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THE UNIVERSITY OF TEXAS AT AUSTIN

AN INTRODUCTION AND GUIDE TO THE SITE LOCATION OF PUBLIC FACILITIES UTILIZING THE "GAS" PROGRAM

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Special Project Report

AN INTRODUCTION AND GUIDE TO THE SITE LOCATION OF PUBLIC FACILITIES UTILIZING THE "GAS" PROGRAM

Appendix C to the Report for the "Health Facility Location in Colombia" Project; USAID Contract Number AID/ta-C-1363, Project Number 931-11-998-001 to the University of Texas at Austin; David J. Eaton, Ph.D., Principal Investigator.

April 1, 1979

AN INTRODUCTION AND GUIDE TO THE SITE LOCATION OF PUBLIC FACILITIES UTILIZING THE "GAS" PROGRAM

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PART ONE

AN INTRODUCTION TO MAXIMAL COVERING AND THE GAS ALGORITHM

CHAPTER ONE

INTRODUCTION TO MAXIMAL COVERING

The intent of this monograph is to present general instructions on the use of the GAS program in solving maximal covering location problems. The maximal covering location problem was originally introduced by Church and ReVelle in 1973 (1). In the development of the maximal cover problem, Church and ReVelle realized that it could become a valuable technique in the location of public facilities. Proposed applications of the maximal covering location problem have included the location of health clinics, ambulance stations, fire stations, postal service centers, libraries, drilling rigs and storage centers in the north sea, and the location of strategic defenses.

The maximal covering location problem (MCLP) can be defined in the following way:

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

This problem identifies a solution which serves the largest possible percentage of the population that can be served, given a fixed number of available facilities for allocation. Such coverage or access is often times a desirable goal in the location of public facilities.

Eaton et. al. (2) have introduced the maximal covering problem as an approach to locating health services. ReVelle

et. al. (3) have reviewed a number of location models within a health services context and emphasize the importance of the maximal covering problem in that it is particularly useful in planning and evaluating medical systems.

This presentation includes a number of programmed examples. After becoming acquainted with the material in this monograph, the reader should be able to use the GAS program in solving maximal covering problems.

The remainder of this introduction covers both a description of the GAS approach as well as the history behind the GAS algorithm. An example problem is also discussed with the purpose of illustrating the step by step procedure of GAS.

HISTORY

In 1973, research at The Johns Hopkins University revealed that major improvements on the location set covering model could be made. The location set covering problem was developed in 1970 as an approach for locating public facilities. It was originally defined by Toregas as (4):

> Find the minimal number and location of facilities such that all demand can be served within a maximal service distance or time.

As an example, Toregas presented a problem of siting ambulance vehicles within 10 minutes travel time from any possible demand area. If such a standard was maintained, then each area could conceivably never wait more than 10 minutes for an ambulance to respond to a call (assuming that the ambulance is always available when a call is made). In order to determine the number of ambulances necessary to provide such a service, Toregas developed

the location set covering problem. The solution of the location set covering problem provides not only the minimal number of ambulances such that each area can be served within the specified time of response but provides a set of locations (utilizing the minimum number) that yields the desired goal.

Toregas developed two approaches to solving the location set covering problem. The first approach was a linear programming method and the second method was based upon a reductions algorithm. Since the original development, the location set covering problem has been utilized in the location of fire stations in many cities of the United States.

An interesting problem, however, can result when solving a location set covering problem. As an example, let us assume that we are trying to serve an urban area by building fire stations. Suppose that in order to serve an area, a station must be placed within 1 1/2 miles of that area. Upon solving the location set covering problem, we further determine that eight stations are required to serve all areas within the specified 1 1/2 miles. If we have a limited budget which does not allow the building of eight stations, we are forced to compromise on our original objective - that of serving all areas within a mile and a half of a station. If we can only afford six stations an appropriate question might be - "How many areas can we serve within a mile and a half by locating six stations." In other words, knowing that we cannot provide service (called coverage) for all areas, what is the largest number we can provide service with only six facilities. This question is precisely what the maximal

covering location problem is designed to solve. Specifically, the maximal covering location problem can be defined as:

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

This problem was introduced by Church and ReVelle in 1973 and was shown at that time to supplant the original location set covering problem. Church has developed two approaches for solving the maximal covering location problem. The first approach was based on a linear programming formulation and the second basic approach was based on a heuristic called GAS. In addition, Church also showed how to apply two other procedures in solving the maximal covering location problem (5). Further, White and Case have applied a heuristic algorithm to solve problems similar to the maximal covering problem (6). Thus, a number of approaches are available for the solution of a maximal covering location problem.

An important question is which solution approach is the best to apply when solving maximal covering location problems. The answer to such a question is based upon need, problem size, availability of computer software, size and efficiency of computer, and expertise of the user. The only approach that can guarantee optimal solutions is the approach developed by Church that is based on linear programming. Solving the MCLP as a linear program requires a modest size computer and software capable of handling linear programming problems. The amount of computation time necessary to solve one problem is usually much larger than one of the heuristic algorithms. However, the approach is very general

and has been used to solve problems as large as 500 demand areas. There is no reason why linear programming cannot solve larger problems, but such a problem has not arisen. If many problems are to be solved the optimal linear programming approach may be expensive. In such cases, the available heuristics may be less costly to apply. Of the heuristic approaches identified, including the Ignizio heuristic, Church has concluded that the GAS algorithm is the most appropriate to solve maximal covering problems.

Although the Ignizio heuristic is a very good warehouse location program, it can be shown that the performance of the program on MCLP problems is generally not as good as the GAS program. Numerous examples can be developed which show that the GAS program is more robust in making location decisions.

It is important to note that the GAS program is a heuristic program and cannot guarantee optimal solutions. However, in most circumstances GAS does identify either an optimal solution or a solution that is very close to optimality. In fact, GAS has proved to be an extremely efficient and effective method for solving MCLP problems (7). Because of ease of use, performance in actual operation, and flexibility with respect to problem size, type, and computer installation, GAS is the best way of solving large numbers of MCLP problems.

DESCRIPTION OF THE GAS ALGORITHM

The GAS algorithm is a procedure that identifies good if not optimal solutions to maximal covering location problems.

The GAS procedure is based on a simple algorithm called the Greedy Adding Algorithm with Substitution (GAS). Basically, the GAS program is comprised of the GA algorithm along with a substitution improvement method. Before describing what the substitution improvement procedure does, we will first describe the GA algorithm.

THE GA ALGORITHM

In order to achieve a maximal cover solution for p-facilities under a given maximal service distance, the algorithm starts with an empty solution set and then adds to this set the best facility sites one at a time. The best facility site in a given iteration is defined to be that site which covers at least as much of the existing uncovered population as any other site. The existing uncovered population is that population left "uncovered" by the current facility solution set. There can be more than one facility site meeting the "best facility site" criterion in a given iteration. In this case, the heuristic picks the facility site meeting the criterion with the lowest index number.

For example, GA picks for the first facility that site which covers the most of the total population. For the second facility, GA picks the site that covers the most of the population not covered by the first facility. Then, for the third facility, GA picks the site that covers the most of the population not covered by the first and second facilities. This process is continued until either p-facilities have been selected or all

the population is covered. A detailed sketch of the algorithm is given in Church (6).

When solving for the p-facility solution, the GA algorithm automatically calculates maximal cover values for the one-to p-facility problems. It should be noted here that the one-facility solution is by definition the site which covers the most of the total population. Optimality is not guaranteed, however, for solutions where $p > 1$.

It is important to note that the GA algorithm never removes facility sites from the solution set. Therefore, it is possible that a facility site added to the solution set in the early iterations of the algorithm may not be justified later in the algorithm due to subsequent facility site assignments. The presence of a "no longer justified" site in the solution set would imply nonoptimality. The GA algorithm, then, could be improved by including a technique that would reduce the probability of maintaining "no longer justified" sites in the solution set.

The essential idea is that a facility site in the solution set is "no longer justified" when total coverage increases upon replacement by another unused site. The improvement technique is simply to attempt to replace one-at-a-time each facility in the solution in order to improve (if possible) the solution.

By incorporating this solution improvement technique into the Greedy Adding Algorithm, a second heuristic can be developed; it is designated as the Greedy Adding with Substitution (GAS) algorithm. In short, GAS determines new facility locations at each iteration like the Greedy Adding Algorithm and, in addition, seeks to improve the solution at each iteration by replacing

one-at-a-time each facility by an unused site if coverage increases. The GAS algorithm, like the GA algorithm, automatically calculates maximal coverage for problems with one, two, . . . to p-facilities. Again, however, global optimality is not guaranteed.

AN EXAMPLE PROBLEM FOR THE GAS ALGORITHM

Suppose there exists a region of 12 villages which we would like to serve with health outposts. Figure 1 gives a road network of the 12 villages. Each village is represented by a point, called a node. Each node representing a village has been given a number or index. The number is used only for identification purposes, and is in no way related to priority or need. The population of each village is given in table 1.

The road network in figure 1 consists of a number of roads that connect various villages. Each link in the network is called an arc. For example, the road connecting village 5 and village 6 is arc (5,6). For each arc a distance is given in figure 1. The distance of arc (5,6) is 15 kilometers. Let us assume that it has been determined that a health outpost can serve anyone within 10 kilometers of the outpost and further suppose that we have money to develop only two health outposts. Then, what is necessary is to determine the placement of two facilities which will serve (provide coverage to) the largest number of people within 10 kilometers.

Prior to solving the above problem, we must first determine which villages are within 10 kilometers of any given village;

FIGURE 1

ROAD NETWORK OF THE REGION

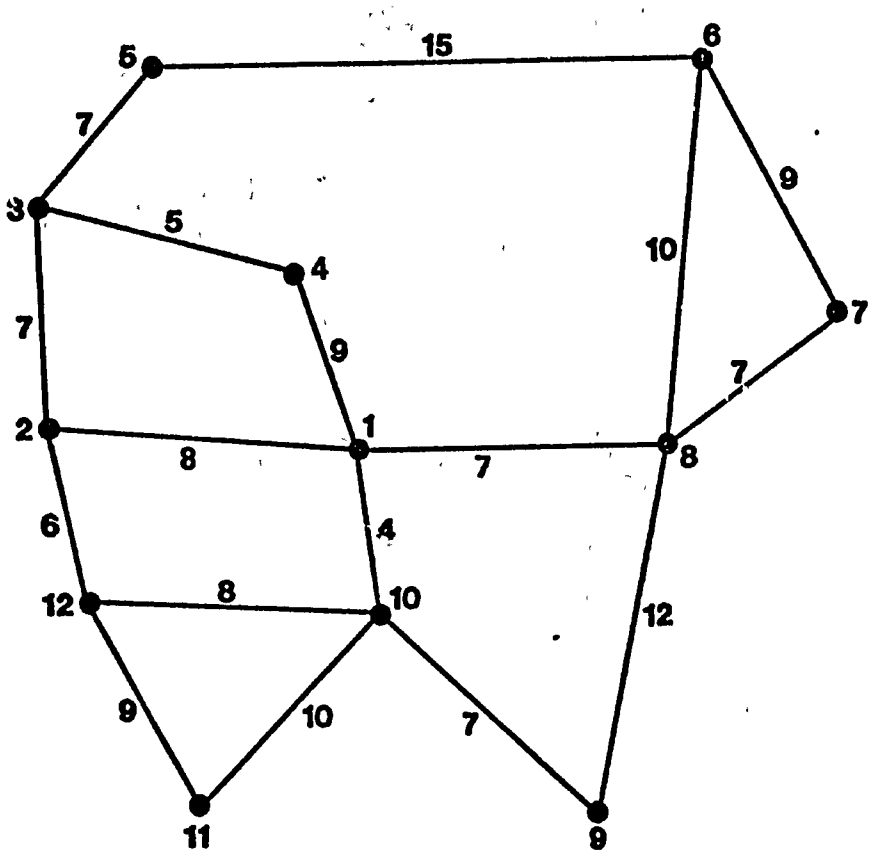


TABLE 1

VILLAGE POPULATIONS

VILLAGE	POPULATION
1	100
2	150
3	250
4	100
5	100
6	50
7	50
8	100
9	50
10	200
11	100
12	50

that is, what villages can a facility in a given village serve? In order to answer this question, one would need to know the distances separating each village. For example, before one could tell whether a health outpost in village 8 can serve the inhabitants of village 12, the shortest distance separating village 8 and 12 must be determined. If the shortest distance between 8 and 12 is less than 10 kilometers, a health outpost in village 8 can serve village 12. But if the shortest distance between 8 and 12 is greater than 10 kilometers, then a health outpost in village 8 cannot serve village 12.

There are a number of routes that can be taken in traveling from village 8 to village 12. An example would be to travel from village 8 to village 1 to village 2 to village 12 at a total distance of 7+8+6 or 21. The complete number of possible routes are given in table 2. The shortest of all possible routes is traveling from village 8 to village 1 to village 10 to village 12, or a distance of 19 kilometers. To actually insure that the shortest route is identified, one must either enumerate all possibilities (as shown in table 2) or use an approach developed specifically for finding the shortest path between two villages without enumerating all possibilities. Whichever approach is utilized, one can develop a matrix of shortest distances like that given in table 3. The entries in table 3 give the distance from village I to village J. For example, the shortest distance from village 3 to village 6 is 22. A special algorithm in the GAS program is utilized to develop a shortest distance matrix (7).

TABLE 2

COMPLETE LISTING OF POSSIBLE ROUTES
BETWEEN VILLAGE 8 AND VILLAGE 12

	Routes	Distance (Km)
1)	8-1-2-12	21
2)	8-1-10-12	19
3)	8-1-10-11-12	30
4)	8-9-10-12	27
5)	8-9-10-11-12	38
6)	8-1-4-3-2-12	34
7)	8-9-10-1-2-12	37
8)	8-9-10-1-4-3-2-12	50
9)	8-6-5-3-2-12	45
10)	8-7-6-5-3-2-12	51
11)	8-6-5-3-4-1-10-12	58
12)	8-7-6-5-3-4-1-10-12	64
13)	8-6-5-3-4-1-2-12	60
14)	8-7-6-5-3-4-1-2-12	66
15)	8-6-5-3-4-1-10-11-12	69
16)	8-7-6-5-3-4-1-10-11-12	75
17)	8-6-5-3-2-1-10-12	59
18)	8-7-6-5-3-2-1-10-12	65
19)	8-6-5-3-2-1-10-11-12	70
20)	8-7-6-5-3-2-1-10-11-12	76

Now that the shortest distances between each pair of villages is known it is possible to determine which villages can be served by a health outpost in any given village. For example, if a health outpost is located at village 3, all villages within 10 kilometers can be served by that health outpost. From the shortest path distance matrix of table 3, it is easy to see that only villages 2, 3, 4, and 5 are within 10 kilometers of village 3. This means that a health outpost located in village 3 can serve the village itself plus villages 2, 4, and 5. Given the shortest distance matrix, we can now develop a cover matrix which indicates which villages can be served by a health outpost in any given village. This cover matrix can be generated by taking the distance matrix, and replacing all entries that are less than or equal to 10 kilometers with a one. All entries that are greater than 10 kilometers should be replaced with zeroes. As an example, the shortest distance matrix of table 3 can be transformed into a cover matrix like that given in table 4. As an example of how to generate an element in table 4, note that village 3 is 14 kilometers from village 1. Thus a zero is entered in the cover matrix in the same position. That is, for village $i = 3$, and village $j = 1$, let the entry be zero.

Generating the zero-one cover matrix is a convenient method for determining which villages can be served by a given village j. For example, if we want to know which villages can be served by a health outpost located in village 3, we can look at column 3 in the cover matrix. Each entry of one indicates that service

TABLE 3

SHORTEST DISTANCE MATRIX FOR TWELVE VILLAGE PROBLEM

VILLAGE J

VILLAGE I	1	2	3	4	5	6	7	8	9	10	11	12
1	0	8	14	9	21	17	14	7	11	4	14	12
2	8	0	7	12	14	25	22	15	19	12	15	6
3	14	7	0	5	7	22	28	21	25	18	22	13
4	9	12	5	0	12	26	23	16	20	13	23	18
5	21	14	7	12	0	15	25	25	32	25	29	20
6	17	25	22	26	15	0	9	10	22	21	31	29
7	14	22	28	23	24	9	0	7	19	18	28	26
8	7	15	21	16	25	10	7	0	12	11	21	19
9	11	19	25	20	32	22	19	12	0	7	17	15
10	4	12	18	13	25	21	18	11	7	0	10	8
11	14	15	22	23	29	31	28	21	17	10	0	9
12	12	6	13	18	20	29	26	19	15	8	9	0

TABLE 4

COVER MATRIX FOR THE TWELVE VILLAGE PROBLEM

VILLAGE J

VILLAGE I	1	2	3	4	5	6	7	8	9	10	11	12
1	1	1	0	1	0	0	0	1	0	1	0	0
2	1	1	1	0	0	0	0	0	0	0	0	1
3	0	1	1	1	1	0	0	0	0	0	0	0
4	1	0	1	1	0	0	0	0	0	0	0	0
5	0	0	1	0	1	0	0	0	0	0	0	0
6	0	0	0	0	0	1	1	1	0	0	0	0
7	0	0	0	0	0	1	1	1	0	0	0	0
8	1	0	0	0	0	1	1	1	0	0	0	0
9	0	0	0	0	0	0	0	0	1	1	0	0
10	1	0	0	0	0	0	0	0	1	1	1	1
11	0	0	0	0	0	0	0	0	0	1	1	1
12	0	1	0	0	0	0	0	0	0	1	1	1

or coverage can be obtained within 10 kilometers. For village 3, ones occur in column 3 for i = 2, 3, 4, and 5. This means that a facility in village 3 can serve villages 2, 3, 4, and 5.

Up to this point, we have started with a road network of known travel times or distances and the population of each village. From the road network, we are able to generate a shortest distance matrix. From the shortest distance matrix, a zero-one cover matrix can be developed by utilizing the desired maximum time or distance standard. With the zero-one cover matrix and the village populations, we can now solve the desired Maximal Covering Problem by utilizing the GAS algorithm.

In determining the two facilities that maximize coverage, the GAS algorithm first determines the site that can cover the largest amount of population. For the twelve village problem, it is assumed that each village is a potential site for a health outpost. In order to determine the site that can cover the largest amount of population it is necessary to know the amount of coverage affored by each potential site. From the zero-one cover matrix we can easily determine what each potential site (village) can serve. For example, site 1 can cover villages 1, 2, 4, 8, and 10. From the population list in table 1 and the coverage matrix of table 4 and using the GAS heuristic, we can determine the locations of two best facilities sites, such that the largest possible fraction of the population can be served within 10 kilometers. Villages 1, 2, 4, 8, and 10 have populations of 100, 150, 100, 100, and 200 respectively. This means that a health outpost located in village 1 can serve

a total population of 100+150+100+100+200 = 650. Determining the population covered by each of the twelve villages is equally simple. Table 5 shows all the necessary computations for each site. From among the twelve sites, village 1 can cover the largest amount of population. Thus, village 1 is selected as the location for the first facility.

As described in an earlier section, the GAS algorithm is now ready to select the location of the second facility given that the first facility is located at village 1. The criteria for selecting the second facility is to determine the site that covers the most of the unserved population. In other words, GAS selects the second facility site because it is the location that can serve the greatest portion of the population not served by the facility located at village 1. Since a facility in village 1 can serve villages 1, 2, 4, 8, and 10, the second site must cover as much as possible of unserved villages 3, 5, 6, 7, 9, 11, and 12. At this point, each village not selected for a facility is a potential site. Thus, the set of eligible sites includes villages 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, and 12. Each village needs to be reevaluated on the basis of what it can cover independent of village 1. For example, village 2 can cover 1, 2, 3, and 12 of which 1 and 2 are already served by the facility at village 1. The placement of a facility at village 2 would increase coverage to villages 3 and 12 at a population increase of 250+50 = 300.

The amount of additional coverage (that is, over and above what village 1 can serve) for each eligible site can be easily generated using information given in table 5. For example, for village 2 the coverage possible before site 1 was selected included villages 1, 2, 3, and 12. By taking this

TABLE 5

DETERMINING THE FIRST FACILITY LOCATION

SITE	AREAS COVERED	AMOUNT OF COVERAGE
1	1,2,4,8,10	100 + 150 + 100 + 100 + 200 = 650
2	1,2,3,12	100 + 150 + 250 + 50 = 550
3	2,3,4,5	150 + 250 + 100 + 100 = 600
4	1,3,4	100 + 250 + 100 = 450
5	3,5	250 + 100 = 350
6	6,7,8	50 + 50 + 100 = 200
7	6,7,8	50 + 50 + 100 = 200
8	1,6,7,8	100 + 50 + 50 + 100 = 300
9	9,10	50 + 200 = 250
10	1,9,10,11,12	100 + 50 + 200 + 100 + 50 = 500
11	10,11,12	200 + 100 + 50 = 350
12	10,11,12	200 + 100 + 50 = 350

list and eliminating villages now served by village 1, (that is, villages 1 and 2) one can see that village 2 can cover villages 3 and 12 above and beyond what village 1 can serve. As previously calculated, this additional amount totals 300. The additional coverage gained by selecting any one of the eligible sites is easily calculated. Table 6 gives the gains in coverage possible for each eligible site. It can be seen by inspecting table 6 that village 3 increases the coverage by the largest amount (350). Thus, the GAS algorithm selects village 3 as the second facility location.

Now, the GAS algorithm has selected two facility sites. Before selection of the third site begins, the GAS algorithm determines if any one of the facilities can be moved to another location with a resulting increase in coverage. This may be possible due to the existence of villages being served by more than one facility within 10 kilometers.

In order to check if any possible movement of the current facility locations can be made with overall improvement of coverage, GAS picks a facility location and then checks to see if that specific location can be changed with a gain in overall coverage. In this case, GAS would first check to see if any village could replace village 1 as a facility site and improve coverage. For example, if village 2 replaces village 1 as the facility location, coverage would increase due to gaining village 12 and would decrease due to losing villages 8 and 10. The net result would be a gain in 50 and a loss of 100 and 200, or a net change of -250. This

TABLE 6

DETERMINING THE SECOND FACILITY LOCATION

FACILITY LOCATIONS 1

COVERED 1,2,4,8,10

UNCOVERED 3,5,6,7,9,11,12

ELIGIBLE SITES 2,3,4,5,6,7,8,9,10

GAIN IN COVERAGE		AMOUNT OF COVERAGE
2	3,12	250 + 50 = 300
*3	3,5	250 + 100 = 350
4	3	250
5	3,5	250 + 100 = 350
6	6,7	50 + 50 = 100
7	6,7	50 + 50 = 100
8	6,7	50 + 50 = 100
9	9	50
10	9,11,12	50 + 150 + 100 = 300
11	11,12	100 + 50 = 150
12	11,12	100 + 50 = 150

*Site 3 has the highest value of added coverage

means that replacing village 1 with village 2 as the facility location would decrease coverage by 250 when the facility at village 3 remains fixed. Table 7 compares coverage of all possible replacements for the facility at village 1 assuming that a companion facility is located at village 3. Note that if the facility is moved from village 1 to village 10, coverage increases by 100; this is the best of all possible moves. GAS will then change the location of facility in village 1 to village 10. At this point the locations of facilities are villages 3 and 10.

After checking to see if a shift in facility site can improve the solution, GAS moves the facility from village 1 to village 10. GAS then checks to see if the second facility can be replaced with a gain in coverage. All possibilities for moving the facility in village 3 to some other site are tabulated in table 8. It should be noted that no changes increase coverage; all possible moves result in a decrease in coverage. Thus, there is no reason to shift the facility from village 3. This ends the substitution-improvement phase and GAS has now completed the determination of the best two villages for facility placement. The health outposts will be sited in villages 3 and 10.

If we had initially wanted GAS to locate three facilities instead of two facilities, GAS would take the two facility solution and add to that the next best site. The next best site is that site which will cover the most of the population not served by facilities at villages 3 and 10. The eligible

TABLE 7

CHECKING FOR POSSIBLE SUBSTITUTIONS FOR SITE 1

FACILITY LOCATIONS 1,3

COVERED 1,2,3,4,5,8,10 AMOUNT = 1000

UNCOVERED 6,7, ,11,12

ELIGIBLE SITES 2,4,5,6,7,8,9,10,11,12

Site Changes in Coverage

Site	Replaces	Gain	Loss	Amount of Changes	Net
2	1	12	8,10	50 - 100 - 200	= -250
4	1		8,10	- 100 - 200	= -300
5	1		1,8,10	- 100 - 100 - 200	= -400
6	1	6,7	1,10	50 + 50 - 100 - 200	= -200
7	1	6,7	1,10	50 + 50 - 100 - 200	= -200
8	1	6,7	10	50 + 50 + -200	= -100
9	1	9	1	50 - 100	= - 50
*10	1	9,11,12	8	50 + 100 + 50 - 100	= +100
11	1	11,12	8	100 + 50 - 100	= + 50
12	1	11,12	8	100 + 50 - 100	= + 50

*If site 10 replaces site 1, coverage will increase by 100, since 9,11,12 will be additionally covered while only 8 loses coverage.

TABLE 8

CHECKING FOR POSSIBLE SUBSTITUTIONS FOR SITE 3

FACILITY LOCATIONS 10,3

COVERED 1,2,3,4,5,9,10,11,12

UNCOVERED 6,7,8

ELIGIBLE SITES 1,2,4,5,6,7,8,9,11,12

Site Changes in Coverage

Site	Replaces	Gain	Loss	Net*	
1	3	8	3,5	100-250-100	= -250
2	3		4,5	-100-100	= -200
4	3		2,5	-150-100	= -250
5	3		2,4	-150-100	= -250
6	3	6,7,8	2,3,4,5	50+50+100-150-250-100-100	= -400
7	3	6,7,8	2,3,4,5	50+50+100-150-250-100-100	= -400
8	3	6,7,8	2,3,4,5	50+50+100-150-250-100-100	= -400
9	3		2,3,4,5	-150-250-100-100	= -600
11	3		2,3,4,5	-150-250-100-100	= -600
12	3		3,4,5	-250-100-100	= -450

*No substitutions can be made with a net gain in coverage.

sites are villages 1, 2, 4, 5, 6, 7, 8, 9, 11, and 12. This means that the third facility will be located at one of these sites and will be the one which provides access to the largest fraction of the population that is not currently covered by facilities at villages 3 and 10. The gains in coverage for each eligible site are given in table 9. Note that only 3 sites can increase coverage. In fact, the gains in coverage by each of those three sites are exactly the same. Thus, any one of the three sites can be considered as a location for the third facility. When a tie exists, such as this, GAS picks the site with the lowest index. In this case GAS will pick village 6 for the location of the third facility. At this point GAS has now located three facilities.

Note that table 9 indicates that the villages needing coverage when the third facility site is chosen are villages 6, 7, and 8. Since villages 6, 7, and 8 are covered by site 6 (village 6), choosing village 6 for the third facility location increases coverage to 100% of the total population.

When this happens GAS automatically terminates, even though the user might want to locate more facilities. Since all areas are now covered, coverage cannot be used as a criteria for additional facility placement. One possibility when this happens is to consider decreasing the size of the maximal service distance or time (which usually requires the placement of more facilities) and starting the GAS algorithm at the beginning. If, however, coverage was not complete when GAS had initially located the third facility at village 6, then GAS would consider

TABLE 9

DETERMINING THE THIRD FACILITY LOCATION

FACILITY LOCATIONS 10,3

COVERED 1,2,3,4,5,9,10,11,12

UNCOVERED 6,7,8

ELIGIBLE SITES 1,2,4,5,6,7,8,9,11,12

	Gain in Coverage	Amount of Gain
1	-	0
2	-	0
4	-	0
6	6,7,8	50+50+100=200
7	6,7,8	50+50+100=200
8	6,7,8	50+50+100=200
9	-	0
11	-	0
12	-	0

the movement of each current facility in turn. GAS would attempt to increase coverage in a manner similar to the substitution of village 10 for village 1.

CHAPTER TWO

RESULTS OF A GAS PROGRAM RUN

The previous chapter dealt with the use of the GAS algorithm in solving a maximal covering problem based upon the twelve village problem given in figure 1. This chapter presents results from the GAS computer program solving the same problem.

The GAS program is a Fortran IV computer program that solves many different forms of the maximal covering location problem. The various options available with the current version of the GAS program are listed in chapter three of part one of this manual. The GAS program was applied to the twelve village problem and the output from the program is given in figure 2. A description of the input card deck necessary to solve the twelve village problem is given in part two.

Figure 2 is composed of eight pages. Each page contains the information from one printed output page. The first page of output is given on page 1 of figure 2. The information on this page is essentially the population data for the twelve villages. The second page of output in figure 2 gives the information about each road link in the twelve village road network of figure 1. There are a total of 17 arcs. Each arc connects a pair of villages and has an associated distance or time of travel. For example, arc number 4 connects villages 1 and 8 and is a distance of 7 kilometers. By specifying each link in the road network, the computer program can generate a

shortest distance matrix. The first two pages of output basically summarize input data for the desired covering problem.

Pages three and four, given in figure 2, display the shortest distance matrix that is generated by the computer program given the information on page 2. Notice that this shortest distance matrix is essentially the same as that given in table 2 of chapter one.

The fifth page of the computer printout (figure 2) gives a list of the options and specifications utilized by the GAS program. For this simple problem, no options or specifications are made other than the definition of the maximal service distance as 10 kilometers.

The sixth page of the computer printout (figure 2) gives the information about the first iteration of the GAS algorithm. Note that village 1 has been selected as the first facility site. The population served by the facility at village 1 is 650 which is 50% of the total population.

The second facility placement, chosen in the next iteration of the GAS program, is given on page 7 in figure 2. Village 3 has been selected for the second facility. At this point, facilities at villages 1 and 3 cover 76.92% of the population. On the same page of printout, the results of the substitution process are also given. GAS has found that moving a facility from village 1 to village 10 increases coverage from 76.92% to 84.62%.

The last page of output is page 8 of figure 2. This last page gives the results of the third iteration of the GAS algorithm.

In this iteration village 6 is chosen for the third facility. Now population covered by the three facilities is 100%. This represents a condition for the GAS algorithm to terminate execution.

Utilizing the information from the computer results allows one to generate a coverage curve like that shown in figure 3. The coverage curve shows the fraction of coverage obtainable over a range of numbers of facilities.

It should be noted that all results of the computer program on the twelve village problem are exactly the same as those produced by hand calculations in the previous section. The hand calculations are, of course, easy to perform on small problems. However, when the problem is large and complex, it is very difficult to solve by hand. In fact, many of the example problems given in parts two and three are of a size which is manageable only with a computer program.

FIGURE 2

OUTPUT FOR TWELVE VILLAGE PROBLEM

POPULATION DATA

1	100.*	3	250.*	5	100.*	7	50.*	9	50.*	11	100.*
2	150.*	4	100.*	6	50.*	8	100.*	10	200.*	12	50.*

FIGURE 2

(continued, page 2)

INPUT ARC INFORMATION IS AS FOLLOWS

ARC NO.	FROM NODE	TO NODE	DISTANCE
1	1	4	9.000
2	1	2	8.000
3	1	10	4.000
4	1	8	7.000
5	10	9	7.000
6	8	9	12.000
7	8	7	7.000
8	8	6	10.000
9	6	7	9.000
10	6	5	15.000
11	5	3	7.000
12	3	4	5.000
13	3	2	7.000
14	2	12	6.000
15	12	10	8.000
16	12	11	9.000
17	11	10	10.000

FIGURE 2

(continued, page 3)

DISTANCE MATRIX

	1	2	3	4	5	6	7	8	9	10
1	0.0	8.00	14.00	9.00	21.00	17.00	14.00	7.00	11.00	4.00
2	8.00	0.0	7.00	12.00	14.00	25.00	22.00	15.00	19.00	12.00
3	14.00	7.00	0.0	5.00	7.00	22.00	28.00	21.00	25.00	18.00
4	9.00	12.00	5.00	0.0	12.00	26.00	23.00	16.00	20.00	13.00
5	21.00	14.00	7.00	12.00	0.0	15.00	24.00	25.00	32.00	25.00
6	17.00	25.00	22.00	26.00	15.00	0.0	9.00	10.00	22.00	21.00
7	14.00	22.00	28.00	23.00	24.00	9.00	0.0	7.00	19.00	18.00
8	7.00	15.00	21.00	16.00	25.00	10.00	7.00	0.0	12.00	11.00
9	11.00	19.00	25.00	20.00	32.00	22.00	19.00	12.00	0.0	7.00
10	4.00	12.00	18.00	13.00	25.00	21.00	18.00	11.00	7.00	0.0
11	14.00	15.00	22.00	23.00	29.00	31.00	28.00	21.00	17.00	10.00
12	12.00	6.00	13.00	18.00	20.00	29.00	26.00	19.00	15.00	8.00

FIGURE 2

(continued, page 4)

DISTANCE MATRIX

	11	12
1	14.00	12.00
2	15.00	6.00
3	22.00	13.00
4	23.00	18.00
5	29.00	20.00
6	31.00	29.00
7	28.00	26.00
8	21.00	19.00
9	17.00	15.00
10	10.00	8.00
11	0.0	9.00
12	9.00	0.0

FIGURE 2

(continued, page 5)

```
SUBPROGRAM MATBLD HAS BEEN CALLED TO GENERATE A COVER MATRIX
   THE MAXIMUM DISTANCE/TIME OF  10.00 HAS BEEN UTILIZED
*****************************************************************
```

FIGURE 2

(continued, page 6)

```
   ITERATION NUMBER,    1
THIS IS AN EXAMPLE OF THE TWELVE VILLAGE PROBLEM

   NUMBER OF FACILITIES   1
   SERVICE DISTANCE =    10.000

   NEW FACILITY LOCATION NUMBER     1

   FACILITIES ARE LOCATED AT     1,
   ----------------------------------------------------------------------
   POPULATION SERVED     650.00          PERCENT OF TOTAL POPULATION SERVED   50.00
   ----------------------------------------------------------------------
```

FIGURE 2

(continued, page 7)

```
   ITERATION NUMBER.    2
THIS IS AN EXAMPLE OF THE TWELVE VILLAGE PROBLEM

   NUMBER OF FACILITIES   2
   SERVICE DISTANCE =    10.000

   NEW FACILITY LOCATION NUMBER     3

   FACILITIES ARE LOCATED AT     1.    3.
   ----------------------------------------------------------------------
   POPULATION SERVED    1000.00          PERCENT OF TOTAL POPULATION SERVED   76.92
   ----------------------------------------------------------------------

   SUBSTITUTION  ALGORITHM USED

   NODE     10 REPLACES FACILITY LOCATION      1
   THIS IS NOW FACILITY NUMBER      1

   FACILITIES ARE LOCATED AT    10.    3.
   ----------------------------------------------------------------------
   POPULATION SERVED    1100.00          PERCENT OF TOTAL POPULATION SERVED   84.62
   ----------------------------------------------------------------------
```

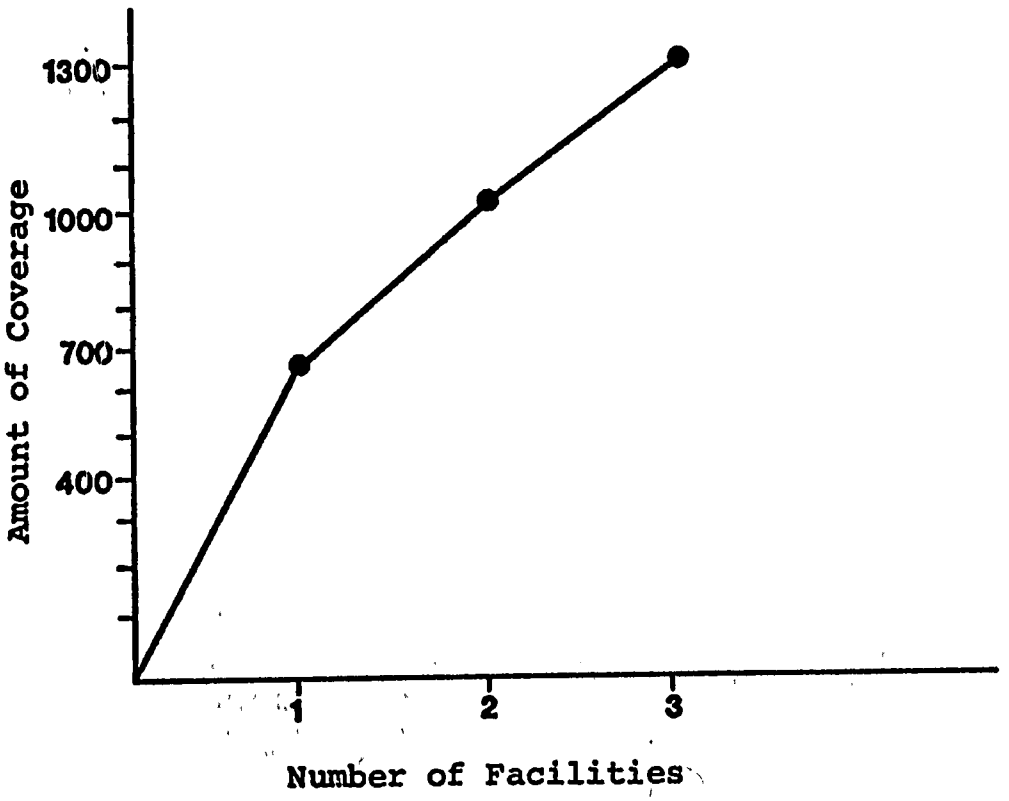
FIGURE 2

(continued, page 8)

```
   ITERATION NUMBER,    3
THIS IS AN EXAMPLE OF THE TWELVE VILLAGE PROBLEM

   NUMBER OF FACILITIES   3
   SERVICE DISTANCE =    10.000

   NEW FACILITY LOCATION NUMBER     6

   FACILITIES ARE LOCATED AT    10,    3,    6.
   ------------------------------------------------------------------------
   POPULATION SERVED    1300.00          PERCENT OF TOTAL POPULATION SERVED  100.00
   ------------------------------------------------------------------------
THIS SOLUTION WAS GENERATED BY THE GAS ALGORITHM
```

FIGURE 3

COVERAGE CURVE FOR TWELVE NODE PROBLEM



CHAPTER THREE

OPTIONS IN THE GAS PROGRAM

The major purpose of this chapter is to define a number of the options available on the GAS computer program. Parts two and three give a number of example computer problems which illustrate a number of options discussed briefly in this chapter. There are five appendices which follow part three with specific input information. It is intended that the user become familiar with the input and output of the GAS program by reading Parts two and three. For specific problems and definitions, the reader is encouraged to consult the proper appendix.

Before a detailed description can be given in reference to solving a specific maximal covering location problem, it is important to know the broad structure of the GAS program. This chapter defines several major terms associated with the GAS program. The reader, by becoming familiar with the terms defined here, will find the material in parts two and three easier to master.

BASIC STRUCTURE OF THE GAS PROGRAM

The GAS computer program is designed to input on cards a data set which describes a specific maximal covering location problem. After the data deck has been read by GAS, the program will perform the desired problem. The program has not been developed so that it will detect format or logical

errors in a data deck. It is up to the user to follow the simple rules in this manual for the successful application of the GAS program. The program is structured so that it is possible to solve many problems with one run of the program.

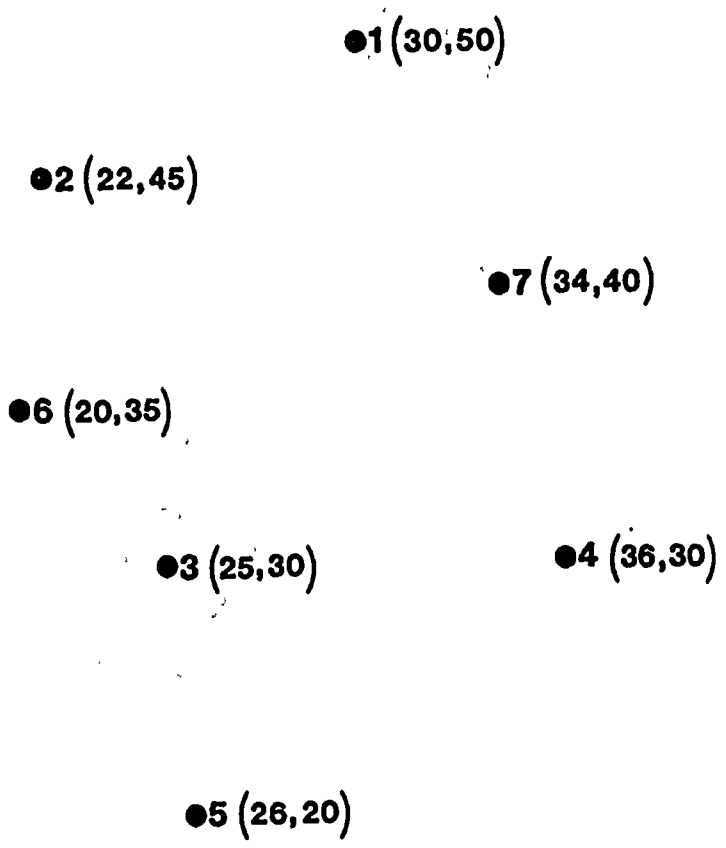
In order to specify some of the options of the GAS program it is important to begin with the two basic types of problems solved by GAS:

> PLANAR PROBLEM: a problem is defined as a planar problem when demand areas and potential facility sites are described by a pair of coordinates on a Cartesian plane. In addition the distance or time of travel between two points on the plane is a function of their coordinates. An example of a planar problem is given in figure 4.
>
> NETWORK PROBLEM: a problem is defined as a network problem when demand areas and potential facility sites are restricted to points on a network of nodes and arcs. An example of a network is given in figure 1. The distance or time of travel between a demand area and a potential facility site is the shortest arc path between the two areas. See chapter one for a description of nodes and arcs.

A network problem can be defined in two basic ways: (a) only nodes are potential facility sites and demand areas, or (b) any point on the network (nodes or along arcs) can represent a facility site or a demand area. In chapter one, a network problem was described where only nodes are potential facility sites. It will be assumed throughout the remainder of this manual that nodes may represent either facility sites or demand areas (e.g., villages) or both. It will be also assumed that a point along an arc will not be considered as a potential facility site or a demand area unless that point is defined as a node and the arc is divided into two segments. The distance

FIGURE 4

AN EXAMPLE OF A PLANAR PROBLEM
WITH (X,Y) - COORDINATES



or time of travel from one node to another node will be associated with the shortest path between the two nodes. An example of determining a shortest path between nodes of a network is given in chapter one.

A planar problem can be defined such that each demand area or village is represented by a prespecified point. Facility sites, on the other hand, can be either prespecified or allowed to be anywhere on the plane. For this manual, it is assumed that all potential facility sites in planar models are prespecified (determined in advance).

The distance or travel time between a point representing a facility site and a point representing a demand area in a planar problem can be defined by a number of mathematical functions. The most common method is the Euclidean distance function which defines the shortest possible distance between two points as:

$$d_{ij} = \sqrt{(x_i - x_j)^2 + (y_i - y_j)^2} \qquad (3\text{-}1)$$

where

d_{ij} = Euclidean distance from point i to point j.

(x_i, y_i) = the coordinates of point i.

(x_j, y_j) = the coordinates of point j.

Figure 5 gives a graphical description of Euclidean distance measure. When plane travel is utilized, the straight line travel distance is an accurate representation of the flight path. Unfortunately in many circumstances, the straight line distance underestimates the true travel distance. This is because road networks restrict the path of travel so that it

FIGURE 5

EUCLIDEAN DISTANCE MEASURE

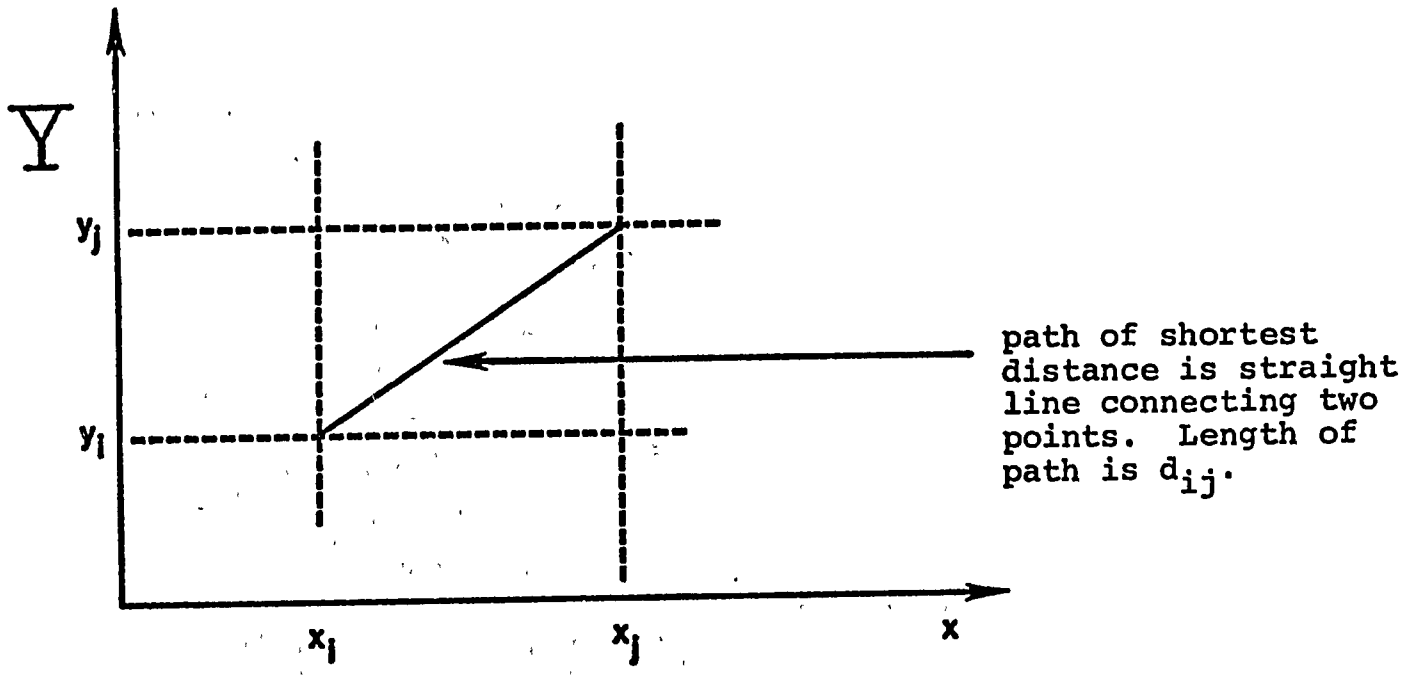
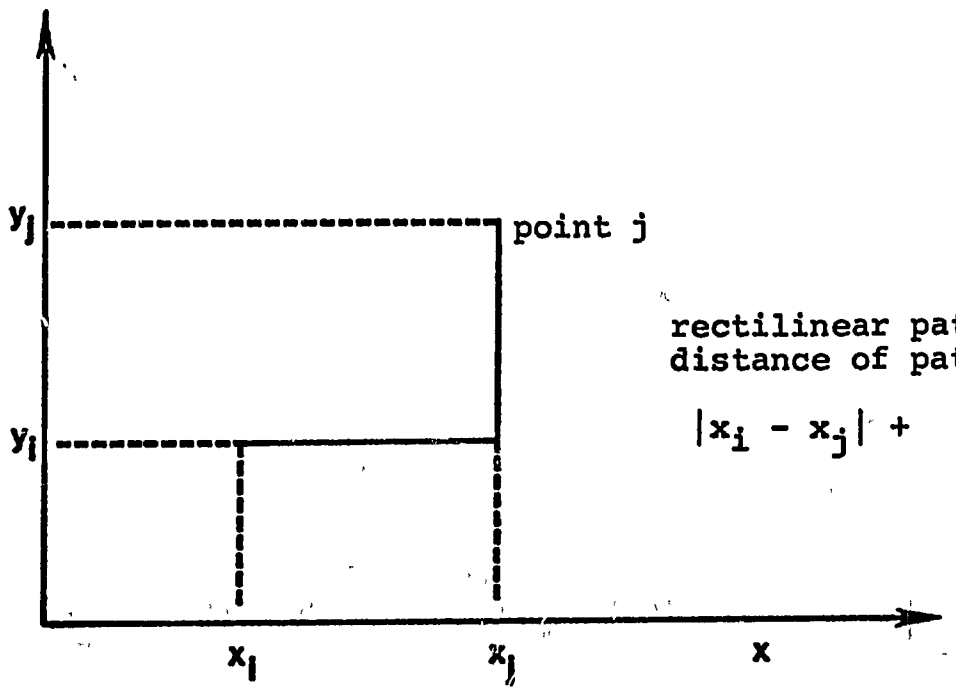


FIGURE 6

RECTILINEAR DISTANCE MEASURE



rectilinear path is a and b.
distance of path is:

$$|x_i - x_j| + |y_i - y_j|$$

exceeds in length a straight path connecting the two points. If actual travel distances are a linear function of the Euclidean distance, then the Euclidean distance measure can be used. For example, if real travel distances were found to be approximately 30% greater than straight line distance, then the actual distance can be estimated by:

$$\bar{d}_{ij} = 1.3\ d_{ij} \tag{3-2}$$

where $\bar{d}_{ij}$ is the actual travel distance.

When travel distance between two points cannot be approximated as a linear function of euclidean measure, then another measure may be more appropriate. An example of a different measure is the rectilinear or grid distance metric. A graphical example of rectilinear measure is given in figure 6. Rectilinear measure is an accurate measure when the road network is developed in a block pattern. The rectilinear distance between two points is defined as:

$$d_{ij} = |x_i - x_j| + |y_i - y_j| \tag{3-3}$$

The GAS computer program will utilize either rectilinear distance measure or Euclidean distance measure according to the input information. This will be described in a later chapter.

The information necessary to define a network problem differs from that of a planar problem. The difference is that the planar problem needs coordinates of facility sites and demand areas and the network problem needs the information associated with the arcs. Because of the large difference between a problem with a network base and one with a planar base, the remaining part of the manual is divided into two categories.

Part two deals with solving network problems and part three deals with solving planar problems. However, there are similarities in the options available for the planar and network problems. Thus, the remaining part of this chapter deals with those general options available on the GAS computer program.

OPTIONS AVAILABLE ON THE GAS COMPUTER PROGRAM

The GAS computer program has a number of options which may be used in solving a maximal covering location problem. Each one of the options allows one to constrain or further restrict the processing of the GAS program. For example, suppose that in the 12 village problem given in chapter one, a health facility was already located in village two. Then the question to be answered might be - where should two additional facilities be placed in order that the largest amount of population be covered by the three facilities? This problem is restrictive in the sense that one facility is already allocated and must be considered in solving the remaining problem. The GAS program will allow for this possibility.

The GAS program is structured in its most general form so that each demand area is considered a potential facility. This may, however, not be true for a given circumstance. For example, in the twelve village problem, village 5 may not be a potential location for a health outpost because a source of safe water is not available. This restriction can be placed on the GAS program by utilizing another available option.

The output from the GAS program can either be streamlined

so that the printout can list facility locations and coverage obtained or it can be expanded to give information about "which areas are covered," "what is the average distance of user groups from their closest facility," and the shortest distance matrix. The type of output and the form is controlled by parameter values given on the input data cards. Examples of output form are given in parts two and three.

When a master data deck is developed for a certain problem, changes can be made in parts of the original data without altering the master deck. For example, suppose that we have keypunched a deck representing the twelve village problem. However, suppose that for some purpose in solving the twelve village problem we do not want to consider the demand of village 9. This can be done by selecting the GAS option which allows for the demand of a list of villages not to be considered. The list is given apart from the master deck. Thus the original data deck remains unchanged, even when a modified problem is solved. Several examples are given in parts two and three for utilizing such an option.

The major structure of the input data is given in appendices A through F. Each appendix gives the definition of an option or input information along with the form in which it must be given. Along with the appendices, parts two and three give a number of examples which utilize the various options and forms. By reviewing the appendices and studying the examples, a reader should be able to develop a working knowledge of the GAS program.

PART TWO

THE GAS PROGRAM APPLIED TO NETWORK PROBLEMS

CHAPTER FOUR

NETWORK PROBLEM ONE

This chapter deals with utilizing the GAS program in solving maximal covering location problems defined on a network. Figure 7 is an example of a network problem involving 12 villages and the location of several health outposts. The basic definition of a network problem was given in chapter three.

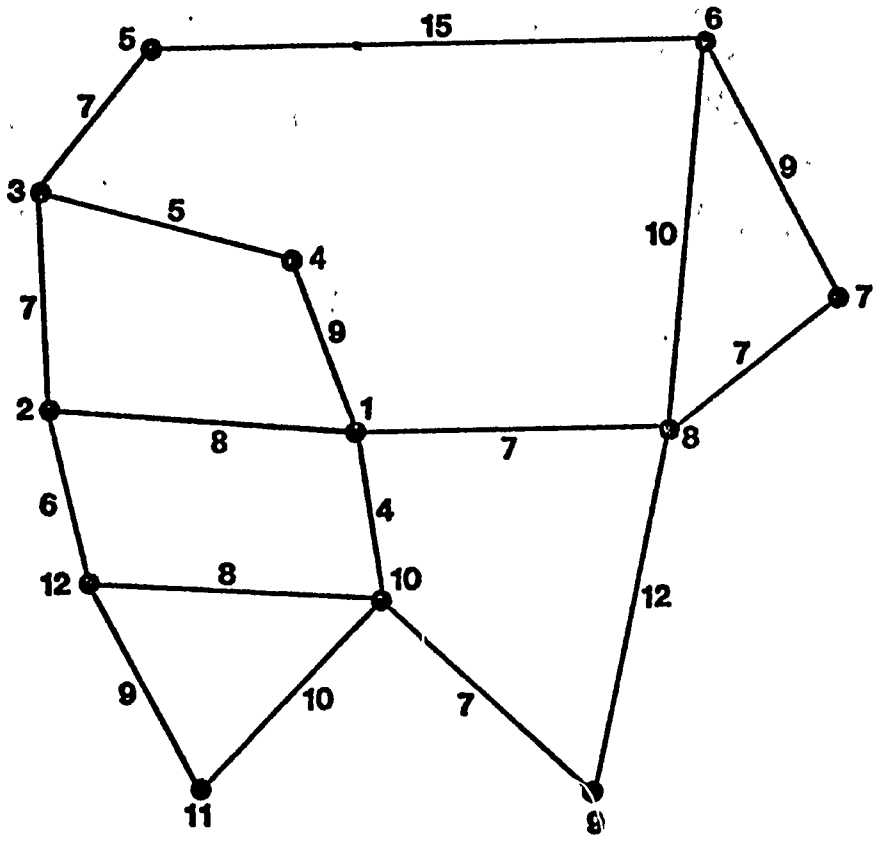
The material given in part two is organized in six separate examples. The first example deals with structuring a data card deck that would be necessary to solve the twelve village problem discussed in part one. The second example is exactly the same, except that it deals with a thirty city problem and utilizes several different output options. The third example deals with the thirty city problem, does not consider the demand of several areas, and allows several previous health centers to exist. The fourth example deals with the thirty city problem where several health facilities already exist and the GAS program is utilized to add to this set of facilities. The fifth example deals with utilizing elevation data in a network problem. The sixth example solves a multiple number of problems with one computer run.

THE TWELVE VILLAGE PROBLEM

Suppose that a planner wishes to site health outposts in

FIGURE 7

A TWELVE VILLAGE NETWORK



a region with twelve villages. Figure 7 gives a road network of a 12 village region. The population of each village is given in table 10 along with the distance of each arc*. Further suppose we would like to locate three facilities in such a way that the largest possible fraction of population would be covered within ten kilometers by the closest facility.

In order to develop a data card deck with the information necessary to solve a maximal covering problem, it is first instructive to see a conceptualized form of the data deck that can be used in solving the above maximal covering problem. This conceptualization is given in figure 8. Notice that the first two data cards are called master control cards. The next set of data cards list the population data of the twelve villages. The data cards that follow list arc information associated with the road network. This is followed by two problem control cards. The card set before the problem control cards specify a specific maximal covering location problem deck. All the data cards are followed by two blank cards which signal the end of the data deck.

Before inspecting how the master control cards structure the twelve village problem for the GAS program, the reader should first look at appendix A and then return to this section. From appendix A, the reader should recognize that seven parameter values are given on the first master control card. The seven parameters that are assigned values on this first card are: IPTS, IDEM, ADD, NETWOR, WEIGHT, DIST, and IFSAP. According to the definition, IPTS must equal the number of nodes

*Definition of arc given in chapter one.

FIGURE 8

CONCEPTUAL FORM OF THE DATA DECK FOR

THE TWELVE VILLAGE RPOBLEM

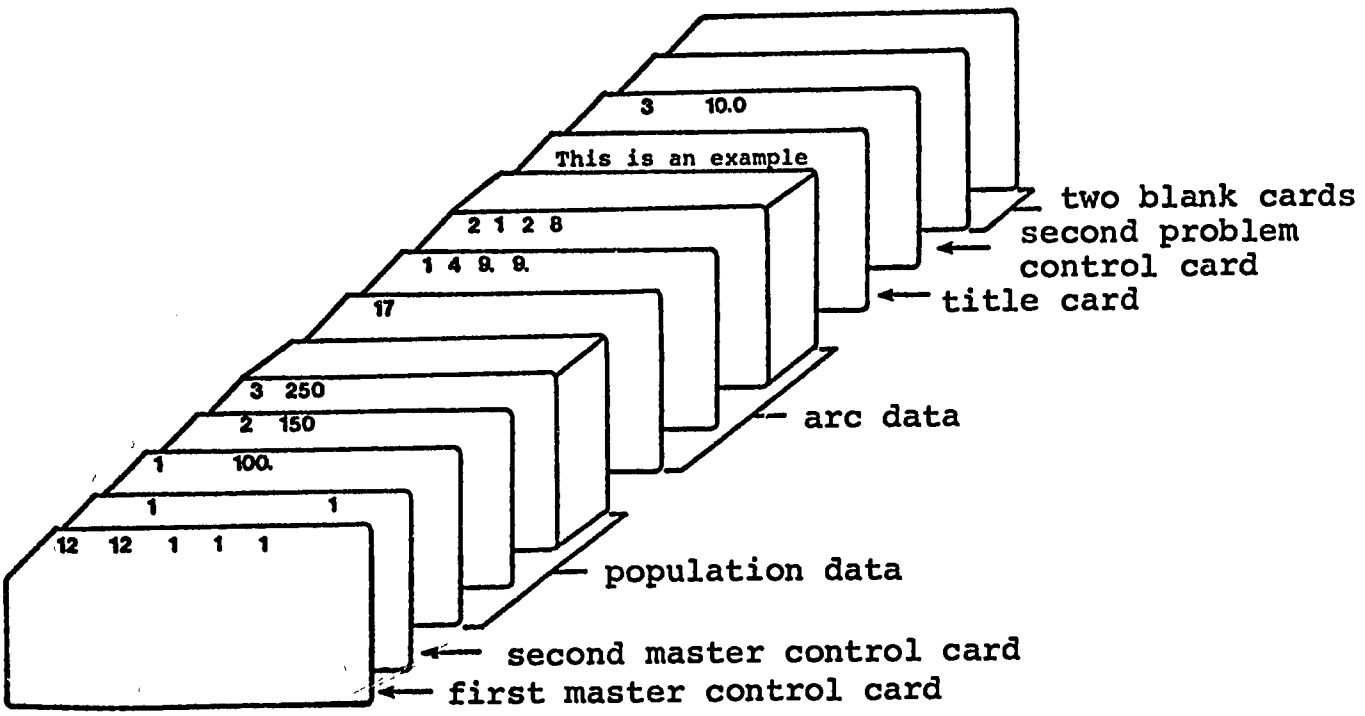


TABLE 10

VILLAGE POPULATIONS

VILLAGE	POPULATION
1	100
2	150
3	250
4	100
5	100
6	50
7	50
8	100
9	50
10	200
11	100
12	50

in the network, or 12. IDEM should equal 12 too. The ADD parameter is utilized only in planar problems and should be set at zero value for network problems. The NETWOR parameter is used to indicate whether the problem is network or planar and should be set at a value of one to indicate that a network problem is being solved. The WEIGHT parameter should be set at a value of one since population values are to be utilized. To have a printout of the distance matrix, the DIST parameter should be set to a value of one. Since we are not interested in generating a statistics output, IFSAP should be defined as a value of zero. Thus, the first master control card should have the parameter values given in table 11.

Each parameter value must appear in a specific field on the data card. Table 11 also gives the card columns for which the parameter values must be given.

Figure 9 gives a listing of the complete data deck associated with solving the twelve village maximal covering problem given in chapter one. Note that the first line of this listing is the first master control card. Since blanks are imputed as zero values, the first line gives the above information with blanks in columns 15 and 35.

The second master control card contains the values of seven parameters (ARCS, RECT, ELE, CONS, IALT1, IALT2, GAS). According to the definition of the ARCS parameter in appendix A, it should be assigned a value of one. The RECT parameter should be set at a zero value, because a network problem is to be solved. Since elevation data is not utilized, the ELE

TABLE 11

FIRST MASTER CONTROL CARD FOR

TWELVE VILLAGE PROBLEM

Parameter Name	Assumption	Assigned Value	Card Column(s) Containing Value
IPTS	Number of Nodes in Network	12	4 and 5
IDEM	Must equal IPTS for network problems	12	9 and 10
ADD	Must equal zero for network problems	0, blank	15
NETWOR	Value of one signifies network problem	1	20
WEIGHT	Value of one signifies population values will be given	1	25
DIST	Value of one signifies distance matrix will be listed	1	30
IFSAP	Value of zero signifies that statistics output will not be printed	0, blank	35

FIGURE 9

LISTING OF TWELVE VILLAGE DATA DECK

```
 12   12          1    1    1          1
  1
  1       100.
  2       150.
  3       250.
  4       100.
  5       100.
  6       50.
  7       50.
  8       100.
  9       50.
 10       200.
 11       100.
 12       50.
  17
   1     1     4    9.00
   2     1     2    8.00
   3     1    10    4.00
   4     1     8    7.00
   5    10     9    7.00
   6     8     9   12.00
   7     8     7    7.00
   8     8     6   10.00
   9     6     7    9.00
  10     6     5   15.00
  11     5     3    7.00
  12     3     4    5.00
  13     3     2    7.00
  14     2    12    6.00
  15    12    10    8.00
  16    12    11    9.00
  17    11    10   10.00
THIS IS AN EXAMPLE OF THE TWELVE VILLAGE PROBLEM
   3      10.00
```

parameter must be assigned a zero value. Since we have not selected any special constraint features, the CONS parameter should be set at a zero value.

Because no political data is being utilized, the IPOL parameter should be set at a zero value. Because the ELE parameter is set at a zero value, the values of IALT1 and IALT2 are ignored and can be left blank on the data card. The last parameter is the GAS parameter and should be set at the one value in order to indicate that the GAS algorithm should be used. Figure A.2 of appendix A gives the card columns for each parameter field in the second master control card. The parameters of the second card must be punched according to information given in table 12. The second line on figure 9 gives the listing of the second master control card.

As illustrated in figure 8, the population cards must be given after the two master control cards. Before looking closely at the population cards of figure 9 and reading the following explanation for the twelve village problem, the readers should first review section 3 of appendix D. Appendix D indicates that there should be one population card for each node in the problem. Thus, there should be twelve population cards. The cards must be given in the order of increasing node index. This means that the first population card gives the population of node one; the second population card must give the population of node two, and the last population card must give the population of node 12. Note that

TABLE 12

SECOND MASTER CONTROL CARD

FOR TWELVE VILLAGE PROBLEM

Parameter Name	Assumption	Assigned Value	Card Column(s) Containing Value
ARCS	Arc data will be given when value is set at one	1	5
RECT	For a network problem, value must be set at zero	0,blank	10
ELE	Since no elevation data is given, value must be set at zero	0,blank	15
CONS	Value of zero signifies no special constraint features are selected	0,blank	20
IPOL	Value of zero signifies that political data will not be given	0,blank	25
IALT1	Since elevation data is not given, value is ignored	0,blank	30
IALT2	Since elevation data is not given, value is ignored	0,blank	35
GAS	When value is set at one, GAS program will be executed	1	40

TABLE 13

POPULATION DATA CARDS FOR

TWELVE VILLAGE PROBLEM

Node Index	Card Column(s) Containing Index	Population	Card Column(s) Containing Population
1	4	100.	11-20
2	4	150.	11-20
3	4	250.	11-20
4	4	100.	11-20
5	4	100.	11-20
6	4	50.	11-20
7	4	50.	11-20
8	4	100.	11-20
9	4	50.	11-20
10	3-4	200.	11-20
11	3-4	100.	11-20
12	3-4	50.	11-20

the index of the node is given in columns 1 through 4 and the population of the node is given in columns 11 through 20. The index must appear right justified with no decimal point and the population or weight must appear with a decimal point and need not be right justified. Thus, the twelve population cards should be of the form given in table 13. Figure 9 gives a listing of the twelve population cards immediately after the two master control cards.

The ARC data follows the population data. In order to fully understand the following description of the ARC data cards, the reader should first review appendix E which deals with ARC data. In order to set up the arc data set, one should first determine the number of arcs in the problem network. For the twelve village problem, there are seventeen (17) arcs. The first arc data card must contain the number 17 in columns 4 and 5 as illustrated in table 14 and figure 9. The following seventeen cards contain the information about the seventeen arcs. The first card of the set of seventeen gives the distance of 9, for the arc connecting nodes 1 and 4. The second card of this set gives the distance of 8, for the arc connecting nodes 1 and 2. Note that there is one card for each arc given in figure 7. In this case each arc is indexed by numbers that appear in columns 1 through 5. However, such indices do not need to be given. Two problem control cards follow the seventeen arc cards, as illustrated in figure 8. Since the two problem control cards are discussed in appendix

TABLE 14

ARC DATA CARDS FOR TWELVE VILLAGE PROBLEM

Card Number(s)	Parameter Value	Value(s)	Card Column(s) Containing Value
1.	Number of Arcs	17	4-5
2-18	Arc Index	e.g. 1	1-5 RJ
	Node I	1	6-10 RJ
	Node J	4	11-15 RJ
	Distance of Arc	8	16-21 D

RJ - number must be punched right justified.

D - decimal point must be punched with number.

B, the reader should review it before continuing. In appendix B, the first problem control card is a title card. Any desired name or title may appear on this card. The title that was chosen is: "This is an Example of the Twelve Village Problem." The title that appears on the title card will be printed on the output pages.

The second problem control card gives the values of eight parameters: IP, S, SCS, EMAXL, EMAXS, CONS, ICOV, ILIST. The IP parameter represents the maximum number of facilities the GAS program is allowed to locate. For this example, we will set IP to the value of 5. The maximal service distance is 10 kilometers for the twelve village covering problem. This means that the S value should be set to the value of 10. Since the IFSAP parameter is at a zero value in the master control card, the value of the SCS parameter will be left blank. Note that the EMAXL and EMAXS parameters are utilized only when the IALT2 parameter is set at a value of one, in this example we will leave EMAXS and EMAXL blank on the data card. Since no special constraints are considered the CONS parameter will be assigned a zero value. For this example, we will not generate a zero-one covering matrix or a coverage listing by assigning ICOV and ILIST to zero values. Thus, the second problem control card should appear as in table 15. The second problem control card is followed by two blank cards. This completes the data deck necessary to solve the twelve village problem. The complete deck is given in figure 9. The deck contains 32 punched cards and two blank cards. Output from this problem deck is given in figure

TABLE 15

SECOND PROBLEM CONTROL CARD

FOR TWELVE VILLAGE PROBLEM

Parameter Name	Assumption	Assigned Value	Card Column(s) Containing Value
IP	Must equal largest number of allowable facilities	5	5
S	Maximal service distance	10	6-15
SCS	Secondary service distance is not given	blank	16-25
EMAXL	Parameter not used because elevation data is not given	blank	26-35
EMAXS	Parameter not used because elevation data is not given	blank	36-45
CONS	Value of zero means special contraint features are not utilized	0, blank	55
ICOV	Value of zero means zero-one cover matrix is not given	0, blank	60
ILIST	Value of zero means coverage listing is not given	0, blank	65

CHAPTER FIVE

NETWORK PROBLEM TWO

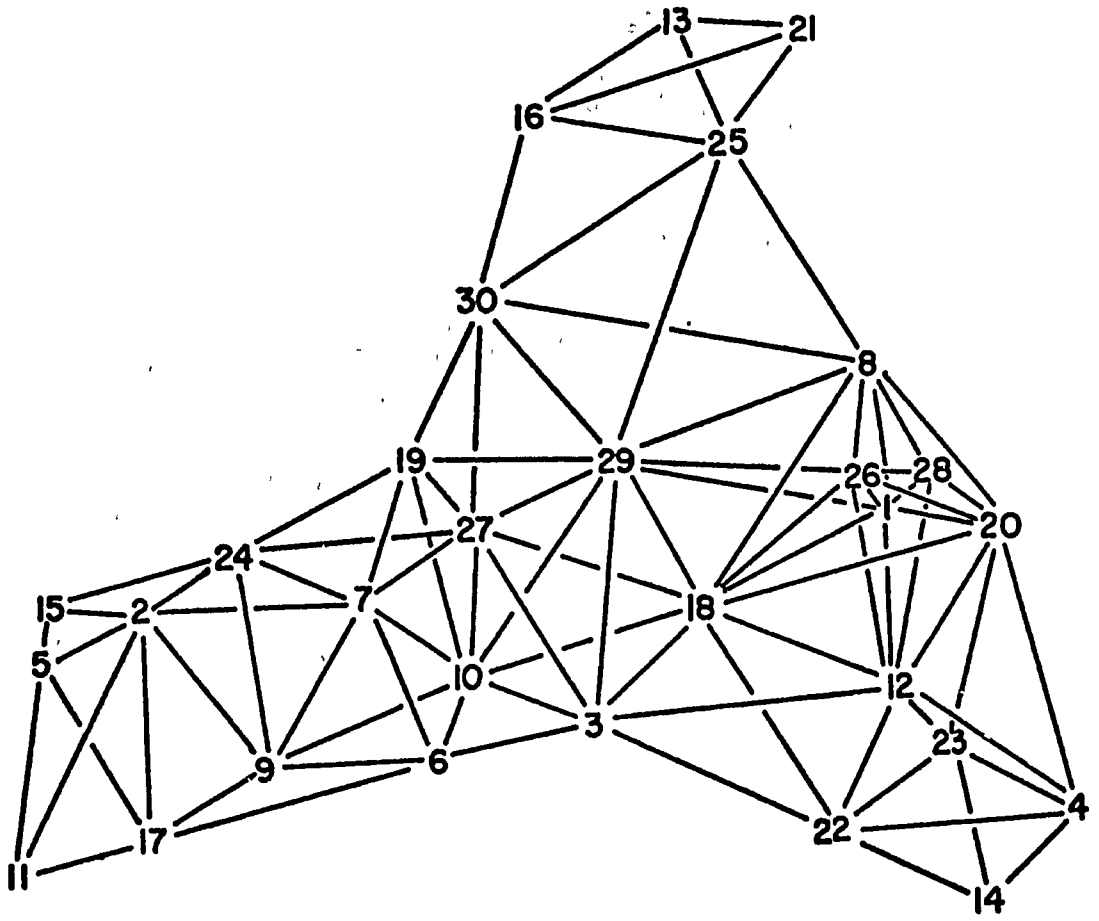
Suppose that there exists a region of thirty cities which we would like to serve with health clinics. Figure 10 gives a road network of the thirty city problem along with population weights of each of the nodes. ARC information for the thirty city problem is given in table 16. Suppose no more than ten facilities are to be sited and that the maximal service time is assumed to be 75 minutes. Since this is a network problem we can structure the data deck in a similar way to that outlined in chapter four for the twelve village problem.

Since this is a thirty node network problem with population values, the first master control card parameters should be set to the values given in table 17. To generate a distance matrix, we can set IDIST equal to one. We can also have statistics output by setting IFSAP to a value of one. The second master control card should appear according to the information in table 18. Population data follows the two master control cards. The form of the population data is identical to that given for the twelve village problem in table 13 except that there are now thirty nodes and thirty population cards required.

Figure 11 gives the complete listing of the data input. The first two cards are the master control cards. The following thirty cards are the population cards. After the population

FIGURE 10

A 30 NODE 90 ARC NETWORK OF TOREGAS(8)*



*The respective node weights are: 10, 20, 25, 18, 12, 23, 43, 30, 24, 15, 10, 20, 35, 15, 20, 20, 10, 25, 35, 15, 10, 15, 10, 20, 10, 20, 10, 10, 35, and 15. These weights are the same as those of Khumawala (9).

TABLE 16

ARC INFORMATION FOR THIRTY NODE NETWORK PROBLEM

INPUT ARC INFORMATION IS AS FOLLOWS

ARC NO.	FROM NODE	TO NODE	DISTANCE
1	1	26	16.000
2	1	28	7.000
3	26	28	15.000
4	1	20	38.000
5	20	28	37.000
6	8	28	48.000
7	8	20	81.000
8	4	20	100.000
9	12	20	65.000
10	4	12	90.000
11	4	23	70.000
12	4	14	61.000
13	14	23	75.000
14	14	22	69.000
15	22	23	60.000
16	12	23	20.000
17	12	22	58.000
18	1	12	54.000
19	12	18	86.000
20	18	22	124.000
21	3	22	105.000
22	8	26	41.000
23	18	26	67.000
24	1	18	78.000
25	3	18	62.000
26	3	6	56.000
27	3	10	46.000
28	10	18	93.000
29	18	29	64.000
30	26	29	77.000
31	10	29	94.000
32	27	29	52.000
33	19	29	79.000
34	19	27	36.000
35	10	27	57.000
36	7	27	49.000
37	24	27	85.000
38	7	10	47.000
39	9	10	87.000
40	6	10	34.000
41	6	17	104.000
42	6	9	61.000
43	7	9	67.000
44	7	24	46.000
45	9	24	60.000

TABLE 16

(continued, page 2)

46	2	24	33.000
47	2	9	60.000
48	9	17	56.000
49	2	17	77.000
50	11	17	55.000
51	2	11	101.000
52	5	11	69.000
53	2	5	37.000
54	5	15	19.000
55	2	15	51.000
56	15	24	84.000
57	19	24	73.000
58	19	30	60.000
59	29	30	83.000
60	16	30	58.000
61	25	30	120.000
62	13	16	66.000
63	16	25	92.000
64	13	21	60.000
65	13	25	46.000
66	21	25	52.000
67	8	25	106.000
68	25	29	147.000
69	5	17	74.000
70	5	9	92.000
71	2	7	66.000
72	7	6	60.000
73	19	10	79.000
74	3	27	78.000
75	3	12	137.000
76	3	29	92.000
77	18	27	94.000
78	27	30	70.000
79	16	21	126.000
80	8	18	108.000
81	7	19	59.000
82	4	22	106.000
83	20	23	76.000
84	18	20	118.000
85	12	26	69.000
86	1	8	51.000
87	12	28	61.000
88	20	26	52.000
89	1	29	93.000
90	8	29	107.000

TABLE 17

FIRST MASTER CONTROL CARD FOR

THIRTY NODE NETWORK PROBLEM

Parameter Name	Assumption	Assigned Value	Card Column(s) Containing Value
IPTS	Number of nodes in network	30	4 and 5
IDEM	Must equal IPTS for network problems	30	9 and 10
ADD	Must equal zero for network problems	0, blank	15
NETWOR	Value of one signifies network problem	1	20
WEIGHT	Value of one signifies population value will be given	1	25
DIST	Value of zero signifies distance matrix will not be listed	0, blank	30
IFSAP	Value of zero signifies that statistics output will not be printed	0, blank	35

TABLE 18

SECOND MASTER CONTROL CARD

FOR THIRTY NODE NETWORK PROBLEM

Parameter Name	Assumption	Assigned Value	Card Column(s) Containing Value
ARCS	Arc data will be given when value is set at one	1	5
RECT	For a network problem, value must be set at zero	0, blank	10
ELE	Since no elevation data is given, value must be set at zero	0, blank	15
CONS	Value of zero signifies no special constraint features are selected	0, blank	20
IPOI	Value of zero signifies that political data will not be given	0, blank	25
IALT	Since elevation data is not given, value is ignored	0, blank	30
IALT	Since elevation data is not given, value is ignored	0, blank	35
GAS	When value is set at one, GAS program will be executed	1	40

FIGURE 11

LISTING OF THIRTY NODE NETWORK DATA DECK

```
30   30          1    1    1    1
 1                                    1
 1      10.00
 2      20.00
 3      25.00
 4      18.00
 5      12.00
 6      23.00
 7      43.00
 8      30.00
 9      24.00
10      15.00
11      10.00
12      20.00
13      35.00
14      15.00
15      20.00
16      20.00
17      10.00
18      25.00
19      35.00
20      15.00
21      10.00
22      15.00
23      10.00
24      20.00
25      10.00
26      20.00
27      10.00
28      10.00
29      35.00
30      15.00
 90
  1    1    26    16.
  2    1    28     7.
  3   26    28    15.
  4    1    20    38.
  5   20    28    37.
  6    8    28    48.
  7    8    20    81.
  8    4    20   100.
  9   12    20    65.
 10    4    12    90.
 11    4    23    70.
 12    4    14    61.
 13   14    23    75.
 14   14    22    69.
 15   22    23    60.
 16   12    23    20.
 17   12    22    58.
 18    1    12    54.
 19   12    18    86.
 20   18    22   124.
 21    3    22   105.
 22    8    26    41.
 23   18    26    67.
 24    1    18    78.
 25    3    18    62.
 26    3     6    56.
 27    3    10    46.
 28   10    18    93.
 29   18    29    64.
```

FIGURE 11

(continued, page 2)

30	26	29	77.
31	10	29	94.
32	27	29	52.
33	19	29	79.
34	19	27	36.
35	10	27	57.
36	7	27	49.
37	24	27	85.
38	7	10	47.
39	9	10	87.
40	6	10	34.
41	6	17	104.
42	6	9	61.
43	7	9	67.
44	7	24	46.
45	9	24	60.
46	2	24	33.
47	2	9	60.
48	9	17	56.
49	2	17	77.
50	11	17	55.
51	2	11	101.
52	5	11	69.
53	2	5	37.
54	5	15	19.
55	2	15	51.
56	15	24	84.
57	19	24	73.
58	19	30	60.
59	29	30	83.
60	16	30	58.
61	25	30	120.
62	13	16	66.
63	16	25	92.
64	13	21	60.
65	13	25	46.
66	21	25	52.
67	8	25	106.
68	25	29	147.
69	5	17	74.
70	5	9	92.
71	2	7	66.
72	7	6	60.
73	19	10	79.
74	3	27	78.
75	3	12	137.
76	3	29	92.
77	18	27	94.
78	27	30	70.
79	16	21	126.
80	8	18	108.
81	7	19	59.
82	4	22	106.
83	20	23	76.
84	18	20	118.
85	12	26	69.
86	1	8	51.
87	12	28	61.
88	20	26	52.
89	1	29	93.
90	8	29	107.

THIS IS EXAMPLE NUMBER TWO-NETWORK

10 75.00 100.00

cards, the arc cards must be given. There are ninety-one cards in this group. The first card gives the value of IARCS equal to 90 indicating that there are 90 arcs. The following 90 cards give the arc information in the same format used in the twelve village problem. The arc cards are followed by the two problem control cards.

The first problem control card gives the title of the problem and the second card gives the values of the parameters discussed in appendix B. Since we are going to locate up to ten facilities IP is set at 10. The maximal service time S should be given as 75. Since the IFSAP parameter has been set at a value of one, a value should be given to the SCS parameter. For the output suppose we are interested in SCS = 100. The values of EMAXL and EMAXS can be left blank because elevation data is not being used. Since no special constraints are being used the parameter CONS should be set to a zero value. In order to give an example of the zero-one cover matrix output, we will set ICOV equal to one. In addition, we will set ILIST equal to one, so that cover listings will be generated. Thus, all the parameters to the second problem control card are set at appropriate values. The two problem control cards are followed by two blank cards. Table 19 gives a summary of the second control card information for this problem.

The output associated with this data deck is given in figure 12. The figure contains twenty five pages giving the complete output from the GAS computer program. The first page

TABLE 19

SECOND PROBLEM CONTROL CARD

FOR THIRTY NODE NETWORK PROBLEM

Parameter Name	Assumption	Assigned Value	Card Column(s) Containing Value
IP	Must equal largest number of allowable facilities	10	4-5
S	Maximal service distance	75.	6-15
SCS	Secondary service distance must be given since IPSAP=1	100.	16-25
EMAXL	Parameter not used because elevation data is not given	blank	26-35
EMAXS	Parameter not used because elevation data is not given	blank	36-45
CONS	Value of zero means special constraint features are not utilized	0	55
ICOV	value of one means zero-one cover matrix is given	1	60
ILIST	Value of one means coverage listing is given	1	65

lists the population values. The second and third pages display arc information. Pages four, five, and six give the shortest distance matrix. Page 7 states the value of the maximum service time as 75. Page 9 is an illustration of a zero-one cover matrix along with a beginning of a list indicating which areas a given facility can serve. Page 10 gives the output from the first iteration of the GAS algorithm. Notice that a listing of which demand areas are covered is given. This listing is given because the ILIST parameter was set equal to one. On the next page the GAS program gives the statistics associated with the solution given on page 10. The statistics are generated by assigning each demand area to their closest facility and then determining the following features (associated with the partition of demand assigning to a particular facility):

1) Population served by each facility.
2) Population covered by each facility (i.e. served within S distance or time from the facility).
3) Population served outside of S distance but inside the SCS distance from the facility.
4) Population served outside of the SCS distance.
5) The largest traveled distance in each partition.
6) The node that is the farthest from the facility in the partition around that facility.
7) The total weighted distance of travel in the partition.
8) The weighted distance of the covered population.
9) The weighted distance of those outside of S distance but inside the SCS distance.

10) The weighted distance of those not covered within the S distance.

11) The partition to which each demand area is assigned.

The population served by a facility is labeled on the output as the *POPULATION IN PARTITION*. For example, there are 580 in the partition associated with the facility located at node seven*. The population that is covered is labeled as the *PRIMARY SERVED POP*. In this case, 190 are served within the time of 75 minutes. The population served between 75.(S) and 100.(SCS) is labeled as the *SECONDARY SERVED POP*. The population that is served by the facility at node seven between the times of 75. and 100. minutes is 25. The population that assigns to a facility, but is outside the time or distance of SCS is labeled as the *POPULATION OUTSIDE SECONDARY*. For the first iteration output, 365 are in this category when the facility is located at node seven. For the partition of the facility at node seven, the largest traveled time to node 7 is made by node 4 at a time of 304 minutes. This time is given under the heading of *LARGEST TRAVELED DISTANCE*. The node is given under the heading of *NODE NUMBER*. The weighted distance of the covered population is called: *WT. DIST. PRIMARY COVERED*. For this iteration, the weighted distance of the primary covered population is 8488. Since the primary served population is 190, the average distance from the facility of those served within the distance of S is 8488/190 which equals 44.6 minutes. The weighted distance of those served within 100 but outside S is

---

*Iteration 1 output, page 12 of figure 12.

called *WEIGHTED DISTANCE SECONDARY COVERED* . For this example, the weighted distance of the population of 25 is 2325. The average time of travel to the facility for this group is 2325/25 which equals 93. minutes. The weighted distance of those outside the primary time of 75 minutes is also given. Thus, the average travel distance or time to the facility of those not covered is 71513/(25+365) which equals 183. minutes. The total weighted distance is given as the last column of the tabulations. For the first iteration it is 80001. Therefore, the average distance of the whole population to their closest facility is 80001/580 which equals 137.

The remainder of figure 12 gives the final iterations of the GAS algorithm. It should be noted that the algorithm terminated at seven facilities even though we had allowed for the placement of ten facilities. The program terminated with the placement of the seventh facility when population coverage increased to 100 per cent. It is also important to note that the substitution algorithm was useful in the fourth iteration of the program.

POPULATION DATA

1	10.*	4	18.*	7	43.*	10	15.*	13	35.*	16	20.*	19	35.*	22	15.*	25	10.*	28	10.*
2	20.*	5	12.*	8	30.*	11	10.*	14	15.*	17	10.*	20	15.*	23	10.*	26	20.*	29	35.*
3	25.*	6	23.*	9	24.*	12	20.*	15	20.*	18	25.*	21	10.*	24	20.*	27	10.*	30	15.*

FIGURE 12

THIRTY NODE NETWORK PROBLEM OUTPUT

FIGURE 12

(continued, page 2)

INPUT ARC INFORMATION IS AS FOLLOWS

ARC NO.	FROM NODE	TO NODE	DISTANCE
1	1	26	16.000
2	1	28	7.000
3	26	28	15.000
4	1	20	38.000
5	20	28	37.000
6	8	28	48.000
7	8	20	81.000
8	4	20	100.000
9	12	20	65.000
10	4	12	90.000
11	4	23	70.000
12	4	14	61.000
13	14	23	75.000
14	14	22	69.000
15	22	23	60.000
16	12	23	20.000
17	12	22	58.000
18	1	12	54.000
19	12	18	86.000
20	18	22	124.000
21	3	22	105.000
22	8	26	41.000
23	18	26	67.000
24	1	18	78.000
25	3	18	62.000
26	3	6	56.000
27	3	10	46.000
28	10	18	93.000
29	18	29	64.000
30	26	29	77.000
31	10	29	94.000
32	27	29	52.000
33	19	29	79.000
34	19	27	36.000
35	10	27	57.000
36	7	27	49.000
37	24	27	85.000
38	7	10	47.000
39	9	10	87.000
40	6	10	34.000
41	6	17	104.000
42	6	9	61.000
43	7	9	67.000
44	7	24	46.000
45	9	24	60.000
46	2	24	33.000
47	2	9	60.000
48	9	17	56.000
49	2	17	77.000
50	11	17	55.000
51	2	11	101.000
52	5	11	69.000
53	2	5	37.000
54	5	15	19.000
55	2	15	51.000
56	15	24	84.000
57	19	24	73.000
58	19	30	60.000
59	29	30	83.000

FIGURE 12

(continued, page 3)

60	16	30	58.000
61	25	30	120.000
62	13	16	66.000
63	16	25	92.000
64	13	21	60.000
65	13	25	46.000
66	21	25	52.000
67	8	25	106.000
68	25	29	147.000
69	5	17	74.000
70	5	9	92.000
71	2	7	66.000
72	7	6	60.000
73	19	10	79.000
74	3	27	78.000
75	3	12	137.000
76	3	29	92.000
77	18	27	94.000
78	27	30	70.000
79	16	21	126.000
80	8	18	108.000
81	7	19	59.000
82	4	22	106.000
83	20	23	76.000
84	18	20	118.000
85	12	26	69.000
86	1	8	51.000
87	12	28	61.000
88	20	26	52.000
89	1	29	93.000
90	8	29	107.000

DISTANCE MATRIX

	1	2	3	4	5	6	7	8	9	10
1	0.0	260.00	140.00	138.00	297.00	196.00	194.00	51.00	257.00	171.00
2	260.00	0.0	159.00	370.00	37.00	121.00	66.00	274.00	60.00	113.00
3	140.00	159.00	0.0	211.00	196.00	56.00	93.00	170.00	117.00	46.00
4	138.00	370.00	211.00	0.0	407.00	267.00	304.00	181.00	328.00	257.00
5	297.00	37.00	196.00	407.00	0.0	153.00	103.00	311.00	92.00	150.00
6	196.00	121.00	56.00	267.00	153.00	0.0	60.00	226.00	61.00	34.00
7	194.00	66.00	93.00	304.00	103.00	60.00	0.0	208.00	67.00	47.00
8	51.00	274.00	170.00	181.00	311.00	226.00	208.00	0.0	275.00	201.00
9	257.00	60.00	117.00	328.00	92.00	61.00	67.00	275.00	0.0	87.00
10	171.00	113.00	46.00	257.00	150.00	34.00	47.00	201.00	87.00	0.0
11	355.00	101.00	215.00	426.00	69.00	159.00	167.00	375.00	111.00	193.00
12	54.00	292.00	137.00	90.00	329.00	193.00	226.00	105.00	254.00	179.00
13	203.00	290.00	272.00	333.00	327.00	285.00	243.00	152.00	310.00	251.00
14	149.00	333.00	174.00	61.00	370.00	230.00	267.00	200.00	291.00	220.00
15	311.00	51.00	210.00	421.00	19.00	172.00	117.00	325.00	111.00	164.00
16	234.00	224.00	206.00	370.00	261.00	219.00	177.00	198.00	244.00	185.00
17	300.00	77.00	160.00	371.00	74.00	104.00	123.00	330.00	56.00	138.00
18	78.00	206.00	62.00	176.00	243.00	118.00	140.00	108.00	179.00	93.00
19	172.00	106.00	114.00	306.00	143.00	113.00	59.00	186.00	126.00	79.00
20	38.00	296.00	178.00	109.00	333.00	234.00	230.00	81.00	295.00	209.00
21	209.00	338.00	291.00	339.00	375.00	327.00	291.00	158.00	358.00	293.00
22	112.00	264.00	105.00	106.00	301.00	161.00	198.00	163.00	222.00	151.00
23	74.00	312.00	157.00	70.00	349.00	213.00	246.00	125.00	274.00	199.00
24	230.00	33.00	139.00	350.00	70.00	106.00	46.00	244.00	60.00	93.00
25	157.00	286.00	239.00	287.00	323.00	275.00	239.00	106.00	306.00	241.00
26	16.00	244.00	129.00	152.00	281.00	185.00	178.00	41.00	245.00	160.00
27	145.00	115.00	78.00	270.00	152.00	91.00	49.00	159.00	116.00	57.00
28	7.00	259.00	144.00	137.00	296.00	200.00	193.00	48.00	260.00	175.00
29	93.00	167.00	92.00	229.00	204.00	128.00	101.00	107.00	168.00	94.00
30	176.00	166.00	148.00	312.00	203.00	161.00	119.00	190.00	186.00	127.00

FIGURE 12

(continued, page 4)

DISTANCE MATRIX

	11	12	13	14	15	16	17	18	19	20
1	355.00	54.00	203.00	149.00	311.00	234.00	300.00	78.00	172.00	38.00
2	101.00	292.00	290.00	333.00	51.00	224.00	77.00	206.00	106.00	296.00
3	215.00	137.00	272.00	174.00	210.00	206.00	160.00	62.00	114.00	178.00
4	426.00	90.00	333.00	61.00	421.00	370.00	371.00	176.00	306.00	100.00
5	69.00	329.00	327.00	370.00	19.00	261.00	74.00	243.00	143.00	333.00
6	159.00	193.00	285.00	230.00	172.00	219.00	104.00	118.00	113.00	234.00
7	167.00	226.00	243.00	267.00	117.00	177.00	123.00	140.00	59.00	230.00
8	375.00	105.00	152.00	200.00	325.00	198.00	330.00	108.00	186.00	81.00
9	111.00	254.00	310.00	291.00	111.00	244.00	56.00	179.00	126.00	295.00
10	193.00	179.00	251.00	220.00	164.00	185.00	138.00	93.00	79.00	209.00
11	0.0	352.00	391.00	389.00	88.00	325.00	55.00	277.00	207.00	393.00
12	352.00	0.0	257.00	95.00	343.00	287.00	297.00	86.00	216.00	65.00
13	391.00	257.00	0.0	352.00	341.00	66.00	366.00	257.00	184.00	233.00
14	389.00	95.00	352.00	0.0	384.00	380.00	334.00	181.00	288.00	151.00
15	88.00	343.00	341.00	384.00	0.0	275.00	93.00	257.00	157.00	347.00
16	325.00	287.00	66.00	380.00	275.00	0.0	300.00	205.00	118.00	270.00
17	55.00	297.00	366.00	334.00	93.00	300.00	0.0	222.00	182.00	338.00
18	277.00	86.00	257.00	181.00	257.00	205.00	222.00	0.0	130.00	116.00
19	207.00	216.00	184.00	288.00	157.00	118.00	182.00	130.00	0.0	208.00
20	393.00	65.00	233.00	151.00	347.00	270.00	338.00	116.00	208.00	0.0
21	439.00	263.00	60.00	358.00	389.00	126.00	414.00	263.00	232.00	239.00
22	320.00	58.00	315.00	69.00	315.00	311.00	265.00	124.00	219.00	123.00
23	372.00	20.00	277.00	75.00	363.00	307.00	317.00	106.00	236.00	76.00
24	134.00	265.00	257.00	313.00	84.00	191.00	110.00	179.00	73.00	266.00
25	387.00	211.00	46.00	306.00	337.00	92.00	362.00	211.00	180.00	187.00
26	344.00	69.00	193.00	164.00	295.00	218.00	289.00	67.00	156.00	52.00
27	216.00	180.00	194.00	252.00	166.00	128.00	172.00	94.00	36.00	181.00
28	359.00	61.00	200.00	156.00	310.00	233.00	304.00	82.00	171.00	37.00
29	268.00	146.00	193.00	241.00	218.00	141.00	224.00	64.00	79.00	129.00
30	267.00	229.00	124.00	322.00	217.00	58.00	242.00	147.00	60.00	212.00

FIGURE 12

(continued, page 5)

DISTANCE MATRIX

	21	22	23	24	25	26	27	28	29	30
1	209.00	112.00	74.00	230.00	157.00	16.00	145.00	7.00	93.00	176.00
2	338.00	264.00	312.00	33.00	286.00	244.00	115.00	259.00	167.00	166.00
3	291.00	105.00	157.00	139.00	239.00	129.00	78.00	144.00	92.00	148.00
4	339.00	106.00	70.00	350.00	287.00	152.00	270.00	137.00	229.00	312.00
5	375.00	301.00	349.00	70.00	323.00	281.00	152.00	296.00	204.00	203.00
6	327.00	161.00	213.00	106.00	275.00	185.00	91.00	200.00	128.00	161.00
7	291.00	198.00	246.00	46.00	239.00	178.00	49.00	193.00	101.00	119.00
8	158.00	163.00	125.00	244.00	106.00	41.00	159.00	48.00	107.00	190.00
9	358.00	222.00	274.00	60.00	306.00	245.00	116.00	260.00	168.00	186.00
10	293.00	151.00	199.00	93.00	241.00	160.00	57.00	175.00	94.00	127.00
11	439.00	320.00	372.00	134.00	387.00	344.00	216.00	359.00	268.00	267.00
12	263.00	58.00	20.00	265.00	211.00	69.00	180.00	61.00	146.00	229.00
13	60.00	315.00	277.00	257.00	46.00	193.00	194.00	200.00	193.00	124.00
14	358.00	69.00	75.00	313.00	306.00	164.00	252.00	156.00	241.00	322.00
15	389.00	315.00	363.00	84.00	337.00	295.00	166.00	310.00	218.00	217.00
16	126.00	311.00	307.00	191.00	92.00	218.00	128.00	233.00	141.00	58.00
17	414.00	265.00	317.00	110.00	362.00	289.00	172.00	304.00	224.00	242.00
18	263.00	124.00	106.00	179.00	211.00	67.00	94.00	82.00	64.00	147.00
19	232.00	219.00	236.00	73.00	180.00	156.00	36.00	171.00	79.00	60.00
20	239.00	123.00	76.00	266.00	187.00	52.00	181.00	37.00	129.00	212.00
21	0.0	321.00	283.00	305.00	52.00	199.00	242.00	206.00	199.00	172.00
22	321.00	0.0	60.00	244.00	269.00	127.00	183.00	119.00	188.00	253.00
23	283.00	60.00	0.0	285.00	231.00	89.00	200.00	81.00	166.00	249.00
24	305.00	244.00	285.00	0.0	253.00	214.00	85.00	229.00	137.00	133.00
25	52.00	269.00	231.00	253.00	0.0	147.00	190.00	154.00	147.00	120.00
26	199.00	127.00	89.00	214.00	147.00	0.0	129.00	15.00	77.00	160.00
27	242.00	183.00	200.00	85.00	190.00	129.00	0.0	144.00	52.00	70.00
28	206.00	119.00	81.00	229.00	154.00	15.00	144.00	0.0	92.00	175.00
29	199.00	188.00	166.00	137.00	147.00	77.00	52.00	92.00	0.0	83.00
30	172.00	253.00	249.00	133.00	120.00	160.00	70.00	175.00	83.00	0.0

FIGURE 12

(continued, page 6)

FIGURE 12

(continued, page 7)

```
SUBPROGRAM MATBLD HAS BEEN CALLED TO GENERATE A COVER MATRIX
   THE MAXIMUM DISTANCE/TIME OF  75.00 HAS BEEN UTILIZED
```

FIGURE 12

(continued, page 8)

```
 1  100000010001000000010010010100
 2  010010101000001000000001000000
 3  001001000100000001000000000000
 4  000100000000010000000010000000
 5  010010000010001010000001000000
 6  001001101100000000000000000000
 7  010001101100000000100001001000
 8  100000010000000000000000010100
 9  010001101000000010000001000000
10  001001100100000000000000001000
11  000010000010000010000000000000
12  100000000000100000000101100101 00
13  000000000000100100001000100000
14  000100000000010000000110000000
15  010010000000001000000000000000
16  000000000000100100000000000001
17  000010001010000010000000000000
18  001000000000000001000000010010
19  000000100000000000100001001001
20  100000000001000000010000010100
21  000000000000100000001000100000
22  000000000001010000000110000000
23  100100000001010000000110000000
24  010010101000000000100001000000
25  000000000000100000001000100000
26  100000010001000001010000010100
27  000000100100000000100000001011
28  100000010001000000010000010100
29  000000000000000001000000001010
30  000000000000000100100000001001
    1 CAN BE SERVED BY     1
    1 CAN BE SERVED BY     8
    1 CAN BE SERVED BY    12
    1 CAN BE SERVED BY    20
    1 CAN BE SERVED BY    23
    1 CAN BE SERVED BY    26
    1 CAN BE SERVED BY    28
    2 CAN BE SERVED BY     2
    2 CAN BE SERVED BY     5
    2 CAN BE SERVED BY     7
    2 CAN BE SERVED BY     9
    2 CAN BE SERVED BY    15
    2 CAN BE SERVED BY    24
    3 CAN BE SERVED BY     3
    3 CAN BE SERVED BY     6
    3 CAN BE SERVED BY    10
    3 CAN BE SERVED BY    18
    4 CAN BE SERVED BY     4
    4 CAN BE SERVED BY    14
    4 CAN BE SERVED BY    23
    5 CAN BE SERVED BY     2
    5 CAN BE SERVED BY     5
    5 CAN BE SERVED BY    11
    5 CAN BE SERVED BY    15
    5 CAN BE SERVED BY    17
    5 CAN BE SERVED BY    24
    6 CAN BE SERVED BY     3
    6 CAN BE SERVED BY     6
    6 CAN BE SERVED BY     7
    6 CAN BE SERVED BY     9
```

FIGURE 12

(continued, page 9)

```
 6 CAN BE SERVED BY    10
 7 CAN BE SERVED BY     2
 7 CAN BE SERVED BY     6
 7 CAN BE SERVED BY     7
 7 CAN BE SERVED BY     9
 7 CAN BE SERVED BY    10
 7 CAN BE SERVED BY    19
 7 CAN BE SERVED BY    24
 7 CAN BE SERVED BY    27
 8 CAN BE SERVED BY     1
 8 CAN BE SERVED BY     8
 8 CAN BE SERVED BY    26
 8 CAN BE SERVED BY    28
 9 CAN BE SERVED BY     2
 9 CAN BE SERVED BY     6
 9 CAN BE SERVED BY     7
 9 CAN BE SERVED BY     9
 9 CAN BE SERVED BY    17
 9 CAN BE SERVED BY    24
10 CAN BE SERVED BY     3
10 CAN BE SERVED BY     6
10 CAN BE SERVED BY     7
10 CAN BE SERVED BY    10
10 CAN BE SERVED BY    27
11 CAN BE SERVED BY     5
11 CAN BE SERVED BY    11
11 CAN BE SERVED BY    17
12 CAN BE SERVED BY     1
12 CAN BE SERVED BY    12
12 CAN BE SERVED BY    20
12 CAN BE SERVED BY    22
12 CAN BE SERVED BY    23
12 CAN BE SERVED BY    26
12 CAN BE SERVED BY    28
13 CAN BE SERVED BY    13
13 CAN BE SERVED BY    16
13 CAN BE SERVED BY    21
13 CAN BE SERVED BY    25
14 CAN BE SERVED BY     4
14 CAN BE SERVED BY    14
14 CAN BE SERVED BY    22
14 CAN BE SERVED BY    23
15 CAN BE SERVED BY     2
15 CAN BE SERVED BY     5
15 CAN BE SERVED BY    15
16 CAN BE SERVED BY    13
16 CAN BE SERVED BY    16
16 CAN BE SERVED BY    30
17 CAN BE SERVED BY     5
17 CAN BE SERVED BY     9
17 CAN BE SERVED BY    11
17 CAN BE SERVED BY    17
18 CAN BE SERVED BY     3
18 CAN BE SERVED BY    18
18 CAN BE SERVED BY    26
18 CAN BE SERVED BY    29
19 CAN BE SERVED BY     7
19 CAN BE SERVED BY    19
19 CAN BE SERVED BY    24
19 CAN BE SERVED BY    27
19 CAN BE SERVED BY    30
```

FIGURE 12

(continued, page 10)

```
20 CAN BE SERVED BY    1
20 CAN BE SERVED BY   12
20 CAN BE SERVED BY   20
20 CAN BE SERVED BY   26
20 CAN BE SERVED BY   28
21 CAN BE SERVED BY   13
21 CAN BE SERVED BY   21
21 CAN BE SERVED BY   25
22 CAN BE SERVED BY   12
22 CAN BE SERVED BY   14
22 CAN BE SERVED BY   22
22 CAN BE SERVED BY   23
23 CAN BE SERVED BY    1
23 CAN BE SERVED BY    4
23 CAN BE SERVED BY   12
23 CAN BE SERVED BY   14
23 CAN BE SERVED BY   22
23 CAN BE SERVED BY   23
24 CAN BE SERVED BY    2
24 CAN BE SERVED BY    5
24 CAN BE SERVED BY    7
24 CAN BE SERVED BY    9
24 CAN BE SERVED BY   19
24 CAN BE SERVED BY   24
25 CAN BE SERVED BY   13
25 CAN BE SERVED BY   21
25 CAN BE SERVED BY   25
26 CAN BE SERVED BY    1
26 CAN BE SERVED BY    8
26 CAN BE SERVED BY   12
26 CAN BE SERVED BY   18
26 CAN BE SERVED BY   20
26 CAN BE SERVED BY   26
26 CAN BE SERVED BY   28
27 CAN BE SERVED BY    7
27 CAN BE SERVED BY   10
27 CAN BE SERVED BY   19
27 CAN BE SERVED BY   27
27 CAN BE SERVED BY   29
27 CAN BE SERVED BY   30
28 CAN BE SERVED BY    1
28 CAN BE SERVED BY    8
28 CAN BE SERVED BY   12
28 CAN BE SERVED BY   20
28 CAN BE SERVED BY   26
28 CAN BE SERVED BY   28
29 CAN BE SERVED BY   18
29 CAN BE SERVED BY   27
29 CAN BE SERVED BY   29
30 CAN BE SERVED BY   16
30 CAN BE SERVED BY   19
30 CAN BE SERVED BY   27
30 CAN BE SERVED BY   30
```

FIGURE 12

(continued, page 11)

```
   ITERATION NUMBER,    1
 THIS  IS EXAMPLE NUMBER TWO-NETWORK

   NUMBER OF FACILITIES   1
   SERVICE DISTANCE =    75.000

   NEW FACILITY LOCATION NUMBER     7

   FACILITIES ARE LOCATED AT     7,
   ------------------------------------------------------------------------------
   POPULATION SERVED     190.00          PERCENT OF TOTAL POPULATION SERVED   32.76
   ------------------------------------------------------------------------------
THE FACILITY LOCATED AT:   7 CAN COVER THE FOLLOWING  DEMANDS:
  2,   6,   7,   9,  10,  19,  24,  27,
DEMAND POINT      CAN BE COVERED BY FACILITIES AT:
         1       NO CURRENT FACILITY LOCATION
         2         7,
         3       NO CURRENT FACILITY LOCATION
         4       NO CURRENT FACILITY LOCATION
         5       NO CURRENT FACILITY LOCATION
         6         7,
         7         7,
         8       NO CURRENT FACILITY LOCATION
         9         7,
        10         7,
        11       NO CURRENT FACILITY LOCATION
        12       NO CURRENT FACILITY LOCATION
        13       NO CURRENT FACILITY LOCATION
        14       NO CURRENT FACILITY LOCATION
        15       NO CURRENT FACILITY LOCATION
        16       NO CURRENT FACILITY LOCATION
        17       NO CURRENT FACILITY LOCATION
        18       NO CURRENT FACILITY LOCATION
        19         7,
        20       NO CURRENT FACILITY LOCATION
        21       NO CURRENT FACILITY LOCATION
        22       NO CURRENT FACILITY LOCATION
        23       NO CURRENT FACILITY LOCATION
        24         7,
        25       NO CURRENT FACILITY LOCATION
        26       NO CURRENT FACILITY LOCATION
        27         7,
        28       NO CURRENT FACILITY LOCATION
        29       NO CURRENT FACILITY LOCATION
        30       NO CURRENT FACILITY LOCATION
```

```
  THIS  IS EXAMPLE NUMBER TWO-NETWORK

FACILITIES ARE LOCATED AT     7,
PRIMARY DISTANCE    = 75.00
SECONDARY DISTANCE =100.00
*****************************************************************************************************************
          *         *PRIMARY*SECONDARY*POPULATION*POPULATION*LARGEST,*       *WT.DIST*WT.DIST. *WT.DIST* TOTAL  *
PARTITION*FACILITY*SERVED * SERVED  * OUTSIDE  *     IN     *TRAVELED* NODE *PRIMARY*SECONDARY*OUTSIDE*WEIGHTED*
 NUMBER  * NUMBER *  POP. *  POP.   *SECONDARY *PARTITION *DISTANCE*NUMBER*COVERED* COVERED *PRIMARY*DISTANCE*
    1          7     190.00     25.00     365.00     580.00     304.0     4   8488.0    2325.0  71513.   80001.
*****************************************************************************************************************
                     190.00     25.00     365.00     580.00                 8488.0    2325.0   71513.    80001.
PARTITION  1  FACILITY   7
**   1 D= 194.0**   2 D=  66.0**   3 D=  93.0**   4 D= 304.0**   5 D= 103.0**   6 D=  60.0

*   7 D=   0.0**   8 D= 208.0**   9 D=  67.0**  10 D=  47.0**  11 D= 167.0**  12 D= 226.0

*  13 D= 243.0**  14 D= 267.0**  15 D= 117.0**  16 D= 177.0**  17 D= 123.0**  18 D= 140.0

*  19 D=  59.0**  20 D= 230.0**  21 D= 291.0**  22 D= 198.0**  23 D= 246.0**  24 D=  46.0

*  25 D= 239.0**  26 D= 178.0**  27 D=  49.0**  28 D= 193.0**  29 D= 101.0**  30 D= 119.0
```

FIGURE 12

(continued, page 12)

FIGURE 12

(continued, page 13)

```
   ITERATION NUMBER,    2
 THIS  IS EXAMPLE NUMBER TWO-NETWORK

   NUMBER OF FACILITIES   2
   SERVICE DISTANCE =    75.000

   NEW FACILITY LOCATION NUMBER    26

   FACILITIES ARE LOCATED AT     7,   26,
   ------------------------------------------------------------------------
   POPULATION SERVED     320.00          PERCENT OF TOTAL POPULATION SERVED   55.17
   ------------------------------------------------------------------------
THE FACILITY LOCATED AT:   7 CAN COVER THE FOLLOWING  DEMANDS:
  2,   6,   7,   9,  10,  19,  24,  27,
THE FACILITY LOCATED AT:  26 CAN COVER THE FOLLOWING  DEMANDS:
  1,   8,  12,  18,  20,  26,  28,
DEMAND POINT      CAN BE COVERED BY FACILITIES AT:
         1         26,
         2          7,
         3        NO CURRENT FACILITY LOCATION
         4        NO CURRENT FACILITY LOCATION
         5        NO CURRENT FACILITY LOCATION
         6          7,
         7          7,
         8         26,
         9          7,
        10          7,
        11        NO CURRENT FACILITY LOCATION
        12         26,
        13        NO CURRENT FACILITY LOCATION
        14        NO CURRENT FACILITY LOCATION
        15        NO CURRENT FACILITY LOCATION
        16        NO CURRENT FACILITY LOCATION
        17        NO CURRENT FACILITY LOCATION
        18         26,
        19          7,
        20         26,
        21        NO CURRENT FACILITY LOCATION
        22        NO CURRENT FACILITY LOCATION
        23        NO CURRENT FACILITY LOCATION
        24          7,
        25        NO CURRENT FACILITY LOCATION
        26         26,
        27          7,
        28         26,
        29        NO CURRENT FACILITY LOCATION
        30        NO CURRENT FACILITY LOCATION
```

```
  THIS  IS EXAMPLE NUMBER TWO-NETWORK

FACILITIES ARE LOCATED AT    7,  26,
PRIMARY DISTANCE    = 75.00
SECONDARY DISTANCE =100.00
*****************************************************************************************************************
          *         *PRIMARY*SECONDARY*POPULATION*POPULATION*LARGEST,*       *WT.DIST*WT.DIST. *WT.DIST* TOTAL  *
PARTITION*FACILITY*SERVED * SERVED  * OUTSIDE  *    IN    *TRAVELED* NODE *PRIMARY*SECONDARY*OUTSIDE*WEIGHTED*
 NUMBER  * NUMBER *  POP. *  POP.   *SECONDARY *PARTITION *DISTANCE*NUMBER*COVERED* COVERED *PRIMARY*DISTANCE*
    1         7     190.00     25.00      87.00     302.00     177.0   16   8488.0    2325.0  14126.   22614.
    2        26     130.00     45.00     103.00     278.00     199.0   21   5375.0    3585.0  20901.   26276.
*****************************************************************************************************************
                    320.00     70.00     190.00     580.00                 13863.0    5910.0   35027.    48890.
PARTITION  1  FACILITY   7
**   2 D=  66.0**   3 D=  93.0**   5 D= 103.0**   6 D=  60.0**   7 D=   0.0**   9 D=  67.0

*  10 D=  47.0**  11 D= 167.0**  15 D= 117.0**  16 D= 177.0**  17 D= 123.0**  19 D=  59.0

*  24 D=  46.0**  27 D=  49.0**  30 D= 119.0**
PARTITION  2  FACILITY  26
**   1 D=  16.0**   4 D= 152.0**   8 D=  41.0**  12 D=  69.0**  13 D= 193.0**  14 D= 164.0

*  18 D=  67.0**  20 D=  52.0**  21 D= 199.0**  22 D= 127.0**  23 D=  89.0**  25 D= 147.0

*  26 D=   0.0**  28 D=  15.0**  29 D=  77.0**
```

FIGURE 12

(continued, page 14)

FIGURE 12

(continued, page 15)

```
   ITERATION NUMBER,    3
 THIS  IS EXAMPLE NUMBER TWO-NETWORK

   NUMBER OF FACILITIES   3
   SERVICE DISTANCE =    75.000

   NEW FACILITY LOCATION NUMBER    13

   FACILITIES ARE LOCATED AT     7,   26,   13,
   ---------------------------------------------------------------------------
   POPULATION SERVED     395.00          PERCENT OF TOTAL POPULATION SERVED   68.10
   ---------------------------------------------------------------------------
THE FACILITY LOCATED AT:   7 CAN COVER THE FOLLOWING  DEMANDS:
  2,   6,   7,   9,  10,  19,  24,  27,
THE FACILITY LOCATED AT:  26 CAN COVER THE FOLLOWING  DEMANDS:
  1,   8,  12,  18,  20,  26,  28,
THE FACILITY LOCATED AT:  13 CAN COVER THE FOLLOWING  DEMANDS:
 13,  16,  21,  25,
DEMAND POINT       CAN BE COVERED BY FACILITIES AT:
        1          26,
        2           7,
        3         NO CURRENT FACILITY LOCATION
        4         NO CURRENT FACILITY LOCATION
        5         NO CURRENT FACILITY LOCATION
        6           7,
        7           7,
        8          26,
        9           7,
       10           7,
       11         NO CURRENT FACILITY LOCATION
       12          26,
       13          13,
       14         NO CURRENT FACILITY LOCATION
       15         NO CURRENT FACILITY LOCATION
       16          13,
       17         NO CURRENT FACILITY LOCATION
       18          26,
       19           7,
       20          26,
       21          13,
       22         NO CURRENT FACILITY LOCATION
       23         NO CURRENT FACILITY LOCATION
       24           7,
       25          13,
       26          26,
       27           7,
       28          26,
       29         NO CURRENT FACILITY LOCATION
       30         NO CURRENT FACILITY LOCATION
```

THIS IS EXAMPLE NUMBER TWO-NETWORK

FACILITIES ARE LOCATED AT 7, 26, 13,
PRIMARY DISTANCE = 75.00
SECONDARY DISTANCE =100.00

PARTITION NUMBER	FACILITY NUMBER	PRIMARY SERVED POP.	SECONDARY SERVED POP.	POPULATION OUTSIDE SECONDARY	POPULATION IN PARTITION	LARGEST TRAVELED DISTANCE	NODE NUMBER	WT.DIST PRIMARY COVERED	WT.DIST. SECONDARY COVERED	WT.DIST OUTSIDE PRIMARY	TOTAL WEIGHTED DISTANCE
1	7	190.00	25.00	67.00	282.00	167.0	11	8488.0	2325.0	10586.	19074.
2	26	130.00	45.00	48.00	223.00	164.0	14	5375.0	3585.0	10686.	16061.
3	13	75.00	0.0	0.0	75.00	66.0	16	2380.0	0.0	0.	2380.
		395.00	70.00	115.00	580.00			16243.0	5910.0	21272.	37515.

PARTITION 1 FACILITY 7
** 2 D= 66.0** 3 D= 93.0** 5 D= 103.0** 6 D= 60.0** 7 D= 0.0** 9 D= 67.0

* 10 D= 47.0** 11 D= 167.0** 15 D= 117.0** 17 D= 123.0** 19 D= 59.0** 24 D= 46.0

* 27 D= 49.0** 30 D= 119.0**
PARTITION 2 FACILITY 26
** 1 D= 16.0** 4 D= 152.0** 8 D= 41.0** 12 D= 69.0** 14 D= 164.0** 18 D= 67.0

* 20 D= 52.0** 22 D= 127.0** 23 D= 89.0** 26 D= 0.0** 28 D= 15.0** 29 D= 77.0

PARTITION 3 FACILITY 13
** 13 D= 0.0** 16 D= 66.0** 21 D= 60.0** 25 D= 46.0**

FIGURE 12

(continued, page 16)

FIGURE 12

(continued, page 17)

```
   ITERATION NUMBER,     4
  THIS  IS EXAMPLE NUMBER TWO-NETWORK

   NUMBER OF FACILITIES   4
   SERVICE DISTANCE =    75.000

   NEW FACILITY LOCATION NUMBER    18

   FACILITIES ARE LOCATED AT     7,   26,   13,   18,
   ---------------------------------------------------------------------------
   POPULATION SERVED     455.00          PERCENT OF TOTAL POPULATION SERVED   78.45
   ---------------------------------------------------------------------------
THE FACILITY LOCATED AT:   7 CAN COVER THE FOLLOWING  DEMANDS:
  2,   6,   7,   9,  10,  19,  24,  27,
THE FACILITY LOCATED AT:  26 CAN COVER THE FOLLOWING  DEMANDS:
  1,   8,  12,  18,  20,  26,  28,
THE FACILITY LOCATED AT:  13 CAN COVER THE FOLLOWING  DEMANDS:
 13,  16,  21,  25,
THE FACILITY LOCATED AT:  18 CAN COVER THE FOLLOWING  DEMANDS:
  3,  18,  26,  29,
DEMAND POINT      CAN BE COVERED BY FACILITIES AT:
        1         26,
        2          7,
        3         18,
        4        NO CURRENT FACILITY LOCATION
        5        NO CURRENT FACILITY LOCATION
        6          7,
        7          7,
        8         26,
        9          7,
       10          7,
       11        NO CURRENT FACILITY LOCATION
       12         26,
       13         13,
       14        NO CURRENT FACILITY LOCATION
       15        NO CURRENT FACILITY LOCATION
       16         13,
       17        NO CURRENT FACILITY LOCATION
       18         26,  18,
       19          7,
       20         26,
       21         13,
       22        NO CURRENT FACILITY LOCATION
       23        NO CURRENT FACILITY LOCATION
       24          7,
       25         13,
       26         26,  18,
       27          7,
       28         26,
       29         18,
       30        NO CURRENT FACILITY LOCATION

   SUBSTITUTION  ALGORITHM USED

   NODE      1 REPLACES FACILITY LOCATION     26
   THIS IS NOW FACILITY NUMBER      2

   FACILITIES ARE LOCATED AT     7,    1,   13,   18,
   ---------------------------------------------------------------------------
```

FIGURE 12

(continued, page 18)

```
POPULATION SERVED      465.00          PERCENT OF TOTAL POPULATION SERVED   80.17
-----------------------------------------------------------------------------------
THE FACILITY LOCATED AT:   7 CAN COVER THE FOLLOWING  DEMANDS:
  2,   6,   7,   9,  10,  19,  24,  27,
THE FACILITY LOCATED AT:   1 CAN COVER THE FOLLOWING  DEMANDS:
  1,   8,  12,  20,  23,  26,  28,
THE FACILITY LOCATED AT:  13 CAN COVER THE FOLLOWING  DEMANDS:
 13,  16,  21,  25,
THE FACILITY LOCATED AT:  18 CAN COVER THE FOLLOWING  DEMANDS:
  3,  18,  26,  29,
DEMAND POINT      CAN BE COVERED BY FACILITIES AT:
        1          1,
        2          7,
        3         18,
        4        NO CURRENT FACILITY LOCATION
        5        NO CURRENT FACILITY LOCATION
        6          7,
        7          7,
        8          1,
        9          7,
       10          7,
       11        NO CURRENT FACILITY LOCATION
       12          1,
       13         13,
       14        NO CURRENT FACILITY LOCATION
       15        NO CURRENT FACILITY LOCATION
       16         13,
       17        NO CURRENT FACILITY LOCATION
       18         18,
       19          7,
       20          1,
       21         13,
       22        NO CURRENT FACILITY LOCATION
       23          1,
       24          7,
       25         13,
       26          1,  18,
       27          7,
       28          1,
       29         18,
       30        NO CURRENT FACILITY LOCATION
```

THIS IS EXAMPLE NUMBER TWO-NETWORK

FACILITIES ARE LOCATED AT 7, 1, 13, 18,
PRIMARY DISTANCE = 75.00
SECONDARY DISTANCE =100.00

PARTITION NUMBER	FACILITY NUMBER	PRIMARY SERVED POP.	SECONDARY SERVED POP.	POPULATION OUTSIDE SECONDARY	POPULATION IN PARTITION	LARGEST TRAVELED DISTANCE	NODE NUMBER	WT.DIST PRIMARY COVERED	WT.DIST. SECONDARY COVERED	WT.DIST OUTSIDE PRIMARY	TOTAL WEIGHTED DISTANCE
1	7	190.00	0.0	67.00	257.00	167.0	11	8488.0	0.0	8261.	16749.
2	1	115.00	0.0	48.00	163.00	149.0	14	4310.0	0.0	6399.	10709.
3	13	75.00	0.0	0.0	75.00	66.0	16	2380.0	0.0	0.	2380.
4	18	85.00	0.0	0.0	85.00	64.0	29	3790.0	0.0	0.	3790.
		465.00	0.0	115.00	580.00			18968.0	0.0	14660.	33628.

PARTITION 1 FACILITY 7
** 2 D= 66.0** 5 D= 103.0** 6 D= 60.0** 7 D= 0.0** 9 D= 67.0** 10 D= 47.0

* 11 D= 167.0** 15 D= 117.0** 17 D= 123.0** 19 D= 59.0** 24 D= 46.0** 27 D= 49.0

* 30 D= 119.0**
PARTITION 2 FACILITY 1
** 1 D= 0.0** 4 D= 138.0** 8 D= 51.0** 12 D= 54.0** 14 D= 149.0** 20 D= 38.0

* 22 D= 112.0** 23 D= 74.0** 26 D= 16.0** 28 D= 7.0**
PARTITION 3 FACILITY 13
** 13 D= 0.0** 16 D= 66.0** 21 D= 60.0** 25 D= 46.0**
PARTITION 4 FACILITY 18
** 3 D= 62.0** 18 D= 0.0** 29 D= 64.0**

FIGURE 12

(continued, page 19)

FIGURE 12

(continued, page 20)

```
   ITERATION NUMBER,    5
  THIS  IS EXAMPLE NUMBER TWO-NETWORK

   NUMBER OF FACILITIES   5
   SERVICE DISTANCE =    75.000

   NEW FACILITY LOCATION NUMBER     5

   FACILITIES ARE LOCATED AT     7,    1,   13,   18,    5,
   ---------------------------------------------------------------------------
   POPULATION SERVED     517.00          PERCENT OF TOTAL POPULATION SERVED   89.14
   ---------------------------------------------------------------------------
THE FACILITY LOCATED AT:   7 CAN COVER THE FOLLOWING  DEMANDS:
  2,   6,   7,   9,  10,  19,  24,  27,
THE FACILITY LOCATED AT:   1 CAN COVER THE FOLLOWING  DEMANDS:
  1,   8,  12,  20,  23,  26,  28,
THE FACILITY LOCATED AT:  13 CAN COVER THE FOLLOWING  DEMANDS:
 13,  16,  21,  25,
THE FACILITY LOCATED AT:  18 CAN COVER THE FOLLOWING  DEMANDS:
  3,  18,  26,  29,
THE FACILITY LOCATED AT:   5 CAN COVER THE FOLLOWING  DEMANDS:
  2,   5,  11,  15,  17,  24,
DEMAND POINT      CAN BE COVERED BY FACILITIES AT:
         1         1,
         2         7,   5,
         3        18,
         4       NO CURRENT FACILITY LOCATION
         5         5,
         6         7,
         7         7,
         8         1,
         9         7,
        10         7,
        11         5,
        12         1,
        13        13,
        14       NO CURRENT FACILITY LOCATION
        15         5,
        16        13,
        17         5,
        18        18,
        19         7,
        20         1,
        21        13,
        22       NO CURRENT FACILITY LOCATION
        23         1,
        24         7,   5,
        25        13,
        26         1,  18,
        27         7,
        28         1,
        29        18,
        30       NO CURRENT FACILITY LOCATION
```

THIS IS EXAMPLE NUMBER TWO-NETWORK

FACILITIES ARF LOCATED AT 7, 1, 13, 18, 5,
PRIMARY DISTANCE = 75.00
SECONDARY DISTANCE =100.00

PARTITION NUMBER	FACILITY NUMBER	PRIMARY SERVED POP.	SECONDARY SERVED POP.	OUTSIDE SECONDARY	POPULATION IN PARTITION	LARGEST TRAVELLED DISTANCE	NODE NUMBER	WT.DIST PRIMARY COVERED	WT.DIST. SECONDARY COVERED	WT.DIST OUTSIDE PRIMARY	TOTAL WEIGHTED DISTANCE
1	7	170.00	0.0	15.00	185.00	119.0	30	7168.0	0.0	1785.	8953.
2	1	115.00	0.0	48.00	163.00	149.0	14	4310.0	0.0	6399.	10709.
3	13	75.00	0.0	0.0	75.00	66.0	16	2380.0	0.0	0.	2380.
4	18	85.00	0.0	0.0	85.00	64.0	29	3790.0	0.0	0.	3790.
5	5	72.00	0.0	0.0	72.00	74.0	17	2550.0	0.0	0.	2550.
		517.00	0.0	63.00	580.00			20198.0	0.0	8184.	28382.

PARTITION 1 FACILITY 7
** 6 D= 60.0** 7 D= 0.0** 9 D= 67.0** 10 D= 47.0** 19 D= 59.0** 24 D= 46.0

* 27 D= 49.0** 30 D= 119.0**
PARTITION 2 FACILITY 1
** 1 D= 0.0** 4 D= 138.0** 8 D= 51.0** 12 D= 54.0** 14 D= 149.0** 20 D= 38.0

* 22 D= 112.0** 23 D= 74.0** 26 D= 16.0** 28 D= 7.0**
PARTITION 3 FACILITY 13
** 13 D= 0.0** 16 D= 66.0** 21 D= 60.0** 25 D= 46.0**
PARTITION 4 FACILITY 18
** 3 D= 62.0** 18 D= 0.0** 29 D= 64.0**
PARTITION 5 FACILITY 5
** 2 D= 37.0** 5 D= 0.0** 11 D= 69.0** 15 D= 19.0** 17 D= 74.0**

FIGURE 12

(continued, page 21)

FIGURE 12

(continued, page 22)

```
   ITERATION NUMBER,     6
 THIS  IS EXAMPLE NUMBER TWO-NETWORK ----

   NUMBER OF FACILITIES    6
   SERVICE DISTANCE =     75.000

   NEW FACILITY LOCATION NUMBER     14

   FACILITIES ARE LOCATED AT      7,     1,    13,    18,     5,    14,
   ---------------------------------------------------------------------
   POPULATION SERVED      565.00          PERCENT OF TOTAL POPULATION SERVED   97.41
   ---------------------------------------------------------------------
THE FACILITY LOCATED AT:   7 CAN COVER THE FOLLOWING  DEMANDS:
  2,   6,   7,   9,  10,  19,  24,  27,
THE FACILITY LOCATED AT:   1 CAN COVER THE FOLLOWING  DEMANDS:
  1,   8,  12,  20,  23,  26,  28,
THE FACILITY LOCATED AT:  13 CAN COVER THE FOLLOWING  DEMANDS:
 13,  16,  21,  25,
THE FACILITY LOCATED AT:  18 CAN COVER THE FOLLOWING  DEMANDS:
  3,  18,  26,  29,
THE FACILITY LOCATED AT:   5 CAN COVER THE FOLLOWING  DEMANDS:
  2,   5,  11,  15,  17,  24,
THE FACILITY LOCATED AT:  14 CAN COVER THE FOLLOWING  DEMANDS:
  4,  14,  22,  23,
DEMAND POINT      CAN BE COVERED BY FACILITIES AT:
          1        1,
          2        7,    5,
          3       18,
          4       14,
          5        5,
          6        7,
          7        7,
          8        1,
          9        7,
         10        7,
         11        5,
         12        1,
         13       13,
         14       14,
         15        5,
         16       13,
         17        5,
         18       18,
         19        7,
         20        1,
         21       13,
         22       14,
         23        1,   14,
         24        7,    5,
         25       13,
         26        1,   18,
         27        7,
         28        1,
         29       18,
         30      NO CURRENT FACILITY LOCATION
```

THIS IS EXAMPLE NUMBER TWO-NETWORK

FACILITIES ARE LOCATED AT 7, 1, 13, 18, 5, 14,
PRIMARY DISTANCE = 75.00
SECONDARY DISTANCE =100.00

PARTITION NUMBER	FACILITY NUMBER	PRIMARY SERVED POP.	SECONDARY SERVED POP.	POPULATION OUTSIDE SECONDARY	POPULATION IN PARTITION	LARGEST, TRAVELED DISTANCE	NODE NUMBER	WT.DIST PRIMARY COVERED	WT.DIST. SECONDARY COVERED	WT.DIST OUTSIDE PRIMARY	TOTAL WEIGHTED DISTANCE
1	7	170.00	0.0	15.00	185.00	119.0	30	7168.0	0.0	1785.	8953.
2	1	115.00	0.0	0.0	115.00	74.0	23	4310.0	0.0	0.	4310.
3	13	75.00	0.0	0.0	75.00	66.0	16	2380.0	0.0	0.	2380.
4	18	85.00	0.0	0.0	85.00	64.0	29	3790.0	0.0	0.	3790.
5	5	72.00	0.0	0.0	72.00	74.0	17	2550.0	0.0	0.	2550.
6	14	48.00	0.0	0.0	48.00	69.0	22	2133.0	0.0	0.	2133.
		565.00	0.0	15.00	580.00			22331.0	0.0	1785.	24116.

PARTITION 1 FACILITY 7
** 6 D= 60.0** 7 D= 0.0** 9 D= 67.0** 10 D= 47.0** 19 D= 59.0** 24 D= 46.0

* 27 D= 49.0** 30 D= 119.0**
PARTITION 2 FACILITY 1
** 1 D= 0.0** 8 D= 51.0** 12 D= 54.0** 20 D= 38.0** 23 D= 74.0** 26 D= 16.0

* 28 D= 7.0**
PARTITION 3 FACILITY 13
** 13 D= 0.0** 16 D= 66.0** 21 D= 60.0** 25 D= 46.0**
PARTITION 4 FACILITY 18
** 3 D= 62.0** 18 D= 0.0** 29 D= 64.0**
PARTITION 5 FACILITY 5
** 2 D= 37.0** 5 D= 0.0** 11 D= 69.0** 15 D= 19.0** 17 D= 74.0**
PARTITION 6 FACILITY 14
** 4 D= 61.0** 14 D= 0.0** 22 D= 69.0**

FIGURE 12

(continued, page 23)

FIGURE 12

(continued, page 24)

```
   ITERATION NUMBER,    7
 THIS  IS EXAMPLE NUMBER TWO-NETWORK

   NUMBER OF FACILITIES   7
   SERVICE DISTANCE =    75.000

   NEW FACILITY LOCATION NUMBER    16

   FACILITIES ARE LOCATED AT     7,    1,   13,   18,    5,   14,   16,
   ---------------------------------------------------------------------
   POPULATION SERVED     580.00          PERCENT OF TOTAL POPULATION SERVED  100.00
   ---------------------------------------------------------------------
THE FACILITY LOCATED AT:   7 CAN COVER THE FOLLOWING  DEMANDS:
  2,   6,   7,   9,  10,  19,  24,  27,
THE FACILITY LOCATED AT:   1 CAN COVER THE FOLLOWING  DEMANDS:
  1,   8,  12,  20,  23,  26,  28,
THE FACILITY LOCATED AT:  13 CAN COVER THE FOLLOWING  DEMANDS:
 13,  16,  21,  25,
THE FACILITY LOCATED AT:  18 CAN COVER THE FOLLOWING  DEMANDS:
  3,  18,  26,  29,
THE FACILITY LOCATED AT:   5 CAN COVER THE FOLLOWING  DEMANDS:
  2,   5,  11,  15,  17,  24,
THE FACILITY LOCATED AT:  14 CAN COVER THE FOLLOWING  DEMANDS:
  4,  14,  22,  23,
THE FACILITY LOCATED AT:  16 CAN COVER THE FOLLOWING  DEMANDS:
 13,  16,  30,
DEMAND POINT      CAN BE COVERED BY FACILITIES AT:
         1         1,
         2         7,   5,
         3        18,
         4        14,
         5         5,
         6         7,
         7         7,
         8         1,
         9         7,
        10         7,
        11         5,
        12         1,
        13        13,  16,
        14        14,
        15         5,
        16        13,  16,
        17         5,
        18        18,
        19         7,
        20         1,
        21        13,
        22        14,
        23         1,  14,
        24         7,   5,
        25        13,
        26         1,  18,
        27         7,
        28         1,
        29        18,
        30        16,
```

THIS IS EXAMPLE NUMBER TWO-NETWORK

FACILITIES ARE LOCATED AT 7, 1, 13, 18, 5, 14, 16,
PRIMARY DISTANCE = 75.00
SECONDARY DISTANCE =100.00

PARTITION NUMBER	FACILITY NUMBER	PRIMARY SERVED POP.	SECONDARY SERVED POP.	POPULATION OUTSIDE SECONDARY	POPULATION IN PARTITION	LARGEST TRAVELED DISTANCE	NODE NUMBER	WT.DIST PRIMARY COVERED	WT.DIST. SECONDARY COVERED	WT.DIST OUTSIDE PRIMARY	TOTAL WEIGHTED DISTANCE
1	7	170.00	0.0	0.0	170.00	67.0	9	7168.0	0.0	0.	7168.
2	1	115.00	0.0	0.0	115.00	74.0	23	4310.0	0.0	0.	4310.
3	13	55.00	0.0	0.0	55.00	60.0	21	1060.0	0.0	0.	1060.
4	18	85.00	0.0	0.0	85.00	64.0	29	3790.0	0.0	0.	3790.
5	5	72.00	0.0	0.0	72.00	74.0	17	2550.0	0.0	0.	2550.
6	14	48.00	0.0	0.0	48.00	69.0	22	2133.0	0.0	0.	2133.
7	16	35.00	0.0	0.0	35.00	58.0	30	870.0	0.0	0.	870.
		580.00	0.0	0.0	580.00			21881.0	0.0	0.	21881.

PARTITION 1 FACILITY 7
** 6 D= 60.0** 7 D= 0.0** 9 D= 67.0** 10 D= 47.0** 19 D= 59.0** 24 D= 46.0

* 27 D= 49.0**
PARTITION 2 FACILITY 1
** 1 D= 0.0** 8 D= 51.0** 12 D= 54.0** 20 D= 38.0** 23 D= 74.0** 26 D= 16.0

* 28 D= 7:0**
PARTITION 3 FACILITY 13
** 13 D= 0.0** 21 D= 60.0** 25 D= 46.0**
PARTITION 4 FACILITY 18
** 3 D= 62.0** 18 D= 0.0** 29 D= 64.0**
PARTITION 5 FACILITY 5
** 2 D= 37.0** 5 D= 0.0** 11 D= 69.0** 15 D= 19.0** 17 D= 74.0**
PARTITION 6 FACILITY 14
** 4 D= 61.0** 14 D= 0.0** 22 D= 69.0**
PARTITION 7 FACILITY 16
** 16 D= 0.0** 30 D= 58.0**
COVERRAGE CANNOT BE CHANGED BY ADDITIONAL FACILITIES
THIS SOLUTION WAS GENERATED BY THE GAS ALGORITHM

FIGURE 12

(continued, page 25)

CHAPTER 6

NETWORK PROBLEM THREE

Suppose that we want to solve the exact same problem as the problem of chapter five, except that several cities are not available for a facility placement as shown in table 20. We can easily eliminate these areas from consideration as potential facility sites by using one of the constraint options described in appendix C. In order to utilize the constraint option, the second problem control card given in the problem of chapter 5 (see table 19) must be modified along with the addition of a constraint card deck.

Because network problem 3 requires only slight modifications from the deck described for problem 2, only the necessary changes to the data deck developed for problem 2 will be considered. A conceptualized version of the data deck set up is given in figure 13. The data deck necessary for problem 3 is exactly the same as the data deck necessary for problem 2 up to the first problem control card. The title card (first problem control card) will change to reflect the new example number. The second problem control card is modified by changing the value of the CONS parameter from zero (blank) to a value of one (see table 21). By making this change, the GAS program will expect specific problem constraints to be established in a constraint card deck which immediately follows the second problem control card.

TABLE 20

CITIES NOT AVAILABLE FOR FACILITY PLACEMENT

NODE	REASONS
3	No good source of water available
8	No good source of water available
20	No electricity
25	No electricity
14	Special problems

TABLE 21

SECOND PROBLEM CONTROL CARD

FOR NETWORK PROBLEM THREE

Parameter Name	Assumption	Assigned Value	Card Column(s) Containing Value
IP	Must equal the largest number of facilities	10	4-5
S	Maximal service distance	75.	6-15
SCS	Secondary service distance must be given since IFSAP=1	100.	16-25
EMAXL	Parameter not utilized because elevation data is not given	blank	26-35
EMAXS	Parameter not utilized because elevation data is not given	blank	36-45
CONS	Value of one means special constraint options are utilized	0	55
ICOV	Value of one means zero-one cover matrix is given	1	60
ILIST	Value of one means coverage listing is given	1	65

The format of the constraint card deck is given in appendix C. The reader should first read appendix C before continuing with the description given in this section.

As noted in appendix C, the constraint card set is composed of a parameter card containing the parameters ND, NDAS, and NANCF. The parameter card is followed by three sets of cards as indicated in figure C.1.

The ND parameter represents the number of demand nodes that are to be deleted from the established list of potential facility sites. Since we plan to make 5 nodes ineligible for facility placement, we should set the value of ND at five. The NDAS parameter represents the number of areas that are to be deleted from the demand list. Since there are no nodes which we want to eliminate from the demand list, the value of NDAS should be set to a zero (or blank) value. The NANCF parameter represents the number of potential facility locations that should automatically be allocated to specific sites. At this point, we have not identified any sites that should be allocated a facility. Thus, the NANCF parameter should be set at a value of zero (or blank). Therefore, the first constraint card has the following parameter values: ND equal to 5; NDAS equal to 0; and NANCF equal to 0. Appendix C indicates that the number of constraint cards following the parameter card should be equal to ND + NDAS + NANCF. According to appendix C, there are three sets of cards: ND cards, NDAS cards, and NANCF cards, respectively. Since the

ND and NDAS parameters are both set at a zero value, there are no cards in the second and third sets. The number of cards in the first set is equal to the value of the ND parameter. In this case, there will be five cards, because ND has been set at five. Each card of the ND cards gives the index of a demand area that is to be deleted from the list of potential facility sites. On each card, the program will accept a two letter code used to indicate why a particular node is not to be considered as a potential facility site. Each card must be punched according to the formats given in appendix C. An example of one of the ND cards is to eliminate node 14 due to its special problems. If we use the two letters SP to indicate special problems as a code, we can punch a card in the following form:

Punching:	_	_	1	4	_	S	P
Card Columns:	1	2	3	4	5	6	7

By setting up special codes (which are printed on the output listing) we can easily set up all five ND cards. After the five ND cards, two blank cards are given to signify the end of the deck. A complete listing of the data deck necessary to solve example problem three is given in figure 14. Notice that the data listing is identical to the deck for network problem 2 (see figure 11) except that the two problem control cards are different and a set of constraint cards has been

added. By looking at the last five cards in the listing in figure 14, one can easily see that areas 3, 8, 20, 25, and 14 will be eliminated from the list of potential facility sites.

The output from the GAS program is given in its entirety in figure 15. Notice that before the output of the first iteration is given, the output indicates that nodes 3, 8, 20, 25, and 14 will not be considered as potential facility sites. The program gives results of seven iterations. It should be noted that the solutions of iterations six and seven are different from that of example 2 because node 14 is not allowed in the solution by example run three. For this problem no change in coverage resulted by eliminating 3, 8, 20, 25, and 14 for potential facility placement; however the elimination of combinations of other sites can significantly effect the solution.

FIGURE 13

CONCEPTUAL FORM OF THE DATA DECK FOR

NETWORK PROBLEM THREE

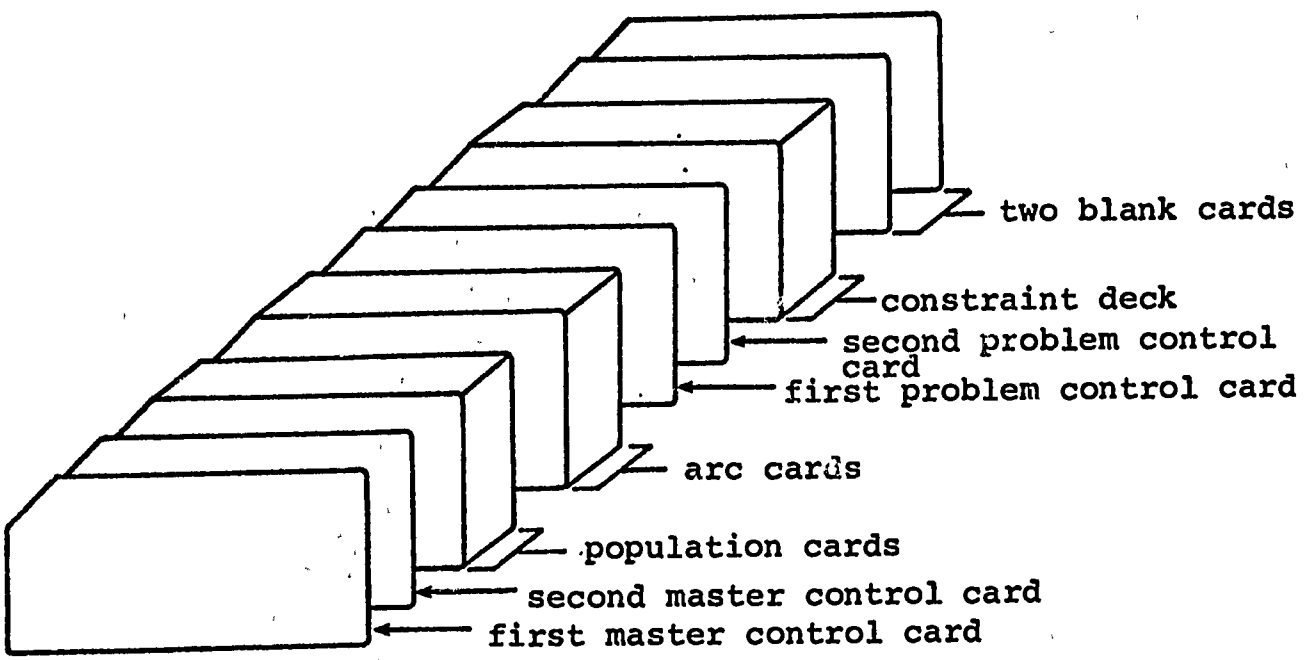


FIGURE 14

LISTING OF NETWORK PROBLEM THREE DATA DECK

```
 30   30          1    1    1    1
  1                                        1
  1       10.00
  2       20.00
  3       25.00
  4       18.00
  5       12.00
  6       23.00
  7       43.00
  8       30.00
  9       24.00
 10       15.00
 11       10.00
 12       20.00
 13       35.00
 14       15.00
 15       20.00
 16       20.00
 17       10.00
 18       25.00
 19       35.00
 20       15.00
 21       10.00
 22       15.00
 23       10.00
 24       20.00
 25       10.00
 26       20.00
 27       10.00
 28       10.00
 29       35.00
 30       15.00
 90
  1    1   26   16.
  2    1   28    7.
  3   26   28   15.
  4    1   20   38.
  5   20   28   37.
  6    8   28   48.
  7    8   20   81.
  8    4   20  100.
  9   12   20   65.
 10    4   12   90.
 11    4   23   70.
 12    4   14   61.
 13   14   23   75.
 14   14   22   69.
 15   22   23   60.
 16   12   23   20.
 17   12   22   58.
 18    1   12   54.
 19   12   18   86.
 20   18   22  124.
 21    3   22  105.
 22    8   26   41.
 23   18   26   67.
 24    1   18   78.
 25    3   18   62.
 26    3    6   56.
 27    3   10   46.
 28   10   18   93.
 29   18   29   64.
 30   26   29   77.
 31   10   29   94.
 32   27   29   52.
```

FIGURE 14

(continued, page 2)

```
 33   19   29   79.
 34   19   27   36.
 35   10   27   57.
 36    7   27   49.
 37   24   27   85.
 38    7   10   47.
 39    9   10   87.
 40    6   10   34.
 41    6   17  104.
 42    6    9   61.
 43    7    9   67.
 44    7   24   46.
 45    9   24   60.
 46    2   24   33.
 47    2    9   60.
 48    9   17   56.
 49    2   17   77.
 50   11   17   55.
 51    2   11  101.
 52    5   11   69.
 53    2    5   37.
 54    5   15   19.
 55    2   15   51.
 56   15   24   84.
 57   19   24   73.
 58   19   30   60.
 59   29   30   83.
 60   16   30   58.
 61   25   30  120.
 62   13   16   66.
 63   16   25   92.
 64   13   21   60.
 65   13   25   46.
 66   21   25   52.
 67    8   25  100.
 68   25   29  147.
 69    5   17   74.
 70    5    9   92.
 71    2    7   66.
 72    7    6   60.
 73   19   10   79.
 74    3   27   78.
 75    3   12  137.
 76    3   29   92.
 77   18   27   94.
 78   27   30   70.
 79   16   21  126.
 80    8   18  108.
 81    7   19   59.
 82    4   22  106.
 83   20   23   76.
 84   18   20  118.
 85   12   26   69.
 86    1    8   51.
 87   12   28   61.
 88   20   26   52.
 89    1   29   93.
 90    8   29  107.
THIS IS EXAMPLE NUMBER THREE-NETWORK
 10      75.00     100.00                                  1    1    1
  5
  3 NG
  8 NG
 20 NE
 25 NE
 14 SP
```

POPULATION DATA

1	10.*	4	18.*	7	43.*	10	15.*	13	35.*	16	20.*	19	35.*	22	15.*	25	10.*	28	10.*
2	20.*	5	12.*	8	30.*	11	10.*	14	15.*	17	10.*	20	15.*	23	10.*	26	20.*	29	35.*
3	25.*	6	23.*	9	24.*	12	20.*	15	20.*	18	25.*	21	10.*	24	20.*	27	10.*	30	15.*

FIGURE 15

NETWORK PROBLEM THREE OUTPUT

FIGURE 15

(continued, page 2)

INPUT ARC INFORMATION IS AS FOLLOWS

ARC NO.	FROM NODE	TO NODE	DISTANCE
1	1	26	16.000
2	1	28	7.000
3	26	28	15.000
4	1	20	38.000
5	20	28	37.000
6	8	28	48.000
7	8	20	81.000
8	4	20	100.000
9	12	20	65.000
10	4	12	90.000
11	4	23	70.000
12	4	14	61.000
13	14	23	75.000
14	14	22	69.000
15	22	23	60.000
16	12	23	20.000
17	12	22	58.000
18	1	12	54.000
19	12	18	86.000
20	18	22	124.000
21	3	22	105.000
22	8	26	41.000
23	18	26	67.000
24	1	18	78.000
25	3	18	62.000
26	3	6	56.000
27	3	10	46.000
28	10	18	93.000
29	18	29	64.000
30	26	29	77.000
31	10	29	94.000
32	27	29	52.000
33	19	29	79.000
34	19	27	36.000
35	10	27	57.000
36	7	27	49.000
37	24	27	85.000
38	7	10	47.000
39	9	10	87.000
40	6	10	34.000
41	6	17	104.000
42	6	9	61.000
43	7	9	67.000
44	7	24	46.000
45	9	24	60.000
46	2	24	33.000
47	2	9	60.000
48	9	17	56.000
49	2	17	77.000
50	11	17	55.000
51	2	11	101.000
52	5	11	69.000
53	2	5	37.000
54	5	15	19.000
55	2	15	51.000
56	15	24	84.000
57	19	24	73.000
58	19	30	60.000
59	29	30	83.000

FIGURE 15

(continued, page 3)

60	16	30	58.000
61	25	30	120.000
62	13	16	66.000
63	16	25	92.000
64	13	21	60.000
65	13	25	46.000
66	21	25	52.000
67	8	25	106.000
68	25	29	147.000
69	5	17	74.000
70	5	9	92.000
71	2	7	66.000
72	7	6	60.000
73	19	10	79.000
74	3	27	78.000
75	3	12	137.000
76	3	29	92.000
77	18	27	94.000
78	27	30	70.000
79	16	21	126.000
80	8	18	108.000
81	7	19	59.000
82	4	22	106.000
83	20	23	76.000
84	18	20	118.000
85	12	26	69.000
86	1	8	51.000
87	12	28	61.000
88	20	26	52.000
89	1	29	93.000
90	8	29	107.000

DISTANCE MATRIX

	1	2	3	4	5	6	7	8	9	10
1	0.0	260.00	140.00	138.00	297.00	196.00	194.00	51.00	257.00	171.00
2	260.00	0.0	159.00	370.00	37.00	121.00	66.00	274.00	60.00	113.00
3	140.00	159.00	0.0	211.00	196.00	56.00	93.00	170.00	117.00	46.00
4	138.00	370.00	211.00	0.0	407.00	267.00	304.00	181.00	328.00	257.00
5	297.00	37.00	196.00	407.00	0.0	153.00	103.00	311.00	92.00	150.00
6	196.00	121.00	56.00	267.00	153.00	0.0	60.00	226.00	61.00	34.00
7	194.00	66.00	93.00	304.00	103.00	60.00	0.0	208.00	67.00	47.00
8	51.00	274.00	170.00	181.00	311.00	226.00	208.00	0.0	275.00	201.00
9	257.00	60.00	117.00	328.00	92.00	61.00	67.00	275.00	0.0	87.00
10	171.00	113.00	46.00	257.00	150.00	34.00	47.00	201.00	87.00	0.0
11	355.00	101.00	215.00	426.00	69.00	159.00	167.00	375.00	111.00	193.00
12	54.00	292.00	137.00	90.00	329.00	193.00	226.00	105.00	254.00	179.00
13	203.00	290.00	272.00	333.00	327.00	285.00	243.00	152.00	310.00	251.00
14	149.00	333.00	174.00	61.00	370.00	230.00	267.00	200.00	291.00	220.00
15	311.00	51.00	210.00	421.00	19.00	172.00	117.00	325.00	111.00	164.00
16	234.00	224.00	206.00	370.00	261.00	219.00	177.00	198.00	244.00	185.00
17	300.00	77.00	160.00	371.00	74.00	104.00	123.00	330.00	56.00	138.00
18	78.00	206.00	62.00	176.00	243.00	118.00	140.00	108.00	179.00	93.00
19	172.00	106.00	114.00	306.00	143.00	113.00	59.00	186.00	126.00	79.00
20	38.00	296.00	178.00	100.00	333.00	234.00	230.00	81.00	295.00	209.00
21	209.00	338.00	291.00	339.00	375.00	327.00	291.00	158.00	358.00	293.00
22	112.00	264.00	105.00	106.00	301.00	161.00	198.00	163.00	222.00	151.00
23	74.00	312.00	157.00	70.00	349.00	213.00	246.00	125.00	274.00	199.00
24	230.00	33.00	139.00	350.00	70.00	106.00	46.00	244.00	60.00	93.00
25	157.00	286.00	239.00	287.00	323.00	275.00	239.00	106.00	306.00	241.00
26	16.00	244.00	129.00	152.00	281.00	185.00	178.00	41.00	245.00	160.00
27	145.00	115.00	78.00	270.00	152.00	91.00	49.00	159.00	116.00	57.00
28	7.00	259.00	144.00	137.00	296.00	200.00	193.00	48.00	260.00	175.00
29	93.00	167.00	92.00	229.00	204.00	128.00	101.00	107.00	168.00	94.00
30	176.00	166.00	148.00	312.00	203.00	161.00	119.00	190.00	186.00	127.00

FIGURE 15

(continued, page 4)

DISTANCE MATRIX

	11	12	13	14	15	16	17	18	19	20
1	355.00	54.00	203.00	149.00	311.00	234.00	300.00	78.00	172.00	38.00
2	101.00	292.00	290.00	333.00	51.00	224.00	77.00	206.00	106.00	296.00
3	215.00	137.00	272.00	174.00	210.00	206.00	160.00	62.00	114.00	178.00
4	426.00	90.00	333.00	61.00	421.00	370.00	371.00	176.00	306.00	100.00
5	69.00	329.00	327.00	370.00	19.00	261.00	74.00	243.00	143.00	333.00
6	159.00	193.00	285.00	230.00	172.00	219.00	104.00	118.00	113.00	234.00
7	167.00	226.00	243.00	267.00	117.00	177.00	123.00	140.00	59.00	230.00
8	375.00	105.00	152.00	200.00	325.00	198.00	330.00	108.00	186.00	81.00
9	111.00	254.00	310.00	291.00	111.00	244.00	56.00	179.00	126.00	295.00
10	193.00	179.00	251.00	220.00	164.00	185.00	138.00	93.00	79.00	209.00
11	0.0	352.00	391.00	389.00	88.00	325.00	55.00	277.00	207.00	393.00
12	352.00	0.0	257.00	95.00	343.00	287.00	297.00	86.00	216.00	65.00
13	391.00	257.00	0.0	352.00	341.00	66.00	366.00	257.00	184.00	233.00
14	389.00	95.00	352.00	0.0	384.00	380.00	334.00	181.00	288.00	151.00
15	88.00	343.00	341.00	384.00	0.0	275.00	93.00	257.00	157.00	347.00
16	325.00	287.00	66.00	380.00	275.00	0.0	300.00	205.00	118.00	270.00
17	55.00	297.00	366.00	334.00	93.00	300.00	0.0	222.00	182.00	338.00
18	277.00	86.00	257.00	181.00	257.00	205.00	222.00	0.0	130.00	116.00
19	207.00	216.00	184.00	288.00	157.00	118.00	182.00	130.00	0.0	208.00
20	393.00	65.00	233.00	151.00	347.00	270.00	338.00	116.00	208.00	0.0
21	439.00	263.00	60.00	358.00	389.00	126.00	414.00	263.00	232.00	239.00
22	320.00	58.00	315.00	69.00	315.00	311.00	265.00	124.00	219.00	123.00
23	372.00	20.00	277.00	75.00	363.00	307.00	317.00	106.00	236.00	76.00
24	134.00	265.00	257.00	313.00	84.00	191.00	110.00	179.00	73.00	266.00
25	387.00	211.00	46.00	306.00	337.00	92.00	362.00	211.00	180.00	187.00
26	344.00	69.00	193.00	164.00	295.00	218.00	289.00	67.00	156.00	52.00
27	216.00	180.00	194.00	252.00	166.00	128.00	172.00	94.00	36.00	181.00
28	359.00	61.00	200.00	156.00	310.00	233.00	304.00	82.00	171.00	37.00
29	268.00	146.00	193.00	241.00	218.00	141.00	224.00	64.00	79.00	129.00
30	267.00	229.00	124.00	322.00	217.00	58.00	242.00	147.00	60.00	212.00

FIGURE 15

(continued, page 5)

DISTANCE MATRIX

	21	22	23	24	25	26	27	28	29	30
1	209.00	112.00	74.00	230.00	157.00	16.00	145.00	7.00	93.00	176.00
2	338.00	264.00	312.00	33.00	286.00	244.00	115.00	259.00	167.00	166.00
3	291.00	105.00	157.00	139.00	239.00	129.00	78.00	144.00	92.00	148.00
4	339.00	106.00	70.00	350.00	287.00	152.00	270.00	137.00	229.00	312.00
5	375.00	301.00	349.00	70.00	323.00	281.00	152.00	296.00	204.00	203.00
6	327.00	161.00	213.00	106.00	275.00	185.00	91.00	200.00	128.00	161.00
7	291.00	198.00	246.00	46.00	239.00	178.00	49.00	193.00	101.00	119.00
8	158.00	163.00	125.00	244.00	106.00	41.00	159.00	48.00	107.00	190.00
9	358.00	222.00	274.00	60.00	306.00	245.00	116.00	260.00	168.00	186.00
10	293.00	151.00	199.00	93.00	241.00	160.00	57.00	175.00	94.00	127.00
11	439.00	320.00	372.00	134.00	387.00	344.00	216.00	359.00	268.00	267.00
12	263.00	58.00	20.00	265.00	211.00	69.00	180.00	61.00	146.00	229.00
13	60.00	315.00	277.00	257.00	46.00	193.00	194.00	200.00	193.00	124.00
14	358.00	69.00	75.00	313.00	306.00	164.00	252.00	156.00	241.00	322.00
15	389.00	315.00	363.00	84.00	337.00	295.00	166.00	310.00	218.00	217.00
16	120.00	311.00	307.00	191.00	92.00	218.00	128.00	233.00	141.00	58.00
17	414.00	265.00	317.00	110.00	362.00	289.00	172.00	304.00	224.00	242.00
18	263.00	124.00	106.00	179.00	211.00	67.00	94.00	82.00	64.00	147.00
19	232.00	219.00	236.00	73.00	180.00	156.00	36.00	171.00	79.00	60.00
20	239.00	123.00	76.00	266.00	187.00	52.00	181.00	37.00	129.00	212.00
21	0.0	321.00	283.00	305.00	52.00	199.00	242.00	206.00	199.00	172.00
22	321.00	0.0	60.00	244.00	269.00	127.00	183.00	119.00	188.00	253.00
23	283.00	60.00	0.0	285.00	231.00	89.00	200.00	81.00	166.00	249.00
24	305.00	244.00	285.00	0.0	253.00	214.00	85.00	229.00	137.00	133.00
25	52.00	269.00	231.00	253.00	0.0	147.00	190.00	154.00	147.00	120.00
26	199.00	127.00	89.00	214.00	147.00	0.0	129.00	15.00	77.00	160.00
27	242.00	183.00	200.00	85.00	190.00	129.00	0.0	144.00	52.00	70.00
28	206.00	119.00	81.00	229.00	154.00	15.00	144.00	0.0	92.00	175.00
29	199.00	188.00	166.00	137.00	147.00	77.00	52.00	92.00	0.0	83.00
30	172.00	253.00	249.00	133.00	120.00	160.00	70.00	175.00	83.00	0.0

FIGURE 15

(continued, page 6)

FIGURE 15

(continued, page 7)

```
SUBPROGRAM MATBLD HAS BEEN CALLED TO GENERATE A COVER MATRIX
   THE MAXIMUM DISTANCE/TIME OF  75.00 HAS BEEN UTILIZED
```

FIGURE 15

(continued, page 8)

```
 1  100000010001000000010010010100
 2  010010101000001000000001000000
 3  001001000100000001000000000000
 4  000100000000010000000010000000
 5  010010000010001010000001000000
 6  001001101100000000000000000000
 7  010001101100000000100001001000
 8  100000010000000000000000010100
 9  010001101000000010000001000000
10  001001100100000000000000001000
11  000010000010000010000000000000
12  100000000001000000010110010100
13  000000000000100100001000100000
14  000100000000010000000110000000
15  010010000000001000000000000000
16  000000000000100100000000000001
17  000010001010000001000000000000
18  001000000000000001000000010010
19  000000100000000000100001001001
20  100000000001000000010000010100
21  000000000000100000001000100000
22  000000000001010000000110000000
23  100100000001010000000110000000
24  010010101000000000100001000000
25  000000000000100000001000100000
26  100000010001000000101000010100
27  000000100100000000100000001011
28  100000010001000000010000010100
29  000000000000000001000000001010
30  000000000000000100100000001001
     1 CAN BE SERVED BY      1
     1 CAN BE SERVED BY      8
     1 CAN BE SERVED BY     12
     1 CAN BE SERVED BY     20
     1 CAN BE SERVED BY     23
     1 CAN BE SERVED BY     26
     1 CAN BE SERVED BY     28
     2 CAN BE SERVED BY      2
     2 CAN BE SERVED BY      5
     2 CAN BE SERVED BY      7
     2 CAN BE SERVED BY      9
     2 CAN BE SERVED BY     15
     2 CAN BE SERVED BY     24
     3 CAN BE SERVED BY      3
     3 CAN BE SERVED BY      6
     3 CAN BE SERVED BY     10
     3 CAN BE SERVED BY     18
     4 CAN BE SERVED BY      4
     4 CAN BE SERVED BY     14
     4 CAN BE SERVED BY     23
     5 CAN BE SERVED BY      2
     5 CAN BE SERVED BY      5
     5 CAN BE SERVED BY     11
     5 CAN BE SERVED BY     15
     5 CAN BE SERVED BY     17
     5 CAN BE SERVED BY     24
     6 CAN BE SERVED BY      3
     6 CAN BE SERVED BY      6
     6 CAN BE SERVED BY      7
     6 CAN BE SERVED BY      9
```

FIGURE 15

(continued, page 9)

```
 6 CAN BE SERVED BY    10
 7 CAN BE SERVED BY     2
 7 CAN BE SERVED BY     6
 7 CAN BE SERVED BY     7
 7 CAN BE SERVED BY     9
 7 CAN BE SERVED BY    10
 7 CAN BE SERVED BY    19
 7 CAN BE SERVED BY    24
 7 CAN BE SERVED BY    27
 8 CAN BE SERVED BY     1
 8 CAN BE SERVED BY     8
 8 CAN BE SERVED BY    26
 8 CAN BE SERVED BY    28
 9 CAN BE SERVED BY     2
 9 CAN BE SERVED BY     6
 9 CAN BE SERVED BY     7
 9 CAN BE SERVED BY     9
 9 CAN BE SERVED BY    17
 9 CAN BE SERVED BY    24
10 CAN BE SERVED BY     3
10 CAN BE SERVED BY     6
10 CAN BE SERVED BY     7
10 CAN BE SERVED BY    10
10 CAN BE SERVED BY    27
11 CAN BE SERVED BY     5
11 CAN BE SERVED BY    11
11 CAN BE SERVED BY    17
12 CAN BE SERVED BY     1
12 CAN BE SERVED BY    12
12 CAN BE SERVED BY    20
12 CAN BE SERVED BY    22
12 CAN BE SERVED BY    23
12 CAN BE SERVED BY    26
12 CAN BE SERVED BY    28
13 CAN BE SERVED BY    13
13 CAN BE SERVED BY    16
13 CAN BE SERVED BY    21
13 CAN BE SERVED BY    25
14 CAN BE SERVED BY     4
14 CAN BE SERVED BY    14
14 CAN BE SERVED BY    22
14 CAN BE SERVED BY    23
15 CAN BE SERVED BY     2
15 CAN BE SERVED BY     5
15 CAN BE SERVED BY    15
16 CAN BE SERVED BY    13
16 CAN BE SERVED BY    16
16 CAN BE SERVED BY    30
17 CAN BE SERVED BY     5
17 CAN BE SERVED BY     9
17 CAN BE SERVED BY    11
17 CAN BE SERVED BY    17
18 CAN BE SERVED BY     3
18 CAN BE SERVED BY    18
18 CAN BE SERVED BY    26
18 CAN BE SERVED BY    29
19 CAN BE SERVED BY     7
19 CAN BE SERVED BY    19
19 CAN BE SERVED BY    24
19 CAN BE SERVED BY    27
19 CAN BE SERVED BY    30
```

FIGURE 15 •

(continued, page 10)

```
20 CAN BE SERVED BY     1
20 CAN BE SERVED BY    12
20 CAN BE SERVED BY    20
20 CAN BE SERVED BY    26
20 CAN BE SERVED BY    28
21 CAN BE SERVED BY    13
21 CAN BE SERVED BY    21
21 CAN BE SERVED BY    25
22 CAN BE SERVED BY    12
22 CAN BE SERVED BY    14
22 CAN BE SERVED BY    22
22 CAN BE SERVED BY    23
23 CAN BE SERVED BY     1
23 CAN BE SERVED BY     4
23 CAN BE SERVED BY    12
23 CAN BE SERVED BY    14
23 CAN BE SERVED BY    22
23 CAN BE SERVED BY    23
24 CAN BE SERVED BY     2
24 CAN BE SERVED BY     5
24 CAN BE SERVED BY     7
24 CAN BE SERVED BY     9
24 CAN BE SERVED BY    19
24 CAN BE SERVED BY    24
25 CAN BE SERVED BY    13
25 CAN BE SERVED BY    21
25 CAN BE SERVED BY    25
26 CAN BE SERVED BY     1
26 CAN BE SERVED BY     8
26 CAN BE SERVED BY    12
26 CAN BE SERVED BY    18
26 CAN BE SERVED BY    20
26 CAN BE SERVED BY    26
26 CAN BE SERVED BY    28
27 CAN BE SERVED BY     7
27 CAN BE SERVED BY    10
27 CAN BE SERVED BY    19
27 CAN BE SERVED BY    27
27 CAN BE SERVED BY    29
27 CAN BE SERVED BY    30
28 CAN BE SERVED BY     1
28 CAN BE SERVED BY     8
28 CAN BE SERVED BY    12
28 CAN BE SERVED BY    20
28 CAN BE SERVED BY    26
28 CAN BE SERVED BY    28
29 CAN BE SERVED BY    18
29 CAN BE SERVED BY    27
29 CAN BE SERVED BY    29
30 CAN BE SERVED BY    16
30 CAN BE SERVED BY    19
30 CAN BE SERVED BY    27
30 CAN BE SERVED BY    30
```

FIGURE 15

(continued, page 11)

```
THE FOLLOWING NODES WILL NOT BE CONSIDERED AS POTENTIAL FACILITY SITES:
  3-NG,   8-NG,  20-NE,  25-NE,  14-SP,
*****************************************************************************
```

FIGURE 15

(continued, page 12)

```
   ITERATION NUMBER,    1
 THIS IS EXAMPLE NUMBER THREE-NETWORK

   NUMBER OF FACILITIES   1
   SERVICE DISTANCE =    75.000

   NEW FACILITY LOCATION NUMBER     7

   FACILITIES ARE LOCATED AT     7,
   ---------------------------------------------------------------------------
   POPULATION SERVED     190.00          PERCENT OF TOTAL POPULATION SERVED   32.76
   ---------------------------------------------------------------------------
THE FACILITY LOCATED AT:   7 CAN COVER THE FOLLOWING  DEMANDS:
  2,   6,   7,   9,  10,  19,  24,  27,
DEMAND POINT      CAN BE COVERED BY FACILITIES AT:
        1        NO CURRENT FACILITY LOCATION
        2          7,
        3        NO CURRENT FACILITY LOCATION
        4        NO CURRENT FACILITY LOCATION
        5        NO CURRENT FACILITY LOCATION
        6          7,
        7          7,
        8        NO CURRENT FACILITY LOCATION
        9          7,
       10          7,
       11        NO CURRENT FACILITY LOCATION
       12        NO CURRENT FACILITY LOCATION
       13        NO CURRENT FACILITY LOCATION
       14        NO CURRENT FACILITY LOCATION
       15        NO CURRENT FACILITY LOCATION
       16        NO CURRENT FACILITY LOCATION
       17        NO CURRENT FACILITY LOCATION
       18        NO CURRENT FACILITY LOCATION
       19          7,
       20        NO CURRENT FACILITY LOCATION
       21        NO CURRENT FACILITY LOCATION
       22        NO CURRENT FACILITY LOCATION
       23        NO CURRENT FACILITY LOCATION
       24          7,
       25        NO CURRENT FACILITY LOCATION
       26        NO CURRENT FACILITY LOCATION
       27          7,
       28        NO CURRENT FACILITY LOCATION
       29        NO CURRENT FACILITY LOCATION
       30        NO CURRENT FACILITY LOCATION
```

```
THIS IS EXAMPLE NUMBER THREE-NETWORK

FACILITIES ARE LOCATED AT     7,
PRIMARY DISTANCE    = 75.00
SECONDARY DISTANCE =100.00
*****************************************************************************************************************
          *         *PRIMARY*SECONDARY*POPULATION*POPULATION*LARGEST,*       *WT.DIST*WT.DIST. *WT.DIST* TOTAL  *
PARTITION*FACILITY*SERVED * SERVED  * OUTSIDE  *    IN    *TRAVELED* NODE *PRIMARY*SECONDARY*OUTSIDE*WEIGHTED*
 NUMBER  * NUMBER *  POP. *  POP.   *SECONDARY *PARTITION *DISTANCE*NUMBER*COVERED* COVERED *PRIMARY*DISTANCE*
    1         7     190.00     25.00     365.00     580.00    304.0     4   8488.0    2325.0  71513.   80001.
*****************************************************************************************************************
                    190.00     25.00     365.00     580.00                 8488.0    2325.0   71513.    80001.
PARTITION  1  FACILITY   7
**   1 D= 194.0**   2 D=  66.0**   3 D=  93.0**   4 D= 304.0**   5 D= 103.0**   6 D=  60.0

*   7 D=   0.0**   8 D= 208.0**   9 D=  67.0**  10 D=  47.0**  11 D= 167.0**  12 D= 226.0

*  13 D= 243.0**  14 D= 267.0**  15 D= 117.0**  16 D= 177.0**  17 D= 123.0**  18 D= 140.0

*  19 D=  59.0**  20 D= 230.0**  21 D= 291.0**  22 D= 198.0**  23 D= 246.0**  24 D=  46.0

*  25 D= 239.0**  26 D= 178.0**  27 D=  49.0**  28 D= 193.0**  29 D= 101.0**  30 D= 119.0
```

FIGURE 15

(continued, page 13)

FIGURE 15

(continued, page 14)

```
   ITERATION NUMBER,    2
 THIS IS EXAMPLE NUMBER THREE-NETWORK

   NUMBER OF FACILITIES   2
   SERVICE DISTANCE =    75.000

   NEW FACILITY LOCATION NUMBER    26

   FACILITIES ARE LOCATED AT     7,   26,
   ---------------------------------------------------------------------------
   POPULATION SERVED     320.00          PERCENT OF TOTAL POPULATION SERVED   55.17
   ---------------------------------------------------------------------------
THE FACILITY LOCATED AT:   7 CAN COVER THE FOLLOWING  DEMANDS:
  2,   6,   7,   9,  10,  19,  24,  27,
THE FACILITY LOCATED AT:  26 CAN COVER THE FOLLOWING  DEMANDS:
  1,   8,  12,  18,  20,  26,  28,
DEMAND POINT      CAN BE COVERED BY FACILITIES AT:
        1          26,
        2           7,
        3        NO CURRENT FACILITY LOCATION
        4        NO CURRENT FACILITY LOCATION
        5        NO CURRENT FACILITY LOCATION
        6           7,
        7           7,
        8          26,
        9           7,
       10           7,
       11        NO CURRENT FACILITY LOCATION
       12          26,
       13        NO CURRENT FACILITY LOCATION
       14        NO CURRENT FACILITY LOCATION
       15        NO CURRENT FACILITY LOCATION
       16        NO CURRENT FACILITY LOCATION
       17        NO CURRENT FACILITY LOCATION
       18          26,
       19           7,
       20          26,
       21        NO CURRENT FACILITY LOCATION
       22        NO CURRENT FACILITY LOCATION
       23        NO CURRENT FACILITY LOCATION
       24           7,
       25        NO CURRENT FACILITY LOCATION
       26          26,
       27           7,
       28          26,
       29        NO CURRENT FACILITY LOCATION
       30        NO CURRENT FACILITY LOCATION
```

THIS IS EXAMPLE NUMBER THREE-NETWORK

FACILITIES ARE LOCATED AT 7, 26,
PRIMARY DISTANCE = 75.00
SECONDARY DISTANCE =100.00

PARTITION NUMBER	FACILITY NUMBER	PRIMARY SERVED POP.	SECONDARY SERVED POP.	POPULATION OUTSIDE SECONDARY	POPULATION IN PARTITION	LARGEST, TRAVELED DISTANCE	NODE NUMBER	WT.DIST PRIMARY COVERED	WT.DIST. SECONDARY COVERED	WT.DIST OUTSIDE PRIMARY	TOTAL WEIGHTED DISTANCE
1	7	190.00	25.00	87.00	302.00	177.0	16	8488.0	2325.0	14126.	22614.
2	26	130.00	45.00	103.00	278.00	199.0	21	5375.0	3585.0	20901.	26276.
		320.00	70.00	190.00	580.00			13863.0	5910.0	35027.	48890.

PARTITION 1 FACILITY 7
** 2 D= 66.0** 3 D= 93.0** 5 D= 103.0** 6 D= 60.0** 7 D= 0.0** 9 D= 67.0

* 10 D= 47.0** 11 D= 167.0** 15 D= 117.0** 16 D= 177.0** 17 D= 123.0** 19 D= 59.0

* 24 D= 46.0** 27 D= 49.0** 30 D= 119.0**

PARTITION 2 FACILITY 26
** 1 D= 16.0** 4 D= 152.0** 8 D= 41.0** 12 D= 69.0** 13 D= 193.0** 14 D= 164.0

* 18 D= 67.0** 20 D= 52.0** 21 D= 199.0** 22 D= 127.0** 23 D= 89.0** 25 D= 147.0

* 26 D= 0.0** 28 D= 15.0** 29 D= 77.0**

FIGURE 15

(continued, page 15)

FIGURE 15

(continued, page 16)

```
   ITERATION NUMBER,    3
THIS IS EXAMPLE NUMBER THREE-NETWORK

   NUMBER OF FACILITIES   3
   SERVICE DISTANCE =    75.000

   NEW FACILITY LOCATION NUMBER    13

   FACILITIES ARE LOCATED AT     7,   26,   13,
   ---------------------------------------------------------------------------
   POPULATION SERVED     395.00          PERCENT OF TOTAL POPULATION SERVED   68.10
   ---------------------------------------------------------------------------
THE FACILITY LOCATED AT:   7 CAN COVER THE FOLLOWING  DEMANDS:
  2,   6,   7,   9,  10,  19,  24,  27,
THE FACILITY LOCATED AT:  26 CAN COVER THE FOLLOWING  DEMANDS:
  1,   8,  12,  18,  20,  26,  28,
THE FACILITY LOCATED AT:  13 CAN COVER THE FOLLOWING  DEMANDS:
 13,  16,  21,  25,
DEMAND POINT      CAN BE COVERED BY FACILITIES AT:
        1          26,
        2           7,
        3        NO CURRENT FACILITY LOCATION
        4        NO CURRENT FACILITY LOCATION
        5        NO CURRENT FACILITY LOCATION
        6           7,
        7           7,
        8          26,
        9           7,
       10           7,
       11        NO CURRENT FACILITY LOCATION
       12          26,
       13          13,
       14        NO CURRENT FACILITY LOCATION
       15        NO CURRENT FACILITY LOCATION
       16          13,
       17        NO CURRENT FACILITY LOCATION
       18          26,
       19           7,
       20          26,
       21          13,
       22        NO CURRENT FACILITY LOCATION
       23        NO CURRENT FACILITY LOCATION
       24           7,
       25          13,
       26          26,
       27           7,
       28          26,
       29        NO CURRENT FACILITY LOCATION
       30        NO CURRENT FACILITY LOCATION
```

THIS IS EXAMPLE NUMBER THREE-NETWORK

FACILITIES ARE LOCATED AT 7, 26, 13,
PRIMARY DISTANCE = 75.00
SECONDARY DISTANCE =100.00

PARTITION NUMBER	FACILITY NUMBER	PRIMARY SERVED POP.	SECONDARY SERVED POP.	POPULATION OUTSIDE SECONDARY	POPULATION IN PARTITION	LARGEST DISTANCE	NODE NUMBER	WT.DIST PRIMARY COVERED	WT.DIST. SECONDARY COVERED	WT.DIST OUTSIDE PRIMARY	TOTAL WEIGHTED DISTANCE
1	7	190.00	25.00	67.00	282.00	167.0	11	8488.0	2325.0	10586.	19074.
2	26	130.00	45.00	48.00	223.00	164.0	14	5375.0	3585.0	10686.	16061.
3	13	75.00	0.0	0.0	75.00	66.0	16	2380.0	0.0	0.	2380.
		395.00	70.00	115.00	580.00			16243.0	5910.0	21272.	37515.

PARTITION 1 FACILITY 7
** 2 D= 66.0** 3 D= 93.0** 5 D= 103.0** 6 D= 60.0** 7 D= 0.0** 9 D= 67.0

* 10 D= 47.0** 11 D= 167.0** 15 D= 117.0** 17 D= 123.0** 19 D= 59.0** 24 D= 46.0

* 27 D= 49.0** 30 D= 119.0**
PARTITION 2 FACILITY 26
** 1 D= 16.0** 4 D= 152.0** 8 D= 41.0** 12 D= 69.0** 14 D= 164.0** 18 D= 67.0

* 20 D= 52.0** 22 D= 127.0** 23 D= 89.0** 26 D= 0.0** 28 D= 15.0** 29 D= 77.0

PARTITION 3 FACILITY 13
** 13 D= 0.0** 16 D= 66.0** 21 D= 60.0** 25 D= 46.0**

FIGURE 15

(continued, page 17)

FIGURE 15

(continued, page 18)

```
   ITERATION NUMBER,    4
 THIS IS EXAMPLE NUMBER THREE-NETWORK

   NUMBER OF FACILITIES   4
   SERVICE DISTANCE =    75.000

   NEW FACILITY LOCATION NUMBER    18

   FACILITIES ARE LOCATED AT     7,   26,   13,   18,
   ---------------------------------------------------------------------------
   POPULATION SERVED     455.00          PERCENT OF TOTAL POPULATION SERVED   78.45
   ---------------------------------------------------------------------------
THE FACILITY LOCATED AT:   7 CAN COVER THE FOLLOWING  DEMANDS:
  2,   6,   7,   9,  10,  19,  24,  27,
THE FACILITY LOCATED AT:  26 CAN COVER THE FOLLOWING  DEMANDS:
  1,   8,  12,  18,  20,  26,  28,
THE FACILITY LOCATED AT:  13 CAN COVER THE FOLLOWING  DEMANDS:
 13,  16,  21,  25,
THE FACILITY LOCATED AT:  18 CAN COVER THE FOLLOWING  DEMANDS:
  3,  18,  26,  29,
DEMAND POINT      CAN BE COVERED BY FACILITIES AT:
        1         26,
        2          7,
        3         18,
        4        NO CURRENT FACILITY LOCATION
        5        NO CURRENT FACILITY LOCATION
        6          7,
        7          7,
        8         26,
        9          7,
       10          7,
       11        NO CURRENT FACILITY LOCATION
       12         26,
       13         13,
       14        NO CURRENT FACILITY LOCATION
       15        NO CURRENT FACILITY LOCATION
       16         13,
       17        NO CURRENT FACILITY LOCATION
       18         26,  18,
       19          7,
       20         26,
       21         13,
       22        NO CURRENT FACILITY LOCATION
       23        NO CURRENT FACILITY LOCATION
       24          7,
       25         13,
       26         26,  18,
       27          7,
       28         26,
       29         18,
       30        NO CURRENT FACILITY LOCATION

   SUBSTITUTION  ALGORITHM USED

   NODE      1 REPLACES FACILITY LOCATION     26
   THIS IS NOW FACILITY NUMBER      2

   FACILITIES ARE LOCATED AT     7,    1,   13,   18,
   ---------------------------------------------------
```

FIGURE 15

(continued, page 19)

```
    POPULATION SERVED      465.00          PERCENT OF TOTAL POPULATION SERVED   80.17
    ---------------------------------------------------------------------------------
THE FACILITY LOCATED AT:   7 CAN COVER THE FOLLOWING  DEMANDS:
  2,   6,   7,   9,  10,  19,  24,  27,
THE FACILITY LOCATED AT:   1 CAN COVER THE FOLLOWING  DEMANDS:
  1,   8,  12,  20,  23,  26,  28,
THE FACILITY LOCATED AT:  13 CAN COVER THE FOLLOWING  DEMANDS:
 13,  16,  21,  25,
THE FACILITY LOCATED AT:  18 CAN COVER THE FOLLOWING  DEMANDS:
  3,  18,  26,  29,
DEMAND POINT       CAN BE COVERED BY FACILITIES AT:
         1          1,
         2          7,
         3         18,
         4        NO CURRENT FACILITY LOCATION
         5        NO CURRENT FACILITY LOCATION
         6          7,
         7          7,
         8          1,
         9          7,
        10          7,
        11        NO CURRENT FACILITY LOCATION
        12          1,
        13         13,
        14        NO CURRENT FACILITY LOCATION
        15        NO CURRENT FACILITY LOCATION
        16         13,
        17        NO CURRENT FACILITY LOCATION
        18         18,
        19          7,
        20          1,
        21         13,
        22        NO CURRENT FACILITY LOCATION
        23          1,
        24          7,
        25         13,
        26          1,  18,
        27          7,
        28          1,
        29         18,
        30        NO CURRENT FACILITY LOCATION
```

THIS IS EXAMPLE NUMBER THREE-NETWORK

FACILITIES ARE LOCATED AT 7, 1, 13, 18,
PRIMARY DISTANCE = 75.00
SECONDARY DISTANCE =100.00

PARTITION NUMBER	FACILITY NUMBER	PRIMARY SERVED POP.	SECONDARY SERVED POP.	POPULATION OUTSIDE SECONDARY	POPULATION IN PARTITION	LARGEST DISTANCE	TRAVELED NODE NUMBER	WT.DIST PRIMARY COVERED	WT.DIST. SECONDARY COVERED	WT.DIST OUTSIDE PRIMARY	TOTAL WEIGHTED DISTANCE
1	7	190.00	0.0	67.00	257.00	167.0	11	8488.0	0.0	8261.	16749.
2	1	115.00	0.0	48.00	163.00	149.0	14	4310.0	0.0	6399.	10709.
3	13	75.00	0.0	0.0	75.00	66.0	16	2380.0	0.0	0.	2380.
4	18	85.00	0.0	0.0	85.00	64.0	29	3790.0	0.0	0.	3790.
		465.00	0.0	115.00	580.00			18968.0	0.0	14660.	33628.

PARTITION 1 FACILITY 7
** 2 D= 66.0** 5 D= 103.0** 6 D= 60.0** 7 D= 0.0** 9 D= 67.0** 10 D= 47.0

* 11 D= 167.0** 15 D= 117.0** 17 D= 123.0** 19 D= 59.0** 24 D= 46.0** 27 D= 49.0

* 30 D= 119.0**
PARTITION 2 FACILITY 1
** 1 D= 0.0** 4 D= 138.0** 8 D= 51.0** 12 D= 54.0** 14 D= 149.0** 20 D= 38.0

* 22 D= 112.0** 23 D= 74.0** 26 D= 16.0** 28 D= 7.0**
PARTITION 3 FACILITY 13
** 13 D= 0.0** 16 D= 66.0** 21 D= 60.0** 25 D= 46.0**
PARTITION 4 FACILITY 18
** 3 D= 62.0** 18 D= 0.0** 29 D= 64.0**

FIGURE 15

(continued, page 20)

FIGURE 15

(continued, page 21)

```
   ITERATION NUMBER,    5
THIS IS EXAMPLE NUMBER THREE-NETWORK

   NUMBER OF FACILITIES   5
   SERVICE DISTANCE =    75.000

   NEW FACILITY LOCATION NUMBER     5

   FACILITIES ARE LOCATED AT     7,    1,   13,   18,    5,
   ---------------------------------------------------------------------------
   POPULATION SERVED     517.00          PERCENT OF TOTAL POPULATION SERVED   89.14
   ---------------------------------------------------------------------------
THE FACILITY LOCATED AT:   7 CAN COVER THE FOLLOWING  DEMANDS:
  2,   6,   7,   9,  10,  19,  24,  27,
THE FACILITY LOCATED AT:   1 CAN COVER THE FOLLOWING  DEMANDS:
  1,   8,  12,  20,  23,  26,  28,
THE FACILITY LOCATED AT:  13 CAN COVER THE FOLLOWING  DEMANDS:
 13,  16,  21,  25,
THE FACILITY LOCATED AT:  18 CAN COVER THE FOLLOWING  DEMANDS:
  3,  18,  26,  29,
THE FACILITY LOCATED AT:   5 CAN COVER THE FOLLOWING  DEMANDS:
  2,   5,  11,  15,  17,  24,
DEMAND POINT      CAN BE COVERED BY FACILITIES AT:
         1          1,
         2          7,   5,
         3         18,
         4        NO CURRENT FACILITY LOCATION
         5          5,
         6          7,
         7          7,
         8          1,
         9          7,
        10          7,
        11          5,
        12          1,
        13         13,
        14        NO CURRENT FACILITY LOCATION
        15          5,
        16         13,
        17          5,
        18         18,
        19          7,
        20          1,
        21         13,
        22        NO CURRENT FACILITY LOCATION
        23          1,
        24          7,   5,
        25         13,
        26          1,  18,
        27          7,
        28          1,
        29         18,
        30        NO CURRENT FACILITY LOCATION
```

THIS IS EXAMPLE NUMBER THREE-NETWORK

FACILITIES ARE LOCATED AT 7, 1, 13, 18, 5,
PRIMARY DISTANCE = 75.00
SECONDARY DISTANCE =100.00

PARTITION NUMBER	FACILITY NUMBER	PRIMARY SERVED POP.	SECONDARY SERVED POP.	POPULATION OUTSIDE SECONDARY	POPULATION IN PARTITION	LARGEST TRAVELED DISTANCE	NODE NUMBER	WT.DIST PRIMARY COVERED	WT.DIST. SECONDARY COVERED	WT.DIST OUTSIDE PRIMARY	TOTAL WEIGHTED DISTANCE
1	7	170.00	0.0	15.00	185.00	119.0	30	7168.0	0.0	1785.	8953.
2	1	115.00	0.0	48.00	163.00	149.0	14	4310.0	0.0	6399.	10709.
3	13	75.00	0.0	0.0	75.00	66.0	16	2380.0	0.0	0.	2380.
4	18	85.00	0.0	0.0	85.00	64.0	29	3790.0	0.0	0.	3790.
5	5	72.00	0.0	0.0	72.00	74.0	17	2550.0	0.0	0.	2550.
		517.00	0.0	63.00	580.00			20198.0	0.0	8184.	28382.

PARTITION 1 FACILITY 7
** 6 D= 60.0** 7 D= 0.0** 9 D= 67.0** 10 D= 47.0** 19 D= 59.0** 24 D= 46.0

* 27 D= 49.0** 30 D= 119.0**
PARTITION 2 FACILITY 1
** 1 D= 0.0** 4 D= 138.0** 8 D= 51.0** 12 D= 54.0** 14 D= 149.0** 20 D= 38.0

* 22 D= 112.0** 23 D= 74.0** 26 D= 16.0** 28 D= 7.0**
PARTITION 3 FACILITY 13
** 13 D= 0.0** 16 D= 66.0** 21 D= 60.0** 25 D= 46.0**
PARTITION 4 FACILITY 18
** 3 D= 62.0** 18 D= 0.0** 29 D= 64.0**
PARTITION 5 FACILITY 5
** 2 D= 37.0** 5 D= 0.0** 11 D= 69.0** 15 D= 19.0** 17 D= 74.0**

FIGURE 15

(continued, page 22)

FIGURE 15

(continued, page 23)

```
   ITERATION NUMBER,    6
 THIS IS EXAMPLE NUMBER THREE-NETWORK

   NUMBER OF FACILITIES   6
   SERVICE DISTANCE =    75.000

   NEW FACILITY LOCATION NUMBER    23

   FACILITIES ARE LOCATED AT     7,    1,   13,   18,    5,   23,
   ---------------------------------------------------------------------------
   POPULATION SERVED     565.00          PERCENT OF TOTAL POPULATION SERVED   97.61
   ---------------------------------------------------------------------------
THE FACILITY LOCATED AT:   7 CAN COVER THE FOLLOWING  DEMANDS:
  2,   6,   7,   9,  10,  19,  24,  27,
THE FACILITY LOCATED AT:   1 CAN COVER THE FOLLOWING  DEMANDS:
  1,   8,  12,  20,  23,  26,  28,
THE FACILITY LOCATED AT:  13 CAN COVER THE FOLLOWING  DEMANDS:
 13,  16,  21,  25,
THE FACILITY LOCATED AT:  18 CAN COVER THE FOLLOWING  DEMANDS:
  3,  18,  26,  29,
THE FACILITY LOCATED AT:   5 CAN COVER THE FOLLOWING  DEMANDS:
  2,   5,  11,  15,  17,  24,
THE FACILITY LOCATED AT:  23 CAN COVER THE FOLLOWING  DEMANDS:
  1,   4,  12,  14,  22,  23,
DEMAND POINT       CAN BE COVERED BY FACILITIES AT:
         1          1,  23,
         2          7,   5,
         3         18,
         4         23,
         5          5,
         6          7,
         7          7,
         8          1,
         9          7,
        10          7,
        11          5,
        12          1,  23,
        13         13,
        14         23,
        15          5,
        16         13,
        17          5,
        18         18,
        19          7,
        20          1,
        21         13,
        22         23,
        23          1,  23,
        24          7,   5,
        25         13,
        26          1,  18,
        27          7,
        28          1,
        29         18,
        30        NO CURRENT FACILITY LOCATION
```

THIS IS EXAMPLE NUMBER THREE-NETWORK

FACILITIES ARE LOCATED AT 7, 1, 13, 18, 5, 23,
PRIMARY DISTANCE = 75.00
SECONDARY DISTANCE =100.00

PARTITION NUMBER	FACILITY NUMBER	PRIMARY SERVED POP.	SECONDARY SERVED POP.	POPULATION OUTSIDE SECONDARY	POPULATION IN PARTITION	LARGEST TRAVELED DISTANCE	NODE NUMBER	WT.DIST PRIMARY COVERED	WT.DIST. SECONDARY COVERED	WT.DIST OUTSIDE PRIMARY	TOTAL WEIGHTED DISTANCE
1	7	170.00	0.0	15.00	185.00	119.0	30	7168.0	0.0	1785.	8953.
2	1	85.00	0.0	0.0	85.00	51.0	8	2490.0	0.0	0.	2490.
3	13	75.00	0.0	0.0	75.00	66.0	16	2380.0	0.0	0.	2380.
4	18	85.00	0.0	0.0	85.00	64.0	29	3790.0	0.0	0.	3790.
5	5	72.00	0.0	0.0	72.00	74.0	17	2550.0	0.0	0.	2550.
6	23	78.00	0.0	0.0	78.00	75.0	14	3685.0	0.0	0.	3685.
		565.00	0.0	15.00	580.00			22063.0	0.0	1785.	23848.

PARTITION 1 FACILITY 7
** 6 D= 60.0** 7 D= 0.0** 9 D= 67.0** 10 D= 47.0** 19 D= 59.0** 24 D= 46.0

* 27 D= 49.0** 30 D= 119.0**
PARTITION 2 FACILITY 1
** 1 D= 0.0** 8 D= 51.0** 20 D= 38.0** 26 D= 16.0** . 28 D= 7.0**
PARTITION 3 FACILITY 13
** 13 D= 0.0** 16 D= 66.0** 21 D= 60.0** 25 D= 46.0**
PARTITION 4 FACILITY 18
** 3 D= 62.0** 18 D= 0.0** 29 D= 64.0**
PARTITION 5 FACILITY 5
** 2 D= 37.0** 5 D= 0.0** 11 D= 69.0** 15 D= 19.0** 17 D= 74.0**
PARTITION 6 FACILITY 23
** 4 D= 70.0** 12 D= 20.0** 14 D= 75.0** 22 D= 60.0** 23 D= 0.0**

FIGURE 15

(continued, page 24

FIGURE 15

(continued, page 25)

```
   ITERATION NUMBER,    7
THIS IS EXAMPLE NUMBER THREE-NETWORK

   NUMBER OF FACILITIES   7
   SERVICE DISTANCE =    75.000

   NEW FACILITY LOCATION NUMBER    16

   FACILITIES ARE LOCATED AT     7,    1,   13,   18,    5,   23,   16,
   ---------------------------------------------------------------------
   POPULATION SERVED     580.00          PERCENT OF TOTAL POPULATION SERVED  100.00
   ---------------------------------------------------------------------
THE FACILITY LOCATED AT:   7 CAN COVER THE FOLLOWING  DEMANDS:
  2,   6,   7,   9,  10,  19,  24,  27,
THE FACILITY LOCATED AT:   1 CAN COVER THE FOLLOWING  DEMANDS:
  1,   8,  12,  20,  23,  26,  28,
THE FACILITY LOCATED AT:  13 CAN COVER THE FOLLOWING  DEMANDS:
 13,  16,  21,  25,
THE FACILITY LOCATED AT:  18 CAN COVER THE FOLLOWING  DEMANDS:
  3,  18,  26,  29,
THE FACILITY LOCATED AT:   5 CAN COVER THE FOLLOWING  DEMANDS:
  2,   5,  11,  15,  17,  24,
THE FACILITY LOCATED AT:  23 CAN COVER THE FOLLOWING  DEMANDS:
  1,   4,  12,  14,  22,  23,
THE FACILITY LOCATED AT:  16 CAN COVER THE FOLLOWING  DEMANDS:
 13,  16,  30,
DEMAND POINT       CAN BE COVERED BY FACILITIES AT:
        1           1,  23,
        2           7,   5,
        3          18,
        4          23,
        5           5,
        6           7,
        7           7,
        8           1,
        9           7,
       10           7,
       11           5,
       12           1,  23,
       13          13,  16,
       14          23,
       15           5,
       16          13,  16,
       17           5,
       18          18,
       19           7,
       20           1,
       21          13,
       22          23,
       23           1,  23,
       24           7,   5,
       25          13,
       26           1,  18,
       27           7,
       28           1,
       29          18,
       30          16,
```

THIS IS EXAMPLE NUMBER THREE-NETWORK

FACILITIES ARE LOCATED AT 7, 1, 13, 18, 5, 23, 16,
PRIMARY DISTANCE = 75.00
SECONDARY DISTANCE =100.00

PARTITION NUMBER	FACILITY NUMBER	PRIMARY SERVED POP.	SECONDARY SERVED POP.	POPULATION OUTSIDE SECONDARY	POPULATION IN PARTITION	LARGEST TRAVELED DISTANCE	NODE NUMBER	WT.DIST PRIMARY COVERED	WT.DIST. SECONDARY COVERED	WT.DIST OUTSIDE PRIMARY	TOTAL WEIGHTED DISTANCE
1	7	170.00	0.0	0.0	170.00	67.0	9	7168.0	0.0	0.	7168.
2	1	85.00	0.0	0.0	85.00	51.0	8	2490.0	0.0	0.	2490.
3	13	55.00	0.0	0.0	55.00	60.0	21	1060.0	0.0	0.	1060.
4	18	85.00	0.0	0.0	85.00	64.0	29	3790.0	0.0	0.	3790.
5	5	72.00	0.0	0.0	72.00	74.0	17	2550.0	0.0	0.	2550.
6	23	78.00	0.0	0.0	78.00	75.0	14	3685.0	0.0	0.	3685.
7	16	35.00	0.0	0.0	35.00	58.0	30	870.0	0.0	0.	870.
		580.00	0.0	0.0	580.00			21613.0	0.0	0.	21613.

PARTITION 1 FACILITY 7
** 6 D= 60.0** 7 D= 0.0** 9 D= 67.0** 10 D= 47.0** 19 D= 59.0** 24 D= 46.0

* 27 D= 49.0**
PARTITION 2 FACILITY 1
** 1 D= 0.0** 8 D= 51.0** 20 D= 38.0** 26 D= 16.0** 28 D= 7.0**
PARTITION 3 FACILITY 13
** 13 D= 0.0** 21 D= 60.0** 25 D= 46.0**
PARTITION 4 FACILITY 18
** 3 D= 62.0** 18 D= 0.0** 29 D= 64.0**
PARTITION 5 FACILITY 5
** 2 D= 37.0** 5 D= 0.0** 11 D= 69.0** 15 D= 19.0** 17 D= 74.0**
PARTITION 6 FACILITY 23
** 4 D= 70.0** 12 D= 20.0** 14 D= 75.0** 22 D= 60.0** 23 D= 0.0**
PARTITION 7 FACILITY 16
** 16 D= 0.0** 30 D= 58.0**
COVERRAGE CANNOT BE CHANGED BY ADDITIONAL FACILITIES
THIS SOLUTION WAS GENERATED BY THE GAS ALGORITHM

FIGURE 15

(continued, page 26)

```
TK-OSMVTV21.8-HASPIIV4.0C  END   0240  *----------------------*        *----------------------*  0240  END   RECYCLE-OLD-OUTPUT
TK-OSMVTV21.8-HASPIIV4.0C  END   0240  * JOB NAME:     GASTEX *        * JOB NAME:     GASTEX *  0240  END   RECYCLE-OLD-OUTPUT
TK-OSMVTV21.8-HASPIIV4.0C  END   0240  *----------------------*        *----------------------*  0240  END   RECYCLE-OLD-OUTPUT
TK-OSMVTV21.8-HASPIIV4.0C  END   0240                                                            0240  END   RECYCLE-OLD-OUTPUT
TK-OSMVTV21.8-HASPIIV4.0C  END   0240    REMOTE1                          REMOTE1                 0240  END   RECYCLE-OLD-OUTPUT
TK-OSMVTV21.8-HASPIIV4.0C  END   0240    REMOTE1                          REMOTE1                 0240  END   RECYCLE-OLD-OUTPUT
TK-OSMVTV21.8-HASPIIV4.0C  END   0240                                                            0240  END   RECYCLE-OLD-OUTPUT
TK-OSMVTV21.8-HASPIIV4.0C  END   0240                                                            0240  END   RECYCLE-OLD-OUTPUT
TK-OSMVTV21.8-HASPIIV4.0C  END   0240                                                            0240  END   RECYCLE-OLD-OUTPUT
TK-OSMVTV21.8-HASPIIV4.0C  END   0240                                                            0240  END   RECYCLE-OLD-OUTPUT
TK-OSMVTV21.8-HASPIIV4.0C  END   0240    CHURCH                           CHURCH                  0240  END   RECYCLE-OLD-OUTPUT
TK-OSMVTV21.8-HASPIIV4.0C  END   0240    CHURCH                           CHURCH                  0240  END   RECYCLE-OLD-OUTPUT
TK-OSMVTV21.8-HASPIIV4.0C  END   0240                                                            0240  END   RECYCLE-OLD-OUTPUT
TK-OSMVTV21.8-HASPIIV4.0C  END   0240  *----------------------*        *----------------------*  0240  END   RECYCLE-OLD-OUTPUT
TK-OSMVTV21.8-HASPIIV4.0C  END   0240  * TIME:      2.34.40 PM *        * TIME:      2.34.40 PM *  0240  END   RECYCLE-OLD-OUTPUT
TK-OSMVTV21.8-HASPIIV4.0C  END   0240  * DATE:        1 APR 78 *        * DATE:        1 APR 78 *  0240  END   RECYCLE-OLD-OUTPUT
TK-OSMVTV21.8-HASPIIV4.0C  END   0240  * LINES:          1,125 *        * LINES:          1,125 *  0240  END   RECYCLE-OLD-OUTPUT
TK-OSMVTV21.8-HASPIIV4.0C  END   0240  *----------------------*        *----------------------*  0240  END   RECYCLE-OLD-OUTPUT
TK-OSMVTV21.8-HASPIIV4.0C  END   0240  * JOB NAME:     GASTEX *        * JOB NAME:     GASTEX *  0240  END   RECYCLE-OLD-OUTPUT
TK-OSMVTV21.8-HASPIIV4.0C  END   0240  *----------------------*        *----------------------*  0240  END   RECYCLE-OLD-OUTPUT
```

FIGURE 15

(continued, page 27)

CHAPTER 7

NETWORK PROBLEM FOUR

Suppose that we are interested in solving the thirty node problem of examples 2 and 3 except that we have the restrictions listed in table 22. Given this set of constraints in table 22, one can solve the associated covering problem by making modifications to the data deck developed for network problem 3. Modifications are necessary only to the problem control cards and the constraint card set. A listing of the data deck that solves example 4 is given in figure 16. The change of the problem control cards reflects the change in title for problem 4. All other changes are made in the constraint card set that follows the problem control cards.

According to the definitions given in appendix C, we need to set the parameters in the first card of the constraint deck to the following values: ND equal to 4; NDAS equal to 2; and NANCF equal to 5. This means that there will be four ND cards, two NDAS cards, and five NANCF cards following the parameter card. The four ND cards will have the same format as described in the previous example. The four ND cards necessary for eliminating areas 5, 8, 9, and 12 from consideration follow the parameter card containing the values of ND, NDAS, and NANCF, as illustrated in figure 16.

The forms of the NDAS and NANCF are exactly the same as

that of the ND cards, except the two letter code is not given. After the ND cards the NANCF cards should be given. Since there are to be 5 facilities automatically allocated to specified nodes, there will be five cards (i.e. one card per allocated facility). Notice that in figure 16, the five cards following the ND cards contain the five indices of the areas that will automatically be assigned a facility. After the NANCF cards, the NDAS cards should be given. For this problem there will be two cards, one card for each area that is eliminated from coverage computations. The last two punched cards give 30 and 6 as the indices of sites to be eliminated from coverage computation.

The output of the GAS program utilizing the data for the fourth problem is given as figure 17. It is important to study the differences between the outputs given for example 2, 3, and 4. Before the GAS algorithm gives output of iteration one, it lists initial starting information. In problem 2, the initial starting information was not given because no constraints on the problem were imposed. In problem 3 output, the initial starting information page listed the five areas that could not be selected to house a facility. For problem 4, the initial starting information is quite detailed. Facilities are automatically added to nodes 1, 25, 14, 18, and 7. In addition, the population to be covered has been reduced by 38 which represents the demand of nodes 6 and 30 that is not to be considered in coverage computations. Furthermore, it is indicated that the nodes 5, 8, 13, and 12 will not be considered

as potential facility sites. The output from the GAS algorithm follows the initial starting information. Because of the position of the initially allocated facilities, a total of 9 facilities are necessary to complete coverage as compared to 7 facilities in problems 2 and 3.

TABLE 22

RESTRICTIONS FOR NETWORK PROBLEM FOUR

1. All nodes are potential facility sites except:

NODE	REASON
5	SP
8	NG
9	NE
12	SP

2. The demand at nodes 30 and 6 are not to be considered in determining coverage.

3. Facilities are to be automatically allocated to nodes 1, 25, 14, 18, and 7.

FIGURE 16

LISTING OF NETWORK PROBLEM FOUR DATA DECK

```
 30   30          1    1    1    1
  1                                    1
  1       10.00
  2       20.00
  3       25.00
  4       18.00
  5       12.00
  6       23.00
  7       43.00
  8       30.00
  9       24.00
 10       15.00
 11       10.00
 12       20.00
 13       35.00
 14       15.00
 15       20.00
 16       20.00
 17       10.00
 18       25.00
 19       35.00
 20       15.00
 21       10.00
 22       15.00
 23       10.00
 24       20.00
 25       10.00
 26       20.00
 27       10.00
 28       10.00
 29       35.00
 30       15.00
 90
  1    1   26   16.
  2    1   28    7.
  3   26   28   19.
  4    1   20   30.
  5   20   28   37.
  6    8   28   48.
  7    8   20   81.
  8    4   20  100.
  9   12   20   65.
 10    4   12   90.
 11    4   23   70.
 12    4   14   61.
 13   14   23   75.
 14   14   22   69.
 15   22   23   60.
 16   12   23   20.
 17   12   22   58.
 18    1   12   54.
 19   12   18   86.
 20   18   22  124.
 21    3   22  105.
 22    8   26   41.
 23   18   26   67.
 24    1   18   78.
 25    3   18   62.
 26    3    6   56.
 27    3   10   46.
 28   10   18   93.
 29   18   29   64.
 30   26   29   77.
 31   10   29   94.
 32   27   29   52.
 33   19   29   79.
 34   19   27   36.
 35   10   27   57.
```

FIGURE 16

(continued, page 2)

```
 36    7   27   49.
 37   24   27   85.
 38    7   10   47.
 39    9   10   87.
 40    6   10   34.
 41    6   17  104.
 42    6    9   61.
 43    7    9   67.
 44    7   24   46.
 45    9   24   60.
 46    2   24   33.
 47    2    9   60.
 48    9   17   56.
 49    2   17   77.
 50   11   17   55.
 51    2   11  101.
 52    5   11   69.
 53    2    5   37.
 54    5   15   19.
 55    2   15   51.
 56   15   24   84.
 57   19   24   73.
 58   19   30   60.
 59   29   30   83.
 60   16   30   58.
 61   25   30  120.
 62   13   16   66.
 63   16   25   92.
 64   13   21   60.
 65   13   25   46.
 66   21   25   52.
 67    8   25  106.
 68   25   29  147.
 69    5   17   74.
 70    5    9   92.
 71    2    7   66.
 72    7    6   60.
 73   19   10   79.
 74    3   27   78.
 75    3   12  137.
 76    3   29   92.
 77   18   27   94.
 78   27   30   70.
 79   16   21  126.
 80    8   18  108.
 81    7   19   59.
 82    4   22  106.
 83   20   23   76.
 84   18   20  118.
 85   12   20   69.
 86    1    8   51.
 87   12   28   61.
 88   20   26   52.
 89    1   29   93.
 90    8   29  107.
7HIS IS EXAMPLE NUMBER FOUR-NETWORK
 10      75.00     100.00                                  1    1    1
  4    2    5
  5 SP
  8 NG
  9 NE
 12 SP
  1
 25
 14
 18
  7
 30
  6
```

POPULATION DATA

1	10.*	4	18.*	7	43.*	10	15.*	13	35.*	16	20.*	19	35.*	22	15.*	25	10.*	28	10.*
2	20.*	5	12.*	8	30.*	11	10.*	14	15.*	17	10.*	20	15.*	23	10.*	26	20.*	29	35.*
3	25.*	6	23.*	9	24.*	12	20.*	15	20.*	18	25.*	21	10.*	24	20.*	27	10.*	30	15.*

FIGURE 17

NETWORK PROBLEM FOUR OUTPUT

FIGURE 17

(continued, page 2)

INPUT ARC INFORMATION IS AS FOLLOWS

ARC NO.	FROM NODE	TO NODE	DISTANCE
1	1	26	16.000
2	1	28	7.000
3	26	28	15.000
4	1	20	38.000
5	20	28	37.000
6	8	28	48.000
7	8	20	81.000
8	4	20	100.000
9	12	20	65.000
10	4	12	90.000
11	4	23	70.000
12	4	14	61.000
13	14	23	75.000
14	14	22	69.000
15	22	23	60.000
16	12	23	20.000
17	12	22	58.000
18	1	12	54.000
19	12	18	86.000
20	18	22	124.000
21	3	22	105.000
22	8	26	41.000
23	18	26	67.000
24	1	18	78.000
25	3	18	62.000
26	3	6	56.000
27	3	10	46.000
28	10	18	93.000
29	18	29	64.000
30	26	29	77.000
31	10	29	94.000
32	27	29	52.000
33	19	29	79.000
34	19	27	36.000
35	10	27	57.000
36	7	27	49.000
37	24	27	85.000
38	7	10	47.000
39	9	10	87.000
40	6	10	34.000
41	6	17	104.000
42	6	9	61.000
43	7	9	67.000
44	7	24	46.000
45	9	24	60.000
46	2	24	33.000
47	2	9	60.000
48	9	17	56.000
49	2	17	77.000
50	11	17	55.000
51	2	11	101.000
52	5	11	69.000
53	2	5	37.000
54	5	15	19.000
55	2	15	51.000
56	15	24	84.000
57	19	24	73.000
58	19	30	60.000
59	29	30	83.000

FIGURE 17

(continued, page 3)

60	16	30	58.000
61	25	30	120.000
62	13	16	66.000
63	16	25	92.000
64	13	21	60.000
65	13	25	46.000
66	21	25	52.000
67	8	25	106.000
68	25	29	147.000
69	5	17	74.000
70	5	9	92.000
71	2	7	66.000
72	7	6	60.000
73	19	10	79.000
74	3	27	78.000
75	3	12	137.000
76	3	29	92.000
77	18	27	94.000
78	27	30	70.000
79	16	21	126.000
80	8	18	108.000
81	7	19	59.000
82	4	22	106.000
83	20	23	76.000
84	18	20	118.000
85	12	26	69.000
86	1	8	51.000
87	12	28	61.000
88	20	26	52.000
89	1	29	93.000
90	8	29	107.000

DISTANCE MATRIX

	1	2	3	4	5	6	7	8	9	10
1	[illegible]	260.00	140.00	138.00	297.00	196.00	194.00	51.00	257.00	171.00
2	260.00	0.0	159.00	370.00	37.00	121.00	66.00	274.00	60.00	113.00
3	140.00	159.00	0.0	211.00	196.00	56.00	93.00	170.00	117.00	46.00
4	138.00	[illegible]	211.00	0.0	407.00	267.00	3[illegible]4.00	181.00	328.00	257.00
5	297.00	37.00	196.00	401.00	0.0	153.00	103.00	311.00	92.00	150.00
6	196.00	121.00	56.00	267.00	[illegible]	0.0	60.00	226.00	61.00	34.00
7	194.00	66.00	93.00	304.00	103.00	60.00	0.0	208.00	[illegible]7.00	47.00
8	51.00	274.00	170.00	181.00	311.00	226.00	208.00	0.0	27[illegible].00	[illegible]
9	257.00	60.00	117.00	328.00	92.00	61.00	67.00	275.00	0.0	[illegible]
10	171.00	113.00	46.00	257.00	150.00	34.00	47.00	201.00	87.00	0.0
11	355.00	101.00	215.00	426.00	69.00	159.00	167.00	375.00	111.00	193.00
12	54.00	292.00	137.00	90.00	329.00	193.00	226.00	105.00	254.00	179.00
13	203.00	290.00	272.00	333.00	327.00	285.00	243.00	152.00	310.00	251.00
14	149.00	333.00	174.00	61.00	370.00	230.00	267.00	200.00	291.00	220.00
15	311.00	51.00	210.00	421.00	19.00	172.00	117.00	325.00	111.00	164.00
16	234.00	224.00	206.00	370.00	261.00	219.00	177.00	198.00	244.00	185.00
17	300.00	77.00	160.00	371.00	74.00	104.00	123.00	330.00	56.00	138.00
18	78.00	206.00	62.00	176.00	243.00	118.00	140.00	108.00	179.00	93.00
19	172.00	106.00	114.00	306.00	143.00	113.00	59.00	186.00	126.00	79.00
20	38.00	296.00	178.00	100.00	333.00	234.00	230.00	81.00	295.00	209.00
21	209.00	338.00	291.00	339.00	375.00	327.00	291.00	158.00	358.00	293.00
22	112.00	264.00	105.00	106.00	301.00	161.00	198.00	163.00	22[illegible].00	151.00
23	74.00	312.00	157.00	70.00	349.00	213.00	246.00	125.00	274.00	199.00
24	230.00	33.00	139.00	350.00	70.00	106.00	46.00	244.00	60.00	93.00
25	157.00	286.00	239.00	287.00	323.00	275.00	239.00	106.00	306.00	241.00
26	16.00	244.00	129.00	152.00	281.00	185.00	178.00	41.00	245.00	160.00
27	145.00	115.00	78.00	270.00	152.00	91.00	49.00	159.00	116.00	57.00
28	7.00	259.00	144.00	137.00	296.00	200.00	193.00	48.00	260.00	175.00
29	93.00	167.00	92.00	229.00	204.00	128.00	101.00	107.00	168.00	94.00
30	176.00	166.00	148.00	312.00	203.00	161.00	119.00	190.00	186.00	127.00

FIGURE 17

(continued, page 4)

DISTANCE MATRIX

	11	12	13	14	15	16	17	18	19	20
1	355.00	54.00	203.00	149.00	311.00	234.00	300.00	78.00	172.00	38.00
2	101.00	292.00	290.00	333.00	51.00	224.00	77.00	206.00	106.00	296.00
3	215.00	137.00	272.00	174.00	210.00	206.00	160.00	62.00	114.00	178.00
4	426.00	90.00	333.00	61.00	421.00	370.00	371.00	176.00	306.00	100.00
5	69.00	329.00	327.00	370.00	19.00	261.00	74.00	243.00	143.00	333.00
6	159.00	193.00	285.00	230.00	172.00	219.00	104.00	118.00	113.00	234.00
7	167.00	226.00	243.00	267.00	117.00	177.00	123.00	140.00	59.00	230.00
8	375.00	105.00	152.00	200.00	325.00	198.00	330.00	108.00	186.00	81.00
9	111.00	254.00	310.00	291.00	111.00	244.00	56.00	179.00	126.00	295.00
10	193.00	179.00	251.00	220.00	164.00	185.00	138.00	93.00	79.00	209.00
11	0.0	352.00	391.00	389.00	88.00	325.00	55.00	277.00	207.00	393.00
12	352.00	0.0	257.00	95.00	343.00	287.00	297.00	86.00	216.00	65.00
13	391.00	257.00	0.0	352.00	341.00	66.00	366.00	257.00	184.00	233.00
14	389.00	95.00	352.00	0.0	384.00	380.00	334.00	181.00	288.00	151.00
15	88.00	343.00	341.00	384.00	0.0	275.00	93.00	257.00	157.00	347.00
16	325.00	287.00	66.00	380.00	275.00	0.0	300.00	205.00	118.00	270.00
17	55.00	297.00	366.00	334.00	93.00	300.00	0.0	222.00	182.00	338.00
18	277.00	86.00	257.00	181.00	257.00	205.00	222.00	0.0	130.00	116.00
19	207.00	216.00	184.00	288.00	157.00	118.00	182.00	130.00	0.0	208.00
20	393.00	65.00	233.00	151.00	347.00	270.00	338.00	116.00	208.00	0.0
21	439.00	263.00	60.00	358.00	389.00	126.00	414.00	263.00	232.00	239.00
22	320.00	58.00	315.00	69.00	315.00	311.00	265.00	124.00	219.00	123.00
23	372.00	20.00	277.00	75.00	363.00	307.00	317.00	106.00	236.00	76.00
24	134.00	265.00	257.00	313.00	84.00	191.00	110.00	179.00	73.00	266.00
25	387.00	211.00	46.00	306.00	337.00	92.00	362.00	211.00	180.00	187.00
26	344.00	69.00	193.00	164.00	295.00	218.00	289.00	67.00	156.00	52.00
27	216.00	180.00	194.00	252.00	166.00	128.00	172.00	94.00	36.00	181.00
28	359.00	61.00	200.00	150.00	310.00	233.00	304.00	82.00	171.00	37.00
29	268.00	146.00	193.00	241.00	218.00	141.00	224.00	64.00	79.00	129.00
30	267.00	229.00	124.00	322.00	217.00	58.00	242.00	147.00	60.00	212.00

FIGURE 17

(continued, page 5)

DISTANCE MATRIX

	21	22	23	24	25	26	27	28	29	30
1	209.00	112.00	74.00	230.00	157.00	16.00	145.00	7.00	93.00	176.00
2	338.00	264.00	312.00	33.00	286.00	244.00	115.00	259.00	167.00	166.00
3	291.00	105.00	157.00	139.00	239.00	129.00	78.00	144.00	92.00	148.00
4	339.00	106.00	70.00	350.00	287.00	152.00	270.00	137.00	229.00	312.00
5	375.00	301.00	349.00	70.00	323.00	281.00	152.00	296.00	204.00	203.00
6	327.00	161.00	213.00	106.00	275.00	185.00	91.00	200.00	128.00	161.00
7	291.00	198.00	246.00	40.00	239.00	178.00	49.00	193.00	101.00	119.00
8	158.00	163.00	125.00	244.00	106.00	41.00	159.00	48.00	107.00	190.00
9	358.00	222.00	274.00	60.00	306.00	245.00	116.00	260.00	168.00	186.00
10	293.00	151.00	199.00	93.00	241.00	160.00	57.00	175.00	94.00	127.00
11	439.00	320.00	372.00	134.00	387.00	344.00	216.00	359.00	268.00	267.00
12	263.00	58.00	20.00	265.00	211.00	69.00	180.00	61.00	146.00	229.00
13	60.00	315.00	277.00	257.00	46.00	193.00	194.00	200.00	193.00	124.00
14	358.00	69.00	75.00	313.00	306.00	164.00	252.00	156.00	241.00	322.00
15	389.00	315.00	363.00	84.00	337.00	295.00	166.00	310.00	218.00	217.00
16	126.00	311.00	307.00	191.00	92.00	218.00	128.00	233.00	141.00	58.00
17	414.00	265.00	317.00	110.00	362.00	289.00	172.00	304.00	224.00	242.00
18	263.00	124.00	106.00	179.00	211.00	67.00	94.00	82.00	64.00	147.00
19	232.00	219.00	236.00	73.00	180.00	156.00	36.00	171.00	79.00	60.00
20	239.00	123.00	76.00	266.00	187.00	52.00	181.00	37.00	129.00	212.00
21	0.0	321.00	283.00	305.00	52.00	199.00	242.00	206.00	199.00	172.00
22	321.00	0.0	60.00	244.00	269.00	127.00	183.00	119.00	188.00	253.00
23	283.00	60.00	0.0	285.00	231.00	89.00	200.00	81.00	166.00	249.00
24	305.00	244.00	285.00	0.0	253.00	214.00	85.00	229.00	137.00	133.00
25	52.00	269.00	231.00	253.00	0.0	147.00	190.00	154.00	147.00	120.00
26	199.00	127.00	89.00	214.00	147.00	0.0	129.00	15.00	77.00	160.00
27	242.00	183.00	200.00	85.00	190.00	129.00	0.0	144.00	52.00	70.00
28	206.00	119.00	81.00	229.00	154.00	15.00	144.00	0.0	92.00	175.00
29	199.00	188.00	166.00	137.00	147.00	77.00	52.00	92.00	0.0	83.00
30	172.00	253.00	249.00	133.00	120.00	160.00	70.00	175.00	83.00	0.0

FIGURE 17

(continued, page 6)

FIGURE 17

(continued, page 7)

```
SUBPROGRAM MATBLD HAS BEEN CALLED TO GENERATE A COVER MATRIX
   THE MAXINUM DISTANCE/TIME OF  75.00 HAS BEEN UTILIZED
```

FIGURE 17

(continued, page 8)

```
 1  100000010001000000010010010100
 2  010010101000001000000001000000
 3  001001000100000001000000000000
 4  000100000000010000000010000000
 5  010010000010001010000001000000
 6  001001101100000000000000000000
 7  010001101100000000100001001000
 8  100000010000000000000000010100
 9  010001101000000010000001000000
10  001001100100000000000000001000
11  000010000010000010000000000000
12  100000000001000000010110010100
13  000000000000100100001000100000
14  000100000000010000000110000000
15  010010000000000100000000000000
16  000000000000100100000000000001
17  000010001010000010000000000000
18  001000000000000001000000010010
19  000000100000000000100001001001
20  100000000001000000010000010100
21  000000000000100000001000100000
22  000000000001010000000110000000
23  100100000001010000000110000000
24  010010101000000000100001000000
25  000000000000100000001000100000
26  100000010001000001010000010100
27  000000100100000000100000001011
28  100000010001000000010000010100
29  000000000000000001000000001010
30  000000000000000100100000001001
    1 CAN BE SERVED BY     1
    1 CAN BE SERVED BY     8
    1 CAN BE SERVED BY    12
    1 CAN BE SERVED BY    20
    1 CAN BE SERVED BY    23
    1 CAN BE SERVED BY    26
    1 CAN BE SERVED BY    28
    2 CAN BE SERVED BY     2
    2 CAN BE SERVED BY     5
    2 CAN BE SERVED BY     7
    2 CAN BE SERVED BY     9
    2 CAN BE SERVED BY    15
    2 CAN BE SERVED BY    24
    3 CAN BE SERVED BY     3
    3 CAN BE SERVED BY     6
    3 CAN BE SERVED BY    10
    3 CAN BE SERVED BY    18
    4 CAN BE SERVED BY     4
    4 CAN BE SERVED BY    14
    4 CAN BE SERVED BY    23
    5 CAN BE SERVED BY     2
    5 CAN BE SERVED BY     5
    5 CAN BE SERVED BY    11
    5 CAN BE SERVED BY    15
    5 CAN BE SERVED BY    17
    5 CAN BE SERVED BY    24
    6 CAN BE SERVED BY     3
    6 CAN BE SERVED BY     6
    6 CAN BE SERVED BY     7
    6 CAN BE SERVED BY     9
```

FIGURE 17

(continued, page 9)

```
 6 CAN BE SERVED BY    10
 7 CAN BE SERVED BY     2
 7 CAN BE SERVED BY     6
 7 CAN BE SERVED BY     7
 7 CAN BE SERVED BY     9
 7 CAN BE SERVED BY    10
 7 CAN BE SERVED BY    19
 7 CAN BE SERVED BY    24
 7 CAN BE SERVED BY    27
 8 CAN BE SERVED BY     1
 8 CAN BE SERVED BY     8
 8 CAN BE SERVED BY    26
 8 CAN BE SERVED BY    28
 9 CAN BE SERVED BY     2
 9 CAN BE SERVED BY     6
 9 CAN BE SERVED BY     7
 9 CAN BE SERVED BY     9
 9 CAN BE SERVED BY    17
 9 CAN BE SERVED BY    24
10 CAN BE SERVED BY     3
10 CAN BE SERVED BY     6
10 CAN BE SERVED BY     7
10 CAN BE SERVED BY    10
10 CAN BE SERVED BY    27
11 CAN BE SERVED BY     5
11 CAN BE SERVED BY    11
11 CAN BE SERVED BY    17
12 CAN BE SERVED BY     1
12 CAN BE SERVED BY    12
12 CAN BE SERVED BY    20
12 CAN BE SERVED BY    22
12 CAN BE SERVED BY    23
12 CAN BE SERVED BY    26
12 CAN BE SERVED BY    28
13 CAN BE SERVED BY    13
13 CAN BE SERVED BY    16
13 CAN BE SERVED BY    21
13 CAN BE SERVED BY    25
14 CAN BE SERVED BY     4
14 CAN BE SERVED BY    14
14 CAN BE SERVED BY    22
14 CAN BE SERVED BY    23
15 CAN BE SERVED BY     2
15 CAN BE SERVED BY     5
15 CAN BE SERVED BY    15
16 CAN BE SERVED BY    13
16 CAN BE SERVED BY    16
16 CAN BE SERVED BY    30
17 CAN BE SERVED BY     5
17 CAN BE SERVED BY     9
17 CAN BE SERVED BY    11
17 CAN BE SERVED BY    17
18 CAN BE SERVED BY     3
18 CAN BE SERVED BY    18
18 CAN BE SERVED BY    26
18 CAN BE SERVED BY    29
19 CAN BE SERVED BY     7
19 CAN BE SERVED BY    19
19 CAN BE SERVED BY    24
19 CAN BE SERVED BY    27
19 CAN BE SERVED BY    30
```

FIGURE 17

(continued, page 10)

```
20 CAN BE SERVED BY     1
20 CAN BE SERVED BY    12
20 CAN BE SERVED BY    20
20 CAN BE SERVED BY    26
20 CAN BE SERVED BY    28
21 CAN BE SERVED BY    13
21 CAN BE SERVED BY    21
21 CAN BE SERVED BY    25
22 CAN BE SERVED BY    12
22 CAN BE SERVED BY    14
22 CAN BE SERVED BY    22
22 CAN BE SERVED BY    23
23 CAN BE SERVED BY     1
23 CAN BE SERVED BY     4
23 CAN BE SERVED BY    12
23 CAN BE SERVED BY    14
23 CAN BE SERVED BY    22
23 CAN BE SERVED BY    23
24 CAN BE SERVED BY     2
24 CAN BE SERVED BY     5
24 CAN BE SERVED BY     7
24 CAN BE SERVED BY     9
24 CAN BE SERVED BY    19
24 CAN BE SERVED BY    24
25 CAN BE SERVED BY    13
25 CAN BE SERVED BY    21
25 CAN BE SERVED BY    25
26 CAN BE SERVED BY     1
26 CAN BE SERVED BY     8
26 CAN BE SERVED BY    12
26 CAN BE SERVED BY    18
26 CAN BE SERVED BY    20
26 CAN BE SERVED BY    26
26 CAN BE SERVED BY    28
27 CAN BE SERVED BY     7
27 CAN BE SERVED BY    10
27 CAN BE SERVED BY    19
27 CAN BE SERVED BY    27
27 CAN BE SERVED BY    29
27 CAN BE SERVED BY    30
28 CAN BE SERVED BY     1
28 CAN BE SERVED BY     8
28 CAN BE SERVED BY    12
28 CAN BE SERVED BY    20
28 CAN BE SERVED BY    26
28 CAN BE SERVED BY    28
29 CAN BE SERVED BY    18
29 CAN BE SERVED BY    27
29 CAN BE SERVED BY    29
30 CAN BE SERVED BY    16
30 CAN BE SERVED BY    19
30 CAN BE SERVED BY    27
30 CAN BE SERVED BY    30
```

```
*****************************************************************************************
INITIAL STARTING INFORMATION
NODES WHICH ARE AUTOMATICALLY ALLOCATED AN UNCHANGEABLE FACILITY ARE:
  1  25  14  18   7
THIS SET OF FACILITIES SERVES      470.00  OUT OF A TOTAL POPULATION OF      542.00  PERCENTAGE =       86.72
*****************************************************************************************
THIS DOES NOT INCLUDE THE POPULATION AT THE FOLLOWING NODES:
 30,   6,
THIS ELIMINATED POPULATION AMOUNTS TO:       36.00
*****************************************************************************************
THE FOLLOWING NODES WILL NOT BE CONSIDERED AS POTENTIAL FACILITY SITES:
  5-SP,   8-NG,   9-NE,  12-SP,
*****************************************************************************************
THE FACILITY LOCATED AT:   1 CAN COVER THE FOLLOWING  DEMANDS:
  1,   8,  12,  20,  23,  26,  28,
THE FACILITY LOCATED AT:  25 CAN COVER THE FOLLOWING  DEMANDS:
 13,  21,  25,
THE FACILITY LOCATED AT:  14 CAN COVER THE FOLLOWING  DEMANDS:
  4,  14,  22,  23,
THE FACILITY LOCATED AT:  18 CAN COVER THE FOLLOWING  DEMANDS:
  3,  18,  26,  29,
THE FACILITY LOCATED AT:   7 CAN COVER THE FOLLOWING  DEMANDS:
  2,   6,   7,   9,  10,  19,  24,  27,
DEMAND POINT      CAN BE COVERED BY FACILITIES AT:
         1         1,
         2         7,
         3        18,
         4        14,
         5       NO CURRENT FACILITY LOCATION
         6         7,
         7         7,
         8         1,
         9         7,
        10         7,
        11       NO CURRENT FACILITY LOCATION
        12         1,
        13        25,
        14        14,
        15       NO CURRENT FACILITY LOCATION
        16       NO CURRENT FACILITY LOCATION
        17       NO CURRENT FACILITY LOCATION
        18        18,
        19         7,
        20         1,
        21        25,
        22        14,
        23         1,  14,
        24         7,
        25        25,
        26         1,  18,
        27         7,
        28         1,
        29        18,
        30       NO CURRENT FACILITY LOCATION
```

FIGURE 17

(continued, page 11)

FIGURE 17

(continued, page 12)

```
   ITERATION NUMBER,    1
 THIS IS EXAMPLE NUMBER FOUR-NETWORK

   NUMBER OF FACILITIES   6
   SERVICE DISTANCE =    75.000

   NEW FACILITY LOCATION NUMBER     2

   FACILITIES ARE LOCATED AT     1,   25,   14,   18,    7,    2,
   ---------------------------------------------------------------------------
   POPULATION SERVED     502.00          PERCENT OF TOTAL POPULATION SERVED   92.02
   ---------------------------------------------------------------------------
 THE FACILITY LOCATED AT:   1 CAN COVER THE FOLLOWING  DEMANDS:
  1,   8,  12,  20,  23,  26,  28,
 THE FACILITY LOCATED AT:  25 CAN COVER THE FOLLOWING  DEMANDS:
 13,  21,  25,
 THE FACILITY LOCATED AT:  14 CAN COVER THE FOLLOWING  DEMANDS:
  4,  14,  22,  23,
 THE FACILITY LOCATED AT:  18 CAN COVER THE FOLLOWING  DEMANDS:
  3,  18,  26,  29,
 THE FACILITY LOCATED AT:   7 CAN COVER THE FOLLOWING  DEMANDS:
  2,   6,   7,   9,  10,  19,  24,  27,
 THE FACILITY LOCATED AT:   2 CAN COVER THE FOLLOWING  DEMANDS:
  2,   5,   7,   9,  15,  24,
 DEMAND POINT      CAN BE COVERED BY FACILITIES AT:
          1         1,
          2         7,   2,
          3        18,
          4        14,
          5         2,
          6         7,
          7         7,   2,
          8         1,
          9         7,   2,
         10         7,
         11       NO CURRENT FACILITY LOCATION
         12         1,
         13        25,
         14        14,
         15         2,
         16       NO CURRENT FACILITY LOCATION
         17       NO CURRENT FACILITY LOCATION
         18        18,
         19         7,
         20         1,
         21        25,
         22        14,
         23         1,  14,
         24         7,   2,
         25        25,
         26         1,  18,
         27         7,
         28         1,
         29        18,
         30       NO CURRENT FACILITY LOCATION
```

THIS IS EXAMPLE NUMBER FOUR-NETWORK

FACILITIES ARE LOCATED AT 1, 25, 14, 18, 7, 2,
PRIMARY DISTANCE = 75.00
SECONDARY DISTANCE =100.00

PARTITION NUMBER	FACILITY NUMBER	PRIMARY SERVED POP.	SECONDARY SERVED POP.	POPULATION OUTSIDE SECONDARY	POPULATION IN PARTITION	LARGEST TRAVELED DISTANCE	NODE NUMBER	WT.DIST PRIMARY COVERED	WT.DIST. SECONDARY COVERED	WT.DIST OUTSIDE PRIMARY	TOTAL WEIGHTED DISTANCE
1	1	115.00	0.0	0.0	115.00	74.0	23	4310.0	0.0	0.	4310.
2	25	55.00	20.00	0.0	75.00	92.0	16	2130.0	1840.0	1840.	3970.
3	14	48.00	0.0	0.0	48.00	69.0	22	2133.0	0.0	0.	2133.
4	18	85.00	0.0	0.0	85.00	64.0	29	3790.0	0.0	0.	3790.
5	7	103.00	0.0	0.0	103.00	119.0	30	3260.0	0.0	0.	3260.
6	2	96.00	10.00	10.00	116.00	101.0	11	3564.0	770.0	1780.	5344.
		502.00	30.00	10.00	542.00			19187.0	2610.0	3620.	22807.

PARTITION 1 FACILITY 1
** 1 D= 0.0** 8 D= 51.0** 12 D= 54.0** 20 D= 38.0** 23 D= 74.0** 26 D= 16.0

* 28 D= 7.0**
PARTITION 2 FACILITY 25
** 13 D= 46.0** 16 D= 92.0** 21 D= 52.0** 25 D= 0.0**
PARTITION 3 FACILITY 14
** 4 D= 61.0** 14 D= 0.0** 22 D= 69.0**
PARTITION 4 FACILITY 18
** 3 D= 62.0** 18 D= 0.0** 29 D= 64.0**
PARTITION 5 FACILITY 7
** 6 D= 60.0** 7 D= 0.0** 10 D= 47.0** 19 D= 59.0** 27 D= 49.0** 30 D= 119.0

PARTITION 6 FACILITY 2
** 2 D= 0.0** 5 D= 37.0** 9 D= 60.0** 11 D=101.0** 15 D= 51.0** 17 D= 77.0

* 24 D= 33.0**

FIGURE 17

(continued, page 13)

FIGURE 17

(continued, page 14)

```
   ITERATION NUMBER,    2
 THIS IS EXAMPLE NUMBER FOUR-NETWORK

   NUMBER OF FACILITIES   7
   SERVICE DISTANCE =    75.000

   NEW FACILITY LOCATION NUMBER    11

   FACILITIES ARE LOCATED AT     1,   25,   14,   18,    7,    2,   11,
   ---------------------------------------------------------------------
   POPULATION SERVED     522.00          PERCENT OF TOTAL POPULATION SERVED = 96.81
   ---------------------------------------------------------------------
THE FACILITY LOCATED AT:   1 CAN COVER THE FOLLOWING  DEMANDS:
  1,   8,  12,  20,  23,  26,  28,
THE FACILITY LOCATED AT:  25 CAN COVER THE FOLLOWING  DEMANDS:
 13,  21,  25,
THE FACILITY LOCATED AT:  14 CAN COVER THE FOLLOWING  DEMANDS:
  4,  14,  22,  23,
THE FACILITY LOCATED AT:  18 CAN COVER THE FOLLOWING  DEMANDS:
  3,  18,  26,  29,
THE FACILITY LOCATED AT:   7 CAN COVER THE FOLLOWING  DEMANDS:
  2,   6,   7,   9,  10,  19,  24,  27,
THE FACILITY LOCATED AT:   2 CAN COVER THE FOLLOWING  DEMANDS:
  2,   5,   7,   9,  15,  24,
THE FACILITY LOCATED AT:  11 CAN COVER THE FOLLOWING  DEMANDS:
  5,  11,  17,
DEMAND POINT       CAN BE COVERED BY FACILITIES AT:
         1          1,
         2          7,   2,
         3         18,
         4         14,
         5          2,  11,
         6          7,
         7          7,   2,
         8          1,
         9          7,   2,
        10          7,
        11         11,
        12          1,
        13         25,
        14         14,
        15          2,
        16        NO CURRENT FACILITY LOCATION
        17         11,
        18         18,
        19          7,
        20          1,
        21         25,
        22         14,
        23          1,  14,
        24          7,   2,
        25         25,
        26          1,  18,
        27          7,
        28          1,
        29         18,
        30        NO CURRENT FACILITY LOCATION
```

THIS IS EXAMPLE NUMBER FOUR-NETWORK

FACILITIES ARE LOCATED AT 1, 25, 14, 18, 7, 2, 11,
PRIMARY DISTANCE = 75.00
SECONDARY DISTANCE =100.00

PARTITION NUMBER	FACILITY NUMBER	PRIMARY SERVED POP.	SECONDARY SERVED POP.	POPULATION OUTSIDE SECONDARY	POPULATION IN PARTITION	LARGEST TRAVELED DISTANCE	NODE NUMBER	WT.DIST PRIMARY COVERED	WT.DIST. SECONDARY COVERED	WT.DIST OUTSIDE PRIMARY	TOTAL WEIGHTED DISTANCE
1	1	115.00	0.0	0.0	115.00	74.0	23	4310.0	0.0	0.	4310.
2	25	55.00	20.00	0.0	75.00	92.0	16	2130.0	1840.0	1840.	3970.
3	14	48.00	0.0	0.0	48.00	69.0	22	2133.0	0.0	0.	2133.
4	18	85.00	0.0	0.0	85.00	64.0	29	3790.0	0.0	0.	3790.
5	7	103.00	0.0	0.0	103.00	119.0	30	3260.0	0.0	0.	3260.
6	2	96.00	0.0	0.0	96.00	60.0	9	3564.0	0.0	0.	3564.
7	11	20.00	0.0	0.0	20.00	55.0	17	550.0	0.0	0.	550.
		522.00	20.00	0.0	542.00			19737.0	1840.0	1840.	21577.

PARTITION 1 FACILITY 1
** 1 D= 0.0** 8 D= 51.0** 12 D= 54.0** 20 D= 38.0** 23 D= 74.0** 26 D= 16.0

* 28 D= 7.0**
PARTITION 2 FACILITY 25
** 13 D= 46.0** 16 D= 92.0** 21 D= 52.0** 25 D= 0.0**
PARTITION 3 FACILITY 14
** 4 D= 61.0** 14 D= 0.0** 22 D= 69.0**
PARTITION 4 FACILITY 18
** 3 D= 62.0** 18 D= 0.0** 29 D= 64.0**
PARTITION 5 FACILITY 7
** 6 D= 60.0** 7 D= 0.0** 10 D= 47.0** 19 D= 59.0** 27 D= 49.0** 30 D= 119.0

PARTITION 6 FACILITY 2
** 2 D= 0.0** 5 D= 37.0** 9 D= 60.0** 15 D= 51.0** 24 D= 33.0**
PARTITION 7 FACILITY 11
** 11 D= 0.0** 17 D= 55.0**

FIGURE 17

(continued, page 15)

FIGURE 17

(continued, page 16)

```
   ITERATION NUMBER,    3
 THIS IS EXAMPLE NUMBER FOUR-NETWORK

   NUMBER OF FACILITIES   8
   SERVICE DISTANCE =    75.000

   NEW FACILITY LOCATION NUMBER    13

   FACILITIES ARE LOCATED AT     1,   25,   14,   18,    7,    2,   11,   13,
   ---------------------------------------------------------------------------
   POPULATION SERVED     542.00          PERCENT OF TOTAL POPULATION SERVED  100.00
   ---------------------------------------------------------------------------
THE FACILITY LOCATED AT:   1 CAN COVER THE FOLLOWING  DEMANDS:
  1,   8,  12,  20,  23,  26,  28,
THE FACILITY LOCATED AT:  25 CAN COVER THE FOLLOWING  DEMANDS:
 13,  21,  25,
THE FACILITY LOCATED AT:  14 CAN COVER THE FOLLOWING  DEMANDS:
  4,  14,  22,  23,
THE FACILITY LOCATED AT:  18 CAN COVER THE FOLLOWING  DEMANDS:
  3,  18,  26,  29,
THE FACILITY LOCATED AT:   7 CAN COVER THE FOLLOWING  DEMANDS:
  2,   6,   7,   9,  10,  19,  24,  27,
THE FACILITY LOCATED AT:   2 CAN COVER THE FOLLOWING  DEMANDS:
  2,   5,   7,   9,  15,  24,
THE FACILITY LOCATED AT:  11 CAN COVER THE FOLLOWING  DEMANDS:
  5,  11,  17,
THE FACILITY LOCATED AT:  13 CAN COVER THE FOLLOWING  DEMANDS:
 13,  16,  21,  25,
DEMAND POINT      CAN BE COVERED BY FACILITIES AT:
        1          1,
        2          7,   2,
        3         18,
        4         14,
        5          2,  11,
        6          7,
        7          7,   2,
        8          1,
        9          7,   2,
       10          7,
       11         11,
       12          1,
       13         25,  13,
       14         14,
       15          2,
       16         13,
       17         11,
       18         18,
       19          7,
       20          1,
       21         25,  13,
       22         14,
       23          1,  14,
       24          7,   2,
       25         25,  13,
       26          1,  18,
       27          7,
       28          1,
       29         18,
       30       NO CURRENT FACILITY LOCATION
```

THIS IS EXAMPLE NUMBER FOUR-NETWORK

FACILITIES ARE LOCATED AT 1, 25, 14, 18, 7, 2, 11, 13,
PRIMARY DISTANCE = 75.00
SECONDARY DISTANCE =100.00

PARTITION NUMBER	FACILITY NUMBER	PRIMARY SERVED POP.	SECONDARY SERVED POP.	POPULATION OUTSIDE SECONDARY	POPULATION IN PARTITION	LARGEST TRAVELED DISTANCE	NODE NUMBER	WT.DIST PRIMARY COVERED	WT.DIST. SECONDARY COVERED	WT.DIST OUTSIDE PRIMARY	TOTAL WEIGHTED DISTANCE
1	1	115.00	0.0	0.0	115.00	74.0	23	4310.0	0.0	0.	4310.
2	25	20.00	0.0	0.0	20.00	52.0	21	520.0	0.0	0.	520.
3	14	48.00	0.0	0.0	48.00	69.0	22	2133.0	0.0	0.	2133.
4	18	85.00	0.0	0.0	85.00	64.0	29	3790.0	0.0	0.	3790.
5	7	103.00	0.0	0.0	103.00	119.0	30	3260.0	0.0	0.	3260.
6	2	96.00	0.0	0.0	96.00	60.0	9	3564.0	0.0	0.	3564.
7	11	20.00	0.0	0.0	20.00	55.0	17	550.0	0.0	0.	550.
8	13	55.00	0.0	0.0	55.00	66.0	16	1320.0	0.0	0.	1320.
		542.00	0.0	0.0	542.00			19447.0	0.0	0.	19447.

PARTITION 1 FACILITY 1
** 1 D= 0.0** 8 D= 51.0** 12 D= 54.0** 20 D= 38.0** 23 D= 74.0** 26 D= 16.0

** 28 D= 7.0**
PARTITION 2 FACILITY 25
** 21 D= 52.0** 25 D= 0.0**
PARTITION 3 FACILITY 14
** 4 D= 61.0** 14 D= 0.0** 22 D= 69.0**
PARTITION 4 FACILITY 18
** 3 D= 62.0** 18 D= 0.0** 29 D= 64.0**
PARTITION 5 FACILITY 7
** 6 D= 60.0** 7 D= 0.0** 10 D= 47.0** 19 D= 59.0** 27 D= 49.0** 30 D= 119.0

PARTITION 6 FACILITY 2
** 2 D= 0.0** 5 D= 37.0** 9 D= 60.0** 15 D= 51.0** 24 D= 33.0**
PARTITION 7 FACILITY 11
** 11 D= 0.0** 17 D= 55.0**
PARTITION 8 FACILITY 13
** 13 D= 0.0** 16 D= 66.0**
COVERRAGE CANNOT BE CHANGED BY ADDITIONAL FACILITIES
THIS SOLUTION WAS GENERATED BY THE GAS ALGORITHM

FIGURE 17

(continued, page 17)

CHAPTER 8

NETWORK PROBLEM FIVE

Suppose elevation data for the thirty node problem exists and is a factor in determining whether one town can cover another. Assume that a facility can cover an area only if (a) it is within seventy five minutes travel time and (b) it is no more than 300 meters lower in elevation than the demand area and no more than 200 meters higher in elevation than the demand area. In addition, suppose we want to allocate facilities to nodes 1 and 20 as well as eliminate nodes 5, 8, 12, 19, and 26 as potential facility sites. Elevation data for the thirty node problem is given in table 23.

In order to solve problem 5, the master data deck must be modified to include elevation values. The basic master data deck of problem 2 will be the point of departure to solve problem 5. In order to utilize elevation data, the first change that must be made to the master data deck is to the ELE parameter. In problem 2, the ELE parameter is set at a zero value. However, since the problem involves elevation data, the value of the ELE parameter must be set to one. When the ELE parameter is set at a value of one, elevation data must be given in the master data deck. Figure 18 is a conceptualized view of a data deck containing elevation data. The elevation data is given right after the second master control card. A format summary is given for elevation data

cards in appendix D.

There must be one elevation data card for each node of the network. The order of the elevation cards must be the same as the order of the population data cards, if population data cards are included. The order must be given in order of increasing index. Figure 19 gives a complete listing of the data necessary to solve network problem 5. The set of thirty data cards appearing after the two master control cards is the set of elevation data. By changing the elevation parameter ELE to a value of one and including elevation data in the master data deck, it is now necessary to indicate how the GAS program is to utilize this data. There are two master control card parameters that pertain to the use of elevation data. These two parameters are called IALT1 and IALT2 and are defined in appendix A. Since the IALT1 parameter is utilized only when the problem is defined on a plane we will keep the parameter at a value of zero. The IALT2 parameter is to be set to a value of one when a maximum positive or negative elevation difference can affect coverage. One example is when a demand area cannot be served by a facility unless it is no farther than 300 meters above the facility (maximum negative elevation difference) or 200 meters below a facility (maximum positive elevation difference). Since this is precisely the type of constraint we wish to place on service, we should also change the value of the IALT2 parameter on the second master control card to a value of one. Now the two master control cards contain the parameter values given in tables

24 and 25.

We have also changed the value of IFSAP to zero, because the statistics output should never be generated when altitude (elevation) data is being utilized to limit coverage. Following the two master control cards will be the thirty elevation cards. Next, thirty population cards should be given. Fourth, the ARC data associated with the network of thirty nodes must be given. This completes the master data deck.

After the master data, the problem control cards must be given. The first problem control card is a title card which we will indicate that it is the fifth network problem. The second problem control card gives a number of parameter values. Since we want to locate up to ten facilities the IP parameter should be set at the value of 10. The value of the S parameter should be set at 75. Since we are not using the statistics output (i.e. IFSAP=0) we should leave SCS at zero (or blank). The EMAXL parameter should be set at 200. The EMAXS parameter should be set at a value of -300 (see appendix B). Since we have several special constraints, the value of CONS should be set at one. For this problem, set the values of ILIST and ICOV at one in order to increase covering information given at each solution. Thus the second problem card contains the values displayed in table 26.

After the second problem control card, the constraint cards should be given in the manner described in problems three and four. The first constraint card should contain the values of ND, NDAS and NANCF. For this example ND equals 5, NDAS

equals zero and NANCF equals 2. The next five cards then contain the indices of the nodes that are to be eliminated from consideration as potential facility sites. The following two cards give the indices of the two areas (nodes) that are to be automatically allocated a facility (nodes 1 and 20). Two blank cards should follow which indicate the end of the data deck. The complete input listing is given in figure 19. The output of the GAS program associated with this problem is given in figure 20.

MULTIPLE RUNS

Suppose we are interested in solving examples three and four in the same computer run of GAS. This can be easily done, since both examples utilize the same master data deck. In order to solve both problems, the master data deck should be followed by the problem control and constraint cards associated with one problem and then continued by the problem control and constraint cards of the other problem. At the end of the deck, two blank cards should be added. Figure 21 gives a listing of the data deck necessary to solve both examples with the same computer job. Submitting grouped problems increases the efficiency of the GAS program, since it spreads the set up costs over several problems. The GAS program can solve as many problems in one computer run as the user requests, subject only to a user-specified upper limit on computer time use.

TABLE 23

ELEVATION DATA

NODE	ELEVATION
1	100
2	275
3	1000
4	650
5	300
6	400
7	950
8	980
9	150
10	800
11	700
12	550
13	600
14	1200
15	900
16	200
17	300
18	400
19	200
20	600
21	650
22	1100
23	950
24	100
25	350
26	75
27	400
28	500
29	1000
30	750

TABLE 24

FIRST MASTER CONTROL CARD

FOR NETWORK PROBLEM FIVE

Parameter Name	Assumption	Assigned Value	Card Column(s) Containing Value
IPTS	Number of nodes in network	30	4 and 5
IDEM	Must equal IPTS for network problems	30	9 and 10
ADD	Must equal zero for network problems	0, blank	15
NETWOR	Value of one signifies network problem	1	20
WEIGHT	Value of one signifies population values will be given	1	25
IDIST	Value of zero signifies distance matrix will not be printed	0, blank	30
IFSAP	Value of zero signifies that statistics output will not be printed	0, blank	35

TABLE 25

SECOND MASTER CONTROL CARD

FOR NETWORK PROBLEM FIVE

Parameter Name	Assumption	Assigned Value	Card Column(s) Containing Value
ARCS	Arc data will be given when value is set at one	1	5
RECT	For a network problem, value must be set at zero	0	10
ELE	When elevation data is given, value should be set at one	1	15
CONS	Value of zero signifies no special constraint features are selected	0	20
IPOL	Value of zero signifies that political data will not be given	0	25
IALT1	For network problem value should be set at zero when elevation is given	0	30
IALT2	Value of one signifies that elevation constrainst will be imposed on coverage	1	35
GAS	When value is set at one, GAS program will be executed	1	40

TABLE 26

SECOND PROBLEM CONTROL CARD

FOR NETWORK PROBLEM FIVE

Parameter Name	Assumption	Assigned Value	Card Column(s) Containing Value
IP	Must equal largest number of allowable facilities	10	4 and 5
S	Maximal Service Distance	75.	6-15
SCS	Secondary Service Distance is not given since IFSAP is set at zero	blank	16-25
EMAXL	Value of largest elevation difference up to facility	200.	26-35
EMAXS	Value of largest elevation difference down to facility (negative)	-300.	36-45
CONS	Value of one means special constraints will be given	1	55
ICOV	Value of one means zero-one cover matrix will be given	1	60
ILIST	Value of one means coverage listing will be given	1	65

FIGURE 18

CONCEPTUAL FORM OF A CARD DECK

CONTAINING ELEVATION DATA

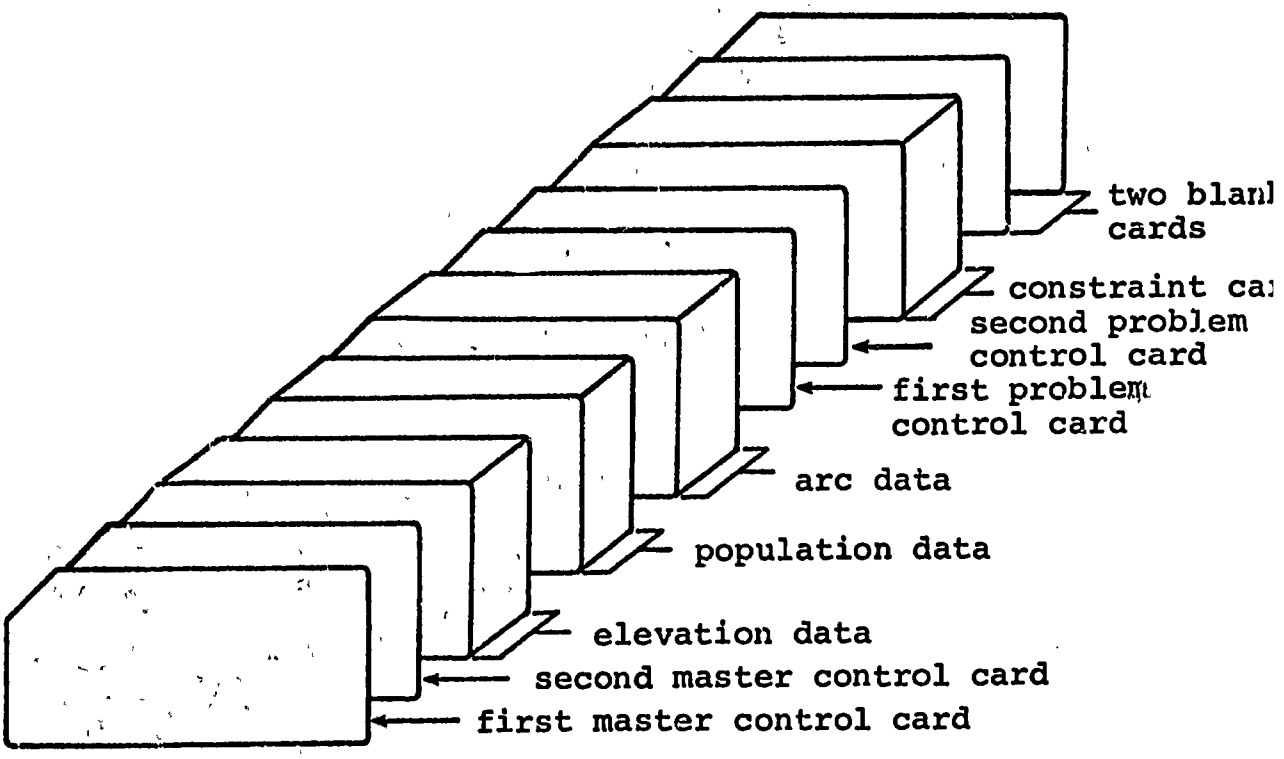


FIGURE 19

LISTING OF NETWORK PROBLEM FIVE DATA DECK

```
30   30          1    1
 1          1                    1    1
 1      100.
 2      275.
 3      1000.
 4      650.
 5      300.
 6      400.
 7      950.
 8      980.
 9      150
10      800.
11      700.
12      550.
13      600.
14      1200.
15      900.
16      200.
17      300.
18      400.
19      200.
20      600.
21      650.
22      1100.
23      950.
24      100.
25     350.
26      75.
27      400.
28      500.
29      1000.
30      750.
 1      10.00
 2      20.00
 3      25.00
 4      18.00
 5      12.00
 6      23.00
 7      43.00
 8      30.00
 9      24.00
10      15.00
11      10.00
12      20.00
13      35.00
14      15.00
15      20.00
16      20.00
17      10.00
18      25.00
19      35.00
20      15.00
21      10.00
22      15.00
23      10.00
24      20.00
25      10.00
26      20.00
27      10.00
28      10.00
```

FIGURE 19

(continued, page 2)

```
29        35.00
30        15.00
 90
  1    1   26   16.
  2    1   28    7.
  3   26   28   15.
  4    1   20   38.
  5   20   28   37.
  6    8   28   48.
  7    8   20   81.
  8    4   20  100.
  9   12   20   65.
 10    4   12   90.
 11    4   23   70.
 12    4   14   61.
 13   14   23   75.
 14   14   22   69.
 15   22   23   60.
 16   12   23   20.
 17   12   22   58.
 18    1   12   54.
 19   12   18   86.
 20   18   22  124.
 21    3   22  105.
 22    8   26   41.
 23   18   26   67.
 24    1   18   78.
 25    3   18   62.
 26    3    6   56.
 27    3   10   46.
 28   10   18   93.
 29   18   29   64.
 30   26   29   77.
 31   10   29   94.
 32   27   29   52.
 33   19   29   79.
 34   19   27   36.
 35   10   27   57.
 36    7   27   49.
 37   24   27   85.
 38    7   10   47.
 39    9   10   87.
 40    6   10   34.
 41    6   17  104.
 42    6    9   61.
 43    7    9   67.
 44    7   24   46.
 45    9   24   60.
 46    2   24   33.
 47    2    9   60.
 48    9   17   56.
 49    2   17   77.
 50   11   17   55.
 51    2   11  101.
 52    5   11   69.
 53    2    5   37.
 54    5   15   19.
 55    2   15   51.
 56   15   24   84.
 57   19   24   73.
 58   19   20   60.
```

FIGURE 19

(continued, page 3)

```
 59   29   30   83.
 60   16   30   58.
 61   25   30  120.
 62   13   16   66.
 63   16   25   92.
 64   13   21   60.
 65   13   25   46.
 66   21   25   54.
 67    8   25  106.
 68   25   29  147.
 69    5   17   74.
 70    5    9   92.
 71    2    7   66.
 72    7    6   60.
 73   19   10   79.
 74    3   27   78.
 75    3   12  137.
 76    3   29   92.
 77   18   27   94.
 78   27   30   70.
 79   16   21  126.
 80    8   18  108.
 81    7   19   59.
 82    4   22  106.
 83   20   23   76.
 84   18   20  118.
 85   12   26   69.
 86    1    8   51.
 87   12   28   61.
 88   20   26   54.
 89    1   29   93.
 90    8   29  107.
THIS IS EXAMPLE NUMBER FIVE-NETWORK
 10      75.00    100100      200.     -300.          1    1    1
  5          2
  5
  8
 12
 19
 26
 20
  1
```

POPULATION DATA

1	10.*	4	18.*	7	43.*	10	15.*	13	35.*	16	20.*	19	35.*	22	15.*	25	10.*	28	10.*
2	20.*	5	12.*	8	30.*	11	10.*	14	15.*	17	10.*	20	15.*	23	10.*	26	20.*	29	35.*
3	25.*	6	23.*	9	24.*	12	20.*	15	20.*	18	25.*	21	10.*	24	20.*	27	10.*	30	15.*

FIGURE 20

NETWORK PROBLEM FIVE OUTPUT

FIGURE 20

(continued, page 2)

INPUT ARC INFORMATION IS AS FOLLOWS

ARC NO.	FROM NODE	TO NODE	DISTANCE
1	1	26	16.000
2	1	28	7.000
3	26	28	15.000
4	1	20	38.000
5	20	28	37.000
6	8	28	48.000
7	8	20	81.000
8	4	20	100.000
9	12	20	65.000
10	4	12	90.000
11	4	23	70.000
12	4	14	61.000
13	14	23	75.000
14	14	22	69.000
15	22	23	60.000
16	12	23	20.000
17	12	22	58.000
18	1	12	54.000
19	12	18	86.000
20	18	22	124.000
21	3	22	105.000
22	8	26	41.000
23	18	26	67.000
24	1	18	78.000
25	3	18	62.000
26	3	6	56.000
27	3	10	46.000
28	10	18	93.000
29	18	29	64.000
30	26	29	77.000
31	10	29	94.000
32	27	29	52.000
33	19	29	79.000
34	19	27	36.000
35	10	27	57.000
36	7	27	49.000
37	24	27	85.000
38	7	10	47.000
39	9	10	87.000
40	6	10	34.000
41	6	17	104.000
42	6	9	61.000
43	7	9	67.000
44	7	24	46.000
45	9	24	60.000
46	2	24	33.000
47	2	9	60.000
48	9	17	56.000
49	2	17	77.000
50	11	17	55.000
51	2	11	101.000
52	5	11	69.000
53	2	5	37.000
54	5	15	19.000
55	2	15	51.000
56	15	24	84.000
57	19	24	73.000
58	19	30	60.000
59	29	30	83.000

FIGURE 20

(continued, page 3)

60	16	30	58.000
61	25	30	120.000
62	13	16	66.000
63	16	25	92.000
64	13	21	60.000
65	13	25	46.000
66	21	25	52.000
67	8	25	106.000
68	25	29	147.000
69	5	17	74.000
70	5	9	92.000
71	2	7	66.000
72	7	6	60.000
73	19	10	79.000
74	3	27	78.000
75	3	12	137.000
76	3	29	92.000
77	18	27	94.000
78	27	30	70.000
79	16	21	126.000
80	8	18	108.000
81	7	19	59.000
82	4	22	106.000
83	20	23	76.000
84	18	20	118.000
85	12	26	69.000
86	1	8	51.000
87	12	28	61.000
88	20	26	52.000
89	1	29	93.000
90	6	29	107.000

FIGURE 20

(continued, page 4)

```
SUBPROGRAM MATBLD HAS BEEN CALLED TO GENERATE A COVER MATRIX
   THE MAXIMUM DISTANCE/TIME OF  75.00 HAS BEEN UTILIZED
   ELEVATIONS ARE ALSO UTILIZED IN  DEVELOPING THE COVER MATRIX
   THE LARGEST ELEVATION DIFFERENCE DOWN TO A FACILITY IS  200.0
   THE LARGEST ELEVATION DIFFERENCE UP TO A FACILITY IS  300.0
```

FIGURE 20

(continued, page 5)

```
 1  100000000000000000000000010000
 2  010010000000000000000001000000
 3  001000000100000000000000000000
 4  000100000000000000000010000000
 5  010010000000000010000001000000
 6  000001000000000000000000000000
 7  000000100100000000000000000000
 8  000000010000000000000000000000
 9  000000001000000000000000000000
10  001000100100000000000000000000
11  000000000010000000000000000000
12  000000000001000000010000000100
13  000000000000100000001000000000
14  000000000000010000000100000000
15  000000000000001000000000000000
16  000000000000000100000000000000
17  000010000000000001000000000000
18  000000000000000000100000000000
19  000000000000000000100001001000
20  000000000010000000010000000100
21  000000000000100000001000000000
22  000000000000010000000110000000
23  000000000000001000000110000000
24  010010000000000000100001000000
25  000000000000000000000000100000
26  100000000000000000000000010000
27  000000000000000000010000001000
28  000000000001000000010000000100
29  000000000000000000000000000010
30  000000000000000000000000000001
```

```
 1 CAN BE SERVED BY     1
 1 CAN BE SERVED BY    26
 2 CAN BE SERVED BY     2
 2 CAN BE SERVED BY     5
 2 CAN BE SERVED BY    24
 3 CAN BE SERVED BY     3
 3 CAN BE SERVED BY    10
 4 CAN BE SERVED BY     4
 4 CAN BE SERVED BY    23
 5 CAN BE SERVED BY     2
 5 CAN BE SERVED BY     5
 5 CAN BE SERVED BY    17
 5 CAN BE SERVED BY    24
 6 CAN BE SERVED BY     6
 7 CAN BE SERVED BY     7
 7 CAN BE SERVED BY    10
 8 CAN BE SERVED BY     8
 9 CAN BE SERVED BY     9
10 CAN BE SERVED BY     3
10 CAN BE SERVED BY     7
10 CAN BE SERVED BY    10
11 CAN BE SERVED BY    11
12 CAN BE SERVED BY    12
12 CAN BE SERVED BY    20
12 CAN BE SERVED BY    28
13 CAN BE SERVED BY    13
13 CAN BE SERVED BY    21
14 CAN BE SERVED BY    14
14 CAN BE SERVED BY    22
15 CAN BE SERVED BY    15
```

FIGURE 20

(continued, page 6)

```
16 CAN BE SERVED BY    16
17 CAN BE SERVED BY     5
17 CAN BE SERVED BY    17
18 CAN BE SERVED BY    18
19 CAN BE SERVED BY    19
19 CAN BE SERVED BY    24
19 CAN BE SERVED BY    27
20 CAN BE SERVED BY    12
20 CAN BE SERVED BY    20
20 CAN BE SERVED BY    28
21 CAN BE SERVED BY    13
21 CAN BE SERVED BY    21
22 CAN BE SERVED BY    14
22 CAN BE SERVED BY    22
22 CAN BE SERVED BY    23
23 CAN BE SERVED BY    14
23 CAN BE SERVED BY    22
23 CAN BE SERVED BY    23
24 CAN BE SERVED BY     2
24 CAN BE SERVED BY     5
24 CAN BE SERVED BY    14
24 CAN BE SERVED BY    24
25 CAN BE SERVED BY    25
26 CAN BE SERVED BY     1
26 CAN BE SERVED BY    26
27 CAN BE SERVED BY    19
27 CAN BE SERVED BY    27
28 CAN BE SERVED BY    12
28 CAN BE SERVED BY    20
28 CAN BE SERVED BY    28
29 CAN BE SERVED BY    29
30 CAN BE SERVED BY    30
```

```
*****************************************************************************************
INITIAL STARTING INFORMATION
NODES WHICH ARE AUTOMATICALLY ALLOCATED AN UNCHANGEABLE FACILITY ARE:
 20   1
THIS SET OF FACILITIES SERVES       75.00  OUT OF A TOTAL POPULATION OF      580.00  PERCENTAGE =       12.93
*****************************************************************************************
THE FOLLOWING NODES WILL NOT BE CONSIDERED AS POTENTIAL FACILITY SITES:
  5-  ,   8-  ,  12-  ,  19-  ,  26-  ,
*****************************************************************************************
THE FACILITY LOCATED AT:  20 CAN COVER THE FOLLOWING  DEMANDS:
 12,  20,  28,
THE FACILITY LOCATED AT:   1 CAN COVER THE FOLLOWING  DEMANDS:
  1,  26,
DEMAND POINT       CAN BE COVERED BY FACILITIES AT:
         1          1,
         2        NO CURRENT FACILITY LOCATION
         3        NO CURRENT FACILITY LOCATION
         4        NO CURRENT FACILITY LOCATION
         5        NO CURRENT FACILITY LOCATION
         6        NO CURRENT FACILITY LOCATION
         7        NO CURRENT FACILITY LOCATION
         8        NO CURRENT FACILITY LOCATION
         9        NO CURRENT FACILITY LOCATION
        10        NO CURRENT FACILITY LOCATION
        11        NO CURRENT FACILITY LOCATION
        12         20,
        13        NO CURRENT FACILITY LOCATION
        14        NO CURRENT FACILITY LOCATION
        15        NO CURRENT FACILITY LOCATION
        16        NO CURRENT FACILITY LOCATION
        17        NO CURRENT FACILITY LOCATION
        18        NO CURRENT FACILITY LOCATION
        19        NO CURRENT FACILITY LOCATION
        20         20,
        21        NO CURRENT FACILITY LOCATION
        22        NO CURRENT FACILITY LOCATION
        23        NO CURRENT FACILITY LOCATION
        24        NO CURRENT FACILITY LOCATION
        25        NO CURRENT FACILITY LOCATION
        26          1,
        27        NO CURRENT FACILITY LOCATION
        28         20,
        29        NO CURRENT FACILITY LOCATION
        30        NO CURRENT FACILITY LOCATION
```

FIGURE 20

(continued, page 7)

FIGURE 20

(continued, page 8)

```
   ITERATION NUMBER,    1
 THIS IS EXAMPLE NUMBER FIVE-NETWORK

   NUMBER OF FACILITIES   3
   SERVICE DISTANCE =    75.000

   NEW FACILITY LOCATION NUMBER    24

   FACILITIES ARE LOCATED AT    20,    1,   24,
   ---------------------------------------------------------------------------
   POPULATION SERVED     162.00          PERCENT OF TOTAL POPULATION SERVED   27.93
   ---------------------------------------------------------------------------
THE FACILITY LOCATED AT:  20 CAN COVER THE FOLLOWING  DEMANDS:
 12,  20,  28,
THE FACILITY LOCATED AT:   1 CAN COVER THE FOLLOWING  DEMANDS:
  1,  26,
THE FACILITY LOCATED AT:  24 CAN COVER THE FOLLOWING  DEMANDS:
  2,   5,  19,  24,
DEMAND POINT      CAN BE COVERED BY FACILITIES AT:
        1          1,
        2         24,
        3        NO CURRENT FACILITY LOCATION
        4        NO CURRENT FACILITY LOCATION
        5         24,
        6        NO CURRENT FACILITY LOCATION
        7        NO CURRENT FACILITY LOCATION
        8        NO CURRENT FACILITY LOCATION
        9        NO CURRENT FACILITY LOCATION
       10        NO CURRENT FACILITY LOCATION
       11        NO CURRENT FACILITY LOCATION
       12         20,
       13        NO CURRENT FACILITY LOCATION
       14        NO CURRENT FACILITY LOCATION
       15        NO CURRENT FACILITY LOCATION
       16        NO CURRENT FACILITY LOCATION
       17        NO CURRENT FACILITY LOCATION
       18        NO CURRENT FACILITY LOCATION
       19         24,
       20         20,
       21        NO CURRENT FACILITY LOCATION
       22        NO CURRENT FACILITY LOCATION
       23        NO CURRENT FACILITY LOCATION
       24         24,
       25        NO CURRENT FACILITY LOCATION
       26          1,
       27        NO CURRENT FACILITY LOCATION
       28         20,
       29        NO CURRENT FACILITY LOCATION
       30        NO CURRENT FACILITY LOCATION
```

FIGURE 20

(continued, page 9)

```
   ITERATION NUMBER,    2
THIS IS EXAMPLE NUMBER FIVE-NETWORK

   NUMBER OF FACILITIES   4
   SERVICE DISTANCE =    75.000

   NEW FACILITY LOCATION NUMBER    10

   FACILITIES ARE LOCATED AT    20,    1,   24,   10,
   ---------------------------------------------------------------------
   POPULATION SERVED      245.00          PERCENT OF TOTAL POPULATION SERVED   42.24
   ---------------------------------------------------------------------
THE FACILITY LOCATED AT:  20 CAN COVER THE FOLLOWING  DEMANDS:
 12,  20,  28,
THE FACILITY LOCATED AT:   1 CAN COVER THE FOLLOWING  DEMANDS:
  1,  26,
THE FACILITY LOCATED AT:  24 CAN COVER THE FOLLOWING  DEMANDS:
  2,   5,  19,  24,
THE FACILITY LOCATED AT:  10 CAN COVER THE FOLLOWING  DEMANDS:
  3,   7,  10,
DEMAND POINT      CAN BE COVERED BY FACILITIES AT.
         1         1,
         2        24,
         3        10,
         4       NO CURRENT FACILITY LOCATION
         5        24,
         6       NO CURRENT FACILITY LOCATION
         7        10,
         8       NO CURRENT FACILITY LOCATION
         9       NO CURRENT FACILITY LOCATION
        10        10,
        11       NO CURRENT FACILITY LOCATION
        12        20,
        13       NO CURRENT FACILITY LOCATION
        14       NO CURRENT FACILITY LOCATION
        15       NO CURRENT FACILITY LOCATION
        16       NO CURRENT FACILITY LOCATION
        17       NO CURRENT FACILITY LOCATION
        18       NO CURRENT FACILITY LOCATION
        19        24,
        20        20,
        21       NO CURRENT FACILITY LOCATION
        22       NO CURRENT FACILITY LOCATION
        23       NO CURRENT FACILITY LOCATION
        24        24,
        25       NO CURRENT FACILITY LOCATION
        26         1,
        27       NO CURRENT FACILITY LOCATION
        28        20,
        29       NO CURRENT FACILITY LOCATION
        30       NO CURRENT FACILITY LOCATION
```

FIGURE 20

(continued, page 10)

```
   ITERATION NUMBER,    3
 THIS IS EXAMPLE NUMBER FIVE-NETWORK

   NUMBER OF FACILITIES   5
   SERVICE DISTANCE =    75.000

   NEW FACILITY LOCATION NUMBER    13

   FACILITIES ARE LOCATED AT    20,    1,   24,   10,   13,
   ---------------------------------------------------------------------------
   POPULATION SERVED     290.00          PERCENT OF TOTAL POPULATION SERVED   50.00
   ---------------------------------------------------------------------------
THE FACILITY LOCATED AT:  20 CAN COVER THE FOLLOWING  DEMANDS:
 12,  20,  28,
THE FACILITY LOCATED AT:   1 CAN COVER THE FOLLOWING  DEMANDS:
  1,  26,
THE FACILITY LOCATED AT:  24 CAN COVER THE FOLLOWING  DEMANDS:
  2,   5,  19,  24,
THE FACILITY LOCATED AT:  10 CAN COVER THE FOLLOWING  DEMANDS:
  3,   7,  10,
THE FACILITY LOCATED AT:  13 CAN COVER THE FOLLOWING  DEMANDS:
 13,  21,
DEMAND POINT       CAN BE COVERED BY FACILITIES AT:
         1          1,
         2         24,
         3         10,
         4        NO CURRENT FACILITY LOCATION
         5         24,
         6        NO CURRENT FACILITY LOCATION
         7         10,
         8        NO CURRENT FACILITY LOCATION
         9        NO CURRENT FACILITY LOCATION
        10         10,
        11        NO CURRENT FACILITY LOCATION
        12         20,
        13         13,
        14        NO CURRENT FACILITY LOCATION
        15        NO CURRENT FACILITY LOCATION
        16        NO CURRENT FACILITY LOCATION
        17        NO CURRENT FACILITY LOCATION
        18        NO CURRENT FACILITY LOCATION
        19         24,
        20         20,
        21         13,
        22        NO CURRENT FACILITY LOCATION
        23        NO CURRENT FACILITY LOCATION
        24         24,
        25        NO CURRENT FACILITY LOCATION
        26          1,
        27        NO CURRENT FACILITY LOCATION
        28         20,
        29        NO CURRENT FACILITY LOCATION
        30        NO CURRENT FACILITY LOCATION
```

FIGURE 20

(continued, page 11)

```
   ITERATION NUMBER,    4
 THIS IS EXAMPLE NUMBER FIVE-NETWORK

   NUMBER OF FACILITIES   6
   SERVICE DISTANCE =    75.000

   NEW FACILITY LOCATION NUMBER    23

   FACILITIES ARE LOCATED AT    20,    1,   24,   10,   13,   23,
   ---------------------------------------------------------------------------
   POPULATION SERVED     333.00          PERCENT OF TOTAL POPULATION SERVED   57.41
   ---------------------------------------------------------------------------
THE FACILITY LOCATED AT:  20 CAN COVER THE FOLLOWING  DEMANDS:
 12,  20,  28,
THE FACILITY LOCATED AT:   1 CAN COVER THE FOLLOWING  DEMANDS:
  1,  26,
THE FACILITY LOCATED AT:  24 CAN COVER THE FOLLOWING  DEMANDS:
  2,   5,  19,  24,
THE FACILITY LOCATED AT:  10 CAN COVER THE FOLLOWING  DEMANDS:
  3,   7,  10,
THE FACILITY LOCATED AT:  13 CAN COVER THE FOLLOWING  DEMANDS:
 13,  21,
THE FACILITY LOCATED AT:  23 CAN COVER THE FOLLOWING  DEMANDS:
  4,  22,  23,
DEMAND POINT      CAN BE COVERED BY FACILITIES AT:
        1          1,
        2         24,
        3         10,
        4         23,
        5         24,
        6        NO CURRENT FACILITY LOCATION
        7         10,
        8        NO CURRENT FACILITY LOCATION
        9        NO CURRENT FACILITY LOCATION
       10         10,
       11        NO CURRENT FACILITY LOCATION
       12         20,
       13         13,
       14        NO CURRENT FACILITY LOCATION
       15        NO CURRENT FACILITY LOCATION
       16        NO CURRENT FACILITY LOCATION
       17        NO CURRENT FACILITY LOCATION
       18        NO CURRENT FACILITY LOCATION
       19         24,
       20         20,
       21         13,
       22         23,
       23         23,
       24         24,
       25        NO CURRENT FACILITY LOCATION
       26          1,
       27        NO CURRENT FACILITY LOCATION
       28         20,
       29        NO CURRENT FACILITY LOCATION
       30        NO CURRENT FACILITY LOCATION
```

FIGURE 20

(continued, page 12)

```
   ITERATION NUMBER,    5
 THIS IS EXAMPLE NUMBER FIVE-NETWORK

   NUMBER OF FACILITIES$   7
   SERVICE DISTANCE =    75.000

   NEW FACILITY LOCATION NUMBER    29

   FACILITIES ARE LOCATED AT    20,    1,   24,   10,   13,   23,   29,
   ---------------------------------------------------------------------
   POPULATION SERVED     368.00          PERCENT OF TOTAL POPULATION SERVED   63.55
   ---------------------------------------------------------------------
THE FACILITY LOCATED AT:  20 CAN COVER THE FOLLOWING  DEMANDS:
 12,  20,  28,
THE FACILITY LOCATED AT:   1 CAN COVER THE FOLLOWING  DEMANDS:
  1,  26,
THE FACILITY LOCATED AT:  24 CAN COVER THE FOLLOWING  DEMANDS:
  2,   5,  19,  24,
THE FACILITY LOCATED AT:  10 CAN COVER THE FOLLOWING  DEMANDS:
  3,   7,  10,
THE FACILITY LOCATED AT:  13 CAN COVER THE FOLLOWING  DEMANDS:
 13,  21,
THE FACILITY LOCATED AT:  23 CAN COVER THE FOLLOWING  DEMANDS:
  4,  22,  23,
THE FACILITY LOCATED AT:  29 CAN COVER THE FOLLOWING  DEMANDS:
 29,
DEMAND POINT       CAN BE COVERED BY FACILITIES AT:
         1          1,
         2         24,
         3         10,
         4         23,
         5         24,
         6        NO CURRENT FACILITY LOCATION
         7         10,
         8        NO CURRENT FACILITY LOCATION
         9        NO CURRENT FACILITY LOCATION
        10         10,
        11        NO CURRENT FACILITY LOCATION
        12         20,
        13         13,
        14        NO CURRENT FACILITY LOCATION
        15        NO CURRENT FACILITY LOCATION
        16        NO CURRENT FACILITY LOCATION
        17        NO CURRENT FACILITY LOCATION
        18        NO CURRENT FACILITY LOCATION
        19         24,
        20         20,
        21         13,
        22         23,
        23         23,
        24         24,
        25        NO CURRENT FACILITY LOCATION
        26          1,
        27        NO CURRENT FACILITY LOCATION
        28         20,
        29         29,
        30        NO CURRENT FACILITY LOCATION
```

FIGURE 20

(continued, page 13)

```
   ITERATION NUMBER,    6
THIS IS EXAMPLE NUMBER FIVE-NETWORK

   NUMBER OF FACILITIES   8
   SERVICE DISTANCE =    75.000

   NEW FACILITY LOCATION NUMBER    18

   FACILITIES ARE LOCATED AT    20,    1,   24,   10,   13,   23,   29,   18,
   ---------------------------------------------------------------------------
   POPULATION SERVED     393.00          PERCENT OF TOTAL POPULATION SERVED   67.76
   ---------------------------------------------------------------------------
THE FACILITY LOCATED AT:  20 CAN COVER THE FOLLOWING  DEMANDS:
 12,  20,  28,
THE FACILITY LOCATED AT:   1 CAN COVER THE FOLLOWING  DEMANDS:
  1,  26,
THE FACILITY LOCATED AT:  24 CAN COVER THE FOLLOWING  DEMANDS:
  2,   5,  19,  24,
THE FACILITY LOCATED AT:  10 CAN COVER THE FOLLOWING  DEMANDS:
  3,   7,  10,
THE FACILITY LOCATED AT:  13 CAN COVER THE FOLLOWING  DEMANDS:
 13,  21,
THE FACILITY LOCATED AT:  23 CAN COVER THE FOLLOWING  DEMANDS:
  4,  22,  23,
THE FACILITY LOCATED AT:  29 CAN COVER THE FOLLOWING  DEMANDS:
 29,
THE FACILITY LOCATED AT:  18 CAN COVER THE FOLLOWING  DEMANDS:
 18,
DEMAND POINT      CAN BE COVERED BY FACILITIES AT:
        1          1,
        2         24,
        3         10,
        4         23,
        5         24,
        6        NO CURRENT FACILITY LOCATION
        7         10,
        8        NO CURRENT FACILITY LOCATION
        9        NO CURRENT FACILITY LOCATION
       10         10,
       11        NO CURRENT FACILITY LOCATION
       12         20,
       13         13,
       14        NO CURRENT FACILITY LOCATION
       15        NO CURRENT FACILITY LOCATION
       16        NO CURRENT FACILITY LOCATION
       17        NO CURRENT FACILITY LOCATION
       18         18,
       19         24,
       20         20,
       21         13,
       22         23,
       23         23,
       24         24,
       25        NO CURRENT FACILITY LOCATION
       26          1,
       27        NO CURRENT FACILITY LOCATION
       28         20,
       29         29,
       30        NO CURRENT FACILITY LOCATION
```

FIGURE 20

(continued, page 14)

```
   ITERATION NUMBER,    7
THIS IS EXAMPLE NUMBER FIVE-NETWORK

   NUMBER OF FACILITIES   9
   SERVICE DISTANCE =    75.000

   NEW FACILITY LOCATION NUMBER     9

   FACILITIES ARE LOCATED AT    20,    1,   24,   10,   13,   23,   29,   18,    9,
   ---------------------------------------------------------------------------------
   POPULATION SERVED     417.00          PERCENT OF TOTAL POPULATION SERVED   71.90
   ---------------------------------------------------------------------------------
THE FACILITY LOCATED AT:  20 CAN COVER THE FOLLOWING  DEMANDS:
 12,  20,  28,
THE FACILITY LOCATED AT:   1 CAN COVER THE FOLLOWING  DEMANDS:
  1,  26,
THE FACILITY LOCATED AT:  24 CAN COVER THE FOLLOWING  DEMANDS:
  2,   5,  19,  24,
THE FACILITY LOCATED AT:  10 CAN COVER THE FOLLOWING  DEMANDS:
  3,   7,  10,
THE FACILITY LOCATED AT:  13 CAN COVER THE FOLLOWING  DEMANDS:
 13,  21,
THE FACILITY LOCATED AT:  23 CAN COVER THE FOLLOWING  DEMANDS:
  4,  22,  23,
THE FACILITY LOCATED AT:  29 CAN COVER THE FOLLOWING  DEMANDS:
 29,
THE FACILITY LOCATED AT:  18 CAN COVER THE FOLLOWING  DEMANDS:
 18,
THE FACILITY LOCATED AT:   9 CAN COVER THE FOLLOWING  DEMANDS:
  9,
DEMAND POINT       CAN BE COVERED BY FACILITIES AT:
        1           1,
        2          24,
        3          10,
        4          23,
        5          24,
        6         NO CURRENT FACILITY LOCATION
        7          10,
        8         NO CURRENT FACILITY LOCATION
        9           9,
       10          10,
       11         NO CURRENT FACILITY LOCATION
       12          20,
       13          13,
       14         NO CURRENT FACILITY LOCATION
       15         NO CURRENT FACILITY LOCATION
       16         NO CURRENT FACILITY LOCATION
       17         NO CURRENT FACILITY LOCATION
       18          18,
       19          24,
       20          20,
       21          13,
       22          23,
       23          23,
       24          24,
       25         NO CURRENT FACILITY LOCATION
       26           1,
       27         NO CURRENT FACILITY LOCATION
       28          20,
       29          29,
       30         NO CURRENT FACILITY LOCATION
```

FIGURE 20

(continued, page 15)

```
   ITERATION NUMBER,    8
THIS IS EXAMPLE NUMBER FIVE-NETWORK

   NUMBER OF FACILITIES  10
   SERVICE DISTANCE =    75.000

   NEW FACILITY LOCATION NUMBER     6

   FACILITIES ARE LOCATED AT    20,    1,   24,   10,   13,   23,   29,   18,    9,    6,
   ---------------------------------------------------------------------------------------
   POPULATION SERVED     440.00          PERCENT OF TOTAL POPULATION SERVED   75.86
   ---------------------------------------------------------------------------------------
THE FACILITY LOCATED AT:  20 CAN COVER THE FOLLOWING  DEMANDS:
 12,  20,  28,
THE FACILITY LOCATED AT:   1 CAN COVER THE FOLLOWING  DEMANDS:
  1,  26,
THE FACILITY LOCATED AT:  24 CAN COVER THE FOLLOWING  DEMANDS:
  2,   5,  19,  24,
THE FACILITY LOCATED AT:  10 CAN COVER THE FOLLOWING  DEMANDS:
  3,   7,  10,
THE FACILITY LOCATED AT:  13 CAN COVER THE FOLLOWING  DEMANDS:
 13,  21,
THE FACILITY LOCATED AT:  23 CAN COVER THE FOLLOWING  DEMANDS:
  4,  22,  23,
THE FACILITY LOCATED AT:  29 CAN COVER THE FOLLOWING  DEMANDS:
 29,
THE FACILITY LOCATED AT:  18 CAN COVER THE FOLLOWING  DEMANDS:
 18,
THE FACILITY LOCATED AT:   9 CAN COVER THE FOLLOWING  DEMANDS:
  9,
THE FACILITY LOCATED AT:   6 CAN COVER THE FOLLOWING  DEMANDS:
  6,
DEMAND POINT       CAN BE COVERED BY FACILITIES AT:
        1           1,
        2          24,
        3          10,
        4          23,
        5          24,
        6           6,
        7          10,
        8          NO CURRENT FACILITY LOCATION
        9           9,
       10          10,
       11          NO CURRENT FACILITY LOCATION
       12          20,
       13          13,
       14          NO CURRENT FACILITY LOCATION
       15          NO CURRENT FACILITY LOCATION
       16          NO CURRENT FACILITY LOCATION
       17          NO CURRENT FACILITY LOCATION
       18          18,
       19          24,
       20          20,
       21          13,
       22          23,
       23          23,
       24          24,
       25          NO CURRENT FACILITY LOCATION
       26           1,
       27          NO CURRENT FACILITY LOCATION
       28          20,
       29          29,
       30          NO CURRENT FACILITY LOCATION
```

FIGURE 20

(continued, page 16)

```
   ITERATION NUMBER,    9
 THIS IS EXAMPLE NUMBER FIVE-NETWORK

   NUMBER OF FACILITIES  11
   SERVICE DISTANCE =    75.000

   NEW FACILITY LOCATION NUMBER    15

   FACILITIES ARE LOCATED AT    20,    1,   24,   10,   13,   23,   29,   18,    9,    6,   15,
   ---------------------------------------------------------------------------------------------
   POPULATION SERVED     460.00          PERCENT OF TOTAL POPULATION SERVED   79.41
   ---------------------------------------------------------------------------------------------
THE FACILITY LOCATED AT:  20 CAN COVER THE FOLLOWING  DEMANDS:
 12,  20,  28,
THE FACILITY LOCATED AT:   1 CAN COVER THE FOLLOWING  DEMANDS:
  1,  26,
THE FACILITY LOCATED AT:  24 CAN COVER THE FOLLOWING  DEMANDS:
  2,   5,  19,  24,
THE FACILITY LOCATED AT:  10 CAN COVER THE FOLLOWING  DEMANDS:
  3,   7,  10,
THE FACILITY LOCATED AT:  13 CAN COVER THE FOLLOWING  DEMANDS:
 13,  21,
THE FACILITY LOCATED AT:  23 CAN COVER THE FOLLOWING  DEMANDS:
  4,  22,  23,
THE FACILITY LOCATED AT:  29 CAN COVER THE FOLLOWING  DEMANDS:
 29,
THE FACILITY LOCATED AT:  18 CAN COVER THE FOLLOWING  DEMANDS:
 18,
THE FACILITY LOCATED AT:   9 CAN COVER THE FOLLOWING  DEMANDS:
  9,
THE FACILITY LOCATED AT:   6 CAN COVER THE FOLLOWING  DEMANDS:
  6,
THE FACILITY LOCATED AT:  15 CAN COVER THE FOLLOWING  DEMANDS:
 15,
DEMAND POINT       CAN BE COVERED BY FACILITIES AT:
         1          1,
         2         24,
         3         10,
         4         23,
         5         24,
         6          6,
         7         10,
         8        NO CURRENT FACILITY LOCATION
         9          9,
        10         10,
        11        NO CURRENT FACILITY LOCATION
        12         20,
        13         13,
        14        NO CURRENT FACILITY LOCATION
        15         15,
        16        NO CURRENT FACILITY LOCATION
        17        NO CURRENT FACILITY LOCATION
        18         18,
        19         24,
        20         20,
        21         13,
        22         23,
        23         23,
        24         24,
        25        NO CURRENT FACILITY LOCATION
        26          1,
        27        NO CURRENT FACILITY LOCATION
        28         20,
        29         29,
        30        NO CURRENT FACILITY LOCATION
```

FIGURE 20

(continued, page 17)

```
   ITERATION NUMBER,   10
THIS IS EXAMPLE NUMBER FIVE-NETWORK

   NUMBER OF FACILITIES  12
   SERVICE DISTANCE =    75.000

   NEW FACILITY LOCATION NUMBER    16

   FACILITIES ARE LOCATED AT    20,    1,   24,   10,   13,   23,   29,   18,    9,    6,   15,   16,
   ---------------------------------------------------------------------------------------------------
   POPULATION SERVED     480.00          PERCENT OF TOTAL POPULATION SERVED   82.76
   ---------------------------------------------------------------------------------------------------
THE FACILITY LOCATED AT:  20 CAN COVER THE FOLLOWING  DEMANDS:
 12,  20,  28,
THE FACILITY LOCATED AT:   1 CAN COVER THE FOLLOWING  DEMANDS:
  1,  26,
THE FACILITY LOCATED AT:  24 CAN COVER THE FOLLOWING  DEMANDS:
  2,   5,  19,  24,
THE FACILITY LOCATED AT:  10 CAN COVER THE FOLLOWING  DEMANDS:
  3,   7,  10,
THE FACILITY LOCATED AT:  13 CAN COVER THE FOLLOWING  DEMANDS:
 13,  21,
THE FACILITY LOCATED AT:  23 CAN COVER THE FOLLOWING  DEMANDS:
  4,  22,  23,
THE FACILITY LOCATED AT:  29 CAN COVER THE FOLLOWING  DEMANDS:
 29,
THE FACILITY LOCATED AT:  18 CAN COVER THE FOLLOWING  DEMANDS:
 18,
THE FACILITY LOCATED AT:   9 CAN COVER THE FOLLOWING  DEMANDS:
  9,
THE FACILITY LOCATED AT:   6 CAN COVER THE FOLLOWING  DEMANDS:
  6,
THE FACILITY LOCATED AT:  15 CAN COVER THE FOLLOWING  DEMANDS:
 15,
THE FACILITY LOCATED AT:  16 CAN COVER THE FOLLOWING  DEMANDS:
 16,
DEMAND POINT       CAN BE COVERED BY FACILITIES AT:
         1          1,
         2         24,
         3         10,
         4         23,
         5         24,
         6          6,
         7         10,
         8        NO CURRENT FACILITY LOCATION
         9          9,
        10         10,
        11        NO CURRENT FACILITY LOCATION
        12         20,
        13         13,
        14        NO CURRENT FACILITY LOCATION
        15         15,
        16         16,
        17        NO CURRENT FACILITY LOCATION
        18         18,
        19         24,
        20         20,
        21         13,
        22         23,
        23         23,
        24         24,
        25        NO CURRENT FACILITY LOCATION
        26          1,
        27        NO CURRENT FACILITY LOCATION
        28         20,
        29         29,
        30        NO CURRENT FACILITY LOCATION
THIS SOLUTION WAS GENERATED BY THE GAS ALGORITHM
```

FIGURE 21

LISTING FOR MULTIPLE RUNS

```
30   30          1    1    1    1
 1                                        1
 1       10.00
 2       20.00
 3       25.00
 4       18.00
 5       12.00
 6       23.00
 7       43.00
 8       30.00
 9       24.00
10       15.00
11       10.00
12       20.00
13       35.00
14       15.00
15       20.00
16       20.00
17       10.00
18       25.00
19       35.00
20       15.00
21       10.00
22       15.00
23       10.00
24       20.00
25       10.00
26       20.00
27       10.00
28       10.00
29       35.00
30       15.00
 90
  1    1   26   16.
  2    1   28    7.
  3   26   28   15.
  4    1   20   38.
  5   20   28   37.
  6    8   28   48.
  7    8   20   81.
  8    4   20  100.
  9   12   20   65.
 10    4   12   90.
 11    4   23   70.
 12    4   14   61.
 13   14   23   75.
 14   14   22   69.
 15   22   23   60.
 16   12   23   20.
 17   12   22   58.
 18    1   12   54.
 19   12   18   86.
 20   18   22  124.
 21    3   22  105.
 22    8   26   41.
 23   18   26   67.
 24    1   18   74.
 25    3   18   62.
 26    3    6   56.
 27    3   10   46.
```

FIGURE 21

(continued, page 2)

28	10	18	93.
29	18	29	64.
30	26	29	77.
31	10	29	94.
32	27	29	52.
33	19	29	79.
34	19	27	36.
35	10	27	57.
36	7	27	49.
37	24	27	85.
38	7	10	47.
39	9	10	87.
40	6	10	34.
41	6	17	104.
42	6	9	61.
43	7	9	67.
44	7	24	46.
45	9	24	60.
46	2	24	34.
47	2	9	60.
48	9	17	56.
49	2	17	77.
50	11	17	59.
51	2	11	101.
52	5	11	69.
53	2	5	37.
54	5	15	19.
55	2	15	51.
56	15	24	84.
57	19	24	73.
58	19	30	60.
59	29	30	82.
60	16	30	58.
61	25	30	120.
62	13	16	66.
63	16	25	92.
64	13	21	60.
65	13	25	46.
66	21	25	52.
67	8	25	106.
68	25	29	147.
69	5	17	74.
70	5	9	92.
71	2	7	66.
72	7	6	60.
73	19	10	79.
74	3	27	78.
75	3	12	137.
76	3	29	92.
77	18	27	94.
78	27	30	70.
79	16	21	126.
80	8	18	108.
81	7	19	59.
82	4	22	106.
83	20	23	76.
84	18	20	118.
85	12	26	69.
86	1	8	51.
87	12	28	61.
88	20	26	52.

FIGURE 21

(continued, page 3)

```
  89     1    29    93.
  90     8    29   107.
THIS IS EXAMPLE NUMBER THREE-NETWORK
  10      75.00     100.00                                  1    1    1
  5
  3 NG
  8 NG
 20 NE
 25 NE
 14 SP
THIS IS EXAMPLE NUMBER FOUR-NETWORK
  10      75.00     100.00                                  1    1    1
  4     2     6
  5 SP
  8 NG
  9 NE
 12 SP
  1
 25
 14
 18
  7
 30
  6
```

PART THREE

THE GAS PROGRAM APPLIED TO PLANAR PROBLEMS

CHAPTER 9

PLANAR PROBLEM ONE

The GAS program will solve a maximal covering location problem on a Euclidean plane. As an example, consider the planar point set given in table 27. This list contains 55 points each described by an (x,y) pair of coordinates. Figure 22 gives a figure depicting the 55 points, each numbered according to table 27. Let each point represent a village in a region where primary health care facilities are to be located. If the straight line distance between any two villages (points) approximates the actual distance or time of travel between those two villages, then one can easily define a distance or travel time matrix which indicates the distance from any village to any other village. For example, village 1 is located at (32,31) and village 4 is located at (29,29) and the distance separating village 1 from village 4 is:

$$d_{1,4} = \sqrt{(x_1-x_4)^2 + (y_1-y_4)^2}$$

where

$d_{1,4}$ = distance from village 1 to village 4.
(x_1,y_1) = coordinates of village 1.
(x_4,y_4) = coordinates of village 4.

thus

$$d_{1,4} = \sqrt{(32-29)^2 + (31-29)^2} = \sqrt{9+4} = \sqrt{13}$$

$$d_{1,4} = 3.61$$

Suppose, we are interested in placing several health facilities in such a way that as many people as possible are within an Euclidean distance of 10 of a facility. For this problem, we may be interested in locating up to 15 facilities. The question is what percentage of the population can be served with various numbers of facilities up to 15. This problem can be easily structuted and solved by the GAS computer program. Figure 23 gives a listing of the computer card data deck necessary to solve this problem and figure 24 gives a complete output listing of the program utilizing the data given in figure 23.

Before a detailed explanation is given for the form and order of the data input stream, let us first analyze the output given in figure 24. Output from the GAS program can be divided into two parts. The first part specifies the data that is actually used by the GAS program. This is represented by the first nine pages of figure 24. The second part gives the actual solution to the problem or problems specified (pages 10-27 in figure 24). To begin the output section (pages 1-9), the population data portion lists for each of the 55 points, its associated population. The next statement indicates that demand points are the only potential facility sites. It is possible to have a situation where this in not the case; in fact, several such examples are cited in a later section of this program users manual.

Next on the output, a listing of 110 points along with the associated (x,y) coordinates is given. Notice that the first 55 points on the list are the points given in table 27.

This first part of the list represents the locations of the demand populations. The second 55 points in the list are the facility locations. A quick inspection will indicate that this second part of the list is exactly the same as the first half of the list. This means, of course, that the potential facility locations are the same as those of the demand areas.

A distance matrix follows the list of coordinate point information on pages 3 through 8. This matrix gives the distances between each demand area and all potential facility sites. For example, the distance from demand area 1 to facility site 23 is 18.60. The distance from demand area 30 to facility site 4 is 12.17.

Page 9 of figure 24 indicates that the maximal service distance or time of 10.0 will be utilized in the problem. Pages 10 through 22 give the output from the GAS program for the maximal covering location problem with S = 10.0 on the Swain 55 node problem where all demand points are potential facility sites. Page 10 indicates that for the first facility GAS has chosen to place a facility at area 2. This placement covers 4,130 or 64.53% of the population.

Page 11 of figure 24 gives statistics associated with a facility located at area 2. Notice that the primary distance is 10, and the secondary distance is 15. According to the listing 4130 are served within a distance 10,730 are served outside 10 but inside 15, and 1540 are outside 15. Node 14 is the farthest node from 2 at a distance of 28.3. Total population-distance for those covered within 10 is 17129 or the average distance from a facility of one that is covered

is 17129/4130 = 4.14.

Page 12 of figure 24 shows what GAS has chosen on iteration number two. First, GAS places a second facility at site 22. Then, GAS moves the facility placed at 2 to site 4. The addition of site 22 increases the covered population to 4840. The subsequent move to 4 increases coverage to 4840.

Page 13 of figure 24 gives the statistics associated with facilities located at 4 and 22. Each area is assigned to the closest facility. The areas that are closest to facility at site 4 are in partition number 1, and the areas closest to facility at site 22 are in partition number 2. This analysis is provided by the facility site analysis subprogram.

Pages 14 through 22 of figure 24 give the remainder of the output associated with this problem run. The GAS program ends with iteration 9 when it accomplishes coverage of 100%, although up to 15 facilities could have been placed. GAS will automatically stop when total coverage is complete even though more facilities may be available for allocation.

Figure 23 is a list of data that produced the results of figure 24. The first two cards of the deck specify the major options that the GAS program is to use. The next 55 cards give the (x,y) coordinates of each demand point. The following 55 cards give the population for each of the 55 points. Then a title card is given. This is followed by a card that specifies the maximum number of facilities (15), the primary service distance (10.) and the secondary service distance (15.). All of the punched data cards are followed

by two blank data cards.

In order to describe the data deck in further detail the reader should now turn to appendix A which gives definitions and format specifications of each parameter in the first two data cards (called master control cards) of all data deck sets. Upon completion of appendix A, the reader should then return to this section for the specific details of the data deck preparation for the problem just described.

The first card of the data deck in figure 23 is a master control card. This card contains the parameters given in table 28. From the definitions given in appendix A, the reader should recognize that the problem is defined on the plane since NETWOR is set equal to zero and population values are included in the data set as WEIGHT is set equal to one. Because the distance matrix is to be printed, and the facility site analysis program is to be utilized at the end of each iteration, DIST is set equal to one and IFSAP should have a value of one. For this problem, IPTS = IDEM = 55. When IPTS = IDEM, the GAS program will expect IPTS points (x,y coordinates) in the data deck and will consider each point as a demand point and a potential facility site. The ADD parameter in this case could be 1 or 0 because the program automatically sets ADD = 1 when IPTS = IDEM. Therefore, the data deck must include 55 points and 55 population values.

The second card of the data deck in figure 23 is a master control card which contains the parameters given in table 29. From the definitions given in appendix A, the planar problem

utilizes Euclidean distance measure (i.e. RECT = 0), does not include political, elevational, or extra constraints (i.e. IPOL = 0, ELE = 0, CONS = 0, respectively). In addition, elevations are not used in distance determination or constraints (i.e. IALT1 = 0, and IALT2 = 0). The GAS program is to be performed because GAS = 1. Thus, the data that is necessary according to the master control cards is (a) population data, and (b) (x,y) coordinate information.

The (x,y) coordinate point information begins right after the two master control cards. Each card must be in order of increasing index. Each card has the following format:

Integer field	Real field	Real field
"	"	"
Index	x - coordinate	y - coordinate

The index must be right justified in the 4 digit field. The x-coordinate is to appear in columns 5-14 and must include a decimal point. The y-coordinate should appear in card columns 15-24 and also must include a decimal point. There should be one card for each (x,y) coordinate pair.

After the 55 cards of (x,y) point information, the population cards are given. Each card has the population of a given area. The order of the areas must be the same as that of the coordinate point information. Each card has the following

format:

```
- - - - - - - - - - - - - - -
Integer field   Real field
      "             "
    Index       Population
```

The index must be right justified in the 4-digit field. The population is to appear in columns 5-14 and must include a decimal point. The point and population cards comprise the master data set.

The two cards following the master data set are problem control cards. A set of problem control cards specifies one problem for the GAS algorithm. The forms and parameters of the problem control cards are given in appendix B. In order to describe the data deck further in figure 23, the reader should acquaint himself with the material given in appendix B. When appendix B material is mastered, the reader should return to this section for the specific details of the problem control cards associated with the example of figures 23 and 24.

The first problem control card contains the title that will be printed on output solutions of the GAS program. The second problem control card contains the values given in table 30. From the definitions given in appendix A, the GAS program is to locate up to 15 facilities. The maximal service distance is 10(S). This is the value that is utilized in the GAS program for determining coverage. The value of the secondary distance is 15(SCS). This distance is used only in

generating the statistics output presented by FSAP. The values of EMAXL and EMAXS are both zero. Whatever the value of EMAXL and EMAXS for this example, the GAS program will not utilize them because IALT2 in the master control card is at a zero value. Since CONS equals zero, no extra constraint cards are given in the problem data deck. Since ICOV equals zero, a printout of the zero-one coverage matrix will not be given. The listing, indicating coverage by each facility as well as which facilities cover each demand, is not given because ILIST = 0. The data deck ends with two blank cards. Figure 25 gives a conceptual view of the data deck utilized in this example.

TABLE 27

GEOGRAPHIC AND POPULATION DATA FOR

PLANAR PROBLEM ONE

i	a_i	x_i	y_i	i	a_i	x_i	y_i
1	710	32	31	28	60	12	47
2	620	29	32	29	60	19	38
3	560	27	36	30	60	27	41
4	390	29	29	31	60	21	35
5	350	32	29	32	50	32	45
6	210	26	25	33	50	27	45
7	200	24	33	34	50	32	38
8	190	30	35	35	50	8	22
9	170	29	27	36	50	15	25
10	170	29	21	37	50	35	16
11	160	33	28	38	40	36	47
12	150	17	53	39	40	46	51
13	140	34	40	40	40	50	40
14	120	25	60	41	40	23	22
15	120	21	28	42	40	27	30
16	110	30	51	43	40	48	39
17	100	19	47	44	40	36	32
18	100	17	33	45	30	32	41
19	90	22	40	46	30	42	36
20	90	25	14	47	30	36	26
21	90	29	12	48	30	15	19
22	80	24	48	49	30	19	14
23	80	17	42	50	30	45	19
24	80	6	26	51	30	27	5
25	80	19	21	52	20	52	24
26	70	10	32	53	20	40	22
27	60	34	56	54	20	40	52
				55	20	42	42

FIGURE 22

55 TOWNS

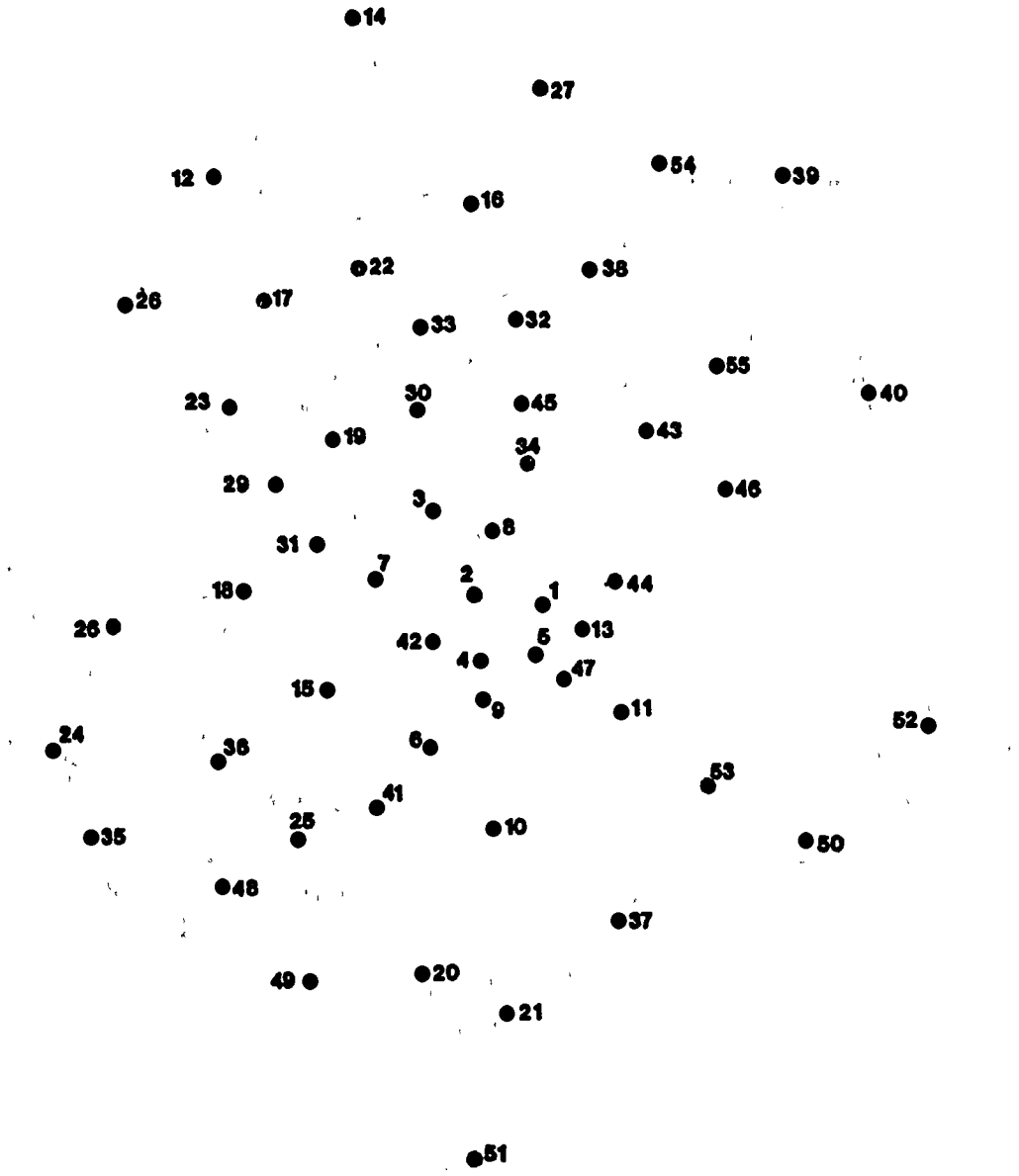


FIGURE 23

LISTING OF PLANAR PROBLEM ONE DATA DECK

```
55   55                1    1    1
                                     1
 1      32.      31.
 2      29.      32.
 3      27.      36.
 4      29.      29.
 5      32.      29.
 6      26.      25.
 7      24.      33.
 8      30.      35.
 9      29.      27.
10      29.      21.
11      33.      28.
12      17.      53.
13      34.      40.
14      25.      60.
15      21.      28.
16      30.      51.
17      19.      47.
18      17.      33.
19      22.      40.
20      25.      14.
21      29.      12.
22      24.      48.
23      17.      42.
24      6.       26.
25      19.      21.
26      10.      32.
27      34.      56.
28      12.      47.
29      19.      38.
30      27.      41.
31      21.      35.
32      32.      45.
33      27.      45.
34      32.      38.
35      8.       22.
36      15.      25.
37      35.      16.
38      36.      47.
39      46.      51.
40      50.      40.
41      23.      22.
42      27.      30.
43      38.      39.
44      36.      32.
45      32.      41.
46      42.      36.
47      36.      26.
48      15.      19.
49      19.      14.
50      45.      19.
51      27.      5.
52      52.      24.
53      40.      22.
54      40.      52.
55      42.      42.
 1      710.
 2      620.
 3      560.
```

FIGURE 23

(continued, page 2)

```
 4      390.
 5      350.
 6      210.
 7      200.
 8      190.
 9      170.
10      170.
11      160.
12      150.
13      140.
14      120.
15      120.
16      110.
17      100.
18      100.
19      90.
20      90.
21      90.
22      80.
23      80.
24      80.
25      80.
26      70.
27      60.
28      60.
29      60.
30      60.
31      60.
32      50.
33      50.
34      50.
35      50.
36      50.
37      50.
38      40.
39      40.
40      40.
41      40.
42      40.
43      40.
44      40.
45      30.
46      30.
47      30.
48      30.
49      30.
50      30.
51      30.
52      20.
53      20.
54      20.
55      20.
GAS PLANAR EXAMPLE UNE
 15      10.       15.
```

POPULATION DATA

1	710.00*	7	200.00*	13	140.00*	19	90.00*	25	80.00*	31	60.00*	37	50.00*	43	40.00*	49	30.00*	55	20.00*				
2	620.00*	8	190.00*	14	120.00*	20	90.00*	26	70.00*	32	50.00*	38	40.00*	44	40.00*	50	30.00*						
3	560.00*	9	170.00*	15	120.00*	21	90.00*	27	60.00*	33	50.00*	39	40.00*	45	30.00*	51	30.00*						
4	390.00*	10	170.00*	16	110.00*	22	80.00*	28	60.00*	34	50.00*	40	40.00*	46	30.00*	52	20.00*						
5	350.00*	11	160.00*	17	100.00*	23	80.00*	29	60.00*	35	50.00*	41	40.00*	47	30.00*	53	20.00*						
6	210.00*	12	150.00*	18	100.00*	24	80.00*	30	50.00*	36	50.00*	42	40.00*	48	30.00*	54	20.00*						

THE FOLLOWING OPTIONS ARE DESIGNATED:
DEMAND POINTS ARE THE ONLY POTENTIAL FACILITY SITES
DISTANCES ARE MEASURED AS EUCLIDEAN
COORDINATE POINT DATA IS AS FOLLOWS:

1	32.00000	31.00000	1**	2	29.00000	32.00000	2**	3	27.00000	36.00000	3**
4	29.00000	29.00000	4**	5	32.00000	29.00000	5**	6	26.00000	25.00000	6**
7	24.00000	33.00000	7**	8	30.00000	35.00000	8**	9	29.00000	27.00000	9**
10	29.00000	21.00000	10**	11	33.00000	28.00000	11**	12	17.00000	53.00000	12**
13	34.00000	40.00000	13**	14	25.00000	60.00000	14**	15	21.00000	28.00000	15**
16	30.00000	51.00000	16**	17	19.00000	47.00000	17**	18	17.00000	33.00000	18**
19	22.00000	40.00000	19**	20	25.00000	14.00000	20**	21	29.00000	12.00000	21**
22	24.00000	48.00000	22**	23	17.00000	42.00000	23**	24	6.00000	26.00000	24**
25	19.00000	21.00000	25**	26	10.00000	32.00000	26**	27	34.00000	56.00000	27**
28	12.00000	47.00000	28**	29	19.00000	38.00000	29**	30	27.00000	41.00000	30**
31	21.00000	35.00000	31**	32	32.00000	45.00000	32**	33	27.00000	45.00000	33**
34	32.00000	38.00000	34**	35	8.00000	22.00000	35**	36	15.00000	25.00000	36**
37	35.00000	16.00000	37**	38	36.00000	47.00000	38**	39	46.00000	51.00000	39**
40	50.00000	60.00000	40**	41	23.00000	22.00000	41**	42	27.00000	30.00000	42**
43	38.00000	39.00000	43**	44	36.00000	32.00000	44**	45	32.00000	41.00000	45**
46	42.00000	36.00000	46**	47	36.00000	26.00000	47**	48	15.00000	19.00000	48**
49	19.00000	14.00000	49**	50	45.00000	19.00000	50**	51	27.00000	5.00000	51**

FIGURE 24

PLANAR PROBLEM ONE OUTPUT

52	52.00000	24.00000	52**	53	40.00000	22.00000	53**	54	40.00000	52.00000	54**
55	42.00000	42.00000	55**	56	32.00000	31.00000	1**	57	29.00000	32.00000	2**
58	27.00000	36.00000	3**	59	29.00000	29.00000	4**	60	32.00000	29.00000	5**
61	26.00000	25.00000	6**	62	24.00000	33.00000	7**	63	30.00000	35.00000	8**
64	29.00000	27.00000	9**	65	29.00000	21.00000	10**	66	33.00000	28.00000	11**
67	17.00000	53.00000	12**	68	34.00000	40.00000	13**	69	25.00000	60.00000	14**
70	21.00000	28.00000	15**	71	30.00000	51.00000	16**	72	19.00000	47.00000	17**
73	17.00000	33.00000	18**	74	22.00000	40.00000	19**	75	25.00000	14.00000	20**
76	29.00000	12.00000	21**	77	24.00000	48.00000	22**	78	17.00000	42.00000	23**
79	6.00000	26.00000	24**	80	19.00000	21.00000	25**	81	10.00000	32.00000	26**
82	34.00000	56.00000	27**	83	12.00000	47.00000	28**	84	19.00000	38.00000	29**
85	27.00000	41.00000	30**	86	21.00000	35.00000	31**	87	32.00000	45.00000	32**
88	27.00000	45.00000	33**	89	32.00000	38.00000	34**	90	8.00000	22.00000	35**
91	15.00000	25.00000	36**	92	35.00000	16.00000	37**	93	36.00000	47.00000	38**
94	46.00000	51.00000	39**	95	50.00000	40.00000	40**	96	23.00000	22.00000	41**
97	27.00000	30.00000	42**	98	38.00000	39.00000	43**	99	36.00000	32.00000	44**
100	32.00000	41.00000	45**	101	42.00000	36.00000	46**	102	36.00000	26.00000	47**
103	15.00000	19.00000	48**	104	19.00000	14.00000	49**	105	45.00000	19.00000	50**
106	27.00000	5.00000	51**	107	52.00000	24.00000	52**	108	40.00000	22.00000	53**
109	40.00000	52.00000	54**	110	42.00000	42.00000	55**				

FIGURE 24

(continued, page 2)

DIS[redacted]E M[redacted]K

	1	2	3	4	5	6	7	8	9	10
1	0.0	3.16	7.07	3.61	2.00	8.49	8.25	4.47	5.00	10.44
2	3.16	0.0	4.47	3.00	4.24	7.62	5.10	3.16	5.00	11.00
3	7.07	4.47	0.0	7.28	8.60	11.05	4.24	3.16	9.22	15.13
4	3.61	3.00	7.28	0.0	3.00	5.00	6.40	6.08	2.00	8.00
5	2.00	4.24	8.60	3.00	0.0	7.21	8.94	6.32	3.61	8.54
6	8.49	7.62	11.05	5.00	7.21	0.0	8.25	10.77	3.61	5.00
7	8.25	5.10	4.24	6.40	8.94	8.25	0.0	6.32	7.81	13.00
8	4.47	3.16	3.16	6.08	6.32	10.77	6.32	0.0	8.06	14.04
9	5.00	5.00	9.22	2.00	3.61	3.61	7.81	8.06	0.0	6.00
10	10.44	11.00	15.13	8.00	8.54	5.00	13.00	14.04	6.00	0.0
11	3.16	5.66	10.00	4.12	1.41	7.62	10.30	7.62	4.12	8.06
12	20.63	24.19	19.72	20.83	28.30	29.41	21.19	22.20	28.64	34.18
13	9.22	9.43	8.06	12.08	11.18	17.00	12.21	6.40	13.93	19.65
14	29.83	28.28	24.08	31.26	31.78	35.01	27.02	25.50	33.24	39.20
15	11.40	8.94	10.00	8.06	11.05	5.83	5.83	11.40	8.06	10.63
16	20.10	19.03	15.30	22.02	22.09	26.31	18.97	16.00	24.02	30.02
17	20.62	18.03	13.60	20.59	22.20	23.09	14.87	16.28	22.36	27.86
18	15.13	12.04	10.44	12.65	15.52	12.04	7.00	13.15	13.42	16.97
19	13.45	10.63	6.40	13.04	14.87	15.52	7.28	9.43	14.76	20.25
20	18.38	18.44	22.09	16.52	16.55	11.05	19.03	21.59	13.60	8.06
21	19.24	20.00	24.08	17.00	17.26	13.34	21.59	23.02	15.00	9.00
22	18.79	16.76	12.37	19.65	20.62	23.09	15.00	14.32	21.59	27.46
23	18.60	15.62	11.66	17.69	19.85	19.24	11.40	14.76	19.21	24.19
24	20.48	23.77	23.26	23.19	26.17	20.02	19.31	25.63	23.02	23.54
25	16.40	14.87	17.00	18.81	15.26	8.06	13.00	17.80	11.66	10.00
26	22.02	19.00	17.46	19.24	22.20	17.46	14.04	20.22	19.65	21.95
27	26.08	24.52	21.19	27.46	27.07	32.02	25.08	21.38	29.43	35.36
28	26.61	22.67	18.60	24.79	26.91	26.08	18.44	21.63	26.25	31.06
29	14.76	11.66	8.25	13.45	15.81	14.76	7.07	11.40	14.87	19.72
30	11.18	9.22	5.00	12.17	13.00	16.03	8.54	6.71	14.14	20.10
31	11.70	8.54	6.08	10.00	12.53	11.18	3.61	9.00	11.31	16.12
32	14.00	13.34	10.30	16.28	16.00	20.88	14.42	10.20	18.25	24.19
33	14.87	13.15	9.00	19.12	16.76	20.02	12.37	10.44	18.11	24.08
34	7.00	6.71	5.39	9.49	9.00	14.32	9.43	3.61	11.40	17.26
35	26.63	23.26	23.60	24.14	25.00	18.25	19.42	25.55	21.59	21.02
36	18.03	15.65	16.28	14.56	17.46	11.00	12.04	18.03	14.14	14.56
37	16.30	17.09	21.54	14.32	13.34	12.73	20.25	19.65	12.53	7.81
38	19.49	16.55	14.21	19.31	18.44	24.17	18.44	13.42	21.19	26.93
39	24.41	25.50	24.21	27.80	26.08	32.80	28.43	22.63	29.41	34.48
40	20.12	22.47	23.35	23.71	21.10	28.30	26.93	20.62	24.70	28.32
41	12.73	11.66	14.56	9.22	11.40	4.24	11.05	14.76	7.81	6.08
42	5.10	2.83	6.00	2.24	5.10	5.10	4.24	5.83	3.61	9.22
43	10.00	11.40	11.40	13.45	11.66	18.44	15.23	8.94	15.00	20.12
44	4.12	7.00	9.85	7.62	5.00	12.21	12.04	6.71	8.60	13.04
45	10.00	9.49	7.07	12.37	12.00	17.09	11.31	6.32	14.32	20.22
46	11.18	13.60	15.00	14.76	12.21	19.42	18.25	12.04	15.81	19.85
47	6.40	9.22	13.45	7.62	5.00	10.05	13.89	10.82	7.07	8.60
48	20.81	19.10	20.81	17.20	19.72	12.53	16.64	21.93	16.12	14.14
49	21.40	20.59	23.41	18.03	19.85	13.04	19.65	23.71	16.40	12.21
50	17.69	20.62	24.76	18.87	16.40	19.92	25.24	21.93	17.89	16.12
51	20.48	27.07	31.00	24.08	24.52	20.02	28.16	30.15	22.09	16.12
52	21.19	24.35	27.73	23.54	20.62	26.02	29.41	24.60	23.19	23.19
53	12.04	14.87	19.10	13.04	10.63	14.32	19.42	16.40	12.08	11.05
54	22.47	22.83	20.62	25.50	24.35	30.41	24.84	19.72	27.31	32.89
55	14.87	16.40	16.16	18.38	16.40	23.35	20.12	13.89	19.85	24.70

FIGURE 24

(continued, page 3)

	11	12	13	14	15	16	17	18	19	20
1	2.16	26.63	9.22	29.83	11.40	20.10	20.62	15.13	13.45	18.38
2	5.66	24.19	9.43	28.28	8.94	19.03	18.03	12.04	10.63	18.44
3	10.00	19.72	8.06	24.08	10.00	15.30	13.60	10.44	6.40	22.09
4	4.12	26.83	12.08	31.26	8.06	22.02	20.59	12.65	13.04	15.52
5	1.41	28.30	11.18	31.78	11.05	22.09	22.20	15.52	14.87	16.55
6	7.62	29.41	17.00	35.04	5.83	26.31	23.09	12.04	15.52	11.05
7	10.30	21.19	12.21	27.62	5.83	18.97	14.87	7.00	7.28	19.03
8	7.62	22.20	6.40	25.50	11.40	16.00	16.28	13.15	9.43	21.59
9	4.12	28.64	13.93	33.24	8.06	24.02	22.36	13.42	14.76	13.60
10	8.06	34.18	19.65	39.20	10.63	30.02	27.86	16.97	20.25	8.06
11	0.0	29.68	12.04	32.98	12.00	23.19	23.60	16.76	16.28	16.12
12	29.68	0.0	21.40	10.63	25.32	13.15	6.32	20.00	13.93	39.81
13	12.04	21.40	0.0	21.93	17.69	11.70	16.55	18.38	12.00	27.51
14	32.98	10.63	21.93	0.0	32.25	10.30	14.32	28.16	20.22	46.00
15	12.00	25.32	17.69	32.25	0.0	24.70	19.10	6.40	12.04	14.56
16	23.19	13.15	11.70	10.30	24.70	0.0	11.70	22.20	13.60	37.34
17	23.60	6.32	16.55	14.32	19.10	11.70	0.0	14.14	7.62	33.54
18	10.76	20.00	18.38	28.16	6.40	22.20	14.14	0.0	8.60	20.62
19	16.28	13.93	12.00	20.22	12.04	13.60	7.62	8.60	0.0	26.17
20	10.12	39.81	27.51	46.09	14.56	37.34	33.54	20.62	26.17	0.0
21	10.49	42.72	28.44	48.17	17.89	39.01	36.40	24.19	28.86	4.47
22	21.93	8.60	12.81	12.04	20.22	6.71	5.10	16.55	8.25	34.01
23	21.26	11.00	17.12	19.70	14.56	15.81	5.39	9.00	5.39	29.12
24	27.07	29.15	31.30	38.95	15.13	34.66	24.70	13.04	21.26	22.47
25	15.65	32.06	24.21	39.48	7.28	31.95	26.00	12.17	19.24	9.22
26	23.35	22.14	25.30	31.78	11.70	27.59	17.49	7.07	14.42	23.43
27	28.02	17.26	16.00	9.85	30.87	6.40	17.49	28.60	20.00	42.95
28	28.32	7.81	23.09	18.38	21.02	18.44	7.00	14.87	12.21	35.47
29	17.20	15.13	15.13	22.80	10.20	17.03	9.00	5.39	3.61	24.74
30	14.32	15.62	7.07	19.10	14.32	10.44	10.00	12.81	5.10	27.07
31	13.89	18.44	13.93	25.32	7.00	18.36	12.17	4.47	5.10	21.38
32	17.03	17.00	5.39	16.55	20.25	6.32	13.15	19.21	11.18	31.78
33	18.03	12.81	8.60	15.13	18.03	6.71	8.25	15.62	7.07	31.06
34	10.05	21.21	2.83	23.09	14.87	13.15	15.81	15.81	10.20	25.00
35	25.71	32.28	31.62	41.63	14.32	36.40	27.31	14.21	22.80	18.79
36	18.25	28.07	24.21	36.40	6.71	30.02	22.36	8.25	16.55	14.87
37	12.17	41.15	24.02	45.12	18.44	35.36	34.89	24.76	27.29	10.20
38	19.24	19.92	7.28	17.03	24.21	7.21	17.00	23.60	15.65	34.79
39	26.42	29.07	16.28	22.85	33.97	16.00	27.29	34.13	26.40	42.54
40	20.81	35.47	16.00	32.02	31.38	22.83	31.78	33.73	28.00	36.07
41	11.66	31.58	21.10	38.05	6.32	29.83	25.32	12.53	18.03	8.25
42	6.32	25.08	12.21	30.07	6.32	21.21	18.79	10.44	11.18	16.12
43	12.08	25.24	4.12	24.70	20.25	14.42	20.62	21.84	16.03	28.18
44	5.00	28.32	8.25	30.08	15.52	19.92	22.67	19.03	16.12	21.10
45	13.04	19.21	2.24	20.25	17.03	10.20	14.32	17.00	10.05	27.89
46	12.04	30.23	8.94	29.41	22.47	19.21	25.50	25.18	20.40	27.80
47	3.61	33.02	14.14	35.74	15.13	25.71	27.02	20.25	19.80	16.28
48	20.12	34.06	28.32	42.20	10.82	35.34	28.28	14.14	22.14	11.18
49	19.80	39.05	30.02	46.39	14.14	38.60	33.00	19.10	26.17	6.00
50	15.00	44.05	23.71	45.62	25.63	35.34	38.21	31.30	31.14	20.62
51	23.77	49.03	35.69	55.04	23.77	46.10	42.76	29.73	35.36	9.22
52	19.42	45.45	24.08	45.09	31.26	34.83	40.22	36.14	34.00	28.79
53	9.22	38.60	18.97	40.85	19.92	30.68	32.65	25.50	25.46	17.00
54	25.00	23.02	13.42	17.09	30.61	10.05	21.59	29.83	21.63	40.85
55	16.64	27.31	8.25	24.78	25.24	15.00	23.54	26.57	20.10	32.76

FIGURE 24

(continued, page 4)

DISTANCE MATRIX

	21	22	23	24	25	26	27	28	29	30
1	19.24	18.79	18.60	26.48	16.40	22.02	25.08	25.61	14.76	11.18
2	20.00	16.76	15.62	23.71	14.87	19.00	24.52	22.67	11.66	9.22
3	24.08	12.37	11.66	23.29	17.03	17.46	21.19	18.60	8.25	5.00
4	17.00	19.65	17.69	23.19	12.81	19.24	27.46	24.76	13.45	12.17
5	17.26	20.62	19.85	26.17	15.26	22.20	27.07	26.91	15.81	13.00
6	13.34	23.09	19.24	20.02	8.06	17.46	32.02	26.08	14.76	16.03
7	21.59	15.00	11.40	19.31	13.00	14.04	25.08	18.44	7.07	8.54
8	23.02	14.32	14.76	25.03	17.80	20.22	21.38	21.63	11.40	6.71
9	16.00	21.59	19.21	23.02	11.66	19.65	29.43	26.25	14.87	14.14
10	9.00	27.46	24.19	23.59	10.00	21.95	35.36	31.06	19.72	20.10
11	16.49	21.93	21.26	27.07	15.65	23.35	28.02	28.32	17.20	14.32
12	42.72	8.60	11.00	29.15	32.06	22.14	17.26	7.81	15.13	15.62
13	28.44	12.81	17.12	31.30	24.21	25.30	16.00	23.09	15.13	7.07
14	48.17	12.04	19.70	38.95	39.46	31.76	9.85	18.38	22.80	19.10
15	17.89	20.22	14.56	15.13	7.28	11.70	30.87	21.02	10.20	14.32
16	39.01	6.71	15.81	34.66	31.95	27.59	6.40	18.44	17.03	10.44
17	36.40	5.10	5.39	24.70	26.00	17.49	17.49	7.00	9.00	10.00
18	24.19	16.55	9.00	13.04	12.17	7.07	28.60	14.87	5.39	12.81
19	28.86	8.25	5.39	21.26	19.24	14.42	20.00	12.21	3.61	5.10
20	4.47	34.01	29.12	24.47	9.22	23.43	42.95	35.47	24.74	27.07
21	0.0	36.35	32.31	26.93	13.45	27.59	44.28	38.91	27.86	29.07
22	36.35	0.0	9.22	28.43	27.46	21.26	12.81	12.04	11.18	7.62
23	32.31	9.22	0.0	19.42	21.10	12.21	22.02	7.07	4.47	10.05
24	26.93	28.43	19.42	0.0	13.93	7.21	41.04	21.84	17.69	25.81
25	13.45	27.46	21.10	13.93	0.0	14.21	38.08	26.93	17.00	21.54
26	27.59	21.26	12.21	7.21	14.21	0.0	33.94	15.13	10.82	19.24
27	44.28	12.81	22.02	41.04	38.08	33.94	0.0	23.77	23.43	16.55
28	38.91	12.04	7.07	21.84	26.93	15.13	23.77	0.0	11.40	16.16
29	27.86	11.18	4.47	17.69	17.00	10.82	23.43	11.40	0.0	8.54
30	29.07	7.62	10.05	25.81	21.54	19.24	16.55	16.16	8.54	0.0
31	24.35	13.34	8.06	17.49	14.14	11.40	24.70	15.00	3.61	8.49
32	33.14	8.54	15.30	32.20	27.29	25.55	11.18	20.10	14.76	6.40
33	33.06	4.24	10.44	28.32	25.30	21.40	13.04	15.13	10.63	4.00
34	26.17	12.81	15.52	28.09	21.40	22.80	18.11	21.93	13.00	5.83
35	23.26	30.53	21.93	4.47	11.05	10.20	42.80	25.32	19.42	26.87
36	19.10	24.70	17.12	9.06	5.66	8.60	36.36	22.20	13.60	20.00
37	7.21	33.84	31.62	30.08	16.76	29.68	40.01	38.60	27.20	26.25
38	35.69	12.04	19.65	30.02	31.06	30.02	9.22	24.00	19.24	10.82
39	43.54	22.20	30.36	47.17	40.36	40.71	13.00	34.23	29.97	21.47
40	35.00	27.20	33.06	49.17	36.36	40.79	22.63	38.64	31.06	23.02
41	11.66	26.02	20.88	17.49	4.12	16.40	35.74	27.31	16.49	19.42
42	18.11	18.25	15.62	21.38	12.04	17.12	26.93	22.67	11.31	11.00
43	28.46	16.64	21.21	34.59	26.17	28.86	17.46	27.20	19.03	11.18
44	21.19	20.00	21.47	30.59	20.25	26.00	24.08	28.30	18.03	12.73
45	29.15	10.63	15.03	30.02	23.85	23.77	15.13	20.88	13.34	5.00
46	27.29	21.63	25.71	37.36	27.46	32.25	21.54	31.95	23.09	15.81
47	15.65	25.06	24.84	30.09	17.72	26.68	30.07	31.89	20.81	17.49
48	15.65	30.36	23.09	11.40	4.47	13.93	41.59	28.16	19.42	25.06
49	10.20	34.37	28.07	17.69	7.00	20.12	44.60	33.73	24.00	28.16
50	17.46	35.81	36.24	39.02	26.08	37.34	38.60	43.28	32.20	28.43
51	7.28	43.10	38.33	29.79	17.89	31.91	51.48	44.60	33.96	36.00
52	25.94	36.88	39.36	40.04	33.14	42.76	36.72	46.14	35.85	30.23
53	14.87	30.53	30.48	34.23	21.02	31.62	34.53	37.54	26.40	23.02
54	41.48	16.49	25.08	42.80	37.44	36.06	7.21	28.44	25.24	17.03
55	32.70	18.97	25.00	39.49	31.14	33.53	16.12	30.41	23.35	15.03

FIGURE 24

(continued, page 5)

D[redacted]CE [redacted]IX

	31	32	33	34	35	36	37	38	39	40
1	11.70	14.00	14.87	7.00	25.63	18.03	15.30	16.49	24.41	20.12
2	8.54	13.34	13.15	6.71	23.26	15.65	17.09	16.55	25.50	22.47
3	6.08	10.30	9.00	5.39	23.60	16.28	21.54	14.21	24.21	23.35
4	10.00	16.28	16.12	9.49	22.14	14.56	14.32	19.31	27.80	23.71
5	12.53	16.00	16.76	9.00	25.00	17.46	13.34	18.44	26.08	21.10
6	11.18	20.88	20.02	14.32	18.25	11.00	12.73	24.17	32.80	28.30
7	3.61	14.42	12.37	9.43	19.42	12.04	20.25	18.44	28.43	26.93
8	9.00	10.20	10.44	3.61	25.55	18.03	19.65	13.42	22.63	20.62
9	11.31	18.25	18.11	11.40	21.59	14.14	12.53	21.19	29.41	24.70
10	16.12	24.19	24.08	17.26	21.02	14.56	7.81	26.93	34.48	28.32
11	13.89	17.03	18.03	10.05	25.71	18.25	12.17	19.24	26.42	20.81
12	18.44	17.00	12.81	21.21	32.28	28.07	41.15	19.92	29.07	35.47
13	13.93	5.39	8.60	2.83	31.62	24.21	24.02	7.28	16.28	16.00
14	25.32	16.55	15.13	23.09	41.63	36.40	45.12	17.03	22.85	32.02
15	7.00	20.25	18.03	14.87	14.32	5.71	18.44	24.21	33.97	31.38
16	18.36	6.32	6.71	13.15	36.40	30.02	35.36	7.21	16.00	22.83
17	12.17	13.15	8.25	15.81	27.31	22.36	34.89	17.00	27.29	31.78
18	4.47	19.21	15.62	15.81	14.21	8.25	24.76	23.60	34.13	33.73
19	5.10	11.18	7.07	10.20	22.80	16.55	27.29	15.65	26.40	28.00
20	21.38	31.78	31.06	25.00	18.79	14.87	10.20	34.79	42.54	36.07
21	24.35	33.14	33.06	24.17	23.26	19.10	7.21	35.69	42.54	35.00
22	13.34	8.54	4.24	12.81	30.53	24.70	33.84	12.04	22.20	27.20
23	8.06	15.30	10.44	15.52	21.93	17.12	31.62	19.65	30.36	33.06
24	17.49	32.20	28.32	28.64	4.47	9.06	30.68	36.62	47.17	46.17
25	14.14	27.29	25.30	21.40	11.05	5.66	16.76	31.06	40.36	36.36
26	11.40	25.55	21.40	22.80	10.20	8.60	29.68	30.02	40.71	40.79
27	24.70	11.18	13.04	18.11	42.80	36.36	40.01	9.22	13.00	22.63
28	15.00	20.10	15.13	21.93	25.32	22.20	36.60	24.00	34.23	38.64
29	3.61	14.76	10.63	13.00	19.42	13.60	27.20	19.24	29.97	31.06
30	8.49	6.40	4.00	5.83	26.87	20.00	26.25	10.82	21.47	23.02
31	0.0	14.87	11.66	11.40	18.38	11.66	23.60	19.21	29.68	29.43
32	14.87	0.0	5.00	7.00	33.24	26.25	29.15	4.47	15.23	18.68
33	11.66	5.00	0.0	8.60	29.83	23.32	30.08	9.22	19.92	23.54
34	11.40	7.00	8.60	0.0	28.84	21.40	22.20	9.85	19.10	18.11
35	18.38	33.24	29.83	28.84	0.0	7.62	27.66	37.54	47.80	45.69
36	11.66	26.25	23.32	21.49	7.62	0.0	21.93	30.41	40.46	38.08
37	23.60	29.15	30.08	22.20	27.66	21.93	0.0	31.02	36.69	28.30
38	19.21	4.47	9.22	9.85	37.54	30.41	31.02	0.0	10.77	15.65
39	29.68	15.23	19.92	19.10	47.80	40.46	36.69	10.77	0.0	11.70
40	29.43	18.68	23.54	18.11	45.69	38.08	28.30	15.65	11.70	0.0
41	13.15	24.70	23.35	18.36	15.00	8.54	13.42	28.18	37.01	32.45
42	7.81	15.81	15.00	9.43	20.62	13.00	16.12	19.24	28.32	25.08
43	17.46	8.49	12.53	6.08	34.48	26.93	23.19	8.25	14.42	12.04
44	15.30	13.60	15.81	7.21	29.73	22.14	16.03	15.00	21.47	16.12
45	12.53	4.00	6.40	3.00	30.61	23.35	25.18	7.21	17.20	18.03
46	21.02	13.45	17.49	10.20	36.77	29.15	21.19	12.53	15.52	8.94
47	17.49	19.42	21.02	12.65	28.28	21.02	10.05	21.00	26.93	19.80
48	17.09	31.06	28.64	25.50	7.62	6.00	20.22	35.00	44.55	40.82
49	21.10	33.62	32.02	27.29	13.60	11.70	16.12	37.12	45.80	40.46
50	28.84	29.07	31.62	23.02	37.12	30.59	19.44	29.41	32.02	21.59
51	30.59	40.31	40.00	33.38	25.50	23.32	13.60	42.95	49.77	41.88
52	32.89	29.00	32.65	24.41	44.05	37.01	18.79	28.02	27.66	16.12
53	23.02	24.35	26.42	17.89	32.00	25.18	7.81	25.32	29.61	20.59
54	25.50	10.63	14.76	16.12	43.86	36.80	36.35	6.40	6.08	15.62
55	22.14	10.44	15.30	10.77	39.45	31.91	26.93	7.81	9.85	8.25

FIGURE 24

(continued, page 6)

[redacted]ST[redacted]MA[redacted]

	41	42	43	44	45	46	47	48	49	50
1	12.73	5.10	10.00	4.12	10.00	11.18	6.40	20.81	21.40	17.69
2	11.66	2.83	11.40	7.09	9.49	13.60	9.22	19.10	20.59	20.62
3	14.56	6.00	11.40	9.85	7.07	15.00	13.45	20.81	23.41	24.76
4	9.22	2.24	13.45	7.62	12.37	14.76	7.62	17.20	18.03	18.87
5	11.40	5.10	11.66	6.00	12.00	12.21	5.00	19.72	19.85	16.40
6	4.24	5.10	18.44	12.21	17.09	19.42	10.05	12.53	13.04	19.92
7	11.05	4.24	15.23	12.04	11.31	18.25	13.89	16.64	19.65	25.24
8	14.76	5.83	8.94	9.71	6.32	12.04	10.82	21.93	23.71	21.93
9	7.81	3.61	15.00	8.60	14.32	15.81	7.07	16.12	16.40	17.89
10	6.08	9.22	20.12	13.04	20.22	19.85	8.60	14.14	12.21	16.12
11	11.66	6.32	12.08	6.00	13.04	12.04	3.61	20.12	19.80	15.00
12	31.58	25.08	25.24	28.32	19.21	30.23	33.02	34.06	39.05	44.05
13	21.10	12.21	4.12	8.25	2.24	8.94	14.14	28.32	30.02	23.71
14	38.05	30.07	24.70	30.08	20.25	29.41	35.74	42.20	46.39	45.62
15	6.32	6.32	20.25	15.52	17.03	22.47	15.13	10.82	14.14	25.63
16	29.83	21.21	14.42	19.92	10.20	19.21	25.71	35.34	38.60	35.34
17	25.32	18.79	20.62	22.67	14.32	25.50	27.02	28.28	33.00	38.21
18	12.53	10.44	21.84	19.03	17.00	25.18	20.25	14.14	19.10	31.30
19	18.03	11.18	16.03	10.12	10.05	20.40	19.80	22.14	26.17	31.14
20	8.25	16.12	28.18	21.19	27.89	27.80	16.28	11.18	6.00	20.62
21	11.66	18.11	28.46	21.19	29.15	27.29	15.65	15.65	10.20	17.46
22	26.02	18.25	16.64	20.00	10.63	21.63	25.06	30.36	34.37	35.81
23	29.88	15.62	21.21	21.47	15.03	25.71	24.84	23.09	28.07	36.24
24	17.46	21.38	34.54	30.59	30.02	37.36	30.00	11.40	17.69	39.62
25	4.12	12.04	26.17	20.25	23.85	27.46	17.72	4.47	7.00	26.08
26	16.40	17.12	28.86	26.00	23.77	32.25	26.68	13.93	20.12	37.34
27	35.74	26.93	17.46	24.08	15.13	21.54	30.07	41.59	44.60	38.90
28	27.31	22.67	27.20	28.30	20.88	31.95	31.89	28.16	33.73	43.28
29	16.49	11.31	19.03	18.03	13.34	23.09	20.81	19.42	24.00	32.20
30	19.42	11.00	11.18	12.73	5.00	15.81	17.49	25.06	28.16	28.43
31	13.15	7.81	17.46	15.30	12.53	21.02	17.49	17.09	21.10	28.84
32	24.70	15.81	8.49	13.60	4.00	13.45	19.42	31.06	33.62	29.07
33	23.35	15.00	12.53	15.81	6.40	17.49	21.02	28.64	32.02	31.62
34	18.36	9.43	6.08	7.21	3.00	10.20	12.65	25.50	27.29	23.02
35	16.00	20.62	34.48	29.73	30.61	36.77	28.28	7.62	13.60	37.12
36	8.54	13.00	26.93	22.14	23.35	29.15	21.02	6.00	11.70	30.59
37	13.42	16.12	23.19	16.03	25.18	21.19	10.05	20.22	16.12	10.44
38	28.18	19.24	8.25	15.00	7.21	12.53	21.00	35.00	37.12	29.41
39	31.01	28.32	14.42	21.47	17.20	15.52	26.93	44.55	45.80	32.02
40	32.45	25.08	12.04	16.12	18.03	8.94	19.80	40.82	40.46	21.59
41	0.0	8.94	22.67	16.40	21.02	23.60	13.60	8.54	8.94	22.20
42	8.94	0.0	14.21	9.22	12.08	16.16	9.85	16.28	17.89	21.10
43	22.67	14.21	0.0	7.28	6.32	5.00	13.15	30.48	31.40	21.19
44	16.40	9.22	7.28	0.0	9.85	7.21	6.00	24.70	24.76	15.81
45	21.02	12.08	6.32	9.85	0.0	11.18	15.52	27.80	29.97	25.55
46	23.60	16.16	5.00	7.21	11.18	0.0	11.66	31.91	31.83	17.26
47	13.60	9.85	13.15	6.00	15.52	11.66	0.0	22.14	20.81	11.40
48	8.54	16.28	30.48	24.70	27.80	31.91	22.14	0.0	6.40	30.00
49	8.94	17.89	31.40	24.76	29.97	31.83	20.81	6.40	0.0	26.48
50	22.20	21.10	21.19	15.81	25.55	17.26	11.40	30.00	26.48	0.0
51	17.46	25.00	35.74	28.46	36.35	34.44	22.85	18.44	12.04	22.80
52	29.07	25.71	20.52	17.89	26.25	15.62	16.12	37.34	34.48	8.60
53	17.00	15.26	17.12	10.77	20.62	14.14	5.66	25.18	22.47	5.83
54	34.48	25.55	13.15	20.49	13.60	16.12	26.31	41.40	43.42	33.38
55	27.59	19.21	5.00	11.66	10.05	6.00	17.09	35.47	36.24	23.19

FIGURE 24

(continued, page 7)

DISTANCE MATRIX

	51	52	53	54	55
1	26.48	21.19	12.04	22.47	14.87
2	27.07	24.35	14.87	22.83	16.40
3	31.00	27.73	19.10	20.62	16.16
4	24.08	23.54	13.04	25.50	18.38
5	24.52	20.62	10.63	24.35	16.40
6	20.02	26.02	14.32	30.41	23.35
7	28.16	29.41	19.42	24.84	20.12
8	30.15	24.60	16.40	19.72	13.89
9	22.09	23.19	12.08	27.31	19.85
10	16.12	23.19	11.05	32.89	24.70
11	23.77	19.42	9.22	25.00	16.64
12	49.03	45.45	38.60	23.02	27.31
13	36.69	24.08	18.97	18.42	8.25
14	55.04	45.00	40.85	17.00	24.76
15	22.77	31.26	19.92	30.61	25.24
16	46.10	34.83	30.68	10.05	15.00
17	42.76	40.22	32.65	21.59	23.54
18	29.73	36.14	25.50	29.83	26.57
19	35.36	34.00	25.46	21.63	20.10
20	9.22	28.79	17.00	40.85	32.76
21	7.28	25.94	14.87	41.48	32.70
22	42.10	36.88	30.53	10.49	18.97
23	38.33	39.36	30.48	26.08	25.00
24	29.70	46.04	34.23	42.80	39.40
25	17.89	33.14	21.02	37.49	31.14
26	31.91	42.76	31.62	30.06	33.53
27	51.48	36.72	34.53	7.21	16.12
28	44.60	46.14	37.54	28.44	30.41
29	33.96	35.85	26.40	26.24	23.35
30	36.00	30.23	23.02	17.03	15.03
31	30.59	32.89	23.02	25.50	22.14
32	40.31	29.00	24.35	10.63	10.44
33	40.00	32.65	26.42	14.76	15.30
34	33.38	24.41	17.89	16.12	10.77
35	25.50	44.05	32.00	43.86	39.45
36	23.32	37.01	25.18	36.80	31.91
37	12.60	18.79	7.81	36.35	26.93
38	42.95	28.02	25.32	9.40	7.81
39	49.77	27.66	29.61	6.08	9.85
40	41.88	16.12	20.59	15.62	8.25
41	17.46	29.07	17.00	34.49	27.59
42	25.00	25.71	15.26	25.55	19.21
43	35.74	20.52	17.12	13.15	5.00
44	28.46	17.89	10.77	20.49	11.66
45	36.35	26.25	20.62	13.60	10.05
46	34.44	15.62	14.14	16.12	6.00
47	22.85	16.12	5.66	26.31	17.09
48	18.44	37.34	25.18	41.40	35.47
49	12.04	34.48	22.47	43.42	36.24
50	22.80	8.60	5.83	33.38	23.19
51	0.0	31.40	21.40	48.76	39.92
52	31.40	0.0	12.17	30.46	20.59
53	21.40	12.17	0.0	30.00	20.10
54	48.76	30.46	30.00	0.0	10.20
55	39.92	20.59	20.10	10.20	0.0

FIGURE 24

(continued, page 8)

FIGURE 24

(continued, page 9)

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SUBPROGRAM MATBLD HAS BEEN CALLED TO GENERATE A COVER MATRIX
   THE MAXIMUM DISTANCE/TIME OF  10.00 HAS BEEN UTILIZED
*****************************************************************
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FIGURE 24

(continued, page 10)

```
  ITERATION NUMBER,     1
GAS PLANAR EXAMPLE ONE

  NUMBER OF FACILITIES   1
  SERVICE DISTANCE =    10.000

  NEW FACILITY LOCATION NUMBER     2

  FACILITIES ARE LOCATED AT     2,
  ------------------------------------------------------------------------
  POPULATION SERVED    4130.00          PERCENT OF TOTAL POPULATION SERVED   64.63
  ------------------------------------------------------------------------
```

GAS PLANAR EXAMPLE ONE

FACILITIES ARE LOCATED AT 2.
PRIMARY DISTANCE = 10.00
SECONDARY DISTANCE = 15.00

PARTITION NUMBER	FACILITY NUMBER	PRIMARY SERVED POP.	SECONDARY SERVED POP.	POPULATION OUTSIDE SECONDARY	POPULATION IN PARTITION	LARGEST TRAVELED DISTANCE	NODE NUMBER	WT.DIST PRIMARY COVERED	WT.DIST. SECONDARY COVERED	WT.DIST OUTSIDE PRIMARY	TOTAL WEIGHTED DISTANCE
1	2	4130.00	730.00	1540.00	6400.00	28.3	14	17129.2	8872.5	41177.	58306.
		4130.00	730.00	1540.00	6400.00			17129.2	8872.5	41177.	58306.

PARTITION 1 FACILITY 2

1 D=	3.2	2 D=	0.0	3 D=	4.5	4 D=	3.0	5 D=	4.2	6 D=	7.6
7 D=	5.1	8 D=	3.2	9 D=	5.0	10 D=	11.0	11 D=	5.7	12 D=	24.2
13 D=	9.4	14 D=	28.3	15 D=	8.9	16 D=	19.0	17 D=	18.0	18 D=	12.0
19 D=	10.6	20 D=	18.4	21 D=	20.0	22 D=	16.8	23 D=	15.6	24 D=	23.8
25 D=	14.9	26 D=	19.0	27 D=	24.5	28 D=	22.7	29 D=	11.7	30 D=	9.2
31 D=	8.5	32 D=	13.3	33 D=	13.2	34 D=	6.7	35 D=	23.3	36 D=	15.7
37 D=	17.1	38 D=	16.6	39 D=	25.5	40 D=	22.5	41 D=	11.7	42 D=	2.8
43 D=	11.4	44 D=	7.0	45 D=	9.5	46 D=	13.6	47 D=	9.2	48 D=	19.1
49 D=	20.6	50 D=	20.6	51 D=	27.1	52 D=	24.4	53 D=	14.9	54 D=	22.8
55 D=	16.4										

FIGURE 24

(continued, page 11)

FIGURE 24

(continued, page 12)

```
  ITERATION NUMBER,    2
BAS PLANAR EXAMPLE ONE

  NUMBER OF FACILITIES   2
  SERVICE DISTANCE =    10.000

  NEW FACILITY LOCATION NUMBER    22

  FACILITIES ARE LOCATED AT     2,   22,
  ----------------------------------------------------------------------
  POPULATION SERVED    4840.00          PERCENT OF TOTAL POPULATION SERVED   75.02
  ----------------------------------------------------------------------

  SUBSTITUTION  ALGORITHM USED

  NODE      4 REPLACES FACILITY LOCATION      2
  THIS IS NOW FACILITY NUMBER      1

  FACILITIES ARE LOCATED AT     4,   22,
  ----------------------------------------------------------------------
  POPULATION SERVED    4880.00          PERCENT OF TOTAL POPULATION SERVED   76.35
  ----------------------------------------------------------------------
```

GAS PLANAR EXAMPLE ONE

FACILITIES ARE LOCATED AT 4, 22.
PRIMARY DISTANCE = 10.00
SECONDARY DISTANCE = 15.00

PARTITION NUMBER	FACILITY NUMBER	PRIMARY SERVED POP.	SECONDARY SERVED POP.	POPULATION OUTSIDE SECONDARY	POPULATION IN PARTITION	LARGEST DISTANCE	NODE NUMBER	WT.DIST PRIMARY COVERED	WT.DIST. SECONDARY COVERED	WT.DIST OUTSIDE PRIMARY	TOTAL WEIGHTED DISTANCE
1	4	4110.00	510.00	580.00	5200.00	24.1	51	18426.0	6666.8	18035.	36461.
2	22	770.00	370.00	60.00	1200.00	22.2	39	5114.1	4407.2	5625.	10739.
		4880.00	880.00	640.00	6400.00			23540.1	11074.0	23660.	47200.

PARTITION 1 FACILITY 4

** 1 D= 3.6** 2 D= 3.0** 3 D= 7.3** 4 D= 0.0** 5 D= 3.0** 6 D= 5.0

* 7 D= 6.4** 8 D= 6.1** 9 D= 2.0** 10 D= 8.0** 11 D= 4.1** 13 D= 12.1

* 15 D= 8.1** 18 D= 12.6** 20 D= 15.5** 21 D= 17.0** 24 D= 23.2** 25 D= 12.8

* 26 D= 19.2** 31 D= 10.0** 34 D= 9.5** 35 D= 22.1** 36 D= 14.6** 37 D= 14.3

* 40 D= 23.7** 41 D= 9.2** 42 D= 2.2** 43 D= 13.5** 44 D= 7.6** 46 D= 14.8

* 47 D= 7.6** 48 D= 17.2** 49 D= 18.0** 50 D= 18.9** 51 D= 24.1** 52 D= 23.5

* 53 D= 13.0** 55 D= 18.4**

PARTITION 2 FACILITY 22

** 12 D= 8.6** 14 D= 12.0** 16 D= 6.7** 17 D= 5.1** 19 D= 8.2** 22 D= 0.0

* 23 D= 9.2** 27 D= 12.8** 28 D= 12.0** 29 D= 11.2** 30 D= 7.6** 32 D= 8.5

* 33 D= 4.2** 38 D= 12.0** 39 D= 22.2** 45 D= 10.6** 54 D= 16.5**

FIGURE 24

(continued, page 13)

FIGURE 24

(continued, page 14)

```
  ITERATION NUMBER,    3
GAS PLANAR EXAMPLE ONE

  NUMBER OF FACILITIES   3
  SERVICE DISTANCE =    10.000

  NEW FACILITY LOCATION NUMBER    36

  FACILITIES ARE LOCATED AT     4,   22,   36,
  ----------------------------------------------------------------------
  POPULATION SERVED    5340.00          PERCENT OF TOTAL POPULATION SERVED   83.44
  ----------------------------------------------------------------------

  SUBSTITUTION  ALGORITHM USED

  NODE      2 REPLACES FACILITY LOCATION      4
  THIS IS NOW FACILITY NUMBER      1

  FACILITIES ARE LOCATED AT     2,   22,   36,
  ----------------------------------------------------------------------
  POPULATION SERVED    5340.00          PERCENT OF TOTAL POPULATION SERVED   83.44
  ----------------------------------------------------------------------

  SUBSTITUTION  ALGORITHM USED

  NODE     20 REPLACES FACILITY LOCATION     36
  THIS IS NOW FACILITY NUMBER      3

  FACILITIES ARE LOCATED AT     2,   22,   20,
  ----------------------------------------------------------------------
  POPULATION SERVED    5370.00          PERCENT OF TOTAL POPULATION SERVED   83.91
  ----------------------------------------------------------------------
```

GAS PLANAR EXAMPLE ONE

FACILITIES ARE LOCATED AT 2, 22, 20,
PRIMARY DISTANCE = 10.00
SECONDARY DISTANCE = 15.00

PARTITION NUMBER	FACILITY NUMBER	PRIMARY SERVED POP.	SECONDARY SERVED POP.	POPULATION OUTSIDE SECONDARY	POPULATION IN PARTITION	LARGEST TRAVELED DISTANCE	NODE NUMBER	WT.DIST PRIMARY COVERED	WT.DIST. SECONDARY COVERED	WT.DIST OUTSIDE PRIMARY	TOTAL WEIGHTED DISTANCE
1	2	4070.00	190.00	180.00	4440.00	24.4	52	16576.0	2365.6	6028.	22604.
2	22	770.00	340.00	60.00	1170.00	22.2	39	5114.1	4088.3	5306.	10420.
3	20	530.00	130.00	130.00	790.00	22.5	24	3297.1	1588.6	4326.	7623.
		5370.00	660.00	370.00	6400.00			24987.2	8042.5	15660.	40647.

PARTITION 1 FACILITY 2
** 1 D= 3.2** 2 D= 0.0** 3 D= 4.5** 4 D= 3.0** 5 D= 4.2** 6 D= 7.6

* 7 D= 5.1** 8 D= 3.2** 9 D= 5.0** 11 D= 5.7** 13 D= 9.4** 15 D= 8.9

* 18 D= 12.0** 26 D= 19.0** 31 D= 8.5** 34 D= 6.7** 40 D= 22.5** 42 D= 2.8

* 43 D= 11.4** 44 D= 7.0** 45 D= 9.5** 46 D= 13.6** 47 D= 9.2** 50 D= 20.6

* 52 D= 24.4** 53 D= 14.9** 55 D= 16.4**

PARTITION 2 FACILITY 22
** 12 D= 8.6** 14 D= 12.0** 16 D= 6.7** 17 D= 5.1** 19 D= 8.2** 22 D= 0.0

* 23 D= 9.2** 27 D= 12.8** 28 D= 12.0** 29 D= 11.2** 30 D= 7.6** 32 D= 8.5

* 33 D= 4.2** 38 D= 12.0** 39 D= 22.2** 54 D= 16.5**

PARTITION 3 FACILITY 20
** 10 D= 8.1** 20 D= 0.0** 21 D= 4.5** 24 D= 22.5** 25 D= 9.2** 35 D= 18.8

* 36 D= 14.9** 37 D= 10.2** 41 D= 8.2** 48 D= 11.2** 49 D= 6.0** 51 D= 9.2

FIGURE 24

(continued, page 15)

FIGURE 24

(continued, page 16)

```
  ITERATION NUMBER,    4
GAS PLANAR EXAMPLE ONE

  NUMBER OF FACILITIES   4
  SERVICE DISTANCE =    10.000

  NEW FACILITY LOCATION NUMBER    36

  FACILITIES ARE LOCATED AT     2,   22,   20,   36,
  ----------------------------------------------------------------------
  POPULATION SERVED    5750.00          PERCENT OF TOTAL POPULATION SERVED   89.04
  ----------------------------------------------------------------------

  SUBSTITUTION  ALGORITHM USED

  NODE     21 REPLACES FACILITY LOCATION     20
  THIS IS NOW FACILITY NUMBER      3

  FACILITIES ARE LOCATED AT     2,   22,   21,   36,
  ----------------------------------------------------------------------
  POPULATION SERVED    5770.00          PERCENT OF TOTAL POPULATION SERVED   90.16
  ----------------------------------------------------------------------
```

GAS PLANAR EXAMPLE ONE

FACILITIES ARE LOCATED AT 2, 22, 21, 36,
PRIMARY DISTANCE = 10.00
SECONDARY DISTANCE = 15.00

PARTITION NUMBER	FACILITY NUMBER	PRIMARY SERVED POP.	SECONDARY SERVED POP.	POPULATION OUTSIDE SECONDARY	POPULATION IN PARTITION	LARGEST TRAVELED DISTANCE	NODE NUMBER	WT.DIST PRIMARY COVERED	WT.DIST. SECONDARY COVERED	WT.DIST OUTSIDE PRIMARY	TOTAL WEIGHTED DISTANCE
1	2	3950.00	90.00	80.00	4120.00	24.4	57	15502.7	1161.4	2875.	18378.
2	22	770.00	340.00	60.00	1170.00	22.2	39	5114.1	4088.3	5306.	10420.
3	21	430.00	30.00	30.00	490.00	17.5	59	2511.4	305.9	830.	3341.
4	36	620.00	0.0	0.0	620.00	9.1	24	4311.3	0.0	0.	4311.
		5770.00	460.00	170.00	6400.00			27439.6	5555.7	9012.	36451.

PARTITION 1 FACILITY 2
** 1 D= 3.2** 2 D= 0.0** 3 D= 4.6** 4 D= 3.0** 5 D= 4.2** 6 D= 7.6

* 7 D= 5.1** 8 D= 3.2** 9 D= 5.0** 11 D= 5.7** 13 D= 9.6** 31 D= 8.5

* 34 D= 6.7** 40 D= 22.5** 42 D= 2.8** 43 D= 11.4** 44 D= 7.0** 45 D= 9.5

* 46 D= 13.6** 47 D= 9.2** 52 D= 24.4** 53 D= 14.9** 55 D= 16.4**

PARTITION 2 FACILITY 22
** 12 D= 8.0** 14 D= 12.0** 16 D= 6.7** 17 D= 5.1** 19 D= 8.2** 22 D= 0.0

* 23 D= 9.2** 27 D= 12.8** 28 D= 12.0** 29 D= 11.2** 30 D= 7.6** 32 D= 8.5

* 33 D= 4.2** 38 D= 12.0** 39 D= 22.2** 54 D= 16.5**

PARTITION 3 FACILITY 21
** 10 D= 9.0** 20 D= 4.5** 21 D= 0.0** 37 D= 7.2** 49 D= 10.2** 50 D= 17.5

* 51 D= 7.3**

PARTITION 4 FACILITY 36
** 15 D= 6.7** 18 D= 8.2** 24 D= 9.1** 25 D= 5.7** 26 D= 8.6** 35 D= 7.6

* 36 D= 0.0** 41 D= 8.5** 48 D= 6.0**

FIGURE 24

(continued, page 17)

GAS PLANAR EXAMPLE ONE

FACILITIES ARE LOCATED AT 2, 17, 21, 36, 27,
PRIMARY DISTANCE = 10.00
SECONDARY DISTANCE = 15.00

PARTITION NUMBER	FACILITY NUMBER	PRIMARY SERVED POP.	SECONDARY SERVED POP.	POPULATION OUTSIDE SECONDARY	POPULATION IN PARTITION	LARGEST TRAVELED DISTANCE	NODE NUMBER	WT.DIST PRIMARY COVERED	WT.DIST. SECONDARY COVERED	WT.DIST OUTSIDE PRIMARY	TOTAL WEIGHTED DISTANCE
1	2	4010.00	90.00	60.00	4160.00	24.4	52	16055.9	1161.4	2547.	18603.
2	17	670.00	0.0	0.0	670.00	9.0	29	3845.1	0.0	0.	3845.
3	21	430.00	30.00	30.00	490.00	17.5	50	2511.4	305.9	830.	3341.
4	36	620.00	0.0	0.0	620.00	9.1	24	4311.3	0.0	0.	4311.
5	27	350.00	90.00	20.00	460.00	16.1	55	2399.2	1079.0	1402.	3801.
		6080.00	210.00	110.00	6400.00			29122.9	2546.4	4779.	33902.

PARTITION 1 FACILITY 2
** 1 D= 3.2** 2 D= 0.0** 3 D= 4.8** 4 D= 3.0** 5 D= 4.2** 6 D= 7.6

* 7 D= 5.1** 8 D= 3.2** 9 D= 5.0** 11 D= 5.7** 13 D= 9.4** 30 D= 9.2

* 31 D= 8.5** 34 D= 6.7** 40 D= 22.5** 42 D= 2.8** 43 D= 11.4** 44 D= 7.0

* 45 D= 9.5** 46 D= 13.6** 47 D= 9.2** 52 D= 24.4** 53 D= 14.9**
PARTITION 2 FACILITY 17
** 12 D= 6.3** 17 D= 0.0** 19 D= 7.6** 22 D= 5.1** 23 D= 5.4** 28 D= 7.0

* 29 D= 9.0** 33 D= 8.2**
PARTITION 3 FACILITY 21
** 10 D= 9.0** 20 D= 4.5** 21 D= 0.0** 37 D= 7.2** 49 D= 10.2** 50 D= 17.5

* 51 D= 7.3**
PARTITION 4 FACILITY 36
** 15 D= 6.7** 18 D= 8.2** 24 D= 9.1** 25 D= 5.7** 26 D= 8.6** 35 D= 7.6

* 36 D= 0.0** 41 D= 8.5** 48 D= 6.0**
PARTITION 5 FACILITY 27
** 14 D= 9.8** 16 D= 6.4** 27 D= 0.0** 32 D= 11.2** 38 D= 9.2** 39 D= 13.0

* 54 D= 7.2** 55 D= 16.1**

FIGURE 24

(continued, page 19)

FIGURE 24

(continued, page 18)

```
  ITERATION NUMBER,   5
OAS PLANAR EXAMPLE ONE

  NUMBER OF FACILITIES   5
  SERVICE DISTANCE =    10.000

  NEW FACILITY LOCATION NUMBER    27

  FACILITIES ARE LOCATED AT     2,   22,   21,   36,   27,
  ----------------------------------------------------------------------
  POPULATION SERVED    6010.00          PERCENT OF TOTAL POPULATION SERVED   93.91
  ----------------------------------------------------------------------

  SUBSTITUTION  ALGORITHM USED

  NODE     17 REPLACES FACILITY LOCATION     22
  THIS IS NOW FACILITY NUMBER      2

  FACILITIES ARE LOCATED AT     2,   17,   21,   36,   27,
  ----------------------------------------------------------------------
  POPULATION SERVED    6080.00          PERCENT OF TOTAL POPULATION SERVED   95.00
  ----------------------------------------------------------------------
```

FIGURE 24

(continued, page 20)

```
  ITERATION NUMBER,    6
GAS PLANAR EXAMPLE ONE

  NUMBER OF FACILITIES   6
  SERVICE DISTANCE =    10.000

  NEW FACILITY LOCATION NUMBER    55

  FACILITIES ARE LOCATED AT     2,   17,   21,   36,   27,   55,
  ------------------------------------------------------------------
  POPULATION SERVED    6250.00          PERCENT OF TOTAL POPULATION SERVED   97.06
  ------------------------------------------------------------------
```

GAS PLANAR EXAMPLE ONE

FACILITIES ARE LOCATED AT 2, 17, 21, 36, 27, 55,
PRIMARY DISTANCE = 10.00
SECONDARY DISTANCE = 15.00

PARTITION NUMBER	FACILITY NUMBER	PRIMARY SERVED POP.	SECONDARY SERVED POP.	POPULATION OUTSIDE SECONDARY	POPULATION IN PARTITION	LARGEST TRAVELED DISTANCE	NODE NUMBER	WT.DIST PRIMARY COVERED	WT.DIST. SECONDARY COVERED	WT.DIST OUTSIDE PRIMARY	TOTAL WEIGHTED DISTANCE
1	2	3870.00	20.00	0.0	3890.00	14.9	53	14735.1	297.3	297.	15032.
2	17	670.00	0.0	0.0	670.00	9.0	29	3845.1	0.0	0.	3845.
3	21	430.00	30.00	30.00	490.00	17.5	50	2511.4	305.9	830.	3341.
4	36	620.00	0.0	0.0	620.00	9.1	24	4311.3	0.0	0.	4311.
5	27	310.00	0.0	0.0	310.00	9.8	14	2030.4	0.0	0.	2030.
6	55	350.00	50.00	20.00	420.00	20.6	52	2570.7	522.0	934.	3505.
		6250.00	100.00	50.00	6400.00			30004.1	1125.3	2061.	32065.

PARTITION 1 FACILITY 2
** 1 D= 3.2** 2 D= 0.0** 3 D= 4.5** 4 D= 3.0** 5 D= 4.2** 6 D= 7.6

* 7 D= 5.1** 8 D= 3.2** 9 D= 5.0** 11 D= 5.7** 30 D= 9.2** 31 D= 8.5

* 34 D= 6.7** 42 D= 2.8** 44 D= 7.0** 45 D= 9.5** 47 D= 9.2** 53 D= 14.9

PARTITION 2 FACILITY 17
** 12 D= 6.3** 17 D= 0.0** 19 D= 7.6** 22 D= 5.1** 23 D= 5.4** 28 D= 7.0

* 29 D= 9.0** 33 D= 8.2**
PARTITION 3 FACILITY 21
** 10 D= 9.0** 20 D= 4.5** 21 D= 0.0** 37 D= 7.2** 49 D= 10.2** 50 D= 17.5

* 51 D= 7.3**
PARTITION 4 FACILITY 36
** 15 D= 6.7** 18 D= 8.2** 24 D= 9.1** 25 D= 5.7** 26 D= 8.6** 35 D= 7.6

* 36 D= 0.0** 41 D= 8.5** 48 D= 6.0**
PARTITION 5 FACILITY 27
** 14 D= 9.8** 16 D= 6.4** 27 D= 0.0** 54 D= 7.2**
PARTITION 6 FACILITY 55
** 13 D= 8.2** 32 D= 10.4** 38 D= 7.8** 39 D= 9.8** 40 D= 8.2** 43 D= 5.0

* 46 D= 6.0** 52 D= 20.6** 55 D= 0.0**

FIGURE 24

(continued, page 21)

FIGURE 24

(continued, page 22)

```
  ITERATION NUMBER,    7
GAS PLANAR EXAMPLE ONE

  NUMBER OF FACILITIES   7
  SERVICE DISTANCE =    10.000

  NEW FACILITY LOCATION NUMBER    50

  FACILITIES ARE LOCATED AT     2,   17,   21,   36,   27,   55,   50,
  ----------------------------------------------------------------------
  POPULATION SERVED    6320.00          PERCENT OF TOTAL POPULATION SERVED   98.75
  ----------------------------------------------------------------------
```

GAS PLANAR EXAMPLE ONE

FACILITIES ARE LOCATED AT 2, 17, 21, 36, 27, 55, 50,
PRIMARY DISTANCE = 10.00
SECONDARY DISTANCE = 15.00

PARTITION NUMBER	FACILITY NUMBER	PRIMARY SERVED POP.	SECONDARY SERVED POP.	POPULATION OUTSIDE SECONDARY	POPULATION IN PARTITION	LARGEST TRAVELED DISTANCE	NODE NUMBER	WT.DIST PRIMARY COVERED	WT.DIST. SECONDARY COVERED	WT.DIST OUTSIDE PRIMARY	TOTAL WEIGHTED DISTANCE
1	2	3870.00	0.0	0.0	3870.00	9.5	45	14735.1	0.0	0.	14735.
2	17	670.00	0.0	0.0	670.00	9.0	29	3845.1	0.0	0.	3845.
3	21	430.00	30.00	0.0	460.00	10.2	49	2511.4	305.9	306.	2817.
4	36	620.00	0.0	0.0	620.00	9.1	24	4311.3	0.0	0.	4311.
5	27	310.00	0.0	0.0	310.00	9.8	14	2030.4	0.0	0.	2030.
6	55	350.00	50.00	0.0	400.00	10.4	32	2570.7	522.0	522.	3093.
7	50	70.00	0.0	0.0	70.00	8.6	52	288.7	0.0	0.	289.
		6320.00	80.00	0.0	6400.00			30292.8	828.0	828.	31121.

PARTITION 1 FACILITY 2
** 1 D= 3.2** 2 D= 0.0** 3 D= 4.5** 4 D= 3.0** 5 D= 4.2** 6 D= 7.6

* 7 D= 6.1** 8 D= 3.2** 9 D= 5.0** 11 D= 5.7** 30 D= 9.2** 31 D= 8.5

* 34 D= 6.7** 42 D= 2.8** 44 D= 7.0** 45 D= 9.5** 47 D= 9.2**
PARTITION 2 FACILITY 17
** 12 D= 6.3** 17 D= 0.0** 19 D= 7.6** 22 D= 5.1** 23 D= 5.4** 28 D= 7.0

* 29 D= 9.0** 33 D= 8.2**
PARTITION 3 FACILITY 21
** 10 D= 9.0** 20 D= 4.5** 21 D= 0.0** 37 D= 7.2** 49 D= 10.2** 51 D= 7.3

PARTITION 4 FACILITY 36
** 15 D= 6.7** 18 D= 8.2** 24 D= 9.1** 25 D= 5.7** 26 D= 8.6** 35 D= 7.6

* 36 D= 9.0** 41 D= 8.5** 48 D= 6.0**
PARTITION 5 FACILITY 27
** 14 D= 9.8** 16 D= 6.4** 27 D= 0.0** 54 D= 7.2**
PARTITION 6 FACILITY 55
** 13 D= 8.2** 32 D= 10.4** 38 D= 7.8** 39 D= 9.8** 40 D= 8.2** 43 D= 5.0

* 46 D= 6.0** 55 D= 0.0**
PARTITION 7 FACILITY 50
** 50 D= 0.0** 52 D= 8.6** 53 D= 5.8**

FIGURE 24

(continued, page 23)

FIGURE 24

(continued, page 24)

```
  ITERATION NUMBER,    8
GAS PLANAR EXAMPLE ONE

  NUMBER OF FACILITIES   8
  SERVICE DISTANCE =    10.000

  NEW FACILITY LOCATION NUMBER    13

  FACILITIES ARE LOCATED AT     2,   17,   21,   36,   27,   55,   50,   13,
  ---------------------------------------------------------------------------
  POPULATION SERVED    6370.00          PERCENT OF TOTAL POPULATION SERVED   99.63
  ---------------------------------------------------------------------------
```

GAS PLANAR EXAMPLE ONE

FACILITIES ARE LOCATED AT 2, 17, 21, 36, 27, 55, 50, 13,
PRIMARY DISTANCE = 10.00
SECONDARY DISTANCE = 15.00

PARTITION NUMBER	FACILITY NUMBER	PRIMARY SERVED POP.	SECONDARY SERVED POP.	POPULATION OUTSIDE SECONDARY	POPULATION IN PARTITION	LARGEST TRAVELED DISTANCE	NODE NUMBER	WT.DIST. PRIMARY COVERED	WT.DIST. SECONDARY COVERED	WT.DIST. OUTSIDE	TOTAL WEIGHTED DISTANCE
1	2	3730.00	0.0	0.0	3730.00	9.2	47	13561.9	0.0	0.	13562.
2	17	670.00	0.0	0.0	670.00	9.0	29	3845.1	0.0	0.	3845.
3	21	430.00	30.00	0.0	460.00	10.2	49	2511.4	305.9	306.	2817.
4	36	620.00	0.0	0.0	620.00	9.1	24	4311.3	0.0	0.	4311.
5	27	310.00	0.0	0.0	310.00	9.8	14	2030.4	0.0	0.	2030.
6	55	130.00	0.0	0.0	130.00	9.8	39	903.8	0.0	0.	904.
7	50	70.00	0.0	0.0	70.00	8.6	52	288.7	0.0	0.	289.
8	13	410.00	0.0	0.0	410.00	7.3	38	1358.2	0.0	0.	1358.
		6370.00	30.00	0.0	6400.00			28810.8	305.9	306.	29117.

PARTITION 1 FACILITY 2
** 1 D= 3.2** 2 D= 0.0** 3 D= 4.5** 4 D= 3.0** 5 D= 4.2** 6 D= 7.6

* 7 D= 5.1** 8 D= 3.2** 9 D= 5.0** 11 D= 5.7** 31 D= 8.5** 42 D= 2.8

* 44 D= 7.0** 47 D= 9.2**
PARTITION 2 FACILITY 17
** 12 D= 6.3** 17 D= 0.0** 19 D= 7.6** 22 D= 5.1** 23 D= 5.4** 28 D= 7.0

* 29 D= 9.0** 33 D= 8.2**
PARTITION 3 FACILITY 21
** 10 D= 9.0** 20 D= 4.5** 21 D= 0.0** 37 D= 7.2** 49.D= 10.2** 51 D= 7.3

PARTITION 4 FACILITY 36
** 15 D= 6.7** 18 D= 8.2** 24 D= 9.1** 25 D= 5.7** 26 D= 8.6** 35 D= 7.6

* 36 D= 9.0** 41 D= 8.5** 48 D= 6.0**
PARTITION 5 FACILITY 27
** 14 D= 9.8** 16 D= 6.4** 27 D= 0.0** 54 D= 7.2**
PARTITION 6 FACILITY 55
** 39 D= 9.8** 40 D= 8.2** 46 D= 6.0** 55 D= 0.0**
PARTITION 7 FACILITY 50
** 50 D= 0.0** 52 D= 8.6** 53 D= 5.8**
PARTITION 8 FACILITY 13
** 13 D= 0.0** 30 D= 7.1** 32 D= 5.4** 34 D= 2.8** 38 D= 7.3** 43 D= 4.1

* 45 D= 2.2**

FIGURE 24

(continued, page 25)

FIGURE 24

(continued, page 26)

```
  ITERATION NUMBER,    9
GAS PLANAR EXAMPLE ONE

  NUMBER OF FACILITIES   9
  SERVICE DISTANCE =    10.000

  NEW FACILITY LOCATION NUMBER    20

  FACILITIES ARE LOCATED AT     2,   17,   21,   36,   27,   55,   50,   13,   20,
  ------------------------------------------------------------------------------
  POPULATION SERVED    6400.00          PERCENT OF TOTAL POPULATION SERVED  100.00
  ------------------------------------------------------------------------------
```

GAS PLANAR EXAMPLE ONE

FACILITIES ARE LOCATED AT 2, 17, 21, 36, 27, 55, 50, 13, 20,
PRIMARY DISTANCE = 10.00
SECONDARY DISTANCE = 15.00

PARTITION NUMBER	FACILITY NUMBER	PRIMARY SERVED POP.	SECONDARY SERVED POP.	POPULATION OUTSIDE SECONDARY	POPULATION IN PARTITION	LARGEST TRAVELED DISTANCE	NODE NUMBER	WT.DIST PRIMARY COVERED	WT.DIST. SECONDARY COVERED	WT.DIST OUTSIDE PRIMARY	TOTAL WEIGHTED DISTANCE
1	2	3730.00	0.0	0.0	3730.00	9.2	47	13561.9	0.0	0.	13562.
2	17	670.00	0.0	0.0	670.00	9.0	29	3845.1	0.0	0.	3845.
3	21	170.00	0.0	0.0	170.00	7.3	51	579.0	0.0	0.	579.
4	36	580.00	0.0	0.0	580.00	9.1	24	3969.5	0.0	0.	3970.
5	27	310.00	0.0	0.0	310.00	9.8	14	2030.4	0.0	0.	2030.
6	55	130.00	0.0	0.0	130.00	9.8	39	903.8	0.0	0.	904.
7	50	70.00	0.0	0.0	70.00	8.6	52	288.7	0.0	0.	289.
8	13	410.00	0.0	0.0	410.00	7.3	38	1358.2	0.0	0.	1358.
9	20	330.00	0.0	0.0	330.00	8.2	41	1880.4	0.0	0.	1880.
		6400.00	0.0	0.0	6400.00			28417.0	0.0	0.	28417.

```
PARTITION  1  FACILITY   2
**   1 D=   3.2**   2 D=   0.0**   3 D=   4.5**   4 D=   3.0**   5 D=   4.2**   6 D=   7.6

*   7 D=   5.1**   8 D=   3.2**   9 D=   5.0**  11 D=   5.7**  31 D=   8.5**  42 D=   2.8

*  44 D=   7.0**  47 D=   9.2**
PARTITION  2  FACILITY  17
**  12 D=   6.3**  17 D=   0.0**  19 D=   7.0**  22 D=   5.1**  23 D=   5.4**  28 D=   7.0

*  29 D=   9.0**  33 D=   8.2**
PARTITION  3  FACILITY  21
**  21 D=   0.0**  37 D=   7.2**  51 D=   7.3**
PARTITION  4  FACILITY  36
**  15 D=   6.7**  18 D=   8.2**  24 D=   9.1**  25 D=   5.7**  26 D=   8.6**  35 D=   7.6

*  36 D=   0.0**  48 D=   6.0**
PARTITION  5  FACILITY  27
**  14 D=   9.8**  16 D=   6.4**  27 D=   0.0**  54 D=   7.2**
PARTITION  6  FACILITY  55
**  39 D=   9.8**  40 D=   8.2**  46 D=   6.0**  55 D=   0.0**
PARTITION  7  FACILITY  50
**  50 D=   0.0**  52 D=   8.6**  53 D=   5.8**
PARTITION  8  FACILITY  13
**  13 D=   0.0**  30 D=   7.1**  32 D=   5.4**  34 D=   2.8**  38 D=   7.3**  43 D=   4.1

*  45 D=   2.2**
PARTITION  9  FACILITY  20
**  10 D=   8.1**  20 D=   0.0**  41 D=   8.2**  49 D=   6.0**
COVERRAGE CANNOT BE CHANGED BY ADDITIONAL FACILITIES
THIS SOLUTION WAS GENERATED BY THE GAS ALGORITHM
```

FIGURE 24

(continued, page 27)

FIGURE 25

CONCEPTUAL FORM OF DATA DECK FOR

PLANAR PROBLEM ONE

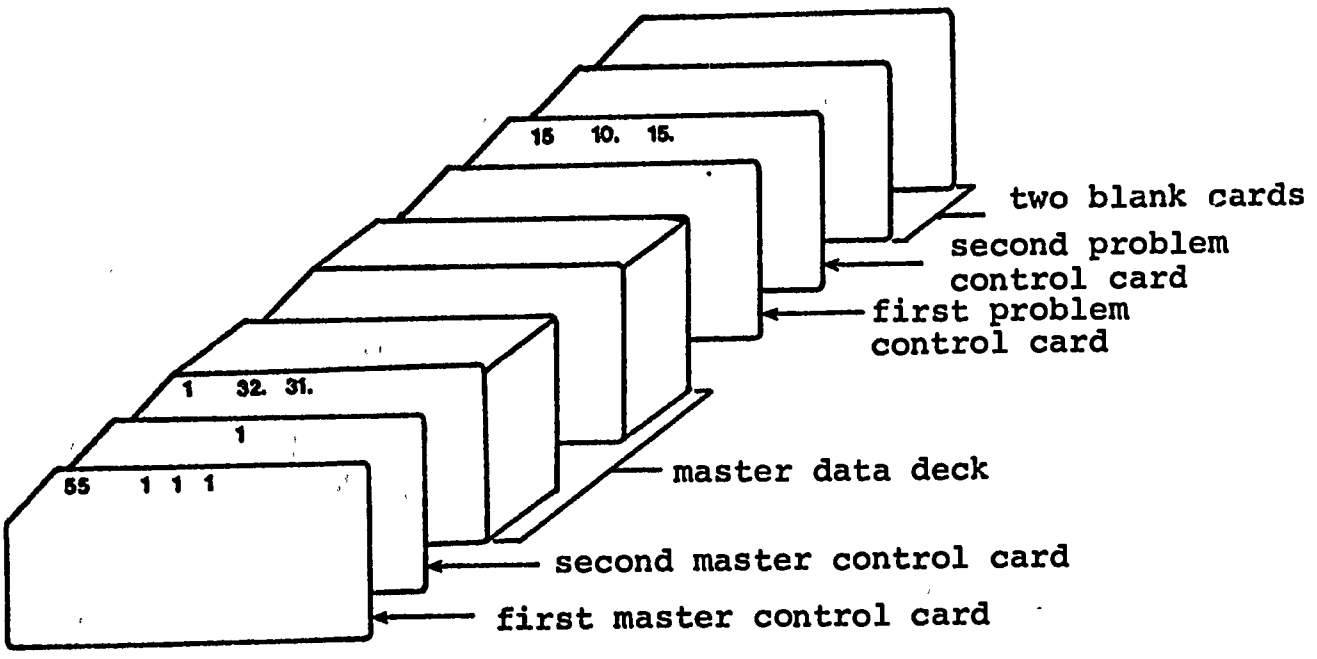

TABLE 28

FIRST MASTER CONTROL CARD

FOR PLANAR PROBLEM ONE

Parameter Name	Assumption	Assigned Value	Card Column(s) Containing Value
IPTS	Total number of points	55	4 and 5
IDEM	Total number of demand points	55	9 and 10
ADD	Since IPTS=IDEM program automatically sets ADD to 1	0,1	15
NETWOR	Since problem is planar, value must be zero	0	20
WEIGHT	Value of one signifies population value will be given	1	25
IDIST	Value of one signifies distance matrix will be listed	1	30
IFSAP	Value of one signifies that statistics output will be given	1	35

TABLE 29

SECOND MASTER CONTROL CARD

FOR PLANAR PROBLEM ONE

Parameter Name	Assumption	Assigned Value	Card Column(s) Containing Value
ARCS	Since problem is planar, value must be zero	0	5
RECT	Since euclidean distance is to be calculated, value must be zero	0	10
ELE	Since no elevation data is given, value must be set at zero	0	15
CONS	Value of zero signifies no political data is given	0	20
IPOL	Value of zero signifies no special constraint features are selected	0	25
IALT1	Value must be zero, since elevation data not given	0	30
IALT2	Value must be zero since elevation data not given	0	35
GAS	When value is set at one, GAS program will be executed	1	40

TABLE 30

SECOND PROBLEM CONTROL CARD

FOR PLANAR PROBLEM ONE

Parameter Name	Assumption	Assigned Value	Card Column(s) Containing Value
IP	Must equal largest number of allowable facilities	15	5
S	Maximal Service Distance	10.	6-15
SCS	Secondary Service Distance	15.	16-25
EMAXL	Parameter not used because elevation data not given	0,blank	26-35
EMAXS	Parameter not used because elevation data not given	0,blank	36-45
CONS	Value of zero signifies no special constraint features are to be used	0	55
ICOV	Value of zero signifies that zero-one matrix will not be given	0	60
ILIST	Value of zero signifies that coverage listing will not be given	0	65

CHAPTER 10

PLANAR PROBLEM TWO

Suppose we are interested in solving the planar problem utilized in planar problem 1, except that an additional four areas exist that we would like to establish as potential facility sites. Thus, we want to have 55 demand areas and 59 facility sites. The coordinates of the extra facility sites are given in table 31.

According to the information given in appendix A, we can solve this planar problem by setting the value of IPTS at 59 and the value of IDEM at 55. In addition, we must set ADD to a value of one. This establishes that there are 55 demand areas; and since ADD equals one, each demand area is a facility site. In addition there are four facility sites that are not demand areas. Thus, the parameters of the two master control cards should be set at the values given in table 32 and table 33.

The (x,y) coordinate information for the 55 demand points must be given after the second master control card. The population data for the 55 demand areas must follow in order of increasing index.

At this point, the information necessary for the four additional potential facility sites must be given. The form for the additional facility sites is the same as that utilized for the coordinate information of the demand areas. There is one card for each additional potential facility point.

After the additional facility points are given, the two problem control cards must appear. Since problem 2 is essentially the same as problem 1 except for the increased number of potential facility areas, the problem control cards will not change. However, the title card will differ to reflect the number of this example. The problem control cards are then followed by two blank cards. A conceptualized view of the data deck necessary for solving planar problem 2 appears in figure 26. A complete output listing from the GAS program utilizing this input information is given in figure 28. Figure 27 is a listing of the input data necessary to solve this problem.

TABLE 31

ADDITIONAL FACILITY SITES FOR PLANAR PROBLEM TWO

INDEX	X-COORD.	Y-COORD.
156	10.	38.
157	40.	40.
158	23.	28.
159	23.	39.

TABLE 32

FIRST MASTER CONTROL CARD

FOR PLANAR PROBLEM TWO

Parameter Name	Assumption	Assigned Value	Card Column(s) Containing Value
IPTS	Total number of points	59	4 and 5
IDEM	Number of demand points	55	9 and 10
ADD	Means demand points are potential facility sites	1	15
NETWOR	Value of zero signifies planar problem	0	20
WEIGHT	Value of one means population data is given	1	25
DIST	Value of zero means distance matrix will not be printed	0	30
IFSAP	Value of zero means coverage listing will not be printed	0	35

TABLE 33

SECOND MASTER CONTROL CARD

FOR PLANAR PROBLEM TWO

Parameter Name	Assumption	Assigned Value	Card Column(s) Containing Value
ARCS	Must be zero for planar problem	0,blank	5
RECT	For planar problem zero signifies euclidean distance measure	0,blank	10
ELE	Zero means elevation data not given	0,blank	15
CONS	Value of zero signifies no special constraint features are selected	0,blank	20
IPOL	Value of zero signifies political data will not be given	0,blank	25
IALT1	Since elevation data is not given, value is ignored	0,blank	30
IALT2	Since elevation data is not given, value is ignored	0,blank	35
GAS	When value is set at one, GAS program will be executed	1	40

FIGURE 26

CONCEPTUAL FORM OF THE DATA DECK FOR

PLANAR PROBLEM TWO

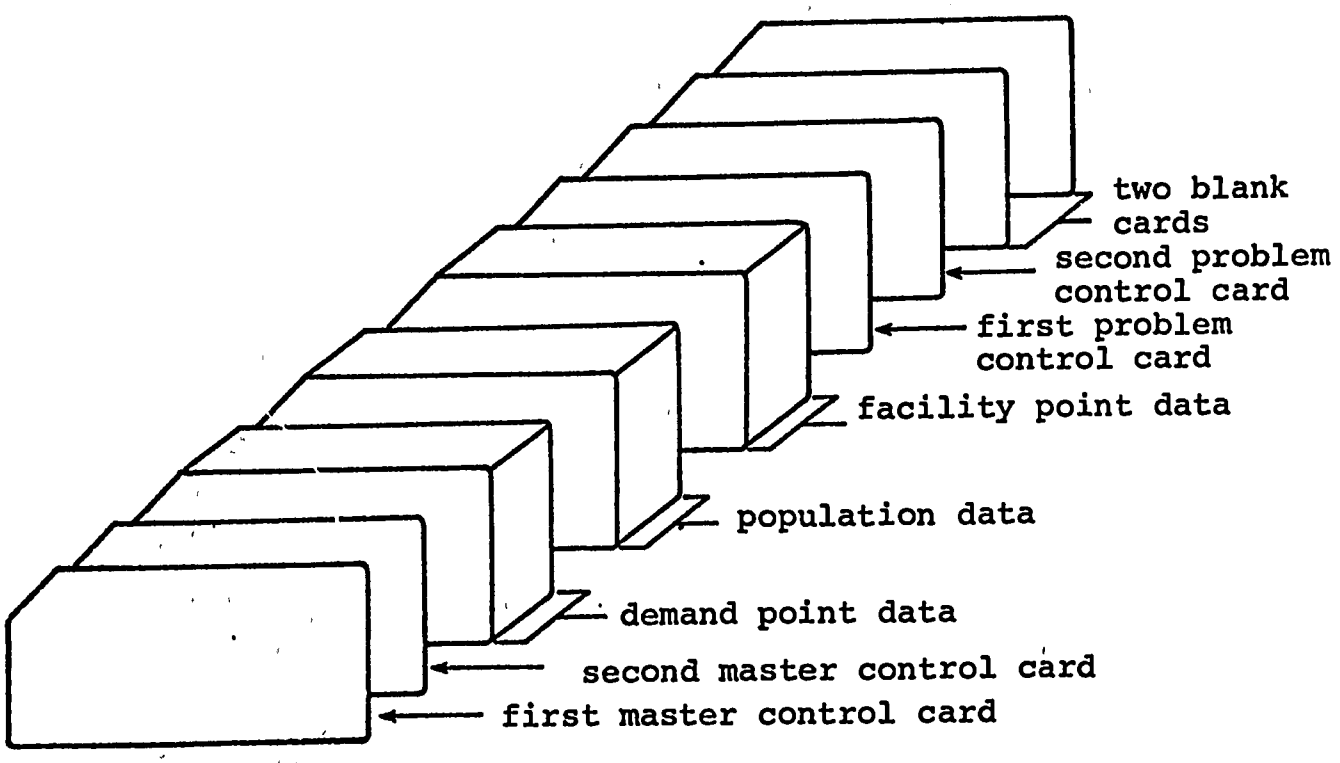

FIGURE 27

LISTING OF PLANAR PROBLEM TWO DATA DECK

```
59   55    1         1         1
                                      1
 1      32.       31.
 2      29.       32.
 3      27.       30.
 4      29.       29.
 5      32.       29.
 6      26.       25.
 7      24.       33.
 8      30.       35.
 9      29.       27.
10      29.       21.
11      33.       28.
12      17.       53.
13      34.       40.
14      25.       60.
15      21.       28.
16      30.       51.
17      19.       47.
18      17.       33.
19      22.       40.
20      25.       14.
21      29.       12.
22      24.       48.
23      17.       42.
24      6.        26.
25      19.       21.
26      10.       32.
27      34.       56.
28      12.       47.
29      19.       38.
30      27.       41.
31      21.       35.
32      32.       45.
33      27.       45.
34      32.       38.
35      8.        22.
36      15.       25.
37      35.       10.
38      36.       47.
39      46.       51.
40      50.       40.
41      23.       22.
42      27.       30.
43      38.       39.
44      36.       32.
45      32.       41.
46      42.       30.
47      36.       20.
48      15.       19.
49      19.       14.
50      45.       19.
51      27.       5.
52      52.       24.
53      40.       22.
54      40.       52.
55      42.       42.
 1      710.
 2      620.
 3      560.
```

FIGURE 27

(continued, page 2)

```
  4      390.
  5      350.
  6      210.
  7      200.
  8      190.
  9      170.
 10      170.
 11      160.
 12      150.
 13      140.
 14      120.
 15      120.
 16      110.
 17      100.
 18      100.
 19      90.
 20      90.
 21      90.
 22      80.
 23      80.
 24      80.
 25      80.
 26      70.
 27      60.
 28      60.
 29      60.
 30      60.
 31      60.
 32      50.
 33      50.
 34      50.
 35      50.
 36      50.
 37      50.
 38      40.
 39      40.
 40      40.
 41      40.
 42      40.
 43      40.
 44      40.
 45      30.
 46      30.
 47      30.
 48      30.
 49      30.
 50      30.
 51      30.
 52      20.
 53      20.
 54      20.
 55      20.
156      10.        38.
157      40.        40.
158      23.        28.
159      23.        39.
 GAS PLANAR EXAMPLE TWO
  15     10.        15.
```

POPULATION DATA

1	710.00*	7	200.00*	13	140.00*	19	90.00*	25	80.00*	31	60.00*	37	50.00*	43	40.00*	49	30.00*	55	20.00*				
2	620.00*	8	190.00*	14	120.00*	20	90.00*	26	70.00*	32	50.00*	38	40.00*	44	40.00*	50	30.00*						
3	560.00*	9	170.00*	15	120.00*	21	90.00*	27	60.00*	33	50.00*	39	40.00*	45	30.00*	51	30.00*						
4	390.00*	10	170.00*	16	110.00*	22	80.00*	28	60.00*	34	50.00*	40	40.00*	46	30.00*	52	20.00*						
5	350.00*	11	160.00*	17	100.00*	23	80.00*	29	60.00*	35	50.00*	41	40.00*	47	30.00*	53	20.00*						
6	210.00*	12	150.00*	18	100.00*	24	80.00*	30	60.00*	36	50.00*	42	40.00*	48	30.00*	54	20.00*						

THE FOLLOWING OPTIONS ARE DESIGNATED:
DEMAND POINTS ARE THE ONLY POTENTIAL FACILITY SITES
DISTANCES ARE MEASURED AS EUCLIDEAN
COORDINATE POINT DATA IS AS FOLLOWS:

1	32.00000	31.00000	1**	2	29.00000	32.00000	2**	3	27.00000	36.00000	3**
4	29.00000	29.00000	4**	5	32.00000	29.00000	5**	6	26.00000	25.00000	6**
7	24.00000	33.00000	7**	8	30.00000	35.00000	8**	9	29.00000	27.00000	9**
10	29.00000	21.00000	10**	11	33.00000	28.00000	11**	12	17.00000	53.00000	12**
13	34.00000	40.00000	13**	14	25.00000	60.00000	14**	15	21.00000	28.00000	15**
16	30.00000	51.00000	16**	17	19.00000	47.00000	17**	18	17.00000	33.00000	18**
19	22.00000	40.00000	19**	20	25.00000	14.00000	20**	21	29.00000	12.00000	21**
22	24.00000	48.00000	22**	23	17.00000	42.00000	23**	24	6.00000	26.00000	24**
25	19.00000	21.00000	25**	26	10.00000	32.00000	26**	27	34.00000	56.00000	27**
28	12.00000	47.00000	28**	29	19.00000	38.00000	29**	30	27.00000	41.00000	30**
31	21.00000	35.00000	31**	32	32.00000	45.00000	32**	33	27.00000	45.00000	33**
34	32.00000	38.00000	34**	35	8.00000	22.00000	35**	36	15.00000	25.00000	36**
37	35.00000	16.00000	37**	38	36.00000	47.00000	38**	39	46.00000	51.00000	39**
40	50.00000	60.00000	40**	41	23.00000	22.00000	41**	42	27.00000	30.00000	42**
43	38.00000	39.00000	43**	44	36.00000	32.00000	44**	45	32.00000	41.00000	45**

FIGURE 28

PLANAR PROBLEM TWO OUTPUT

46	42.00000	36.00000	46**	47	36.00000	26.00000	47**	48	15.00000	19.00000	48**
49	19.00000	14.00000	49**	50	45.00000	19.00000	50**	51	27.00000	5.00000	51**
52	52.00000	24.00000	52**	53	40.00000	22.00000	53**	54	40.00000	52.00000	54**
55	42.00000	42.00000	55**	56	32.00000	31.00000	1**	57	29.00000	32.00000	2**
58	27.00000	36.00000	3**	59	29.00000	29.00000	4**	60	32.00000	29.00000	5**
61	26.00000	25.00000	6**	62	24.00000	33.00000	7**	63	30.00000	35.00000	8**
64	29.00000	27.00000	9**	65	29.00000	21.00000	10**	66	33.00000	28.00000	11**
67	17.00000	53.00000	12**	68	34.00000	40.00000	13**	69	25.00000	60.00000	14**
70	21.00000	28.00000	15**	71	30.00000	51.00000	16**	72	19.00000	47.00000	17**
73	17.00000	33.00000	18**	74	22.00000	40.00000	19**	75	25.00000	14.00000	20**
76	29.00000	12.00000	21**	77	24.00000	48.00000	22**	78	17.00000	42.00000	23**
79	6.00000	26.00000	24**	80	19.00000	21.00000	25**	81	10.00000	32.00000	26**
82	34.00000	56.00000	27**	83	12.00000	47.00000	28**	84	19.00000	38.00000	29**
85	27.00000	41.00000	30**	86	21.00000	35.00000	31**	87	32.00000	45.00000	32**
88	27.00000	45.00000	33**	89	32.00000	38.00000	34**	90	8.00000	22.00000	35**
91	15.00000	25.00000	36**	92	35.00000	16.00000	37**	93	36.00000	47.00000	38**
94	46.00000	51.00000	39**	95	50.00000	40.00000	40**	96	23.00000	22.00000	41**
97	27.00000	30.00000	42**	98	38.00000	39.00000	43**	99	36.00000	32.00000	44**
100	32.00000	41.00000	45**	101	42.00000	36.00000	46**	102	36.00000	26.00000	47**
103	15.00000	19.00000	48**	104	19.00000	14.00000	49**	105	45.00000	19.00000	50**
106	27.00000	5.00000	51**	107	52.00000	24.00000	52**	108	40.00000	22.00000	53**
109	40.00000	32.00000	54**	110	42.00000	42.00000	55**				

FIGURE 28

(continued, page 2)

FIGURE 28

(continued, page 3)

```
SUBPROGRAM MATBLD HAS BEEN CALLED TO GENERATE A COVER MATRIX
   THE MAXIMUM DISTANCE/TIME OF  10.00 HAS BEEN UTILIZED
*****************************************************************
```

FIGURE 28

(continued, page 4)

```
  ITERATION NUMBER,     1
GAS PLANAR EXAMPLE TWO

  NUMBER OF FACILITIES    1
  SERVICE DISTANCE =     10.000

  NEW FACILITY LOCATION NUMBER    158

  FACILITIES ARE LOCATED AT    158,
  ------------------------------------------------------------------------
  POPULATION SERVED     4220.00          PERCENT OF TOTAL POPULATION SERVED    65.94
  ------------------------------------------------------------------------
```

GAS PLANAR EXAMPLE TWO

FACILITIES ARE LOCATED AT 158.
PRIMARY DISTANCE = 10.00
SECONDARY DISTANCE = 15.00

PARTITION NUMBER	FACILITY NUMBER	PRIMARY SERVED POP.	SECONDARY SERVED POP.	OUTSIDE POPULATION	IN POPULATION	LARGEST SECONDARY PARTITION	TRAVELED DISTANCE	NODE NUMBER	WT.DIST PRIMARY COVERED	WT.DIST. SECONDARY COVERED	WT.DIST OUTSIDE PRIMARY	TOTAL WEIGHTED DISTANCE
1	158	4220.00	550.00	1630.00	6400.00		32.5	39	32698.9	7180.3	42751.	75450.
		4220.00	550.00	1630.00	6400.00				32698.9	7180.3	42751.	75450.

PARTITION 1 FACILITY 158

** 1 D= 9.5**	2 D= 7.2**	3 D= 8.9**	4 D= 6.1**	5 D= 9.1**	6 D= 4.2
* 7 D= 5.1**	8 D= 9.9**	9 D= 6.1**	10 D= 9.2**	11 D= 10.0**	12 D= 25.7
* 13 D= 10.3**	14 D= 32.1**	15 D= 2.0**	16 D= 24.0**	17 D= 19.4**	18 D= 7.8
* 19 D= 12.0**	20 D= 14.1**	21 D= 17.1**	22 D= 20.0**	23 D= 15.2**	24 D= 17.1
* 25 D= 8.1**	26 D= 13.6**	27 D= 30.1**	28 D= 22.0**	29 D= 10.8**	30 D= 13.6
* 31 D= 7.3**	32 D= 19.2**	33 D= 17.5**	34 D= 13.5**	35 D= 16.2**	36 D= 8.5
* 37 D= 17.0**	38 D= 23.0**	39 D= 32.5**	40 D= 29.5**	41 D= 6.0**	42 D= 4.5
* 43 D= 18.6**	44 D= 13.6**	45 D= 15.8**	46 D= 20.6**	47 D= 13.2**	48 D= 12.0
* 49 D= 14.6**	50 D= 23.8**	51 D= 23.3**	52 D= 29.3**	53 D= 18.0**	54 D= 29.4
* 55 D= 23.6**					

FIGURE 28

(continued, page 5)

FIGURE 28

(continued, page 6)

```
  ITERATION NUMBER,    2
GAS PLANAR EXAMPLE TWO

  NUMBER OF FACILITIES   2
  SERVICE DISTANCE =    10.000

  NEW FACILITY LOCATION NUMBER    33

  FACILITIES ARE LOCATED AT   158,   33,
  ----------------------------------------------------------------------
  POPULATION SERVED    5020.00          PERCENT OF TOTAL POPULATION SERVED   78.94
  ----------------------------------------------------------------------
```

GAS PLANAR EXAMPLE TWO

FACILITIES ARE LOCATED AT 158, 33,
PRIMARY DISTANCE = 10.00
SECONDARY DISTANCE = 15.00

PARTITION NUMBER	FACILITY NUMBER	PRIMARY SERVED POP.	SECONDARY SERVED POP.	OUTSIDE SECONDARY	POPULATION IN PARTITION	LARGEST, TRAVELED DISTANCE	NODE NUMBER	WT.DIST PRIMARY COVERED	WT.DIST. SECONDARY COVERED	WT.DIST OUTSIDE PRIMARY	TOTAL WEIGHTED DISTANCE
1	158	4220.00	290.00	370.00	4880.00	29.3	52	32698.9	3961.6	10885.	43584.
2	33	800.00	410.00	310.00	1520.00	23.5	40	5223.6	4972.8	10266.	15489.
		5020.00	700.00	680.00	6400.00			37922.5	8934.3	21151.	59073.

PARTITION 1 FACILITY 158

** 1 D= 9.5** 2 D= 7.2** 3 D= 8.9** 4 D= 6.1** 5 D= 9.1** 6 D= 4.2

* 7 D= 5.1** 8 D= 9.9** 9 D= 6.1** 10 D= 9.2** 11 D= 10.0** 15 D= 2.0

* 18 D= 7.8** 20 D= 14.1** 21 D= 17.1** 24 D= 17.1** 25 D= 8.1** 26 D= 13.6

* 31 D= 7.3** 35 D= 16.2** 36 D= 8.5** 37 D= 17.0** 41 D= 6.0** 42 D= 4.5

* 44 D= 13.6** 47 D= 13.2** 48 D= 12.0** 49 D= 14.6** 50 D= 23.8** 51 D= 23.3

* 52 D= 29.3** 53 D= 18.0**

PARTITION 2 FACILITY 33

** 12 D= 12.8** 13 D= 8.6** 14 D= 15.1** 16 D= 6.7** 17 D= 8.2** 19 D= 7.1

* 22 D= 4.2** 23 D= 10.4** 27 D= 13.0** 28 D= 15.1** 29 D= 10.6** 30 D= 4.0

* 32 D= 5.0** 33 D= 0.0** 34 D= 8.6** 38 D= 9.2** 39 D= 19.9** 40 D= 23.5

* 43 D= 12.5** 45 D= 6.4** 46 D= 17.5** 54 D= 14.8** 55 D= 15.3**

FIGURE 28

(continued, page 7)

FIGURE 28

(continued, page 8)

```
  ITERATION NUMBER,     3
GAS PLANAR EXAMPLE TWO

  NUMBER OF FACILITIES    3
  SERVICE DISTANCE =     10.000

  NEW FACILITY LOCATION NUMBER     17

  FACILITIES ARE LOCATED AT    158,    33,    17,
  ------------------------------------------------------------------------------
  POPULATION SERVED     5370.00          PERCENT OF TOTAL POPULATION SERVED    83.91
  ------------------------------------------------------------------------------

  SUBSTITUTION  ALGORITHM USED

  NODE      38 REPLACES FACILITY LOCATION      33
  THIS IS NOW FACILITY NUMBER       2

  FACILITIES ARE LOCATED AT    158,    38,    17,
  ------------------------------------------------------------------------------
  POPULATION SERVED     5510.00          PERCENT OF TOTAL POPULATION SERVED    86.09
  ------------------------------------------------------------------------------
```

GAS PLANAR EXAMPLE TWO

FACILITIES ARE LOCATED AT 158, 38, 17,
PRIMARY DISTANCE = 10.00
SECONDARY DISTANCE = 15.00

PARTITION NUMBER	FACILITY NUMBER	PRIMARY SERVED POP.	SECONDARY SERVED POP.	POPULATION OUTSIDE SECONDARY	POPULATION IN PARTITION	LARGEST DISTANCE	NODE NUMBER	WT.DIST PRIMARY COVERED	WT.DIST. SECONDARY COVERED	WT.DIST OUTSIDE PRIMARY	TOTAL WEIGHTED DISTANCE
1	158	4220.00	290.00	350.00	4860.00	23.8	50	32698.9	3961.6	102[illegible]	42[illegible]
2	38	560.00	70.00	60.00	690.00	28.0	52	3912.1	[illegible]	[illegible]	[illegible]
3	17	730.00	120.00	0.0	850.00	14.3	14	[illegible]	1718.1	1718.	6163.
		5510.00	480.00	410.00	6400.00			[illegible]	6486.4	14.1[illegible]	55067.

PARTITION 1 FACILITY 158
[illegible] 1 D= [illegible] 2 D= 1.2** 3 D= [illegible] 4 [illegible] 6.[illegible]** 5 D= 9.1** 6 D= 4.2

[illegible] 7 D= [illegible]** [illegible] D= 9.9** 9 D= 6.1** 10 D= 9.2** 11 D= 10.0** 15 D= 2.0

[illegible] 8 D= 7.8** 20 D= 14.1** 21 D= 17.1** 24 D= 17.1** 25 D= 8.1** 26 D= 13.6

[illegible] 31 D= 7.3** 35 D= 16.2** 36 D= 8.5** 37 D= 17.0** 41 D= 6.0** 42 D= 4.5

[illegible] 44 D= 13.6** 47 D= 13.2** 48 D= 12.0** 49 D= 14.6** 50 D= 23.8** 51 D= 23.3

[illegible] 53 D= 18.[illegible]

PARTITION 2 FACILITY 38
[illegible] 13 D= 7.3** 16 D= 7.2** 27 D= 9.2** 32 D= 4.5** 34 D= 9.8** 38 D= 0.0

[illegible] 39 D= 10.8** 40 D= 15.7** 43 D= 8.2** 45 D= 7.2** 46 D= 12.5** 52 D= 28.0

54 D= 6.4** 55 D= 7.6**

PARTITION 3 FACILITY 17
[illegible] 12 D= 6.3** 14 D= 14.3** 17 D= 0.0** 19 D= 7.6** 22 D= 5.1** 23 D= 5.4

26 D= 7.0 29 D= 9.0** 30 D= 10.0** 33 D= 8.2**

FIGURE 28

(continued, page 9)

FIGURE 28

(continued, page 10)

```
 ITERATION NUMBER,     4
GAS PLANAR EXAMPLE TWO

 NUMBER OF FACILITIES    4
 SERVICE DISTANCE =     10.000

 NEW FACILITY LOCATION NUMBER     10

 FACILITIES ARE LOCATED AT    158,    38,    17,    10,
 ----------------------------------------------------------------------------
 POPULATION SERVED     5770.00          PERCENT OF TOTAL POPULATION SERVED    90.16
 ----------------------------------------------------------------------------
```

GAS PLANAR EXAMPLE TWO

FACILITIES ARE LOCATED AT 158, 38, 17, 10,
PRIMARY DISTANCE = 10.00
SECONDARY DISTANCE = 15.00

PARTITION NUMBER	FACILITY NUMBER	PRIMARY SERVED POP.	SECONDARY SERVED POP.	POPULATION OUTSIDE SECONDARY	POPULATION IN PARTITION	LARGEST TRAVELED DISTANCE	NODE NUMBER	WT.DIST PRIMARY COVERED	WT.DIST. SECONDARY COVERED	WT.DIST OUTSIDE PRIMARY	TOTAL WEIGHTED DISTANCE
1	158	3370.00	100.00	130.00	3600.00	17.1	24	25328.1	1313.3	3490.	28819.
2	38	560.00	70.00	40.00	670.00	15.7	40	3912.1	806.7	1433.	5345.
3	17	730.00	120.00	0.0	850.00	14.3	14	4445.1	1718.1	1718.	6163.
4	10	1110.00	90.00	80.00	1280.00	23.2	52	7484.5	1108.6	2540.	10025.
		5770.00	380.00	250.00	6400.00			41169.9	4946.8	9181.	50351.

PARTITION 1 FACILITY 158
** 1 D= 9.5** 2 D= 7.2** 3 D= 8.9** 4 D= 6.1** 6 D= 4.2** 7 D= 5.1

* 8 D= 9.9** 15 D= 2.0** 18 D= 7.8** 24 D= 17.1** 25 D= 8.1** 26 D= 13.6

* 31 D= 7.3** 35 D= 16.2** 36 D= 8.5** 41 D= 6.0** 42 D= 4.5** 48 D= 12.0

PARTITION 2 FACILITY 38
** 13 D= 7.3** 16 D= 7.2** 27 D= 9.2** 32 D= 4.5** 34 D= 9.8** 38 D= 0.0

* 39 D= 10.8** 40 D= 15.7** 43 D= 8.2** 45 D= 7.2** 46 D= 12.5** 54 D= 6.4

* 55 D= 7.8**
PARTITION 3 FACILITY 17
** 12 D= 6.3** 14 D= 14.3** 17 D= 0.0** 19 D= 7.6** 22 D= 5.1** 23 D= 5.4

* 28 D= 7.0** 29 D= 9.0** 30 D= 10.0** 33 D= 8.2**
PARTITION 4 FACILITY 10
** 5 D= 8.5** 9 D= 6.0** 10 D= 0.0** 11 D= 8.1** 20 D= 8.1** 21 D= 9.0

* 37 D= 7.8** 44 D= 13.0** 47 D= 8.6** 49 D= 12.2** 50 D= 16.1** 51 D= 16.1

* 52 D= 23.2** 53 D= 11.0**

FIGURE 28

(continued, page 11)

FIGURE 28

(continued, page 12)

```
  ITERATION NUMBER,    5
GAS PLANAR EXAMPLE TWO

  NUMBER OF FACILITIES   5
  SERVICE DISTANCE =    10.000

  NEW FACILITY LOCATION NUMBER    36

  FACILITIES ARE LOCATED AT   158,   38,   17,   10,   36,
  ---------------------------------------------------------------------------
  POPULATION SERVED    6000.00          PERCENT OF TOTAL POPULATION SERVED   93.75
  ---------------------------------------------------------------------------

  SUBSTITUTION  ALGORITHM USED

  NODE      2 REPLACES FACILITY LOCATION    158
  THIS IS NOW FACILITY NUMBER      1

  FACILITIES ARE LOCATED AT     2,   38,   17,   10,   36,
  ---------------------------------------------------------------------------
  POPULATION SERVED    6040.00          PERCENT OF TOTAL POPULATION SERVED   94.37
  ---------------------------------------------------------------------------

  SUBSTITUTION  ALGORITHM USED

  NODE     27 REPLACES FACILITY LOCATION     38
  THIS IS NOW FACILITY NUMBER      2

  FACILITIES ARE LOCATED AT     2,   27,   17,   10,   36,
  ---------------------------------------------------------------------------
  POPULATION SERVED    6050.00          PERCENT OF TOTAL POPULATION SERVED   94.53
  ---------------------------------------------------------------------------

  SUBSTITUTION  ALGORITHM USED

  NODE     21 REPLACES FACILITY LOCATION     10
  THIS IS NOW FACILITY NUMBER      4

  FACILITIES ARE LOCATED AT     2,   27,   17,   21,   36,
  ---------------------------------------------------------------------------
  POPULATION SERVED    6080.00          PERCENT OF TOTAL POPULATION SERVED   95.00
  ---------------------------------------------------------------------------
```

GAS PLANAR EXAMPLE TWO

FACILITIES ARE LOCATED AT 2, 27, 17, 21, 36,
PRIMARY DISTANCE = 10.00
SECONDARY DISTANCE = 15.00

PARTITION NUMBER	FACILITY NUMBER	PRIMARY SERVED POP.	SECONDARY SERVED POP.	POPULATION OUTSIDE SECONDARY	POPULATION IN PARTITION	LARGEST, TRAVELED DISTANCE	NODE NUMBER	WT.DIST PRIMARY COVERED	WT.DIST. SECONDARY COVERED	WT.DIST OUTSIDE PRIMARY	TOTAL WEIGHTED DISTANCE
1	2	4010.00	90.00	60.00	4160.00	24.4	52	16055.9	1161.4	2547.	18603.
2	27	350.00	90.00	20.00	460.00	16.1	55	2399.2	1079.0	1402.	3801.
3	17	670.00	0.0	0.0	670.00	9.0	29	3845.1	0.0	0.	3845.
4	21	430.00	30.00	30.00	490.00	17.5	50	2511.4	305.9	830.	3341.
5	36	620.00	0.0	0.0	620.00	9.1	24	4311.3	0.0	0.	4311.
		6080.00	210.00	110.00	6400.00			29122.9	2546.4	4779.	33902.

PARTITION 1 FACILITY 2
** 1 D= 3.2** 2 D= 0.0** 3 D= 4.5** 4 D= 3.0** 5 D= 4.2** 6 D= 7.6

* 7 D= 5.1** 8 D= 3.2** 9 D= 5.0** 11 D= 5.7** 13 D= 9.4** 30 D= 9.2

* 31 D= 8.5** 34 D= 6.7** 40 D= 22.5** 42 D= 2.8** 43 D= 11.4** 44 D= 7.0

* 45 D= 9.5** 46 D= 13.6** 47 D= 9.2** 52 D= 24.4** 53 D= 14.9**
PARTITION 2 FACILITY 27
** 14 D= 9.8** 16 D= 6.4** 27 D= 0.0** 32 D= 11.2** 38 D= 9.2** 39 D= 13.0

* 54 D= 7.2** 55 D= 16.1**
PARTITION 3 FACILITY 17
** 12 D= 6.3** 17 D= 0.0** 19 D= 7.0** 22 D= 5.1** 23 D= 5.4** 28 D= 7.0

* 29 D= 9.0** 33 D= 8.2**
PARTITION 4 FACILITY 21
** 10 D= 9.0** 20 D= 4.5** 21 D= 0.0** 37 D= 7.2** 49 D= 10.2** 50 D= 17.5

* 51 D= 7.3**
PARTITION 5 FACILITY 36
** 15 D= 6.7** 18 D= 8.2** 24 D= 9.1** 25 D= 5.7** 26 D= 8.6** 35 D= 7.6

* 36 D= 0.0** 41 D= 8.5** 48 D= 6.0**

FIGURE 28

(continued, page 13)

FIGURE 28

(continued, page 14)

```
  ITERATION NUMBER,    6
GAS PLANAR EXAMPLE TWO

  NUMBER OF FACILITIES   6
  SERVICE DISTANCE =    10.000

  NEW FACILITY LOCATION NUMBER   157

  FACILITIES ARE LOCATED AT     2,   27,   17,   21,   36,  157,
  ------------------------------------------------------------------------
  POPULATION SERVED    6260.00          PERCENT OF TOTAL POPULATION SERVED   97.01
  ------------------------------------------------------------------------
```

GAS PLANAR EXAMPLE TWO

FACILITIES ARE LOCATED AT 2, 27, 17, 21, 36, 157,
PRIMARY DISTANCE = 10.00
SECONDARY DISTANCE = 15.00

PARTITION NUMBER	FACILITY NUMBER	PRIMARY SERVED POP.	SECONDARY SERVED POP.	POPULATION OUTSIDE SECONDARY	POPULATION IN PARTITION	LARGEST TRAVELED DISTANCE	NODE NUMBER	WT.DIST PRIMARY COVERED	WT.DIST. SECONDARY COVERED	WT.DIST OUTSIDE PRIMARY	TOTAL WEIGHTED DISTANCE
1	2	3840.00	20.00	0.0	3860.00	14.9	53	14450.5	297.3	297.	14748.
2	27	310.00	0.0	0.0	310.00	9.8	14	2030.4	0.0	0.	2030.
3	17	670.00	0.0	0.0	670.00	9.0	29	3845.1	0.0	0.	3845.
4	21	430.00	30.00	30.00	490.00	17.5	50	2511.4	305.9	830.	3341.
5	36	620.00	0.0	0.0	620.00	9.1	24	4311.3	0.0	0.	4311.
6	157	390.00	40.00	20.00	450.00	20.0	52	2556.2	501.2	901.	3457.
		6260.00	90.00	50.00	6400.00			29705.0	1104.5	2028.	31733.

PARTITION 1 FACILITY 2
** 1 D= 3.2** 2 D= 0.0** 3 D= 4.5** 4 D= 3.0** 5 D= 4.2** 6 D= 7.6

* 7 D= 6.1** 8 D= 3.2** 9 D= 5.0** 11 D= 5.7** 30 D= 9.2** 31 D= 8.5

* 34 D= 6.7** 42 D= 2.8** 44 D= 7.0** 47 D= 9.2** 53 D= 14.9**
PARTITION 2 FACILITY 27
** 14 D= 9.8** 16 D= 6.4** 27 D= 0.0** 54 D= 7.2**
PARTITION 3 FACILITY 17
** 12 D= 6.3** 17 D= 0.0** 19 D= 7.6** 22 D= 5.1** 23 D= 5.4** 28 D= 7.0

* 29 D= 9.0** 33 D= 8.2**
PARTITION 4 FACILITY 21
** 10 D= 9.0** 20 D= 4.5** 21 D= 0.0** 37 D= 7.2** 49 D= 10.2** 50 D= 17.5

* 51 D= 7.3**
PARTITION 5 FACILITY 36
** 15 D= 6.7** 18 D= 8.2** 24 D= 9.1** 25 D= 5.7** 26 D= 8.6** 35 D= 7.6

* 36 D= 0.0** 41 D= 8.5** 48 D= 6.0**
PARTITION 6 FACILITY 157
** 13 D= 6.0** 32 D= 9.4** 38 D= 8.1** 39 D= 12.5** 40 D= 10.0** 43 D= 2.2

* 45 D= 8.1** 46 D= 4.5** 52 D= 20.0** 55 D= 2.8**

FIGURE 28

(continued, page 15)

FIGURE 28

(continued, page 16)

```
  ITERATION NUMBER,     7
GAS PLANAR EXAMPLE TWO

  NUMBER OF FACILITIES    7
  SERVICE DISTANCE =    10.000

  NEW FACILITY LOCATION NUMBER    50

  FACILITIES ARE LOCATED AT     2,   27,   17,   21,   36,  157,   50,
  ---------------------------------------------------------------------
  POPULATION SERVED    6330.00          PERCENT OF TOTAL POPULATION SERVED   98.91
  ---------------------------------------------------------------------
```

GAS PLANAR EXAMPLE TWO

FACILITIES ARE LOCATED AT 2, 27, 17, 21, 36, 157, 50,
PRIMARY DISTANCE = 10.00
SECONDARY DISTANCE = 15.00

PARTITION NUMBER	FACILITY NUMBER	PRIMARY SERVED POP.	SECONDARY SERVED POP.	POPULATION OUTSIDE SECONDARY	POPULATION IN PARTITION	LARGEST TRAVELED DISTANCE	NODE NUMBER	WT.DIST PRIMARY COVERED	WT.DIST. SECONDARY COVERED	WT.DIST OUTSIDE PRIMARY	TOTAL WEIGHTED DISTANCE
1	2	3840.00	0.0	0.0	3840.00	9.2	47	14450.5	0.0	0.	14450.
2	27	310.00	0.0	0.0	310.00	9.8	14	2030.4	0.0	0.	2030.
3	17	670.00	0.0	0.0	670.00	9.0	29	3845.1	0.0	0.	3845.
4	21	430.00	30.00	0.0	460.00	10.2	49	2511.4	305.9	306.	2817.
5	36	620.00	0.0	0.0	620.00	9.1	24	4311.3	0.0	0.	4311.
6	157	390.00	40.00	0.0	430.00	12.5	39	2556.2	501.2	501.	3057.
7	50	70.00	0.0	0.0	70.00	8.6	52	288.7	0.0	0.	289.
		6330.00	70.00	0.0	6400.00			29993.7	807.1	807.	30801.

PARTITION 1 FACILITY 2
** 1 D= 3.2** 2 D= 0.0** 3 D= 4.5** 4 D= 3.6** 5 D= 4.2** 6 D= 7.6

* 7 D= 5.1** 8 D= 3.2** 9 D= 5.0** 11 D= 5.7** 30 D= 9.2** 31 D= 8.5

* 34 D= 6.7** 42 D= 2.8** 44 D= 7.0** 47 D= 9.2**
PARTITION 2 FACILITY 27
** 14 D= 9.8** 16 D= 6.4** 27 D= 0.0** 54 D= 7.2**
PARTITION 3 FACILITY 17
** 12 D= 6.3** 17 D= 0.0** 19 D= 7.6** 22 D= 5.1** 23 D= 5.4** 28 D= 7.0

* 29 D= 9.0** 33 D= 8.2**
PARTITION 4 FACILITY 21
** 10 D= 9.0** 20 D= 4.5** 21 D= 0.0** 37 D= 7.2** 49 D= 10.2** 51 D= 7.3

PARTITION 5 FACILITY 36
** 15 D= 6.7** 18 D= 8.2** 24 D= 9.1** 25 D= 5.7** 26 D= 8.6** 35 D= 7.6

* 36 D= 0.0** 41 D= 8.5** 48 D= 6.0**
PARTITION 6 FACILITY 157
** 13 D= 6.0** 32 D= 9.4** 38 D= 8.1** 39 D= 12.5** 40 D= 10.0** 43 D= 2.2

* 45 D= 8.1** 46 D= 4.5** 55 D= 2.8**
PARTITION 7 FACILITY 50
** 50 D= 0.0** 52 D= 8.6** 53 D= 5.8**

FIGURE 28

(continued, page 17)

FIGURE 28

(continued, page 18)

```
  ITERATION NUMBER,     8
GAS PLANAR EXAMPLE TWO

  NUMBER OF FACILITIES   8
  SERVICE DISTANCE =    10.000

  NEW FACILITY LOCATION NUMBER    39

  FACILITIES ARE LOCATED AT     2,   27,   17,   21,   36,  157,   50,   39,
  ------------------------------------------------------------------------
  POPULATION SERVED    6370.00          PERCENT OF TOTAL POPULATION SERVED   99.63
  ------------------------------------------------------------------------
```

GAS PLANAR EXAMPLE TWO

FACILITIES ARE LOCATED AT 2, 27, 17, 21, 36, 157, 50, 39,
PRIMARY DISTANCE = 10.00
SECONDARY DISTANCE = 15.00

PARTITION NUMBER	FACILITY NUMBER	PRIMARY SERVED POP.	SECONDARY SERVED POP.	OUTSIDE SECONDARY	POPULATION IN PARTITION	LARGEST TRAVELED DISTANCE	NODE NUMBER	WT.DIST PRIMARY COVERED	WT.DIST. SECONDARY COVERED	WT.DIST OUTSIDE	TOTAL WEIGHTED PRIMARY DISTANCE
1	2	3840.00	0.0	0.0	3840.00	9.2	47	14450.5	0.0	0.	14450.
2	27	290.00	0.0	0.0	290.00	9.8	14	1886.2	0.0	0.	1886.
3	17	670.00	0.0	0.0	670.00	9.0	29	3845.1	0.0	0.	3845.
4	21	430.00	30.00	0.0	460.00	10.2	49	2511.4	305.9	306.	2817.
5	36	620.00	0.0	0.0	620.00	9.1	24	4311.3	0.0	0.	4311.
6	157	390.00	0.0	0.0	390.00	10.0	40	2556.2	0.0	0.	2556.
7	50	70.00	0.0	0.0	70.00	8.6	52	288.7	0.0	0.	289.
8	39	60.00	0.0	0.0	60.00	6.1	54	121.7	0.0	0.	122.
		6370.00	30.00	0.0	6400.00			29971.1	305.9	306.	30277.

PARTITION 1 FACILITY 2
** 1 D= 3.2** 2 D= 0.0** 3 D= 4.5** 4 D= 3.0** 5 D= 4.2** 6 D= 7.6

* 7 D= 5.1** 8 D= 3.2** 9 D= 5.0** 11 D= 5.7** 30 D= 9.2** 31 D= 8.5

* 34 D= 6.7** 42 D= 2.8** 44 D= 7.0** 47 D= 9.2**
PARTITION 2 FACILITY 27
** 14 D= 9.8** 16 D= 6.4** 27 D= 0.0**
PARTITION 3 FACILITY 17
** 12 D= 6.3** 17 D= 0.0** 19 D= 7.6** 22 D= 5.1** 23 D= 5.4** 28 D= 7.0

* 29 D= 9.0** 33 D= 8.2**
PARTITION 4 FACILITY 21
** 10 D= 9.0** 20 D= 4.5** 21 D= 0.0** 37 D= 7.2** 49 D= 10.2** 51 D= 7.3

PARTITION 5 FACILITY 36
** 15 D= 6.7** 18 D= 8.2** 24 D= 9.1** 25 D= 5.7** 26 D= 8.6** 35 D= 7.6

* 36 D= 0.0** 41 D= 8.5** 48 D= 6.0**
PARTITION 6 FACILITY 157
** 13 D= 6.0** 32 D= 9.4** 38 D= 8.1** 40 D= 10.0** 43 D= 2.2** 45 D= 8.1

* 46 D= 4.5** 55 D= 2.8**
PARTITION 7 FACILITY 50
** 50 D= 0.0** 52 D= 8.6** 53 D= 5.8**
PARTITION 8 FACILITY 39
** 39 D= 0.0** 54 D= 6.1**

FIGURE 28

(continued, page 19)

FIGURE 28

(continued, page 20)

```
  ITERATION NUMBER,    9
GAS PLANAR EXAMPLE TWO

  NUMBER OF FACILITIES   9
  SERVICE DISTANCE =    10.000

  NEW FACILITY LOCATION NUMBER    20

  FACILITIES ARE LOCATED AT     2,   27,   17,   21,   36,  157,   50,   39,   20,
  ---------------------------------------------------------------------------------
  POPULATION SERVED    6400.00          PERCENT OF TOTAL POPULATION SERVED  100.00
  ---------------------------------------------------------------------------------
```

GAS PLANAR EX/ 'LE TWO

FACILITIES ARE LOCATED AT 2, 27, 17, 21, 36, 157, 50, 39, 20,
PRIMARY DISTANCE = 10.00
SECONDARY DISTANCE = 15.00

PARTITION NUMBER	FACILITY NUMBER	PRIMARY SERVED POP.	SECONDARY SERVED POP.	POPULATION OUTSIDE SECONDARY	POPULATION IN PARTITION	LARGEST TRAVELED DISTANCE	NODE NUMBER	WT.DIST PRIMARY COVERED	WT.DIST. SECONDARY COVERED	WT.DIST OUTSIDE PRIMARY	TOTAL WEIGHTED DISTANCE
1	2	3840.00	0.0	0.0	3840.00	9.2	47	14450.5	0.0	0.	14450.
2	27	290.00	0.0	0.0	290.00	9.8	14	1886.2	0.0	0.	1886.
3	17	670.00	0.0	0.0	670.00	9.0	29	3845.1	0.0	0.	3845.
4	21	170.00	0.0	0.0	170.00	7.3	51	579.0	0.0	0.	579.
5	36	580.00	0.0	0.0	580.00	9.1	24	3969.5	0.0	0.	3970.
6	157	390.00	0.0	0.0	390.00	10.0	40	2556.2	0.0	0.	2556.
7	50	70.00	0.0	0.0	70.00	8.6	52	288.7	0.0	0.	289.
8	39	60.00	0.0	0.0	60.00	6.1	54	121.7	0.0	0.	122.
9	20	330.00	0.0	0.0	330.00	8.2	41	1880.4	0.0	0.	1880.
		6400.00	0.0	0.0	6400.00			29577.3	0.0	0.	29577.

PARTITION 1 FACILITY 2
** 1 D= 3.2** 2 D= 0.0** 3 D= 4.5** 4 D= 3.0** 5 D= 4.2** 6 D= 7.6

* 7 D= 5.1** 8 D= 3.2** 9 D= 5.0** 11 D= 5.7** 30 D= 9.2** 31 D= 8.5

* 34 D= 9.7** 42 D= 2.8** 44 D= 7.0** 47 D= 9.2**
PARTITION 2 FACILITY 27
** 14 D= 9.8** 16 D= 6.4** 27 D= 0.0**
PARTITION 3 FACILITY 17
** 12 D= 6.3** 17 D= 0.0** 19 D= 7.6** 22 D= 5.1** 23 D= 5.4** 28 D= 7.0

* 29 D= 9.0** 33 D= 8.2**
PARTITION 4 FACILITY 21
** 21 D= 0.0** 37 D= 7.2** 51 D= 7.3**
PARTITION 5 FACILITY 36
** 15 D= 6.7** 18 D= 8.2** 24 D= 9.1** 25 D= 5.7** 26 D= 8.6** 35 D= 7.6

* 36 D= 9.0** 48 D= 6.0**
PARTITION 6 FACILITY 157
** 13 D= 6.0** 32 D= 9.4** 38 D= 8.1** 40 D= 10.0** 43 D= 2.2** 45 D= 8.1

* 46 D= 4.5** 55 D= 2.8**
PARTITION 7 FACILITY 50
** 50 D= 0.0** 52 D= 8.6** 53 D= 5.8**
PARTITION 8 FACILITY 39
** 39 D= 0.0** 54 D= 6.1**
PARTITION 9 FACILITY 20
** 10 D= 8.1** 20 D= 0.0** 41 D= 8.2** 49 D= 6.0**
COVERAGE CANNOT BE CHANGED BY ADDITIONAL FACILITIES
THIS SOLUTION WAS GENERATED BY THE GAS ALGORITHM

FIGURE 28

(continued, page 21)

CHAPTER 11

ADDITIONAL PLANAR PROBLEMS

Suppose we modify planar problem 2 to include elevation data and the constraint options. Let us assume we want to consider only facilities that (a) can cover demands within 10 time units; (b) are no more than 30 meters above the demand area and (c) are less than 30 meters below the demand area. Further, assume that population data is not to be utilized and that the objective is to cover the largest number of demand areas within the maximal service distance and elevation criteria. In addition, let up suppose that the demand areas listed in table 34 are not acceptable for facility placement.

According to the problem definition, we must modify the master data deck utilized in planar problem 2 to eliminate the population data and to include elevation data. In order to delete the population data from the master deck, set the WEIGHT parameter on the first master control card to a value of zero (or blank). By setting the ELE parameter of the second master control card to a value of one, elevation data can be included in the master data deck. Changing the ELE and the WEIGHT parameters in the master control deck utilized in problem 2 is required in order to solve problem 3. Now delete the population data from the master data deck utilized in example 2 and insert the elevation data.

The elevation data is composed of one card per point in the problem in order of increasing index. Since there are fifty-nine points, there are fifty-nine elevation cards. The elevation cards must appear directly after the second master control card. After the elevation data, the coordinate data must be given for the fifty-five demand points. Since, the population data has been deleted, the additional facility coordinate points information is given directly after the other coordinate point information. This completes the data necessary to structure the master data deck. The problem control and constraint cards follow the master data deck.

The first problem control card is changed to reflect the title of the problem. The second problem control card remains the same as that utilized for planar example 2 except that values are given for EMAXS and EMAXL along with CONS. The format for these three parameters on the second problem control card are given in appendix B. The EMAXL parameter should be set at a value of 30, and the EMAXS parameter should be set at a value of -30. The value of CONS should be set at a value of one so that a constraint data deck can be given.

The first card of the constaint data set is discussed in appendix C. This card must contain the values of the parameters ND, NDAS, and NANCF. Since the number of demand areas that are not allowed to be facility sites is 9, then the value of ND should be set at the value of 9. The other parameters

NDAS and NANCF should be left blank or set at a zero value. The following nine cards are called ND cards and give the indices of the demand areas that are not allowed to be considered as potential facility sites. Each card gives an index of a point to be eliminated from consideration along with a two letter code to indicate the reason why the point is eliminated. After the nine ND cards are given, two blank cards must be given to indicate the end of the data deck. Figure 29 gives a complete listing of the data deck necessary to solve planar problem 3. Figure 30 gives the output listing from the GAS program utilizing the data given in figure 29. Figure 31 gives a conceptualized version of the data deck needed for planar problem 3.

PLANAR PROBLEM 4

Suppose we are interested in solving the 55 point planar problem when population data is to be given. We are interested in locating up to 15 facilities with a maximal service distance of 10. kilometers. Further assume that any facility must be (a) within 10 kilometers of a demand area; (b) no more than 25 meters higher than that demand area, and (c) no more than 15 meters lower than that demand area in order to be considered a site that can serve the demand area. In addition, the four additional facility sites given in problem 2 are to be included. Furthermore, the constraints in table 35 are to be considered.

The master data deck necessary to solve this example can be easily structured by modifying the data deck developed for planar problem 3. In fact the master data deck from planar example 3 differs from that needed for example 4 only in the population data. The population data which we removed from the data deck in order to solve example 3 must be inserted for example 4. The population data of 55 cards must be inserted immediately after (x,y) coordinates are given for the 55 demand points and before the (x,y) coordinates are given for the four additional facility points. In addition, the WEIGHT parameter must also be changed to a value of one. Since rectilinear distances are also to be utilized, the RECT parameter must be modified to a value of one.

The problem control and constraint cards do change to solve problem 4. The title should be changed to reflect a fourth problem. In addition, EMAXL should be changed to 25. and EMAXS should be changed to -15. The value of ICOV will be modified to zero to eliminate the printout of the cover matrix.

The constraint card set begins with a card containing the values of ND, NDAS, and NANCF. The values of ND, NDAS, and NANCF according to the definitions given in appendix C should be: (a) ND = 4, (b) NDAS = 3, and (c) NANCF = 3. There are ten cards which should follow the card giving the values of ND, NDAS, and NANCF. Each card gives an index and for the "ND" cards a two letter code. The form is described in appendix C. Two blank cards follow to complete the data deck.

Figure 32 gives a complete listing of the data deck necessary to solve Problem 4 and figure 33 gives a complete output listing generated by the GAS program in solving this problem.

MULTIPLE PLANAR RUNS

Many planar covering problems can be solved by one computer run of the GAS program by developing a master data deck and following with a multiple number problem control and constraint card sets. An example of a multiple problem run is given in chapter 8. A conceptualized version of a planar data deck set up for multiple problem runs is given in figure 34.

TABLE 34

CITIES NOT AVAILABLE FOR FACILITY PLACEMENT

NODE	REASONS
3	NA (Not Acceptable)
8	NA
10	NA
14	NA
37	NA
22	NA
25	NA
36	NA
51	NA

FIGURE 29

LISTING OF PLANAR PROBLEM THREE DATA DECK

```
59   55    1                    1    1
           1
 1        80.
 2        80.
 3        90.
 4        80.
 5        80.
 6        65.
 7        75.
 8        90.
 9        70.
10        50.
11        75.
12        100.
13        80.
14        155.
15        80.
16        150.
17        75.
18        110.
19        90.
20        60.
21        50.
22        100.
23        70.
24        110.
25        80.
26        100.
27        150.
28        70.
29        70.
30        90.
31        80.
32        100.
33        90.
34        100.
35        110.
36        100.
37        50.
38        140.
39        150.
40        130.
41        60.
42        80.
43        120.
44        90.
45        100.
46        120.
47        80.
48        80.
49        55.
50        50.
51        50.
52        50.
53        40.
54        150.
55        120.
156       90.
157       80.
158       70.
159       90.
  1       32.        31.
  2       29.        32.
  3       27.        36.
  4       29.        29.
  5       32.        29.
  6       26.        25.
```

FIGURE 29

(continued, page 2)

```
  7      24.      33.
  8      30.      35.
  9      29.      27.
 10      29.      21.
 11      33.      28.
 12      17.      53.
 13      34.      40.
 14      25.      60.
 15      21.      28.
 16      30.      51.
 17      19.      47.
 18      17.      33.
 19      22.      40.
 20      25.      14.
 21      29.      12.
 22      24.      48.
 23      17.      42.
 24      6.       26.
 25      19.      21.
 26      10.      32.
 27      34.      56.
 28      12.      47.
 30      27.      41.
 29      19.      38.
 31      21.      35.
 32      32.      45.
 33      27.      45.
 34      32.      38.
 35      8.       22.
 36      15.      25.
 37      35.      16.
 38      36.      47.
 39      46.      51.
 40      50.      40.
 41      23.      22.
 42      27.      30.
 43      38.      39.
 44      36.      32.
 45      32.      41.
 46      42.      36.
 47      36.      26.
 48      15.      19.
 49      19.      14.
 50      45.      19.
 51      27.      5.
 52      52.      24.
 53      40.      22.
 54      40.      52.
 55      42.      42.
156      10.      38.
157      40.      40.
158      23.      28.
159      23.      39.
GAS PLANAR EXAMPLE THREE
 19      10.                30.      -30.      1    1    1
 9
 3 NA
 8 NA
 [illegible] NA
14 NA
37 NA
22 NA
25 NA
36 NA
51 NA
```

POPULATION DATA

1	1.00* 7	1.00* 13	1.00* 19	1.00* 25	1.00* 31	1.00* 37	1.00* 43	1.00* 49	1.00* 55	1.00*	
2	1.00* 8	1.00* 14	1.00* 20	1.00* 26	1.00* 32	1.00* 38	1.00* 44	1.00* 50	1.00*		
3	1.00* 9	1.00* 15	1.00* 21	1.00* 27	1.00* 33	1.00* 39	1.00* 45	1.00* 51	1.00*		
4	1.00* 10	1.00* 16	1.00* 22	1.00* 28	1.00* 34	1.00* 40	1.00* 46	1.00* 52	1.00*		
5	1.00* 11	1.00* 17	1.00* 23	1.00* 29	1.00* 35	1.00* 41	1.00* 47	1.00* 53	1.00*		
6	1.00* 12	1.00* 18	1.00* 24	1.00* 30	1.00* 36	1.00* 42	1.00* 48	1.00* 54	1.00*		

THE FOLLOWING OPTIONS ARE DESIGNATED:
DEMAND POINTS ARE ALSO POTENTIAL FACILITY SITES
DISTANCES ARE MEASURED AS EUCLIDEAN
DEMAND POINTS ARE ALSO POTENTIAL FACILITY SITES
COORDINATE POINT DATA IS AS FOLLOWS:

1	32.00000	31.00000	1**	2	29.00000	32.00000	2**	3	27.00000	36.00000	3**
4	29.00000	29.00000	4**	5	32.00000	29.00000	5**	6	26.00000	25.00000	6**
7	24.00000	33.00000	7**	8	30.00000	35.00000	8**	9	29.00000	27.00000	9**
10	29.00000	21.00000	10**	11	33.00000	28.00000	11**	12	17.00000	53.00000	12**
13	34.00000	40.00000	13**	14	25.00000	60.00000	14**	15	21.00000	28.00000	15**
16	30.00000	51.00000	16**	17	19.00000	47.00000	17**	18	17.00000	33.00000	18**
19	22.00000	40.00000	19**	20	25.00000	14.00000	20**	21	29.00000	12.00000	21**
22	24.00000	48.00000	22**	23	17.00000	42.00000	23**	24	6.00000	26.00000	24**
25	19.00000	21.00000	25**	26	10.00000	32.00000	26**	27	34.00000	56.00000	27**
28	12.00000	47.00000	28**	29	27.00000	41.00000	29**	30	19.00000	38.00000	30**
31	21.00000	35.00000	31**	32	32.00000	45.00000	32**	33	27.00000	45.00000	33**
34	32.00000	38.00000	34**	35	8.00000	22.00000	35**	36	15.00000	25.00000	36**
37	35.00000	16.00000	37**	38	36.00000	47.00000	38**	39	46.00000	51.00000	39**
40	50.00000	40.00000	40**	41	23.00000	22.00000	41**	42	27.00000	30.00000	42**
43	38.00000	39.00000	43**	44	36.00000	32.00000	44**	45	32.00000	41.00000	45**
46	42.00000	36.00000	46**	47	36.00000	26.00000	47**	48	15.00000	19.00000	48**

FIGURE 30

PLANAR PROBLEM THREE OUTPUT

49	19.00000	14.00000	49**	50	45.00000	19.00000	50**	51	27.00000	5.00000	51**
52	52.00000	24.00000	52**	53	40.00000	22.00000	53**	54	40.00000	52.00000	54**
55	42.00000	42.00000	55**	56	10.00000	38.00000	156**	57	40.00000	40.00000	157**
58	23.00000	28.00000	158**	59	23.00000	39.00000	159**	60	32.00000	31.00000	1**
61	29.00000	32.00000	2**	62	27.00000	36.00000	3**	63	29.00000	29.00000	4**
64	32.00000	29.00000	5**	65	26.00000	25.00000	6**	66	24.00000	33.00000	7**
67	30.00000	35.00000	8**	68	29.00000	27.00000	9**	69	29.00000	21.00000	10**
70	33.00000	28.00000	11**	71	17.00000	53.00000	12**	72	34.00000	40.00000	13**
73	25.00000	60.00000	14**	74	21.00000	28.00000	15**	75	30.00000	51.00000	16**
76	19.00000	47.00000	17**	77	17.00000	33.00000	18**	78	22.00000	40.00000	19**
79	25.00000	14.00000	20**	80	29.00000	12.00000	21**	81	24.00000	48.00000	22**
82	17.00000	42.00000	23**	83	6.00000	26.00000	24**	84	19.00000	21.00000	25**
85	10.00000	32.00000	26**	86	34.00000	56.00000	27**	87	12.00000	47.00000	28**
88	27.00000	41.00000	29**	89	19.00000	38.00000	30**	90	21.00000	35.00000	31**
91	32.00000	45.00000	32**	92	27.00000	45.00000	33**	93	32.00000	38.00000	34**
94	8.00000	22.00000	35**	95	15.00000	25.00000	36**	96	35.00000	16.00000	37**
97	36.00000	47.00000	38**	98	46.00000	51.00000	39**	99	50.00000	40.00000	40**
100	23.00000	22.00000	41**	101	27.00000	30.00000	42**	102	38.00000	39.00000	43**
103	36.00000	32.00000	44**	104	32.00000	41.00000	45**	105	42.00000	36.00000	46**
106	36.00000	26.00000	47**	107	15.00000	19.00000	48**	108	19.00000	14.00000	49**
109	45.00000	19.00000	50**	110	27.00000	5.00000	51**	111	52.00000	24.00000	52**
112	40.00000	22.00000	53**	113	40.00000	52.00000	54**	114	42.00000	42.00000	55**

FIGURE 30

(continued, page 2)

FIGURE 30

(continued, page 3)

```
SUBPROGRAM MATBLD HAS BEEN CALLED TO GENERATE A COVER MATRIX
   THE MAXIMUM DISTANCE/TIME OF  10.00 HAS BEEN UTILIZED
   ELEVATIONS ARE ALSO UTILIZED IN  DEVELOPING THE COVER MATRIX
   THE LARGEST ELEVATION DIFFERENCE DOWN TO A FACILITY IS   30.0
   THE LARGEST ELEVATION DIFFERENCE UP TO A FACILITY IS   30.0
```

FIGURE 30

(continued, page 4)

```
 1  0010111111111010100000000000000000000100000001011010000000
 2  0011111111111010101000000000000010100100000001011010000000
 3  0011111110111010101000100000000011101100000001011000000000
 4  0010111111111110001000000000000001001000000011010010000000
 5  0010111111111110000000000000000000001000000010100100000000
 6  0010110111110111001000000000100000000000000011000000000000
 7  0011111111111000001000100000000011100100000001000000000000
 8  0011111110111010100000100000000010100100000001111000000000
 9  0010111111111111001000000000000000000000000011010010000000
10  0010000111001110000000011000100000000000000110000100000000
11  0010111110111110000000000000000000000000000010100100000000
12  0000000000000001000010000100000100000000000000000000000000
13  0100111000010000100000000000000100111000000000110000000000
14  0000000000000000010000000000000100000000000000000000000000
15  0010011101101000001001000000010000010000010000110000000000
16  0000000000000000000010000000000010000000000100000000000000
17  0001000000000000100001010011000001110010000000000000000000
18  1001000000000000000100110000000100011000001000000000000000
19  0001001000110000000011100110000011101000000000000000000000
20  0000000000000010000000001100010000000000000000100000001010
21  0000000000000010000000001100000000000000010000000000000010
22  0001000000000000100001010011000001001100000000000000000000
23  1001000000000000000010100110000101100000000000000000000000
24  0000000000000000000000000001010000000011000000000000000000
25  0010000001000100001000010000100000000001000010000001100000
26  1000000000000000000001000010100000000001000000000000000000
27  0000000000000000010100000000001000000000010000000000000010
28  1000000000000001000010000010000100000000000000000000000000
29  0001011000110000100010100100000011111100000000001000000000
30  1001001000100000000011100010000011100000000000000000000000
31  0011011100110000001001100010000011100000000000100000000000
32  0100000000000000100000000100000010011100000000101000000000
33  0001001000000000100010100100000010011100000000100000000000
34  0101111110110000100000000000000010011100000000111100000000
35  0000000000000000000000000010000000000110000000000010000000
36  0010000000000000001001000001110000000001100000000000010000
37  0000000000000001000000000010000000000000010000000000000100
38  0000000000000000000010000000000010000000000100000100000000
39  0000000000000000000000000000000000000000000100000000000011
40  0000000000000000000000000000000000000000000100000100000001
41  0010000101001100001000001000010000000000000011000001100000
42  0011111111111110001000000000000000100100000011010010000000
43  0000000000100000000000000000000000010100010000111100000001
44  0100111110011010100000000000000000000100000001111110000000
45  0101111000010000100000000000000010011100000000111000000000
46  0000000000000000000000000000000000000000000100110100000001
47  0000110110001110000000000000000000000000000010100100000000
48  0000000000000000000000000000010000000000110000100000011000
49  0000000000000000000000010000100000000000000100000011000000
50  0000000000000000000000000000000000000000000000000000101100
51  0000000000000000000000011000000000000000000000000000010000
52  0000000000000000000000000000000000000000000000000000101000
53  0000000000000000000000000000000000000001000000000000100100
54  0000000000000000000000000000001000000000011000000000000010
55  0000000000000000000000000000000000000000000111001001000001
```

1 CAN BE SERVED BY 3
1 CAN BE SERVED BY 5
1 CAN BE SERVED BY 6
1 CAN BE SERVED BY 7
1 CAN BE SERVED BY 8

FIGURE 30

(continued, page 5)

```
1 CAN BE SERVED BY     9
1 CAN BE SERVED BY    10
1 CAN BE SERVED BY    11
1 CAN BE SERVED BY    12
1 CAN BE SERVED BY    13
1 CAN BE SERVED BY    15
1 CAN BE SERVED BY    17
1 CAN BE SERVED BY    38
1 CAN BE SERVED BY    46
1 CAN BE SERVED BY    48
1 CAN BE SERVED BY    49
1 CAN BE SERVED BY    51
2 CAN BE SERVED BY     3
2 CAN BE SERVED BY     4
2 CAN BE SERVED BY     5
2 CAN BE SERVED BY     6
2 CAN BE SERVED BY     7
2 CAN BE SERVED BY     8
2 CAN BE SERVED BY     9
2 CAN BE SERVED BY    10
2 CAN BE SERVED BY    11
2 CAN BE SERVED BY    12
2 CAN BE SERVED BY    13
2 CAN BE SERVED BY    15
2 CAN BE SERVED BY    17
2 CAN BE SERVED BY    19
2 CAN BE SERVED BY    33
2 CAN BE SERVED BY    35
2 CAN BE SERVED BY    38
2 CAN BE SERVED BY    46
2 CAN BE SERVED BY    48
2 CAN BE SERVED BY    49
2 CAN BE SERVED BY    51
3 CAN BE SERVED BY     3
3 CAN BE SERVED BY     4
3 CAN BE SERVED BY     5
3 CAN BE SERVED BY     6
3 CAN BE SERVED BY     7
3 CAN BE SERVED BY     8
3 CAN BE SERVED BY     9
3 CAN BE SERVED BY    11
3 CAN BE SERVED BY    12
3 CAN BE SERVED BY    13
3 CAN BE SERVED BY    15
3 CAN BE SERVED BY    17
3 CAN BE SERVED BY    19
3 CAN BE SERVED BY    23
3 CAN BE SERVED BY    33
3 CAN BE SERVED BY    34
3 CAN BE SERVED BY    35
3 CAN BE SERVED BY    37
3 CAN BE SERVED BY    38
3 CAN BE SERVED BY    46
3 CAN BE SERVED BY    48
3 CAN BE SERVED BY    49
4 CAN BE SERVED BY     3
4 CAN BE SERVED BY     5
4 CAN BE SERVED BY     6
4 CAN BE SERVED BY     7
4 CAN BE SERVED BY     8
4 CAN BE SERVED BY     9
```

FIGURE 30

(continued, page 6)

```
4 CAN BE SERVED BY    10
4 CAN BE SERVED BY    11
4 CAN BE SERVED BY    12
4 CAN BE SERVED BY    13
4 CAN BE SERVED BY    14
4 CAN BE SERVED BY    15
4 CAN BE SERVED BY    19
4 CAN BE SERVED BY    35
4 CAN BE SERVED BY    38
4 CAN BE SERVED BY    45
4 CAN BE SERVED BY    46
4 CAN BE SERVED BY    48
4 CAN BE SERVED BY    51
5 CAN BE SERVED BY     3
5 CAN BE SERVED BY     5
5 CAN BE SERVED BY     6
5 CAN BE SERVED BY     7
5 CAN BE SERVED BY     8
5 CAN BE SERVED BY     9
5 CAN BE SERVED BY    10
5 CAN BE SERVED BY    11
5 CAN BE SERVED BY    12
5 CAN BE SERVED BY    13
5 CAN BE SERVED BY    14
5 CAN BE SERVED BY    15
5 CAN BE SERVED BY    38
5 CAN BE SERVED BY    46
5 CAN BE SERVED BY    48
5 CAN BE SERVED BY    51
6 CAN BE SERVED BY     3
6 CAN BE SERVED BY     5
6 CAN BE SERVED BY     6
6 CAN BE SERVED BY     8
6 CAN BE SERVED BY     9
6 CAN BE SERVED BY    10
6 CAN BE SERVED BY    11
6 CAN BE SERVED BY    13
6 CAN BE SERVED BY    14
6 CAN BE SERVED BY    15
6 CAN BE SERVED BY    19
6 CAN BE SERVED BY    29
6 CAN BE SERVED BY    45
6 CAN BE SERVED BY    46
7 CAN BE SERVED BY     3
7 CAN BE SERVED BY     4
7 CAN BE SERVED BY     5
7 CAN BE SERVED BY     6
7 CAN BE SERVED BY     7
7 CAN BE SERVED BY     8
7 CAN BE SERVED BY     9
7 CAN BE SERVED BY    10
7 CAN BE SERVED BY    11
7 CAN BE SERVED BY    12
7 CAN BE SERVED BY    13
7 CAN BE SERVED BY    19
7 CAN BE SERVED BY    23
7 CAN BE SERVED BY    33
7 CAN BE SERVED BY    34
7 CAN BE SERVED BY    35
7 CAN BE SERVED BY    38
7 CAN BE SERVED BY    46
```

FIGURE 30

(continued, page 7)

```
 8 CAN BE SERVED BY     3
 8 CAN BE SERVED BY     4
 8 CAN BE SERVED BY     5
 8 CAN BE SERVED BY     6
 8 CAN BE SERVED BY     7
 8 CAN BE SERVED BY     8
 8 CAN BE SERVED BY     9
 8 CAN BE SERVED BY    11
 8 CAN BE SERVED BY    12
 8 CAN BE SERVED BY    13
 8 CAN BE SERVED BY    15
 8 CAN BE SERVED BY    17
 8 CAN BE SERVED BY    23
 8 CAN BE SERVED BY    33
 8 CAN BE SERVED BY    35
 8 CAN BE SERVED BY    38
 8 CAN BE SERVED BY    46
 8 CAN BE SERVED BY    47
 8 CAN BE SERVED BY    48
 8 CAN BE SERVED BY    49
 9 CAN BE SERVED BY     3
 9 CAN BE SERVED BY     5
 9 CAN BE SERVED BY     6
 9 CAN BE SERVED BY     7
 9 CAN BE SERVED BY     8
 9 CAN BE SERVED BY     9
 9 CAN BE SERVED BY    10
 9 CAN BE SERVED BY    11
 9 CAN BE SERVED BY    12
 9 CAN BE SERVED BY    13
 9 CAN BE SERVED BY    14
 9 CAN BE SERVED BY    15
 9 CAN BE SERVED BY    19
 9 CAN BE SERVED BY    45
 9 CAN BE SERVED BY    46
 9 CAN BE SERVED BY    48
 9 CAN BE SERVED BY    51
10 CAN BE SERVED BY     3
10 CAN BE SERVED BY     8
10 CAN BE SERVED BY     9
10 CAN BE SERVED BY    10
10 CAN BE SERVED BY    13
10 CAN BE SERVED BY    14
10 CAN BE SERVED BY    15
10 CAN BE SERVED BY    24
10 CAN BE SERVED BY    25
10 CAN BE SERVED BY    29
10 CAN BE SERVED BY    41
10 CAN BE SERVED BY    45
10 CAN BE SERVED BY    46
10 CAN BE SERVED BY    51
11 CAN BE SERVED BY     3
11 CAN BE SERVED BY     5
11 CAN BE SERVED BY     6
11 CAN BE SERVED BY     7
11 CAN BE SERVED BY     8
11 CAN BE SERVED BY     9
11 CAN BE SERVED BY    10
11 CAN BE SERVED BY    12
11 CAN BE SERVED BY    13
11 CAN BE SERVED BY    14
```

FIGURE 30

(continued, page 8)

```
11 CAN BE SERVED BY    15
11 CAN BE SERVED BY    46
11 CAN BE SERVED BY    48
11 CAN BE SERVED BY    51
12 CAN BE SERVED BY    16
12 CAN BE SERVED BY    21
12 CAN BE SERVED BY    26
12 CAN BE SERVED BY    32
13 CAN BE SERVED BY     2
13 CAN BE SERVED BY     5
13 CAN BE SERVED BY     6
13 CAN BE SERVED BY     7
13 CAN BE SERVED BY    12
13 CAN BE SERVED BY    17
13 CAN BE SERVED BY    33
13 CAN BE SERVED BY    36
13 CAN BE SERVED BY    37
13 CAN BE SERVED BY    38
13 CAN BE SERVED BY    48
13 CAN BE SERVED BY    49
14 CAN BE SERVED BY    18
14 CAN BE SERVED BY    31
15 CAN BE SERVED BY     3
15 CAN BE SERVED BY     6
15 CAN BE SERVED BY     7
15 CAN BE SERVED BY     8
15 CAN BE SERVED BY    10
15 CAN BE SERVED BY    11
15 CAN BE SERVED BY    13
15 CAN BE SERVED BY    19
15 CAN BE SERVED BY    22
15 CAN BE SERVED BY    29
15 CAN BE SERVED BY    35
15 CAN BE SERVED BY    40
15 CAN BE SERVED BY    45
15 CAN BE SERVED BY    46
16 CAN BE SERVED BY    20
16 CAN BE SERVED BY    31
16 CAN BE SERVED BY    42
17 CAN BE SERVED BY     4
17 CAN BE SERVED BY    16
17 CAN BE SERVED BY    21
17 CAN BE SERVED BY    23
17 CAN BE SERVED BY    26
17 CAN BE SERVED BY    27
17 CAN BE SERVED BY    32
17 CAN BE SERVED BY    33
17 CAN BE SERVED BY    34
17 CAN BE SERVED BY    37
18 CAN BE SERVED BY     1
18 CAN BE SERVED BY     4
18 CAN BE SERVED BY    19
18 CAN BE SERVED BY    22
18 CAN BE SERVED BY    23
18 CAN BE SERVED BY    30
18 CAN BE SERVED BY    34
18 CAN BE SERVED BY    35
18 CAN BE SERVED BY    40
19 CAN BE SERVED BY     4
19 CAN BE SERVED BY     7
19 CAN BE SERVED BY    11
```

FIGURE 30

(continued, page 9)

19	CAN	BE	SERVED	BY	12
19	CAN	BE	SERVED	BY	21
19	CAN	BE	SERVED	BY	22
19	CAN	BE	SERVED	BY	23
19	CAN	BE	SERVED	BY	26
19	CAN	BE	SERVED	BY	27
19	CAN	BE	SERVED	BY	33
19	CAN	BE	SERVED	BY	34
19	CAN	BE	SERVED	BY	35
19	CAN	BE	SERVED	BY	37
20	CAN	BE	SERVED	BY	14
20	CAN	BE	SERVED	BY	24
20	CAN	BE	SERVED	BY	25
20	CAN	BE	SERVED	BY	29
20	CAN	BE	SERVED	BY	45
20	CAN	BE	SERVED	BY	53
20	CAN	BE	SERVED	BY	55
21	CAN	BE	SERVED	BY	14
21	CAN	BE	SERVED	BY	24
21	CAN	BE	SERVED	BY	25
21	CAN	BE	SERVED	BY	41
21	CAN	BE	SERVED	BY	55
22	CAN	BE	SERVED	BY	4
22	CAN	BE	SERVED	BY	16
22	CAN	BE	SERVED	BY	21
22	CAN	BE	SERVED	BY	23
22	CAN	BE	SERVED	BY	26
22	CAN	BE	SERVED	BY	27
22	CAN	BE	SERVED	BY	33
22	CAN	BE	SERVED	BY	36
22	CAN	BE	SERVED	BY	37
23	CAN	BE	SERVED	BY	1
23	CAN	BE	SERVED	BY	4
23	CAN	BE	SERVED	BY	21
23	CAN	BE	SERVED	BY	23
23	CAN	BE	SERVED	BY	26
23	CAN	BE	SERVED	BY	27
23	CAN	BE	SERVED	BY	32
23	CAN	BE	SERVED	BY	34
23	CAN	BE	SERVED	BY	35
24	CAN	BE	SERVED	BY	28
24	CAN	BE	SERVED	BY	30
24	CAN	BE	SERVED	BY	39
24	CAN	BE	SERVED	BY	40
25	CAN	BE	SERVED	BY	3
25	CAN	BE	SERVED	BY	10
25	CAN	BE	SERVED	BY	14
25	CAN	BE	SERVED	BY	19
25	CAN	BE	SERVED	BY	24
25	CAN	BE	SERVED	BY	29
25	CAN	BE	SERVED	BY	40
25	CAN	BE	SERVED	BY	45
25	CAN	BE	SERVED	BY	52
25	CAN	BE	SERVED	BY	53
26	CAN	BE	SERVED	BY	1
26	CAN	BE	SERVED	BY	22
26	CAN	BE	SERVED	BY	28
26	CAN	BE	SERVED	BY	30
26	CAN	BE	SERVED	BY	40
27	CAN	BE	SERVED	BY	18
27	CAN	BE	SERVED	BY	20

FIGURE 30

(continued, page 10)

```
27 CAN BE SERVED BY    31
27 CAN BE SERVED BY    42
27 CAN BE SERVED BY   158
28 CAN BE SERVED BY     1
28 CAN BE SERVED BY    16
28 CAN BE SERVED BY    21
28 CAN BE SERVED BY    27
28 CAN BE SERVED BY    32
29 CAN BE SERVED BY     4
29 CAN BE SERVED BY     6
29 CAN BE SERVED BY     7
29 CAN BE SERVED BY    11
29 CAN BE SERVED BY    12
29 CAN BE SERVED BY    17
29 CAN BE SERVED BY    21
29 CAN BE SERVED BY    23
29 CAN BE SERVED BY    26
29 CAN BE SERVED BY    33
29 CAN BE SERVED BY    34
29 CAN BE SERVED BY    35
29 CAN BE SERVED BY    36
29 CAN BE SERVED BY    37
29 CAN BE SERVED BY    38
29 CAN BE SERVED BY    49
30 CAN BE SERVED BY     1
30 CAN BE SERVED BY     4
30 CAN BE SERVED BY     7
30 CAN BE SERVED BY    11
30 CAN BE SERVED BY    21
30 CAN BE SERVED BY    22
30 CAN BE SERVED BY    23
30 CAN BE SERVED BY    27
30 CAN BE SERVED BY    33
30 CAN BE SERVED BY    34
30 CAN BE SERVED BY    35
31 CAN BE SERVED BY     3
31 CAN BE SERVED BY     4
31 CAN BE SERVED BY     6
31 CAN BE SERVED BY     7
31 CAN BE SERVED BY     8
31 CAN BE SERVED BY    11
31 CAN BE SERVED BY    12
31 CAN BE SERVED BY    19
31 CAN BE SERVED BY    22
31 CAN BE SERVED BY    23
31 CAN BE SERVED BY    27
31 CAN BE SERVED BY    33
31 CAN BE SERVED BY    34
31 CAN BE SERVED BY    35
31 CAN BE SERVED BY    46
32 CAN BE SERVED BY     2
32 CAN BE SERVED BY    17
32 CAN BE SERVED BY    26
32 CAN BE SERVED BY    33
32 CAN BE SERVED BY    36
32 CAN BE SERVED BY    37
32 CAN BE SERVED BY    38
32 CAN BE SERVED BY    47
32 CAN BE SERVED BY    49
33 CAN BE SERVED BY     4
33 CAN BE SERVED BY     7
```

FIGURE 30

(continued, page 11)

33	CAN	BE	SERVED	BY	17
33	CAN	BE	SERVED	BY	21
33	CAN	BE	SERVED	BY	23
33	CAN	BE	SERVED	BY	26
33	CAN	BE	SERVED	BY	33
33	CAN	BE	SERVED	BY	36
33	CAN	BE	SERVED	BY	37
33	CAN	BE	SERVED	BY	38
33	CAN	BE	SERVED	BY	49
34	CAN	BE	SERVED	BY	2
34	CAN	BE	SERVED	BY	4
34	CAN	BE	SERVED	BY	5
34	CAN	BE	SERVED	BY	6
34	CAN	BE	SERVED	BY	7
34	CAN	BE	SERVED	BY	8
34	CAN	BE	SERVED	BY	9
34	CAN	BE	SERVED	BY	11
34	CAN	BE	SERVED	BY	12
34	CAN	BE	SERVED	BY	17
34	CAN	BE	SERVED	BY	33
34	CAN	BE	SERVED	BY	36
34	CAN	BE	SERVED	BY	37
34	CAN	BE	SERVED	BY	38
34	CAN	BE	SERVED	BY	46
34	CAN	BE	SERVED	BY	47
34	CAN	BE	SERVED	BY	48
34	CAN	BE	SERVED	BY	49
35	CAN	BE	SERVED	BY	28
35	CAN	BE	SERVED	BY	39
35	CAN	BE	SERVED	BY	40
35	CAN	BE	SERVED	BY	52
36	CAN	BE	SERVED	BY	3
36	CAN	BE	SERVED	BY	19
36	CAN	BE	SERVED	BY	22
36	CAN	BE	SERVED	BY	28
36	CAN	BE	SERVED	BY	29
36	CAN	BE	SERVED	BY	30
36	CAN	BE	SERVED	BY	39
36	CAN	BE	SERVED	BY	40
36	CAN	BE	SERVED	BY	52
37	CAN	BE	SERVED	BY	14
37	CAN	BE	SERVED	BY	25
37	CAN	BE	SERVED	BY	41
37	CAN	BE	SERVED	BY	157
38	CAN	BE	SERVED	BY	20
38	CAN	BE	SERVED	BY	31
38	CAN	BE	SERVED	BY	42
38	CAN	BE	SERVED	BY	47
38	CAN	BE	SERVED	BY	158
38	CAN	BE	SERVED	BY	159
39	CAN	BE	SERVED	BY	43
39	CAN	BE	SERVED	BY	158
39	CAN	BE	SERVED	BY	159
40	CAN	BE	SERVED	BY	44
40	CAN	BE	SERVED	BY	50
40	CAN	BE	SERVED	BY	159
41	CAN	BE	SERVED	BY	3
41	CAN	BE	SERVED	BY	8
41	CAN	BE	SERVED	BY	10
41	CAN	BE	SERVED	BY	13
41	CAN	BE	SERVED	BY	14

FIGURE 30

(continued, page 12)

```
41 CAN BE SERVED BY    19
41 CAN BE SERVED BY    24
41 CAN BE SERVED BY    29
41 CAN BE SERVED BY    45
41 CAN BE SERVED BY    46
41 CAN BE SERVED BY    52
41 CAN BE SERVED BY    53
42 CAN BE SERVED BY     3
42 CAN BE SERVED BY     4
42 CAN BE SERVED BY     5
42 CAN BE SERVED BY     6
42 CAN BE SERVED BY     7
42 CAN BE SERVED BY     8
42 CAN BE SERVED BY     9
42 CAN BE SERVED BY    10
42 CAN BE SERVED BY    11
42 CAN BE SERVED BY    12
42 CAN BE SERVED BY    13
42 CAN BE SERVED BY    14
42 CAN BE SERVED BY    15
42 CAN BE SERVED BY    19
42 CAN BE SERVED BY    35
42 CAN BE SERVED BY    38
42 CAN BE SERVED BY    45
42 CAN BE SERVED BY    46
42 CAN BE SERVED BY    48
42 CAN BE SERVED BY    51
43 CAN BE SERVED BY    12
43 CAN BE SERVED BY    36
43 CAN BE SERVED BY    38
43 CAN BE SERVED BY    42
43 CAN BE SERVED BY    47
43 CAN BE SERVED BY    48
43 CAN BE SERVED BY    49
43 CAN BE SERVED BY    50
43 CAN BE SERVED BY   159
44 CAN BE SERVED BY     2
44 CAN BE SERVED BY     5
44 CAN BE SERVED BY     6
44 CAN BE SERVED BY     7
44 CAN BE SERVED BY     8
44 CAN BE SERVED BY     9
44 CAN BE SERVED BY    12
44 CAN BE SERVED BY    13
44 CAN BE SERVED BY    15
44 CAN BE SERVED BY    17
44 CAN BE SERVED BY    38
44 CAN BE SERVED BY    46
44 CAN BE SERVED BY    47
44 CAN BE SERVED BY    48
44 CAN BE SERVED BY    49
44 CAN BE SERVED BY    50
44 CAN BE SERVED BY    51
45 CAN BE SERVED BY     2
45 CAN BE SERVED BY     4
45 CAN BE SERVED BY     5
45 CAN BE SERVED BY     6
45 CAN BE SERVED BY     7
45 CAN BE SERVED BY    12
45 CAN BE SERVED BY    17
45 CAN BE SERVED BY    33
```

FIGURE 30

(continued, page 13)

```
45 CAN BE SERVED BY    36
45 CAN BE SERVED BY    37
45 CAN BE SERVED BY    38
45 CAN BE SERVED BY    47
45 CAN BE SERVED BY    48
45 CAN BE SERVED BY    49
46 CAN BE SERVED BY    44
46 CAN BE SERVED BY    47
46 CAN BE SERVED BY    48
46 CAN BE SERVED BY    50
46 CAN BE SERVED BY   159
47 CAN BE SERVED BY     5
47 CAN BE SERVED BY     6
47 CAN BE SERVED BY     8
47 CAN BE SERVED BY     9
47 CAN BE SERVED BY    13
47 CAN BE SERVED BY    14
47 CAN BE SERVED BY    15
47 CAN BE SERVED BY    46
47 CAN BE SERVED BY    48
47 CAN BE SERVED BY    51
48 CAN BE SERVED BY    29
48 CAN BE SERVED BY    39
48 CAN BE SERVED BY    40
48 CAN BE SERVED BY    45
48 CAN BE SERVED BY    52
48 CAN BE SERVED BY    53
49 CAN BE SERVED BY    24
49 CAN BE SERVED BY    29
49 CAN BE SERVED BY    45
49 CAN BE SERVED BY    52
49 CAN BE SERVED BY    53
50 CAN BE SERVED BY    54
50 CAN BE SERVED BY   156
50 CAN BE SERVED BY   157
51 CAN BE SERVED BY    24
51 CAN BE SERVED BY    25
51 CAN BE SERVED BY    55
52 CAN BE SERVED BY    54
52 CAN BE SERVED BY   156
53 CAN BE SERVED BY    41
53 CAN BE SERVED BY    54
53 CAN BE SERVED BY   157
54 CAN BE SERVED BY    31
54 CAN BE SERVED BY    42
54 CAN BE SERVED BY    43
54 CAN BE SERVED BY   158
55 CAN BE SERVED BY    42
55 CAN BE SERVED BY    43
55 CAN BE SERVED BY    44
55 CAN BE SERVED BY    47
55 CAN BE SERVED BY    50
55 CAN BE SERVED BY   159
```

FIGURE 30

(continued, page 14)

```
THE FOLLOWING NODES WILL NOT BE CONSIDERED AS POTENTIAL FACILITY SITES:
  3-NA,   8-NA,  10-NA,  14-NA,  37-NA,  22-NA,  25-NA,  36-NA,  51-NA,
*****************************************************************************
```

```
   ITERATION NUMBER.    1
 GAS PLANAR EXAMPLE THREE

   NUMBER OF FACILITIES   1
   SERVICE DISTANCE =    10.000

   NEW FACILITY LOCATION NUMBER     3

   FACILITIES ARE LOCATED AT     3.
   ---------------------------------------------------------------------------------------
   POPULATION SERVED      20.00          PERCENT OF TOTAL POPULATION SERVED   36.36
   ---------------------------------------------------------------------------------------
THE FACILITY LOCATED AT:   3 CAN COVER THE FOLLOWING  DEMANDS:
  1,   2.   3,   4.   5,   7.   8.   9,  11,  13,  15,  19,  29,  30,  31,  33,  34,  42.  44.  45,
DEMAND POINT      CAN BE COVERED BY FACILITIES AT:
         1          3,
         2          3,
         3          3,
         4          3,
         5          3,
         6        NO CURRENT FACILITY LOCATION
         7          3,
         8          3,
         9          3,
        10        NO CURRENT FACILITY LOCATION
        11          3,
        12        NO CURRENT FACILITY LOCATION
        13          3,
        14        NO CURRENT FACILITY LOCATION
        15          3,
        16        NO CURRENT FACILITY LOCATION
        17        NO CURRENT FACILITY LOCATION
        18        NO CURRENT FACILITY LOCATION
        19          3,
        20        NO CURRENT FACILITY LOCATION
        21        NO CURRENT FACILITY LOCATION
        22        NO CURRENT FACILITY LOCATION
        23        NO CURRENT FACILITY LOCATION
        24        NO CURRENT FACILITY LOCATION
        25        NO CURRENT FACILITY LOCATION
        26        NO CURRENT FACILITY LOCATION
        27        NO CURRENT FACILITY LOCATION
        28        NO CURRENT FACILITY LOCATION
        29          3,
        30          3,
        31          3,
        32        NO CURRENT FACILITY LOCATION
        33          3,
        34          3,
```

FIGURE 30

(continued, page 15)

```
35        NO CURRENT FACILITY LOCATION
36        NO CURRENT FACILITY LOCATION
37        NO CURRENT FACILITY LOCATION
38        NO CURRENT FACILITY LOCATION
39        NO CURRENT FACILITY LOCATION
40        NO CURRENT FACILITY LOCATION
41        NO CURRENT FACILITY LOCATION
42          3,
43        NO CURRENT FACILITY LOCATION
44          3,
45          3,
46        NO CURRENT FACILITY LOCATION
47        NO CURRENT FACILITY LOCATION
48        NO CURRENT FACILITY LOCATION
49        NO CURRENT FACILITY LOCATION
50        NO CURRENT FACILITY LOCATION
51        NO CURRENT FACILITY LOCATION
52        NO CURRENT FACILITY LOCATION
53        NO CURRENT FACILITY LOCATION
54        NO CURRENT FACILITY LOCATION
55        NO CURRENT FACILITY LOCATION
```

FIGURE 30

(continued, page 16)

```
   ITERATION NUMBER,    2
 GAS PLANAR EXAMPLE THREE

   NUMBER OF FACILITIES   2
   SERVICE DISTANCE =    10.000

   NEW FACILITY LOCATION NUMBER    25

   FACILITIES ARE LOCATED AT     3,   25,
   ------------------------------------------------------------------------------------------
   POPULATION SERVED       28.00          PERCENT OF TOTAL POPULATION SERVED   50.91
   ------------------------------------------------------------------------------------------
THE FACILITY LOCATED AT:   3 CAN COVER THE FOLLOWING  DEMANDS:
  1,   2,   3,   4,   5,   7,   8,   9,  11,  13,  15,  19,  29,  30,  31,  33,  39,  42,  44,  45,
THE FACILITY LOCATED AT:  25 CAN COVER THE FOLLOWING  DEMANDS:
  6,  10,  15,  20,  25,  36,  41,  48,  49,
DEMAND POINT       CAN BE COVERED BY FACILITIES AT:
         1          3,
         2          3,
         3          3,
         4          3,
         5          3,
         6         25,
         7          3,
         8          3,
         9          3,
        10         25,
        11          3,
        12        NO CURRENT FACILITY LOCATION
        13          3,
        14        NO CURRENT FACILITY LOCATION
        15          3,  25,
        16        NO CURRENT FACILITY LOCATION
        17        NO CURRENT FACILITY LOCATION
        18        NO CURRENT FACILITY LOCATION
        19          3,
        20         25,
        21        NO CURRENT FACILITY LOCATION
        22        NO CURRENT FACILITY LOCATION
        23        NO CURRENT FACILITY LOCATION
        24        NO CURRENT FACILITY LOCATION
        25         25,
        26        NO CURRENT FACILITY LOCATION
        27        NO CURRENT FACILITY LOCATION
        28        NO CURRENT FACILITY LOCATION
        29          3,
        30          3,
        31          3,
```

FIGURE 30

(continued, page 17)

```
32        NO CURRENT FACILITY LOCATION
33          3,
34          3,
35        NO CURRENT FACILITY LOCATION
36         25,
37        NO CURRENT FACILITY LOCATION
38        NO CURRENT FACILITY LOCATION
39        NO CURRENT FACILITY LOCATION
40        NO CURRENT FACILITY LOCATION
41         25,
42          3,
43        NO CURRENT FACILITY LOCATION
44          3,
45          3,
46        NO CURRENT FACILITY LOCATION
47        NO CURRENT FACILITY LOCATION
48         25,
49         25,
50        NO CURRENT FACILITY LOCATION
51        NO CURRENT FACILITY LOCATION
52        NO CURRENT FACILITY LOCATION
53        NO CURRENT FACILITY LOCATION
54        NO CURRENT FACILITY LOCATION
55        NO CURRENT FACILITY LOCATION
```

FIGURE 30

(continued, page 18)

```
   ITERATION NUMBER,    3
 GAS PLANAR EXAMPLE THREE

   NUMBER OF FACILITIES   3
   SERVICE DISTANCE =    10.000

   NEW FACILITY LOCATION NUMBER    38

   FACILITIES ARE LOCATED AT     3,   25,   38,
   ------------------------------------------------------------------------------------------
   POPULATION SERVED      34.00          PERCENT OF TOTAL POPULATION SERVED   61.82
   ------------------------------------------------------------------------------------------
THE FACILITY LOCATED AT:   3 CAN COVER THE FOLLOWING  DEMANDS:
  1,   2,   3,   4,   5,   7,   8,   9,  11,  13,  15,  19,  29,  30,  31,  33,  34,  42,  44,  45,
THE FACILITY LOCATED AT:  25 CAN COVER THE FOLLOWING  DEMANDS:
  6,  10,  15,  20,  25,  36,  41,  48,  49,
THE FACILITY LOCATED AT:  38 CAN COVER THE FOLLOWING  DEMANDS:
 16,  27,  38,  43,  54,  55,
DEMAND POINT      CAN BE COVERED BY FACILITIES AT:
         1         3,
         2         3,
         3         3,
         4         3,
         5         3,
         6        25,
         7         3,
         8         3,
         9         3,
        10        25,
        11         3,
        12        NO CURRENT FACILITY LOCATION
        13         3,
        14        NO CURRENT FACILITY LOCATION
        15         3,  25,
        16        38,
        17        NO CURRENT FACILITY LOCATION
        18        NO CURRENT FACILITY LOCATION
        19         3,
        20        25,
        21        NO CURRENT FACILITY LOCATION
        22        NO CURRENT FACILITY LOCATION
        23        NO CURRENT FACILITY LOCATION
        24        NO CURRENT FACILITY LOCATION
        25        25,
        26        NO CURRENT FACILITY LOCATION
        27        38,
        28        NO CURRENT FACILITY LOCATION
        29         3,
        30         3,
        31         3,
```

FIGURE 30

(continued, page 19)

```
32        NO CURRENT FACILITY LOCATION
33          3,
34          3,
35        NO CURRENT FACILITY LOCATION
36         25,
37        NO CURRENT FACILITY LOCATION
38         38,
39        NO CURRENT FACILITY LOCATION
40        NO CURRENT FACILITY LOCATION
41         25,
42          3,
43         38,
44          3,
45          3,
46        NO CURRENT FACILITY LOCATION
47        NO CURRENT FACILITY LOCATION
48         25,
49         25,
50        NO CURRENT FACILITY LOCATION
51        NO CURRENT FACILITY LOCATION
52        NO CURRENT FACILITY LOCATION
53        NO CURRENT FACILITY LOCATION
54         38,
55         38,
```

FIGURE 30

(continued, page 20)

```
   ITERATION NUMBER,    4
 GAS PLANAR EXAMPLE THREE

   NUMBER OF FACILITIES   4
   SERVICE DISTANCE =    10.000

   NEW FACILITY LOCATION NUMBER    17

   FACILITIES ARE LOCATED AT     3,   25,   38,   17,
   ---------------------------------------------------------------------------
   POPULATION SERVED       39.00          PERCENT OF TOTAL POPULATION SERVED   70.91
   ---------------------------------------------------------------------------
THE FACILITY LOCATED AT:   3 CAN COVER THE FOLLOWING  DEMANDS:
  1,   2,   3,   4,   5,   7,   8,   9,  11,  13,  15,  19,  29,  30,  31,  33,  39,  42,  44,  45,
THE FACILITY LOCATED AT:  25 CAN COVER THE FOLLOWING  DEMANDS:
  6,  10,  15,  20,  25,  36,  41,  48,  49,
THE FACILITY LOCATED AT:  38 CAN COVER THE FOLLOWING  DEMANDS:
 16,  27,  38,  43,  54,  55,
THE FACILITY LOCATED AT:  17 CAN COVER THE FOLLOWING  DEMANDS:
 12,  17,  19,  22,  23,  28,  29,  30,  33,
DEMAND POINT      CAN BE COVERED BY FACILITIES AT:
         1         3,
         2         3,
         3         3,
         4         3,
         5         3,
         6        25,
         7         3,
         8         3,
         9         3,
        10        25,
        11         3,
        12        17,
        13         3,
        14       NO CURRENT FACILITY LOCATION
        15         3,  25,
        16        38,
        17        17,
        18       NO CURRENT FACILITY LOCATION
        19         3,  17,
        20        25,
        21       NO CURRENT FACILITY LOCATION
        22        17,
        23        17,
        24       NO CURRENT FACILITY LOCATION
        25        25,
        26       NO CURRENT FACILITY LOCATION
        27        38,
        28        17,
        29         3,  17,
        30         3,  17,
```

FIGURE 30

(continued, page 21)

```
31          3,
32        NO CURRENT FACILITY LOCATION
33          3,  17,
34          3,
35        NO CURRENT FACILITY LOCATION
36         25,
37        NO CURRENT FACILITY LOCATION
38         38,
39        NO CURRENT FACILITY LOCATION
40        NO CURRENT FACILITY LOCATION
41         25,
42          3,
43         38,
44          3,
45          3,
46        NO CURRENT FACILITY LOCATION
47        NO CURRENT FACILITY LOCATION
48         25,
49         25,
50        NO CURRENT FACILITY LOCATION
51        NO CURRENT FACILITY LOCATION
52        NO CURRENT FACILITY LOCATION
53        NO CURRENT FACILITY LOCATION
54         38,
55         38,

SUBSTITUTION  ALGORITHM USED

NODE      2 REPLACES FACILITY LOCATION      3
THIS IS NOW FACILITY NUMBER      1

FACILITIES ARE LOCATED AT     2,   25,   38,   17,
-----------------------------------------------------------------------------------
POPULATION SERVED      40.00          PERCENT OF TOTAL POPULATION SERVED   72.73
-----------------------------------------------------------------------------------
THE FACILITY LOCATED AT:   2 CAN COVER THE FOLLOWING  DEMANDS:
  1,   2,   3,   4,   5,   6,   7,   8,   9,  11,  13,  15,  29,  31,  34,  42,  44,  45,  47,
THE FACILITY LOCATED AT:  25 CAN COVER THE FOLLOWING  DEMANDS:
  6,  10,  15,  20,  25,  36,  41,  48,  49,
THE FACILITY LOCATED AT:  38 CAN COVER THE FOLLOWING  DEMANDS:
 16,  27,  38,  43,  54,  55,
THE FACILITY LOCATED AT:  17 CAN COVER THE FOLLOWING  DEMANDS:
 12,  17,  19,  22,  23,  28,  29,  30,  33,
DEMAND POINT      CAN BE COVERED BY FACILITIES AT:
         1         2,
         2         2,
         3         2,
         4         2,
         5         2,
         6         2,  25,
         7         2,
         8         2,
         9         2,
```

FIGURE 30

(continued, page 22)

```
10        25,
11         2,
12        17,
13         2,
14       NO CURRENT FACILITY LOCATION
15         2,  25,
16        38,
17        17,
18       NO CURRENT FACILITY LOCATION
19        17,
20        25,
21       NO CURRENT FACILITY LOCATION
22        17,
23        17,
24       NO CURRENT FACILITY LOCATION
25        25,
26       NO CURRENT FACILITY LOCATION
27        38,
28        17,
29         2,  17,
30        17,
31         2,
32       NO CURRENT FACILITY LOCATION
33        17,
34         2,
35       NO CURRENT FACILITY LOCATION
36        25,
37       NO CURRENT FACILITY LOCATION
38        38,
39       NO CURRENT FACILITY LOCATION
40       NO CURRENT FACILITY LOCATION
41        25,
42         2,
43        38,
44         2,
45         2,
46       NO CURRENT FACILITY LOCATION
47         2,
48        25,
49        25,
50       NO CURRENT FACILITY LOCATION
51       NO CURRENT FACILITY LOCATION
52       NO CURRENT FACILITY LOCATION
53       NO CURRENT FACILITY LOCATION
54        38,
55        38,
```

FIGURE 30

(continued, page 23)

```
SUBSTITUTION  ALGORITHM USED

NODE      20 REPLACES FACILITY LOCATION      25
THIS IS NOW FACILITY NUMBER       2

FACILITIES ARE LOCATED AT      2,   20,   38,   17,
-------------------------------------------------------------------------------
POPULATION SERVED       40.00          PERCENT OF TOTAL POPULATION SERVED   72.73
-------------------------------------------------------------------------------
THE FACILITY LOCATED AT:   2 CAN COVER THE FOLLOWING  DEMANDS:
  1,   2,   3,   4,   5,   6,   7,   8,   9,  11,  13,  15,  29,  31,  34,  42,  44,  45,  47,
THE FACILITY LOCATED AT:  20 CAN COVER THE FOLLOWING  DEMANDS:
 10,  20,  21,  25,  41,  49,  51,
THE FACILITY LOCATED AT:  38 CAN COVER THE FOLLOWING  DEMANDS:
 16,  27,  38,  43,  54,  55,
THE FACILITY LOCATED AT:  17 CAN COVER THE FOLLOWING  DEMANDS:
 12,  17,  19,  22,  23,  28,  29,  30,  33,
DEMAND POINT       CAN BE COVERED BY FACILITIES AT:
        1          2,
        2          2,
        3          2,
        4          2,
        5          2,
        6          2,
        7          2,
        8          2,
        9          2,
       10         20,
       11          2,
       12         17,
       13          2,
       14         NO CURRENT FACILITY LOCATION
       15          2,
       16         38,
       17         17,
       18         NO CURRENT FACILITY LOCATION
       19         17,
       20         20,
       21         20,
       22         17,
       23         17,
       24         NO CURRENT FACILITY LOCATION
       25         20,
       26         NO CURRENT FACILITY LOCATION
       27         38,
       28         17,
       29          2,  17,
       30         17,
       31          2,
       32         NO CURRENT FACILITY LOCATION
```

FIGURE 30

(continued, page 24)

```
33        17,
34         2,
35       NO CURRENT FACILITY LOCATION
36       NO CURRENT FACILITY LOCATION
37       NO CURRENT FACILITY LOCATION
38        38,
39       NO CURRENT FACILITY LOCATION
40       NO CURRENT FACILITY LOCATION
41        20,
42         2,
43        38,
44         2,
45         2,
46       NO CURRENT FACILITY LOCATION
47         2,
48       NO CURRENT FACILITY LOCATION
49        20,
50       NO CURRENT FACILITY LOCATION
51        20,
52       NO CURRENT FACILITY LOCATION
53       NO CURRENT FACILITY LOCATION
54        38,
55        38,

SUBSTITUTION  ALGORITHM USED

NODE     36 REPLACES FACILITY LOCATION     48
THIS IS NOW FACILITY NUMBER      3

FACILITIES ARE LOCATED AT     2,   20,   36,   17,
-----------------------------------------------------------------------------------------
POPULATION SERVED      40.00      PERCENT OF TOTAL POPULATION SERVED   72.73
-----------------------------------------------------------------------------------------
THE FACILITY LOCATED AT:   2 CAN COVER THE FOLLOWING  DEMANDS:
  1,   2,   3,   4,   5,   6,   7,   8,   9,  11,  13,  15,  29,  31,  34,  42,  44,  45,  47,
THE FACILITY LOCATED AT:  20 CAN COVER THE FOLLOWING  DEMANDS:
 10,  20,  21,  25,  41,  49,  51,
THE FACILITY LOCATED AT:  36 CAN COVER THE FOLLOWING  DEMANDS:
 15,  18,  24,  25,  26,  35,  36,  48,
THE FACILITY LOCATED AT:  17 CAN COVER THE FOLLOWING  DEMANDS:
 12,  17,  19,  22,  23,  28,  29,  30,  33,

DEMAND POINT       CAN BE COVERED BY FACILITIES AT:
       1            2,
       2            2,
       3            2,
       4            2,
       5            2,
```

FIGURE 30

(continued, page 25)

```
 6        2,
 7        2,
 8        2,
 9        2,
10       20,
11        2,
12       17,
13        2,
14       NO CURRENT FACILITY LOCATION
15        2,  36,
16       NO CURRENT FACILITY LOCATION
17       17,
18       36,
19       17,
20       20,
21       20,
22       17,
23       17,
24       36,
25       20,  36,
26       36,
27       NO CURRENT FACILITY LOCATION
28       17,
29        2,  17,
30       17,
31        2,
32       NO CURRENT FACILITY LOCATION
33       17,
34        2,
35       36,
36       36,
37       NO CURRENT FACILITY LOCATION
38       NO CURRENT FACILITY LOCATION
39       NO CURRENT FACILITY LOCATION
40       NO CURRENT FACILITY LOCATION
41       20,
42        2,
43       NO CURRENT FACILITY LOCATION
44        2,
45        2,
46       NO CURRENT FACILITY LOCATION
47        2,
48       36,
49       20,
50       NO CURRENT FACILITY LOCATION
51       20,
52       NO CURRENT FACILITY LOCATION
53       NO CURRENT FACILITY LOCATION
54       NO CURRENT FACILITY LOCATION
55       NO CURRENT FACILITY LOCATION
```

FIGURE 30

(continued, page 26)

```
   ITERATION NUMBER,    5
 GAS PLANAR EXAMPLE THREE

   NUMBER OF FACILITIES   5
   SERVICE DISTANCE =    10.000

   NEW FACILITY LOCATION NUMBER    38

   FACILITIES ARE LOCATED AT     2,   20,   36,   17,   38,
   ---------------------------------------------------------------------------
   POPULATION SERVED      46.00          PERCENT OF TOTAL POPULATION SERVED   83.94
   ---------------------------------------------------------------------------
THE FACILITY LOCATED AT:   2 CAN COVER THE FOLLOWING  DEMANDS:
  1,   2,   3,   4,   5,   6,   7,   8,   9,  11,  13,  15,  29,  31,  34,  42,  44,  45,  47,
THE FACILITY LOCATED AT:  20 CAN COVER THE FOLLOWING  DEMANDS:
 10,  20,  21,  24,  41,  49,  51,
THE FACILITY LOCATED AT:  36 CAN COVER THE FOLLOWING  DEMANDS:
 15,  18,  24,  25,  26,  35,  36,  48,
THE FACILITY LOCATED AT:  17 CAN COVER THE FOLLOWING  DEMANDS:
 12,  17,  19,  22,  23,  28,  29,  30,  33,
THE FACILITY LOCATED AT:  38 CAN COVER THE FOLLOWING  DEMANDS:
 16,  27,  38,  43,  54,  55,
DEMAND POINT      CAN BE COVERED BY FACILITIES AT:
        1          2,
        2          2,
        3          2,
        4          2,
        5          2,
        6          2,
        7          2,
        8          2,
        9          2,
       10         20,
       11          2,
       12         17,
       13          2,
       14        NO CURRENT FACILITY LOCATION
       15          2,  36,
       16         38,
       17         17,
       18         36,
       19         17,
       20         20,
       21         20,
       22         17,
       23         17,
       24         36,
       25         20,  36,
       26         36,
```

FIGURE 30

(continued, page 27)

```
27        38,
28        17,
29         2,  17,
30        17,
31         2,
32       NO CURRENT FACILITY LOCATION
33        17,
34         2,
35        36,
36        36,
37       NO CURRENT FACILITY LOCATION
38        38,
39       NO CURRENT FACILITY LOCATION
40       NO CURRENT FACILITY LOCATION
41        20,
42         2,
43        38,
44         2,
45         2,
46       NO CURRENT FACILITY LOCATION
47         2,
48        36,
49        20,
50       NO CURRENT FACILITY LOCATION
51        20,
52       NO CURRENT FACILITY LOCATION
53       NO CURRENT FACILITY LOCATION
54        38,
55        38,
```

FIGURE 30

(continued, page 28)

```
   ITERATION NUMBER,    6
 GAS PLANAR EXAMPLE THREE

   NUMBER OF FACILITIES   6
   SERVICE DISTANCE =    10.000

   NEW FACILITY LOCATION NUMBER    50

   FACILITIES ARE LOCATED AT     2,   20,   36,   17,   38,   50,
   ---------------------------------------------------------------------------
   POPULATION SERVED      49.00          PERCENT OF TOTAL POPULATION SERVED   89.09
   ---------------------------------------------------------------------------
THE FACILITY LOCATED AT:   2 CAN COVER THE FOLLOWING  DEMANDS:
  1,   2,   3,   4,   5,   6,   7,   8,   9,  11,  13,  15,  29,  31,  34,  42,  43,  45,  47,
THE FACILITY LOCATED AT:  20 CAN COVER THE FOLLOWING  DEMANDS:
 10,  20,  21,  25,  41,  49,  51,
THE FACILITY LOCATED AT:  36 CAN COVER THE FOLLOWING  DEMANDS:
 15,  18,  24,  25,  26,  35,  36,  48,
THE FACILITY LOCATED AT:  17 CAN COVER THE FOLLOWING  DEMANDS:
 12,  17,  19,  22,  23,  28,  29,  30,  33,
THE FACILITY LOCATED AT:  38 CAN COVER THE FOLLOWING  DEMANDS:
 16,  27,  38,  43,  54,  55,
THE FACILITY LOCATED AT:  50 CAN COVER THE FOLLOWING  DEMANDS:
 50,  52,  53,
DEMAND POINT       CAN BE COVERED BY FACILITIES AT:
        1           2,
        2           2,
        3           2,
        4           2,
        5           2,
        6           2,
        7           2,
        8           2,
        9           2,
       10          20,
       11           2,
       12          17,
       13           2,
       14         NO CURRENT FACILITY LOCATION
       15           2,  36,
       16          38,
       17          17,
       18          36,
       19          17,
       20          20,
       21          20,
       22          17,
       23          17,
       24          36,
       25          20,  36,
```

FIGURE 30

(continued, page 29)

```
26        36,
27        38,
28        17,
29         2,  17,
30        17,
31         2,
32        NO CURRENT FACILITY LOCATION
33        17,
34         2,
35        36,
36        36,
37        NO CURRENT FACILITY LOCATION
38        38,
39        NO CURRENT FACILITY LOCATION
40        NO CURRENT FACILITY LOCATION
41        20,
42         2,
43        38,
44         2,
45         2,
46        NO CURRENT FACILITY LOCATION
47         2,
48        36,
49        20,
50        50,
51        20,
52        50,
53        50,
54        38,
55        38,
```

FIGURE 30

(continued, page 30)

```
   ITERATION NUMBER.    7
 GAS PLANAR EXAMPLE THREE

   NUMBER OF FACILITIES   7
   SERVICE DISTANCE =    10.000

   NEW FACILITY LOCATION NUMBER    55

   FACILITIES ARE LOCATED AT     2.   20.   36.   17.   38.   50.   55.
   ---------------------------------------------------------------------------
   POPULATION SERVED      52.00          PERCENT OF TOTAL POPULATION SERVED   94.65
   ---------------------------------------------------------------------------
THE FACILITY LOCATED AT:   2 CAN COVER THE FOLLOWING  DEMANDS:
  1.   2.   3.   4.   5.   6.   7.   8.   9.  11.  13.  15.  29.  31.  34.  42.  44.  45.  47.
THE FACILITY LOCATED AT:  20 CAN COVER THE FOLLOWING  DEMANDS:
 10.  20.  21.  25.  41.  49.  51.
THE FACILITY LOCATED AT:  36 CAN COVER THE FOLLOWING  DEMANDS:
 15.  18.  24.  25.  26.  35.  36.  48.
THE FACILITY LOCATED AT:  17 CAN COVER THE FOLLOWING  DEMANDS:
 12.  17.  19.  22.  23.  28.  29.  30.  33.
THE FACILITY LOCATED AT:  38 CAN COVER THE FOLLOWING  DEMANDS:
 16.  27.  39.  43.  54.  55.
THE FACILITY LOCATED AT:  50 CAN COVER THE FOLLOWING  DEMANDS:
 50.  52.  53.
THE FACILITY LOCATED AT:  55 CAN COVER THE FOLLOWING  DEMANDS:
 38.  39.  40.  43.  46.  55.
DEMAND POINT      CAN BE COVERED BY FACILITIES AT:
         1         2.
         2         2.
         3         2.
         4         2.
         5         2.
         6         2.
         7         2.
         8         2.
         9         2.
        10        20.
        11         2.
        12        17.
        13         2.
        14       NO CURRENT FACILITY LOCATION
        15         2.  36.
        16        38.
        17        17.
        18        36.
        19        17.
        20        20.
        21        20.
        22        17.
        23        17.
        24        36.
        25        20.  36.
```

FIGURE 30

(continued, page 31)

```
26        36,
27        38,
28        17,
29         2,  17,
30        17,
31         2,
32        NO CURRENT FACILITY LOCATION
33        17,
34         2,
35        36,
36        36,
37        NO CURRENT FACILITY LOCATION
38        38,  55,
39        55,
40        55,
41        20,
42         2,
43        38,  55,
44         2,
45         2,
46        55,
47         2,
48        36,
49        20,
50        50,
51        20,
52        50,
53        50,
54        38,
55        38,  55,

SUBSTITUTION  ALGORITHM USED

NODE     27 REPLACES FACILITY LOCATION
THIS IS NOW FACILITY NUMBER      5

FACILITIES ARE LOCATED AT     2,   20,   36,   17,   27,   50,   55,
-----------------------------------------------------------------------
POPULATION SERVED      53.00          PERCENT OF TOTAL POPULATION SERVED  96.36
-----------------------------------------------------------------------
THE FACILITY LOCATED AT:   2 CAN COVER THE FOLLOWING  DEMANDS:
  1,   2,   3,   4,   5,   6,   7,   8,   9,  11,  13,  15,  29,  31,  34,  42,  44,  45,  47,
THE FACILITY LOCATED AT:  20 CAN COVER THE FOLLOWING  DEMANDS:
 10,  20,  21,  25,  41,  49,  51,
THE FACILITY LOCATED AT:  36 CAN COVER THE FOLLOWING  DEMANDS:
 15,  18,  24,  25,  26,  35,  36,  48,
THE FACILITY LOCATED AT:  17 CAN COVER THE FOLLOWING  DEMANDS:
 12,  17,  19,  22,  23,  28,  29,  30,  33,
THE FACILITY LOCATED AT:  27 CAN COVER THE FOLLOWING  DEMANDS:
 14,  16,  27,  38,  54,
```

FIGURE 30

(continued, page 32)

```
THE FACILITY LOCATED AT:  50 CAN COVER THE FOLLOWING  DEMANDS:
 50,  52,  53,
THE FACILITY LOCATED AT:  55 CAN COVER THE FOLLOWING  DEMANDS:
 38,  39,  40,  43,  46,  55,
DEMAND POINT      CAN BE COVERED BY FACILITIES AT:
         1         2,
         2         2,
         3         2,
         4         2,
         5         2,
         6         2,
         7         2,
         8         2,
         9         2,
        10        20,
        11         2,
        12        17,
        13         2,
        14        27,
        15         2,  36,
        16        27,
        17        17,
        18        36,
        19        17,
        20        20,
        21        20,
        22        17,
        23        17,
        24        36,
        25        20,  36,
        26        36,
        27        27,
        28        17,
        29         2,  17,
        30        17,
        31         2,
        32       NO CURRENT FACILITY LOCATION
        33        17,
        34         2,
        35        36,
        36        36,
        37       NO CURRENT FACILITY LOCATION
        38        27,  55,
        39        55,
        40        55,
        41        20,
        42         2,
        43        55,
        44         2,
        45         2,
        46        55,
        47         2,
        48        36,
        49        20,
        50        50,
        51        20,
        52        50,
        53        50,
        54        27,
        55        55,
```

FIGURE 30

(continued, page 33)

```
   ITERATION NUMBER,    8
 GAS PLANAR EXAMPLE THREE

   NUMBER OF FACILITIES   8
   SERVICE DISTANCE =    10.000

   NEW FACILITY LOCATION NUMBER   157

   FACILITIES ARE LOCATED AT     2,   20,   36,   17,   27,   50,   55,  157,
   ---------------------------------------------------------------------------
   POPULATION SERVED      54.00          PERCENT OF TOTAL POPULATION SERVED   98.18
   ---------------------------------------------------------------------------
THE FACILITY LOCATED AT:   2 CAN COVER THE FOLLOWING  DEMANDS:
  1,   2,   3,   4,   5,   6,   7,   8,   9,  11,  13,  15,  29,  31,  34,  42,  44,  45,  47,
THE FACILITY LOCATED AT:  20 CAN COVER THE FOLLOWING  DEMANDS:
 10,  20,  21,  25,  41,  49,  51,
THE FACILITY LOCATED AT:  36 CAN COVER THE FOLLOWING  DEMANDS:
 15,  18,  24,  25,  26,  35,  36,  48,
THE FACILITY LOCATED AT:  17 CAN COVER THE FOLLOWING  DEMANDS:
 12,  17,  19,  22,  23,  28,  29,  30,  33,
THE FACILITY LOCATED AT:  27 CAN COVER THE FOLLOWING  DEMANDS:
 14,  16,  27,  38,  54,
THE FACILITY LOCATED AT:  50 CAN COVER THE FOLLOWING  DEMANDS:
 50,  52,  53,
THE FACILITY LOCATED AT:  55 CAN COVER THE FOLLOWING  DEMANDS:
 38,  39,  40,  43,  46,  55,
THE FACILITY LOCATED AT: 157 CAN COVER THE FOLLOWING  DEMANDS:
 13,  32,  34,  44,  45,
DEMAND POINT      CAN BE COVERED BY FACILITIES AT:
        1          2,
        2          2,
        3          2,
        4          2,
        5          2,
        6          2,
        7          2,
        8          2,
        9          2,
       10         20,
       11          2,
       12         17,
       13          2, 157,
       14         27,
       15          2,  36,
       16         27,
       17         17,
       18         36,
       19         17,
       20         20,
```

FIGURE 30

(continued, page 34)

21	20,	
22	17,	
23	17,	
24	36,	
25	20,	36,
26	36,	
27	27,	
28	17,	
29	2,	17,
30	17,	
31	2,	
32	157,	
33	17,	
34	2,	157,
35	36,	
36	36,	
37	NO CURRENT FACILITY LOCATION	
38	27,	55,
39	55,	
40	55,	
41	20,	
42	2,	
43	55,	
44	2,	157,
45	2,	157,
46	55,	
47	2,	
48	36,	
49	20,	
50	50,	
51	20,	
52	50,	
53	50,	
54	27,	
55	55,	

FIGURE 30

(continued, page 35)

```
   ITERATION NUMBER,    9
 GAS PLANAR EXAMPLE THREE

   NUMBER OF FACILITIES   9
   SERVICE DISTANCE =    10.000

   NEW FACILITY LOCATION NUMBER    37

   FACILITIES ARE LOCATED AT     2,   20,   36,   17,   27,   50,   55,  157,   37,
   ---------------------------------------------------------------------------------
   POPULATION SERVED      55.00          PERCENT OF TOTAL POPULATION SERVED  100.00
   ---------------------------------------------------------------------------------
THE FACILITY LOCATED AT:   2 CAN COVER THE FOLLOWING  DEMANDS:
  1,   2,   3,   4,   5,   6,   7,   8,   9,  11,  13,  15,  29,  31,  34,  42,  44,  45,  47,
THE FACILITY LOCATED AT:  20 CAN COVER THE FOLLOWING  DEMANDS:
 10,  20,  21,  25,  41,  49,  51,
THE FACILITY LOCATED AT:  36 CAN COVER THE FOLLOWING  DEMANDS:
 15,  18,  24,  25,  26,  35,  36,  48,
THE FACILITY LOCATED AT:  17 CAN COVER THE FOLLOWING  DEMANDS:
 12,  17,  19,  22,  23,  28,  29,  30,  33,
THE FACILITY LOCATED AT:  27 CAN COVER THE FOLLOWING  DEMANDS:
 14,  16,  27,  38,  54,
THE FACILITY LOCATED AT:  50 CAN COVER THE FOLLOWING  DEMANDS:
 50,  52,  53,
THE FACILITY LOCATED AT:  55 CAN COVER THE FOLLOWING  DEMANDS:
 38,  39,  40,  43,  46,  55,
THE FACILITY LOCATED AT: 157 CAN COVER THE FOLLOWING  DEMANDS:
 13,  32,  34,  44,  45,
THE FACILITY LOCATED AT:  37 CAN COVER THE FOLLOWING  DEMANDS:
 10,  21,  27,  53,
DEMAND POINT      CAN BE COVERED BY FACILITIES AT:
        1          2,
        2          2,
        3          2,
        4          2,
        5          2,
        6          2,
        7          2,
        8          2,
        9          2,
       10         20,  37,
       11          2,
       12         17,
       13          2, 157,
       14         27,
       15          2,  36,
       16         27,
       17         17,
       18         36,
       19         17,
       20         20,
```

FIGURE 30

(continued, page 36)

21	20,	37,
22	17,	
23	17,	
24	36,	
25	20,	36,
26	36,	
27	27,	
28	17,	
29	2,	17,
30	17,	
31	2,	
32	157,	
33	17,	
34	2,	157,
35	36,	
36	36,	
37	37,	
38	27,	55,
39	55,	
40	55,	
41	20,	
42	2,	
43	55,	
44	2,	157,
45	2,	157,
46	55,	
47	2,	
48	36,	
49	20,	
50	50,	
51	20,	
52	50,	
53	50,	37,
54	27,	
55	55,	

COVERRAGE CANNOT BE CHANGED BY ADDITIONAL FACILITIES
THIS SOLUTION WAS GENERATED BY THE GAS ALGORITHM

FIGURE 30

(continued, page 37)

FIGURE 31

CONCEPTUAL FORM OF THE DATA DECK FOR

PLANAR PROBLEM THREE

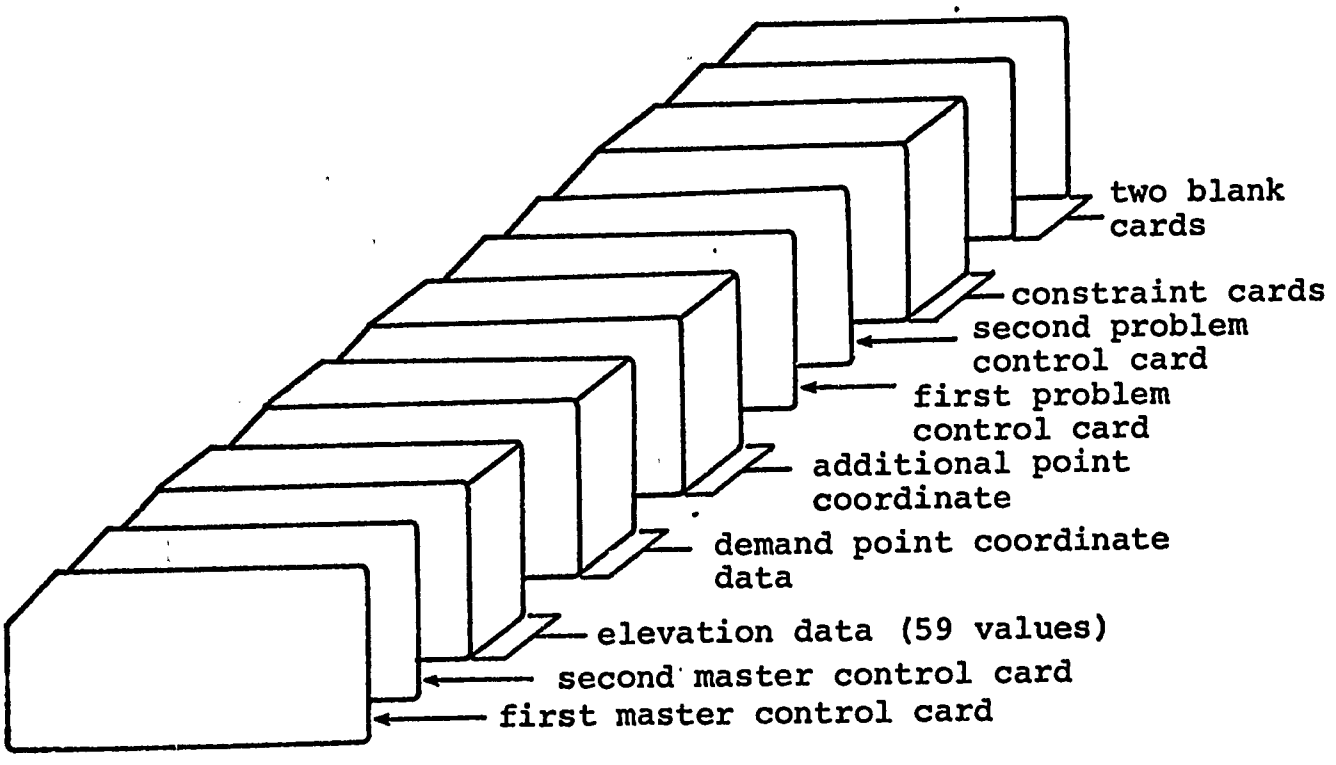

TABLE 35

RESTRICTIONS FOR PLANAR PROBLEM FOUR

1) There are four demand areas not eligible for facility placement. They are:

Area	Reason
8	NA (Not Acceptable)
25	NA
36	NA
50	NA

2) There are three demand areas that are to be automatically allocated a facility. They are 1, 10, and 12.

3) There are three demand areas that are to be eliminated from the master problem. They are 55, 54, and 52.

FIGURE 32

LISTING OF PLANAR PROBLEM FOUR DATA DECK

```
 59   55    1          1
       1    1                    1    1
  1     80.
  2     80.
  3     90.
  4     80.
  5     80.
  6     65.
  7     75.
  8     90.
  9     70.
 10     50.
 11     75.
 12     100.
 13     80.
 14     155.
 15     80.
 16     150.
 17     75.
 18     110.
 19     90.
 20     60.
 21     50.
 22     100.
 23     70.
 24     110.
 25     80.
 26     100.
 27     150.
 28     70.
 29     70.
 30     90.
 31     80.
 32     100.
 33     90.
 34     100.
 35     110.
 36     100.
 37     50.
 38     140.
 39     150.
 40     130.
 41     60.
 42     80.
 43     120.
 44     90.
 45     100.
 46     120.
 47     80.
 48     80.
 49     55.
 50     50.
 51     50.
 52     50.
 53     40.
 54     150.
 55     120.
156     90.
157     80.
158     70.
159     90.
  1     32.        31¢
  2     29.        32¢
  3     27.        36¢
  4     29.        29¢
  5     32.        29¢
```

FIGURE 32

(continued, page 2)

6	26.	25.
7	24.	33.
8	30.	35.
9	29.	27.
10	29.	21.
11	33.	28.
12	17.	53.
13	34.	40.
14	25.	60.
15	21.	28.
16	30.	51.
17	19.	47.
18	17.	33.
19	22.	40.
20	25.	14.
21	29.	12.
22	24.	48.
23	17.	42.
24	6.	26.
25	19.	21.
26	10.	32.
27	34.	56.
28	12.	47.
29	19.	38.
30	27.	41.
31	21.	35.
32	32.	45.
33	27.	45.
34	32.	38.
35	8.	22.
36	15.	25.
37	35.	16.
38	36.	47.
39	46.	51.
40	50.	40.
41	23.	22.
42	27.	30.
43	38.	39.
44	36.	32.
45	32.	41.
46	42.	36.
47	36.	26.
48	15.	19.
49	19.	14.
50	45.	19.
51	27.	5.
52	52.	24.
53	40.	22.
54	40.	52.
55	42.	42.
1	710.	
2	620.	
3	560.	
4	390.	
5	350.	
6	210.	
7	200.	
8	190.	
9	170.	
10	170.	
11	160.	
12	150.	
13	140.	
14	120.	
15	120.	

FIGURE 32

(continued, page 3)

```
16        110.
17        100.
18        100.
19        90.
20        90.
21        90.
22        80.
23        80.
24        80.
25        80.
26        70.
27        60.
28        60.
29        60.
30        60.
31        60.
32        50.
33        50.
34        50.
35        50.
36        50.
37        50.
38        40.
39        40.
40        40.
41        40.
42        40.
43        40.
44        40.
45        30.
46        30.
47        30.
48        30.
49        30.
50        30.
51        30.
52        20.
53        20.
54        20.
55        20.
156       10.        38.
157       40.        40.
158       23.        28.
159       23.        39.
 GAS PLANAR EXAMPLE FOUR
  15        10.                    25.       -15.        1         1
  4     3     3
  8 NA
 25 NA
 36 NA
 50 NA
  1
 10
 12
 55
 54
 52
```

POPULATION DATA

1	710.00*	7	200.00*	13	140.00*	19	90.00*	25	80.00*	31	60.00*	37	50.00*	43	40.00*	49	30.00*	55	20.00*		
2	620.00*	8	190.00*	14	120.00*	20	90.00*	26	70.00*	32	50.00*	38	40.00*	44	40.00*	50	30.00*				
3	560.00*	9	170.00*	15	120.00*	21	90.00*	27	60.00*	33	50.00*	39	40.00*	45	30.00*	51	30.00*				
4	390.00*	10	170.00*	16	110.00*	22	80.00*	28	60.00*	34	50.00*	40	40.00*	46	30.00*	52	20.00*				
5	350.00*	11	160.00*	17	100.00*	23	80.00*	29	60.00*	35	50.00*	41	40.00*	47	30.00*	53	20.00*				
6	210.00*	12	150.00*	18	100.00*	24	80.00*	30	60.00*	36	50.00*	42	40.00*	48	30.00*	54	20.00*				

THE FOLLOWING OPTIONS ARE DESIGNATED:
DEMAND POINTS ARE ALSO POTENTIAL FACILITY SITES
DISTANCES ARE MEASURED AS RECTILINEAR
DEMAND POINTS ARE ALSO POTENTIAL FACILITY SITES
COORDINATE POINT DATA IS AS FOLLOWS:

1	32.00000	31.00000	1**	2	29.00000	32.00000	2**	3	27.00000	36.00000	3**
4	29.00000	29.00000	4**	5	32.00000	29.00000	5**	6	26.00000	25.00000	6**
7	24.00000	33.00000	7**	8	30.00000	35.00000	8**	9	29.00000	27.00000	9**
10	29.00000	21.00000	10**	11	33.00000	28.00000	11**	12	17.00000	53.00000	12**
13	34.00000	40.00000	13**	14	25.00000	60.00000	14**	15	21.00000	28.00000	15**
16	30.00000	51.00000	16**	17	19.00000	47.00000	17**	18	17.00000	33.00000	18**
19	22.00000	40.00000	19**	20	25.00000	14.00000	20**	21	29.00000	12.00000	21**
22	24.00000	48.00000	22**	23	17.00000	42.00000	23**	24	6.00000	26.00000	24**
25	19.00000	21.00000	25**	26	10.00000	32.00000	26**	27	34.00000	56.00000	27**
28	12.00000	47.00000	28**	29	19.00000	38.00000	29**	30	27.00000	41.00000	30**
31	21.00000	35.00000	31**	32	32.00000	45.00000	32**	33	27.00000	45.00000	33**
34	32.00000	38.00000	34**	35	8.00000	22.00000	35**	36	15.00000	25.00000	36**
37	35.00000	16.00000	37**	38	36.00000	47.00000	38**	39	46.00000	51.00000	39**
40	50.00000	40.00000	40**	41	23.00000	22.00000	41**	42	27.00000	30.00000	42**
43	38.00000	39.00000	43**	44	36.00000	32.00000	44**	45	32.00000	41.00000	45**
46	42.00000	36.00000	46**	47	36.00000	26.00000	47**	48	15.00000	19.00000	48**
49	19.00000	14.00000	49**	50	45.00000	19.00000	50**	51	27.00000	5.00000	51**

FIGURE 33

PLANAR PROBLEM FOUR OUTPUT

52	52.00000	24.00000	52**	53	40.00000	22.00000	53**	54	40.00000	52.00000	54**
55	42.00000	42.00000	55**	56	10.00000	38.00000	156**	57	40.00000	40.00000	157**
58	23.00000	28.00000	158**	59	23.00000	39.00000	159**	60	32.00000	31.00000	1**
61	29.00000	32.00000	2**	62	27.00000	36.00000	3**	63	29.00000	29.00000	4**
64	32.00000	29.00000	5**	65	26.00000	25.00000	6**	66	24.00000	33.00000	7**
67	30.00000	35.00000	8**	68	29.00000	27.00000	9**	69	29.00000	21.00000	10**
70	33.00000	28.00000	11**	71	17.00000	53.00000	12**	72	34.00000	40.00000	13**
73	25.00000	40.00000	14**	74	21.00000	28.00000	15**	75	30.00000	51.00000	16**
76	19.00000	47.00000	17**	77	17.00000	33.00000	18**	78	22.00000	40.00000	19**
79	25.00000	14.00000	20**	80	29.00000	12.00000	21**	81	24.00000	48.00000	22**
82	17.00000	42.00000	23**	83	6.00000	26.00000	24**	84	19.00000	21.00000	25**
85	10.00000	32.00000	26**	86	34.00000	56.00000	27**	87	12.00000	47.00000	28**
88	19.00000	38.00000	29**	89	27.00000	41.00000	30**	90	21.00000	35.00000	31**
91	32.00000	45.00000	32**	92	27.00000	45.00000	33**	93	32.00000	38.00000	34**
94	8.00000	22.00000	35**	95	15.00000	25.00000	36**	96	35.00000	16.00000	37**
97	36.00000	47.00000	38**	98	46.00000	51.00000	39**	99	50.00000	40.00000	40**
100	23.00000	22.00000	41**	101	27.00000	30.00000	42**	102	38.00000	39.00000	43**
103	36.00000	32.00000	44**	104	32.00000	41.00000	45**	105	42.00000	36.00000	46**
106	36.00000	26.00000	47**	107	15.00000	19.00000	48**	108	19.00000	14.00000	49**
109	45.00000	19.00000	50**	110	27.00000	5.00000	51**	111	52.00000	24.00000	52**
112	40.00000	22.00000	53**	113	40.00000	52.00000	54**	114	42.00000	42.00000	55**

FIGURE 33

(continued, page 2)

FIGURE 33

(continued, page 3)

```
SUBPROGRAM MATBLD HAS BEEN CALLED TO GENERATE A COVER MATRIX
   THE MAXIMUM DISTANCE/TIME OF  10.00 HAS BEEN UTILIZED
   ELEVATIONS ARE ALSO UTILIZED IN  DEVELOPING THE COVER MATRIX
   THE LARGEST ELEVATION DIFFERENCE DOWN TO A FACILITY IS   25.0
   THE LARGEST ELEVATION DIFFERENCE UP TO A FACILITY IS   15.0
```

```
********   ************************************************   ************************************
INITIAL STARTING INFORMATION
NODES WHICH ARE AUTOMATICALLY ALLOCATED AN UNCHANGEABLE FACILITY ARE:
  5  14  16
THIS SET OF FACILITIES SERVES     4200.00  OUT OF A TOTAL POPULATION OF     6340.00  PERCENTAGE =       66.25
*****************************************************************************************************
THIS DOES NOT INCLUDE THE POPULATION AT THE FOLLOWING NODES:
 55,  54,  52,
THIS ELIMINATED POPULATION AMOUNTS TO:       50.00
*****************************************************************************************************
THE FOLLOWING NODES WILL NOT BE CONSIDERED AS POTENTIAL FACILITY SITES:
  8-NA,  25-NA,  36-NA,  50-NA,
*****************************************************************************************************
THE FACILITY LOCATED AT:   1 CAN COVER THE FOLLOWING  DEMANDS:
  1,   2,   3,   4,   5,   7,   8,   9,  11,  34,  42,  44,  45,  47,
THE FACILITY LOCATED AT:  10 CAN COVER THE FOLLOWING  DEMANDS:
  6,   9,  10,  21,  41,
THE FACILITY LOCATED AT:  12 CAN COVER THE FOLLOWING  DEMANDS:
 12,
DEMAND POINT      CAN BE COVERED BY FACILITIES AT:
         1         1,
         2         1,
         3         1,
         4         1,
         5         1,
         6        10,
         7         1,
         8         1,
         9         1,  10,
        10        10,
        11         1,
        12        12,
        13       NO CURRENT FACILITY LOCATION
        14       NO CURRENT FACILITY LOCATION
        15       NO CURRENT FACILITY LOCATION
        16       NO CURRENT FACILITY LOCATION
        17       NO CURRENT FACILITY LOCATION
        18       NO CURRENT FACILITY LOCATION
        19       NO CURRENT FACILITY LOCATION
        20       NO CURRENT FACILITY LOCATION
        21        10,
        22       NO CURRENT FACILITY LOCATION
        23       NO CURRENT FACILITY LOCATION
        24       NO CURRENT FACILITY LOCATION
        25       NO CURRENT FACILITY LOCATION
        26       NO CURRENT FACILITY LOCATION
        27       NO CURRENT FACILITY LOCATION
```

FIGURE 33

(continued, page 4)

```
28        NO CURRENT FACILITY LOCATION
29        NO CURRENT FACILITY LOCATION
30        NO CURRENT FACILITY LOCATION
31        NO CURRENT FACILITY LOCATION
32        NO CURRENT FACILITY LOCATION
33        NO CURRENT FACILITY LOCATION
34          1,
35        NO CURRENT FACILITY LOCATION
36        NO CURRENT FACILITY LOCATION
37        NO CURRENT FACILITY LOCATION
38        NO CURRENT FACILITY LOCATION
39        NO CURRENT FACILITY LOCATION
40        NO CURRENT FACILITY LOCATION
41         10,
42          1,
43        NO CURRENT FACILITY LOCATION
44          1,
45          1,
46        NO CURRENT FACILITY LOCATION
47          1,
48        NO CURRENT FACILITY LOCATION
49        NO CURRENT FACILITY LOCATION
50        NO CURRENT FACILITY LOCATION
51        NO CURRENT FACILITY LOCATION
52        NO CURRENT FACILITY LOCATION
53        NO CURRENT FACILITY LOCATION
54        NO CURRENT FACILITY LOCATION
55        NO CURRENT FACILITY LOCATION
```

FIGURE 33

(continued, page 5)

```
   ITERATION NUMBER,    1
 GAS PLANAR EXAMPLE FOUR

   NUMBER OF FACILITIES   4
   SERVICE DISTANCE =    10.000

   NEW FACILITY LOCATION NUMBER    17

   FACILITIES ARE LOCATED AT     1,   10,   12,   17,
   ---------------------------------------------------------------------------
   POPULATION SERVED    4720.00          PERCENT OF TOTAL POPULATION SERVED   74.45
   ---------------------------------------------------------------------------
THE FACILITY LOCATED AT:   1 CAN COVER THE FOLLOWING  DEMANDS:
  1,   2,   3,   4,   5,   7,   8,   9,  11,  35,  42,  44,  45,  47,
THE FACILITY LOCATED AT:  10 CAN COVER THE FOLLOWING  DEMANDS:
  6,   9,  10,  21,  41,
THE FACILITY LOCATED AT:  12 CAN COVER THE FOLLOWING  DEMANDS:
 12,
THE FACILITY LOCATED AT:  17 CAN COVER THE FOLLOWING  DEMANDS:
 12,  17,  19,  22,  23,  28,  29,  33,
DEMAND POINT      CAN BE COVERED BY FACILITIES AT:
         1         1,
         2         1,
         3         1,
         4         1,
         5         1,
         6        10,
         7         1,
         8         1,
         9         1,  10,
        10        10,
        11         1,
        12        12,  17,
        13       NO CURRENT FACILITY LOCATION
        14       NO CURRENT FACILITY LOCATION
        15       NO CURRENT FACILITY LOCATION
        16       NO CURRENT FACILITY LOCATION
        17        17,
        18       NO CURRENT FACILITY LOCATION
        19        17,
        20       NO CURRENT FACILITY LOCATION
        21        10,
        22        17,
        23        17,
        24       NO CURRENT FACILITY LOCATION
        25       NO CURRENT FACILITY LOCATION
        26       NO CURRENT FACILITY LOCATION
        27       NO CURRENT FACILITY LOCATION
```

FIGURE 33

(continued, page 6)

```
28        17,
29        17,
30       NO CURRENT FACILITY LOCATION
31       NO CURRENT FACILITY LOCATION
32       NO CURRENT FACILITY LOCATION
33        17,
34         1,
35       NO CURRENT FACILITY LOCATION
36       NO CURRENT FACILITY LOCATION
37       NO CURRENT FACILITY LOCATION
38       NO CURRENT FACILITY LOCATION
39       NO CURRENT FACILITY LOCATION
40       NO CURRENT FACILITY LOCATION
41        10,
42         1,
43       NO CURRENT FACILITY LOCATION
44         1,
45         1,
46       NO CURRENT FACILITY LOCATION
47         1,
48       NO CURRENT FACILITY LOCATION
49       NO CURRENT FACILITY LOCATION
50       NO CURRENT FACILITY LOCATION
51       NO CURRENT FACILITY LOCATION
52       NO CURRENT FACILITY LOCATION
53       NO CURRENT FACILITY LOCATION
54       NO CURRENT FACILITY LOCATION
55       NO CURRENT FACILITY LOCATION
```

FIGURE 33

(continued, page 7)

```
   ITERATION NUMBER.    2
 GAS PLANAR EXAMPLE FOUR

   NUMBER OF FACILITIES   5
   SERVICE DISTANCE =    10.000

   NEW FACILITY LOCATION NUMBER    15

   FACILITIES ARE LOCATED AT     1.   10.   12.   17.   15.
   ---------------------------------------------------------------------------
   POPULATION SERVED    5030.00          PERCENT OF TOTAL POPULATION SERVED   79.34
   ---------------------------------------------------------------------------
THE FACILITY LOCATED AT:   1 CAN COVER THE FOLLOWING  DEMANDS:
  1.   2.   3.   4.   5.   7.   8.   9.  11.  34.  42.  44.  45.  47.
THE FACILITY LOCATED AT:  10 CAN COVER THE FOLLOWING  DEMANDS:
  6.   9.  10.  21.  41.
THE FACILITY LOCATED AT:  12 CAN COVER THE FOLLOWING  DEMANDS:
 12.
THE FACILITY LOCATED AT:  17 CAN COVER THE FOLLOWING  DEMANDS:
 12.  17.  19.  22.  23.  28.  29.  33.
THE FACILITY LOCATED AT:  15 CAN COVER THE FOLLOWING  DEMANDS:
  4.   6.   7.   9.  15.  25.  31.  36.  42.
DEMAND POINT      CAN BE COVERED BY FACILITIES AT:
         1         1.
         2         1.
         3         1.
         4         1.  15.
         5         1.
         6        10.  15.
         7         1.  15.
         8         1.
         9         1.  10.  15.
        10        10.
        11         1.
        12        12.  17.
        13       NO CURRENT FACILITY LOCATION
        14       NO CURRENT FACILITY LOCATION
        15        15.
        16       NO CURRENT FACILITY LOCATION
        17        17.
        18       NO CURRENT FACILITY LOCATION
        19        17.
        20       NO CURRENT FACILITY LOCATION
        21        10.
        22        17.
        23        17.
        24       NO CURRENT FACILITY LOCATION
        25        15.
        26       NO CURRENT FACILITY LOCATION
        27       NO CURRENT FACILITY LOCATION
```

FIGURE 33

(continued, page 8)

```
28        17,
29        17,
30       NO CURRENT FACILITY LOCATION
31        15,
32       NO CURRENT FACILITY LOCATION
33        17,
34         1,
35       NO CURRENT FACILITY LOCATION
36        15,
37       NO CURRENT FACILITY LOCATION
38       NO CURRENT FACILITY LOCATION
39       NO CURRENT FACILITY LOCATION
40       NO CURRENT FACILITY LOCATION
41        10,
42         1,  15,
43       NO CURRENT FACILITY LOCATION
44         1,
45         1,
46       NO CURRENT FACILITY LOCATION
47         1,
48       NO CURRENT FACILITY LOCATION
49       NO CURRENT FACILITY LOCATION
50       NO CURRENT FACILITY LOCATION
51       NO CURRENT FACILITY LOCATION
52       NO CURRENT FACILITY LOCATION
53       NO CURRENT FACILITY LOCATION
54       NO CURRENT FACILITY LOCATION
55       NO CURRENT FACILITY LOCATION
```

FIGURE 33

(continued, page 9)

```
   ITERATION NUMBER.    3
 GAS PLANAR EXAMPLE FOUR

   NUMBER OF FACILITIES   6
   SERVICE DISTANCE =    10.000

   NEW FACILITY LOCATION NUMBER    13

   FACILITIES ARE LOCATED AT     1,   10,   12,   17,   15,   13,
   ---------------------------------------------------------------------------
   POPULATION SERVED    5280.00          PERCENT OF TOTAL POPULATION SERVED   83.28
   ---------------------------------------------------------------------------
THE FACILITY LOCATED AT:   1 CAN COVER THE FOLLOWING  DEMANDS:
  1,   2,   3,   4,   5,   7,   8,   9,  11,  34,  42,  44,  45,  47,
THE FACILITY LOCATED AT:  10 CAN COVER THE FOLLOWING  DEMANDS:
  6,   9,  10,  21,  41,
THE FACILITY LOCATED AT:  12 CAN COVER THE FOLLOWING  DEMANDS:
 12,
THE FACILITY LOCATED AT:  17 CAN COVER THE FOLLOWING  DEMANDS:
 12,  17,  19,  22,  23,  28,  29,  33,
THE FACILITY LOCATED AT:  15 CAN COVER THE FOLLOWING  DEMANDS:
  4,   6,   7,   9,  15,  25,  31,  36,  42,
THE FACILITY LOCATED AT:  13 CAN COVER THE FOLLOWING  DEMANDS:
  8,  13,  20,  32,  34,  44,  45,
DEMAND POINT      CAN BE COVERED BY FACILITIES AT:
        1          1,
        2          1,
        3          1,
        4          1,  15,
        5          1,
        6         10,  15,
        7          1,  15,
        8          1,  13,
        9          1,  10,  15,
       10         10,
       11          1,
       12         12,  17,
       13         13,
       14        NO CURRENT FACILITY LOCATION
       15         15,
       16        NO CURRENT FACILITY LOCATION
       17         17,
       18        NO CURRENT FACILITY LOCATION
       19         17,
       20        NO CURRENT FACILITY LOCATION
       21         10,
       22         17,
       23         17,
       24        NO CURRENT FACILITY LOCATION
       25         15,
       26        NO CURRENT FACILITY LOCATION
```

FIGURE 33

(continued, page 10)

```
27        NO CURRENT FACILITY LOCATION
28         17,
29         17,
30         13,
31         15,
32         13,
33         17,
34          1,  13,
35        NO CURRENT FACILITY LOCATION
36         15,
37        NO CURRENT FACILITY LOCATION
38        NO CURRENT FACILITY LOCATION
39        NO CURRENT FACILITY LOCATION
40        NO CURRENT FACILITY LOCATION
41         10,
42          1,  15,
43        NO CURRENT FACILITY LOCATION
44          1,  13,
45          1,  13,
46        NO CURRENT FACILITY LOCATION
47          1,
48        NO CURRENT FACILITY LOCATION
49        NO CURRENT FACILITY LOCATION
50        NO CURRENT FACILITY LOCATION
51        NO CURRENT FACILITY LOCATION
52        NO CURRENT FACILITY LOCATION
53        NO CURRENT FACILITY LOCATION
54        NO CURRENT FACILITY LOCATION
55        NO CURRENT FACILITY LOCATION
```

FIGURE 33

(continued, page 11)

```
   ITERATION NUMBER,    4
 GAS PLANAR EXAMPLE FOUR

   NUMBER OF FACILITIES   7
   SERVICE DISTANCE =    10.000

   NEW FACILITY LOCATION NUMBER    26

   FACILITIES ARE LOCATED AT     1,   10,   12,   17,   15,   13,   26,
   ---------------------------------------------------------------------
   POPULATION SERVED    5530.00          PERCENT OF TOTAL POPULATION SERVED   87.82
   ---------------------------------------------------------------------
THE FACILITY LOCATED AT:   1 CAN COVER THE FOLLOWING  DEMANDS:
  1,   2,   3,   4,   5,   7,   8,   9,  11,  34,  42,  44,  45,  47,
THE FACILITY LOCATED AT:  10 CAN COVER THE FOLLOWING  DEMANDS:
  6,   9,  10,  21,  41,
THE FACILITY LOCATED AT:  12 CAN COVER THE FOLLOWING  DEMANDS:
 12,
THE FACILITY LOCATED AT:  17 CAN COVER THE FOLLOWING  DEMANDS:
 12,  17,  19,  22,  23,  28,  29,  33,
THE FACILITY LOCATED AT:  15 CAN COVER THE FOLLOWING  DEMANDS:
  4,   6,   7,   9,  15,  25,  31,  36,  42,
THE FACILITY LOCATED AT:  13 CAN COVER THE FOLLOWING  DEMANDS:
  8,  13,  30,  32,  34,  44,  45,
THE FACILITY LOCATED AT:  26 CAN COVER THE FOLLOWING  DEMANDS:
 18,  24,  26,
DEMAND POINT       CAN BE COVERED BY FACILITIES AT:
        1           1,
        2           1,
        3           1,
        4           1,  15,
        5           1,
        6          10,  15,
        7           1,  15,
        8           1,  13,
        9           1,  10,  15,
       10          10,
       11           1,
       12          12,  17,
       13          13,
       14         NO CURRENT FACILITY LOCATION
       15          15,
       16         NO CURRENT FACILITY LOCATION
       17          17,
       18          26,
       19          17,
       20         NO CURRENT FACILITY LOCATION
       21          10,
       22          17,
       23          17,
       24          26,
       25          15,
       26          26,
```

FIGURE 33

(continued, page 12)

```
27        NO CURRENT FACILITY LOCATION
28         17,
29         17,
30         13,
31         15,
32         13,
33         17,
34           1,  13,
35        NO CURRENT FACILITY LOCATION
36         15,
37        NO CURRENT FACILITY LOCATION
38        NO CURRENT FACILITY LOCATION
39        NO CURRENT FACILITY LOCATION
40        NO CURRENT FACILITY LOCATION
41         10,
42           1,  15,
43        NO CURRENT FACILITY LOCATION
44           1,  13,
45           1,  13,
46        NO CURRENT FACILITY LOCATION
47           1,
48        NO CURRENT FACILITY LOCATION
49        NO CURRENT FACILITY LOCATION
50        NO CURRENT FACILITY LOCATION
51        NO CURRENT FACILITY LOCATION
52        NO CURRENT FACILITY LOCATION
53        NO CURRENT FACILITY LOCATION
54        NO CURRENT FACILITY LOCATION
55        NO CURRENT FACILITY LOCATION
```

FIGURE 33

(continued, page 13)

```
   ITERATION NUMBER,    5
 GAS PLANAR EXAMPLE FOUR

   NUMBER OF FACILITIES   3
   SERVICE DISTANCE =    10.000

   NEW FACILITY LOCATION NUMBER    16

   FACILITIES ARE LOCATED AT     1,   10,   12,   17,   15,   13,   26,   16,
   ---------------------------------------------------------------------------
   POPULATION SERVED    5740.00          PERCENT OF TOTAL POPULATION SERVED   90.64
   ---------------------------------------------------------------------------
THE FACILITY LOCATED AT:   1 CAN COVER THE FOLLOWING  DEMANDS:
  1,   2,   3,   4,   5,   7,   8,   9,  11,  35,  42,  44,  45,  47,
THE FACILITY LOCATED AT:  10 CAN COVER THE FOLLOWING  DEMANDS:
  6,   9,  10,  21,  41,
THE FACILITY LOCATED AT:  12 CAN COVER THE FOLLOWING  DEMANDS:
 12,
THE FACILITY LOCATED AT:  17 CAN COVER THE FOLLOWING  DEMANDS:
 12,  17,  19,  22,  23,  28,  29,  33,
THE FACILITY LOCATED AT:  15 CAN COVER THE FOLLOWING  DEMANDS:
  4,   6,   7,   9,  15,  25,  31,  36,  42,
THE FACILITY LOCATED AT:  13 CAN COVER THE FOLLOWING  DEMANDS:
  8,  13,  30,  32,  34,  44,  45,
THE FACILITY LOCATED AT:  26 CAN COVER THE FOLLOWING  DEMANDS:
 18,  24,  26,
THE FACILITY LOCATED AT:  16 CAN COVER THE FOLLOWING  DEMANDS:
 16,  27,  38,
DEMAND POINT      CAN BE COVERED BY FACILITIES AT:
        1          1,
        2          1,
        3          1,
        4          1,  15,
        5          1,
        6         10,  15,
        7          1,  15,
        8          1,  13,
        9          1,  10,  15,
       10         10,
       11          1,
       12         12,  17,
       13         13,
       14        NO CURRENT FACILITY LOCATION
       15         15,
       16         16,
       17         17,
       18         26,
       19         17,
       20        NO CURRENT FACILITY LOCATION
       21         10,
       22         17,
```

FIGURE 33

(continued, page 14)

```
23        17,
24        20,
25        15,
26        20,
27        16,
28        17,
29        17,
30        13,
31        15,
32        13,
33        17,
34         1,  13,
35       NO CURRENT FACILITY LOCATION
36        15,
37       NO CURRENT FACILITY LOCATION
38        16,
39       NO CURRENT FACILITY LOCATION
40       NO CURRENT FACILITY LOCATION
41        10,
42         1,  15,
43       NO CURRENT FACILITY LOCATION
44         1,  13,
45         1,  13,
46       NO CURRENT FACILITY LOCATION
47         1,
48       NO CURRENT FACILITY LOCATION
49       NO CURRENT FACILITY LOCATION
50       NO CURRENT FACILITY LOCATION
51       NO CURRENT FACILITY LOCATION
52       NO CURRENT FACILITY LOCATION
53       NO CURRENT FACILITY LOCATION
54       NO CURRENT FACILITY LOCATION
55       NO CURRENT FACILITY LOCATION
```

FIGURE 33

(continued, page 15)

```
   ITERATION NUMBER,    6
 GAS PLANAR EXAMPLE FOUR

   NUMBER OF FACILITIES   9
   SERVICE DISTANCE =    10.000

   NEW FACILITY LOCATION NUMBER    49

   FACILITIES ARE LOCATED AT     1,   10,   12,   17,   15,   13,   26,   16,   49,
   ---------------------------------------------------------------------------------
   POPULATION SERVED    5890.00          PERCENT OF TOTAL POPULATION SERVED   92.90
   ---------------------------------------------------------------------------------
THE FACILITY LOCATED AT:   1 CAN COVER THE FOLLOWING  DEMANDS:
  1,   2,   3,   4,   5,   7,   8,   9,  11,  32,  42,  44,  45,  47,
THE FACILITY LOCATED AT:  10 CAN COVER THE FOLLOWING  DEMANDS:
  6,   9,  10,  21,  41,
THE FACILITY LOCATED AT:  12 CAN COVER THE FOLLOWING  DEMANDS:
 12,
THE FACILITY LOCATED AT:  17 CAN COVER THE FOLLOWING  DEMANDS:
 12,  17,  19,  22,  23,  28,  29,  33,
THE FACILITY LOCATED AT:  15 CAN COVER THE FOLLOWING  DEMANDS:
  4,   6,   7,   9,  15,  25,  31,  36,  42,
THE FACILITY LOCATED AT:  13 CAN COVER THE FOLLOWING  DEMANDS:
  8,  13,  30,  32,  34,  44,  45,
THE FACILITY LOCATED AT:  26 CAN COVER THE FOLLOWING  DEMANDS:
 18,  24,  26,
THE FACILITY LOCATED AT:  16 CAN COVER THE FOLLOWING  DEMANDS:
 16,  27,  38,
THE FACILITY LOCATED AT:  49 CAN COVER THE FOLLOWING  DEMANDS:
 20,  25,  48,  49,
DEMAND POINT       CAN BE COVERED BY FACILITIES AT:
          1          1,
          2          1,
          3          1,
          4          1,  15,
          5          1,
          6         10,  15,
          7          1,  15,
          8          1,  13,
          9          1,  10,  15,
         10         10,
         11          1,
         12         12,  17,
         13         13,
         14       NO CURRENT FACILITY LOCATION
         15         15,
         16         16,
         17         17,
```

FIGURE 33

(continued, page 16)

```
18        26,
19        17,
20        49,
21        10,
22        17,
23        17,
24        26,
25        15,  49,
26        26,
27        16,
28        17,
29        17,
30        13,
31        15,
32        13,
33        17,
34         1,  13,
35       NO CURRENT FACILITY LOCATION
36        15,
37       NO CURRENT FACILITY LOCATION
38        16,
39       NO CURRENT FACILITY LOCATION
40       NO CURRENT FACILITY LOCATION
41        10,
42         1,  15,
43       NO CURRENT FACILITY LOCATION
44         1,  13,
45         1,  13,
46       NO CURRENT FACILITY LOCATION
47         1,
48        49,
49        49,
50       NO CURRENT FACILITY LOCATION
51       NO CURRENT FACILITY LOCATION
52       NO CURRENT FACILITY LOCATION
53       NO CURRENT FACILITY LOCATION
54       NO CURRENT FACILITY LOCATION
55       NO CURRENT FACILITY LOCATION
```

FIGURE 33

(continued, page 17)

```
ITERATION NUMBER,
GAS PLANAR EXAMPLE FOUR

NUMBER OF FACILITIES  10
SERVICE DISTANCE =    10.000

NEW FACILITY LOCATION NUMBER    14

FACILITIES ARE LOCATED AT     1,   10,   12,   17,   15,   13,   26,   16,   49,   14,
-----------------------------------------------------------------------------------------
POPULATION SERVED    6010.00          PERCENT OF TOTAL POPULATION SERVED   94.7%
-----------------------------------------------------------------------------------------
THE FACILITY LOCATED AT:   1 CAN COVER THE FOLLOWING  DEMANDS:
  1,   2,   3,   4,   5,   7,   8,   9,  11,  39,  42,  44,  45,  47,
THE FACILITY LOCATED AT:  10 CAN COVER THE FOLLOWING  DEMANDS:
  6,   9,  10,  21,  41,
THE FACILITY LOCATED AT:  12 CAN COVER THE FOLLOWING  DEMANDS:
 12,
THE FACILITY LOCATED AT:  17 CAN COVER THE FOLLOWING  DEMANDS:
 12,  17,  19,  22,  23,  28,  29,  33,
THE FACILITY LOCATED AT:  15 CAN COVER THE FOLLOWING  DEMANDS:
  4,   6,   7,   9,  15,  25,  31,  36,  42,
THE FACILITY LOCATED AT:  13 CAN COVER THE FOLLOWING  DEMANDS:
  8,  13,  30,  32,  34,  44,  45,
THE FACILITY LOCATED AT:  26 CAN COVER THE FOLLOWING  DEMANDS:
 18,  24,  26,
THE FACILITY LOCATED AT:  16 CAN COVER THE FOLLOWING  DEMANDS:
 16,  27,  38,
THE FACILITY LOCATED AT:  49 CAN COVER THE FOLLOWING  DEMANDS:
 20,  25,  48,  49,
THE FACILITY LOCATED AT:  14 CAN COVER THE FOLLOWING  DEMANDS:
 14,
DEMAND POINT      CAN BE COVERED BY FACILITIES AT:
        1          1,
        2          1,
        3          1,
        4          1,  15,
        5          1,
        6         10,  15,
        7          1,  15,
        8          1,  13,
        9          1,  10,  15,
       10         10,
       11          1,
       12         12,  17,
       13         13,
       14         14,
       15         15,
       16         16,
```

FIGURE 33

(continued, page 18)

```
17        17,
18        26,
19        17,
20        49,
21        10,
22        17,
23        17,
24        25,
25        15,  49,
26        26,
27        16,
28        17,
29        17,
30        13,
31        15,
32        13,
33        17,
34         1,  13,
35       NO CURRENT FACILITY LOCATION
36        15,
37       NO CURRENT FACILITY LOCATION
38        16,
39       NO CURRENT FACILITY LOCATION
40       NO CURRENT FACILITY LOCATION
41        10,
42         1,  15,
43       NO CURRENT FACILITY LOCATION
44         1,  13,
45         1,  13,
46       NO CURRENT FACILITY LOCATION
47         1,
48        49,
49        49,
50       NO CURRENT FACILITY LOCATION
51       NO CURRENT FACILITY LOCATION
52       NO CURRENT FACILITY LOCATION
53       NO CURRENT FACILITY LOCATION
54       NO CURRENT FACILITY LOCATION
55       NO CURRENT FACILITY LOCATION
```

FIGURE 33

(continued, page 19)

```
   ITERATION NUMBER.     8
 GAS PLANAR EXAMPLE FOUR

   NUMBER OF FACILITIES  11
   SERVICE DISTANCE =    10.000

   NEW FACILITY LOCATION NUMBER    55

   FACILITIES ARE LOCATED AT     1,   10,   12,   17,   15,   13,   26,   16,   49,   14,   55,
   ---------------------------------------------------------------------------------------------
   POPULATION SERVED    6120.00          PERCENT OF TOTAL POPULATION SERVED   96.83
   ---------------------------------------------------------------------------------------------
THE FACILITY LOCATED AT:   1 CAN COVER THE FOLLOWING  DEMANDS:
  1,   2,   3,   4,   5,   7,   8,   9,  11,  35,  42,  44,  45,  47,
THE FACILITY LOCATED AT:  10 CAN COVER THE FOLLOWING  DEMANDS:
  6,   9,  10,  21,  41,
THE FACILITY LOCATED AT:  12 CAN COVER THE FOLLOWING  DEMANDS:
 12,
THE FACILITY LOCATED AT:  17 CAN COVER THE FOLLOWING  DEMANDS:
 12,  17,  19,  22,  23,  28,  29,  33,
THE FACILITY LOCATED AT:  15 CAN COVER THE FOLLOWING  DEMANDS:
  4,   6,   7,   9,  15,  25,  31,  36,  42,
THE FACILITY LOCATED AT:  13 CAN COVER THE FOLLOWING  DEMANDS:
  8,  13,  30,  32,  34,  44,  45,
THE FACILITY LOCATED AT:  26 CAN COVER THE FOLLOWING  DEMANDS:
 18,  24,  26,
THE FACILITY LOCATED AT:  16 CAN COVER THE FOLLOWING  DEMANDS:
 16,  27,  38,
THE FACILITY LOCATED AT:  49 CAN COVER THE FOLLOWING  DEMANDS:
 20,  25,  48,  49,
THE FACILITY LOCATED AT:  14 CAN COVER THE FOLLOWING  DEMANDS:
 14,
THE FACILITY LOCATED AT:  55 CAN COVER THE FOLLOWING  DEMANDS:
 40,  43,  46,  55,
DEMAND POINT      CAN BE COVERED BY FACILITIES AT:
        1          1,
        2          1,
        3          1,
        4          1,  15,
        5          1,
        6         10,  15,
        7          1,  15,
        8          1,  13,
        9          1,  10,  15,
       10         10,
       11          1,
       12         12,  17,
       13         13,
       14         14,
```

FIGURE 33

(continued, page 20)

```
15        15,
16        16,
17        17,
18        26,
19        17,
20        49,
21        10,
22        17,
23        17,
24        26,
25        15,  49,
26        26,
27        16,
28        17,
29        17,
30        13,
31        15,
32        13,
33        17,
34         1,  13,
35       NO CURRENT FACILITY LOCATION
36        15,
37       NO CURRENT FACILITY LOCATION
38        16,
39       NO CURRENT FACILITY LOCATION
40        55,
41        10,
42         1,  15,
43        55,
44         1,  13,
45         1,  13,
46        55,
47         1,
48        49,
49        49,
50       NO CURRENT FACILITY LOCATION
51       NO CURRENT FACILITY LOCATION
52       NO CURRENT FACILITY LOCATION
53       NO CURRENT FACILITY LOCATION
54       NO CURRENT FACILITY LOCATION
55        55,
```

FIGURE 33

(continued, page 21)

```
   ITERATION NUMBER.    9
 GAS PLANAR EXAMPLE FOUR

   NUMBER OF FACILITIES  12
   SERVICE DISTANCE =    10.000

   NEW FACILITY LOCATION NUMBER    24

   FACILITIES ARE LOCATED AT     1.   10.   12.   17.   15.   13.   26.   16.   49.   14.   55.   24.
   ---------------------------------------------------------------------------------------------------
   POPULATION SERVED    6170.00          PERCENT OF TOTAL POPULATION SERVED   97.42
   ---------------------------------------------------------------------------------------------------
THE FACILITY LOCATED AT:   1 CAN COVER THE FOLLOWING  DEMANDS:
  1.   2.   3.   4.   5.   7.   8.   9.  11.  39.  42.  44.  45.  47.
THE FACILITY LOCATED AT:  10 CAN COVER THE FOLLOWING  DEMANDS:
  6.   9.  10.  21.  41.
THE FACILITY LOCATED AT:  12 CAN COVER THE FOLLOWING  DEMANDS:
 12.
THE FACILITY LOCATED AT:  17 CAN COVER THE FOLLOWING  DEMANDS:
 12.  17.  19.  22.  23.  28.  29.  33.
THE FACILITY LOCATED AT:  15 CAN COVER THE FOLLOWING  DEMANDS:
  4.   6.   7.   9.  15.  25.  31.  36.  42.
THE FACILITY LOCATED AT:  13 CAN COVER THE FOLLOWING  DEMANDS:
  8.  13.  30.  32.  34.  44.  45.
THE FACILITY LOCATED AT:  26 CAN COVER THE FOLLOWING  DEMANDS:
 18.  24.  26.
THE FACILITY LOCATED AT:  16 CAN COVER THE FOLLOWING  DEMANDS:
 16.  27.  38.
THE FACILITY LOCATED AT:  49 CAN COVER THE FOLLOWING  DEMANDS:
 20.  25.  48.  49.
THE FACILITY LOCATED AT:  14 CAN COVER THE FOLLOWING  DEMANDS:
 14.
THE FACILITY LOCATED AT:  55 CAN COVER THE FOLLOWING  DEMANDS:
 40.  43.  46.  55.
THE FACILITY LOCATED AT:  24 CAN COVER THE FOLLOWING  DEMANDS:
 24.  26.  35.  36.
DEMAND POINT      CAN BE COVERED BY FACILITIES AT:
         1         1.
         2         1.
         3         1.
         4         1.  15.
         5         1.
         6        10.  15.
         7         1.  15.
         8         1.  13.
         9         1.  10.  15.
```

FIGURE 33

(continued, page 22)

10	10,	
11	1,	
12	12,	17,
13	13,	
14	14,	
15	15,	
16	16,	
17	17,	
18	26,	
19	17,	
20	49,	
21	10,	
22	17,	
23	17,	
24	26,	24,
25	15,	49,
26	26,	24,
27	16,	
28	17,	
29	17,	
30	13,	
31	15,	
32	13,	
33	17,	
34	1,	13,
35	24,	
36	15,	24,
37	NO CURRENT FACILITY LOCATION	
38	16,	
39	NO CURRENT FACILITY LOCATION	
40	55,	
41	10,	
42	1,	15,
43	55,	
44	1,	13,
45	1,	13,
46	55,	
47	1,	
48	49,	
49	49,	
50	NO CURRENT FACILITY LOCATION	
51	NO CURRENT FACILITY LOCATION	
52	NO CURRENT FACILITY LOCATION	
53	NO CURRENT FACILITY LOCATION	
54	NO CURRENT FACILITY LOCATION	
55	55,	

FIGURE 33

(continued, page 23)

```
SUBSTITUTION  ALGORITHM USED

NODE     158 REPLACES FACILITY LOCATION      15
THIS IS NOW FACILITY NUMBER       5

FACILITIES ARE LOCATED AT      1,   10,   12,   17,  158,   13,   26,   16,   49,
-----------------------------------------------------------------------------------
POPULATION SERVED     6170.00          PERCENT OF TOTAL POPULATION SERVED   97.32
-----------------------------------------------------------------------------------
THE FACILITY LOCATED AT:   1 CAN COVER THE FOLLOWING  DEMANDS:
  1,   2,   3,   4,   5,   7,   8,   9,  11,  34,  42,  44,  45,  47,
THE FACILITY LOCATED AT:  10 CAN COVER THE FOLLOWING  DEMANDS:
  6,   9,  10,  21,  41,
THE FACILITY LOCATED AT:  12 CAN COVER THE FOLLOWING  DEMANDS:
 12,
THE FACILITY LOCATED AT:  17 CAN COVER THE FOLLOWING  DEMANDS:
 12,  17,  19,  22,  23,  28,  29,  33,
THE FACILITY LOCATED AT: 158 CAN COVER THE FOLLOWING  DEMANDS:
  2,   4,   5,   6,   7,   9,  11,  15,  31,  41,  42,
THE FACILITY LOCATED AT:  13 CAN COVER THE FOLLOWING  DEMANDS:
  8,  13,  30,  32,  34,  44,  45,
THE FACILITY LOCATED AT:  26 CAN COVER THE FOLLOWING  DEMANDS:
 18,  24,  26,
THE FACILITY LOCATED AT:  16 CAN COVER THE FOLLOWING  DEMANDS:
 16,  27,  28,
THE FACILITY LOCATED AT:  49 CAN COVER THE FOLLOWING  DEMANDS:
 20,  25,  48,  49,
THE FACILITY LOCATED AT:  14 CAN COVER THE FOLLOWING  DEMANDS:
 14,
THE FACILITY LOCATED AT:  55 CAN COVER THE FOLLOWING  DEMANDS:
 40,  43,  46,  55,
THE FACILITY LOCATED AT:  24 CAN COVER THE FOLLOWING  DEMANDS:
 24,  26,  35,  36,
DEMAND POINT      CAN BE COVERED BY FACILITIES AT:
         1         1,
         2         1, 158,
         3         1,
         4         1, 158,
         5         1, 158,
         6        10, 158,
         7         1, 158,
         8         1,  13,
         9         1,  10, 158,
        10        10,
        11         1, 158,
        12        12,  17,
        13        13,
        14        14,
        15       158,
```

FIGURE 33

(continued, page 24)

16	16,
17	17,
18	26,
19	17,
20	49,
21	10,
22	17,
23	17,
24	26, 24,
25	49,
26	26, 24,
27	16,
28	17,
29	17,
30	13,
31	158,
32	13,
33	17,
34	1, 13,
35	24,
36	24,
37	NO CURRENT FACILITY LOCATION
38	16,
39	NO CURRENT FACILITY LOCATION
40	55,
41	10, 158,
42	1, 158,
43	55,
44	1, 13,
45	1, 13,
46	55,
47	1,
48	49,
49	49,
50	NO CURRENT FACILITY LOCATION
51	NO CURRENT FACILITY LOCATION
52	NO CURRENT FACILITY LOCATION
53	NO CURRENT FACILITY LOCATION
54	NO CURRENT FACILITY LOCATION
55	55,

FIGURE 33

(continued, page 25)

```
SUBSTITUTION  ALGORITHM USED

NODE      18 REPLACES FACILITY LOCATION      26
THIS IS NOW FACILITY NUMBER       7

FACILITIES ARE LOCATED AT     1,   10,   12,   17,  158,   13,   18,   16,   49,
-----------------------------------------------------------------------------------
POPULATION SERVED    6170.00          PERCENT OF TOTAL POPULATION SERVED   97.82
-----------------------------------------------------------------------------------
THE FACILITY LOCATED AT:   1 CAN COVER THE FOLLOWING  DEMANDS:
  1,   2,   3,   4,   5,   7,   8,   9,  11,  39,  42,  44,  45,  47,
THE FACILITY LOCATED AT:  10 CAN COVER THE FOLLOWING  DEMANDS:
  6,   9,  10,  21,  41,
THE FACILITY LOCATED AT:  12 CAN COVER THE FOLLOWING  DEMANDS:
 12,
THE FACILITY LOCATED AT:  17 CAN COVER THE FOLLOWING  DEMANDS:
 12,  17,  19,  22,  23,  28,  29,  33,
THE FACILITY LOCATED AT: 158 CAN COVER THE FOLLOWING  DEMANDS:
  2,   4,   5,   6,   7,   9,  11,  15,  31,  41,  42,
THE FACILITY LOCATED AT:  13 CAN COVER THE FOLLOWING  DEMANDS:
  8,  13,  30,  32,  34,  44,  45,
THE FACILITY LOCATED AT:  18 CAN COVER THE FOLLOWING  DEMANDS:
 18,  26,  36,
THE FACILITY LOCATED AT:  16 CAN COVER THE FOLLOWING  DEMANDS:
 16,  27,  38,
THE FACILITY LOCATED AT:  49 CAN COVER THE FOLLOWING  DEMANDS:
 20,  25,  48,  49,
THE FACILITY LOCATED AT:  14 CAN COVER THE FOLLOWING  DEMANDS:
 14,
THE FACILITY LOCATED AT:  55 CAN COVER THE FOLLOWING  DEMANDS:
 40,  43,  46,  55,
THE FACILITY LOCATED AT:  24 CAN COVER THE FOLLOWING  DEMANDS:
 24,  26,  35,  36,
DEMAND POINT      CAN BE COVERED BY FACILITIES AT:
        1          1,
        2          1, 158,
        3          1,
        4          1, 158,
        5          1, 158,
        6         10, 158,
        7          1, 158,
        8          1,  13,
        9          1,  10, 158,
       10         10,
       11          1, 158,
       12         12,  17,
       13         13,
       14         14,
       15        158,
```

FIGURE 33

(continued, page 26)

16	16,
17	17,
18	18,
19	17,
20	49,
21	10,
22	17,
23	17,
24	24,
25	49,
26	18, 24,
27	16,
28	17,
29	17,
30	13,
31	158,
32	13,
33	17,
34	1, 13,
35	24,
36	18, 24,
37	NO CURRENT FACILITY LOCATION
38	16,
39	NO CURRENT FACILITY LOCATION
40	55,
41	10, 158,
42	1, 158,
43	55,
44	1, 13,
45	1, 13,
46	55,
47	1,
48	49,
49	49,
50	NO CURRENT FACILITY LOCATION
51	NO CURRENT FACILITY LOCATION
52	NO CURRENT FACILITY LOCATION
53	NO CURRENT FACILITY LOCATION
54	NO CURRENT FACILITY LOCATION
55	55,

FIGURE 33

(continued, page 27)

```
   ITERATION NUMBER,   10
 GAS PLANAR EXAMPLE FOUR

   NUMBER OF FACILITIES  13
   SERVICE DISTANCE =    10.000

   NEW FACILITY LOCATION NUMBER    37

   FACILITIES ARE LOCATED AT     1,   10,   12,   17,  158,   13,   18,   16,   49,   14,   55,   24,   37,
   ---------------------------------------------------------------------------------------------------------
   POPULATION SERVED    6220.00          PERCENT OF TOTAL POPULATION SERVED   98.11
   ---------------------------------------------------------------------------------------------------------
THE FACILITY LOCATED AT:   1 CAN COVER THE FOLLOWING  DEMANDS:
  1,   2,   3,   4,   5,   7,   8,   9,  11,  34,  42,  44,  45,  47,
THE FACILITY LOCATED AT:  10 CAN COVER THE FOLLOWING  DEMANDS:
  6,   9,  10,  21,  41,
THE FACILITY LOCATED AT:  12 CAN COVER THE FOLLOWING  DEMANDS:
 12,
THE FACILITY LOCATED AT:  17 CAN COVER THE FOLLOWING  DEMANDS:
 12,  17,  19,  22,  23,  28,  29,  33,
THE FACILITY LOCATED AT: 158 CAN COVER THE FOLLOWING  DEMANDS:
  2,   4,   5,   6,   7,   9,  11,  15,  31,  41,  42,
THE FACILITY LOCATED AT:  13 CAN COVER THE FOLLOWING  DEMANDS:
  8,  13,  30,  32,  34,  44,  45,
THE FACILITY LOCATED AT:  18 CAN COVER THE FOLLOWING  DEMANDS:
 18,  26,  36,
THE FACILITY LOCATED AT:  16 CAN COVER THE FOLLOWING  DEMANDS:
 16,  27,  38,
THE FACILITY LOCATED AT:  49 CAN COVER THE FOLLOWING  DEMANDS:
 20,  25,  48,  49,
THE FACILITY LOCATED AT:  14 CAN COVER THE FOLLOWING  DEMANDS:
 14,
THE FACILITY LOCATED AT:  55 CAN COVER THE FOLLOWING  DEMANDS:
 40,  43,  46,  55,
THE FACILITY LOCATED AT:  24 CAN COVER THE FOLLOWING  DEMANDS:
 24,  26,  35,  36,
THE FACILITY LOCATED AT:  37 CAN COVER THE FOLLOWING  DEMANDS:
 21,  37,
DEMAND POINT      CAN BE COVERED BY FACILITIES AT:
         1         1,
         2         1, 158,
         3         1,
         4         1, 158,
         5         1, 158,
         6        10, 158,
         7         1, 158,
         8         1,  13,
         9         1,  10, 158,
```

FIGURE 33

(continued, page 28)

```
10        10,
11         1, 158,
12        12,  17,
13        13,
14        14,
15       158,
16        16,
17        17,
18        18,
19        17,
20        49,
21        10,  37,
22        17,
23        17,
24        24,
25        49,
26        18,  24,
27        16,
28        17,
29        17,
30        13,
31       158,
32        13,
33        17,
34         1,  13,
35        24,
36        18,  24,
37        37,
38        16,
39       NO CURRENT FACILITY LOCATION
40        55,
41        10, 158,
42         1, 158,
43        55,
44         1,  13,
45         1,  13,
46        55,
47         1,
48        49,
49        49,
50       NO CURRENT FACILITY LOCATION
51       NO CURRENT FACILITY LOCATION
52       NO CURRENT FACILITY LOCATION
53       NO CURRENT FACILITY LOCATION
54       NO CURRENT FACILITY LOCATION
55        55,
```

FIGURE 33

(continued, page 29)

```
   ITERATION NUMBER.   11
 GAS PLANAR EXAMPLE FOUR

   NUMBER OF FACILITIES  14
   SERVICE DISTANCE =    10.000

   NEW FACILITY LOCATION NUMBER    50

   FACILITIES ARE LOCATED AT     1,   10,   12,   17,  158,   13,   18,   16,   49,   14,   55,   24,   37,   50,
   ----------------------------------------------------------------------------------------------------------------
   POPULATION SERVED    6270.00          PERCENT OF TOTAL POPULATION SERVED   98.90
   ----------------------------------------------------------------------------------------------------------------
THE FACILITY LOCATED AT:   1 CAN COVER THE FOLLOWING  DEMANDS:
  1,   2,   3,   4,   5,   7,   8,   9,  11,  34,  42,  44,  45,  47,
THE FACILITY LOCATED AT:  10 CAN COVER THE FOLLOWING  DEMANDS:
  6,   9,  10,  21,  41,
THE FACILITY LOCATED AT:  12 CAN COVER THE FOLLOWING  DEMANDS:
 12,
THE FACILITY LOCATED AT:  17 CAN COVER THE FOLLOWING  DEMANDS:
 12,  17,  19,  22,  23,  28,  29,  33,
THE FACILITY LOCATED AT: 158 CAN COVER THE FOLLOWING  DEMANDS:
  2,   4,   5,   6,   7,   9,  11,  15,  31,  41,  42,
THE FACILITY LOCATED AT:  13 CAN COVER THE FOLLOWING  DEMANDS:
  8,  13,  30,  32,  34,  44,  45,
THE FACILITY LOCATED AT:  18 CAN COVER THE FOLLOWING  DEMANDS:
 18,  26,  36,
THE FACILITY LOCATED AT:  16 CAN COVER THE FOLLOWING  DEMANDS:
 16,  27,  38,
THE FACILITY LOCATED AT:  49 CAN COVER THE FOLLOWING  DEMANDS:
 20,  25,  48,  49,
THE FACILITY LOCATED AT:  14 CAN COVER THE FOLLOWING  DEMANDS:
 14,
THE FACILITY LOCATED AT:  55 CAN COVER THE FOLLOWING  DEMANDS:
 40,  43,  46,  55,
THE FACILITY LOCATED AT:  24 CAN COVER THE FOLLOWING  DEMANDS:
 24,  26,  35,  36,
THE FACILITY LOCATED AT:  37 CAN COVER THE FOLLOWING  DEMANDS:
 21,  37,
THE FACILITY LOCATED AT:  50 CAN COVER THE FOLLOWING  DEMANDS:
 50,  53,
DEMAND POINT       CAN BE COVERED BY FACILITIES AT:
         1          1,
         2          1, 158,
         3          1,
         4          1, 158,
         5          1, 158,
         6         10, 158,
         7          1, 158,
         8          1,  13,
         9          1,  10, 158,
```

FIGURE 33

(continued, page 30)

```
10        10,
11         1, 158,
12        12,  17,
13        13,
14        14,
15       158,
16        16,
17        17,
18        18,
19        17,
20        49,
21        10,  37,
22        17,
23        17,
24        24,
25        49,
26        18,  24,
27        16,
28        17,
29        17,
30        13,
31       158,
32        13,
33        17,
34         1,  13,
35        24,
36        18,  24,
37        37,
38        16,
39       NO CURRENT FACILITY LOCATION
40        55,
41        10, 158,
42         1, 158,
43        55,
44         1,  13,
45         1,  13,
46        55,
47         1,
48        49,
49        49,
50        50,
51       NO CURRENT FACILITY LOCATION
52       NO CURRENT FACILITY LOCATION
53        50,
54       NO CURRENT FACILITY LOCATION
55        55,
```

FIGURE 33

(continued, page 31)

```
   ITERATION NUMBER,   12
 GAS PLANAR EXAMPLE FOUR

   NUMBER OF FACILITIES  15
   SERVICE DISTANCE =    10.000

   NEW FACILITY LOCATION NUMBER    39

   FACILITIES ARE LOCATED AT     1,   10,   12,   17,  158,   13,   18,   16,   49,   14,   55,   24,   37,   50,   39,
   ---------------------------------------------------------------------------------------------------------------------
   POPULATION SERVED    6310.00          PERCENT OF TOTAL POPULATION SERVED   99.63
   ---------------------------------------------------------------------------------------------------------------------
THE FACILITY LOCATED AT:   1 CAN COVER THE FOLLOWING  DEMANDS:
  1,   2,   3,   4,   5,   7,   8,   9,  11,  39,  42,  44,  45,  47,
THE FACILITY LOCATED AT:  10 CAN COVER THE FOLLOWING  DEMANDS:
  6,   9,  10,  21,  41,
THE FACILITY LOCATED AT:  12 CAN COVER THE FOLLOWING  DEMANDS:
 12,
THE FACILITY LOCATED AT:  17 CAN COVER THE FOLLOWING  DEMANDS:
 12,  17,  19,  22,  23,  28,  29,  33,
THE FACILITY LOCATED AT: 158 CAN COVER THE FOLLOWING  DEMANDS:
  2,   4,   5,   6,   7,   9,  11,  15,  31,  41,  42,
THE FACILITY LOCATED AT:  13 CAN COVER THE FOLLOWING  DEMANDS:
  8,  13,  30,  32,  34,  44,  45,
THE FACILITY LOCATED AT:  18 CAN COVER THE FOLLOWING  DEMANDS:
 18,  26,  36,
THE FACILITY LOCATED AT:  16 CAN COVER THE FOLLOWING  DEMANDS:
 16,  27,  38,
THE FACILITY LOCATED AT:  49 CAN COVER THE FOLLOWING  DEMANDS:
 20,  25,  48,  49,
THE FACILITY LOCATED AT:  14 CAN COVER THE FOLLOWING  DEMANDS:
 14,
THE FACILITY LOCATED AT:  55 CAN COVER THE FOLLOWING  DEMANDS:
 40,  43,  46,  55,
THE FACILITY LOCATED AT:  24 CAN COVER THE FOLLOWING  DEMANDS:
 24,  26,  35,  36,
THE FACILITY LOCATED AT:  37 CAN COVER THE FOLLOWING  DEMANDS:
 21,  37,
THE FACILITY LOCATED AT:  50 CAN COVER THE FOLLOWING  DEMANDS:
 50,  53,
THE FACILITY LOCATED AT:  39 CAN COVER THE FOLLOWING  DEMANDS:
 39,  54,
DEMAND POINT       CAN BE COVERED BY FACILITIES AT:
        1           1,
        2           1, 158,
        3           1,
        4           1, 158,
        5           1, 158,
        6          10, 158,
```

FIGURE 33

(continued, page 32)

7	1, 158,
8	1, 13,
9	1, 10, 158,
10	10,
11	1, 158,
12	12, 17,
13	13,
14	14,
15	158,
16	16,
17	17,
18	18,
19	17,
20	49,
21	10, 37,
22	17,
23	17,
24	24,
25	49,
26	18, 24,
27	16,
28	17,
29	17,
30	13,
31	158,
32	13,
33	17,
34	1, 13,
35	24,
36	18, 24,
37	37,
38	16,
39	39,
40	55,
41	10, 158,
42	1, 158,
43	55,
44	1, 13,
45	1, 13,
46	55,
47	1,
48	49,
49	49,
50	50,
51	NO CURRENT FACILITY LOCATION
52	NO CURRENT FACILITY LOCATION
53	50,
54	39,
55	55,

FIGURE 33

(continued, page 33)

```
  ITERATION NUMBER.   13
 GAS PLANAR EXAMPLE FOUR

  NUMBER OF FACILITIES  16
  SERVICE DISTANCE =    10.000

  NEW FACILITY LOCATION NUMBER    51

  FACILITIES ARE LOCATED AT     1.   10.   12.   17.  158.   13.   18.   16.   49.   14.   55.   24.   37.   50.   39.
 51.
  ------------------------------------------------------------------------------------------------------------------
  POPULATION SERVED    6340.00          PERCENT OF TOTAL POPULATION SERVED  100.00
  ------------------------------------------------------------------------------------------------------------------
THE FACILITY LOCATED AT:   1 CAN COVER THE FOLLOWING  DEMANDS:
  1.   2.   3.   4.   5.   7.   8.   9.  11.  34.  42.  44.  45.  47.
THE FACILITY LOCATED AT:  10 CAN COVER THE FOLLOWING  DEMANDS:
  6.   9.  10.  21.  41.
THE FACILITY LOCATED AT:  12 CAN COVER THE FOLLOWING  DEMANDS:
 12.
THE FACILITY LOCATED AT:  17 CAN COVER THE FOLLOWING  DEMANDS:
 12.  17.  19.  22.  23.  28.  29.  33.
THE FACILITY LOCATED AT: 158 CAN COVER THE FOLLOWING  DEMANDS:
  2.   4.   5.   6.   7.   9.  11.  25.  31.  41.  42.
THE FACILITY LOCATED AT:  13 CAN COVER THE FOLLOWING  DEMANDS:
  8.  13.  30.  32.  34.  44.  45.
THE FACILITY LOCATED AT:  18 CAN COVER THE FOLLOWING  DEMANDS:
 18.  26.  36.
THE FACILITY LOCATED AT:  16 CAN COVER THE FOLLOWING  DEMANDS:
 16.  27.  38.
THE FACILITY LOCATED AT:  49 CAN COVER THE FOLLOWING  DEMANDS:
 20.  25.  48.  49.
THE FACILITY LOCATED AT:  14 CAN COVER THE FOLLOWING  DEMANDS:
 14.
THE FACILITY LOCATED AT:  55 CAN COVER THE FOLLOWING  DEMANDS:
 40.  43.  46.  55.
THE FACILITY LOCATED AT:  24 CAN COVER THE FOLLOWING  DEMANDS:
 24.  26.  35.  36.
THE FACILITY LOCATED AT:  37 CAN COVER THE FOLLOWING  DEMANDS:
 21.  37.
THE FACILITY LOCATED AT:  50 CAN COVER THE FOLLOWING  DEMANDS:
 50.  53.
THE FACILITY LOCATED AT:  39 CAN COVER THE FOLLOWING  DEMANDS:
 39.  54.
THE FACILITY LOCATED AT:  51 CAN COVER THE FOLLOWING  DEMANDS:
 21.  51.
DEMAND POINT       CAN BE COVERED BY FACILITIES AT:
          1         1.
          2         1. 158.
          3         1.
          4         1. 158.
          5         1. 158.
```

FIGURE 33

(continued, page 34)

```
 6        10, 158,
 7         1, 158,
 8         1,  13,
 9         1,  10, 158,
10        10,
11         1, 158,
12        12,  17,
13        13,
14        14,
15       158,
16        16,
17        17,
18        18,
19        17,
20        49,
21        10,  37,  51,
22        17,
23        17,
24        24,
25        49,
26        18,  24,
27        16,
28        17,
29        17,
30        13,
31       158,
32        13,
33        17,
34         1,  13,
35        24,
36        18,  24,
37        37,
38        16,
39        39,
40        55,
41        10, 158,
42         1, 158,
43        55,
44         1,  13,
45         1,  13,
46        55,
47         1,
48        49,
49        49,
50        50,
51        51,
52        NO CURRENT FACILITY LOCATION
53        50,
54        39,
55        55,
COVERRAGE CANNOT BE CHANGED BY ADDITIONAL FACILITIES
THIS SOLUTION WAS GENERATED BY THE GAS ALGORITHM
```

FIGURE 33

(continued, page 35)

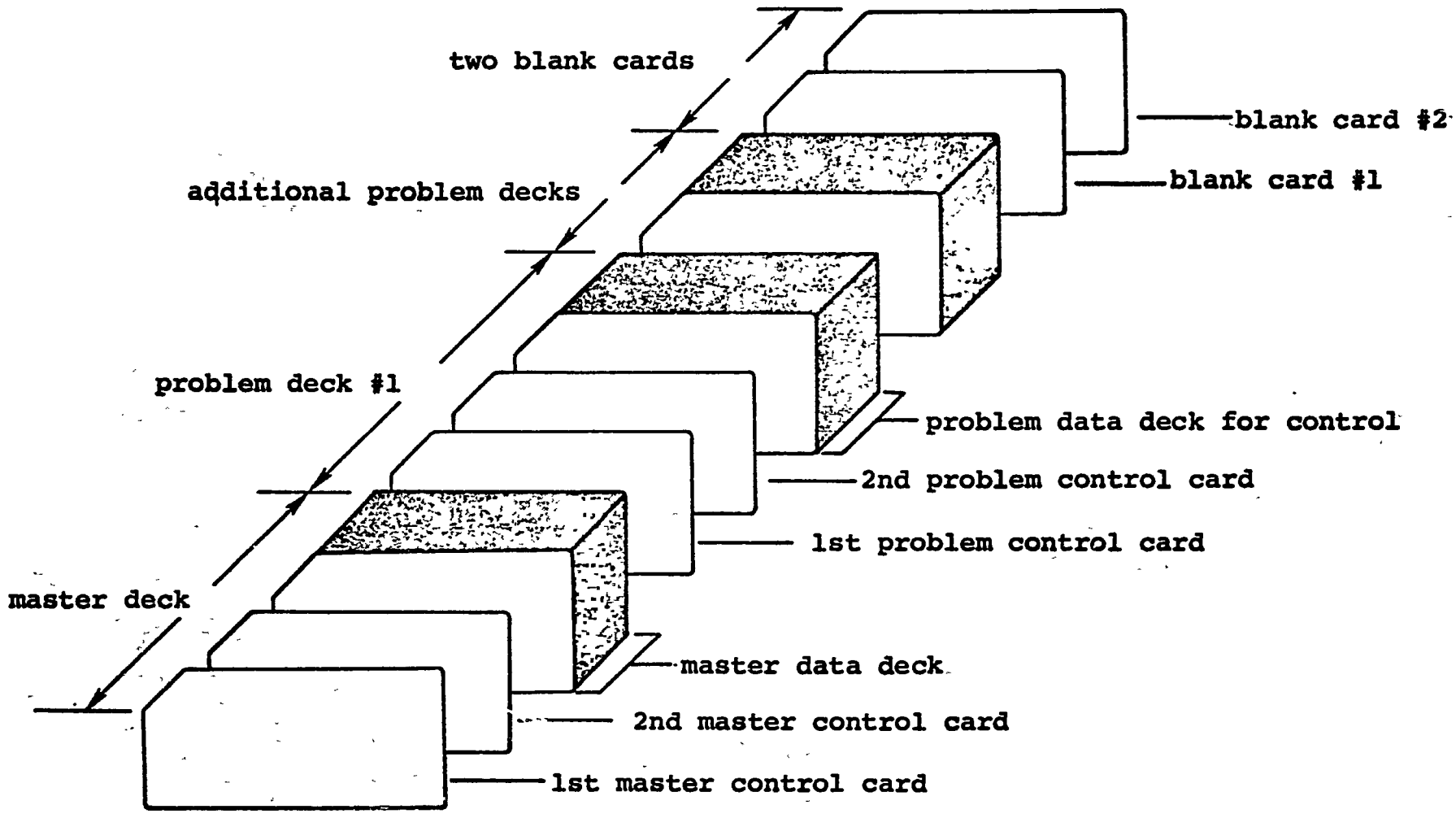

FIGURE 34

CONCEPTUAL FORM OF A DATA DECK FOR A MULTIPLE PROBLEM RUN

APPENDICES

APPENDIX A

DEFINITIONS AND FORMS OF THE PARAMETERS OF THE MASTER CONTROL CARDS

There are two master control cards at the beginning of each data deck. These two master cards contain values for parameters which control and define the appropriate operations the GAS algorithm will perform. The first master control card contains the following parameters: IPTS, IDEM, ADD, NETWOR, WEIGHT, DIST, and IFSAP. The second master control card contains the following parameters: ARCS, RECT, ELE, CONS, IPOL, IALT1, IALT2, and GAS where each parameter is an integer number punched in five digit field. Because of the conventions of FORTRAN, integer numbers are to be punched right justified in a field. If a field is left entirely blank, that field parameter will take a zero value. This is due to the fact that blanks are read as zeroes in an integer field by a Fortran program.

The parameters are defined as follows:

IPTS - the total number of points or nodes in the problem. If the problem is a planar problem IPTS is the total number of points whose coordinates will be inputed. If the problem is a network, IPTS is to equal the number of nodes in the network. The number is to appear in card columns 1-5; it must be right justified.

IDEM - The number of demand points or nodes in the problem. If the problem is a network problem, IDEM must equal IPTS. If the problem is defined on the plane, the value of IDEM must

be less than or equal to the value of IPTS. The number is to be punched in card columns 6-10; it must be right justified.

ADD - the ADD parameter is to be set at zero or one. The ADD parameter is utilized only in planar problems and should be set at a zero value for network problems. If the ADD parameter is set at one for a planar problem, then all demand areas will be considered as potential facility sites, unless modifications are made by the CONSTR subprogram. The value of ADD is to appear in column 15.

NETWOR - This parameter is used to define whether the problem is a network problem or a planar problem. If the value of NETWOR is equal to one, then the problem will be defined on a network. If the NETWOR parameter is set equal to zero, then the problem is assumed to be defined on a plane. The value of NETWOR must appear on card column 20.

WEIGHT - The WEIGHT parameter indicates whether the population (weight) at each node is equal to one or if the weights are to be inputed. If the WEIGHT parameter is set equal to one, then the program expects to input a weight or population value for each of the demand areas. If all node or point populations are to be set equal to one , the weight parameter should be set to a zero value. The value of the WEIGHT parameter must appear in card column 25.

DIST - The DIST parameter is to be set at either a one value or a zero value. If the DIST parameter is set at one, then a distance matrix indicating the distances between all demand areas and all facility sites is given. If the value of DIST is set to zero, the distance matrix will not be printed. The value of DIST appears in card column 30. It should be noted that the printout of the distance matrix is usually long and requires a number of pages, and the use of DIST should not be utilized except when the matrix information is really necessary.

IFSAP - The IFSAP parameter indicates whether a special statistics output is to be printed

at the end of each iteration. If IFSAP parameter is zero then the printout will not be given. However, if the IFSAP parameter is set at the value of one, then the IFSAP output is given. The IFSAP program uses only distances in its analysis and is not appropriate if elevations or political constraints are used. The value of IFSAP must appear in column 35.

ARCS - The ARCS parameter is utilized only in network problems. In all other cases it should be set to a value of zero. When solving a network problem when arc distances are to be utilized in developing a distance matrix, the ARCS parameter is to be set equal to one. The value of ARCS must appear in column 5 of the second master control card.

RECT - The RECT parameter indicates whether Euclidean distance (straight line) or rectilinear distance (grid) measure is to be used. If RECT is set equal to one, then rectilinear measure will be used. If the RECT parameter is set at a value of zero, Euclidean distance measure will be utilized. The RECT parameter is utilized only when the problem is defined on a plane. It should be set at a zero value when solving a network problem. The value of RECT must appear in column 10.

ELE - The ELE parameter is utilized to indicate if elevation data is to be inputed for each demand area and potential facility site. If the ELE parameter is set to a zero value, then the GAS program will not expect elevation data in the data deck. However, if the ELE parameter is set to the value of one, the GAS program will need elevation data in the data deck. The value of the ELE parameter must appear in column 15 of the second data card.

CONS - The CONS parameter indicates whether several special constraint features are to be utilized in setting up a particular problem. If the value of CONS is set at one, then the CONS subroutine will not be used by GAS. The CONS subroutine has three main options. The first option allows the automatic allocation of facilities to prespecified

areas. GAS will add facilities to this initial set of facilities, but will not change any of the locations of the initial set in any of the iterations. This option allows a user to use GAS for the addition of facilities to a region that has already a set of facilities established. The second option allows a user to eliminate any potential site for consideration. Although the data base may in general allow the placement of a facility at a particular location, the user may want in a specific run to eliminate certain areas from consideration. The third option of CONS allows a user to temporarily eliminate demand at one or many nodes in order to analyze the effect that an area exerts on the final solution. One may also eliminate an areas demand, due to the fact that area may already be served by some previously built facility. The value of CONS must appear in card column 20.

IPOL - The IPOL parameter is used to indicate the existence of political compatabilities. If the IPOL parameter is set at a zero value, no political compatibility data is to be given. If political compatability data is to be used, IPOL must be set to a value of one. Political compatabilities can be utilized to limit or restrict the areas that a given area may serve on the basis of conservative or liberal areas. The value of IPOL must appear in card column 25.

IALT1 - The IALT1 parameter is utilized only when a problem is defined on a plane. It should be set to zero for all network problems. If the IALT1 parameter is assigned the value of one in a planar problem, elevation data is utilized in defining distances (either rectilinear or Euclidean). If elevation data is not given the value of IALT1 is ignored. The value of IALT1 is to appear in card column 30.

IALT2 - The IALT2 parameter is to be set to the value of one if elevations are to be utilized as additional restrictions to the maximal service distance value. By setting IALT2 to one, one can establish a maximum

positive elevation difference between a facility and a village that the facility serves as well as a maximum negative elevation difference between a facility and a village that the facility serves. This means that one can, for example, establish that a facility can serve an area if the area is within 12 kilometers of the facility, within 20 meters down from the facility, and within 200 meters up from the facility. The value of IALT2 must appear in card column 35. For problems when the ELE parameter is at a zero value, the value of IALT2 will be ignored. If IALT2 is set at a zero value, then differences in elevations will not be utilized in determining potentials for coverage.

GAS - The GAS parameter is utilized to indicate whether the GA algorithm or the GAS algorithm is to be used. If GAS is set to the value of one then the GAS algorithm will be performed. If the GAS parameter is set to zero, the GA algorithm will be performed. The value of the GAS parameter is set in card column 40 of the second master control card.

The GAS program is designed to solve both network and planar problems. Several of the above option parameters deal specifically with one problem type. The following list specifies which parameters are utilized solely in one problem form.

Parameters Utilized Solely for Problem Type

PLANAR	NETWORK
ADD	ARCS
RECT	
IALT1	

The GAS program can solve many types of problems and several sections of the program manual deal with the use of GAS in both network and planar problems. Full understanding of the parameters can be developed by looking closely at the examples of problem runs given throughout the manual.

FIGURE A.1

MASTER CONTROL CARDS

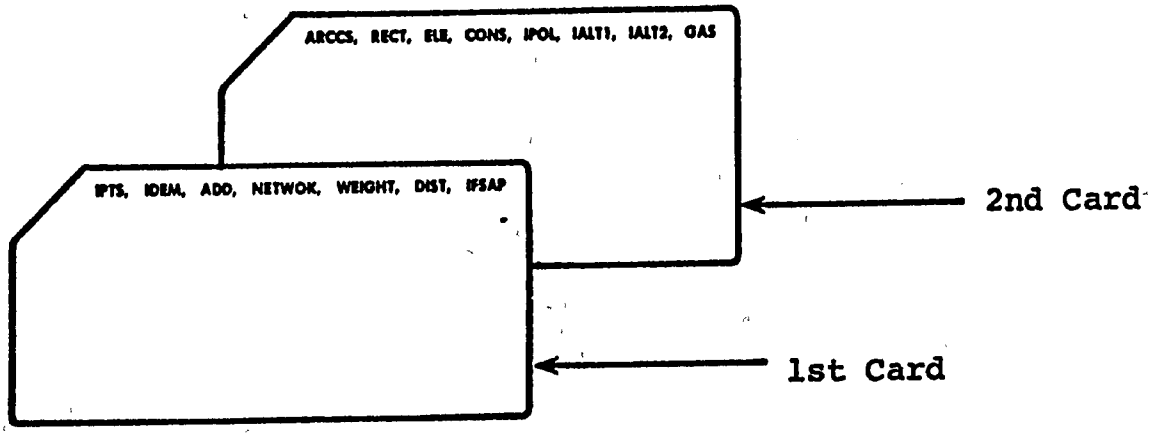

FIGURE A.2

SUMMARY OF MASTER CONTROL CARD SETUP

CARD #	VALUES	FIELD OR CARD COLUMNS	CODE
1	IPTS	1-5	R-J
	IDEM	6-10	R-J
	ADD	15	V1,0
	NETWOR	20	V1,0
	WEIGHT	25	V1,0
	DIST	30	V1,0
	IFSAP	35	V1,0
2	ARCS	5	V1,0
	RECT	10	V1,0
	ELE	15	V1,0
	CONS	20	V1,0
	IPOL	25	V1,0
	IALT1	30	V1,0
	IALT2	35	V1,0
	GAS	40	V1,0

R-J - number must appear right justified with no decimal point.

V1,0 - the value of the parameter must be either 1 or 0.
If the field is left blank, number is assumed to be zero.

APPENDIX B

DEFINITIONS AND FORMS OF THE PARAMETERS OF THE PROBLEM CONTROL CARDS

There are two problem control cards at the beginning of each problem data deck. Each card gives specific information associated with a maximal covering location problem. The first card of the two problem control cards is a title card. This card should contain a problem title associated with the problem one intends to solve. This title can take all eighty columns of the card and is not limited to letters, but can contain numbers and special characters. The title that is given on the title card will appear on each iteration output of GAS.

The second problem control card contains parameters that will define a specific maximal covering location problem. This card contains the following parameters: IP, S, SCS, EMAXL, EMAXS, CONS, ICOV, and ILIST. The parameters are defined as follows:

IP - The IP parameter represents the maximum number of facilities that the GAS algorithm will locate. GAS will start with the location of one facility and then add one at a time until IP facilities have been located. The process of determining locations is described elsewhere. GAS will, however, stop determining additional locations before IP have been located if total coverage has been achieved. The value of IP must be right justified in columns 1-5.

S - The S parameter represents the value of the maximal service distance to be used by the GAS algorithm. The value of S is to be given in columns 6-15. A decimal point must be included with the value.

SCS - The SCS parameter is the secondary distance that is used in the statistics output of the FSAP subroutine. The SCS parameter is not utilized by GAS in determining locations but is useful in analyzing various GAS solutions when only distance is used as a criterion for determining coverage. The SCS parameter does not need to be given unless the IFSAP parameter is set equal to one. The value of the SCS parameter must be given in columns 16-25. A decimal point must be included with the value.

EMAXL - The EMAXL parameter is to be utilized when elevation differences are incorporated in determining which demand areas (villages) can be covered by a given facility. EMAXL represents the largest elevation difference that a facility can be above a given village and still be considered a site that can serve that village (assuming that the facility site and village are within the maximal service distance of each other). If the altitude of the facility site is 2000 m. and the altitude of the village is 1500 m., then the facility site can cover the village only if EMAXL is greater than or equal to 500 m. If EMAXL is set at 400 m., then the facility site would not be considered as a site that could serve the village. The value of EMAXL must be given in columns 26-35 and include a decimal point. The EMAXL parameter must be given whenever the IALT2 parameter on the master control card is set at one.

EMAXS - The EMAXS parameter is to be utilized when elevation differences are incorporated in determining which demand areas (villages) can be covered by a given facility. EMAXS represents the largest elevation difference that a facility can be below a given village and still be considered a site that can serve that village (assuming that the facility site and village are within the maximal service distance of each other).

If the altitude of the facility site is 1000 m. and the altitude of the village is 1500 m., then the facility site can cover the village only if EMAXS is less than or equal to -500 m. If EMAXS is set at -400 m., then the facility site would not be considered as a site that could serve that village. The value of EMAXS must appear in columns 36-45 and include a decimal point and negative sign. The EMAXS parameter must be given whenever the IALT2 parameter or the master control card is set at one.

CONS - The CONS parameter is used to indicate whether the problem data set contains additional cards. The additional cards are called constraint cards and appear directly after the two problem control cards. When the CONS parameter is set to a value of one, the program will expect the additional constraint cards in the problem set. When the value of the CONS parameter is set at a zero value, the program will not utilize problem constraint cards. In fact, when the CONS parameter is set at a zero value, no problem constraint cards can be given. The value of the CONS parameter must appear in card column 55 of the second problem control card. By including a problem constraint section in the data deck, it is possible to include three major problem constraints: (a) eliminate any facility site from potential consideration for whatever reason; (b) eliminate the demand from any area in order to solve a subproblem or a modified problem; and (c) automatically allocate one or more facilities so that the GAS algorithm starts with this set and adds to this initial set facilities which increase coverage above what is covered by the initial allocation. The problem constraint deck is described in detail in appendix C.

ICOV - The ICOV parameter is used to indicate if a zero-one covering matrix is to be printed at the beginning of a problem run. This zero-one matrix shows which facilities can cover a given demand area. A one indicates that an area can be covered by a certain facility and a zero indicates that an

area cannot be covered by a certain facility. If the value of ICOV is set at one, the zero-one cover matrix will be printed out. If the value of ICOV is set at zero, the zero-one cover matrix will not be printed out. The value of ICOV must appear in column 60 of the data card.

ILIST - The ILIST parameter is used to indicate whether coverage information will be given by the program. This information indicates which areas are covered by facilities and which currently established facilities cover a given demand area. This listing is given after each iteration of the algorithm. The ILIST parameter value must appear in column 65 of the second problem master card. If the value of ILIST is one, the listing information will be given. If the value of ILIST is zero, this information will not be given.

FIGURE B.1

PROBLEM CONTROL CARDS

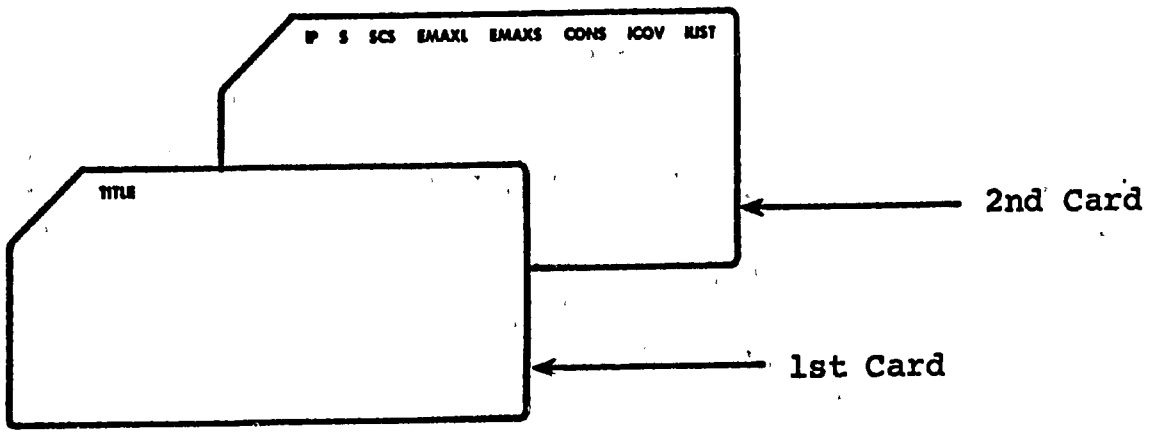

FIGURE B.2

SUMMARY OF THE PROBLEM CONTROL CARDS

CARD #	PARAMETER	CARD COLUMNS	CODE
1	Title	1-80	LET
2	IP	1-5	RJ
	S	6-15	D
	SCS	16-25	D
	EMAXL	26-35	D
	EMAXS	36-45	D
	CONS	55	V1,0
	ICOV	60	V1,0
	ILIST	65	V1,0

APPENDIX C

DEFINITIONS AND FORMS OF THE PARAMETERS OF THE PROBLEM CONSTRAINT CARDS

When additional constraints are to be added to a particular problem, they are structured in the problem constraint cards. The problem constraint cards appear after the problem control cards and are to be included only if the CONS parameter of the problem control cards is set at the value of one. The first card of the constraint cards contains the following parameters: ND, NDAS, and NANCF. The parameters are defined as follows:

ND - The ND parameter represents the number of demand points or nodes that are to be deleted from the established list of potential facility sites. The value of the ND parameter must appear in columns 1 to 4 and be right justified with <u>no</u> decimal point.

NDAS - The NDAS parameter represents the number of demand nodes that are already served or are not considered in coverage patterns and will be deleted from the demand list. The NDAS parameter must appear in columns 6 to 9 and be right justified with no decimal point.

NANCF - The NANCF parameter represents the number of potential facility sites that are to be allocated to a facility that is to remain unchanged by the GAS algorithm. The value of NANCF must appear in columns 11 to 14 and be right justified with no decimal point.

After the first constraint card which has the values of ND, NDAS, and NANCF, a total of ND + NDAS + NANCF cards must follow. The

first set of cards (called ND cards) give the indices of the demand areas that are to be deleted from being considered as potential facility sites. There is to be one card for each area that is deleted, or a total of ND cards. The index of the area to be deleted as a site must appear in card columns 1-4 and must be right justified with no decimal point. The program will accept a two letter code in columns 6 and 7 which will appear on program output sheets. The two letter codes can be used to indicate why a particular site is not to be considered. For example, NE might be used if no electricity is available and electricity is considered necessary. It is not necessary to give a two letter code; this provision is only used in the output documentation. If the value of ND equals 0, then no ND cards should be given.

The second set of cards (called NANCF cards) give the indices of the areas that are to be automatically assigned a facility. Each site automatically assigned a facility will retain that facility through the complete run of GAS. GAS will try to find the best combination of additional facilities in order to increase coverage to a maximum. There should be one card for each allocated facility, or a total of NANCF cards. The index of the area that is to be allocated a facility must appear in columns 1-4 and must be right justified with no decimal point. If the value of NANCF equals 0, then no NANCF cards should be given.

The third set of cards (called NDAS cards) give the indices of the areas that are not to be considered in calculating

coverage. This allows one to structure a coverage problem on a sub-area of that defined by the master data deck. There should be one card for each area that is to be eliminated as needing coverage, or a total of NDAS cards. The index of the area that is to be eliminated must appear in columns 1-4 and must be right justified with no decimal point. If the value of NDAS equals 0, then no NDAS cards should be given.

Figure C.1 gives a conceptual set up of the constraint card data deck. Figure C.2 gives a summary of the fields in the constraint card deck. Several examples of constraint card data decks are given in different sections of this manual.

FIGURE C.1

PROBLEM CONSTRAINT CARDS

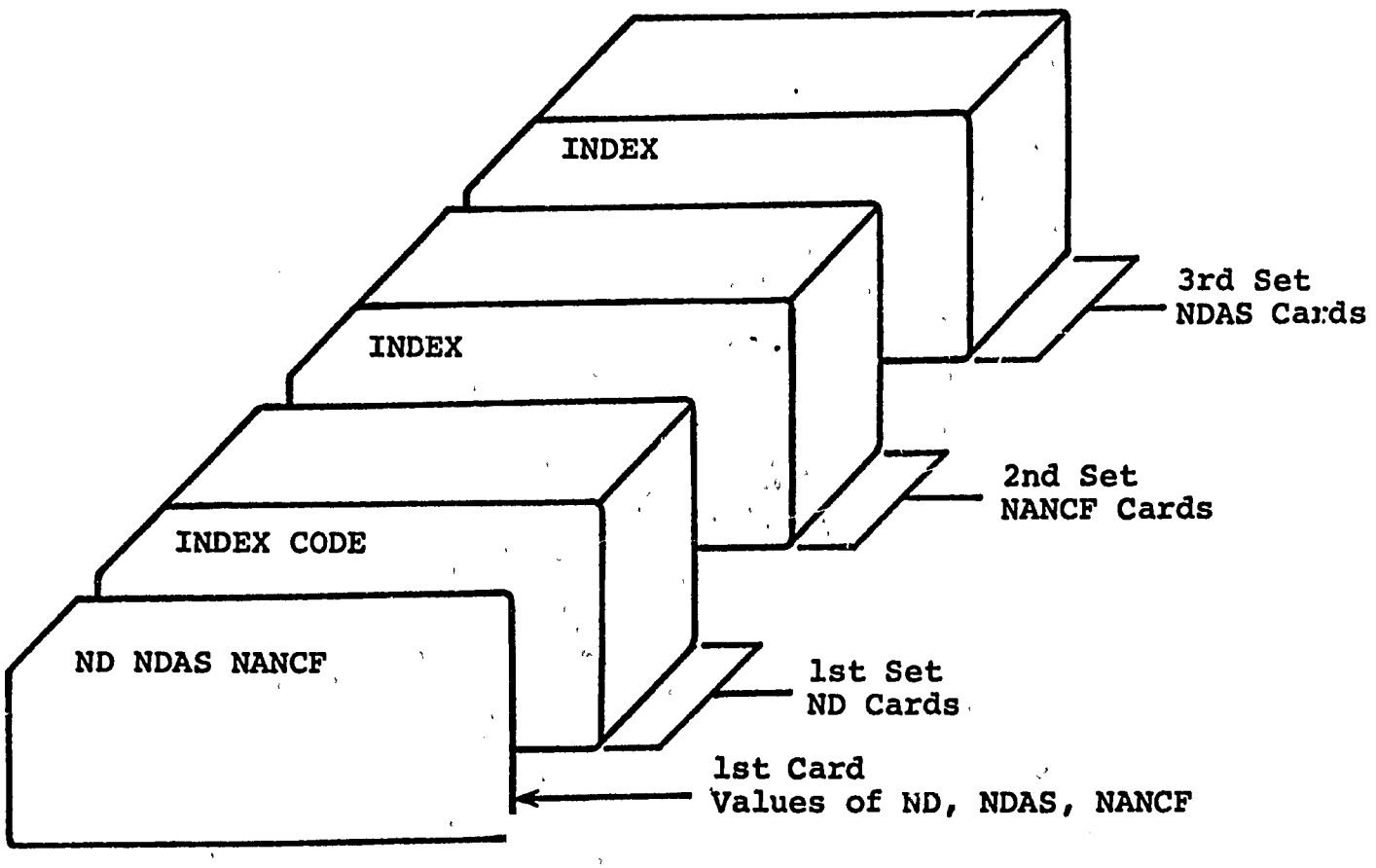

FIGURE C.2

SUMMARY OF CONSTRAINT CARD DECK

CARD #	VALUES & FIELDS
1	ND (1-4;RJ), NDAS (6-9;RJ), NANCF (11-14;RJ)
Next* ND Cards	INDX (1-4;RJ), CODE (6-7;LET)
Next + NANCF Cards	INDX (1-4;RJ)
Next ** NDAS Cards	INDX (1-4;RJ)

RJ - number must be right justified in field with no decimal point

LET - any letters may be used.

*present only if ND>0

+present only if NANCF>0

**present only if NDAS>0

NOTES: The number of cards in constraint card deck is equal to 1 + ND + NDAS + NANCF. The constraint card deck is to be used only when CONS = 1. This implies that one of the parameters on card number 1 should be greater than zero. However, the GAS program will allow all parameter (ND, NDAS, & NANCF) to be zero. Card number one must always be given if CONS = 1.

APPENDIX D

FORMAT SUMMARIES FOR COORDINATE POINT INFORMATION, ELEVATION DATA, AND POPULATION

Data Format for Coordinate Points

When utilizing the GAS program for planar problems, (x,y) coordinate point information is used to develop a distance matrix indicating the shortest distance between each demand area and each facility site. In the data deck there must be one card for each point. The parameters on each card are:

INDEX, X-COORDINATE, Y-COORDINATE,

where

INDEX - The index parameter is the number given to a particular point. The index must appear in columns 1-4 right justified with no decimal point.

X-COORDINATE - The X-Coordinate of the point must appear in columns 5-14 with a decimal point.

Y-COORDINATE - The Y-Coordinate of the point must appear in columns 15-25 with a decimal point.

The cards must be ordered in terms of increasing index value.

Data Format for Elevation Data

In certain cases it may be desirable to utilize elevation data in constraining coverage for any given facility site or

to utilize elevation data in determining distances. If this is the case, elevation data must be given in the master data deck. Each point or node in the problem must be assigned an elevation by the use of an elevation data card. The parameters on each card are:

INDEX, ELEVATION

where

INDEX - The index parameter is the number given to a particular point. The index must appear in columns 1-4 right justified with no decimal point.

ELEVATION - The elevation of the point or node must be given in columns 5-14 with a decimal point.

The cards of elevation data must be given in terms of increasing index value or the exact same order as that given by the coordinate point data if coordinate point data is used.

Data Format for Population

Population data is not necessary in utilizing the GAS program since it will allow for the objective of covering number of points instead of covering population. When population data is to be given, the population of each demand point or node must be given. The population of each area is given by a data card with the following parameters:

INDEX, POPULATION

where

INDEX - The index parameter is the number given to a particular point. The index must appear in columns 1-4 and be right justified with no decimal point.

POPULATION - The population of the point or node must be given in columns 5-14 and include a decimal point.

The population cards must be given in terms of increasing index value or the exact same order as that given by the coordinate point data if coordinate point data is used.

FIGURE D.1

FORMAT SUMMARIES FOR POPULATION,

ELEVATION, AND COORDINATE POINT DATA

CARD TYPE	VALUES AND FIELDS
Population Cards	Index (1-4;RJ), Population (5-14;D)
Elevation Cards	Index (1-4;RJ), Elevation (5-14;D)
Coordinate Points	Index (1-4;RJ), X-Coordinate (5-14;D), Y-Coordinate (15-25;D)

RJ - number must be right justified in field with no decimal point.

D - number must appear with decimal point.

APPENDIX E

FORMAT SUMMARIES FOR ARC DATA

When utilizing the GAS program for solving network problems, either ARC data or a shortest distance matrix must be inputed. When arc data is given, then the arc data is utilized in generating a shortest distance matrix. This matrix generation is produced by the FLOYD Algorithm in the GAS subroutine START2. The GAS program expects ARC data in the master data deck only when the ARCS parameter on the second master control card is set at a value of one. In addition, ARC data must never be given unless the NETWOR parameter on the first master control card is set at a value of one.

When arc data is given, there should be one card for each arc in the road network. For the network given in figure E.1, there should be six (6) arc cards. In addition to the arc cards there must be a card preceding the arc cards which indicates how many arc crads are given. Thus, there are two types of cards in the ARC data deck.

The first card must contain an integer number, right justified in columns 1 through 5, indicating the number of ARCS in the network. This number is called IARCS.

The remaining cards have the following information:

INDEX, I, J, D(I,J)

where

INDEX - the index number given to a particular arc. If an index is given, it must appear right justified

in columns 1-5 as an integer number. Index values may be omitted. If index values are omitted, then the GAS program will assign index values in the order that the arc cards appear in the data deck.

I and J - The indices of the two nodes that the ARC connects. The order of the indexes is not important. The first index must be given right justified in columns 6 through 10 with no decimal point. The second index must be given right justified in columns 11 through 15 with no decimal point.

D(I, J) - The length or time of travel of the arc that connects node I to node J. This value must be given in columns 16 through 21 with a decimal point. Only one arc may be given for any specific pair of nodes.

Table E.1 gives a format summary for the arc data deck along with an example data set for the network in figure E.1.

FIGURE E.1

A SIMPLE SIX ARC NETWORK

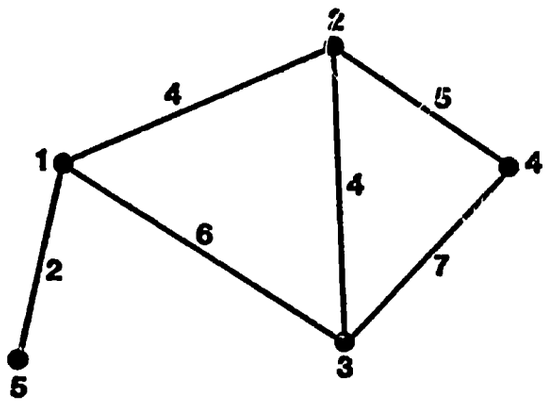

TABLE E.1

FORMAT SUMMARY FOR ARC DATA WITH EXAMPLE

CARD #	VALUES AND FIELDS
1	IARCS (1-5;RJ)
Next IARCS Cards	INDEX (1-5;RJ), I(6-10;RJ), J(11-15;RJ), D(16-21;D)

RJ - number must be right justified in field with no decimal point

D - number must appear with decimal point

CARD #	VALUES AND FIELDS
1	6 (appears in column 5)
2	1,2,4,5. (respective columns; 5,10,15 and 16-17)
3	2,4,3,7.
4	3,3,2,4.
5	4,1,2,4.
6	5,3,1,6.
7	6,1,5,2.

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