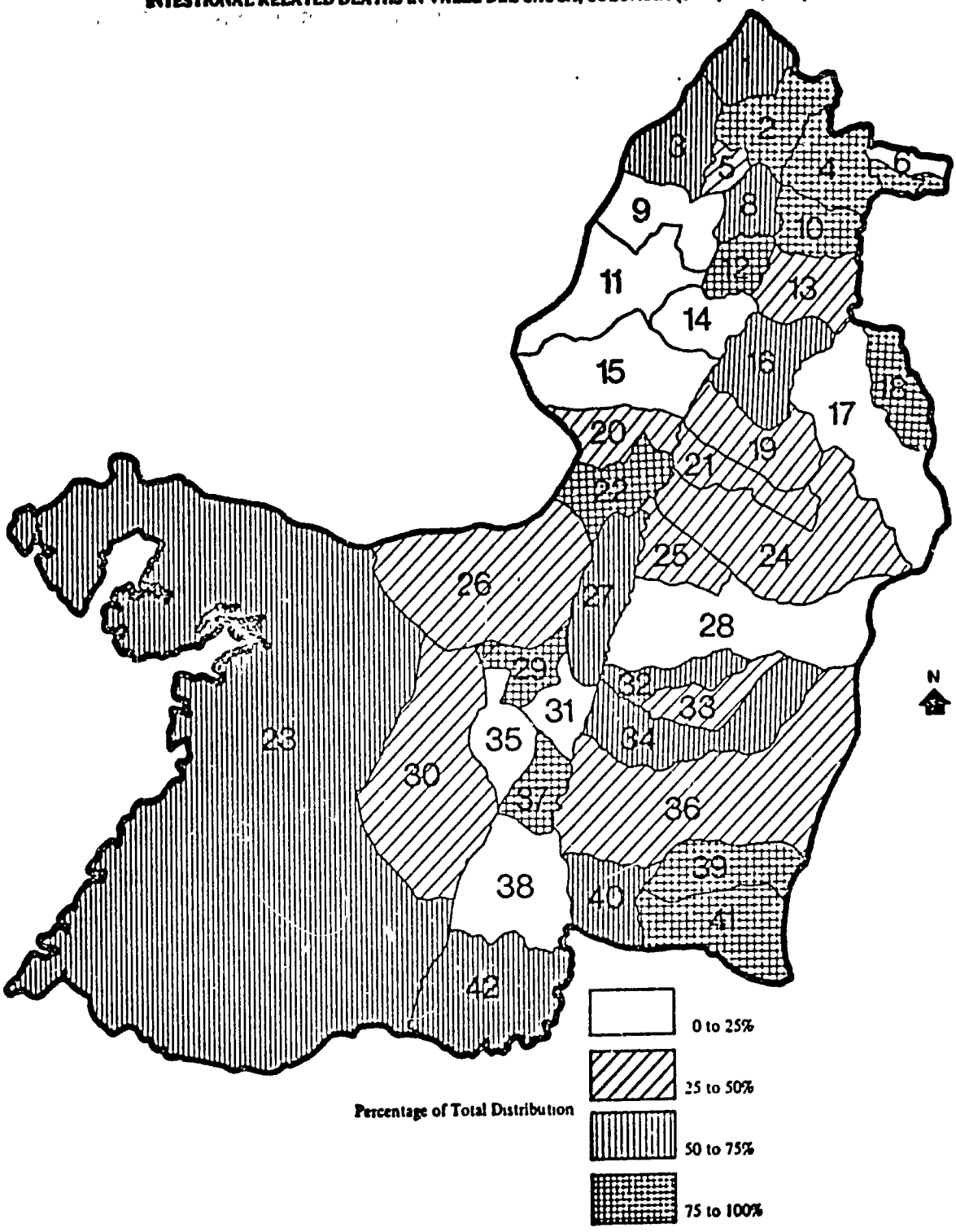


TABLE A6: RESPIRATORY RELATED DEATHS* AND DEATH RATES**
VALLE DEL CAUCA, COLOMBIA (1973, 1974, 1975)

	1973	1974	1975	Rate		1973	1974	1975	Rate
1. El Agulia	8	5	9	70.0	22. Riofrío	12	17	21	116.1
2. Anserma Nueva	31	23	18	185.8	23. Buenaventura	184	185	150	119.6
3. El Cario	20	15	19	126.9	24. Tulua	108	103	81	86.0
4. Cartago	96	105	100	126.1	25. San Pedro	8	7	8	77.1
5. Argelia	11	11	11	148.0	26. Darien	5	9	8	93.0
6. Ullos	4	2	3	53.1	27. Yotoco	13	6	2	70.7
7. Alcalá	11	6	23	130.7	28. Buga	102	63	57	87.1
8. Toro	14	7	11	58.9	29. Restrepo	15	14	11	155.1
9. Versalles	23	10	13	126.8	30. Dagua	27	22	19	94.1
10. Obando	15	17	11	136.4	31. Vijes	2	5	3	32.3
11. El Dovio	22	11	13	103.2	32. Guacari	13	10	16	68.3
12. La Unión	21	14	19	120.5	33. Ginebra	9	15	11	95.3
13. La Victoria	18	15	11	140.3	34. El Corrito	27	18	31	81.1
14. Roldonillo	23	16	13	65.8	35. La Cumbre	5	5	5	40.6
15. Bolívar	35	19	18	136.6	36. Palmira	221	161	144	94.4
16. Zarzal	28	27	18	71.6	37. Yumbo	36	35	18	79.8
17. Sevilla	77	43	46	75.9	38. Cali	565	618	597	62.0
18. Caicedonia	56	24	47	123.8	39. Pradera	22	31	14	100.1
19. Bugalagrande	11	11	10	53.9	40. Candelaria	34	20	14	82.7
20. Trujillo	21	10	12	62.3	41. Florida	37	23	19	75.6
21. Andalucía	13	12	3	66.34	42. Jamundí	45	31	31	122.0

*Included in the general category of respiratory disease are the following:

(a) respiratory infections
(b) influenza
(c) viral pneumonia
(d) other pneumonias
(e) bronchitis, emphysema, and asthma
(f) pulmonary abcess
(g) other respiratory infections

Source: Servicio Seccional de Valle

**Respiratory related death rate calculated as

$$\text{Rate} = \sum_{i=1973}^{1975} \left(\frac{D_i}{P_i}\right) \times 100{,}000$$

Where D_i = Number of respiratory related deaths in year i

P_i = Population in year i

i = 1973, 1974, 1975

FIGURE A-6
RESPIRATORY RELATED DEATHS IN VALLE DEL CAUCA, COLOMBIA (1973, 1974, 1975)

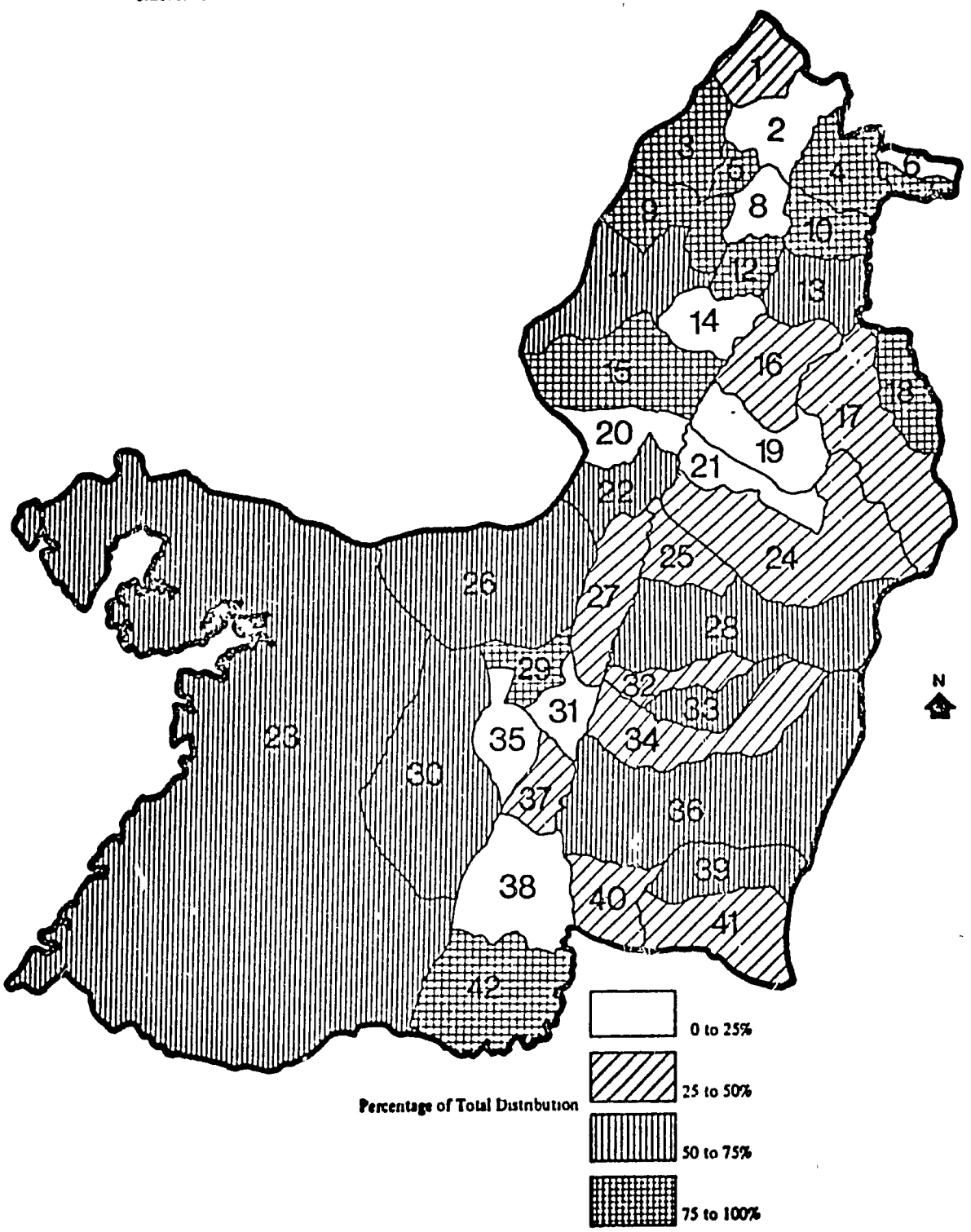


TABLE A7: TRAUMA RELATED DEATHS* AND DEATH RATE**
VALLE DEL CAUCA, COLOMBIA (1973, 1974, 1975)

	1973	1974	1975	Rate
1. El Agulia	11	8	8	120.12
2. Anserma Nueva	19	11	9	123.91
3. El Cario	10	6	4	77.60
4. Cartago	83	76	82	131.18
5. Argelia	17	13	6	287.67
6. Ulloa	0	0	1	17.70
7. Alcalá	6	5	9	80.4
8. Toro	15	8	9	82.59
9. Versalles	9	13	0	118.40
10. Obando	14	14	9	155.97
11. El Dovio	4	3	15	61.96
12. La Unión	8	9	7	53.55
13. La Victoria	10	4	9	76.54
14. Roldonillo	17	12	22	85.24
15. Bolívar	9	5	6	51.23
16. Zarzal	28	16	28	79.09
17. Sevilla	42	38	33	64.86
18. Caicedonia	39	30	32	114.83
19. Bugalagrande	20	5	17	98.08
20. Trujillo	8	11	10	62.30
21. Andalucía	11	7	3	51.60
22. Riofrío	9	8	5	75.15
23. Buenaventura	126	88	81	91.95
24. Tulua	101	76	78	93.19
25. San Pedro	8	6	10	106.07
26. Darien	6	7	2	69.76
27. Yotoco	7	4	1	50.51
28. Buga	97	78	78	117.69
29. Restrepo	8	3	3	51.89
30. Dagua	7	3	10	49.12
31. Vijes	0	0	3	21.55
32. Guacari	5	13	5	57.82
33. Ginebra	7	3	5	71.53
34. El Cerrito	13	16	15	58.43
35. La Cumbre	1	4	0	32.55
36. Palmira	152	115	98	80.97
37. Yumbo	15	4	10	34.58
38. Cali	837	934	730	105.53
39. Pradera	5	8	10	63.70
40. Candelaria	13	13	9	61.14
41. Florida	20	10	11	52.37
42. Jamundí	15	13	15	87.60

*Included in the general category of trauma are the following:

(a) fractures of the skull
(b) fractures of the spinal column
(c) fractures, other
(d) lesions without fractures
(e) intra-cranium trauma excluding fractures
(f) internal trauma; thorax, abdomen, and pelvic area
(g) lacerations and wounds
(h) other lesions and contusions
(i) suffocation
(j) burns
(k) adverse effects of chemical substances

Source: Servicio Seccional de Valle

**Trauma related death rate calculated as

$$\text{Rate} = \sum_{i=1973}^{1975} \left(\frac{D_i}{P_i}\right) \times 100{,}000$$

Where D_i = Number of trauma related deaths in year i

P_i = Population in year i

i = 1973, 1974, 1975

FIGURE A-7
TRAUMA RELATED DEATHS IN VALLE DEL CAUCA, COLOMBIA (1973, 1974, 1975)

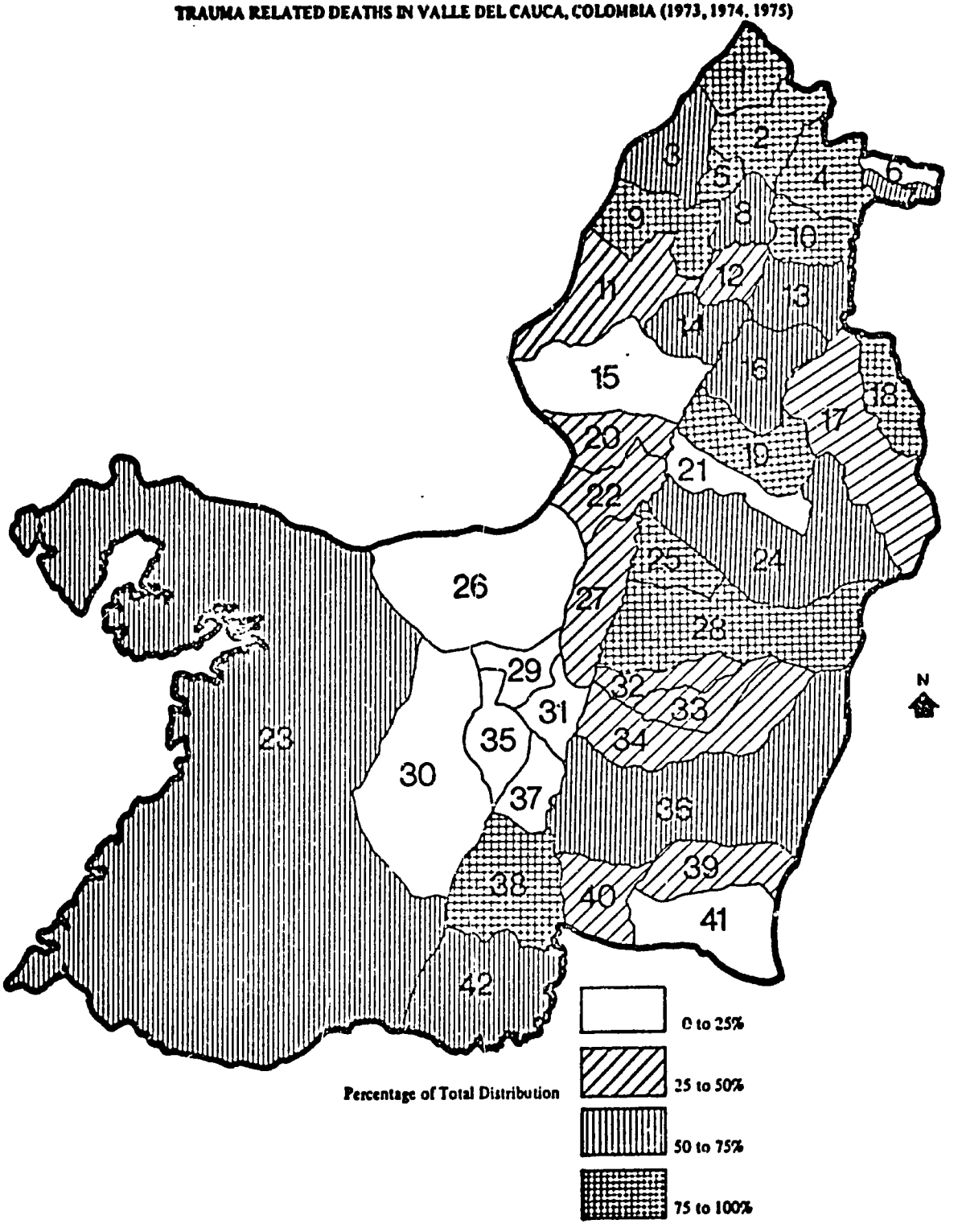


TABLE A8: AVITAMINOSIS RELATED DEATHS* AND DEATH RATES VALLE DEL CAUCA, COLOMBIA (1973, 1974, 1975)

	1973	1974	1975	Rate		1973	1974	1975	Rate
1. El Agulia	5	4	8	60.06	22. Riofrío	5	10	12	61.49
2. Anserma Nueva	10	24	25	147.14	23. Buenaventura	45	59	50	35.26
3. El Cario	13	13	12	91.70	24. Tulua	38	56	45	66.65
4. Cartago	37	85	49	71.89	25. San Pedro	7	7	6	67.50
5. Argelia	9	8	4	94.22	26. Darien	3	8	16	104.65
6. Ulloa	3	5	4	53.11	27. Yotoco	4	2	1	20.20
7. Alcalá	5	17	15	120.07	28. Buga	29	48	36	44.72
8. Toro	9	12	12	64.89	29. Restrepo	6	11	20	124.79
9. Versalles	5	5	6	42.28	30. Dagua	16	15	12	57.31
10. Obando	7	23	20	165.72	31. Vijes	1	0	1	10.77
11. El Dovio	3	2	7	27.53	32. Guacari	5	4	7	26.28
12. La Unión	8	7	13	60.25	33. Ginebra	2	12	11	63.58
13. La Victoria	6	2	8	34.79	34. El Corrito	18	17	10	38.95
14. Roldonillo	13	23	8	58.11	35. La Cumbre	1	5	2	16.27
15. Bolívar	8	6	13	51.23	36. Palmira	72	75	60	37.24
16. Zarzal	13	20	17	50.74	37. Yumbo	8	14	18	34.58
17. Sevilla	26	61	48	62.10	38. Cali	143	136	151	14.97
18. Caicedonia	34	65	39	139.01	39. Predera	8	15	18	63.70
19. Bugalagrande	7	6	9	34.33	40. Candelaria	23	28	13	75.53
20. Trujillo	11	14	10	66.75	41. Florida	15	27	21	61.09
21. Andalucía	14	6	6	147.43	42. Jamundí	24	42	11	81.34

*

$$\text{Rate} = \sum_{i=1973}^{1975} \left(\frac{D_i}{P_i}\right) \times 100{,}000$$

Where D_i = Avitaminosis related deaths in year i

P_i = Population in year i

i = 1973, 1974, 1975

Source: Servicio Seccional de Valle

FIGURE A-8
AVITAMINOSIS RELATED DEATHS IN VALLE DEL CAUCA, COLOMBIA (1973, 1974, 1975)

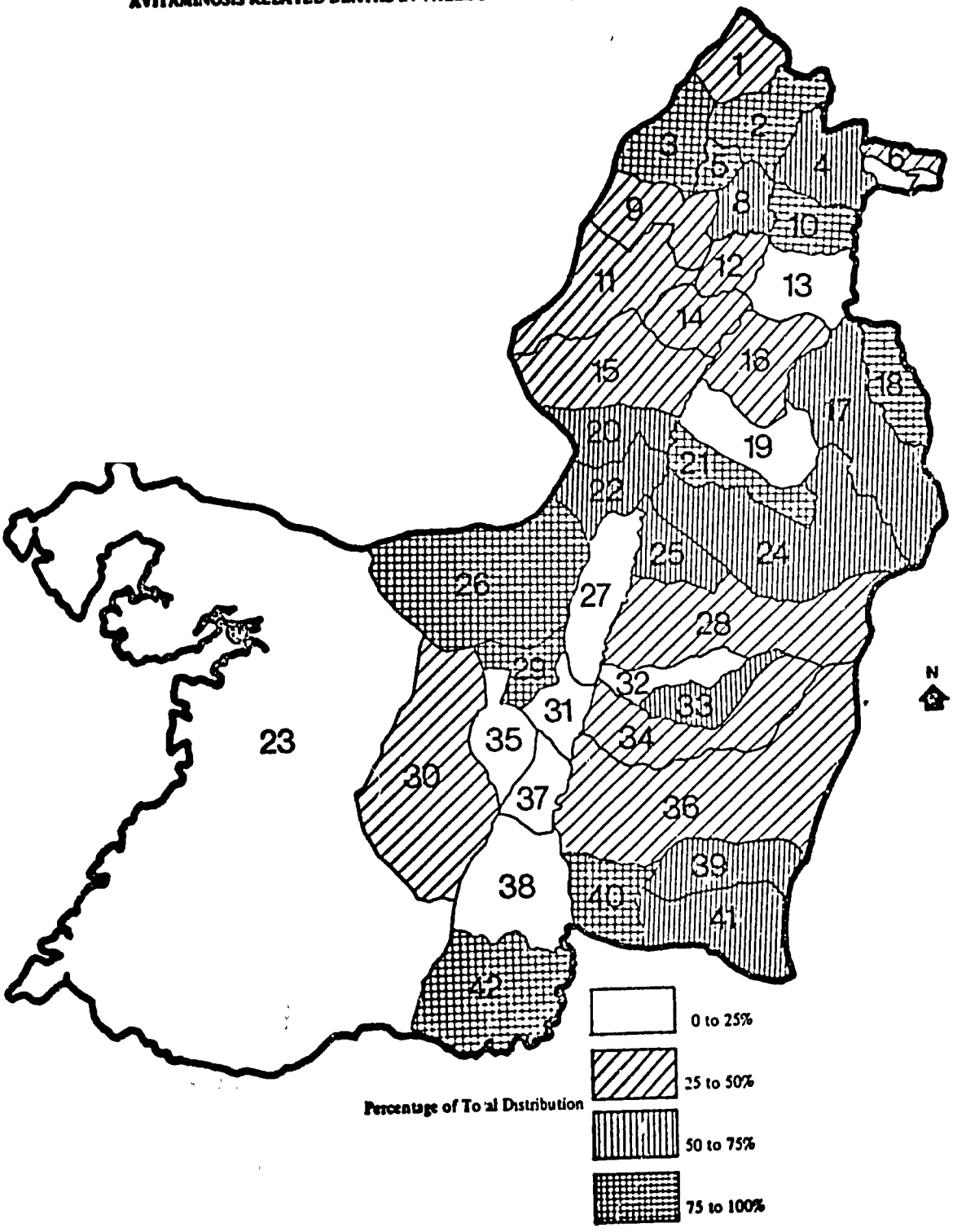


TABLE A9: MEASLE RELATED DEATHS AND DEATH RATE*
VALLE DEL CAUCA, COLOMBIA (1973, 1974, 1975)

	1973	1974	1975	Rate		1973	1974	1975	Rate
1. El Agulia	4	1	0	20.02	22. Riofrío	0	1	0	6.83
2. Anserma Nueva	5	9	0	38.72	23. Buenaventura	5	11	2	4.14
3. El Cario	0	0	0	0.00	24. Tulua	1	6	1	2.66
4. Cartago	6	5	1	5.04	25. San Pedro	0	0	0	0.00
5. Argelia	0	2	0	13.46	26. Darien	0	0	0	0.00
6. Ulloa	0	0	0	0.00	27. Yotoco	0	0	0	0.00
7. Alcalá	0	0	0	0.00	28. Buga	2	0	2	1.17
8. Toro	0	6	2	17.69	29. Restrepo	0	0	0	0.00
9. Versalles	0	0	0	0.00	30. Dagua	0	1	0	4.09
10. Obando	2	3	0	19.49	31. Vijes	0	1	1	10.77
11. El Dovio	1	0	0	6.88	32. Guacari	0	0	1	5.25
12. La Unión	0	0	1	6.69	33. Ginebra	0	0	0	0.00
13. La Victoria	0	0	0	0.00	34. El Corrito	0	1	0	3.24
14. Roldonillo	1	2	0	3.87	35. La Cumbre	0	1	0	8.13
15. Bolívar	0	1	0	5.69	36. Palmira	5	3	0	1.61
16. Zarzal	0	1	2	2.98	37. Yumbo	1	0	0	2.66
17. Sevilla	5	1	0	2.76	38. Cali	39	27	10	2.61
18. Caicedonia	1	2	0	3.02	39. Pradera	0	2	0	4.55
19. Bugalagrande	1	0	0	4.90	40. Candelaria	0	0	0	0.00
20. Trujillo	0	0	1	4.45	41. Florida	3	2	0	5.81
21. Andalucía	0	0	1	7.37	42. Jamundí	2	0	3	6.25

*Measle related death rate calculated as

$$\text{Rate} = \sum_{i=1973}^{1975} \left(\frac{D_i}{P_i}\right) \times 100{,}000$$

Where D_i = Number of measle related deaths in year i

P_i = Population in year i

i = 1973, 1974, 1975

Source: Servicio Seccional de Valle

FIGURE A-9
MEASLES RELATED DEATHS IN VALLE DEL CAUCA, COLOMBIA (1973, 1974, 1975)

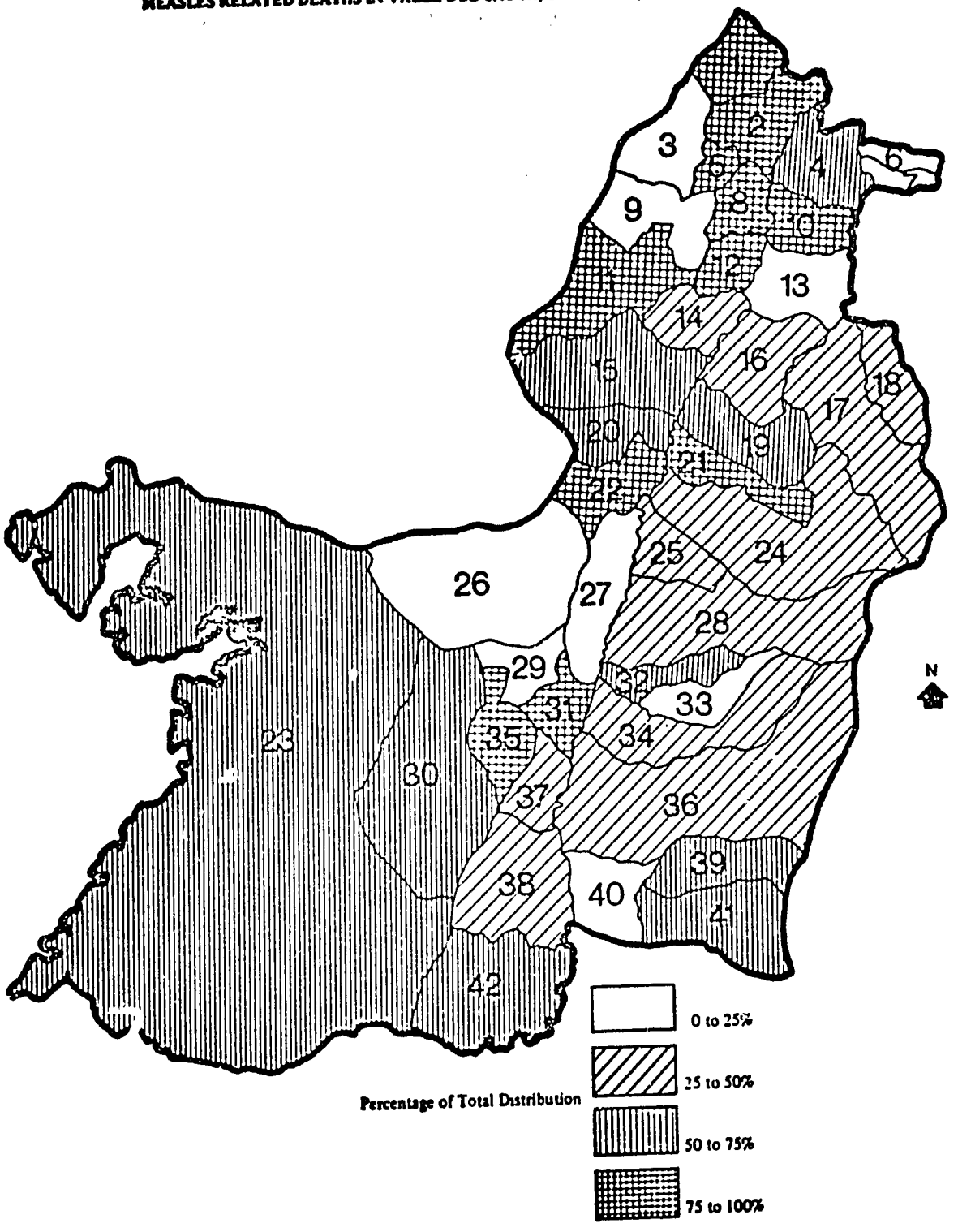


FIGURE A-10
INFANT DEATH, VALLE DEL CAUCA

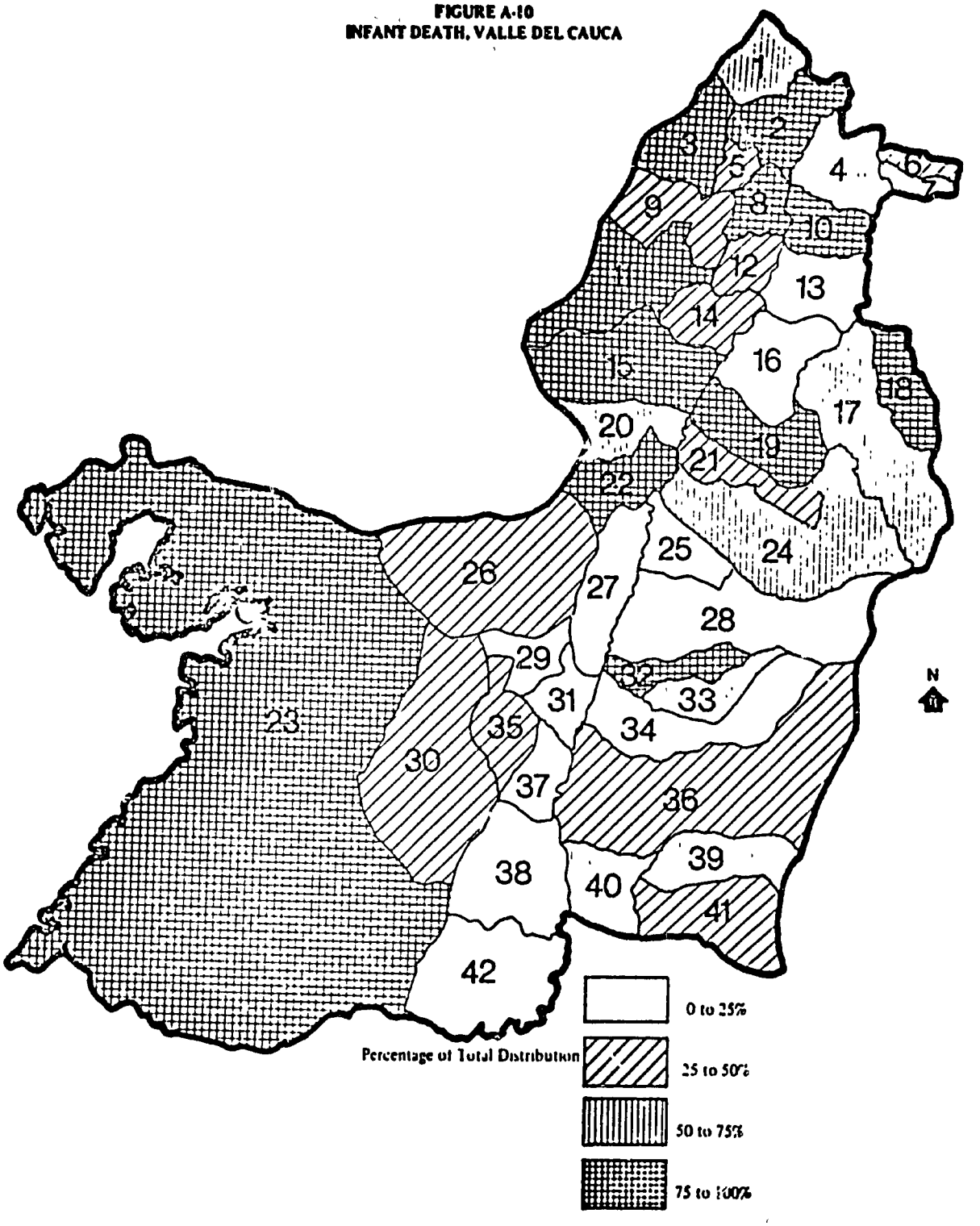


TABLE A-11: TUBERCULOSIS RELATED DEATHS AND DEATH RATE VALLE DEL CAUCA, COLOMBIA (1973, 1974, 1975)

	1973	1974	1975	Rate		1973	1974	1975	Rate
1. El Agulia	2	1	1	10.01	22. Riofrío	0	2	0	6.83
2. Anserma Nueva	4	2	3	30.97	23. Buenaventura	25	47	43	26.27
3. El Cario	8	0	0	21.16	24. Tulua	18	18	22	16.86
4. Cartago	47	40	34	30.45	25. San Pedro	1	1	1	9.64
5. Argelia	0	0	1	13.46	26. Darien	2	0	2	11.62
6. Ulloa	0	1	1	17.70	27. Yotoco	1	1	1	10.10
7. Alcalá	2	6	3	40.2	28. Buga	16	20	24	23.53
8. Toro	1	3	4	17.69	29. Restrepo	1	2	0	10.39
9. Versalles	2	2	0	8.45	30. Dagua	9	6	3	24.56
10. Obando	5	1	3	29.24	31. Vijes	0	0	0	0.00
11. El Dovio	1	0	2	6.88	32. Guacari	0	3	3	10.51
12. La Unión	2	3	2	20.08	33. Ginebra	0	1	0	7.94
13. La Victoria	3	4	0	13.91	34. El Corrito	5	5	4	16.23
14. Roldonillo	7	5	4	54.24	35. La Cumbre	0	0	0	0.00
15. Bolívar	2	1	0	63.30	36. Palmira	38	26	26	16.19
16. Zarzal	4	4	5	11.93	37. Yumbo	4	5	4	10.64
17. Sevilla	21	28	16	30.36	38. Cali	194	222	172	20.51
18. Caicedonia	5	2	14	39.28	39. Pradera	5	2	3	18.2
19. Bugalagrande	0	1	0	4.9	40. Candelaria	9	1	1	14.38
20. Trujillo	3	3	1	8.9	41. Florida	5	1	3	8.72
21. Andalucía	2	3	0	14.74	42. Jamundí	3	24	17	46.92

*Tuberculosis death rate calculated as

$$\text{Rate} = \sum_{i=1973}^{1975} \left(\frac{D_i}{P_i}\right) \times 100{,}000$$

Where D_i = Number of tuberculosis related deaths in year i

P_i = Population in year i

i = 1973, 1974, 1975

Source: Servicio Seccional de Valle

FIGURE A-11
TUBERCULOSIS RELATED DEATHS IN VALLE DEL CAUCA, COLOMBIA (1973, 1974, 1975)

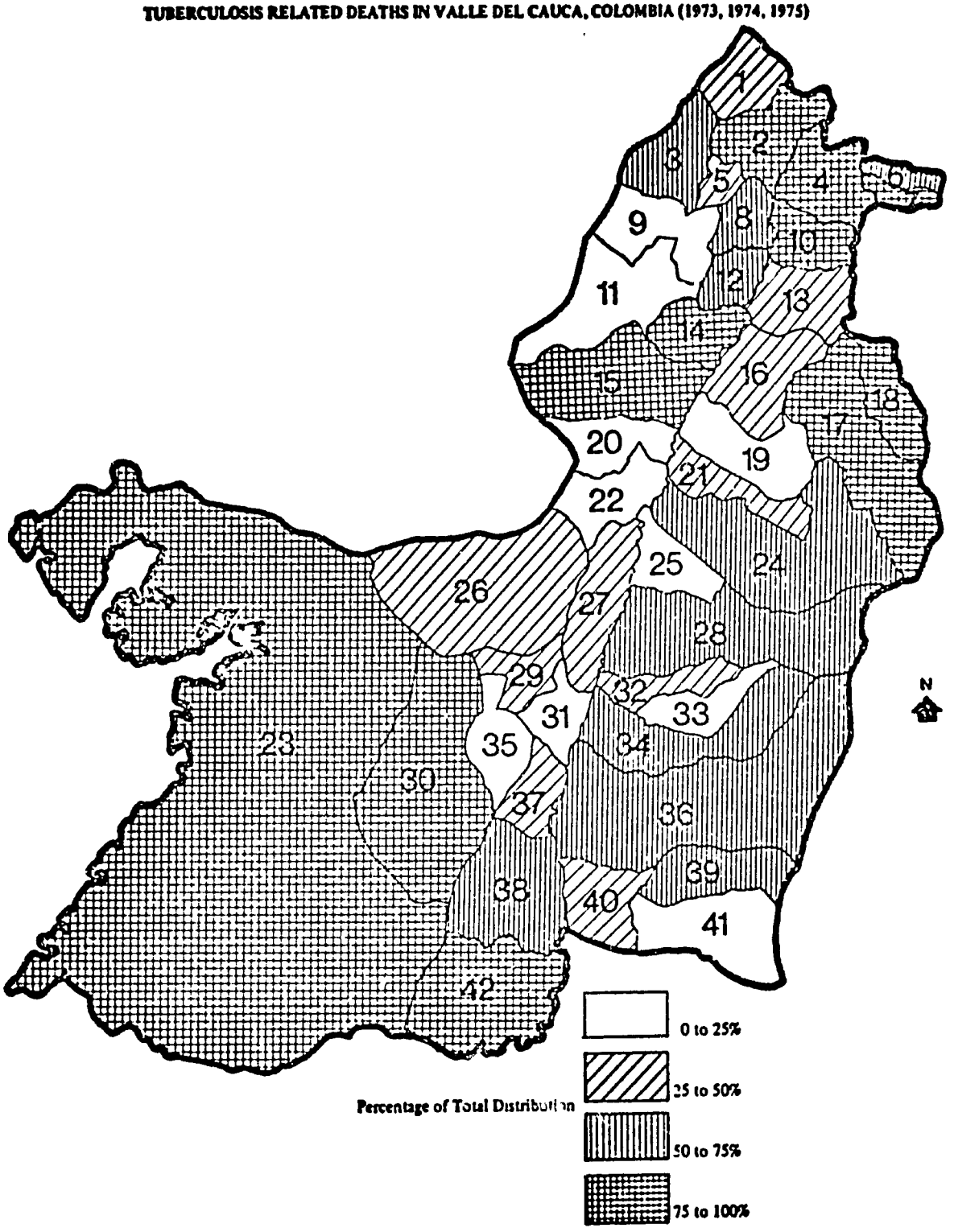


TABLE A12: TUMOR* RELATED DEATHS AND DEATH RATES**
VALLE DEL CAUCA, COLOMBIA (1973, 1974, 1975)

	1973	1974	1975	Rate		1973	1974	1975	Rate
1. El Agulia	2	3	3	30.03	22. Riofrío	3	5	7	39.16
2. Anserma Nueva	9	10	7	154.89	23. Buenaventura	33	46	55	31.11
3. El Cario	9	6	3	42.32	24. Tulua	71	86	68	66.65
4. Cartago	67	87	73	95.86	25. San Pedro	0	7	5	38.57
5. Argelia	3	1	5	40.38	26. Darien	3	4	4	46.51
6. Ulloa	0	1	4	35.41	27. Yotoco	4	0	3	20.20
7. Alcalá	4	5	7	50.03	28. Buga	71	76	60	81.21
8. Toro	10	11	13	64.89	29. Restrepo	8	5	5	62.33
9. Versalles	1	1	7	25.37	30. Dagua	9	4	11	32.74
10. Obando	1	8	5	48.47	31. Vijes	1	0	0	10.77
11. El Dovio	9	2	2	27.53	32. Guacari	6	3	6	26.88
12. La Unión	14	13	15	93.72	33. Ginebra	4	5	5	39.74
13. La Victoria	8	6	15	69.58	34. El Corrito	11	17	16	48.69
14. Roldonillo	15	21	12	61.99	35. La Cumbre	9	6	8	65.10
15. Bolívar	11	1	4	28.46	36. Palmira	122	127	116	65.86
16. Zarzal	26	18	19	62.68	37. Yumbo	12	12	9	29.26
17. Sevilla	50	29	39	53.25	38. Cali	642	689	626	68.24
18. Calcedonia	30	16	25	72.52	39. Pradera	4	12	8	36.40
19. Bugalagrande	9	12	9	49.04	40. Candelaria	20	9	9	46.78
20. Trujillo	6	9	9	36.60	41. Florida	14	17	24	43.64
21. Andalucía	2	6	3	66.34	42. Jamundí	15	13	15	43.80

*Included in the general category of tumors are the following specific diseases:

(a) malignant tumors of the mouth and pharynx
(b) malignant tumors of the esophagus
(c) malignant tumors of the stomach
(d) malignant tumors of the intestinal tract
(e) malignant tumors of the rectum
(f) malignant tumors of the larynx
(g) malignant tumors of the trachea and lungs
(h) malignant tumors of the bones
(i) malignant tumors of the skin
(j) malignant tumors of the breast
(k) malignant tumors of the uterus
(l) malignant tumors of the prostate
(m) other malignant tumors

**Tumor related death rate calculated as

$$\text{Rate} = \sum_{i=1973}^{1975} \left(\frac{D_i}{P_i}\right) \times 100{,}000$$

Where D_i = Number of tumor related deaths in year i

P_i = Population in year i

i = 1973, 1974, 1975

Source: Servicio Seccional de Valle

FIGURE A-12
TUMOR RELATED DEATHS IN VALLE DEL CAUCA, COLOMBIA (1973, 1974, 1975)

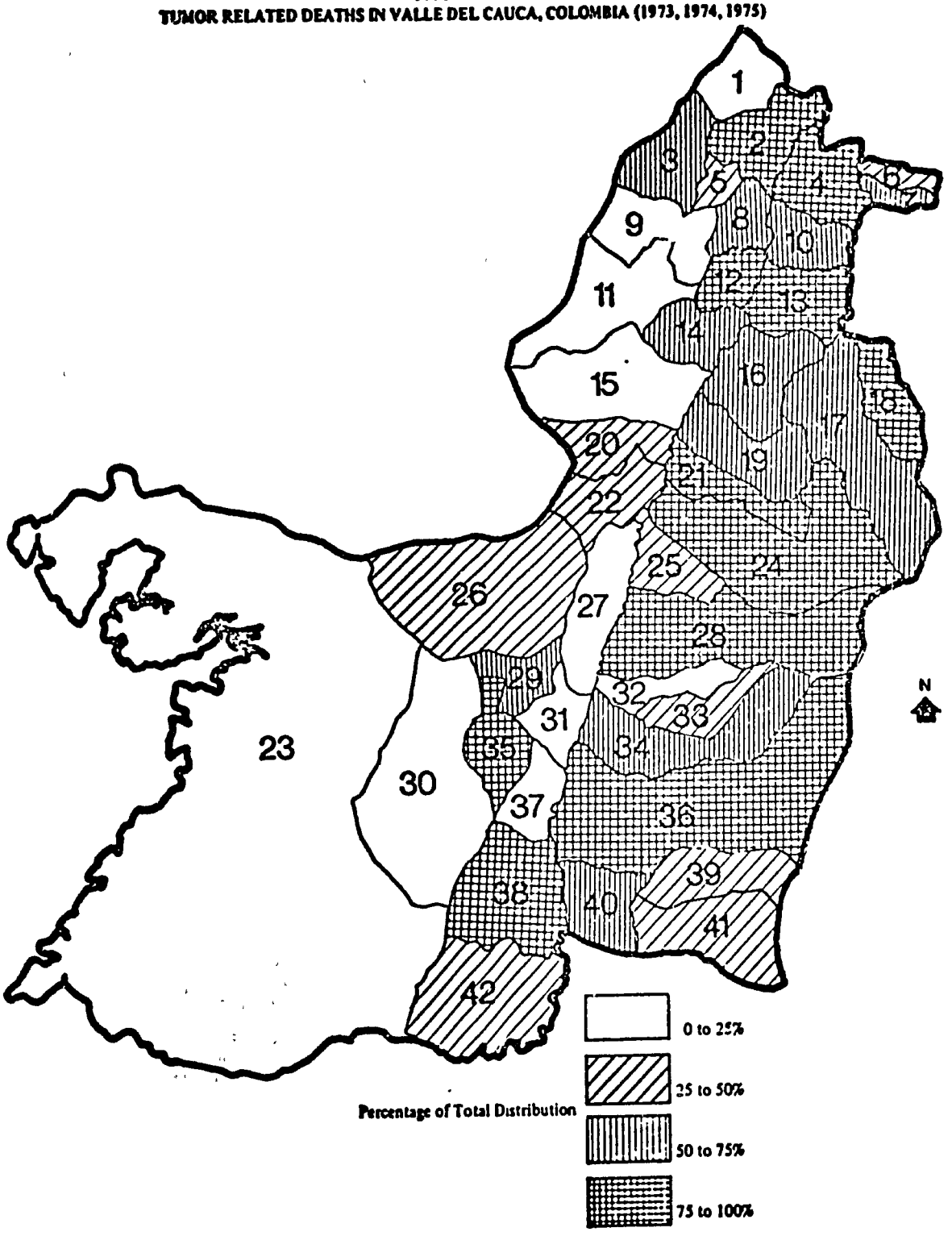


TABLE A13: RURAL HEALTH PROMOTORAS AND PROMOTRA RATE PER 1,000 RURAL POPULATION
VALLE DEL CAUCA, COLOMBIA (1977)

	Number	Promotoras per Thousand Rural Population		Number	Promotoras per Thousand Rural Population
1. El Agulia	5	.71	22. Riofrío	4	.33
2. Anserma Nueva	5	.75	23. Buenaventura	11	.42
3. El Cario	3	.29	24. Tulua	10	.41
4. Cartago	7	.77	25. San Pedro	4	.48
5. Argelia	3	.84	26. Darien	3	.70
6. Ulloa	2	.55	27. Yotoco	8	1.13
7. Alcalá	3	.56	28. Buga	7	.52
8. Toro	5	.65	29. Restrepo	5	.97
9. Versalles	5	.57	30. Dagua	5	.27
10. Obando	5	.98	31. Vijes	5	1.07
11. El Dovio	4	.37	32. Guacari	6	.57
12. La Unión	6	1.18	33. Ginebra	4	.46
13. La Victoria	4	.58	34. El Corrito	4	.29
14. Roldonillo	7	.50	35. La Cumbre	5	.46
15. Bolívar	5	.34	36. Palmira	10	.23
16. Zarzal	3	.24	37. Yumbo	2	.22
17. Sevilla	11	.25	38. Cali	2	.07
18. Caicedonia	10	1.07	39. Pradera	3	.48
19. Bugalagrande	3	.23	40. Candelaria	7	.36
20. Trujillo	6	.40	41. Florida	5	.42
21. Andalucía	3	.45	42. Jamundí	10	.52

Source: Servicio Seccional de Valle

FIGURE A-13
RURAL HEALTH PROMOTORAS IN VALLE DEL CAUCA, COLOMBIA (1977)

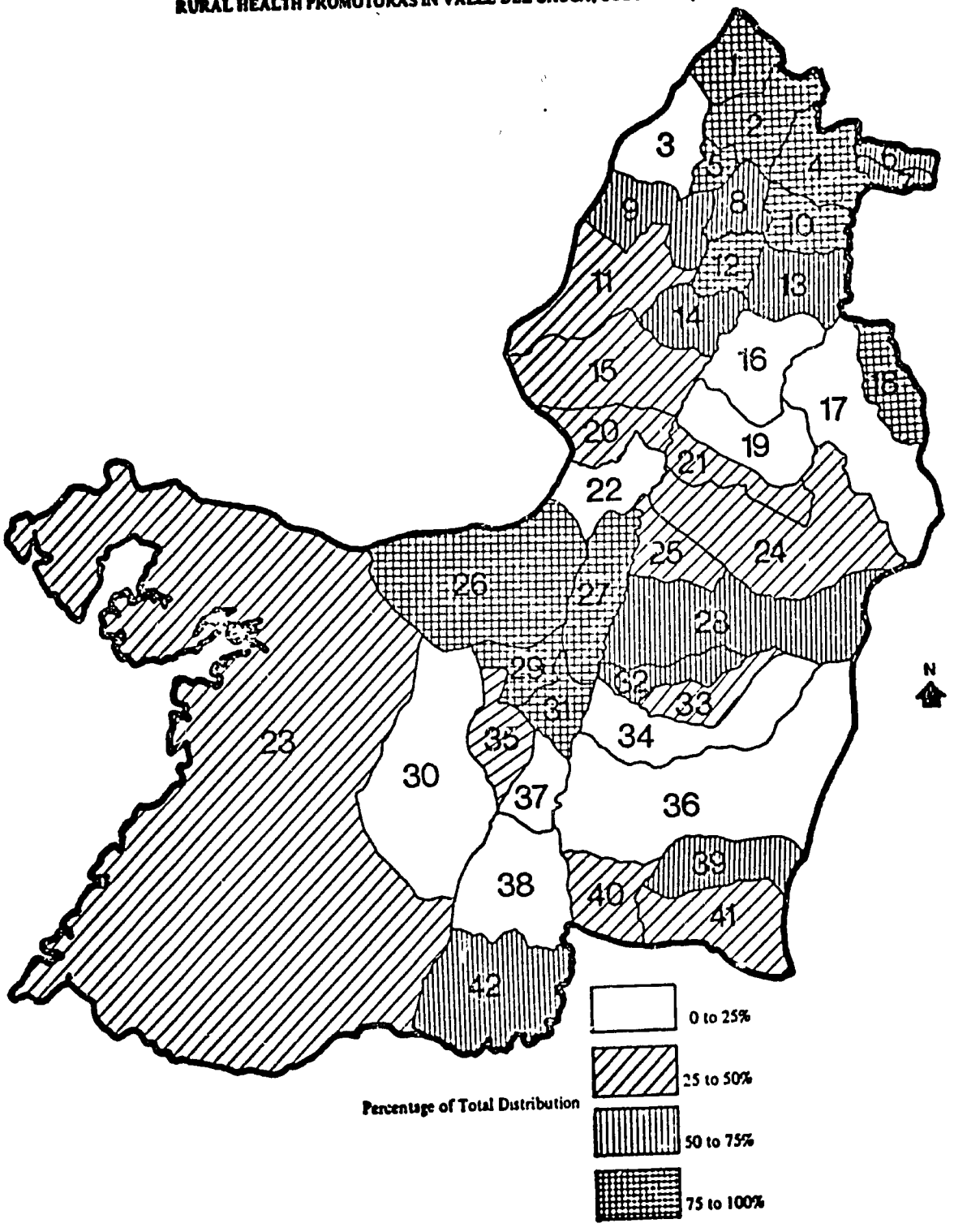
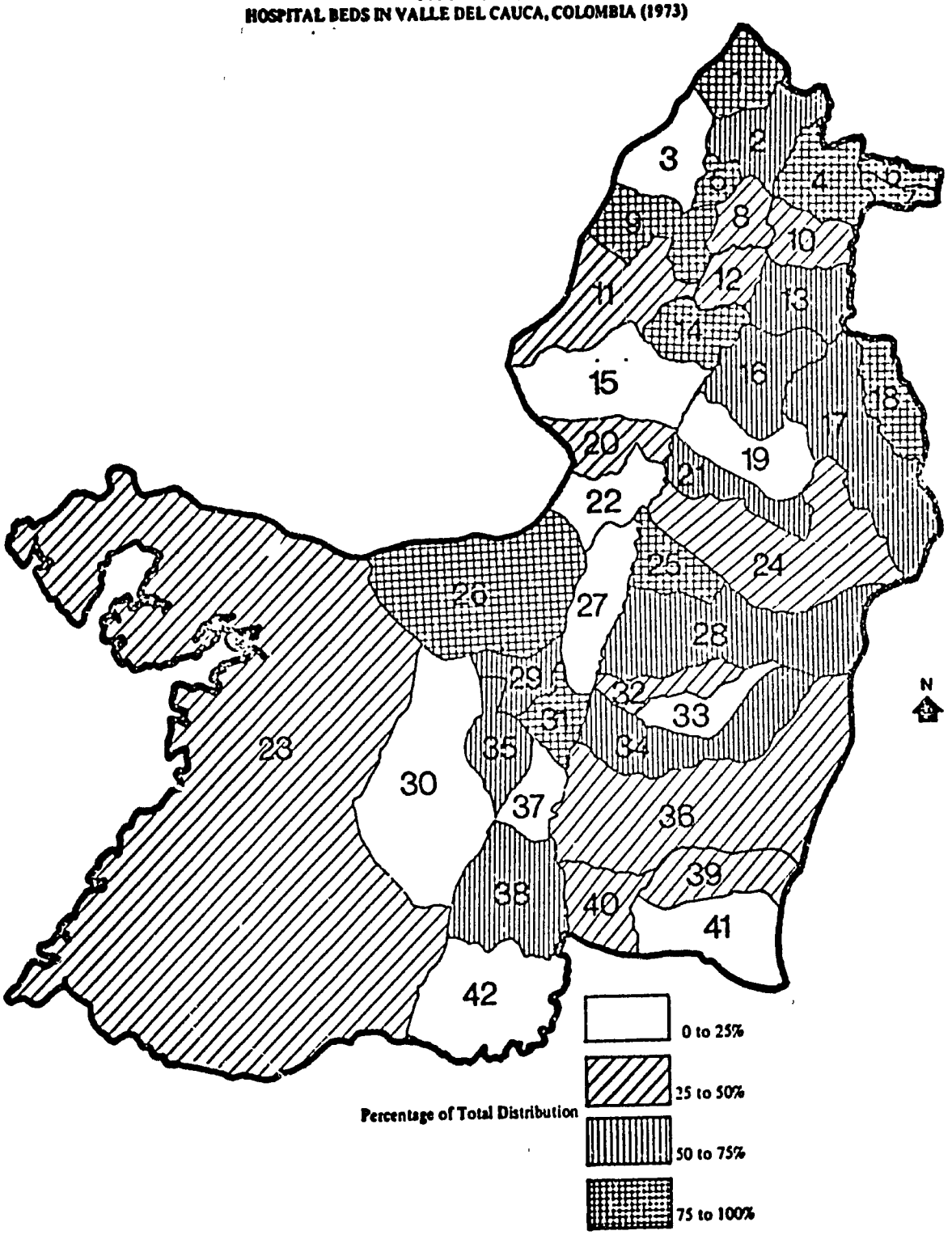


TABLE A14: HOSPITAL BEDS AND HOSPITAL BED RATES PER 1,000 POPULATION
VALLE DEL CAUCA, COLOMBIA (1973)

	Beds	Beds per Thousand Population		Beds	Beds per Thousand Population
1. El Agulia	0	0.00	22. Riofrío	6	.40
2. Anserma Nueva	22	1.65	23. Buenaventura	124	.88
3. El Cario	6	.45	24. Tulua	110	1.00
4. Cartago	184	2.36	25. San Pedro	0	0.00
5. Argelia	20	2.59	26. Darien	18	1.99
6. Ulloa	0	0.00	27. Yotoco	6	.16
7. Alcalí	17	1.66	28. Buga	132	1.57
8. Toro	16	.70	29. Restrepo	13	1.31
9. Versalles	23	1.91	30. Dagua	17	.69
10. Obando	10	.95	31. Vijes	0	0.00
11. El Dovio	12	.83	32. Guacari	15	.79
12. La Unión	11	.73	33. Ginebra	7	.56
13. La Victoria	17	1.18	34. El Corrito	32	1.07
14. Roldonillo	69	2.72	35. La Cumbre	16	1.31
15. Bolívar	12	.67	36. Palmira	173	.95
16. Zarzal	47	1.42	37. Yumbo	11	.30
17. Sevilla	80	1.14	38. Cali	1,083	1.17
18. Caicedonia	55	1.68	39. Pradera	20	.91
19. Bugalagrande	10	.48	40. Candelaria	20	.73
20. Trujillo	18	.80	41. Florida	17	.51
21. Andalucía	16	1.19	42. Jamundí	11	.34

Source: Servicio Seccional de Valle

FIGURE A-14
HOSPITAL BEDS IN VALLE DEL CAUCA, COLOMBIA (1973)



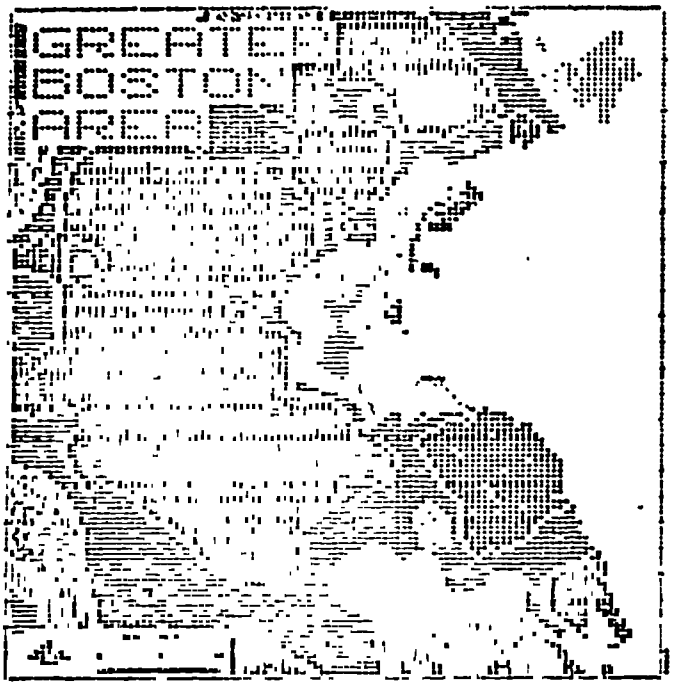
APPENDIX B

COMPUTER MAPPING TECHNIQUE

The computer mapping program used in this study is called SYMAP (1). SYMAP is written in FORTRAN IV and consists of a basic program with 49 sub-routines allowing a variety of types of output response. The SYMAP program is approximately 5,000 cards in length and requires either a 180 K partition (with overlay implementation) or 200 K partition without overlays. SYMAP has been successfully translated with slight modifications for use in many computer systems including IBM, CDC, UNIVAC, and Honeywell. SYMAP, except for the FLEXIN sub-routine, does not require specific programming expertise on the part of the user.

There are three basic types of maps available in the SYMAP program. These are contour maps, conformant maps, and proximal maps. Contour maps as illustrated in figure B-1 show lines representing a uniform quality throughout specific areas. The use of the contour map, also referred to as an isoline or isopleth map, assumes a spacially continuous distribution of data uninterrupted by geopolitical subdivisions. It is best used to show information relating to topography, climatic conditions, and population density.

FIGURE B-1
CONTURE MAP



Conformant maps are defined by their "conformance" to the boundaries of predetermined areas. Conformant, or chloropeth maps are best used for presenting qualitative and quantitative data that is constrained within fixed geographic subdivisions. The value presented for the subdivision is a mean value. Symbolism is assigned according to its numeric class relative to the other subdivisions within the area. Local variation may be implied; however, it is not apparent. For example, figure B-2 is a conformant map of the same data shown in figure B-1.

A proximal map, illustrated in figure B-3, is defined on the basis of its "proximity" to the nearest different value. It is very similar in appearance to the conformant map shown in figure B-2. The main difference between the proximal and conformant map is that divisions in the proximal map are not predetermined.

SYMAP APPLICATION IN COLOMBIA

The central purpose of this study is concerned with the allocation of resources from a central agency to subunits within its area of authority. Because of its ability to structure results within defined boundaries, conformant mapping is used in this study. The construction and application of mapping procedures pertain only to the conformant map.

FIGURE B-2
CONFORMANT

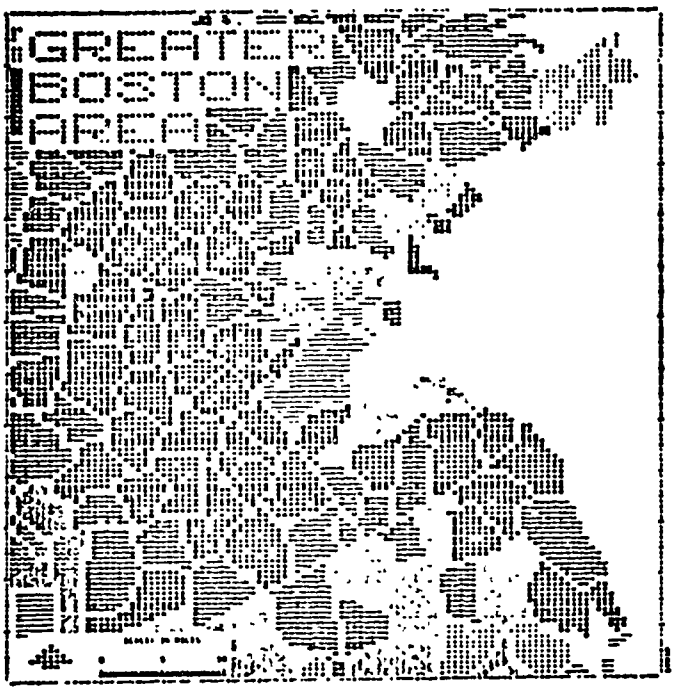


FIGURE B-3
PROXIMAL MAP

Construction of the source map of the study area is accomplished through the reproduction of the geographical area and its subdivisions into a series of coordinate points locations. Location points on the source map are determined by two coordinates, the first measured vertically from the top map border, the second measured horizontally from the left map border. This procedure is called conformant outlines, or A-conformolines.

A geopolitical map of the Department of Valle del Cauca was placed under an equal measure coordinate graph (1 centimeter/10 subunits). A rectangle (w. 82 cm./1.88 cm.) was drawn enclosing the geographic area. Delineations of one millimeter were labeled along the rectangle starting from left to right for the width and from top to bottom for the length.

The originating point for labeling coordinates is determined by that point upper-most and to the right of the map. In the case of Valle, this corresponded to the county of El Agulia. From this point (63.4, 2) the coordinates are located in a clock-wise manner around the area until the original starting point (63.4, 2) is reached. This process is repeated, using the rule constraint of "uppermost and to the right" in determining both area and point location until all subunits (counties) are assigned coordinate points. The computer connects adjacent coordinate points by straight

line. Graphic precision is a function of the number of coordinates used. These coordinates are then transferred to computer cards.

The data to be displayed in a conformant map must be arranged in a specific format and order (E-value package). These values are identified on computer cards by a corresponding number associated with the area from the source map that the data represents. Data can be submitted singularly or compiled into a data bank.

The SYMAP program's "F-map package" instructs the computer how to construct the desired map based on the information supplied in the prior packages. There are a number of "electives" available that can be used to determine the precise form of the map. These electives are shown in table B-1.

REFERENCES TO APPENDIX B

(1) Anon. "LAB-LOG," Cambridge, Mass.: Harvard University, January, 1977.

TABLE B-1

SYMAP ELECTIVES

1. SIZE OF MAP. This elective allows the user to determine the size of a map.
2. EXTREME POINTS. This elective allows the user to obtain either a complete reproduction of the map or any portion of the map.
3. NUMBER OF LEVELS. This elective determines the number of levels or class intervals (from 2 to 10) into which the distribution of E-values is divided.
4. VALUE RANGE MINIMUM. This elective specifies a particular value as the minimum accepted value that will be distributed according to the shaded value ranges. Those values falling below that specified number are represented by a single character "L" (low).
5. MAXIMUM VALUE RANGE. This elective specifies a particular value as the maximum value that will be distributed. Values falling above that will be represented on the map by the single character "H" (high).
6. VALUE RANGE INTERVAL. This elective allows the user to specify the range for each value in a distribution.
7. SYMBOLISM. This elective determines the specific symbolism accorded to the different value divisions.
8. SUPPRESSION OF CONTOUR LINES. This elective allows for the separation of white contour lines surroudning each subdivision.
9. SUPPRESSION OF HISTOGRAM BARS. The frequency distribution of data point values for each level, shown by separate histograms, can be eliminated with this elective.
10. TEXT. This elective allows the user to show supplementary information below the source of data.
11. ACTUAL VALUE. This elective allows for the actual value to printed at each data point.
12. MULTIPLE ELECTIVE REPEAT is the elective available to the user when more than one map is to be produced by the computer in a single run.
13. SCALE. This elective specifies the scale of the output map.
14. MARGIN. This elective is used in determining the area between the extreme points (see elective 2) and the borders of the output map.

15. NUMBER OF OUTPUT CHARACTERS PER INCH. The function of this elective is to normalize the output maps being generated from line printers other than those printing at 8 lines per inch.
16. LARGE SIZE MAPS. This elective is used along with number 1 when the output map desired is larger than 72 inches.
17. SUPPRESSION OF TABULAR OUTPUT DATA. This elective suppresses the output printout material including the value, location, and level assigned to each conformoline.
18. INVALIDATION OF MINUS ZERO AND BLANK VALUES. This elective allows user to invalidate values less than zero and blank date.
19. MINIMUM INVALID-DATA VALUE. This elective allows the user to establish a minimum value for invalid data.
20. MAXIMUM INVALID DATA. The elective allows the user to establish a maximum value for invalid data.
21. STORE MAP ON TAPE. This elective stores map on tape.
22. CONTINUOUS CONTOURS. Not applicable to conformant mapping.
23. SUPPRESSION OF INVALID DATA POINT SYMBOL. Allows user to suppress symbol.
24. SUPPRESSIONOF NUMERIC INTERPRETATION. Allows the user to suppress the printing of numeric interpretation.
25. SUPPRESSION OF DATA POINT SYMBOLS. Allows user to suppress data point symbols.
26. OVERPRINT ALIGNMENT. This elective corrects overprint lines.

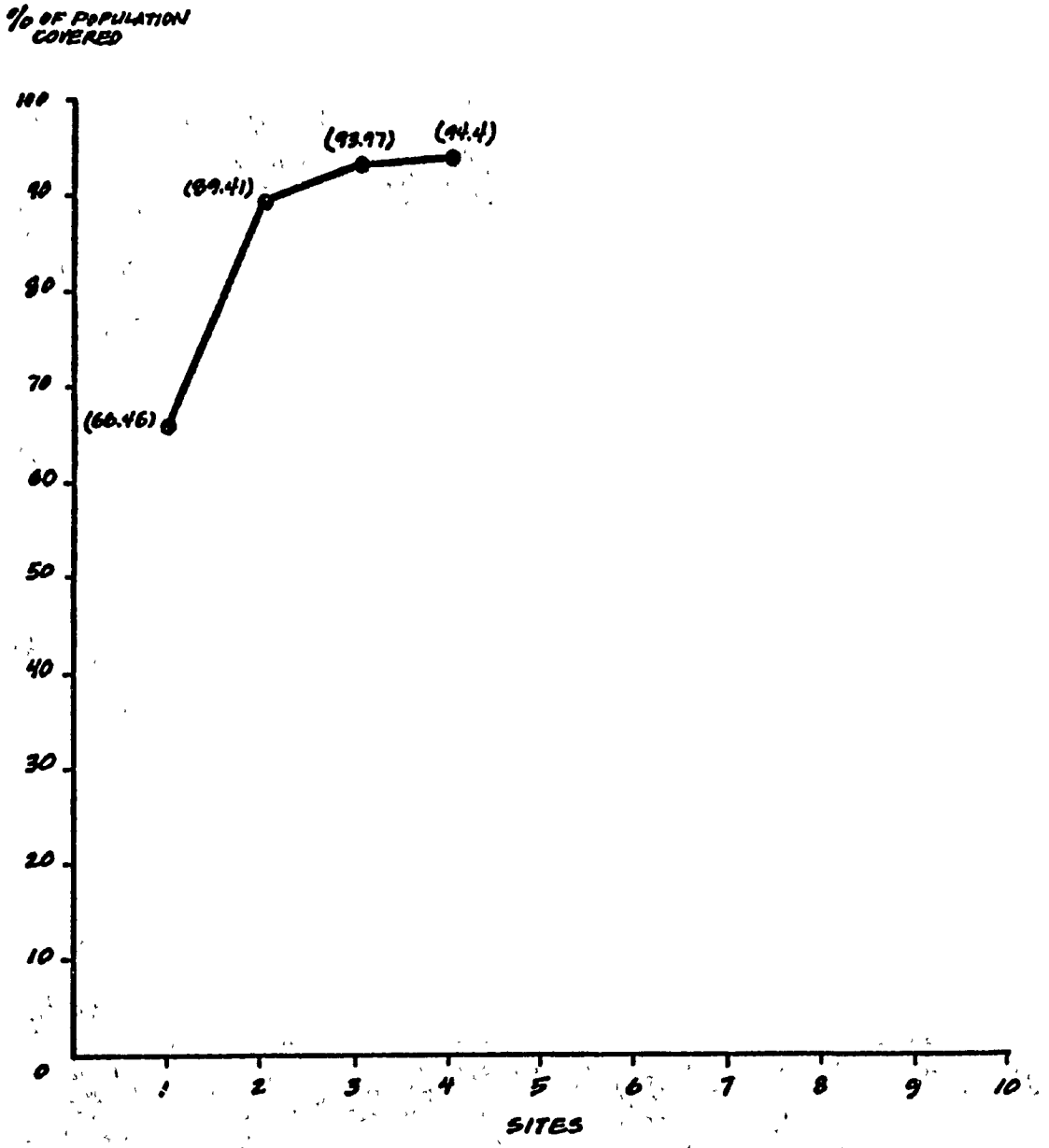
APPENDIX C

```
      PROGRAM INDEX (INPUT, OUTPUT, TAPE 6)
      DIMENSION TITLE (8,10), NARRAY (42), NEW (42,10), ARRAY (42,10), SUM (42),
         IIC (42), NSUM (42)
      INTEGER TITLE
      DATE NARRAY/1,1,1,1,1,1,1,1,1,1,2,2,2,2,2,2,2,2,2,2,2,3,3,3,3,3,3,
         13,3,3,3,4,4,4,4,4,4,4,4,4,4,4 /
      N = 3
      DO 5 J = 1,N
      READ 6, (TITLE(I,J), I = 1,8)
    6 FORMAT (8A10)
      READ 7, (ARRAY(I,K), I = 1,42)
    7 FORMAT (13X,F5)
    5 CONTINUE
      DO 10 J = 1,N
      DO 11 I = 1,42
   11 IC (I) = I
      CALL TSORT (42,ARRAY(1,J), IC(1) )
      DO 12 I = 1,42
      IN = IC(I)
      NEW (IN,J) = NARRAY (I)
   12 CONTINUE
      WRITE (6,6) TITLE(I,J), I = 1,8)
      DO 10 I = 1,42
      WRITE (6,9) I,NEW (I,J)
    9 FORMAT (I4,6X,I10)
   10 CONTINUE
      DO 15 I = 1,42
      DO 15 J = 1,N
   15 SUM(I) = SUM(I) + NEW(I,J)
      DO 16 I = 1,42
   16 IC(I) = 1
      CALL TSORT (42,SUM(1), IC(1) )
      DO 17 I = 1,42
      IN = IC(1)
      NSUM (IN) = NARRAY (I)
   17 CONTINUE
      WRITE (6,8)
    8 FORMAT (1X,*TOTAL INDEX*)
      DO 18 I = 1,42
      WRITE (6,9) I,NSUM (I)
   18 CONTINUE
      END
```

APPENDIX D

AMBULANCE LOCATION MAPS AND TRADE-OFF CURVES

FIGURE D-1
AMBULANCE LOCATION IN HOSPITALS: A TRADE-OFF CURVE
(two hour service time)



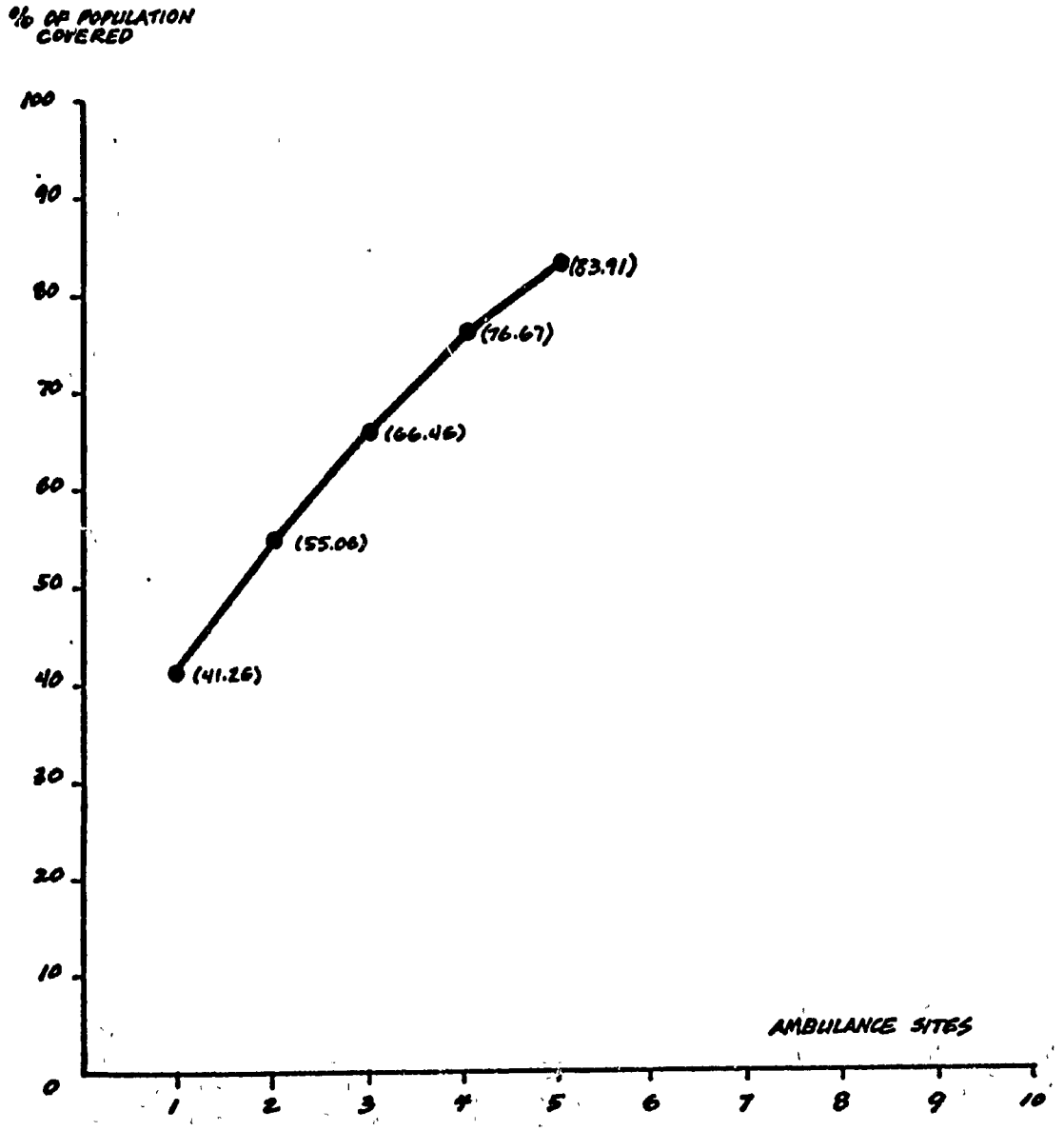
numbers in parentheses refer to the percentage of population covered

FIGURE D-2
AMBULANCE LOCATION IN HOSPITALS
(one hour service time)

■ facility

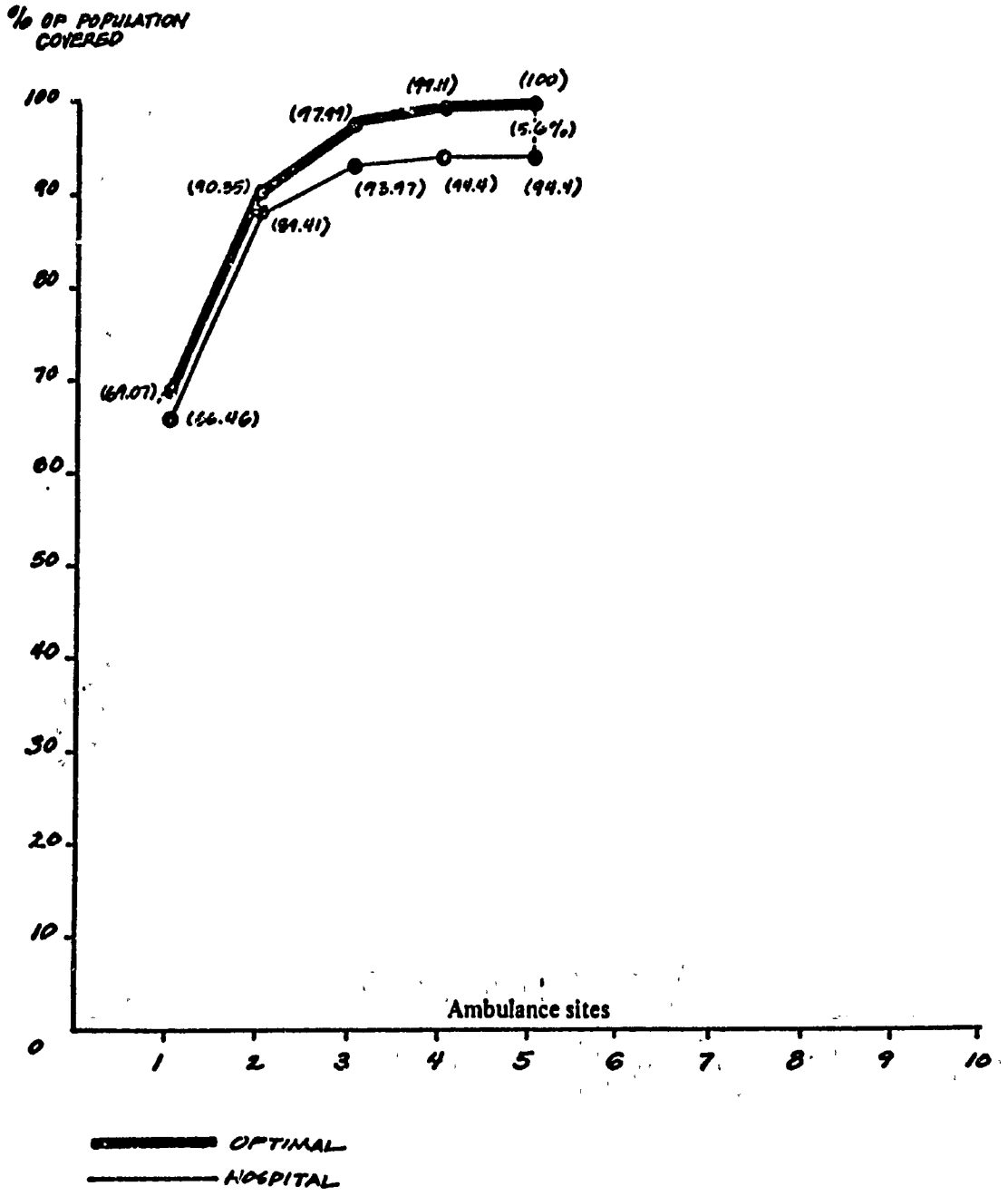
• village

FIGURE D-3
AMBULANCE LOCATION IN HOSPITALS
(one hour maximum service time)



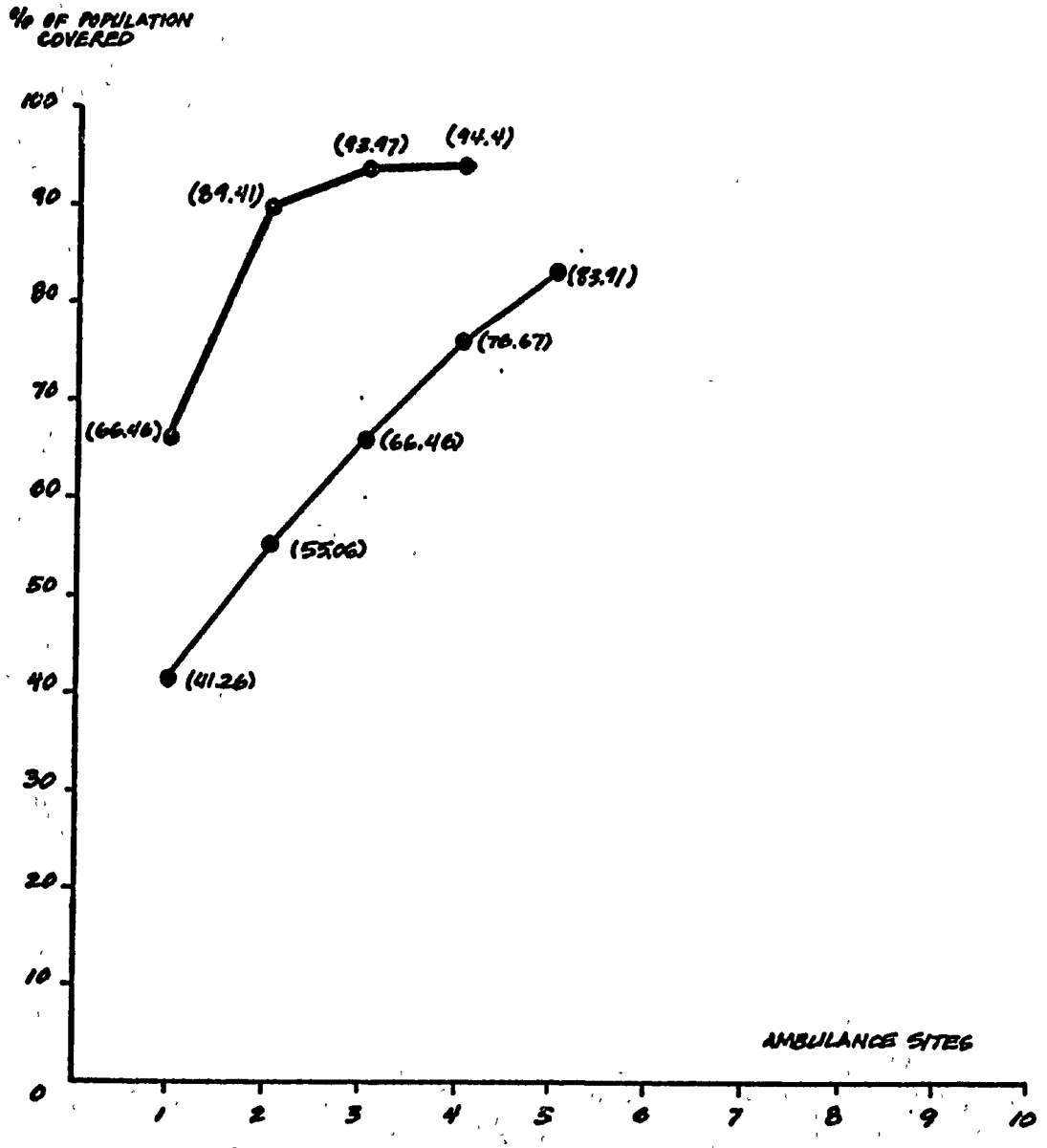
numbers in parentheses refer to the percentage of total population covered

FIGURE D-4
AMBULANCE LOCATION COMPARISION–HOSPITAL VS. NO RESTRICTION: A TRADE-OFF CURVE
(two hour-plus maximum service time)



numbers in parentheses refer to the percentage of total population covered

FIGURE D-5
AMBULANCE LOCATION IN HOSPITALS: A COMPARATIVE TRADE-OFF CURVE
(one hour vs. two hour service time)



two hour service time

one hour service time

numbers in parentheses refer to the percentage of total population coverage

FIGURE D-6
AMBULANCE LOCATION AT HOSPITALS AND WITH NO RESTRICTIONS: A COMPARATIVE TRADE-OFF CURVE
(one hour service time)

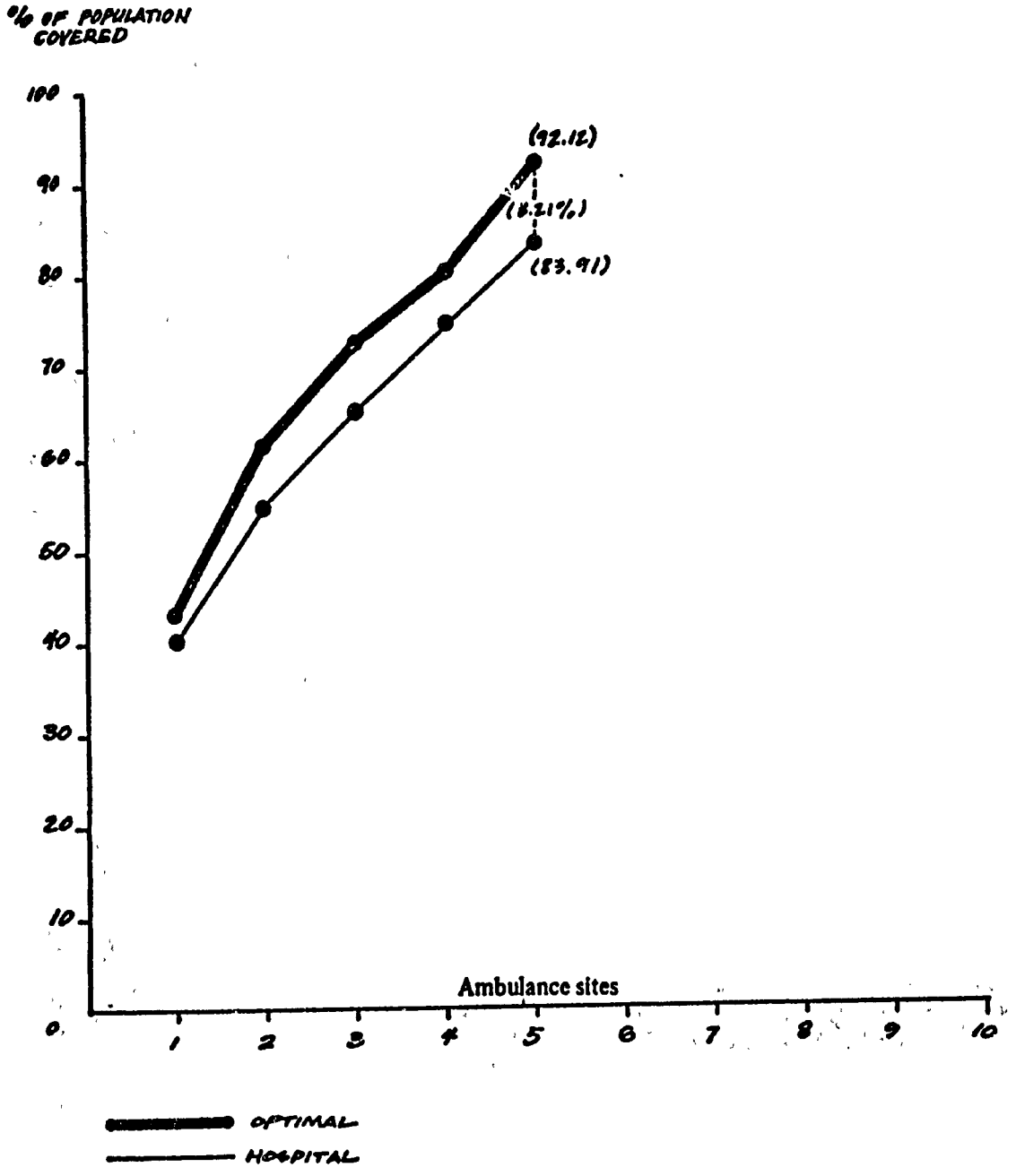
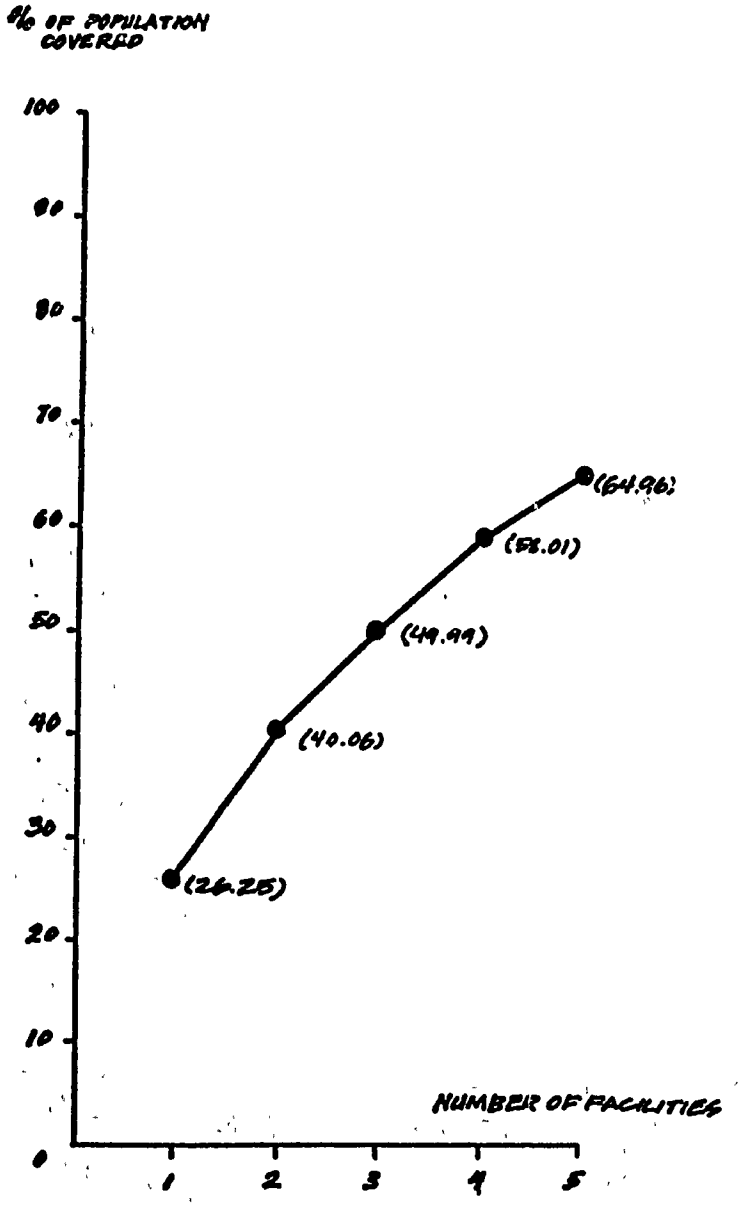
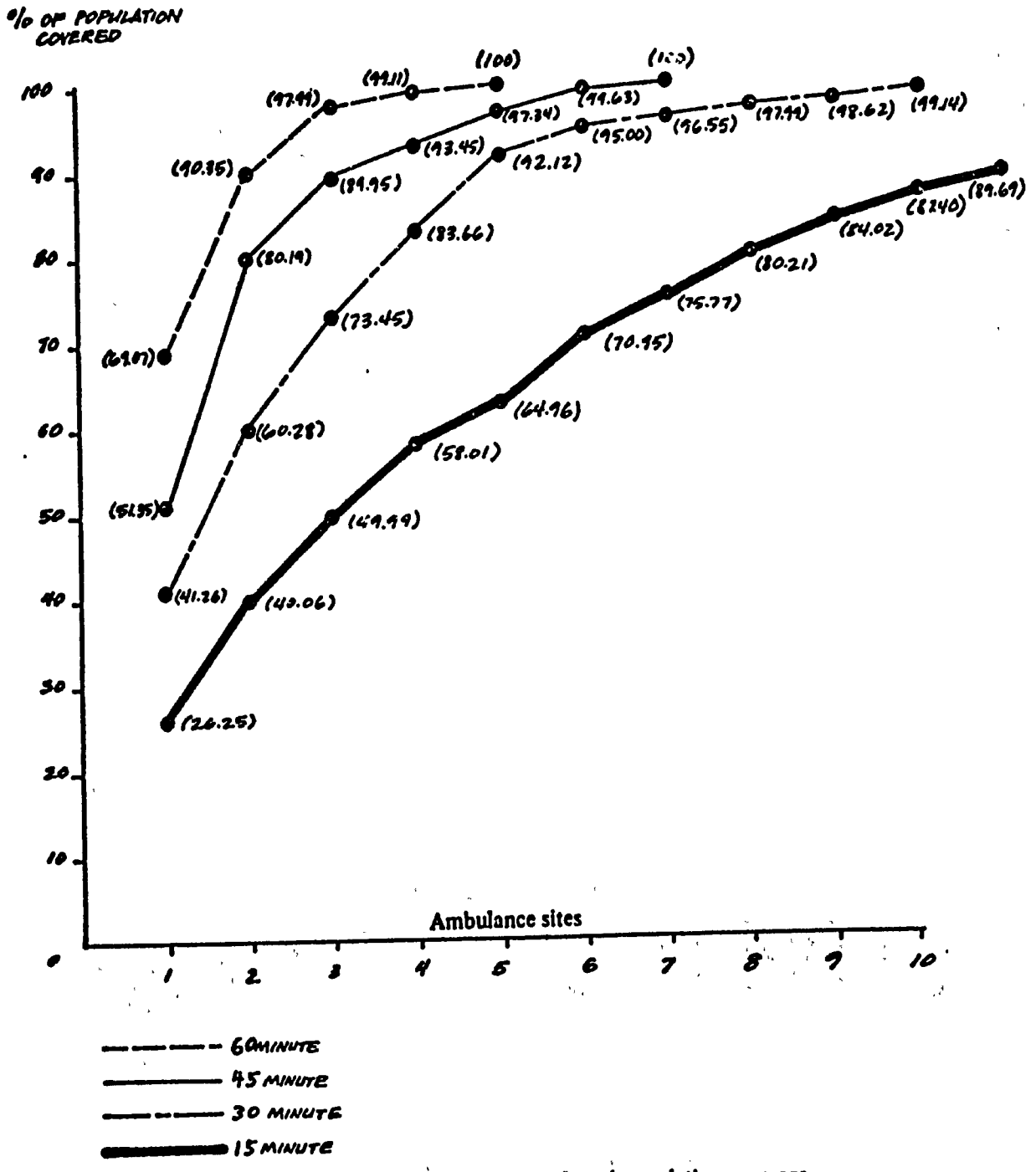


FIGURE D-7
AMBULANCE LOCATION WITH NO RESTRICTION: A TRADE-OFF CURVE
(30 minute-plus service time)



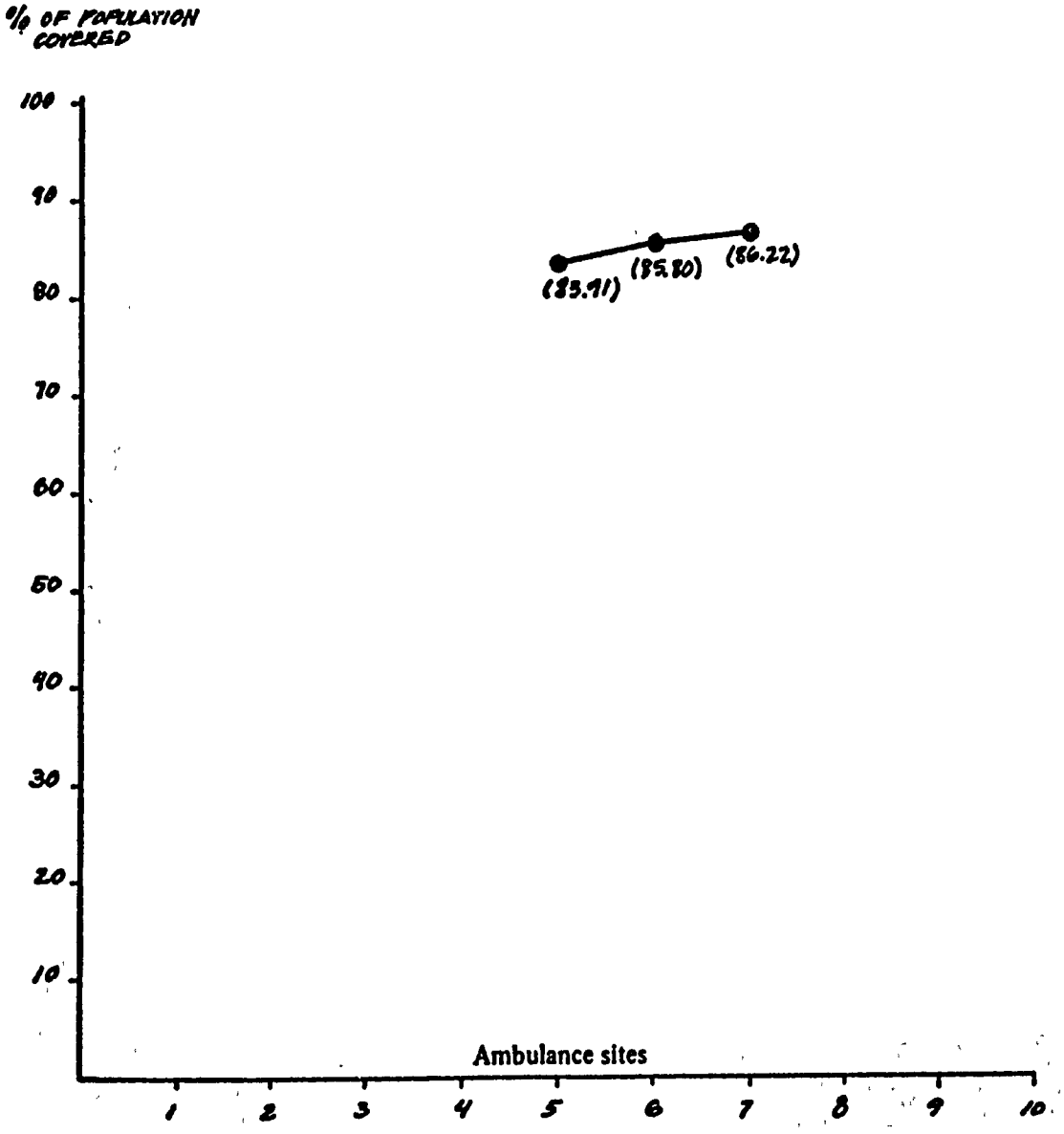
numbers in parentheses refer to the percentage of total population covered

FIGURE D-8
AMBULANCE LOCATION WITH NO RESTRICTIONS: COMPARATIVE TRADE-OFF CURVES
(30-60-90-120 minute service time)



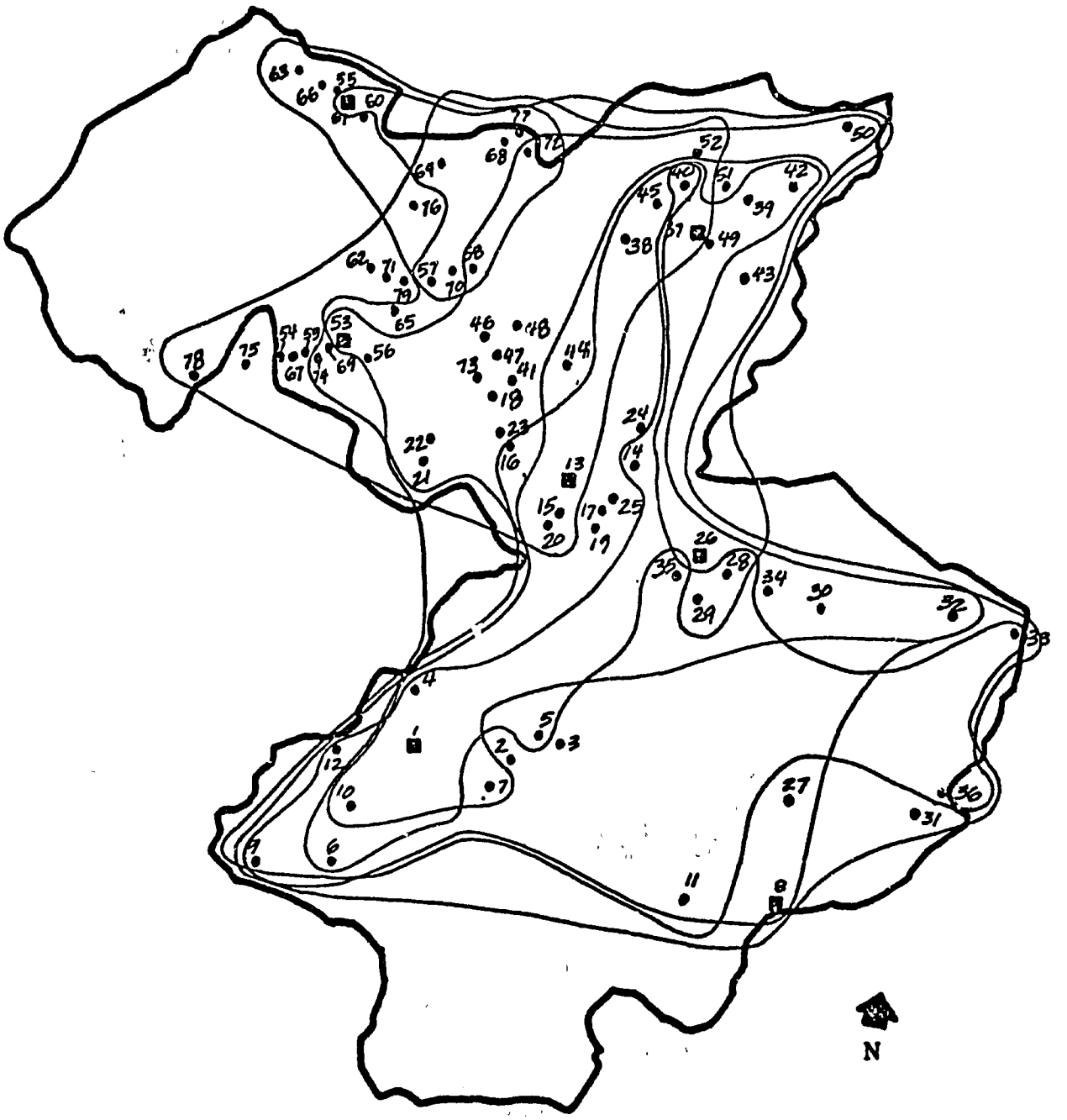
numbers in parentheses refer to the percentage of total population coverage

FIGURE D-9
AMBULANCE EXTENSION TO VILLAGES WITH POPULATIONS > 900:
A TRADE-OFF CURVE
(one hour service time)



numbers in parentheses refer to the percentage of total population coverage

FIGURE D-10
AMBULANCE EXTENSION TO PROMOTORA SITES
(two hour service time)



■ facility
● village

FIGURE D-11
AMBULANCE EXTENSION TO PROMOTORA SITES
(one hour service time)

■ facility
• village

FIGURE D-12
AMBULANCE EXTENSION WITH NO RESTRICTIONS
(two hour service time)

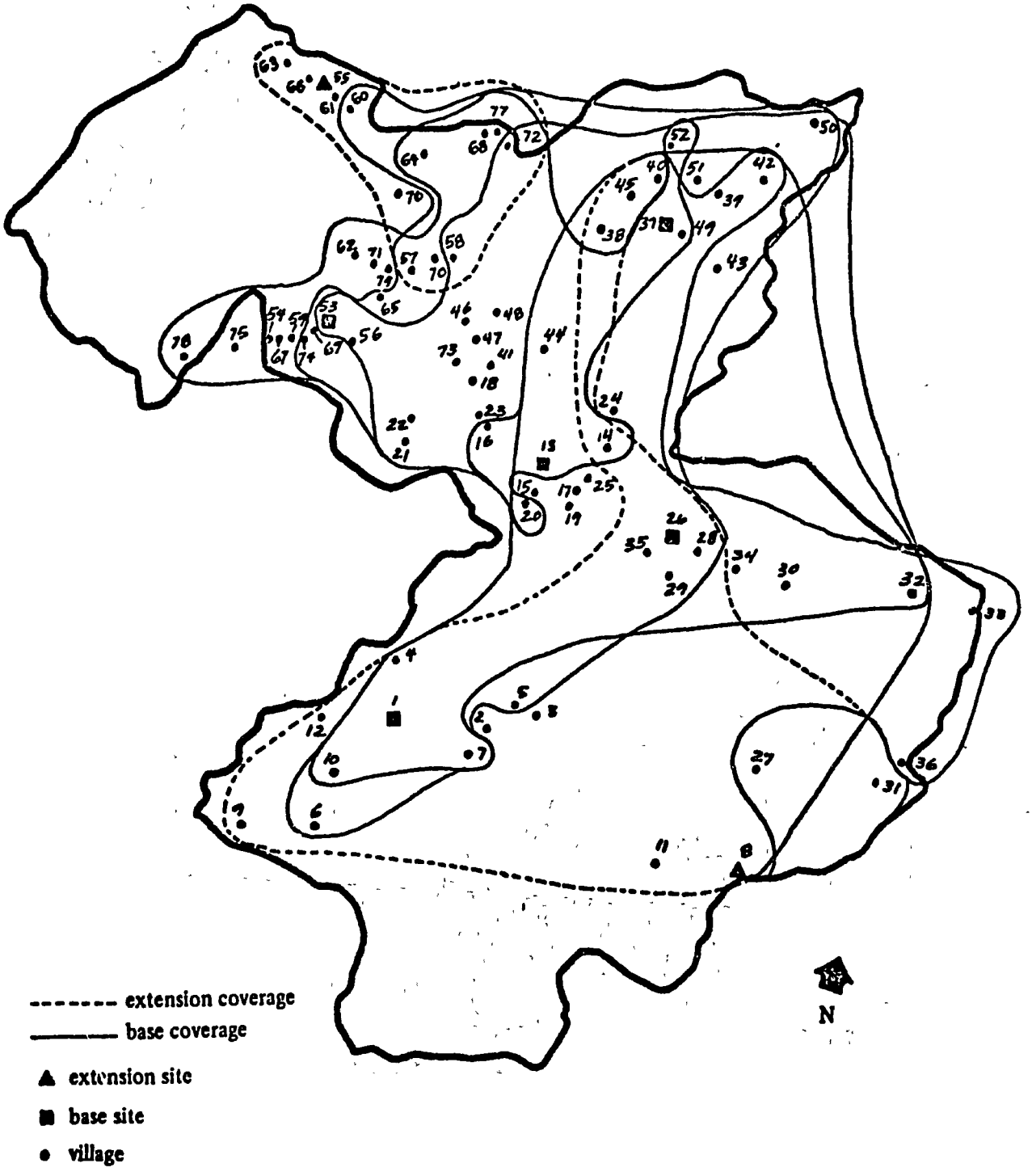


FIGURE D-13
AMBULANCE LOCATION WITH NO RESTRICTIONS
(combination–one hour and two hour service times)

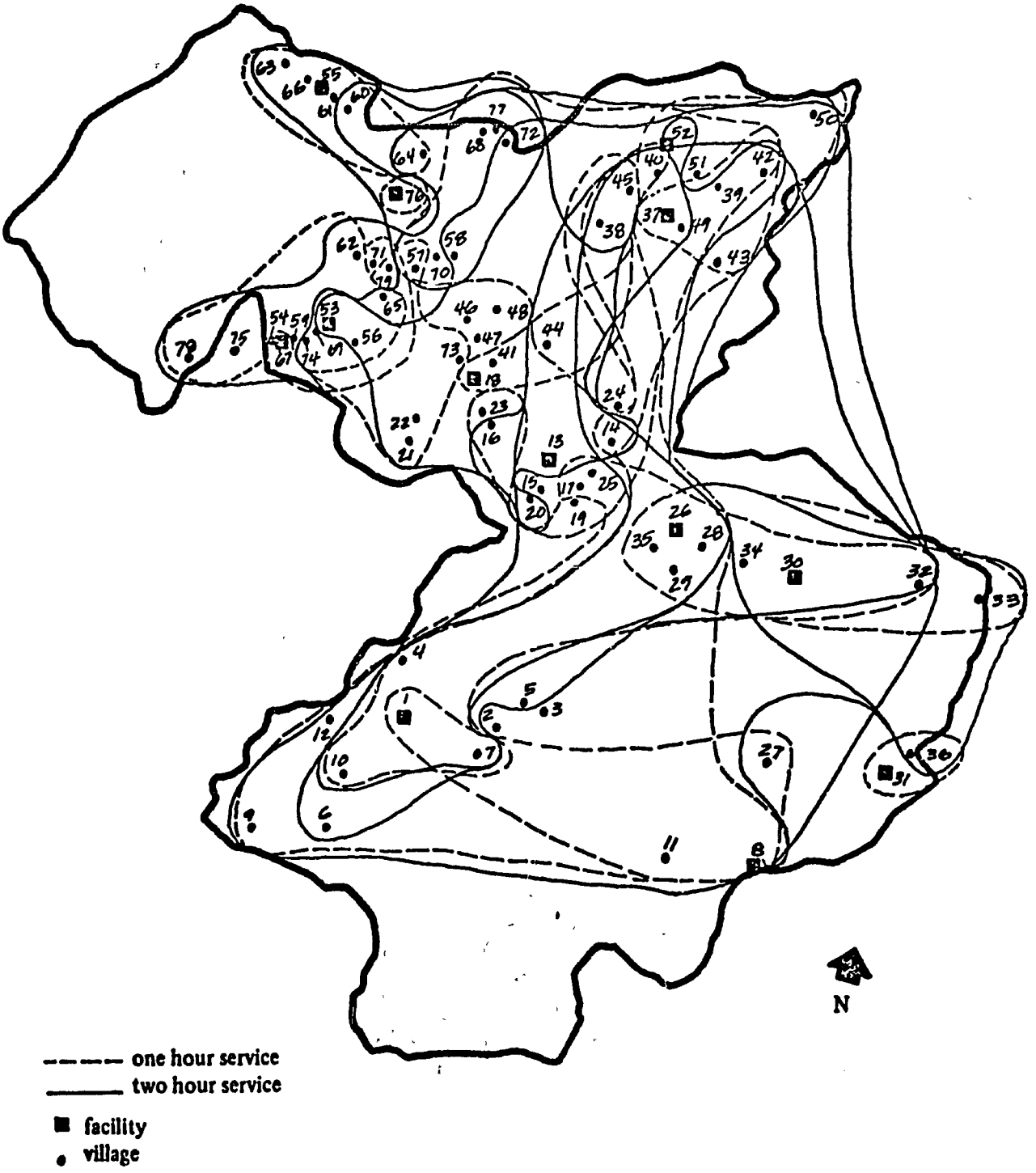


FIGURE D-14
AMBULANCE EXTENSION WITH NO RESTRICTION
(one hour service time)

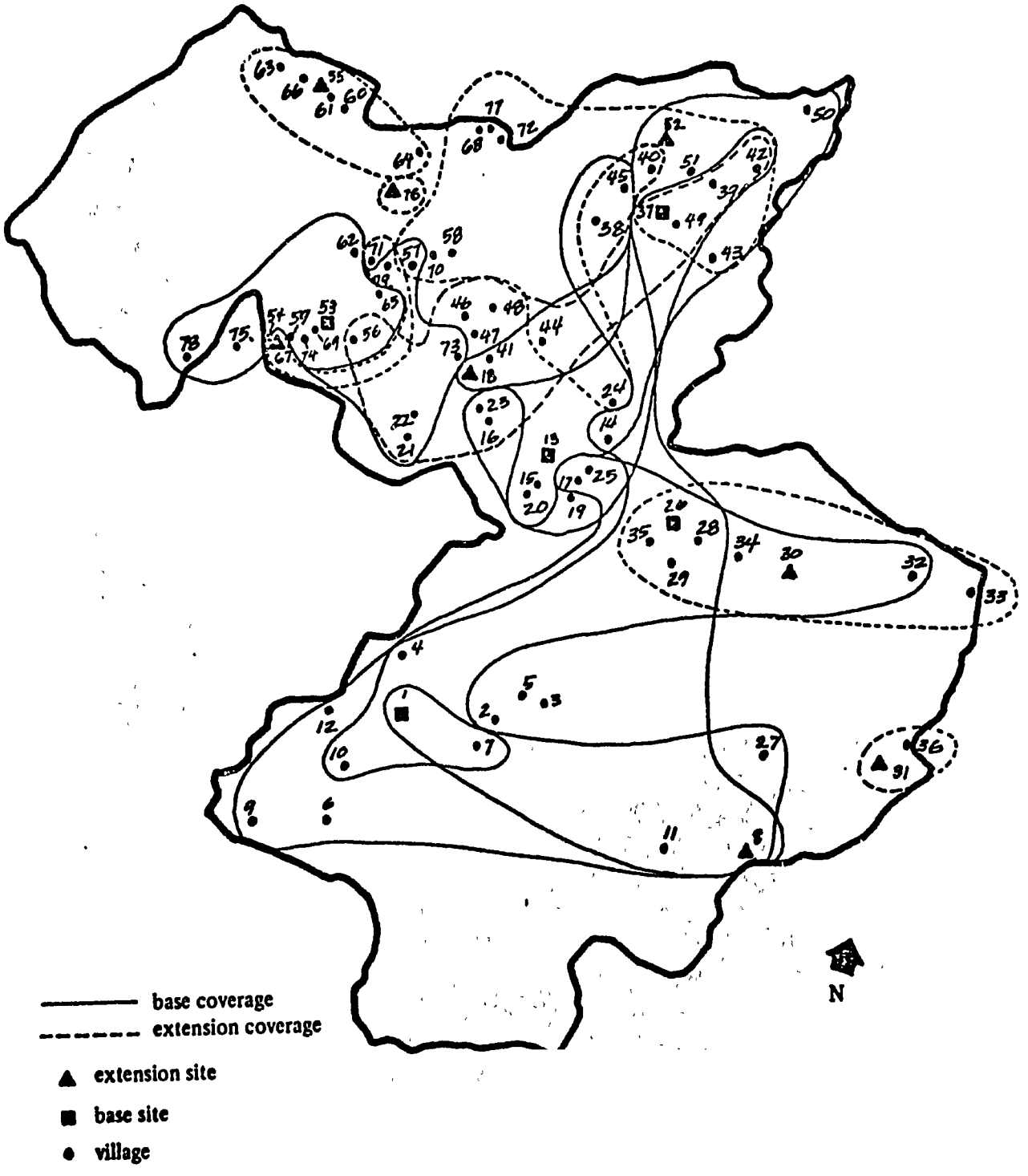
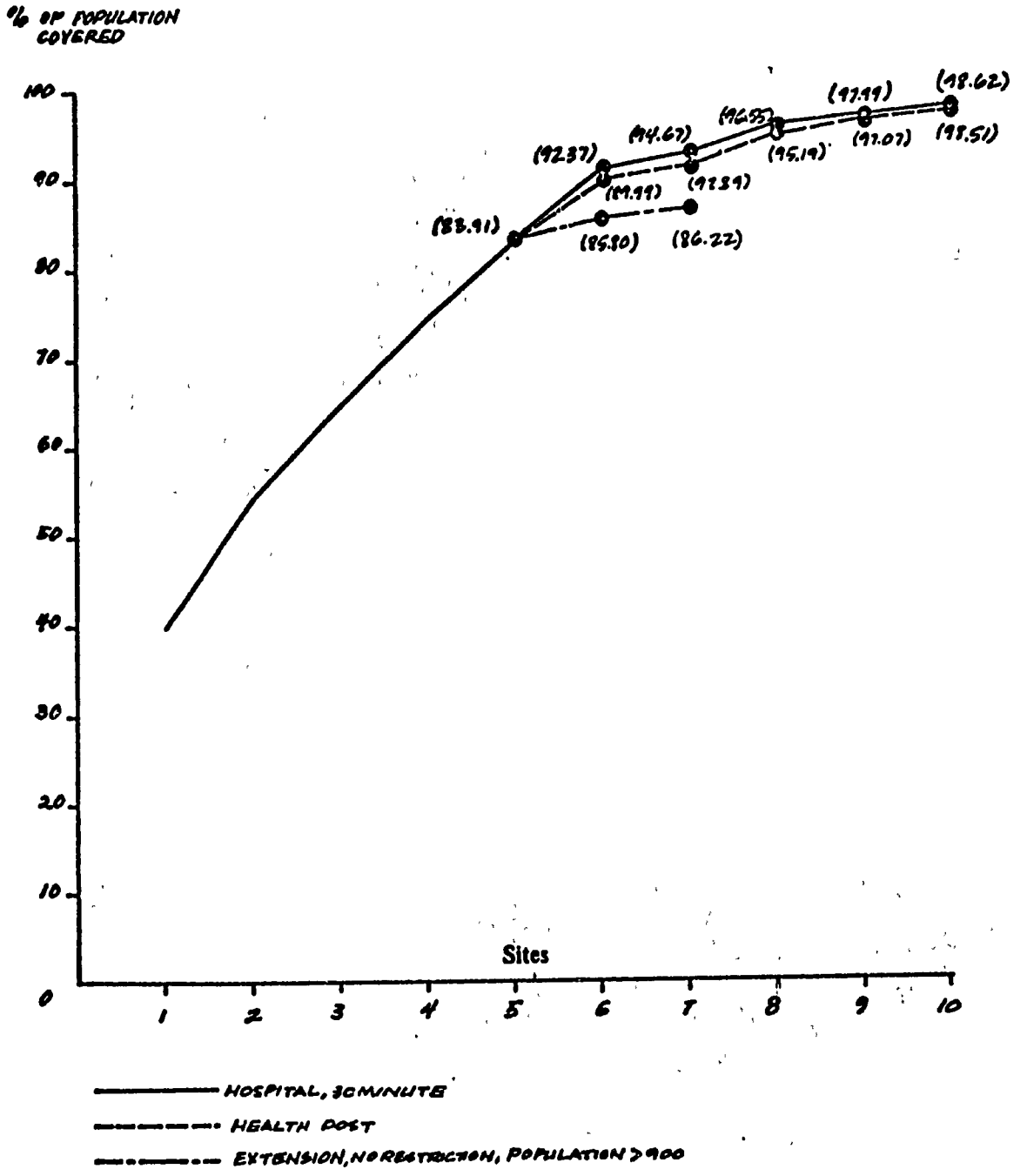


FIGURE D-15
AMBULANCE EXTENSIONS: A COMPARATIVE TRADE-OFF CURVE
(one hour-plus service time)



numbers in parentheses refer to the percent of total population covered