TECHNICAL REPORT NUMBER 8

A LAND USE PLAN DESIGN MODEL

VOLUME ONE
MODEL DEVELOPMENT

SOUTHEASTERN WISCONSIN REGIONAL PLANNING COMMISSION

Special acknowledgment is due Mr. Kenneth J. Schlager, SEWRPC Systems Engineer, Messrs. Richard J. Gottschalk and Marshall A. Anderson, SEWRPC Senior Planners, and Mr. Bruce Boehlen, SEWRPC Systems Analyst, for their direction and extensive participation in the formulation of the land use design model and in the preparation of this report.

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Prepared by the
Southeastern Wisconsin Regional Planning Commission
for the
U. S. Department of Housing and Urban Development

The development of the land use plan design model described in this report and the preparation of the report itself was financed by an Urban Planning Research and Demonstration project grant from the U.S. Department of Housing and Urban Development under the provisions of Section 701 (b) of the Housing Act of 1954, as amended.

January 1968

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SOUTHEASTERN WISCONSIN REGIONAL PLANNING COMMISSION

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December 7, 1967

STATEMENT OF THE EXECUTIVE DIRECTOR

On October 28, 1966 the U. S. Department of Housing and Urban Development awarded to the Southeastern Wisconsin Regional Planning Commission a federally funded contract for the development of a land use plan design model. The objective of the program was to produce a mathematical model which could be used in the synthesis of land use plans; that is, given certain land use requirements and land development costs, the purpose of a land use design model would be to produce a land use plan which would meet stated development objectives and standards at a minimum cost. This emphasis on design is unusual since mathematical model development efforts to date in the area of land use planning have been directed primarily at producing forecasts of future land use patterns rather than at producing optimal designs for such patterns.

Complete development of the land use plan design model is to be accomplished in three phases. The first phase was directed at a review of the literature on land use models, the development of concepts previously advanced into a computer program for the execution of the design model itself, the identification of model input data requirements and means for satisfying these requirements, and the application of the model to a local area as a pilot test. The first phase of the model development program has been completed and this report describes the results which have been most encouraging. The model, as developed to date, provides plausible and logical outputs in response to input data, input data requirements are not excessive, and data reduction and model computer programs are operational.

In subsequent phases of the model development program, the land use plan design model will be applied to develop a land use plan for an actual urban region; data collection and reduction programs, as well as programs for the execution of the model itself, will be subjected to more rigorous tests; and comparisons will be made between land use plans developed by conventional techniques and those developed by application of the model. If the results of the subsequent phases of the model development are as favorable as the results of the first phase, a new and powerful tool will be made available for urban land use planning.

Respectfully submitted,

Kurt W. Bauer

K. W. Bauer
Executive Director

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Chapter I
INTRODUCTION

PROGRAM DEFINITION AND STATUS

During the course of the regional land use-transportation study conducted by the Southeastern Wisconsin Regional Planning Commission, the need for a mathematical model that could be used as an aid in the design of a land use plan became very apparent. The need for such a "design model" was not being satisfied by the extensive efforts in land use forecasting and simulation model development underway at SEWRPC and other agencies. What was needed was not a forecast of what future land development might be but a design for what future land development should be.

Some preliminary investigations of a land use plan design model were, therefore, conducted during the land use-transportation study; but no sustained research program was possible because this work area was not included as part of the original study. To initiate a full-scale research program to develop a land use plan design model, application was made by SEWRPC to the U. S. Department of Housing and Urban Development in January of 1966. The project was approved in June of 1966 as Urban Planning Research and Demonstration Project No. Wis. PD-1.

Actual work on the Land Use Plan Design Model was initiated in July of 1966 with the general objective of developing a model that could be used to synthesize (design) land use plans that would satisfy predetermined design criteria and minimize the use of financial resources (costs). The project is being performed in three phases.

During Phase I of the three-phase program, the following activities were scheduled for completion:

1. Preparation of a report on the state of the art of mathematical land use models (termed "land use design models") which can be used to determine land use patterns that satisfy market demands, comply with community development objectives, and minimize public and private development costs.

2. Preparation of hypothetical sets of community development objectives and design standards in a form ready for application in a "land use design model," and report the results of such preparation.

3. Preparation of typical community development cost functions for use in a "land use design model" using data from the area within the jurisdiction of the Southeastern Wisconsin Regional Planning Commission, and report the results of the study.

4. Refinement of computer programs needed to operate a "land use design model."

5. Preparation of a work program for a pilot test of a "land use design model" and preparation of a work program for a full-scale application of the "land use design model" to a variety of metropolitan areas.

The first of the above tasks, which includes the preparation and publication of a state-of-the-art report, has been completed and is the subject of the third chapter of this document. Since the use of design models in urban planning is a fairly recent concept, a very extensive literature on the subject does not exist. For this reason, the state-of-the-art report has been expanded to include the state of the art in supporting activities, such as design standards and cost functions, in order to present a comprehensive picture of the overall state of the art prior to the initiation of this design model research program.

The second, third, and fourth of the above tasks involved the preparation of input data and computer programs for the demonstration of the design model. A preliminary set of data and programs have been used for a local pilot test demonstration of the model at the community level. An additional task involving a pilot test of the model in a developing community in southeastern Wisconsin, not included in the original work program, has been added to the program. This task has served to tie together all of the work elements into a total design model system package in anticipation of the larger scale regional tests to be conducted and reported on in Phase II.

The fifth of the above tasks, the preparation of a work program for a pilot test of a "land use design model," is discussed in the next section of this chapter. The second part of the fifth task, involving the preparation of a full-scale application of models to a variety of metropolitan areas, will be the primary task of Phase III, which will include the preparation of training manuals and courses so that the program may be implemented in other metropolitan areas. The Phase III Work Program is detailed in Appendix III of this report.

PHASE II WORK PROGRAM

In essence, the Phase II program for the Land Use Plan Design Model relates to the preparation of a regional land use plan in southeastern Wisconsin using the Land Use Plan Design Model developed in Phase I. Since a regional land use plan has just been prepared in southeastern Wisconsin utilizing conventional techniques without the benefits of a design model, the Phase II program will provide for a direct comparison between application of the design model and of conventional land use planning techniques. It will also serve to expose the many practical problems involved in the implementation of a model approach to regional planning. The following work activities will be requisite to evaluating the utility of the design model as a regional planning tool:

1. The measuring and coding of soil characteristics by quarter section and watershed boundaries for the seven-county Region to provide the basis for determining the cost input parameters to the model.

2. The preparation of auxiliary computer programs to convert forecast variables, such as population and employment, directly into module inputs for the model. This would allow a "package" use of the model by planners who are satisfied with the typical module definitions and design standards formulated in the project.

3. The execution and evaluation of a "full-scale" application of the model to the seven-county Southeastern Wisconsin Region. This would include the evaluation of the limitations inherent in using the model to determine an optimal solution.

4. The test and evaluation of the results using the model for a "target date" optimal solution versus a recursive optimal solution in time increments consistent with traditional capital improvement budgeting. Staged testing of the model is needed since the optimal solution for land allocation for the target date, say the year 1990, will not result in the same land use configuration if the optimal solution is phased in five-year increments.

5. The test and evaluation of the sensitivity of the model to imputed objectives, design standards, and estimated cost functions. Such sensitivity analysis will allow for the determination of the data required (and its accuracy) for application of the design model to a community or region.

6. The implementation of the design model as a complete urban design system for application on a small computer for use in smaller regions or in community planning programs. Such implementation would supplement the application on a larger computer for larger scale planning programs and allow for the widespread use of the design model in urban and regional planning.

7. An investigation of data acquisition and information retrieval requirements for operational use of the urban design system in urban planning applications.

The remaining chapters of this volume are devoted to reporting the results of the Phase I program. In Chapter II the urban design problem is defined, and the basic approach to its solution using a land use plan design model with supporting input data and computer programs is generally described. Succeeding chapters discuss the state of the art of design models (Chapter III) and present the design system in more detail beginning with the definition of design modules in Chapter IV and continuing in Chapter V and VI with objectives, design standards, and development cost functions. Chapter VII follows on the detailed theory and operation of the model and Chapter VIII concludes on model operation as exemplified in a pilot test in a small Wisconsin community.

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Chapter II
THE URBAN DESIGN PROBLEM

BASIC CONCEPTS AND DEFINITIONS

Succinctly stated, the urban design problem involves the optimal use of land space. More specifically, it involves the placement of discrete land use activities or elements, such as schools, hospitals, neighborhoods, and parks, in topographic space. In placing these elements, the designer must consider:

1. The nature of the elements.

2. The nature of the space in which the elements may be located.

3. The design standards or criteria as reflected in constraints to the placement process.

4. The costs (site and linkage) associated with placement of elements in a spatial configuration.

After placing these elements in land space, the designer must then determine the routes of the linkages, such as streets and water lines, that are necessary to connect these elements. This placement and routing process is illustrated in the diagram in Figure 1. The solution of the above design problem is the objective of the urban design model.[1]

An urban design model may be defined as a mathematical model which is used to aid the planner in the synthesis or design of a land use plan. The land use plan defines a desired spatial distribution of land use activities in a given land area. The model provides for a design solution that will satisfy market demands and also will comply with community development objectives while minimizing public and private development costs (or maximizing return on public and private investment).

The model furnishes a convenient tool for the generation and evaluation of alternate spatial arrangements of land uses. In the process of generating and evaluating a large number of spatial land use patterns, the model also searches for the optimal design; that is, the design that satisfies stated development objectives while minimizing development costs.

Because the placement of land use activities interacts very strongly with the spatial location and capacities of streets, sewers, water mains, and other facilities needed to support the land uses, the model is really a comprehensive planning model or, broadly speaking, an urban plan design model. It is a comprehensive urban plan design model in the sense that it considers the construction, operation, and maintenance costs of the public works facilities which serve and support the land use pattern, as well as the construction, operation, and maintenance costs of the land use pattern itself. Thus, although the final output of the model is a land use plan, in the design of the plan the cost of the supporting facilities necessary to support the proposed land use pattern has been considered.

Most model-building efforts in urban planning have not been concerned with the problems of design. They have been concerned rather with other planning functions, such as economic forecasting, land use forecasting, and traffic assignment. Most existing models, therefore, differ not only in their end objective but also in their basic nature from the type of model required to solve the urban design problem. The most significant structural difference relates to the aggregative characteristics of most models. These models manipulate aggregate variables, such as the quantity of land, rather than the discrete elements alluded to above. Institutional land rather than a discrete hospital is the type of variable that is manipulated.

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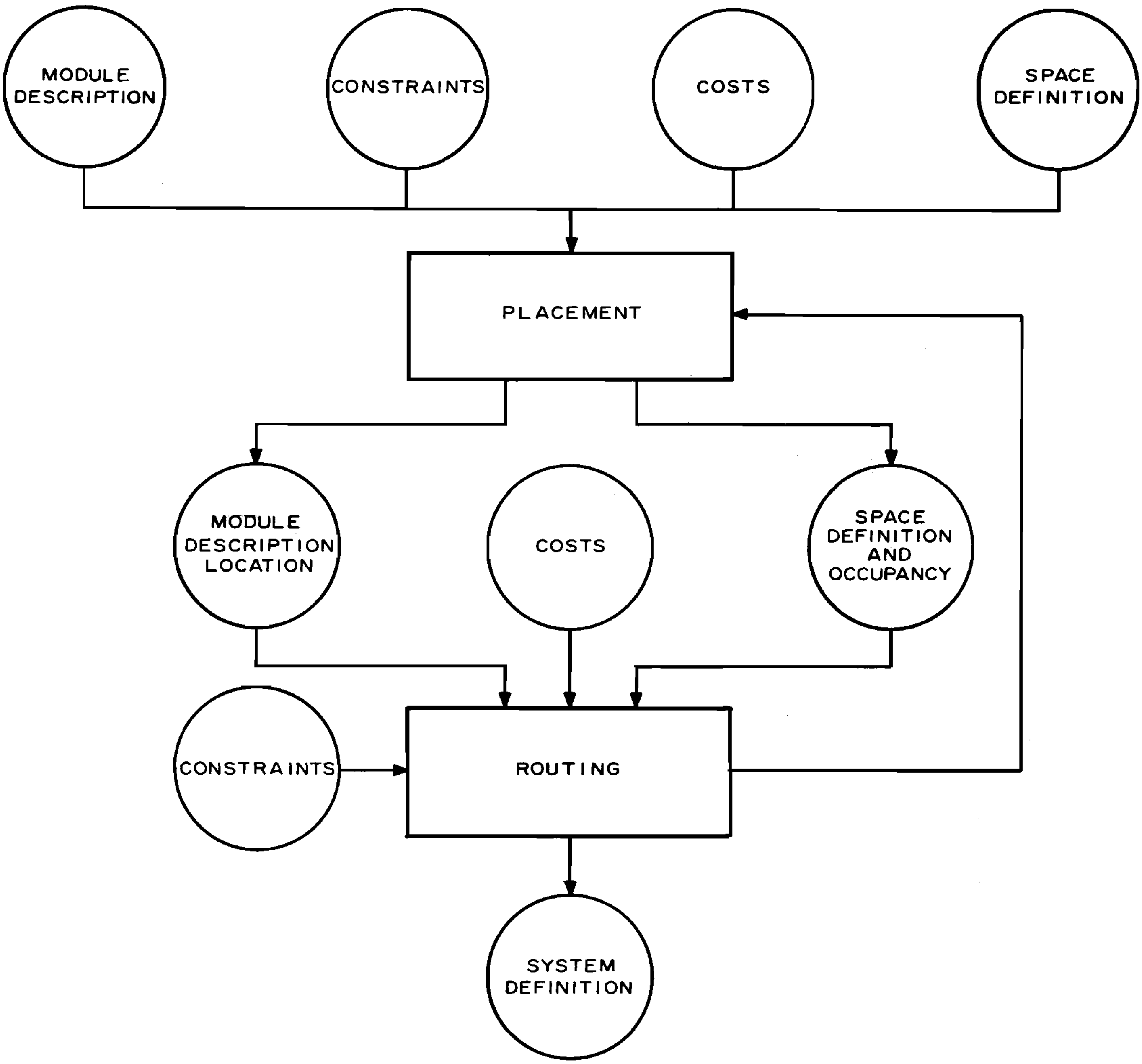
[1] *The term "urban design model" will be used interchangeably with the term "land use plan design model" throughout this report. Strictly speaking the term "urban design model" is more correct since the model provides more output information on supporting facility design than is normally provided by a land use plan per se.*

Figure 1
PLACEMENT AND ROUTING PROCESS



Most of the mathematical techniques used in other planning models also do not directly relate to the urban design problem. The primary feature of the urban design problem is one of connectivity. Since connectivity is a topological concept, and since most models do not embrace topological techniques, they are not able to deal directly with connectivity. Even optimization techniques, such as linear programming, are poorly adapted to the urban design problem because they do not deal with discrete variables. Exceptions to the general rule are linear graph theory and certain discrete forms of dynamic programming. These techniques are capable of dealing with connectivity and are extremely valuable in urban design models. These two techniques have not been extensively utilized in planning models up to this time.

The preceding theoretical discussion is best understood in the light of an example. The original structure of the Land Use Plan Design Model was described in the May 1965 issue of the Journal of the American Institute of Planners and was further developed using Waukesha, Wisconsin, as a pilot example in SEWRPC Technical Report No. 3, A Mathematical Approach to Urban Design. This model, as originally structured, provided for the optimal allocation of land based on site development costs considering the need to meet total land demand within land capacity constraints. The pilot project used only residential cost data, but the model was capable of accepting cost (and constraint) data on other land uses as it was developed. This model used a linear programming algorithm to calculate the optimal solution.

Although the original model provided the basis for a feasible and potentially useful land use plan design model and a framework for all initial thinking, it suffered from two serious shortcomings requiring correction in order to allow further progress:

1. The model did not deal directly with the problem of locating land use activity units, such as neighborhood units, secondary schools, and hospitals, at various geographic site locations but dealt instead with the apportionment of land as a commodity to various land uses. The difference is subtle but important, with the latter approach being less flexible and more clumsy.

2. The model could not practically handle development costs dependent on interrelationships with other land uses as reflected in linkages, such as roads and utility lines. Only site-dependent costs were practical in the original model.

Both of the above limitations are the direct result of the use of linear programming as the framework for the model. The first reflects the inability of linear programming to deal with discrete as opposed to continuous variables, and the second limitation has the same origins. Both could theoretically be corrected through the use of integer programming, but integer programming is not computationally feasible for large-scale problems.

The proposed revised approach uses set decomposition techniques to accomplish the mathematical task of the Land Use Plan Design Model, which is to provide a land use plan design that minimizes the combination of site (intra-site) and linkage (inter-site) costs while complying with given design criteria (standards) derived from stated development objectives.

AN URBAN DESIGN MODEL

Basic Structure and Operation

The structure of the model is made up of the following elements:

1. Modules—land use activity units, such as shopping centers, hospitals, or residential neighborhood elements.

2. Cells As Subareas—land units representing geographic subareas of a planning area in which modules are "located" in the operation of the model.

3. Linkages—interconnecting elements between two or more modules necessary in the operation of the module; for example, a road, a sewer line, or a water main.

The operation of the model was originally subdivided into four phases:

1. CLUSTERCOMP

2. PLACECOMP

3. ROUTCOMP

4. MAPCOMP

The first phase, CLUSTERCOMP, was later merged with the second, PLACECOMP, for more effective operation of the model. In its first phase of operation, CLUSTERCOMP, the modules are grouped into clusters so as to minimize the interconnection linkages with other modules in the system. A set decomposition technique is used to form these clusters or "super-modules" in order to simplify the task of the second phase, PLACECOMP. The input to CLUSTERCOMP is a module matrix designating the required interconnections (linkages) between modules. The output of CLUSTERCOMP is a set of module clusters.

In the second phase, PLACECOMP, the module clusters synthesized in CLUSTERCOMP are located in the cells of regional space so as to comply with design standards and minimize combined site and linkage costs. A dynamic programming algorithm was originally used to determine the optimal solution. The inputs to PLACECOMP are the set of module clusters with their associated cost, space, and linkage requirements, together with data describing regional space. The output is a land use pattern.

Later experience with the CLUSTERCOMP and PLACECOMP computer programs indicated that these two programs could be combined into one PLACECOMP II program in which the modules are "clustered" and "placed" in the same program. This merger of the two programs was not only desirable from a theoretical viewpoint to avoid the suboptimization inherent in considering linkage costs and site costs sequentially rather than simultaneously, but it also has proven to be more computationally efficient. A set decomposition algorithm is used to provide "clustering" and "placing" in PLACECOMP II.

ROUTCOMP provides path locations for the linkages that will minimize total weighted linkage length in the system. Input consists of a set of linkage requirements expressed in matrix form. ROUTCOMP output defines the cell-to-cell routes of all of the linkages. The computational algorithm used for ROUTCOMP is similar to the Moore Algorithm used to determine minimal time paths in transportation networks.

MAPCOMP provides a display in map form of the land use plan design determined in PLACECOMP II and ROUTCOMP.

Objective: An Urban Design System

It is quite important to understand that an urban design model by itself is not a comprehensive design system. Without supporting input data and computer programs (software) capable of efficient operation on computer hardware, it is unlikely that the model will ever be used extensively in urban design. Present traditional intuitive urban design procedures are complete design systems in the sense that a whole set of procedures has been developed to facilitate their application. Any system, however automatic or optimal, developed to supplement or even replace existing traditional methods must at a minimum provide for all the elements of a workable design system.

Many urban planning models and models in other areas of application have floundered and have been relegated to the academic curiosity category because their development was not accompanied by the supporting peripheral procedures to make their application practical. Indeed, a real urban design system must consider more than input data, computer programs, and computer equipment. It must consider the urban design process itself and its relation to an interface between the designer and the urban design system. A proper man-machine interface will do much to increase the effectivity of the partnership between the designer and his tool: the system. In this part of the report, some of the basic questions involved in the synthesis of an urban design system will be considered. More detailed consideration will be given in a later chapter, but final answers to many practical aspects of the system will not become apparent until Phase III when training manuals and orientation courses are developed.

The first, and in some ways the most difficult, problem to be considered is that of input data.

Input Data

Operation of the model requires the following general classes of data as input to operate in conjunction in the model computer programs: forecasts, objectives and design standards, module elements, linkage elements, and development costs.

After processing through a series of data analysis programs, this data input to the model takes the following final form:

1. Soil Inventory Data

   For each of the areal cells used in the planning area being modeled, the land area represented by each of the soil types used in the cost functions must be measured.

2. Site Development Cost Data

   For each module-soil category combination, the site development costs associated with locating the module on that kind of soil must be estimated.

3. Areal Requirements and Connectivity Data

   For each module the land area required and the connectivity costs for linking that module with each of the other types of modules must be developed.

4. Partitioning Sequence

   Placement of each module in a cell occurs in a sequence of partitions in which the design area is successively divided in half and module elements are located in one of the two halves of the partition. For areas of uniform topography, this sequence may be fixed for any area of a given size; but areas of non-uniform topography and major facility links, such as freeways, benefit from a partition sequence which considers these natural (or man-made) boundaries in the partition sequence. In such cases, the planner has the option of selecting his own partition sequence. Each cell must be designated in a "half-area" for each of the successive partitions.

5. Partition Center-to-Center Distances

   The center-to-center distances between the half-areas of each partition must be entered to permit the calculation of connectivity costs.

These are the data requirements, but what are the implications for an urban design system? Is the data easily obtainable at both the community and the regional level? How costly is data collection and processing? Can it be obtained from other public or private agencies? Does it vary significantly in different regions of the county? These questions must be answered in the development of an urban design system. The problems of implementation, however, are better understood after a brief description of model operation.

Model Operation

Given the input information described above, the model operation is initiated with a random initial placement of modules in the two halves of the first partition. From this starting point, model operation attempts to improve the initial partition by transferring modules to the other half of the partition so as to minimize the combination of site costs and connectivity (linkage) costs in the selected partition. A hill-climb procedure is used in the model algorithm, but only adjacent partitions are examined. An adjacent partition is one that can be formed by moving only one element from one-half of the partition to the other half. The hill-climb process continues until no improved partition can be found by moving a single element from one-half of the partition to the other half.

In the next phase of model operation, a second set of partitions is synthesized from the halves of the first partition. Each element is then assigned to one of the halves of the second set of partitions. No module once assigned to a half of a partition can ever be reassigned back to the other half in a later partition. In other words, the assignment of modules to areal cells occurs as a series of binary decisions in which the modules are sequentially divided in half and then divided in half again and again until all are assigned to cells in the last partition. The final result is a placement of modules in areal cells that will minimize site development and connectivity costs within the restrictions imposed by design constraints. Such constraints are imposed through the use of "real" or "dummy" costs which are either very high or very low (even negative) so as to insure or prevent the adjacent location of particular sets of modules.

The output is now presented in tabular form with the location of each module being specified in a list of cells designating the modules located in each cell. A map-type presentation of the plan design is under development and will represent only a slight modification of an existing mapping program at the Southeastern Wisconsin Regional Planning Commission.

Second only to the problems of input data preparation are the procedures used in the actual operation of the model program in a well-conceived urban design system. The strong recent trend toward larger digital computers with giant-size memories and incredible speeds has tended to isolate the user from computer operation to such an extent that he has lost touch somewhat with the problem of model operations and has lost his "feel" for the problem solution. The typical computer operator of such a larger computer has little background and sometimes less interest in the operation of the model other than that it "runs" in a technical sense, so that the computing time will be reimbursable.

Although large "closed shop" type computer operations may be quite suitable and perhaps most efficient for some forms of business data processing or repetitive technical calculations, the operation of an urban design model seems to have more in common with the recent on-line use of computers in laboratory experimentation and man-machine graphic design than it does with the more conventional forms of data processing. For this reason, the urban design system should provide for the active participation of the planner or engineer in the operation of the model. Such a participation would seem to call for the use of a smaller special-purpose computer with visual display to allow the planner to follow the module assignment process and allow him to mediate or influence this process in a real-time sense. Experience with simulation models in land use-transportation planning, which do not require such active participation from the planner as a design model, gives support to the contention that much of the wasted effort and time in the application of a model results from the inability of the planner to monitor actual model operations and thus prevent the errors and resulting re-runs that might have been avoided had the planner been able to monitor model operation. How much more so then is such monitoring a necessity in a design model with its more qualitative design criteria.

The problems of implementing a practical and useful urban design system in the form of both input data preparation and computer operation will be discussed more fully in Chapter VIII of this report.

The Land Use Planning Process

Plan design is only one of the functions that comprise the total sequence of developing and implementing a regional or community plan.[2] Other major functions in the planning process include:

1. Inventory, in which the present status of a planning area is determined through the collection, processing, and analysis of data on soil and water resources, land use activities, and existing facilities.

2. Forecast, in which elements exogenous to the system being planned are forecast. These include future levels of population and economic activity and related demand for land and resources within the planning area.

3. Formulation of development objectives and supporting plan design standards.

4. Testing of the plans for feasibility of implementation.

5. Actual implementation of the plan.

[2] *See SEWRPC Technical Report No. 3, A Mathematical Approach to Urban Design, January 1966, pp. 2-4.*

The sequence of these planning functions is shown in Figure 2. Land use plan design, it can be seen, occurs after the formulation of plan objectives and design criteria and before the testing of the plan.

Plan design is, however, a crucial function in that it interacts strongly with the other functions of the planning process. It establishes the classification and accuracy requirements for the forecasting function. It determines the mode of expression of design standards. It develops the plans for feasibility testing. Finally, it determines the rationale for plan implementation.

Non-Design Models

Mathematical models are today used extensively in most of the non-design functions of the planning sequence.[3] In all of the non-design functions, the model problem differs fundamentally from the design model problem. The non-design model problem is one of explaining or describing rather than prescribing as in the design model. The emphasis is on the explanation of how events are happening rather than how they should be happening.[4] Technically speaking, the non-design models are positivistic[5] rather than normative.[6]

The problem of a positivistic model, such as a forecasting model, may be stated as follows:

1. Determine a set of mathematical relationships that replicate real life phenomena.
2. Estimate the parameters that support these relationships.
3. Define and estimate exogenous variables affecting model operation.
4. Exercise the model in order to determine a range of possible outcomes for different values of the exogenous variables.

The normative model problem is distinctly different and may be stated as follows:[7]

1. Determine an objective function which represents the goals of the design.
2. Determine technical and other design constraints.
3. Provide an efficient search procedure for determining an optimal solution; that is, a solution which maximizes the objective function while abiding by the constraints.

Examples of positivistic models would include:

1. An economic forecasting model.
2. A trip generation model.
3. A trip distribution model.
4. A traffic assignment model.

All of the above models attempt to replicate or simulate a real life situation. An example of a design model is, of course, the Land Use Plan Design Model (or urban design model) that is the subject of this report.

[3] *See Bibliography reference No. 47.*

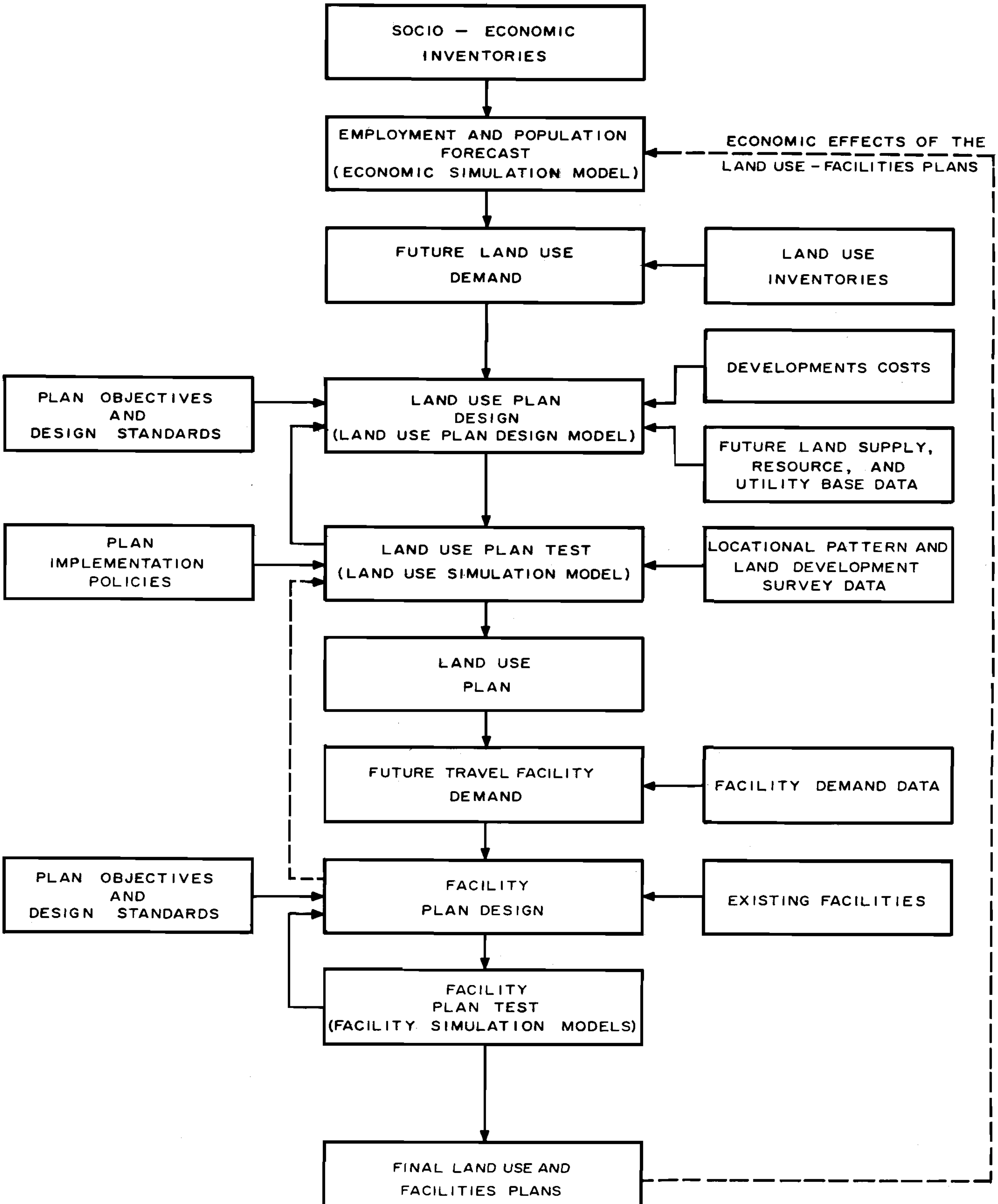
[4] *See Bibliography reference No. 41.*

[5] *See Bibliography reference No. 16.*

[6] *See Bibliography reference No. 26.*

[7] *See SEWRPC Technical Report No. 3, A Mathematical Approach to Urban Design, January 1966, pp. 9-22.*

Figure 2
COMPREHENSIVE PLANNING SYSTEM DIAGRAM



Chapter III
STATE OF THE ART IN URBAN PLAN DESIGN

DESIGN MODELS IN URBAN PLANNING AND DEVELOPMENT

Two major design model development efforts have preceded this project. One such effort was concerned with application to the urban design problem. The other was concerned with application to design problems in other fields. The latter effort has produced a more extensive set of design models that actually provide more theoretical support for the current land use plan design model development than has the effort to date actually concerned with urban design application.

Models that serve to generate and assist in the evaluation of alternative spatial patterns of land use are almost nonexistent in current land use planning programs. The closest parallel to such a model is found in less comprehensive models that attempt to optimize the location of facility modules, such as shopping centers, industrial plants, hospitals, or schools. There is evidence of the existence of a large number of such models, many of which have not been adequately documented in published literature.[1] Because of their less comprehensive and specialized nature, these models do not provide direct support for the design model of this project.

There is a class of urban design models of a different type, however, that has received wide attention in recent years. These urban design models, originally conceived and developed by Christopher Alexander, deal with the analysis of design criteria rather than with the generation and evaluation of alternative spatial patterns.[2] These models, which have been classified under the general category of set decomposition models, provide for the decomposition of design criteria into subsets. Such a subset classification is intended to aid the designer through the sequential design of a series of simpler plan layouts, which may be then superimposed for an ultimate design solution.

Although this set decomposition approach, as it relates to design criteria, was not directly applicable to this project, the work of Alexander and his associates is important for the following reasons:

1. Alexander has provided a clear definition of the design problem.

2. Some of the set decomposition mathematical techniques used by Alexander and Manheim in their "HIDECS" programs were found to be useful in the design model development for this project.

Alexander defines the design problem as one of providing a "fit" between the context of the problem and the form of its solution. In essence, the context is the definition of the problem; and the form is its solution. In the conventional terminology of urban planning, the context would consist of the set of design standards encompassing the requirements or criteria resulting from the development objectives to be achieved by the plan. The Land Use Plan Design Model is a means for determining this form of the design through a systematic search procedure that discovers a solution within the limits of the design standards that is minimal with respect to development costs.

The set decomposition techniques of Alexander and Manheim[3] are discussed in greater detail in Chapter VII of this report.

DESIGN MODELS IN OTHER FIELDS

Extensive development of design models quite similar to those conceived in this project has been underway for several years in the field of electronic design. These models relate to the problems associated with

[1] *See Bibliography reference No. 27.*

[2] *See Bibliography reference No. 1.*

[3] *See Bibliography reference No. 2.*

electronic packaging.[4] Electronic packaging design is concerned with the placement and interconnection of electronic equipment modules in equipment shelves, racks, or cabinets. It is also concerned with the routing of the interconnecting wires between these modules.[5] The analogy between the problem of electronic packaging and urban land use design is quite apparent. Land use plan design is concerned with the placement of land use activities and the routing of interconnecting facilities, such as streets and utility lines. This placement and routing process, which is illustrated in Figure 1, is identical whether the problem is one of electronic packaging or one of land use plan design.

The conceptual background and experience gained in placement and routing modules in electronic packaging design were invaluable aids in the model development under this project. Although the specific mathematical techniques used in these electronic design models were not directly useful in the urban design model, the background and conceptual framework were nonetheless of great importance.

With this brief description of historical background of design models, the details of the state of the art of each of the other components of urban design systems will now be examined.

CURRENT STATUS OF THE SUPPORTING COMPONENTS OF A PLAN DESIGN SYSTEM

The state of the art of plan design systems cannot be understood without an examination of the status of each of the supporting (non-model) components of such a system. Although the supporting components to be discussed have rarely, if ever, been considered as supporting elements of a plan design model system, it is necessary to investigate these components, as such, in order to determine their influence on the effectiveness of the total design system. Inasmuch as these components are not usually combined into an urban design system, it is not surprising that the development of these components is both uneven and seemingly unrelated. The model input data component will be discussed first, followed by the computer hardware and computer software components.

Model Input Data

Forecasts: There exist many qualitative and quantitative techniques for forecasting population and economic activity levels which, in turn, determine land use and facility requirements. The economic approach to such forecasts is generally included under the subject designation of econometrics, and the population approach to such forecasts is included under the designation of demography. A complete discussion of either of these two vast fields is obviously beyond the scope of this report. The commentary will relate only to the manner in which forecasts developed by these two classes of techniques relate to the input requirements of the Land Use Plan Design Model.

A significant characteristic of both econometric and demographic forecasts is their high degree of aggregation. Econometric forecasts usually deal with variables, such as gross national product (or gross regional product), industrial production, or employment. At a somewhat greater level of detail, these forecasts may be made in terms of standard industries as defined by the Standard Industrial Code (S. I. C.) of the U. S. Bureau of the Budget. Demographic forecasts are usually expressed in terms of age, sex, and race of various population groups. It should be quite apparent that the outputs of such forecasts do not necessarily meet the discrete forecast needs of modules used in a Land Use Plan Design Model. To be useful, such forecasts must undergo a matrix transformation to convert their outputs into forecasts of module type needs as classified under the Land Use Plan Design Model. Such transformations are, of course, crucially dependent on the accuracy of the matrix coefficients. Special forecasts of needs for various types of facilities, such as schools, hospitals, and parks, may provide a second source of model input information. In most cases, however, such special facility forecasts are also based on transformations of population or economic activity furnished by econometric or demographic techniques.

It would seem, then, that the most practical approach to meeting the forecast needs in an urban design system is to develop a transformation matrix that will be applicable to conventional econometric or demographic forecasts. Such an approach is necessary if the design model project is to avoid becoming involved

[4] *See Bibliography reference No. 22.*

[5] *See Bibliography reference No. 54.*

with the field of forecasting itself. Experimenting in such a large and complex field would obviously deplete the resources of the research effort. Since most econometric and demographic forecasts tend to agree within a certain level of tolerance, it would seem that the transformation matrix approach would be practical in most instances. Such a transformation matrix would relate directly to the design standards developed for each of the module types. Such design standards would specify the number of modules required per unit of population or economic activity and are designated "allocation standards" in the land use plan design model system. Some modules will be directly dependent on population or economic variables. Other modules will be indirectly related through their numeric relationship with these primary modules.

Objectives and Design Standards: The terms "objective" and "design standard" have been subject to a wide range of interpretation and application. For this reason, it is important to provide definitions to orient future discussion to a common reference base. The following definitions will provide this common frame of reference:

1. Objective: a goal or end toward the attainment of which plans are directed.

2. Standard: a criterion used as a basis of comparison to determine the adequacy of plan proposals to attain objectives.

Based on the above definitions, it will become apparent that the design model is concerned directly only with standards and not objectives. Objectives are used in the formulation of design standards as criteria for the desirability of alternative plans, but the design model itself is confronted only with the design standards as such, whatever their source or origin.

There is no lack of descriptive literature relating to planning objectives and design standards. The better community and regional planning reports today make some statement regarding objectives and standards. What is usually lacking is a comprehensive statement relating to a classification of objectives and design standards. For the Land Use Plan Design Model, all objectives must be translated into design standards, which must be expressed in terms of the module elements that they affect. This module-based organization of design standards seems to be completely lacking in the literature.

There have been attempts to classify objectives and design standards in a systematic way. A good example resulted from a study in northeastern Illinois[6] which defined basic goals of: economic health, education and culture, physical and mental health and safety, aesthetics, transportation, choice of physical and social environment, social position, participation in decisions, best land use, and leisure. Under these basic goals, an aspatial goal was defined; and a series of spatial goals was elaborated. This classification was more thorough than most, but it is still difficult to translate into useful design standards to constrain the spatial placement of modules in the design model. For this reason, it is of indirect rather than direct benefit to the project. Since no set of objectives and design standards was directly applicable to the design model, it was decided that the SEWRPC objectives and design standards should be modified to comply with design model input requirements. These modified objectives and design standards were then used as the pilot model application.

Module Definition: The module concept is not new to planning. This concept has been presented as an alternative approach to the manipulation of spatial arrangements in site planning.[7] At a larger scale, the neighborhood unit has served as a basic module in the formulation of many community plans. The module manipulation process has remained intuitive, however; and there has been little detailed discussion of the methodology involved. An exception is a discussion of a sequential heuristic module manipulation planning application in the United Kingdom.[8]

In the Katesgrove application, a series of residential, commercial, industrial, recreational, and educational modules was located in a preselected area so as to satisfy certain design standards. The process

[6] *See Bibliography reference No. 36.*

[7] *Kevin Lynch, Site Planning, (Cambridge, Massachusetts: The M.I.T. Press, 1962), p. 117.*

[8] *See Bibliography reference No. 11.*

was sequential and intuitive. Apparently, neither site nor linkage costs were directly considered, though there may have been an indirect effect through the design standards constraints. In essence, this example is a systematic explanation of the thought processes of intuitive land use planning.

The module approach has even been hailed as the key to understanding a wide range of physical and social processes.[9] This discussion is at a general level that is difficult to apply to a plan design model, but does serve to stimulate thought.

Linkage Definition: The concept of a linkage is complementary to that of a module in the land use plan design model concept. In the sense of a linear graph,[10] the modules represent the nodes of the graph and the linkages represent the interconnecting links.[11] The concept of a linkage, although not generally defined by that term, is more generally accepted in planning practice than that of a module. The idea of a linkage is closely related to the more general concept of a network. Planners and engineers have visualized electrical systems, highway systems, and sewer systems for many years in terms of a connected network. The general acceptance of the network concept and the straightforward analogy between a linkage and a linear physical facility, such as a highway, make the problem of linkage definition almost trivial. It is important in linkage definition, however, to consider the effects of such definition on the estimating of the development costs of these linkages. If the linkages are not properly defined, it may be quite difficult to obtain development cost data consistent with these definitions.

Cost Parameters: The collection of cost data and the subsequent estimation of cost parameters are perhaps the most formidable tasks of data collection and reduction in a plan design model system. Although great quantities of cost data exist from many sources, these data are generally fragmentary, scattered, and unrelated. It, therefore, has been necessary in the design model project to gather cost data from a variety of sources for different land and facility development application.[12] The procedures used in the estimation of development costs are described in Chapter VI of this report.

Computer Hardware

The third generation of computer hardware as exemplified by the IBM System 360 series, Burroughs System 3500, and smaller systems, such as the Digital Equipment Corporation PDP-8, is fully capable of the data handling and model computation tasks involved in the implementation of the Land Use Plan Design Model. In fact, it is likely that second generation machines, such as the IBM 1620, were fully capable of handling system implementation. The barriers to progress have not been primarily hardware barriers but have been instead:

1. The lack of a model and its associated computer programs.

2. The lack of an efficient information file software system for handling the model input data.

Computer Software

Third generation computers have been accompanied by extensive developments of system software (programs) to increase their operational efficiency. These programs consist of user language programs, such as Fortran and Cobol, and operating systems to provide automatic management of computer operations. The Fortran language has been extremely important for the design model since it has been the programming language for all programming to date. Operating systems are not of direct importance to the design model, but they are of indirect importance in their effect on overall computer efficiency in conjunction with other programs.

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[9] *See Bibliography reference No. 24.*

[10] *See Bibliography reference No. 5.*

[11] *See Bibliography reference No. 15.*

[12] *See Bibliography reference Nos. 3,9,10,12-14,17,29,31-33,38,42,50-53, and 55.*

The primary software requirement that would materially assist the model system is a file information system for the definition, organization, maintenance, and retrieval of model input data. Some significant effort has been in evidence in this area in recent years,[13] and such generalized file information systems are beginning to become practical.[14] In the near future, it should be possible to adopt existing file information systems to the needs of the plan design system. File information systems, as they relate to an urban design system, are discussed in detail in Chapter VII of this report.

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[13] *See Bibliography reference No. 49.*

[14] *See Bibliography reference Nos. 19-21 and 44-46.*

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Chapter IV
MODULE DEFINITION

THE MODULE

The module is the basic element of the plan design model. It is the unit that is manipulated in the placement process in model operation. It is also the vehicle for the expression of design standards in the form of constraints to this spatial manipulation. The module is both a physical entity in that it has a spatial dimension and associated development costs and a functional entity in its defined activity and its relationship with other modules. The modular nature of the model makes it necessary that the module be defined as a discrete entity that has well-defined internal characteristics and distinct interchange relationships with other modules. The definition of a set of modules must include the internal organization of each module, as well as its external relations. Such a definition implies the detailing of characteristics, such as physical size, functional and physical descriptions, and external linkage requirements.

A PHYSICAL ENTITY

The module as a physical entity must be described in terms of the areal requirements of each of the physical units making up the module. The definition of these units and their dimensions illustrate the basic internal organization and structure of the module.

A compromise is involved in the size definition of the module. The size selected for each module type must be related to the functional and locational requirements of the land use activity involved. The module logically consists of a primary land use activity area and all contiguous appurtenant areas requisite to its support and proper functioning. For example, a medical center module may consist of a hospital building site, off-street parking areas, heating plant and accessory buildings, internal vehicular circulation areas, pedestrian circulation areas, open space and landscape areas, ingress-egress zones, and the module share of the arterial street and collector street rights-of-way which serve the medical center and upon which it may front. This approach insures that the facilities required to serve each activity or module, and the costs of imposing desirable design constraints, are properly charged against that activity. In addition, this approach facilitates the control of the gross acreage to be assigned to development. In the definition of the modules, an attempt was made to minimize the size of the module within the limitation that each module must represent a self-sufficient, viable unit.

A particular point of potential confusion may concern the incorporation of street rights-of-way as part of the module area and the contrasting role of rights-of-way as a linkage in the model organization. This apparent contradiction is also apparent with other linkages in addition to rights-of-way; as, for example, gas transmission lines, telephone cables, electric power transmission lines, sanitary sewer mains, and public water supply mains. This disparity in usage may be rationalized as follows: the sanitary sewer laterals and mains servicing the module are included as site development costs and are viewed as marginal capital costs incurred to service the module. The sewage treatment plant, pumping stations, and trunk sewers, however, are considered linkage costs of module interconnection. The same reasoning may be applied to other site costs when they appear to infringe upon the identity of linkages.

A FUNCTIONAL ENTITY

Each module performs a function or functions based on its land use activity. These functional characteristics become critical in the classification and definition of each module type inasmuch as locational requirements depend upon function. Since location is discrete, function, too, must be discrete. In fact, the function of the module generates the interchange between modules and conditions the need for accessibility and compatibility to other modules.

Functional Requirements

The Accessibility Dimension: The function of each module determines the physical interchange requirements between it and other module types. For each module type, an inter-module standard specifies the desired distance or time limits between modules of different types. These limits represent the accessibility dimension of the module's function. For example, a specification that elementary schools be located within one-half mile of each residential module would comprise such an inter-module standard. It ostensibly reflects the need for proximity because of frequent physical and social interchange between residences and elementary schools. As previously pointed out in Chapter II, accessibility requirements are reflected in the inter-module linkage cost segment of input data. High accessibility requirements between a given set of modules are equivalent to high linkage costs between these same modules. Such linkage costs reflect both the cost of providing facility links (such as highways) between the modules and the cost of operation.

Connectivity: The linkages between modules as specified in the intra-modular and inter-modular design standards represent the connectivity requirements. These linkages and their associated costs will condition the spatial configuration developed by the model in the placement process since the model operates so as to minimize the site and linkage development costs within the limits imposed by design standard constraints.

The Compatibility Concept: The term compatibility, as used in design standards, is meant to define the desirability or the undesirability of locating modules contiguously with one another. Although the concept of compatibility is usually considered separate from the concept of accessibility, both concepts basically represent the same type of requirement. Both convey the requirement for either time or distance spacing between modules. As typically applied, they differ in that accessibility emphasizes physically unreasonable variables, such as time, distance, and cost, while compatibility stresses more qualitative variables, such as aesthetic and environmental considerations.

Compatibility design standards, since they are very qualitative in nature, must be expressed as artificial or "dummy" cost inputs to the model. In this sense they are unlike accessibility standards, which represent real costs of facility construction or module-to-module communication. Since compatibility standards will tend to override accessibility standards, the real cost of accessibility will provide a price which may be used to evaluate the degree of desirability of any compatibility standard.

THE MODULE TYPE SET

Based on the above considerations of a module as a physical and a functional entity, a set of module types was identified and defined using a standard format. Although the actual module types used in any application of the model in a region or community may vary from the list below, the present module type set is considered typical.

The following modules have been selected, defined, and dimensioned for use as model inputs:

1. Residential (low-density), see Appendix I.

2. Residential (medium-density), see Appendix I.

3. Residential (high-density).

4. Neighborhood commercial center (low-density), see Appendix I.

5. Neighborhood commercial center (medium-density).

6. Neighborhood commercial center (high-density).

7. Community commercial center, see Appendix I.

8. Regional commercial center.

9. Highway commercial center (center auxiliary).

10. Highway commercial center (arterial auxiliary).

11. Highway commercial center (freeway and expressway auxiliary).

12. Highway commercial center (recreational auxiliary).

13. Planned industrial district (light), see Appendix I.

14. Planned industrial district (heavy).

15. Junior high school (public).

16. Junior high school (private).

17. Senior high school (public), see Appendix I.

18. Senior high school (private).

19. Medical center (short term).

20. Medical center (long term).

21. Medical center (nursing and related).

22. Public college.

23. Private college.

24. Library (regional).

25. Library (community).

26. Library (branch).

27. Church.

28. Cemetery.

29. Police station.

30. Fire station.

31. Community recreational center.

32. Regional recreational center.

33. Community cultural center (intensive).

34. Regional cultural center (intensive).

35. Regional cultural center (extensive).

36. Incinerator and sanitary land fill.

37. Institutional center (regional).

38. Municipal hall (community), see Appendix I.

39. Municipal hall (regional).

40. Airport (community).

41. Airport (regional).

42. Intra-regional rapid transit terminal (rail).

43. Inter-regional rail transit terminal (passenger).

44. Intra-regional rapid transit terminal (bus).

45. Inter-regional bus transit terminal.

46. Gas storage and distribution terminal.

47. Water treatment plant.

48. Water pumping plant.

49. Water source.

50. Sewage treatment plant.

51. Electric power generation plant.

52. Electric power substation.

MODULE DEFINITION PROCEDURE

Module definition is itself a form of design since to define a module in detail is to design it. Indeed, it would be possible to apply the Land Use Plan Design Model at this microscopic level to aid in this definition of a module. In this project, however, modules were defined heuristically according to the following sequence:

1. Module name designation.
2. Module area specification.
3. Allocation of the module area to module components.
4. Definition of land use categories represented in the module.
5. Definition of module purpose.
6. Specification of intra-module design standards.
7. Specification of the following inter-module design standards.
    a. Allocation standards.
    b. Spatial accessibility and compatibility standards.
    c. Resource conservation standards.

d. Linkage requirements standards.

Examples of Module Definitions

Examples of module definitions are included in the Appendix to this report. These sample modules are intended to illustrate typical examples of modules and are not intended to be absolute or optimal in any sense. The structure of the Land Use Plan Design Model is quite flexible and does not depend for its operation on any particular module definitions. Modules may be modified by the designer as required.

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Chapter V
OBJECTIVES AND DESIGN STANDARDS

INTRODUCTION

The purpose of this chapter is to define the terms "objective" and "standard" and to explain the classes of design standards used as inputs to the design model and the manner in which these design standards affect model operation. It is not the intent of this chapter to present specific objectives or design standards of universal applicability to many urban areas.

The terms objective and design standard have been defined previously herein, but the definitions are repeated here for convenience.

1. Objective: a goal or end toward the attainment of which plans are directed.

2. Standard: a criterion used as a basis of comparison to determine the adequacy of plan proposals to attain objectives.

THE DESIGN STANDARD AS A CONSTRAINT

The role of design standards in the model is best understood in the light of the nature of the design model as a placement and routing process. This process is illustrated in Figure 1. From the diagram it can be seen that the first phase of model operation involves the placement of the modules in space. Four primary inputs are required to this placement process: 1) module descriptions, 2) constraints on the design solution, 3) the costs of development (both site and linkage), and 4) space definition.

In the placement and routing process, design standards act as constraints on the design solution. They tend to reduce the number of feasible solutions; that is, the number of combinations the model must search in order to attain an optimal solution.

The nature of a design standard as a constraint provides a definite requirement as to the manner in which these standards must be defined. The most fundamental requirement is that the standards be quantifiable, at least in the binary sense. A binary standard is one in which it must be possible to state whether the standard is met by a certain plan or whether it is not. Some standards must be more extensively quantified in the sense that a scalar number must be provided; but the overwhelming number of standards, since they act as constraints, are really only "yes" or "no" binary criteria.

It is really not possible to discuss in a general way the nature of standards since different standards tend to affect model operation in different ways. The discussion in the following paragraphs will classify standards in the way that they affect model operation. One important distinction, however, must be made even before standards are classified. This distinction relates to the difference between the design standard as a criterion for a design and the quite different application of a design standard as a partial design solution. The only legitimate design standard, from the viewpoint of a design model, is a standard that provides a value or criterion to judge or evaluate a solution. The standard must never be a solution in itself. If used to provide a design solution, a standard precludes the need for a design model at all. In this chapter, we will be concerned only with standards that act as design criteria and not with standards that provide preconceived solutions.

CLASSIFICATION OF DESIGN STANDARDS

Analysis of the development objectives and design standards formulated to date in southeastern Wisconsin has indicated that design standards may be classified into two basic groups based on their effects on model operation.

Design standards may be classified by a number of different methods, but the most basic separation is between standards that affect the internal organization of a module versus those that affect the external relationships between modules. The internal type of design standard will be designated here as an intra-module standard, while the external design standard will be designated as an inter-module standard.

An intra-module standard affects the definition of the module only and affects model operation only indirectly in its definition of module size and physical characteristics. An inter-module standard is one that affects the relationships between modules. This type of standard has a direct effect on model operation. In this chapter, we will be concerned further only with inter-module standards.

The classification of inter-module standards to be described is based upon the design standards formulated in the regional land use-transportation study of the Southeastern Wisconsin Regional Planning Commission. These standards are believed to be, however, typical of the design standards that might be formulated in other areas. Analysis of the design standards used in southeastern Wisconsin has indicated four basic classes of design standards:

1. Allocation Standards

   An allocation design standard designates the number of modules of one type in relation to the number of modules of other types. This type of standard affects only the numbers of each module type that are provided as input data to the model. It does not affect directly the operation of the model itself. The final plan design, however, can be profoundly influenced by the number of modules of each type provided as input.

2. Spatial Accessibility and Compatibility Standards

   These standards specify the spatial distance or access time requirements needed between modules. This type of standard directly affects model operation in the module placement process. It is important to understand that a given set of accessibility and compatibility standards may be infeasible in that they present conflicting and unattainable accessibility and compatibility requirements. In model operation the need for a close accessibility is obtained by the insertion of a high "dummy" linkage cost in the model. Such a high cost will tend to locate the modules as close together as allowed by other constraints. A standard designating certain modules as incompatible is expressed in terms of a very low "dummy" linkage cost. Such a low cost will tend to provide for the separation of these modules in the final plan design.

3. Resource Conservation Standards

   These standards provide for the exclusion of certain land from development by certain types of modules. This standard also directly affects the module placement process. It is implemented in model operation by the provision of high "dummy" site costs for those module-resource combinations which are considered incompatible. Such high site costs will tend to prevent the location of the modules on the incompatible land space which should be preserved for sound resource conservation reasons.

4. Linkage Requirement Standards

   These standards require that various utility, transportation, and other services be provided to designated modules. This standard affects the module linkages that are provided as input data with each module. In this sense, it is like the allocation standard in that it affects input data and, therefore, plan design but does not affect the operation of the model itself.

Chapter VI
DEVELOPMENT COSTS: SITE AND LINKAGE

ROLE OF DEVELOPMENT COSTS IN THE MODEL

The primary objective of the Land Use Plan Design Model is to spatially allocate land uses within a planning area so as to minimize development costs within the constraints imposed by stated development objectives and standards. The model thus requires, as one of its necessary inputs, construction, maintenance, and operation costs for each of the various supporting facilities, such as streets, sewer lines, and water mains, and for each of the several elements associated with site development, such as grading, building foundations, and parking lots. Moreover, these development costs must be relatable to various possible spatial locations within the planning area.

A means for readily relating development costs to specific geographic subareas of a planning area or region was not at once evident. After some search for such a means, the concept of utilizing detailed operational soil surveys as the basis for relating costs to geographic location was developed.[1] Development costs vary with soil type, and the detailed operational soil survey provides a ready means for relating these costs to mapped areas. Moreover, the necessary soil surveys are based on relatively well-developed and standardized techniques and are available nationwide on request.

Cost values are input to the model in two basic forms: cost per unit distance of inter-module linkages and as total cost of land development of complete unit modules of land use. An inter-module linkage may be defined as a service utility line; for example, a water main, forming a necessary connection between two modules of land use. A linkage is inter-modular in nature and implies linearity as opposed to area.

Internally each module type has been defined as containing certain areas allocated for such uses as building site, parking, vehicular circulation, landscaping, loading facilities, and certain service utility improvements, such as water, gas, electric, and telephone transmission lines, as required for that module type. Site development cost then is the total cost of construction of all facilities and necessary associated service utility lines internal to a particular module type.

The foregoing definition of site development cost needs to be modified in light of one of the basic concepts underlying the model; namely, that construction costs are variable with soil characteristics and condition obtaining at the job site. Thus, only those components of each facility whose cost is related to soil type need be priced. For example, a building of given dimensions and weight will require more elaborate and hence more costly foundations if placed on marsh than if located on soil containing a high percentage of coarse grained material having comparatively high bearing strength. The superstructure becomes irrelevant, and only the comparative costs of placing the foundation on the two different soils need be considered. Again, a parking lot of given size and capacity will require different thicknesses of surface and corresponding capital expenditures depending upon the bearing capacity of the soil upon which it is constructed. Costs of grading of sites are a function of both the quantities of earth moved as determined by topography and of soil type.

One may visualize a module unit of, say, one city block square containing certain facilities in fixed quantities and arrangements. As this unit is moved about over a planning area, the costs of construction of all soil-related components of the facilities and hence the site development cost will in theory be continually changing with change in soil type and topography. Costs of construction of the inter-modular linkages, too, will, of course, be a function of the terrain upon which they are placed. Hence, as module locations change, associated linkage costs will change.

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[1] *This concept was first advanced in connection with the land use simulation model developed under the Southeastern Wisconsin Regional Planning Commission's Regional Land Use-Transportation Study.*

Dollar costs, as such, are of no consequence to the model. Only the relative dimensions of the various linkage and site development costs are significant, and all costs may be reduced to relative terms. A subroutine was developed to generate a matrix of soil category-module type values. This matrix becomes an input to the model itself.

EXPLORATORY TECHNIQUES

The initial emphasis in the development cost phase of the project was the conception and formulation of methods and processes for compiling the required data, followed by investigation of some of the possible sources of data to determine whether the preconceived methods were feasible and, if not, what compilation techniques were best suited to the data sources as they existed in fact. The development cost study then entered a second stage, the objective of which was analysis of the data obtained to provide input for trial runs of the model.

Compilation Procedures Explored

A number of procedures for developing urban development cost data suitable for the design model application were explored. At the outset it was hoped that comprehensive compilations of development costs in the existing technical literature would provide the major portion of the cost functions needed for model operation. A careful search of materials in the engineering libraries of the University of Wisconsin, Madison, Wisconsin, and of Marquette University, Milwaukee, Wisconsin, produced only relatively piecemeal references to, and listings of, urban development costs. No comprehensive listings of the kinds of cost data required have been discovered.

The apparent absence of any previously prepared rosters of urban development, maintenance, and operating costs necessitated the assembling of one. Primary sources of information have been the historical cost records of certain governmental agencies within the Region; notably, the Bureau of Engineers, City of Milwaukee, and the District 2 Office of the State Highway Commission of Wisconsin.

"Basic Items" Approach: The "basic items" approach was conceived during the early efforts to formulate a systematic method for compiling development costs. The construction operation for each of the improvements necessary to support urban land development was to be separated into what were believed to be basic items of procedure and operation for both the preconstruction and construction phases. For example, in the case of streets and highways, the total construction operation was seen as the sum of three preconstruction items and eight construction items, namely: 1) preconstruction engineering (design and surveying), 2) right-of-way acquisition, 3) overhead, 4) construction engineering (inspection), 5) clearing, 6) grubbing, 7) topsoil, 8) grading, 9) pavement, 10) drainage, and 11) signs and guardrails.

This approach was believed to have two advantages. First, it was thought that the synthesis of total construction costs by summation of typical costs of the several items would yield a more representative development cost than would the averaging of the total construction costs of actual projects. Secondly, those construction operations which are heavily influenced by soil character and condition could be separated from those items which are only slightly affected by soil character and condition at the job site. For example, in street and highway construction, the grading, pavement, and drainage items are markedly influenced by the soil conditions encountered, while the remaining eight items are relatively independent of those conditions.

Study of historical cost records at the sources available forced the conclusion that this approach, advantageous as it appeared to be, was impractical. Generally, the data was available only as bid prices per unit distance; and no rational means for breaking down these figures to correspond with the basic items mentioned above could be found. At those sources, notably the State Highway Commission of Wisconsin, District 2 Office, Waukesha, Wisconsin, where it appeared that the nature of the data would permit use of the itemized format, it soon became apparent that the research effort required to "pull" the data from the historical cost records and rearrange it into the desired form would require appreciably more time than was practically available for the task.

Historical Cost Records Search: Originally, it was hoped that the soil-construction cost correlation could be demonstrated by taking data from the historical cost records more or less at random and relating those costs to the soil character and condition known to exist at each job site. For example, the costs of several jobs each involving, say, eight-inch diameter concrete sanitary sewer pipe laid at a constant average depth would be correlated with certain soil characteristics and conditions at the corresponding job sites. Multiple correlation techniques were to have been used to establish correlation of cost with such specific soil characteristics as, for example, the percentage of fines passing the No. 200 sieve and soil permeability.

It was soon recognized, however, that the values used, that is, bid prices per unit distance of successful bidders, were for several reasons sensitive to other factors, as well as to soil conditions; and the level of research necessary to develop such a correlation, if it could in fact be established from historical records at all, was beyond the scope of the current project.

The factors exercising significant influence on the values of successful bid prices are basically two: contractors' bidding practices and soils information. A contractor's need or desire for work and his anticipated competition and labor costs sometimes motivate him to offer bids known to be unrealistic in relation to true costs of performance. Bid prices are often further unbalanced by the necessity, or at least the practice, of preparing bids without adequate soils information at hand, the element of risk operating to increase the proffered bid. Even where adequate soils information is available and used, actual field conditions are generally so complex that risk cannot be entirely eliminated.

Preselection of Gross Soil Categories: Recognition of the operation of other factors to mask any de facto relation between soil characteristics and construction cost led to the adoption of more gross categories of soil character and condition than originally intended. Three broad divisions of soil characteristics, together with the possibility of bedrock outcrops, were finally selected for use. All soils identified and mapped in the detailed operational soil surveys may be classified into one of the three divisions. As shown in Table 1, each division is cross-referenced against three soil conditions simultaneously: depth to water table, depth to bedrock, and slope or degree of terrain ruggedness.

In theory the soil category system (Table 1) which has been adopted for use with the model differs from the scheme originally conceived principally in the degree of refinement of the soil character groupings selected. The three divisions—fine grained soils, coarse grained soils, and highly organic soils—seem reasonable for a first attempt to demonstrate the soil-cost correlation. The task is virtually without precedent. With further research more refinement in the correlation may prove to be feasible.

The decision was made to abandon use of historical cost records in favor of expert estimates in the effort to establish a soil-cost correlation. This was done because of the realization that the undertaking of the alternative approaches, if possible at all, was too extensive to be accomplished within the time and cost limitations imposed in the current project. Before passing to a discussion of the use of expert estimates, a singular aspect of the historic cost records search technique deserves mention.

Energy Approach: Study of the records of the Metropolitan Sewerage Commission of the County of Milwaukee; the Bureau of Engineers, City of Milwaukee; and of the State Highway Commission of Wisconsin disclosed data on man-hours and machine-hours expended on each job. The logs are kept by project engineers or inspectors on a daily basis. The existence of these records suggests the possibility of measuring construction costs in man-hours and machine-hours rather than in dollars, which, as noted, frequently do not accurately reflect actual energy expenditures required. This approach should override not only the effects of erratic bidding practices mentioned earlier but regional differences in construction costs and wage scales would become irrelevant as well. As a check, the daily logs of City of Milwaukee inspectors were used to calculate man- and machine-hours expended on three sewer construction jobs. The results are shown in Table 2. It can be seen that man- and machine-hours show the expected general relationships to diameter and trench depth.

The energy expenditure approach deserves consideration for further research and development as a source of accurate cost data and is perhaps the most promising means for precisely demonstrating the soil-cost correlation. Apparently, many public works agencies already keep logs of man- and machine-hours as

Table I

SOIL CATEGORY RELATIONSHIP MATRIX

Unified Soil Classification	Slope Group[a]	Less Than 1 ft. To Water Table			1 ft. To 5 ft. To Water Table			5 ft. And Over To Water Table		
		Less than 2ft. to Bedrock	2ft.-5ft. to Bedrock	5ft. and over to Bedrock	Less than 2ft. to Bedrock	2ft.-5ft. to Bedrock	5ft. and over to Bedrock	Less than 2ft. to Bedrock	2ft.-5ft. to Bedrock	5ft. and over to Bedrock
Fine Grained Soils	A	1111[b]	1121	1131	1211	1221	1231	1311	1321	1331
	B									
	C_1									
	C_2	1112	1122	1132	1212	1222	1232	1312	1322	1332
	D_1									
	D_2									
	E	1113	1123	1133	1213	1223	1233	1313	1323	1333
	F									
Coarse Grained Soils	A	2111	2121	2131	2211	2221	2231	2311	2321	2331
	B									
	C_1									
	C_2	2112	2122	2132	2212	2222	2232	2312	2322	2332
	D_1									
	D_2									
	E	2113	2123	2133	2213	2223	2233	2313	2323	2333
	F									
Organic Soils	A	3111	3121	3131	3211	3221	3231	3311	3321	3331
	B									
	C_1									
	C_2	3112	3122	3132	3212	3222	3232	3312	3322	3332
	D_1									
	D_2									
	E	3113	3123	3133	3213	3223	3233	3313	3323	3333
	F									
Bedrock	A	---	---	---	---	---	---	4311	---	---
	B									
	C_1									
	C_2	---	---	---	---	---	---	4312	---	---
	D_1									
	D_2									
	E	---	---	---	---	---	---	4313	---	---
	F									

[a] *The percent average slope for each slope group is as follows: A equals 0.5 percent, B equals 3.5 percent, C_1 equals 7 percent, C_2 equals 10 percent, D_1 equals 13 percent, D_2 equals 17 percent, E equals 24.5 percent, F equals 37.5 percent.*

[b] *This four digit code number synthesizes four significant soil characteristics deemed requisite for cost estimation. Critical ranges of these characteristics; soil texture, depth to water table, depth to bedrock, and slope; are represented by the first, second, third, and fourth digits, respectively.*

Source: SEWRPC.

Table 2

COMPARISON OF MAN-AND MACHINE-HOURS

Pipe Diameter	Average Trench Depth	Man	Machine
8 inches	14.1 feet	76 hours	21 hours
12 inches	7.7 feet	27 hours	6 hours
72 inches	13.2 feet	203 hours	90 hours

Source: SEWRPC.

a standard practice. It may be possible to make those data more directly adaptable to the forms required by design models with comparatively minor modifications to existing daily logs.

Compilation Procedure Adopted

The method of development cost compilation adopted from among the several possible approaches explored as being the most workable within the limitations of the current project was the "expert estimates" approach. The soil categories in Table 1 were used as the basis for all service utility improvement cost estimates. Estimates of costs, and in certain cases quantities, were developed for each of the categories in Table 3 for each of the service utility improvements.

The costs obtained were for either unit lengths of the complete utility line or for certain specific operations inherent in the construction of the utility. For example, in the case of a sanitary sewer of given pipe diameter and trench depth, the construction cost was obtained as dollars per linear foot for each category. In the case of streets and highways, estimates of both the quantity of excavation as a function of topography and the cost of handling a unit quantity were estimated for each of the categories in Table 1, the product of these two values being used to adjust a base cost of street or highway construction to obtain cost per unit distance.

SIGNIFICANCE OF DEVELOPMENT COSTS

Only after further experience with the model application will the effect of variation in accuracy of cost data upon spatial land use allocations be known. From the point of view of development costs, one of the most important pieces of information to be gained from trial runs of the model is the percent inaccuracy of the input costs that can be tolerated without inducing significant change in the land use patterns produced. Again, from the development cost standpoint, the tolerable percent error of the cost figures is singularly important because the level of effort required to obtain cost values varies directly, but probably not linearly, with the degree of accuracy needed. Should the preliminary runs show need for relatively high levels of accuracy of cost data, and the model were to be widely adopted, it would seem highly important to ascertain the most efficient methods and sources for obtaining the level of accuracy known to be necessary as a guide to all future model users.

Time limitations implicit in the current project did not permit establishment of the soil character-construction cost correlation from historical evidence. Conceptually this initial phase will serve to expose and outline directions, methods, and research needs for the task of creating a rational method for development cost compilation and analysis.

Development Costs

In the latter stage of the development cost phase of the project, emphasis has been on the development of costs of construction of the several service utility linkages, such as sanitary sewers, water lines, and freeways, and the cost of providing each of the several elements, such as parking areas, paved play areas, and site grading, which are incorporated into the modules of land use. Also, road user and vehicle operating costs for each of the typical rural and urban highways, as defined by the Southeastern Wisconsin Regional Planning Commission, have been developed.[2]

[2] *See SEWRPC Planning Report No. 7, Volume 2, Forecasts and Alternative Plans--1990, June 1966, pages 24 and 25.*

All of the construction costs have been correlated with the categories of soil character and conditions. These soil categories are shown in Table 1. The final set of slope groups conform to those defined by the Southeastern Wisconsin Regional Planning Commission and permit closer approximations to the maximum slopes permissible for different land uses, such as, residential, industrial, and active recreation.

Other refinements to the soil categories (Table 1) are theoretically possible. For example, each of the three major divisions of the Unified Soil Classification—fine-grained soils, coarse-grained soils, and organic soils—could be expanded to the individual texture groups within each division. The bedrock category could be further subdivided into the subcategories of rippable and non-rippable rock. Also, the soil condition, 1 foot to 5 feet to water table, may be divided into two parts: 1 foot to 3 feet and 3 feet to 5 feet to water table.

In view of the present state of the art of service utility construction cost compilation and analysis and the existing level of refinement of soils information, further expansion of the soil categories in Table was not considered justified. The number of soil categories would be disproportionate to the accuracies of construction cost data and soils information now available. At such time as more precise cost figures and more detailed soils information become available, however, Table 1 may be expanded accordingly while retaining its present basic format.

It is significant that all of the categories of soil character (that is, the major divisions of the Unified Soil Classification) and of soil condition (slope group, depth to water table, and depth to bedrock) shown in Table 1 are identical with the forms of soil data available in Southeastern Wisconsin Regional Planning Commission publications and from soils maps.[3] For example, Table 4 of SEWRPC Planning Report No. 8 contains columns of data on Unified Soil Classification, estimated water table depth, and estimated bedrock depth for each soil found in the Southeastern Wisconsin Region. The average percent slope of each soil area in the Region is also readily available from soil maps, such as the one shown on page 15 of SEWRPC Planning Report No. 8.

RATIONALE OF COST DEVELOPMENT

Each module is made up of elements which occur in one or more of the several module types and in combination with one or more of the other elements as a functional subcomponent of the module. A number of common linkages also serve to interconnect a number of different modules.

It is these intra-modular elements and inter-module linkages for which costs of construction have been prepared. All such costs have been formulated within the framework of Table 1; that is, all costs are a function of soil texture, slope, depth to water table, and depth to bedrock. The common units of cost evaluation are dollars per linear foot for linkages or elements such as water or sewer lines and dollars per acre for elements such as parking lots.

The bulk of the raw data used in the development of costs was obtained from three sources: the Metropolitan Sewerage Commission of the County of Milwaukee; the District 2 Office of the State Highway Commission of Wisconsin, Waukesha; and the Department of Public Works, City of Milwaukee. Within the latter Department, assistance in the form of cost data and information was provided by the Bureau of Bridges and Public Buildings, Bureau of Engineers, Bureau of Street and Sewer Maintenance, and the Milwaukee Water Works.

To eliminate the need to perform numerous tedious manual computations, computer programs were written to generate costs in the format of Table 1 for most of the elements and linkages. Study of the computer analysis revealed certain consistent and predictable patterns of variation in costs. Generally, costs increased as depth to bedrock decreased and as depth to water table decreased. In those instances, such as a highway right-of-way or a paved play area, where grading of right-of-way or of site entered as a cost factor, cost increased with increase of slope due to the greater quantities of material to be moved.

[3] *See SEWRPC Planning Report No. 8, Soils of Southeastern Wisconsin, June 1966.*

COMPARISONS OF COSTS

Utilities and Thoroughfares

A comparison of the costs of construction of some of the linkages with one another and with vehicle operating costs is of interest. For water distribution lines, costs were found to range from about $40,000 per mile to $500,000 per mile for pipe diameters from 6 to 60 inches. Storm sewer costs were found to range from about $28,000 to $200,000 per mile for pipe diameters from 8 to 54 inches. For sanitary sewer pipe diameters of 8 to 24 inches, construction costs were found to range from about $48,000 to $190,000 per mile.

Conventionally, service mains are located under the pavement. An alternative is to place them between the pavement edge and the right-of-way line (see Figure 3). The latter arrangement is used by the City of Milwaukee in newly developing residential areas. If sidewalks are to be used, they may be placed over the mains after complete consolidation of the trench backfill material has occurred.

The latter locations have the advantage of minimizing disruption of pavement during construction or repairs and reducing interference with traffic flow. Since the backfill material need not support a pavement and traffic surcharge, the original earth may be used for the backfill instead of selected granular material. In the more conventional arrangement where the mains are placed under the pavement, the excavated material must be removed from the site and granular backfill hauled in unless it is feasible to delay pavement construction until the following construction season when an earth backfill will have had time to consolidate. The use of earth backfill will, of course, reduce the construction costs of service mains in the "curb-lawn" location below those to be expected in the "under the pavement" case.

Lateral line trenches to buildings may be shared in common by the sanitary, water, and storm services at nominal depths of nine feet, six feet, and four and one-half feet, respectively. Earth backfill will suffice for lateral trenches across private property, but generally gravel backfill will be required within the right-of-way.

Construction costs of thoroughfares were found to range from about $200,000 to $1,100,000 per mile for facilities ranging from urban land access streets to urban 8-lane freeways, respectively. The equivalent rural facility costs were found to range from $150,000 to $950,000 per mile. Railroad line costs were found to range from $100,000 per mile for single-track industrial sidings to $200,000 per mile for single-track main line.

The construction cost ranges given above as examples for water lines and sewers are for an assumed field condition of fine grained soil, slope group A (0 to 1 percent), and more than five feet to both water table and to bedrock. In Table 1 this corresponds to the soil category position in the extreme upper right "box" of the table. Other soil categories would, of course, yield different cost values for each of the linkages.

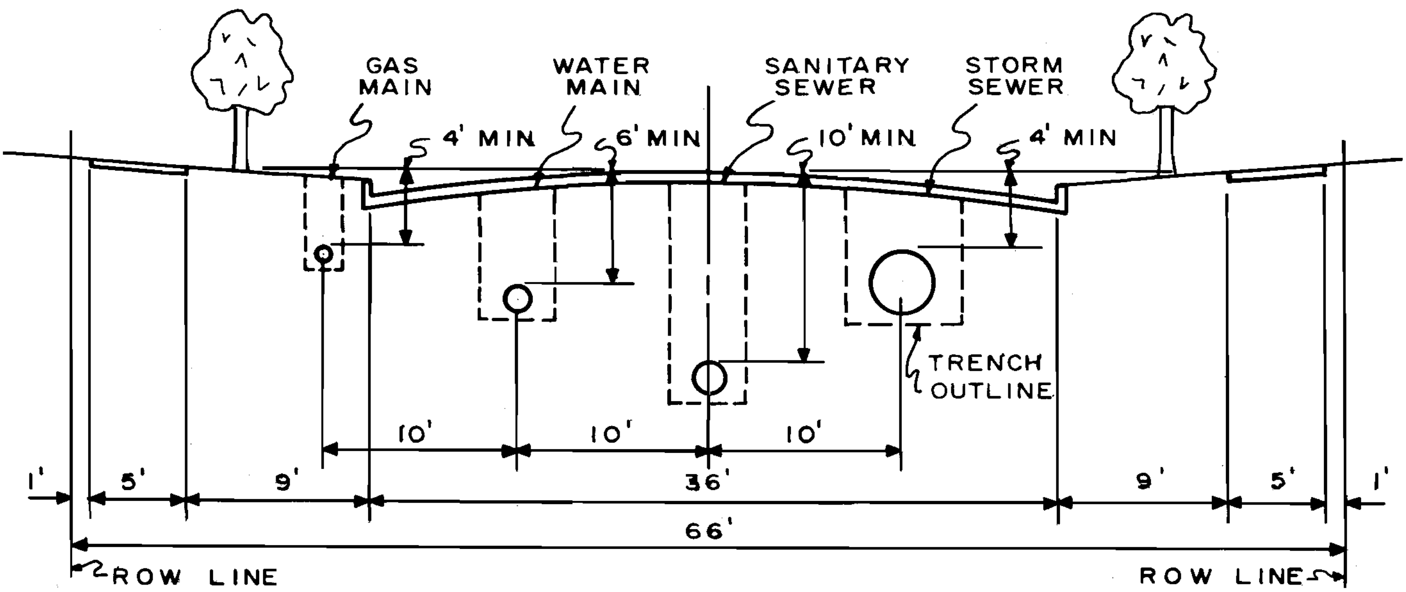
Thoroughfare and railroad main-line costs are averages of the costs per mile based upon the most favorable and the most adverse categories of Table 1. In addition, the three highest figures for thoroughfares and railroads include factors of about 25 percent for bridges, interchanges, and/or other right-of-way structures.

Road User and Operating Costs

A comparison of these capital costs with vehicle operating and road user costs on the several urban and rural freeways and expressways is of interest. To make a direct comparison, the annual road user cost of each facility based upon capacity was discounted to its present value. The discounting was done using an interest rate of 6 percent and a term of 20 years. The results are tabulated in part in Table 3.

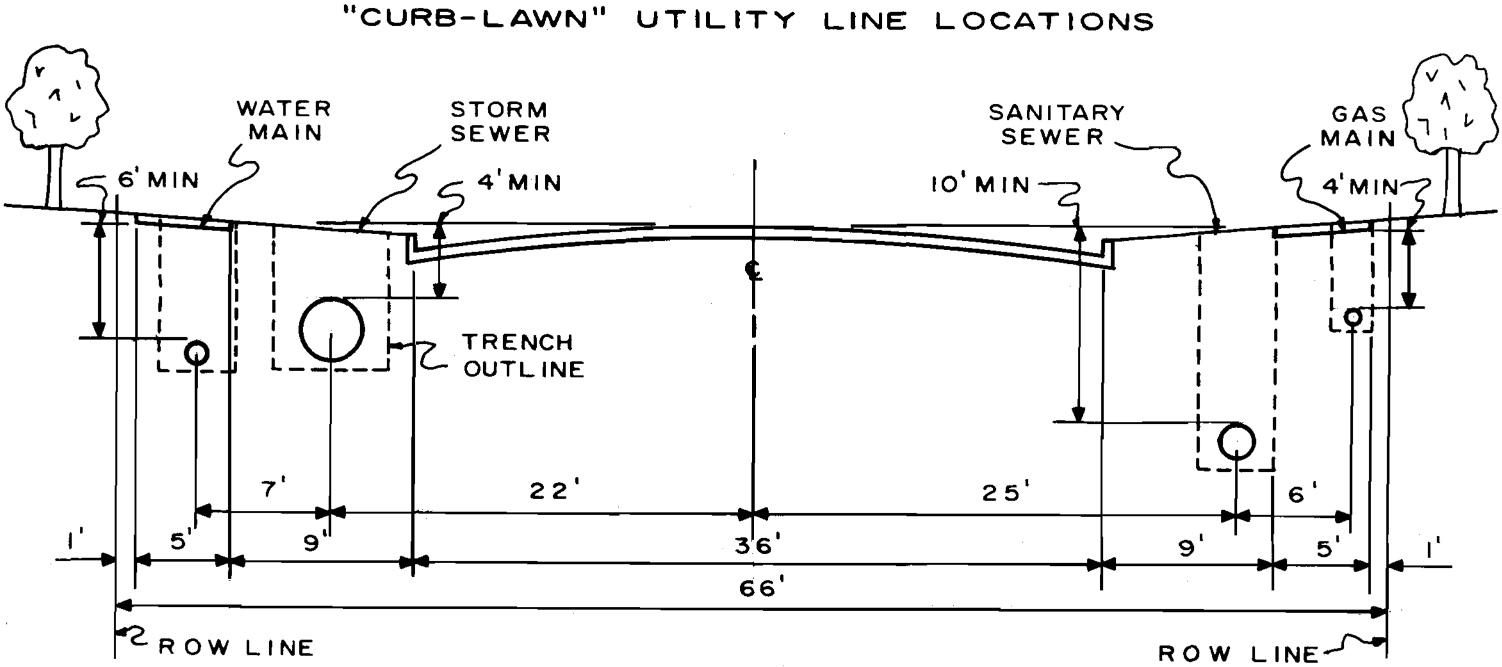
It can be seen that the present value of vehicle operating cost is many times greater than street and highway capital cost. In the operation of the model when the division halves are joined by the appropriate linkages, such as thoroughfares, storm and sanitary sewers, and water lines, needed to connect the land use modules which have been allocated to each of the halves, present value of vehicle operating cost will gen-

Figure 3
TYPICAL RESIDENTIAL STREET CROSS SECTIONS
SHOWING
"UNDER THE PAVEMENT"
STANDARD UTILITY LINE LOCATIONS



SCALE 1"= 10'

SHOWING
"CURB-LAWN" UTILITY LINE LOCATIONS



SCALE 1"=10'

erally comprise a large percent of the total linkage cost. The range of difference between vehicle operating costs and other linkage costs can be illustrated as follows: if one of the largest unit capital costs of about $1,100,000 per mile for an 8-lane urban freeway and one of the smallest unit capital costs of about $40,000 per mile for 6-inch diameter water main are compared with the present value of vehicle operating cost only (column 1) on a rural standard arterial, the operating cost is 3.4 and 94 times as large, respectively. Other linkages have construction costs intermediate between those for 8-lane urban freeway and 6-inch diameter water main and yield operating cost-capital cost ratios within the range 3.4 to 94. If the two capital costs given above were compared with any one of the remaining three values in columns (1) and (2) of Table 3, considerably larger ratios would result.

All vehicle operating and road user costs were computed using the method of analysis presented and illustrated in Road User Benefit Analyses for Highway Improvements.[4] For each urban and rural freeway and arterial facility, an equation was formulated expressing the average annual road user cost in terms of the annual average daily traffic and the length in miles.

For example, for the rural standard arterial, the equation is:

$$C = 100\ NL$$

where

C = annual average road user cost - dollars

N = annual average daily traffic (AADT)

L = length of facility - miles

When the capacity of this facility in vehicles per day is used, the equation becomes $C = 890,000\ L$. Hence, the average annual road user cost for a one-mile section is $890,000.

Maintenance Costs

The cost of maintenance of thoroughfares appears to be appreciably greater than for buried utilities lines. Annual costs of maintenance of the several types of standard urban and rural arterials and freeways were provided by the Transportation Planning Division of the Southeastern Wisconsin Regional Planning Commission in conjunction with the State Highway Commission of Wisconsin. These were compared with thoroughfare maintenance costs developed from cost information provided by the Department of Public Works of the City of Milwaukee. The costs were discounted to their present values to permit comparisons with the capital costs of providing the facilities. Again, an interest rate of 6 percent and a term of 20 years were used. It was determined that the present worth of maintaining urban arterials and freeways over a 20-year period amounted to about 25 to 30 percent of construction cost.

Table 3

COMPARISON OF OPERATING AND CAPITAL COSTS

Facility	Present Value Vehicle Operating Cost Only	Present Value Vehicle Operating Cost Plus Depreciation Plus Time (road user cost)	Capital Cost	Ratio Column (1) Over Column (3)
Urban Freeway (8-lane)	$20,300,000	$49,000,000	$1,100,000	18
Rural Standard Arterial	$ 3,760,000	$10,200,000	$ 300,000	13

Source: SEWRPC.

[4] *American Association of State Highway Officials, Road User Benefit Analyses for Highway Improvements, Part I, "Passenger Cars in Rural Areas," 1960.*

For the buried utilities lines, specifically storm and sanitary sewer, maintenance values of about \$350 and \$600 per mile per year, respectively, furnished by the Sewer Engineering Division, Bureau of Engineers, City of Milwaukee, were used as the basis for comparison. These figures, when discounted to their present values and compared with the capital costs of the smaller diameters of storm and sanitary sewers, amounted to about 10 percent or less of the initial investments.

Site Development Elements

Certain construction costs associated with the internal development of modules lend themselves to cost evaluation on an area basis rather than a linear basis. The costs of construction of paved play areas, parking areas, foundations for residences, on-site sewage disposal units, and general site grading have been evaluated in dollars per acre.

Initial costs of paved areas were found to vary from about \$13,000 per acre for play areas to \$23,000 per acre for truck parking and unloading areas. Costs of residential foundations were found to range from \$16,000 to \$18,000 per acre of actual net area occupied by dwelling units.

A typical septic tank, drainage field installation was evaluated at about \$1,000 per installation. Since these on-site disposal units are applicable only for low-density residential areas where lot sizes are highly variable, cost per acre was not found to be particularly meaningful in this case. However, the minimum lot size for this module type has been defined as 185 feet by 200 feet or 37,000 square feet. Assuming one installation per minimum lot, initial cost of on-site sewage disposal will approximate \$1,200 per acre.

Severe restrictions as to the character and condition of soils on which septic tank systems will be permitted are imposed by many state and local regulatory agencies. Such restrictions are imposed to insure that disposal systems are not installed in areas where poor soil percolation, high water table and/or bedrock, severe slopes, or other adverse conditions would seriously interfere with their proper functioning or produce conditions detrimental to the public health. With these restrictions in view, only 10 of the 84 soil categories of Table 1 have been designated as suitable for on-site sewage disposal units.

Site grading costs were developed for maximum allowable slopes from 0 to 37 percent. An average percent slope was selected for each slope group A through F in Table 1. The difference between each average percent slope and maximum allowable slope was then multiplied by a factor having the units of cubic yards per percent slope per acre and by cost of excavation per cubic yard for the appropriate soil category to obtain dollars per acre. For fine-grained soils and slope D_1 (average percent slope equals 13), grading costs varied from about \$5,500 per acre for a maximum allowable slope of zero to about \$400 per acre for an allowable slope of 12 percent. For greater allowable percentages of slope, no excavation was theoretically required for slope group D_1 nor for the "flatter" slope groups A through C_2.

Chapter VII
MODEL THEORY AND COMPUTER PROGRAM

INTRODUCTION

Earlier chapters of this report have: 1) outlined the general approach to an urban design model, 2) developed the concept of the module as the basic unit for model manipulation, 3) explained the role of objectives and design standards as constraints to the design process, and 4) traced the origins and effects of land and facility development costs.

In this chapter the rationale and the methodology of the design model itself, together with an explanation of the model computer program, will be presented. Previous chapters have described an urban design model in some detail, but a reiteration here is appropriate as a beginning point for a discussion of model theory. The urban design model is defined as a systematic search procedure for the generalization and evaluation of alternate spatial arrangements of land uses with a view to discovering a least-cost design solution that meets all of the design standard constraints.

A variety of modeling techniques exists that could serve as candidates for a design model. These techniques range from classical calculus to linear and dynamic programming. The selection of a modeling technique for the urban design model must consider certain requirements:

1. The model search procedure involves the manipulation of discrete elements rather than continuous variable quantities. In other words, the model is a finite model rather than a variable model.

2. The technique must provide for consideration of linkage, as well as site-oriented cost and constraints.

3. The technique must be adaptable to unusual features of site topography and conditions.

4. The technique must be easy to understand so that human intervention in the modeling process by the designer is possible, if required.

The requirement for a discrete model eliminates many modeling techniques, such as the calculus and linear programming which deal with continuous variables. The requirement for handling linkages would seem to imply some sort of network-oriented technique.

As a result of the investigation of a number of possible approaches, linear graph theory was selected as the theoretical basis for the modeling technique to be used in the urban design model. Linear graph theory allows for the representation of the modules as nodes in a graph, some of which are joined by links. Linear graph theory seems to provide most of the requirements of a modeling technique for the urban design model.

LINEAR GRAPH MODEL

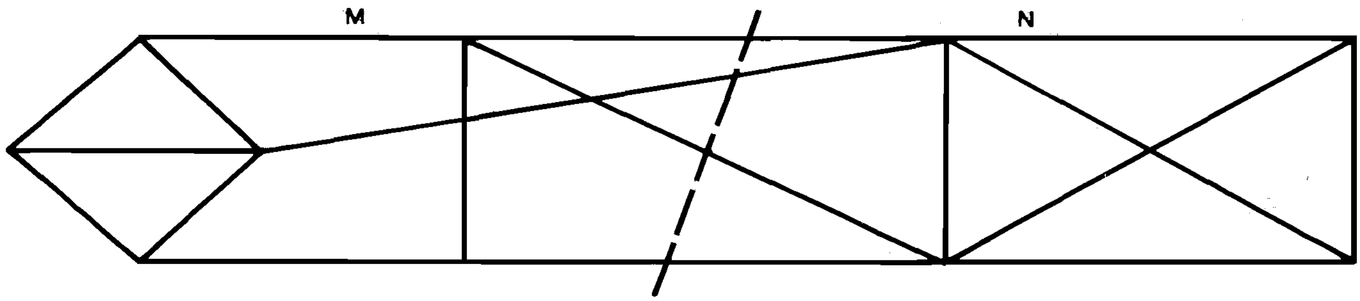
Any discussion of a linear graph model must be preceded by a series of definitions. A "set" is defined as a collection of elements. In the urban design model, these elements are the modules. A "linear graph" is defined as a structure of a set of elements, some of which are joined by links. Such a linear graph is illustrated in Figure 4. "Decomposition" is defined as the subdivision of the set of elements of the linear graph into subsets according to some criterion.

In a previous chapter, the contributions of Christopher Alexander and his associate, Marvin Manheim, were discussed in general terms. In addition to their contributions to the conceptual framework of urban design, Alexander and Manheim provided significant theoretical background for the modeling technique used in the urban design model.[1] Although the use of this technique by Alexander and Manheim was consid-

[1] *See Bibliography reference No. 1.*

Figure 4

LINEAR GRAPH AND PARTITIONS CRITERION



$$STR = \frac{RR - \left(\frac{TOTAL}{NSQI}\right) MN}{\sqrt{MN\,(NSQI - MN)}}$$

$$INFO = (STR)\,(|STR|)$$

RR —NUMBER OF LINKS CONNECTING ANY VERTEX M WITH ANY VERTEX N

M —FIRST OF TWO PARTITION SUBJECTS

N —SECOND OF TWO PARTITION SUBJECTS

TOTAL-TOTAL NUMBER OF LINKS IN THE GRAPH

NSQI -MAXIMUM NUMBER OF LINKS IN THE GRAPH

erably different from its application in the urban design model, much of the technical knowledge developed by Alexander and Manheim was applicable to this project. A brief description of the use of linear graph theory by Alexander and Manheim will make it possible to understand its application to the urban design model.

As already noted herein, Alexander defined the problem of design as one of achieving a "fit" between the requirements of a design and the design form providing the solution to these requirements. To provide a vehicle for the subdivision of interacting design requirements into subsets, Alexander and Manheim developed the HIDECS program.[2] HIDECS is an abbreviation for a program providing for the Hierarchical Decomposition of Systems which have an associated linear graph. The HIDECS program was developed to deal with a linear graph consisting of a set of elements (M) and a set of two element links (L). The linear graph is represented by the function G(M, L). In the Alexander model, the elements represent the design requirements and the links represent the interaction between these requirements.

The HIDECS program provides for the successive partitioning of the elements into subsets based on a partitioning criterion which provides for the minimization of the link connections between the partition subsets. The criteria for the selection of partitions is based on the number of connecting links between the subsets corrected for a bias toward special partitions. An example of such a linear graph and the associated criterion are shown in Figure 4.

The input to the HIDECS program is a binary matrix which represents the linkage connections between each of the set elements. The output of the program is a tree which shows the grouping of the elements into subsets.

[2] *See Bibliography reference No. 2.*

The HIDECS program was not used directly as the basis for the modeling technique of the urban design model, but it provided a substantial framework which was used as a foundation for the modeling technique. The linear graph modeling technique used in the urban design model differs from HIDECS in the following basic ways:

1. Site costs which are associated with an area must be considered, as well as linkage values, in the modeling process.

2. The linkage cost cannot be binary as in HIDECS but must provide for variable values for the cost of link connections.

3. The design model must also provide for special topographic features for modifying the linear graph partitioning process.

PLACECOMP II PROGRAM

In the initial concept of the urban design model computer program, the modeling process was viewed in two stages:

1. CLUSTERCOMP—the CLUSTERCOMP sub-program would group the module elements into subsets independent of site considerations.

2. PLACECOMP—the PLACECOMP sub-program would then place these clusters in site locations so as to minimize the combined site and link cost of the clusters within the design model constraints.

The above approach was taken in order to simplify the computational problem by determining design in a two-stage sequence. The above approach has the disadvantage of sub-optimization in that the clusters rather than the elements are placed. It is conceivable that a different solution would result from the direct placement of the module at the same time that they are formed into sets.

It was later found possible to merge the functions of CLUSTERCOMP and PLACECOMP into one program that partitions the module elements into subsets in which each subset partition half is associated with an area as well as a set of elements. This program, designated as PLACECOMP II, eliminates the sub-optimization inherent in the two-stage modeling process. In the operation of PLACECOMP II, the planning area of interest is divided into a series of subareas. Initialization of the model program provides for a subdivision of the modules into one of the initial halves of the planning area. The model then tests a series of successive adjacent subsets in an attempt to improve the initial partition using a hill-climbing technique which searches for the best partition. After a best partition of modules has been achieved, each module is located in one of the two halves of the planning area. The modeling sequence continues by successive partitions of each of the initial halves into another series of half areas where a new optimal partition is determined. This partitioning process continues until the area is subdivided to the degree of detail desired.

PLACECOMP II Computer Program Organization

The PLACECOMP II program, diagrammed in Figure 5, and as subdivided in Figure 6, into a series of eight sub-programs with the functions as described below:

1. CUCPIN—Mainline program calls data loading programs and initiates operational program sequence.

2. IN1—First data loader reads, prints, and stores on disk (tape) the module type connectivity matrix, module type number vector, and module type-site area vector.

3. IN2—Second data loader reads, prints, and stores on disk (tape) the cell-soil type inventory.

4. IN3—Third data loader reads, prints, and stores on disk (tape) the module type-soil type combination site cost data.

5. IN4—Fourth data loader reads, prints, and stores on disk (tape) the number of partitions, connectivity price for each partition, parent division of each partition, parent division half of each partition, and the cell list for each partition.

6. DVDIN—Tabulates soil type inventory for each partition half and establishes model initial conditions before each partition.

7. DVDSTT—Provides initial module partition and initial site and linkage costs as in model initial conditions before each partition.

8. DIVIDE—This is the optimization subroutine that examines all adjacent partition sets; that is, all partitions that can be formed by moving one module from one partition half to the other until a least cost partition is found. Process continues until no lower cost partition can be formed. Least cost partition is then recorded and the model program returns to DVDIN to start the next partition.

Future Program Improvements

Early experience with the PLACECOMP II program indicates its capabilities in achieving a design that meets the test of reasonableness and seems to approach a design of near optimality. Certain shortcomings, however, are apparent in the PLACECOMP II program that were also recognized in the earlier work of Alexander and Manheim in the HIDECS programs. The basic weakness of PLACECOMP II, like HIDECS II, is that it achieves its set decomposition in a series of two-way partitions. Such a binary partitioning approach fails to account for the possibility that a particular element might have been better placed in a different topographic area after initial partitioning had placed it earlier in a less desirable half-area. A modification of the PLACECOMP II program now being considered would provide for the testing of two-way, three-way, four-way, and higher value partitions in model operations. Such an approach may lead to an improved solution in the urban design model. It is still too early to appreciate the significance of this improvement.

ROUTCOMP and MAPCOMP

The two final programs of the urban design model, ROUTCOMP for the location of linkage paths and MAPCOMP for display of the outputs of both PLACECOMP II and ROUTCOMP, are being developed during the Phase II program.

Figure 5
PLACECOMP II GENERAL FLOW CHART

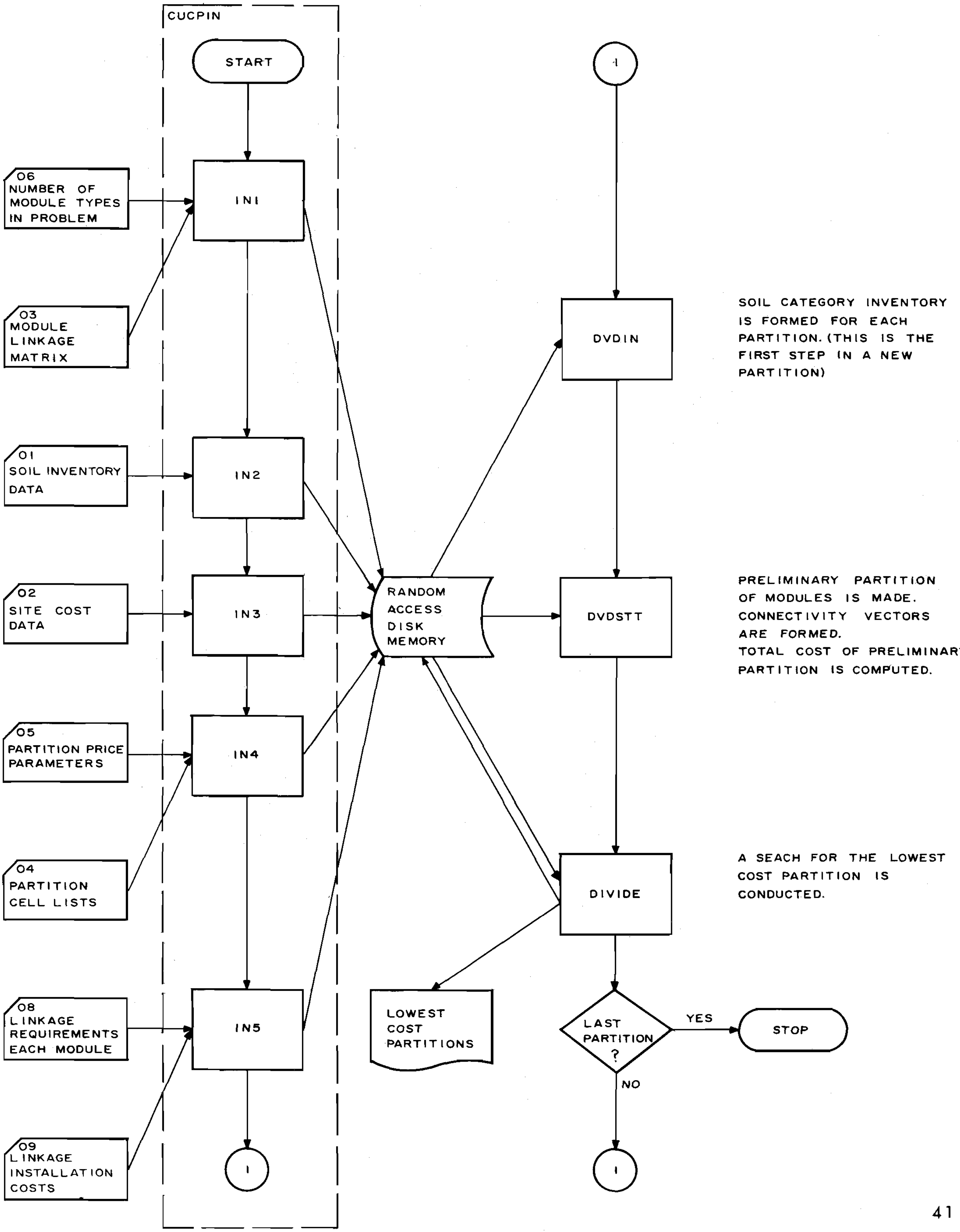


Figure 6
PLACECOMP II DETAIL FLOW CHART

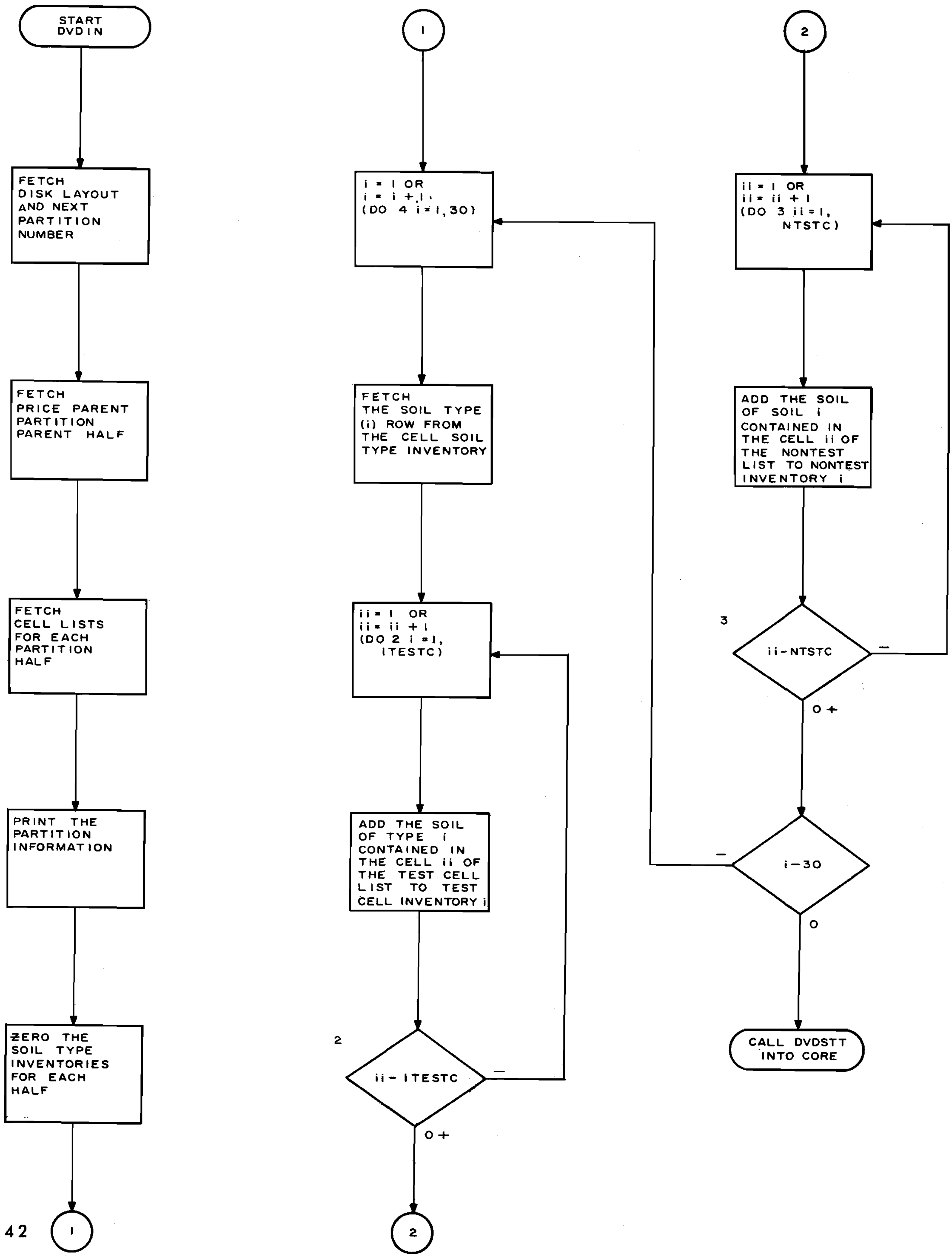


Figure 6 (continued)

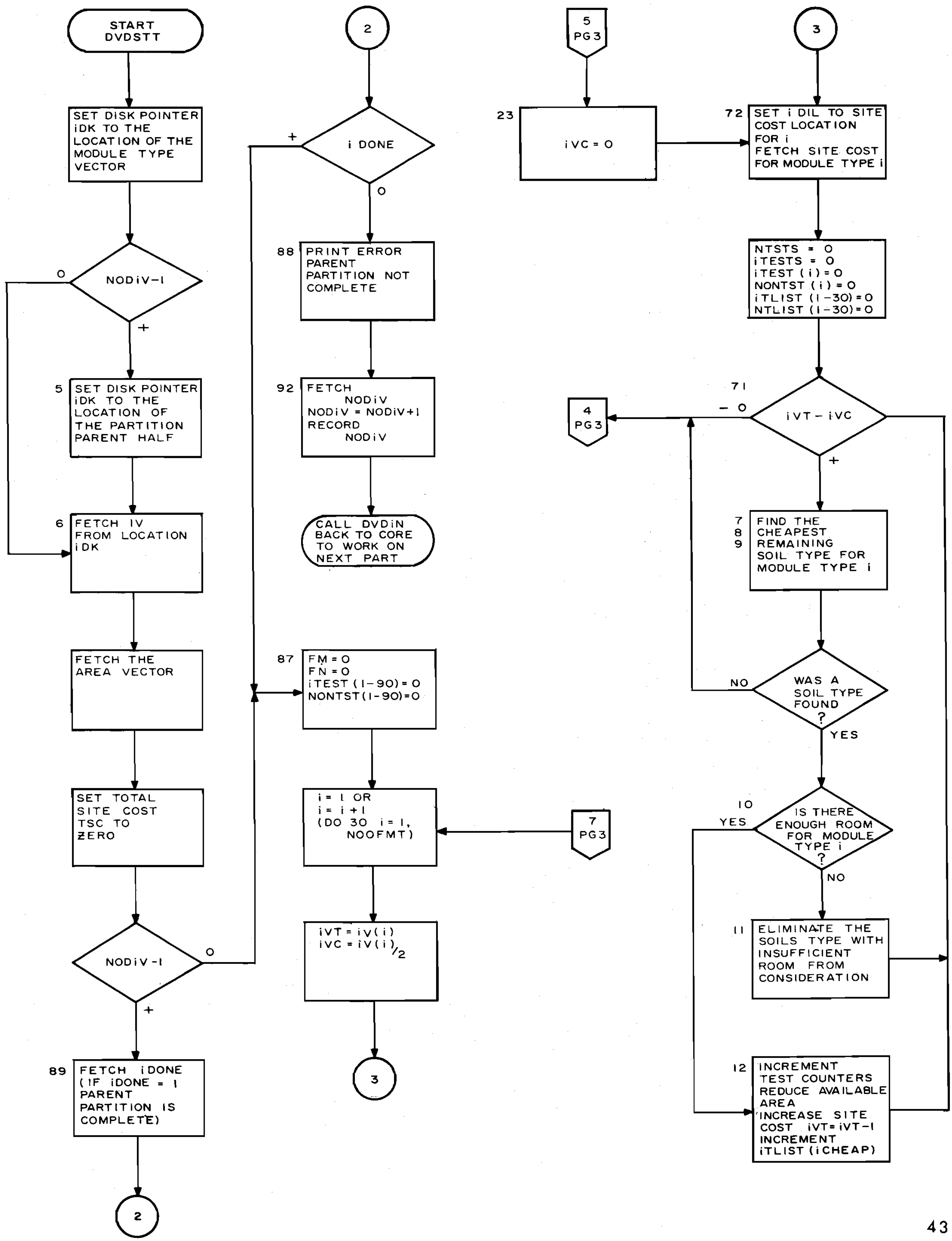
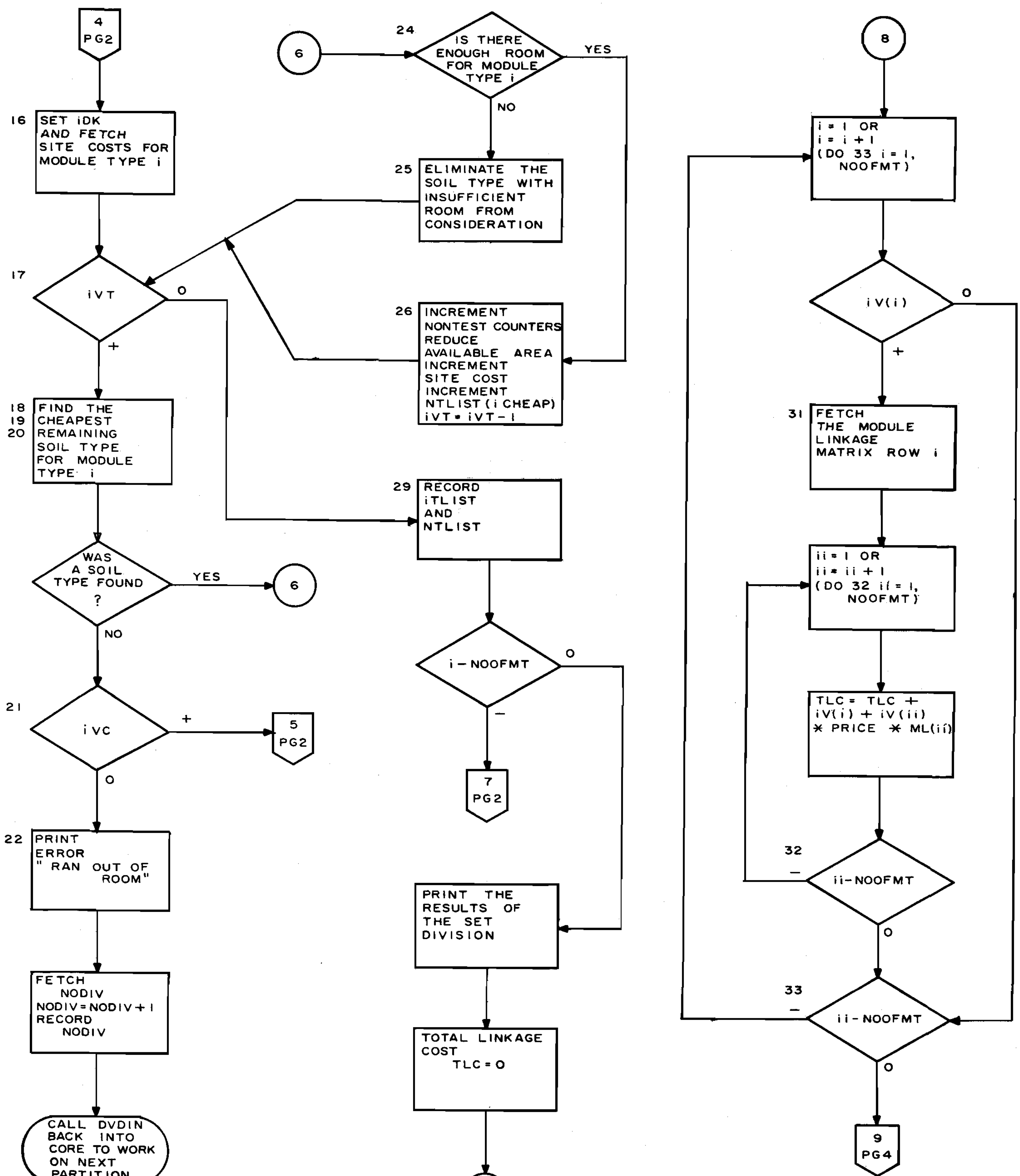


Figure 6 (continued)



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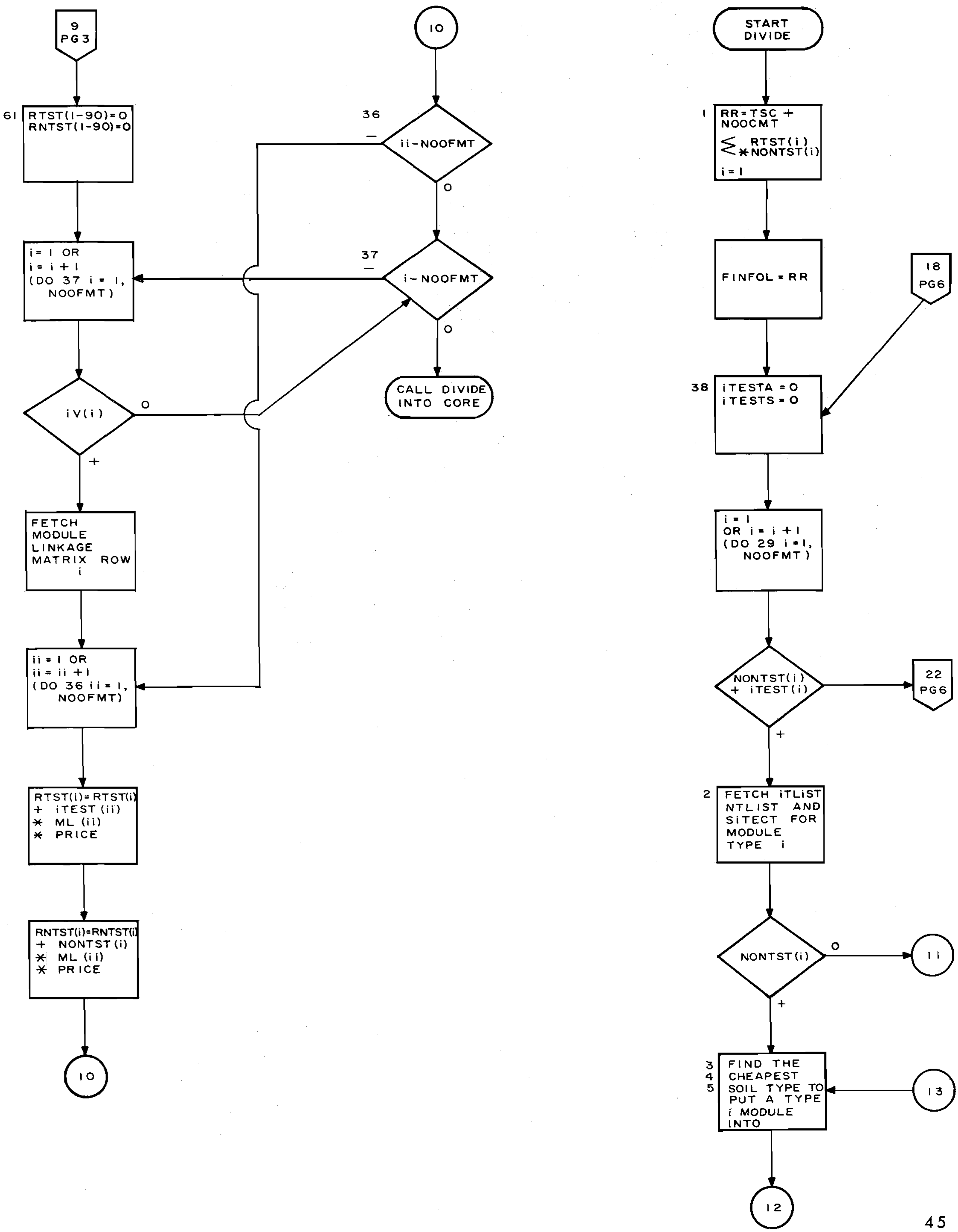


Figure 6 (continued)

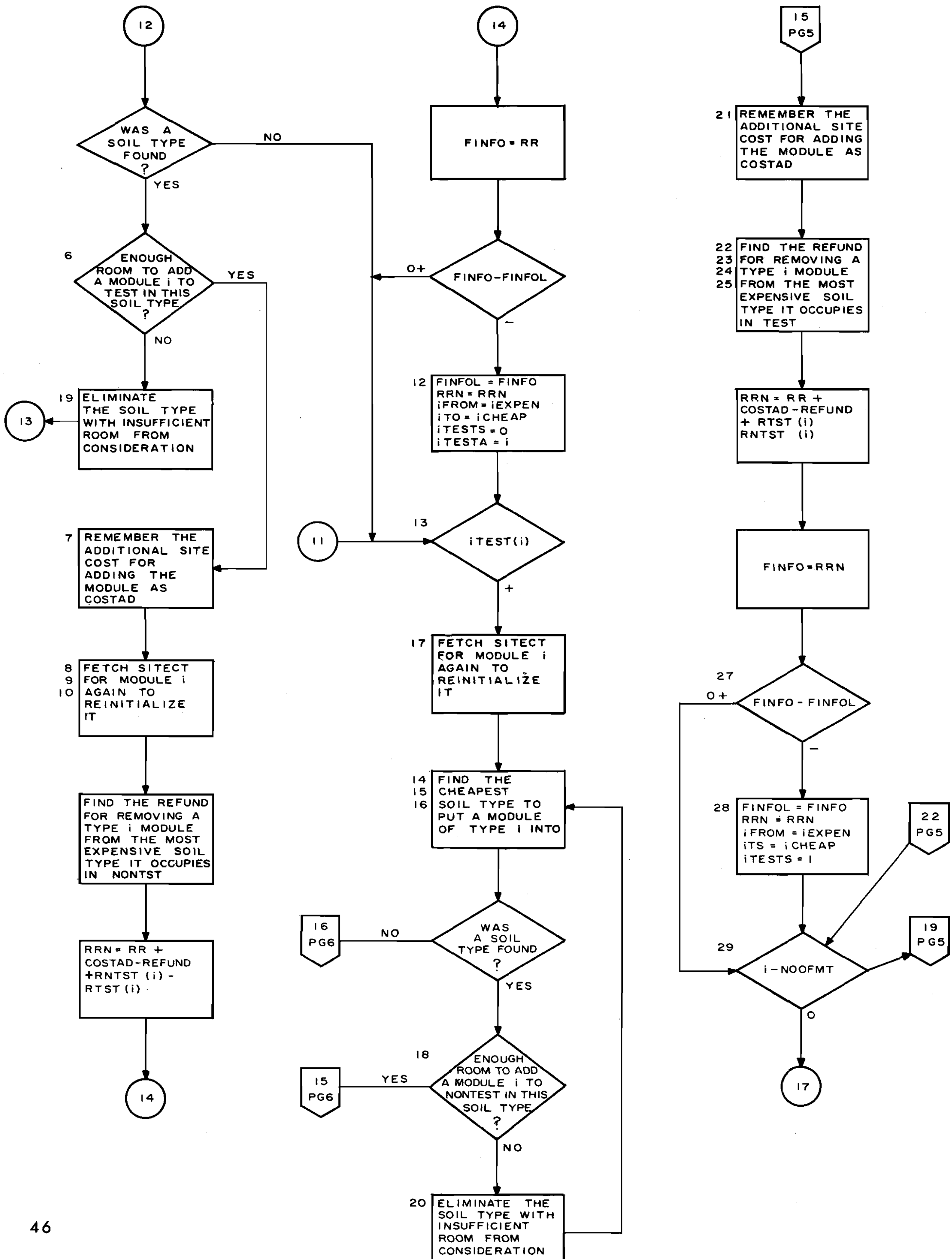
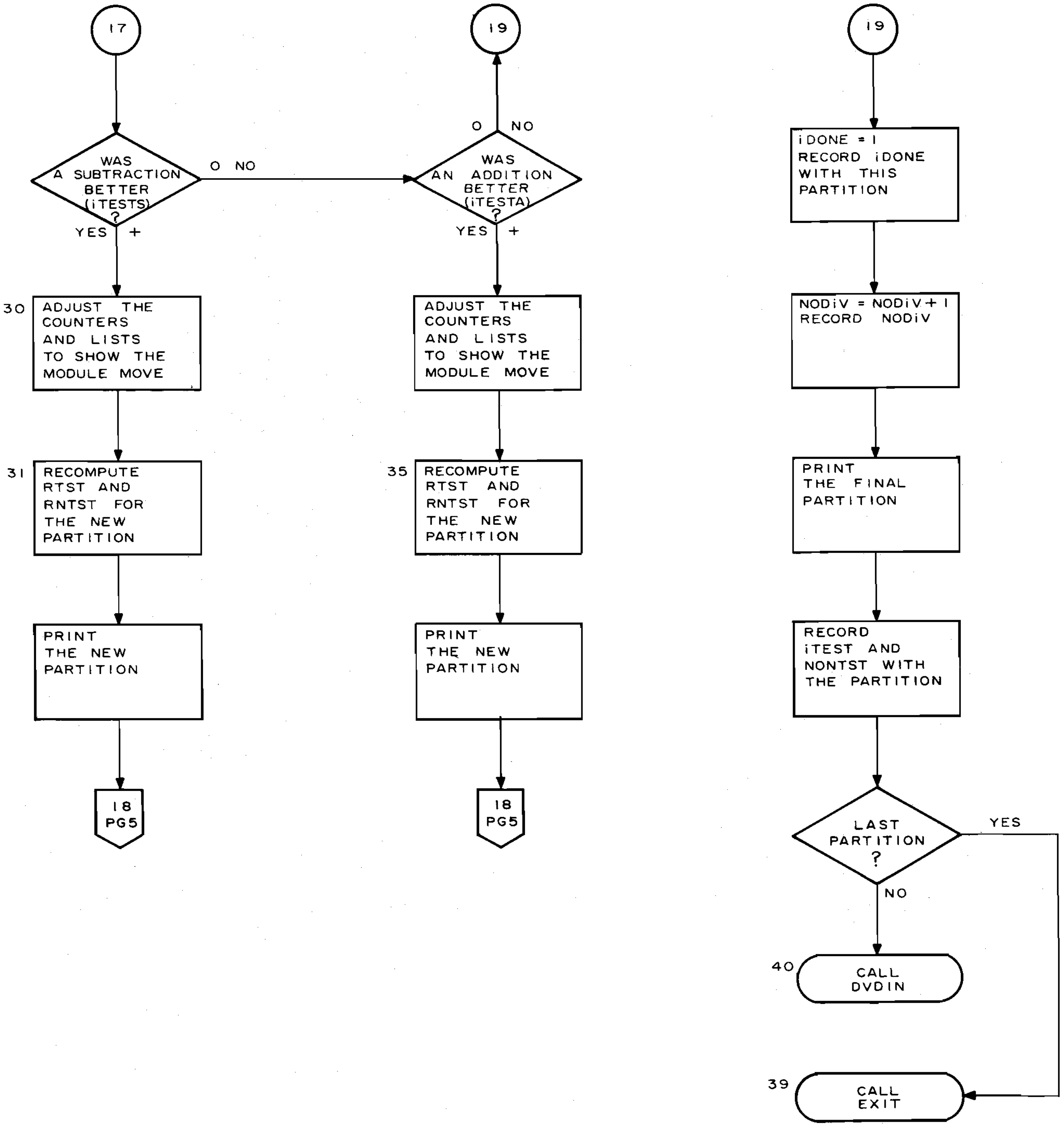


Figure 6 (continued)



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Chapter VIII
MODEL OPERATION

INTRODUCTION

With the model concept established and the computer program prepared, the next logical step in the design model development sequence is to "exercise" the model in a pilot test. The Village of Germantown, Wisconsin, was selected as the model pilot test area; and in this chapter the pilot application of the design model to this Village will be discussed. The objective of the exercise was to provide an experimental verification or "shakedown" of the model in order to reveal any problems that might be involved in a full-scale application. It should be stressed that it was not the objective of this pilot application to develop a recommended plan design for the Village since time and funding did not permit community development objectives and design standards to be extensively explored with the governmental officials and citizen leaders of this community. The pilot model runs were also useful in establishing preliminary model operation procedures that will be useful in future full-scale applications.

THE EXISTING SITUATION IN GERMANTOWN

The Village of Germantown in southeastern Wisconsin was incorporated in 1927 and in 1964 greatly expanded its corporate limits by annexation of a primarily rural area comprising almost a full U. S. Public Land Survey township of 36 square miles in area. Existing urban development within the Village occupies a very small part of the total land area of the former township and is largely confined to the old incorporated urban core area, which served as the center for the rural township. The Village is an integral part of the Milwaukee Standard Metropolitan Statistical Area (SMSA) and is immediately adjacent to the present urbanized area of this metropolitan statistical area. The position of the Village, astride a major radial freeway, brings it under the influence of rapid urbanization. A tabulation of the existing land uses (1963) in Germantown, Wisconsin, is shown in Table 4. The present population of the Village (1963) is 5,000; and the projected population (1990), derived from the regional forecasts and used to provide model input data, is 27,400.

MODEL INPUT DATA

The following modules were provided as input data to the model for the Germantown pilot study and are to be located by the model operation.

Module Type	Number of Modules
1. Residential (low-density)	30
2. Residential (medium-density)	23
3. Park (neighborhood)	6
4. Park (community)	2
5. Sewage Treatment Plant	1
6. Commercial Center (neighborhood)	3
7. Commercial Center (community)	2
8. Elementary School	7
9. Secondary School	1

10. Municipal Hall

The following linkages were considered in developing the module-to-module connectivity matrix for Germantown:

1. Urban standard arterial.
2. Urban collector street.
3. Urban local street.
4. Rural standard arterial.
5. Rural collector street.
6. Rural local street.
7. Water supply distribution line.
8. Sanitary sewer collection lines.

The definition of cells for the Germantown pilot application was based on U. S. Public Land Survey one-quarter sections within the Village. Each one-quarter section (1/4 square mile) was made a cell so that 144 cells were defined in all for Germantown. The location of these cells is shown on Map 1. Groupings of these cells to define the partition sequence for model operations were based on the natural and artificial boundaries existing in the Village. This partition sequence is illustrated in Map 2.

Input Data Format

The specific format for the input data to the model took the following structure:

1. Soil Inventory

Twenty soil categories were defined based on soil texture, depth to water table, depth to bedrock, and topographic slope combinations, as shown on Table 1 in Chapter VI. These soil categories were synthesized from the 110 soil types mapped within the Village in the detailed operational soil

Table 4

LAND USE INVENTORY - VILLAGE OF GERMANTOWN: 1963

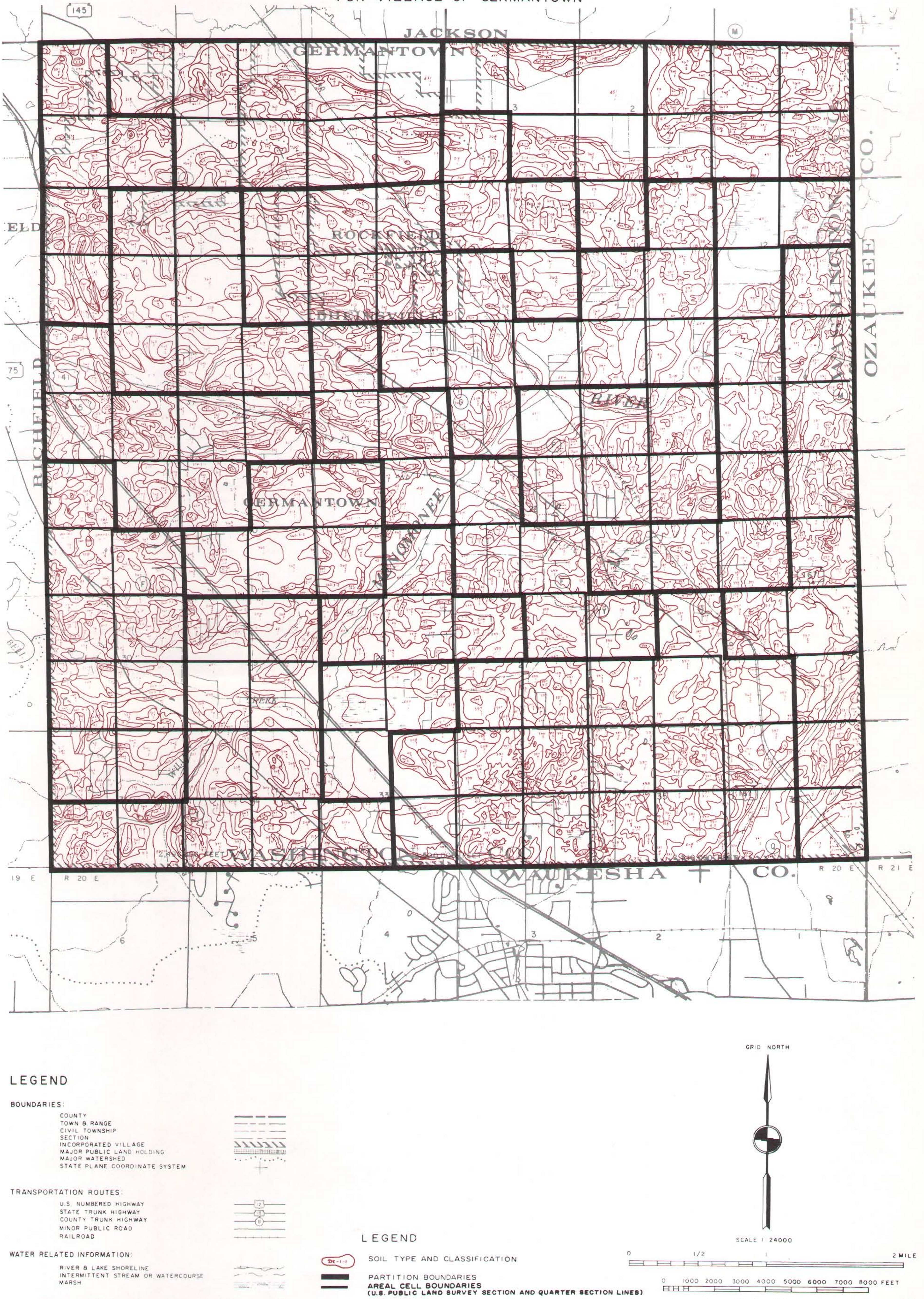
Land Use Type	Acres
Residential	980.2
Commercial[a]	32.1
Industrial[a]	220.2
Governmental[b]	87.9
Transportation[c]	1,084.2
Recreation[d]	35.9
Agriculture & Open Space[e]	20,665.1
Total	23,105.6

[a] *Includes on-site parking.*
[b] *Includes institutional uses and on-site parking.*
[c] *Includes communications and utilities uses.*
[d] *Includes public and nonpublic recreational lands.*
[e] *Includes woodlands, wetlands, water, other open lands, and quarries.*

Source: SEWRPC.

Map I

SOIL CATEGORIES AND AREAL CELLS, FOR VILLAGE OF GERMANTOWN



The partition boundaries either enclose groups of U. S. Public Land Survey quarter sections (areal cells) which are similar with respect to critical elements of the natural resource base or coincide with natural or man-made barriers to development.

The soil types and classes, represented on this map by the code numbers shown within each soil type boundary, are described in SEWRPC Planning Report No. 8, Soils of Southeastern Wisconsin.

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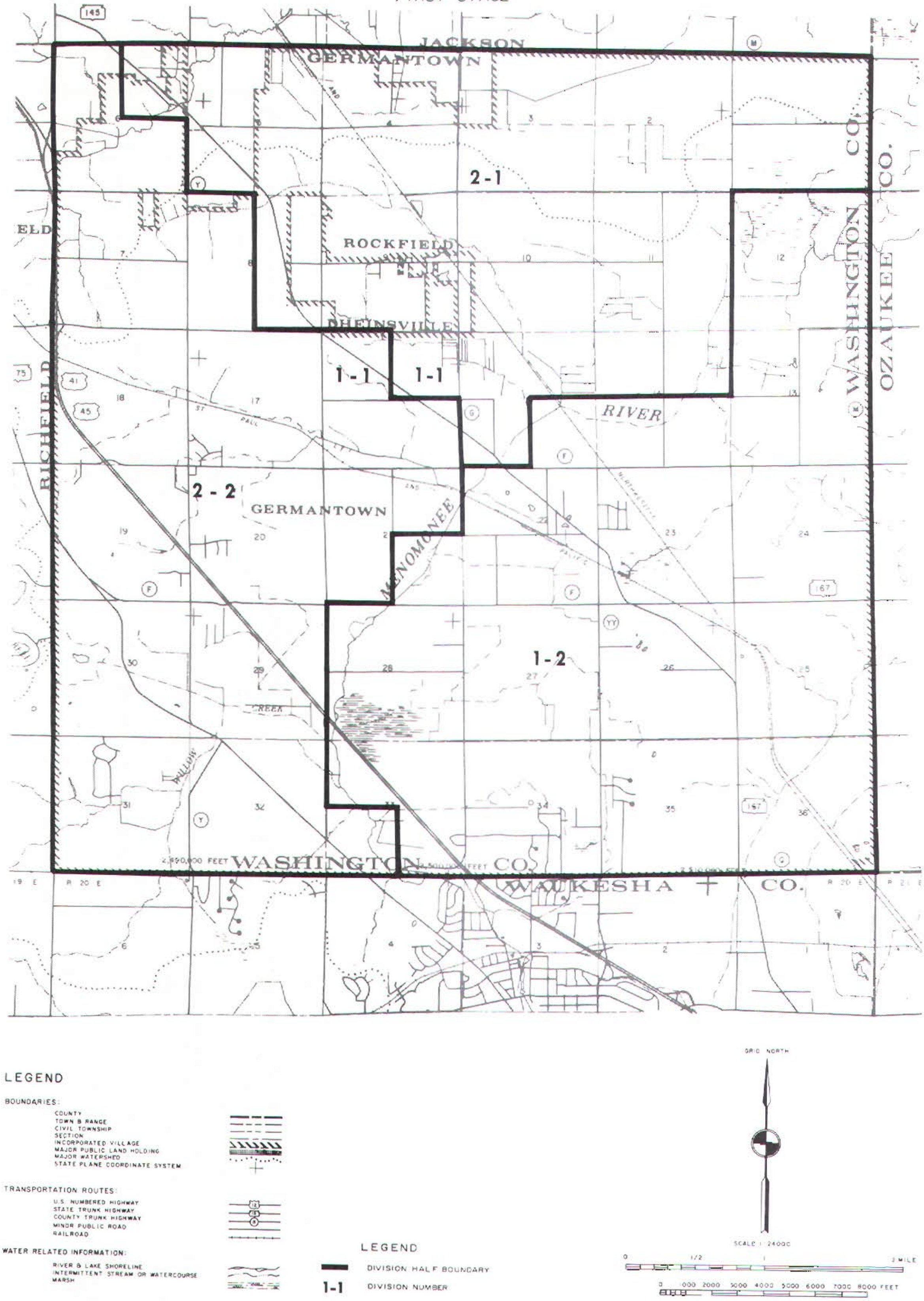
Map 2

PARTITION SEQUENCE FOR VILLAGE OF GERMANTOWN

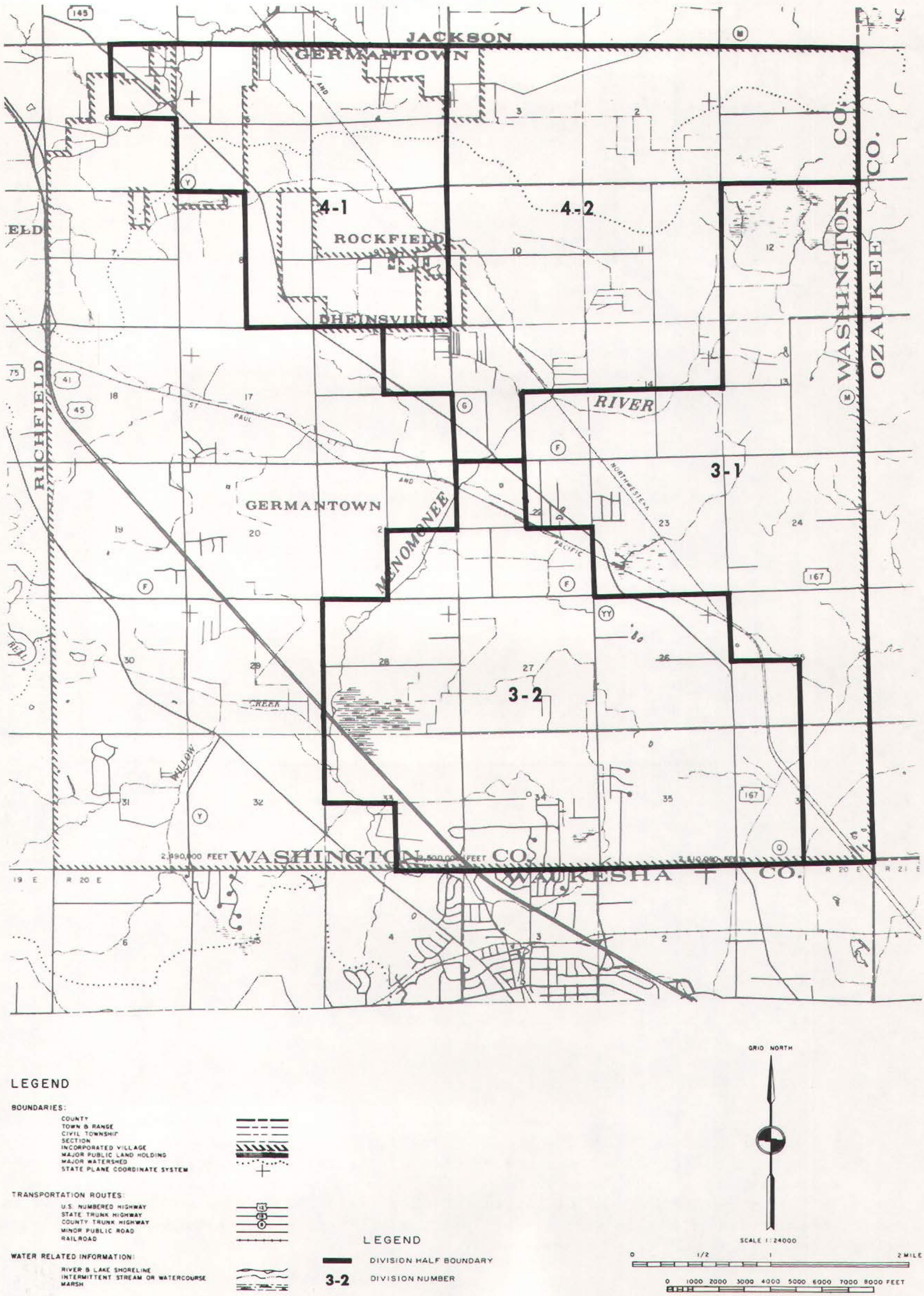
FIRST STAGE



Each division half boundary encloses one or more of the cells shown on Map 1. A division half number is composed of a partition number followed by a dash and a division half number for each of the two halves formed by that partition. Each division half then becomes a parent which is subsequently divided in a later partition. This partitioning sequence continues unitl each division half is conterminous with an areal cell.

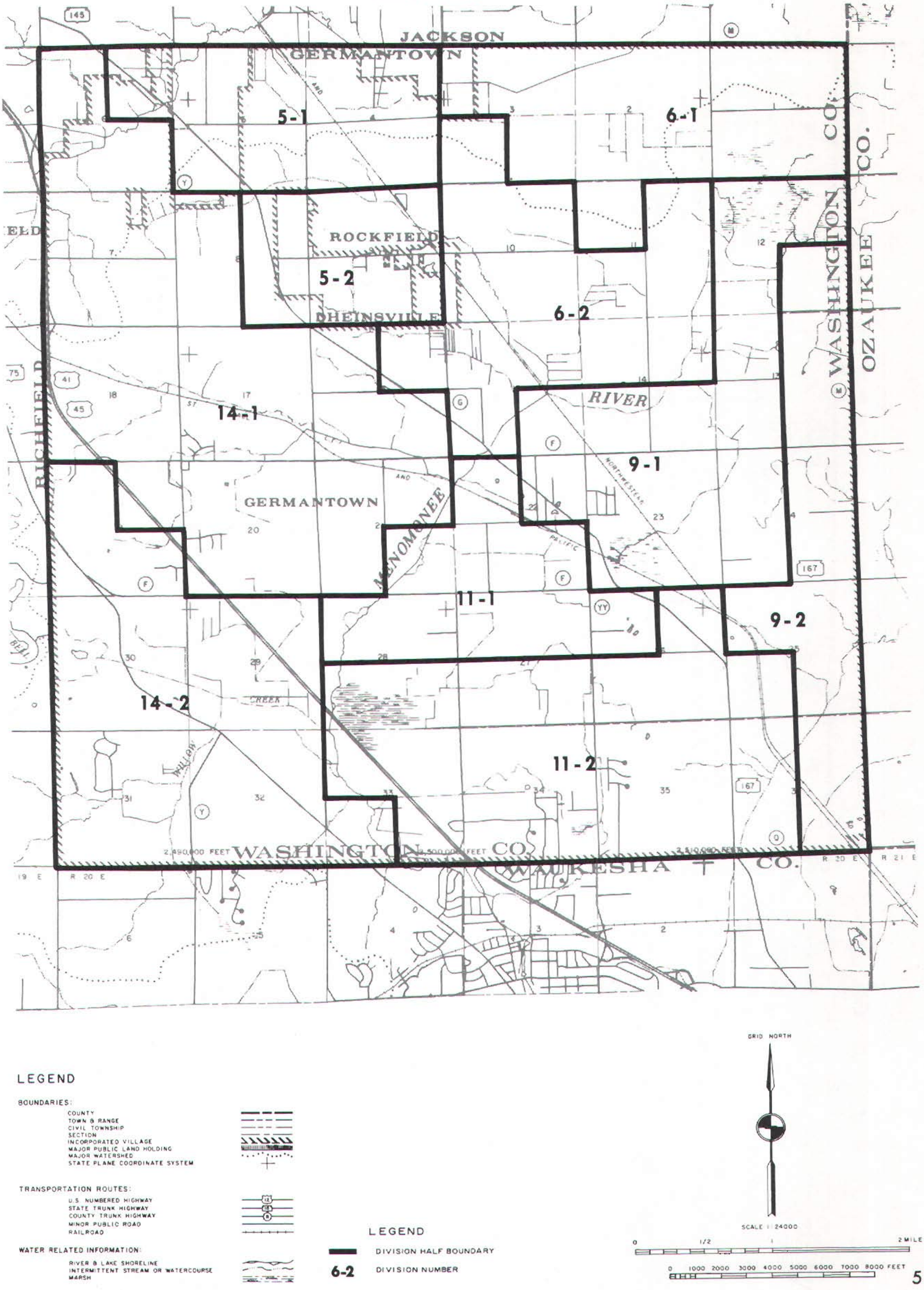
Map 2 (continued)

SECOND STAGE



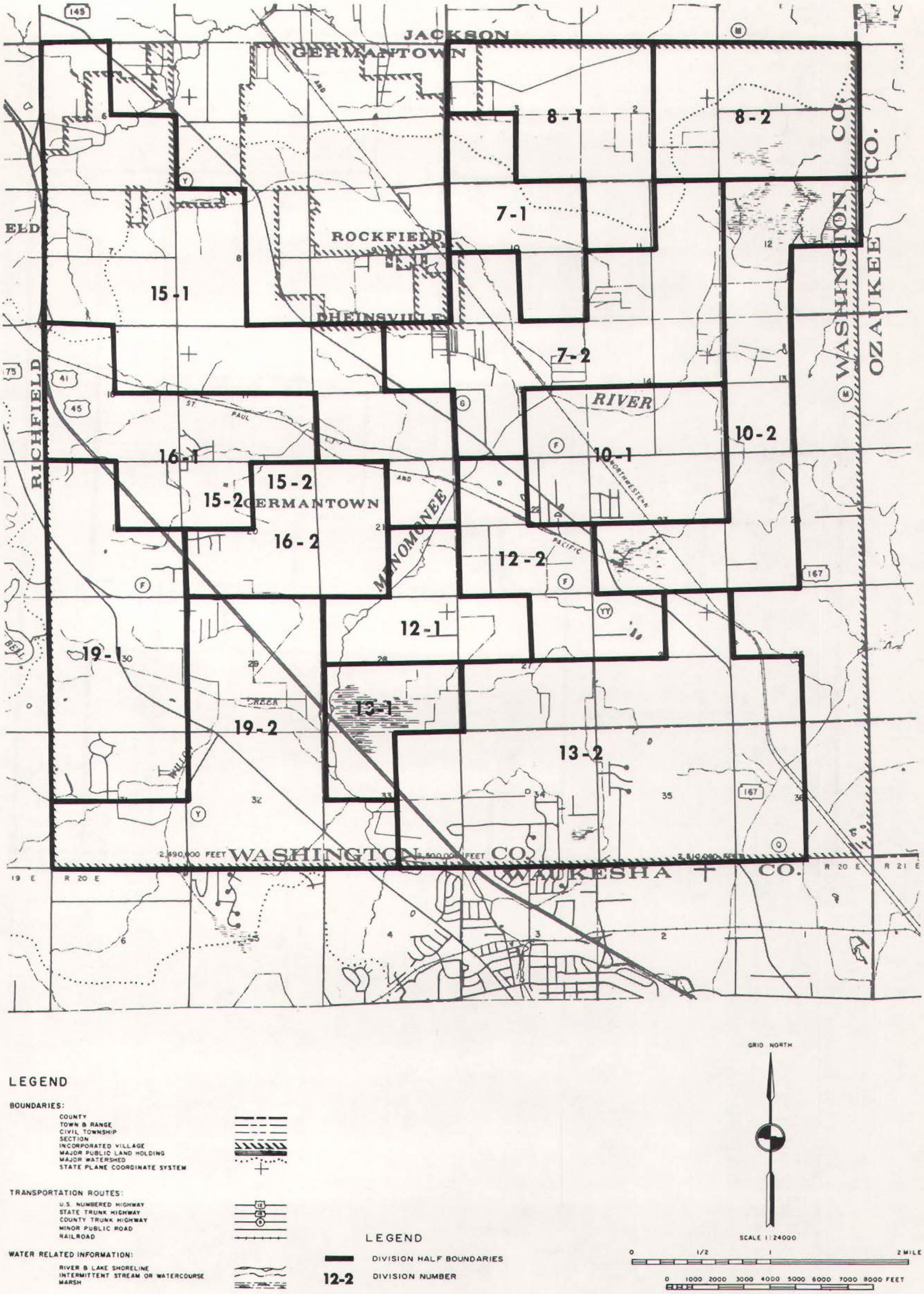
Map 2 (continued)

THIRD STAGE



Map 2 (continued)

FOURTH STAGE



surveys of the Southeastern Wisconsin Regional Planning Commission. The area in acres within each cell covered by each of the soil categories was defined in the soil inventory input data. An example of the data format used is shown in Appendix V.

2. Site Cost Data

   Site development cost data were provided for each soil category and module type combination. These site development costs were calculated from elemental costs for common elements required in the location of particular module types in each of the soil category areas. The site development cost data used are also listed in Appendix V.

3. Module Area and Connectivity Matrix

   This input data category provided the area in acres required for each module type. This input record also contained a normalized connectivity (linkage cost) value between each module and all of the other modules. This connectivity value was normalized in a range of 1 to 99. Again, the format data are shown in Appendix V.

4. The Partition Cell List

   The partitioning sequence of the model requires a previous definition of the location of each cell relative to each successive partition half. The location of each cell relative to these successive partitions is provided in the partition cell list. The partition cell list for Germantown is shown in Appendix V and is illustrated in Map 1.

5. Partition Connectivity Price

   Partition connectivity prices were provided as input data in order to allow for unusual natural or artificial land features that would increase linkage costs between particular cells in a partitioning. The total linkage cost between any two modules in a particular partition was determined by multiplying the value of the connectivity matrix by the partition connectivity price. The Germantown connectivity prices for each partition are also shown in Appendix V.

MODEL OPERATION

Using the input data, the model computer program performed a sequence of six partitions in which each module was assigned to one-half or the other of the partition during the sequence. The results of the first partition are shown below:

Module Type	1st Half	2nd Half
1	30	0
2	23	0
3	6	0
4	2	0
5	2	0
6	3	0
7	2	0
8	7	0
9	1	0
10	1	0

The first partition resulted in all of the modules being located in one-half of the partition. Considering the effects of the natural barrier, a river subdividing the first partition, and the fact that the model is trying to minimize linkage costs, as well as site development costs, it appears quite logical that all of the modules would be put into one-half of the total village area.

The second partition, which attempted to subdivide the first half of the first partition, again assigned all of the modules to one half. This means that all modules were now located in approximately[1] one-quarter of the total village area.

Module Type	1st Half	2nd Half
1	30	0
2	23	0
3	6	0
4	2	0
5	2	0
6	3	0
7	2	0
8	7	0
9	1	0
10	1	0

The third partition would have involved the subdivision of the second half of the first partition, which contained no modules. This partition was not performed because there were no modules to subdivide.

The fourth partition provided the following subdivision of the modules in the occupied quarter (1st half) resulting from the second partition:

Module Type	1st Half	2nd Half
1	8	22

All the remaining modules were assigned to the second half of the partition.

In the fifth partition, the eight low-density residential modules (module type No. 1) of the fourth partition were subdivided equally between the halves of the fifth partition:

Module Type	1st Half	2nd Half
1	4	4

The sixth and final partition used in the test subdivided the second half of the fourth partition in the following manner:

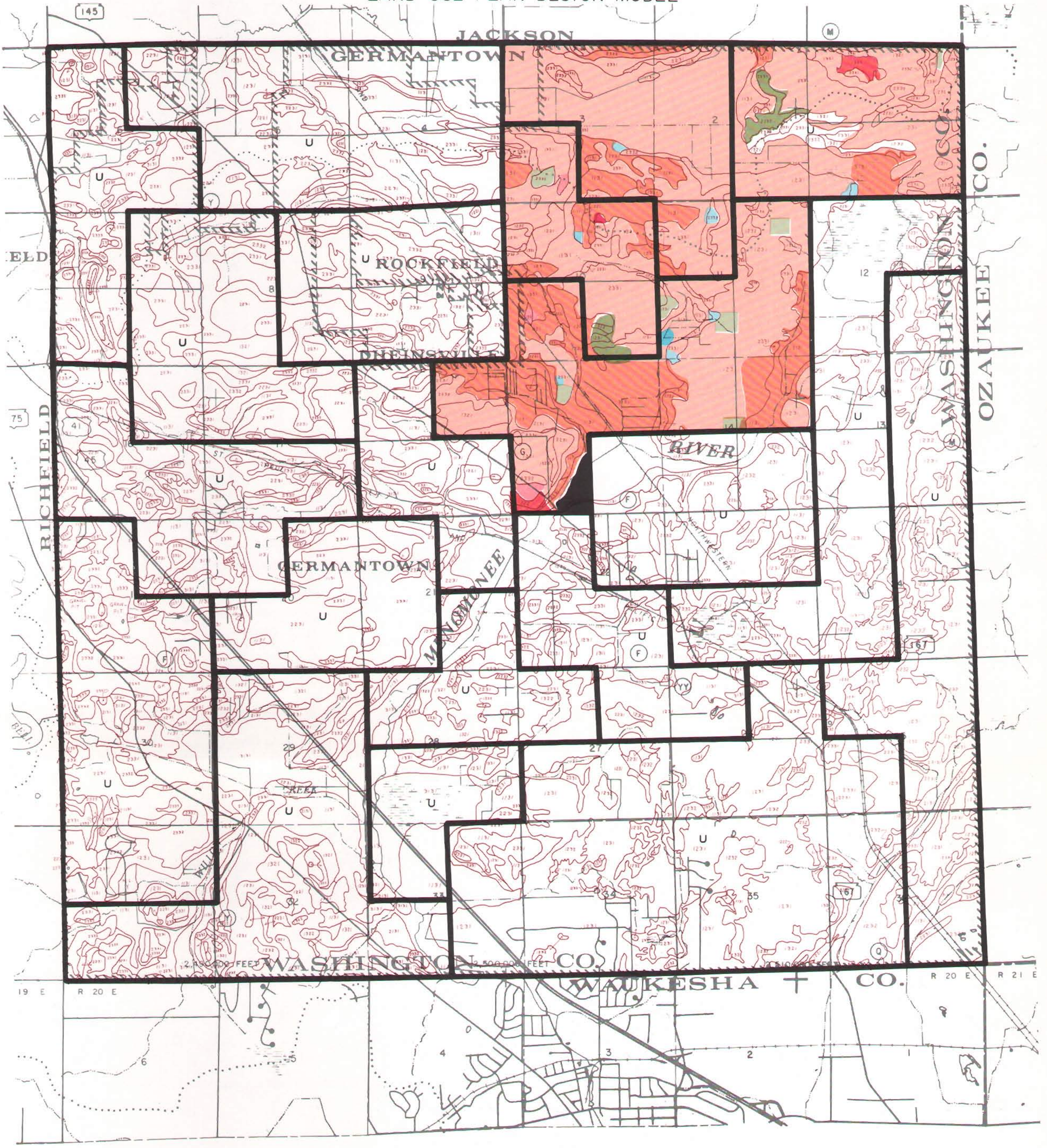
Module Type	1st Half	2nd Half
1	11	11
2	8	15
3	1	5
4	1	1
5	0	2
6	0	3
7	1	1
8	3	4
9	0	1
10	0	1

The final plan design resulting from the partition sequence of the Land Use Plan Design Model is shown on Map 3. This map indicates the location of each of the modules after the final partition. All modules are

[1] *The partition half areas were not always equal in size.*

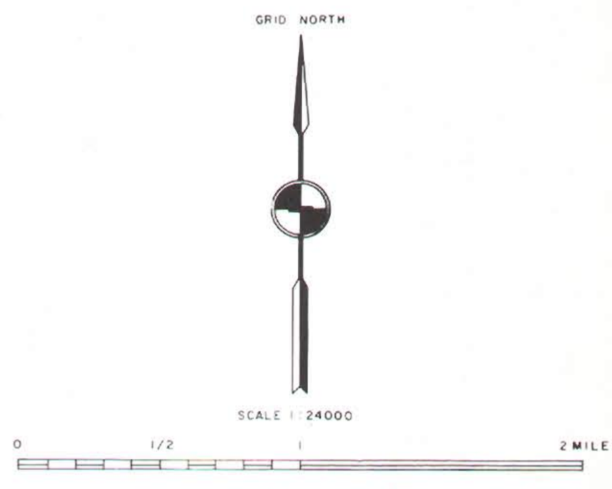
Map 3

EXAMPLE OF PLAN DESIGN FOR THE VILLAGE OF GERMANTOWN, WISCONSIN USING THE LAND USE PLAN DESIGN MODEL



LEGEND

MODULE TYPE	TOTAL ACRES
RESIDENTIAL (LOW DENSITY)	3729.0
RESIDENTIAL (MEDIUM DENSITY)	1044.2
PARK (NEIGHBORHOOD)	46.2
PARK (COMMUNITY)	74.2
SEWAGE TREATMENT PLANT	9.7
COMMERCIAL CENTER (NEIGHBORHOOD)	15.0
COMMERCIAL CENTER (COMMUNITY)	40.0
ELEMENTARY SCHOOL	97.3
SECONDARY SCHOOL	2.0
MUNICIPAL HALL	45.0
SOIL CATEGORIES	
UNDEVELOPED LAND	18507.9



LEGEND

BOUNDARIES:

- COUNTY
- TOWN & RANGE
- CIVIL TOWNSHIP
- SECTION
- INCORPORATED VILLAGE
- MAJOR PUBLIC LAND HOLDING
- MAJOR WATERSHED
- STATE PLANE COORDINATE SYSTEM

TRANSPORTATION ROUTES:

- U.S. NUMBERED HIGHWAY
- STATE TRUNK HIGHWAY
- COUNTY TRUNK HIGHWAY
- MINOR PUBLIC ROAD
- RAILROAD

WATER RELATED INFORMATION:

- RIVER & LAKE SHORELINE
- INTERMITTENT STREAM OR WATERCOURSE
- MARSH

Soil categories are generalized versions of the soil types shown on Map I, and their four-digit codes implicitly describe critical ranges of soil texture, depth to water table, depth of bedrock, and slope. From these critical ranges, the consequent variation in development costs which are attributable to the natural resource base can be determined.

The design solution yields the number of modules of each type which are to be located within a specific soil category in each partition. The resulting land use plan follows soil category boundaries.

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placed based on their location in each partition half and the category of soil to which the module has been allocated. Soil category information permits a more precise placement of each module than would be possible through binary partitions alone since the large number of soil categories pinpoint a limited area in each partition half.

CONCLUSIONS

Evaluation of the pilot test of the plan design model leads to the following conclusions:

1. The design model produces a solution that is quite reasonable considering the nature of the objective function and the design constraints. In this sense, the model "works."

2. The greatest source of difficulty encountered in the pilot study model runs involved the transformation of raw data into finished information for input to the model. A simplified data reduction program set should be developed in Phase II of the project to provide for ease of data transformation. Simplified data reduction is vital if wide usage of the design model is to become a reality.

3. Since the basic element of the design model and its resulting physical plan is the module, there is a need to express the initial conditions of the model—including the initial land use inventory—in module terminology. Since land use data are not usually expressed in module terms, such a requirement imposes a need to transform land use data into module terms. Although such a transformation may seem somewhat artificial since the original land was not developed in module elements, it is necessary in order to initialize the model run. Early model runs have assumed no initial land use development. In other words, the design model started with a "clean slate" with all land initially undeveloped. The model has now been modified to permit the entry of initial land use conditions. All subsequent land development takes place based on these initial land use conditions.

4. One of the deficiencies discovered in the initial programming of the model was a certain amount of "double counting" with regard to linkage costs. The inter-module connectivity matrix expresses the unit distance cost of linkages between two modules. If only two modules were involved in a partition, this connectivity cost could be used to compute the linkage costs between the modules. In a typical partition, however, a large number of modules will be located in each half of the partition; and many of these modules may use the same linkage elements, such as roads and sanitary sewer mains. For this reason, the model must avoid linkage cost duplication in calculating the linkage costs between modules. The model has now been modified to provide a basic cost for the initial linkage element and incremental costs for expansion of this linkage facility as a function of the number and kinds of elements at each end of the linkage.

In summary, it can be stated that the PLACECOMP program provides a flexible and useful land use plan design model. The input data to the model should be available in most areas with a good regional planning data base. The reduction of the data to provide the model input information (with a good data reduction program) and the subsequent operation of the model itself seem to present no formidable problems so that the design model is capable of wide application in both regional and community planning.

In Phase II, a more comprehensive application of the model at a regional level will be attempted using actual objectives and design standards as design model constraints. A comprehensive data reduction system will be developed to expedite model data reduction.

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APPENDICES

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Appendix I
SAMPLE PLAN DESIGN MODULES
(MODULE DEFINITIONS)

A. MODULE TYPE: RESIDENTIAL (low-density)

DEFINITION: The module consists of a total area of 2,521.6 acres allocated to the primary and accessory land uses and facilities listed below.

1. Area: The allocation of land to the functional subcomponents of the module is:

Component	Acres
Gross area	2,521.6[1]
Building area	114.1[2]
Parking, service, access, internal vehicular, and pedestrian circulation areas	11.4[3]
Open space, side, rear, and front yards	1,922.5[4]
Arterial street right-of-way	31.7
Collector street right-of-way	19.4
Local street right-of-way	371.3
Neighborhood park and parkway	38.4
Elementary school	12.8

2. Land Use Characteristics: The primary land use of the module is single-family dwelling units and may include the following representative land use types: single-family homes on various lot sizes combined in such proportions as to average 1.2 dwelling units per net residential acre on lots averaging 185 by 200 feet, an elementary school, a neighborhood park, and facilities needed for day-to-day family life.

PURPOSE: To provide, in a cellular unit, the area necessary to house the population served by one elementary school and neighborhood park, served by an internal street system which discourages penetration of the unit by through traffic, and served by all the community facilities necessary to meet day-to-day living requirements of the family within the immediate vicinity of its dwelling unit.

DESIGN STANDARDS: The following design standards are intended to insure proper site development within the module, to provide requisite functional linkages with other modules, and to maintain a proper balance between the demands of the module and the supporting natural resource base.

[1] *This module was adapted from a 2,560-acre residential planning unit used by SEWRPC and includes all elements of the unit except the necessary neighborhood commercial area and the necessary other public and quasi-public use areas, which together total 38.4 acres and which were included in separate module types. See Appendix A, SEWRPC Planning Report No. 7, Volume 2, Forecasts and Alternative Plans--1990.*

[2] *Assuming 2,485 single-family dwelling units with an average building site of 2,000 square feet per dwelling unit.*

[3] *Assuming 200 square feet per dwelling unit.*

[4] *Assuming an average lot size of 185 by 200 feet.*

1. Intra-Module Standards

   a. The module shall include 10,560 lineal feet of arterial street right-of-way or full width equiva-[5] lent constructed to rural cross section standards.

   b. The module shall include 10,560 lineal feet of collector street right-of-way or full width equiva-[6] lent constructed to rural cross section standards.

   c. The module shall include 245,000 lineal feet of local street right-of-way or full width equivalent[7] constructed to rural cross section standards.

   d. An area of 114.1 acres shall be suitably graded for building sites.

   e. An area of 11.4 acres shall be suitably graded for off-street parking area.

   f. An area of 12.6 acres shall be suitably graded for playgrounds and playfields.

   g. An area of 110.6 acres of building foundation suitable for the appropriate structure types required shall be provided.

   h. There shall be 2,485 on-site sewage disposal units provided.

   i. Public sanitary sewage collection facilities shall be provided for the elementary school in accordance with established standards.

   j. Public water supply facilities shall be provided for the module in accordance with established standards.

   k. Gas transmission and service facilities shall be provided for the module in accordance with established standards.

   l. Electrical power transmission and service facilities shall be provided for the module in accordance with established standards.

   m. Telephone transmission and service facilities shall be provided for the module in accordance with established standards.

   n. Surface storm drainage facilities shall be provided for suitable surface drainage of 2,522 acres of land along 266,720 lineal feet of street full width equivalent.

2. Inter-Module Standards

   a. Allocation Standards

      1. One module shall be allocated in the design for each 8,200 persons residing in Residential (low-density) modules.

   b. Spatial Accessibility and Compatibility Standards

      1. The module shall be located no more than 2 miles from an arterial street linkage.

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[5] *For detailed standards, see SEWRPC Planning Guide No. 1, Land Development Guide, November 1963.*

[6] *Ibid.*

[7] *Ibid.*

2. The location of the module relative to others shall be constrained only by the optimization of combined linkage costs, site development costs, accessibility costs, and compatibility costs.

c. Resource Conservation Standards

1. The location of the module shall be constrained only by the optimization of combined site development costs, linkage costs, accessibility costs, and compatibility costs.

d. Linkage Requirements Standards

1. The module shall be connected by a rural arterial street linkage.

2. The module shall be connected by a public water supply transmission.

3. The module shall be connected by a public sewage collection line linkage.

4. The module shall be connected by a gas transmission line linkage.

5. The module shall be connected by a telephone transmission line linkage.

6. The module shall be connected by an electrical power transmission line linkage.

B. MODULE TYPE: RESIDENTIAL (medium-density)

DEFINITION: The module consists of a total area of 627.2 acres allocated to the primary and accessory land uses and facilities listed below.

1. Area: The allocation of land to the functional subcomponents of the module is:

Component	Acres
Gross area	627.2 [8]
Building area	61.7 [9]
Parking, service, access, internal vehicular, and pedestrian circulation areas	9.1 [10]
Open space, side, rear, and front yards	383.6 [11]
Arterial street right-of-way	7.9
Collector street right-of-way	9.7
Local street right-of-way	129.6

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[8] *This module was adapted from a 640-acre residential planning unit used by the SEWRPC and includes all elements of the unit except the necessary neighborhood commercial area and the necessary other public and quasi-public use areas, which together total 12.8 acres and which were included in separate module types. See Table A-1 and A-2, SEWRPC Planning Report No. 7, Volume 2, Forecasts and Alternative Plans--1990, June 1966.*

[9] *Assuming 355 multi-family dwelling units with an average building size of 750 square feet per dwelling unit and 1,615 single-family units with an average building size of 1,500 square feet per dwelling unit.*

[10] *Assuming 200 square feet per dwelling unit.*

[11] *Assuming an average lot size of 85 by 125 feet.*

Neighborhood park and parkway	16.0
Elementary school	9.6

2. Land Use Characteristics: The primary land use of the module is single- and multi-family dwelling units and may include the following representative land use types: single-family and multi-family homes in such proportions as to average 4.3 dwelling units per net residential acre on lots averaging 85 x 125 feet, an elementary school, a neighborhood park, and facilities needed for day-to-day family life.

PURPOSE: To provide in a cellular unit the area necessary to house the population served by one elementary school and neighborhood park, served by an internal street system which discourages penetration of the unit by through traffic, and served by all the community facilities necessary to meet day-to-day living requirements of the family within the immediate vicinity of its dwelling unit.[12]

DESIGN STANDARDS: The following design standards are intended to insure proper site development within the module, to provide requisite functional linkages with other modules, and to maintain a proper balance between the demands of the module and the supporting natural resource base.

1. Intra-Module Standards

   a. The module shall include 2,640 lineal feet of arterial street right-of-way or full width equivalent constructed to urban cross section standards.

   b. The module shall include 5,280 lineal feet of collector street right-of-way or full width equivalent constructed to urban cross section standards.

   c. The module shall include 94,100 lineal feet of local street right-of-way or full width equivalent constructed to urban cross section standards.

   d. An area of 61.7 acres shall be suitably graded for building sites.

   e. An area of 9.1 acres shall be suitably graded for off-street parking area.

   f. An area of 61.7 acres of building foundation suitable for the appropriate structure types required shall be provided.

   g. Public sanitary sewage collection facilities shall be provided for the module in accordance with established standards.

   h. Public water supply facilities shall be provided for the module in accordance with established standards.

   i. Gas transmission and service facilities shall be provided for the module in accordance with established standards.

   j. Electrical power transmission and service facilities shall be provided for the module in accordance with established standards.

   k. Telephone transmissions and service facilities shall be provided for the module in accordance with established standards.

   l. Storm drainage facilities shall be provided for suitable surface drainage of 627 acres of land along 102,020 lineal feet of street full width equivalent.

[12] *SEWRPC Planning Report No. 7, Volume 2, Forecasts and Alternative Plans--1990, June 1966.*

2. Inter-Module Standards

a. Allocation Standards

1. One module shall be allocated in the design for each 6,500 persons residing in the Residential (medium-density) modules.

b. Spatial Accessibility and Compatibility Standards

1. The module shall be located no more than one mile from an arterial street linkage.

2. The location of the module relative to others shall be constrained only by the optimization of combined linkage costs, site development costs, accessibility costs, and compatibility costs.

c. Resource Conservation Standards

1. The module shall not be located on a major natural watershed boundary.

2. The location of the module shall be constrained only by the optimization of combined site development costs, linkage costs, accessibility costs, and compatibility costs.

d. Linkage Requirements Standards

1. The module shall be connected by an urban arterial street linkage.

2. The module shall be connected by a public water supply transmission line linkage.

3. The module shall be connected by a public sewage collection line linkage.

4. The module shall be connected by storm sewer collection line linkage.

5. The module shall be connected by a gas transmission line linkage.

6. The module shall be connected by a telephone transmission line linkage.

7. The module shall be connected by an electric power transmission line linkage.

C. MODULE TYPE: NEIGHBORHOOD COMMERCIAL CENTER (low-density)

DEFINITION: The module consists of a total area of 6.4 acres allocated to the primary and accessory land uses and facilities listed below.

1. Area: The allocation of land to the functional subcomponents of the module is:

Component	Acres
Gross area	6.4[13][14]
Building area	1.1

[13] This module corresponds to the 12.8 acres allocated to neighborhood commercial uses in the 2,560-acre residential planning unit used by SEWRPC; therefore, the allocation is two (6.4-acre) modules per Residential (low-density) module in the problem. Since 6.4 acres is considered a viable unit for neighborhood commercial centers, the use of two 6.4-acre modules, rather than one 12.8-acre module, allows greater flexibility in model application.

[14] See Appendix A, SEWRPC Planning Report No. 7, Volume 2, Forecasts and Alternative Plans--1990.

Parking, service, access, internal vehicular, and pedestrian circulation areas	2.9[15]
Open space, side, rear, and front yards	0.6
Arterial street right-of-way	0.9
Collector street right-of-way	0.4
Local street right-of-way	0.5

2. Land Use Characteristics: The primary land use of the module is neighborhood commercial and may include the following representative land use types: bakeries, barbershops, bars, beauty shops, business offices, clinics, clothing stores, cocktail lounges, confectioneries, delicatessens, drugstores, fish markets, florists, fraternities, fruit stores, gift stores, grocery stores, hardware stores, house occupations, hobby shops, lodges, meat markets, optical stores, packaged beverage stores, professional offices, restaurants, self-service and pickup laundry and dry cleaning establishments, soda fountains, sporting goods stores, supermarkets, tobacco stores, and vegetable stores.[16]

PURPOSE: To provide the area necessary to house convenience goods and service establishments needed for day-to-day living requirements of the family within the immediate vicinity of its dwelling unit.

DESIGN STANDARDS: The following design standards are intended to insure proper site development within the module, to provide requisite functional linkages with other modules, and to maintain a proper balance between the demands of the module and the supporting natural resource base.

1. Intra-Module Standards

   a. The module shall include 340 lineal feet of arterial street right-of-way or full width equivalent constructed to urban cross section standards.[17]

   b. The module shall include 150 lineal feet of collector street right-of-way or full width equivalent constructed to urban cross section standards.[18]

   c. The module shall include 340 lineal feet of local street right-of-way or full width equivalent constructed to urban cross section standards.[19]

   d. An area of 1.1 acres shall be suitably graded for building sites.

   e. An area of 2.9 acres shall be suitably graded for off-street parking area.

   f. An area of 1.1 acres of building foundation suitable for the appropriate structure types required shall be provided.

   g. Public sanitary sewage collection facilities shall be provided for the module in accordance with established standards.

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[15] *Assuming 300 square feet per 100 square feet of building area.*

[16] *These uses are listed as principal uses in the B-1 Neighborhood Business District in the Model Zoning Ordinance contained in SEWRPC Planning Guide No. 3, Zoning Guide, April 1964.*

[17] *For detailed standards, see SEWRPC Planning Guide No. 1, Land Development Guide, November 1963.*

[18] *Ibid.*

[19] *For detailed standards, see SEWRPC Planning Guide No. 1, Land Development Guide, November 1963.*

h. Public water supply facilities shall be provided for the module in accordance with established standards.

i. Gas transmission and service facilities shall be provided for the module in accordance with established standards.

j. Electrical power transmission and service facilities shall be provided for the module in accordance with established standards.

k. Telephone transmission and service facilities shall be provided for the module in accordance with established standards.

l. Surface storm drainage facilities shall be provided for suitable surface drainage of 6.4 acres of land along 830 lineal feet of street full width equivalent.

2. Inter-Module Standards

a. Allocation Standards

1. Two modules shall be allocated in the design for each Residential (low-density) module in the design.

b. Spatial Accessibility and Compatibility Standards

1. The module shall be located contiguously to a Residential (low-density) module.

2. The location of the module relative to others shall be constrained only by the optimization of combined linkage costs, site development costs, accessibility costs, and compatibility costs.

c. Resource Conservation Standards

1. The location of the module shall be constrained only by the optimization of combined site development costs, linkage costs, accessibility costs, and compatibility costs.

d. Linkage Requirements Standards

1. The module shall be connected by an urban arterial street linkage.

2. The module shall be connected by a public water supply transmission line linkage.

3. The module shall be connected by a public sewage collection line linkage.

4. The module shall be connected by a gas transmission line linkage.

5. The module shall be connected by a telephone transmission line linkage.

6. The module shall be connected by an electrical power transmission line linkage.

D. MODULE TYPE: COMMUNITY COMMERCIAL CENTER

DEFINITION: The module consists of a total area of 28.2 acres allocated to the primary and accessory land uses and facilities listed below.

1. Area: The allocation of land to the functional subcomponents of the module is:

Component	Acres
Gross area	28.2[20]
Building area	4.6
Parking, service, access, internal vehicular, and pedestrian circulation areas	18.3[21]
Open space, side, rear, and front yards	0.9
Arterial street right-of-way	3.0[22]
Collector street right-of-way	0.0
Local street right-of-way	1.4

2. Land Use Characteristics: The primary land use of the module is community commercial and may include the following representative land use types: All uses permitted in the neighborhood commercial centers and the following: appliance stores, caterers, clothing repair shops, crockery stores, electrical supply, financial institutions, food lockers, furniture stores, furniture upholstery shops, heating supply, hotels, laundry and dry-cleaning establishments employing not over seven persons, liquor stores, music stores, newspaper offices and press rooms, night clubs, office supplies, pawn shops, personal service establishments, pet shops, photographic supplies, plumbing supplies, printing, private clubs, publishing, second-hand stores, signs, trade and contractor's offices, upholsterer's shops, and variety stores.[23]

PURPOSE: To provide the area necessary to house convenience and shopper goods and service establishments which serve a larger tributary area than a Residential module but a smaller tributary area than that required to support a regional commercial module.

DESIGN STANDARDS: The following design standards are intended to insure proper site development within the module, to provide requisite functional linkages with other modules, and to maintain a proper balance between the demands of the module and the supporting natural resource base.

1. Intra-Module Standards

   a. The module shall include 990 lineal feet of arterial street right-of-way or full width equivalent constructed to urban cross section standards.[24]

   b. The module shall include 990 lineal feet of local street right-of-way or full width equivalent constructed to urban cross section standards.[25]

   c. An area of 4.6 acres shall be suitably graded for building sites.

   d. An area of 18.3 acres shall be suitably graded for off-street parking area.

[20] *The Community Builder's Handbook, Community Builder's Council of Urban Land Institute, (Washington, D.C.,1960).*

[21] *Assuming 400 square feet per 100 square feet of building area.*

[22] *Assuming the module has access to two arterial streets.*

[23] *These uses are listed as principal uses in the B-2 Community Business District in the Model Zoning Ordinance contained in SEWRPC Planning Guide No. 3, Zoning Guide, April 1964.*

[24] *For detailed standards, see SEWRPC Planning Guide No. 1, Land Development Guide, November 1963.*

[25] *Ibid.*

e. An area of 4.6 acres of building foundation suitable for the appropriate structure types required shall be provided.

f. Public sanitary sewage collection facilities shall be provided for the module in accordance with established standards.

g. Public water supply facilities shall be provided for the module in accordance with established standards.

h. Gas transmission and service facilities shall be provided for the module in accordance with established standards.

i. Electrical power transmission and service facilities shall be provided for the module in accordance with established standards.

j. Telephone transmission and service facilities shall be provided for the module in accordance with established standards.

k. Storm drainage facilities shall be provided for suitable surface drainage of 28.2 acres of land along 1,980 lineal feet of street full width equivalent.

2. Inter-Module Standards

a. Allocation Standards

1. One module shall be allocated in the design for each 71,500 persons residing in the area for which a plan design is being prepared.

b. Spatial Accessibility and Compatibility Standards

1. The location of the module relative to others shall be constrained only by the optimization of combined linkage costs, site development costs, accessibility costs, and compatibility costs.

c. Resource Conservation Standards

1. The location of the module shall be constrained only by the optimization of combined site development costs, linkage costs, accessibility costs, and compatibility costs.

d. Linkage Requirements Standards

1. The module shall be connected by an urban arterial street linkage.

2. The module shall be connected by a public water supply transmission line linkage.

3. The module shall be connected by a public sewage collection line linkage.

4. The module shall be connected by a storm sewer collection line linkage.

5. The module shall be connected by a gas transmission line linkage.

6. The module shall be connected by a telephone transmission line linkage.

7. The module shall be connected by an electrical power transmission line linkage.

E. MODULE TYPE: SENIOR HIGH SCHOOL (public)

DEFINITION: The module consists of a total area of 45.0 acres allocated to the primary and accessory land uses and facilities listed below.

1. Area: The allocation of land to the functional subcomponents of the module is:

Component	Acres
Gross area	45.0[26]
Building area	3.6
Parking, service, access, internal vehicular, and pedestrian circulation areas	5.1
Open space, side, rear, and front yards	11.0
Arterial street right-of-way	2.1
Collector street right-of-way	1.3
Local street right-of-way	1.9
Playfields	20.0

2. Land Use Characteristics: The primary land use of the module is senior high school and may include the following representative land use types: the school classrooms and administrative building, auxiliary structures, playfield and apparatus.

PURPOSE: To provide the area necessary to house the high school facilities and related community activities, such as sports events and adult education.

DESIGN STANDARDS: The following design standards are intended to insure proper site development within the module, to provide requisite functional linkages with other modules, and to maintain a proper balance between the demands of the module and the supporting natural resource base.

1. Intra-Module Standards

   a. The module shall include 700 lineal feet of arterial street right-of-way or full width equivalent constructed to urban cross section standards.[27]

   b. The module shall include 700 lineal feet of collector street right-of-way or full width equivalent constructed to urban cross section standards.[28]

   c. The module shall include 1,400 lineal feet of local street right-of-way or full width equivalent constructed to urban cross section standards.[29]

   d. An area of 3.6 acres shall be suitably graded for building sites.

[26] *Assuming an optimal enrollment of 1,500 pupils and an allocation of 30 acres plus one additional acre per each 100 pupils.*

[27] *For detailed standards, see SEWRPC Planning Guide No. 1, Land Development Guide, November 1963.*

[28] *Ibid.*

[29] *Ibid.*

e. An area of 5.1 acres shall be suitably graded for off-street parking area.

f. An area of 20.0 acres shall be suitably graded for a playfield.

g. An area of 3.6 acres of building foundation suitable for the appropriate structure types required shall be provided.

h. Public sanitary sewage collection facilities shall be provided for the module in accordance with established standards.

i. Public water supply facilities shall be provided for the module in accordance with established standards.

j. Gas transmission and service facilities shall be provided for the module in accordance with established standards.

k. Electrical power transmission and service facilities shall be provided for the module in accordance with established standards.

l. Telephone transmission and service facilities shall be provided for the module in accordance with established standards.

m. Storm drainage facilities shall be provided for suitable surface drainage of 45 acres of land along 2,800 lineal feet of street full width equivalent.

2. Inter-Module Standards

a. Allocation Standards

1. One module shall be allocated in the design for each 63,000 persons residing in the area for which a plan design is being prepared.[30]

b. Spatial Accessibility and Compatibility Standards

1. The location of the module relative to others shall be constrained only by the optimization of combined linkage costs, site development costs, accessibility costs, and compatibility costs.

c. Resource Conservation Standards

1. The location of the module shall be constrained only by the optimization of combined site development costs, linkage costs, accessibility costs, and compatibility costs.

d. Linkage Requirements Standards

1. The module shall be connected by an urban arterial street linkage.

2. The module shall be connected by a public water supply transmission line linkage.

3. The module shall be connected by a public sewage collection line linkage.

4. The module shall be connected by a storm sewer collection line linkage.

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[30] *Assuming 3.96 percent of the total population attends a senior high school and that 60 percent of attendants (or 2.38 percent of total population) are pupils of a public facility.*

5. The module shall be connected by a gas transmission line linkage.

6. The module shall be connected by a telephone transmission line linkage.

7. The module shall be connected by an electrical power transmission line linkage.

F. MODULE TYPE: PLANNED INDUSTRIAL DISTRICT (light)

DEFINITION: The module consists of a total area of 640 acres allocated to the primary and accessory land uses and facilities listed below.

1. Area: The allocation of land to the functional subcomponents of the module is:

Component	Acres
Gross area	640.0[31]
Building area	157.4[32]
Parking, service, access, internal vehicular, and pedestrian circulation areas	114.6
Open space, side, rear, and front yards	157.5
Arterial street right-of-way	7.9
Collector street right-of-way	4.8
Rail spur right-of-way	78.1[33][34]
Truck docks and apron	18.6[35]
Internal circulation ways and cul-de-sacs	101.1[36][37]

2. Land Use Characteristics: The primary land use of the module is light industrial and may include the following representative land use types: automotive body repairs; automotive upholstery; cleaning, pressing, and dyeing establishments; commercial bakeries; commercial greenhouses; distributors; farm machinery; food locker plants; laboratories; machine shops; manufacture and bottling of nonalcholic beverages; painting; printing; publishing; storage and sale of machinery and equipment; trade and contractors' offices; warehousing; and wholesaling. Manufacture, fabrication, packing, packaging, and assembly of products from furs, glass, leather, metals, paper, plaster, plastics, textiles, and wood. Manufacture, fabrication, processing, packaging, and packing of confections; cosmetics; electrical appliances; electronic devices; food except cabbage, fish and

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31 *See SEWRPC Planning Report No. 7, Volume 2, Forecasts and Alternative Plans--1990.*

32 *See Local Planning Administration, The International City Managers Association, (Chicago 1959).*

33 *Ibid.*

34 *Assuming a railway spur right-of-way of 52 feet.*

35 *Ibid, footnote 25.*

36 *Ibid, footnote 25.*

37 *Assuming the internal circulation ways and cul-de-sacs have a right-of-way width of 50 feet.*

fish products, meat and meat products, and pea vining; instruments; jewelry; pharmaceuticals; tobacco; and toiletries.[38]

PURPOSE: To provide the area necessary to house industrial uses in an exclusive zoning district and with the economies afforded by joint use of facilities and utilities.

DESIGN STANDARDS: The following design standards are intended to insure proper site development within the module, to provide requisite functional linkages with other modules, and to maintain a proper balance between the demands of the module and the supporting natural resource base.

1. Intra-Module Standards

   a. The module shall include 2,640 lineal feet of arterial street right-of-way or full width equivalent constructed to urban cross section standards.[39]

   b. The module shall include 7,920 lineal feet of collector street right-of-way or full width equivalent constructed to urban cross section standards.[40]

   c. The module shall include 88,100 lineal feet of internal circulation street right-of-way or full width equivalent constructed in accordance with established standards.[41]

   d. An area of 157.4 acres shall be suitably graded for building sites.

   e. An area of 114.6 acres shall be suitably graded for off-street parking area.

   f. An area of 18.6 acres shall be suitably graded for truck docks and apron.

   g. An area of 157.4 acres of building foundation suitable for the appropriate structure types required shall be provided.

   h. Public sanitary sewage collection facilities shall be provided for the module in accordance with established standards.

   i. Public water supply facilities shall be provided for the module in accordance with established standards.

   j. Gas transmission and service facilities shall be provided for the module in accordance with established standards.

   k. Electrical power transmission and service facilities shall be provided for the module in accordance with established standards.

   l. Telephone transmission and service facilities shall be provided for the module in accordance with established standards.

   m. Storm drainage facilities shall be provided for suitable surface drainage of 640 acres of land along 113.8 lineal feet of street full width equivalent.

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38 *These uses are listed as principal uses of the M-1 Industrial District in the Model Zoning Ordinance contained in SEWRPC Planning Guide No. 3, Zoning Guide, April 1964. Quarrying and other mineral extraction and related uses are not included in either the Planned Industrial (light) or the Planned Industrial (heavy) modules. It is reasoned that, because of the resource orientation of extractive industries, they shall be conditional uses and subject to the established review procedure at the time of initiation of zoning appeal.*

39 *For detailed standards, see SEWRPC Planning Guide No. 1, Land Development Guide, November 1963.*

40 *Ibid.*

41 *Ibid.*

n. The module shall include 66,400 lineal feet of railway spur right-of-way or full width equivalent constructed in accordance with established standards.

2. Inter-Module Standards

a. Allocation Standards

1. One module shall be allocated in the design for each 9,100 persons employed in the area for which a plan design is being prepared.[42]

b. Spatial Accessibility and Compatibility Standards

1. The location of the module relative to others shall be constrained only by the optimization of combined linkage costs, site development costs, accessibility costs, and compatibility costs.

c. Resource Conservation Standards

1. The location of the module shall be constrained only by the optimization of combined site development costs, linkage costs, accessibility costs, and compatibility costs.

d. Linkage Requirements Standards

1. The module shall be connected by an urban arterial street linkage.

2. The module shall be connected by an urban collector street linkage.

3. The module shall be connected by a public water supply transmission line linkage.

4. The module shall be connected by a public sewage collection line linkage.

5. The module shall be connected by a storm sewer collection line linkage.

6. The module shall be connected by a gas transmission line linkage.

7. The module shall be connected by a telephone transmission line linkage.

8. The module shall be connected by a railroad main line linkage.

9. The module shall be connected by an electrical power transmission line linkage.

G. MODULE TYPE: MUNICIPAL HALL (community)

DEFINITION: The module consists of a total area of 2 acres allocated to the primary and accessory land uses and facilities listed below.

1. Area: The allocation of land to the functional subcomponents of the module is:

Component	Acres
Gross area	2.0 [43]
Building area	0.5 [44]

[42] *Assuming an allocation of 7 acres per 100 employees.*

[43] *Assuming a minimum of 2 acres is required for a viable unit.*

[44] *Assuming a need for 200 square feet of building area per employee.*

Parking, service, access, internal vehicular, and pedestrian circulation areas	0.5
Open space, side, rear, and front yards	0.4
Arterial street right-of-way	0.3
Collector street right-of-way	0.2
Local street right-of-way	0.1

2. Land Use Characteristics: The primary land use of the module is generally municipal hall and may include the following representative land use types: city or village administrative offices and auxiliary structures.

PURPOSE: To provide the area necessary to house municipal services and administrative offices, and to centralize municipal offices where practical.

DESIGN STANDARDS: The following design standards are intended to insure proper site development within the module, to provide requisite functional linkages with other modules, and to maintain a proper balance between the demands of the module and the supporting natural resource base.

1. Intra-Module Standards

   a. The module shall include 100 lineal feet of arterial street right-of-way or full width equivalent constructed to urban cross section standards.[45]

   b. The module shall include 140 lineal feet of collector street right-of-way or full width equivalent constructed to urban cross section standards.[46]

   c. The module shall include 100 lineal feet of local street right-of-way or full width equivalent constructed to urban cross section standards.[47]

   d. An area of 0.5 acres shall be suitably graded for building sites.

   e. An area of 0.5 acres shall be suitably graded for off-street parking area.

   f. An area of 0.5 acres of building foundation suitable for the appropriate structure types required shall be provided.

   g. Public sanitary sewage collection facilities shall be provided for the module in accordance with established standards.

   h. Public water supply facilities shall be provided for the module in accordance with established standards.

   i. Gas transmission and service facilities shall be provided for the module in accordance with established standards.

   j. Electrical power transmission and service facilities shall be provided for the module in accordance with established standards.

[45] *For detailed standards, see SEWRPC Planning Guide No. 1, Land Development Guide, November 1963.*

[46] *Ibid.*

[47] *Ibid.*

k. Telephone transmission and service facilities shall be provided for the module in accordance with established standards.

l. Storm drainage facilities shall be provided for suitable surface drainage of 2 acres of land along 340 lineal feet of street full width equivalent.

2. Inter-Module Standards

a. Allocation Standards

1. One module shall be allocated in the design for each 14,000 persons residing in each municipality[48] of the area for which a plan design is being prepared.

b. Spatial Accessibility and Compatibility Standards

1. The location of the module relative to others shall be constrained only by the optimization of combined linkage costs, site development costs, accessibility costs, and compatibility costs.

c. Resource Conservation Standards

1. The location of the module shall be constrained only by the optimization of combined site development costs, linkage costs, accessibility costs, and compatibility costs.

d. Linkage Requirements Standards

1. The module shall be connected by an urban arterial street linkage.

2. The module shall be connected by a public water supply transmission line linkage.

3. The module shall be connected by a public sewage collection line linkage.

4. The module shall be connected by a storm sewer collection line linkage.

5. The module shall be connected by a gas transmission line linkage.

6. The module shall be connected by a telephone transmission line linkage.

7. The module shall be connected by an electrical power transmission line linkage.

[48] *Assuming a need to house 7 municipal employees per 1,000 population.*

Appendix II
LINKAGES

The following linkages were used in developing construction and operating costs for application in the Land Use Plan Design Model:

1. Streets (construction and operating costs)
   a. Minor
      1) urban
      2) rural
   b. Collector
      1) urban
      2) rural
   c. Arterial
      1) urban
      2) rural
   d. Freeway (and other limited access arterials)
      1) urban
      2) rural
2. Water Transmission and Distribution Lines (construction costs only)
3. Sanitary Sewer Lines (construction costs only)
4. Storm Sewer Lines (construction costs only)
5. Gas Transmission and Distribution Lines (construction costs only)
6. Electric Power Transmission and Distribution Lines (construction costs only)
7. Telephone Lines (construction costs only)

Appendix III
COMPUTER PROGRAMS

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*DELETCUCPIN


*LDISKCUCPIN
*LISTPRINTER
*ALLSTATEMENTMAP
*FANDK0804
C     CUCPIN IS THE MAIN LINE PROGRAM FOR PLACECOMP II
C     DISK LAYOUT INFORMATION AND RESTART CONSTANTS
C                                                                     3
C     SECTOR ONE
C         NODIV --- PARTITION NUMBER IN PROCESS
C         IDKML --- SECTOR LOCATION OF THE MODULE LINKAGE MATRIX
C         IDKARE -- SECTOR LOCATION OF THE MODULE AREA VECTOR
C         IDKMTN -- SECTOR LOCATION OF THE MODULE TYPE NUMBER VECTOR
C         IDKSOL -- SECTOR LOCATION OF THE CELL - SOIL TYPE INVENTORY
C         IDKCST -- SECTOR LOCATION OF THE MODULE - SOIL SITE COST MATRIX
C         NDIVC --- THE NUMBER OF PARTITIONS IN THE PROBLEM
C         NOOFMT -- NO OF MODULE TYPES IN THE PROBLEM
C         LOCDIV(1 TO NDIVC) -- SECTOR LOCATION FOR INFORMATION THAT
C                    PERTAINS TO THE INDIVIDUAL PARTITIONS ONE TO NDIVC
C                                                                     4
C     SECTOR  IDKML
C         A 91 BY 90 MODULE LINKAGE MATRIX.  THE 91ST COLUMN OF EACH ROW
C         CONTAINS THE NO OF MODULES OF THE TYPE IN THE PROBLEM.  EACH
C         ROW REPRESENTS A TYPE AS DOES EACH COLUMN EXCEPT THE 91ST.
C         EACH ROW TAKES 4 SECTORS
C                                                                     5
C     SECTOR  IDKARE
C         A VECTOR CONTAINING THE AREA REQUIRED FOR EACH MODULE TYPE
C                                                                     6
C     SECTOR  IDKMTN
C         A VECTOR CONTAINING THE NO. OF MODULES OF EACH TYPE IN THE
C         PROBLEM.  SAME AS ML COLUMN 91
C                                                                     7
C     SECTOR  IDKSOL
C         A 369 COLUMN BY 30 ROW MATRIX CONTAINING THE SOIL OF EACH TYPE      8
C         AVAILABLE IN EACH CELL.  EACH ROW REPRESENTS A SOIL TYPE,
C         EACH COLUMN A CELL.  EACH ROW TAKES 37 SECTORS               9
C                                                                    10
C     SECTOR  IDKCST
C         A 30 COLUMN BY 90 ROW MATRIX CONTAINING THE SITE COSTS FOR        11
C         EACH SOIL TYPE (COLUMN) AND MODULE TYPE (ROW) COMBINATION.       12
C         EACH ROW TAKES FOUR SECTORS                                13
C                                                                    14
C     SECTOR LOCDIV
C         AT EACH LODIV SECTOR THERE IS A RECORD CONTAINING          15
C              NODIV -- THE PARTITION NUMBER
C              PRICE -- THE PRICE OF A SINGEL CONNECTION BETWEEN THE
C                       DIVISION HALFS.
C              IDVPNT - THE PARENT DIVISION NO.
C              IPNTHF - THE PARENT DIVISION HALF
C              NOCELS - NO OF CELS IN THE DIVISION
C             DIST --- THE DISTANCE BETWEEN PARTITION CENTERS          A
C                                                                    16
C     SECTORS WHICH FOLLOW SECTOR LOCDIV CONTAIN                     17
C         ITESTC--  NO OF CELLS IN FIRST HALF OF THE DIVISION
C         ICEL1 --  LIST OF CELLS IN FIRST HALF OF DIVISION
C         NTSTC --  NO OF CELLS IN 2ND HALF OF THE DIVISION
C         ICEL2 --  LIST OF CELLS IN 2ND HALF
C                   FOLLOWED BY TWO 90 POSITION ZERO VECTORS WHICH WILL   18
C                   CONTAIN THE NO. OF EACH MODULE TYPE ASSIGNED TO
C                   EACH HALF AFTER THE DIVISION IS MADE
C                                                                    19
C     SECTOR IDKLNK
C         A 30 COLUMN BY 90 ROW MATRIX CONTAINING ZEROS AND ONES       B
C         TO INDICATE WHICH LINKAGE TYPES ARE REQUIRED BY WHICH
C         MODULE TYPES.  THE 30 COLUMNS ARE THE LINKAGE TYPES
C         AND THE 90 ROWS ARE THE MODULE TYPES. EACH ROW TAXES 2 SECTORS
C     SECTOR IDKFCT
C         A VECTOR CONTAINING THE FIRST COST OR NEW COST PER UNIT      C
C         LENGTH OF EACH LINKAGE TYPE
C
C

      DIMENSION  LOCDIV(300)
      COMMON   NXTIDK, IDKML, IDKARE, IDKMTN,  IDKSOL,  IDKCST, NDIVC,
     $         LOCDIV, NOOFMT
      COMMON  IDKLNK, IDKFCT, NOOFLT, DIST
      DEFINE DISK (10,19000)
C
C     INITIALIZE NEXT AVAILABLE OUT OF CORE RECORD
      NXTIDK=50
C
C     READ, PRINT AND STORE INPUT MATERIAL
C     IN1 IS AN INPUT ROUTINE FOR PLACE COMP.
C     IT IS CALLED BY CUCPIN TO READ PRINT AND STORE
C            MODULE TYPE CONNECTIVITY MATRIX
C            MODULE TYPE NUMBER VECTOR
C            MODULE TYPE SITE AREA VECTOR
      CALL IN1
C     IN2 IS AN INPUT ROUTINE FOR PLACE COMP.  IT IS CALLED BY        25
C     CUCPIN TO READ, PRINT AND STORE THE CELL-SOIL-TYPE INVENTORY    26
      CALL IN2
C     IN3 IS AN INPUT ROUTINE FOR PLACE COMP.  IT IS CALLED BY        32
C     CUCPIN TO READ, PRINT AND STORE THE SITE COST OF EACH           33
C     MODULE TYPE AND SOIL TYPE COMBINATION                           34
      CALL IN3
C     IN4 IS AN INPUT ROUTINE FOR PLACE COMP.
C         THE NUMBER OF DIVISIONS IN THE PROBLEM
C         THE CONNECTIVITY PRICE FOR EACH DIVISION
C         THE PARENT DIVISION OF EACH DIVISION
C         THE PARENT DIVISION HALF OF EACH DIVISION
C         THE CELL LIST FOR EACH DIVISION
      CALL IN4
C     IN35 IS AN INPUT ROUTINE FOR PLACECOMP II
C          IT READS THE LINKAGE TYPE MATRIX AND THE
C          FIRST COST VECTOR AND SOTRES THESE VALUES ON DISK
      CALL IN35
      NXTIDK=NXTIDK+10
C
C     INITIALIZE THE DIVISION NO.
      NODIV=1
C
C     STORE LOCATION MAP
      IDK=1
      RECORD(IDK) NODIV, IDKML, IDKARE, IDKMTN, IDKSOL, IDKCST, NDIVC,
     $  NOOFMT ,  (LOCDIV(I),I=1,NDIVC), NXTIDK
     $ , IDKLNK, IDKFCT, NOOFLT
      PRINT116,    NODIV, IDKML, IDKARE, IDKMTN, IDKSOL, IDKCST, NDIVC,
     $  NOOFMT ,  (LOCDIV(I),I=1,NDIVC), NXTIDK
     $ , IDKLNK, IDKFCT, NOOFLT
  116 FORMAT(1H , 20I5)
      CALL LINK (DVDIN )
      END


*DELETIN1


*LDISK
*LISTPRINTER
*ALLSTATEMENTMAP
*FANDK0804
      SUBROUTINE IN1
C                                                                    21
C     IN1 IS AN INPUT ROUTINE FOR PLACE COMP.                        20
C     IT IS CALLED BY CUCPIN TO READ PRINT AND STORE
C            MODULE TYPE CONNECTIVITY MATRIX
C            MODULE TYPE NUMBER VECTOR
C            MODULE TYPE SITE AREA VECTOR
C                                                                    22
      DIMENSION  AREA(90), MTNO(90), ML(91)
      DIMENSION  LOCDIV(300)
      COMMON   NXTIDK, IDKML, IDKARE, IDKMTN,  IDKSOL,  IDKCST, NDIVC,
     $         LOCDIV, NOOFMT
      COMMON  IDKLNK, IDKFCT, NOOFLT, DIST
C
C     READ NO OF MODULE TYPES
    3 CONTINUE
      READ 100, ICC, NOOFMT, NOOFLT                                   G
C     CHECK FOR CARD CODE SIX                                        23
      IF (ICC-6) 1,2,1
    1 PRINT 101
      PAUSE
      GO TO 3
C     READ, STORE AND PRINT THE MODULE TYPE CONNECTIVITY, AREA AND
C     NUMBER CARDS.
    2 PRINT 102
      PRINT 103,  (I,I=1,90)
C     INITIALIZE MODULE TYPE AREA AND NO. VECTORS
      DO 4 I=1,90
      AREA(I)=0
    4 MTNO(I)=0
C     REMEMBER STORAGE AREA
      IDKML=NXTIDK
C     READ STORE AND PRINT
      DO 7  I=1, NOOFMT
      READ 104, ICC1, MTNO1, AREAC, ( ML(II), II=1,30),
     $          ICC2, MTNO2, FNUMC, ( ML(II), II=31,60),
     $          ICC3, MTNO3, FNUMC, ( ML(II), II=61,90)
      FNUMC=FNUMC*10.0
C     CHECK FOR CARD ORDER
      IF (ICC1-31+ICC2-32+ICC3-33+3*I-MTNO1-MTNO2-MTNO3) 5,6,5
C     CARDS OUT OF ORDER                                             24
    5 PRINT 105
      PRINT 106, ICC1, MTNO1, AREAC, (ML(II),II=1,30 ),
     $           ICC2, MTNO2, FNUMC, (ML(II),II=31,60),
     6           ICC3, MTNO3, FNUMC, (ML(II),II=61,90)
      CALL EXIT
C     STORE
    6 ML(91)=FNUMC
      MTNO(I)=FNUMC
      AREA(I)=AREAC
      IDK=NXTIDK+4*(I-1)
      RECORD (IDK) ML
C     PRINT
      PRINT 107, I, FNUMC, AREAC, (ML(II),II=1,90)
    7 CONTINUE
C     RECORD AREA VECTOR
      IDK=NXTIDK+5+NOOFMT*4
      IDKARE=IDK
      RECORD(IDK) AREA
      IDKMTN=IDK
      RECORD (IDK) MTNO
      NXTIDK=IDK +5
      RETURN
  100 FORMAT ( I2, 3X,2I5)
  101 FORMAT ( 1H1, 10(1H*), 28H READ IN NO. OF MODULE TYPES)
  102 FORMAT (  66H1  CLUSTER COMP INPUT---MODULE TYPE AREA, NUMBER AND
     $ CONNECTIVITY/)
  103 FORMAT (  50H TYPE  NO.        AREA CONNECTIVITY TO MODULE TYPES/
     $          3(1H ,20X, 30I3/))
  104 FORMAT(  I3,2X,I5,F10.1, 30I2)
  105 FORMAT(51H1 CARD ORDER ERROR---MODULE TYPE MATRIX--START OVER)
  106 FORMAT( 1H , I3,I7, F18.8, 30I2)
  107 FORMAT(1H0, I4,I5, F11.3, 30I3, 2( /1H ,20X,30I3))
      END


*DELETIN2


*LDISK
*LISTPRINTER
*ALLSTATEMAP
*FANDK0804
      SUBROUTINE  IN2
C     IN2 IS AN INPUT ROUTINE FOR PLACE COMP.  IT IS CALLED BY        25
C     CUCPIN TO READ, PRINT AND STORE THE CELL-SOIL-TYPE INVENTORY    26
C                                                                    27
C                                                                    28
      DIMENSION  SOILCL(369)
      DIMENSION  LOCDIV(300)
      COMMON   NXTIDK, IDKML, IDKARE, IDKMTN,  IDKSOL,  IDKCST, NDIVC,
     $         LOCDIV, NOOFMT
      COMMON  IDKLNK, IDKFCT, NOOFLT, DIST
C
C     ZERO THE CELL SOIL TYPE MATRIX
      IDKSOL=NXTIDK
      ISOILL=1
```

```
      IDKBCK=NXTIDK
      DO 1 I=1,369
    1 SOILCL(I)=0
      DO 2 I=1,30
      IDK=NXTIDK+37*(I-1)
      RECORD (IDK) SOILCL
    2 CONTINUE
C     READ PRINT AND STORE
      PRINT 100
    6 READ 102, ICC, ICELL,  ISOIL,  AREA
C     CHECK FOR END CODE
      IF(ICC-99) 5,7,5
    7 NXTIDK=NXTIDK+5+30*37
      RETURN
C     CHECK THE CARD CODE
    5 IF(ICC-1) 3,4,3
    3 PRINT 103,  ICC, ICELL, ISOIL, AREA
      CALL EXIT
C     IS THE RIGHT SOIL ROW IN CORE                                     29
    4 IF(ISOIL-ISOILL)9,8,9
C     GET THE RIGHT SOIL ROW  (PUT THE OLD ROW BACK FIRST)              30
    9 RECORD(IDKBCK)SOILCL
      IDK=NXTIDK+37*(ISOIL-1)
      IDKBCK=IDK
      FETCH (IDK) SOILCL
      ISOILL=ISOIL
    8 PRINT 104, ISOIL, ICELL, AREA
C     STORE
      SOILCL(ICELL)=AREA
      GO TO 6
  100 FORMAT(37H1 CLUSTER COMP INPUT---SOIL INVENTORY//
     $       34H  SOIL TYPE CELL                   AREA)
  102 FORMAT( I2, I8, I5, F10.0)
  103 FORMAT(36H1 CARD ORDER ERROR----SOIL INVENTORY/ 1H ,I2,I8,I5,
     $  F18.8)
  104 FORMAT(1H , I10, I5, F18.8)
      END


*DELETIN3


*LDISK
*LISTPRINTER
*ALLSTATEMENTMAP
*FANDK0804
      SUBROUTINE  IN3
C                                                                       31
C     IN3 IS AN INPUT ROUTINE FOR PLACE COMP.  IT IS CALLED BY          32
C     CUCPIN TO READ, PRINT AND STORE THE SITE COST OF EACH             33
C     MODULE TYPE AND SOIL TYPE COMBINATION                             34
      DIMENSION  SITECT(30)
      DIMENSION  LOCDIV(300)
      COMMON   NXTIDK, IDKML, IDKARE, IDKMTN,  IDKSOL,  IDKCST, NDIVC,
     $         LOCDIV, NOOFMT
      COMMON  IDKLNK, IDKFCT, NOOFLT, DIST
C
C     ZERO THE MATRIX
      DO 1 I=1,30
    1 SITECT(I)=9999999000000000000000000000000000000000000000000.0
      DO 2 I=1,90
      IDK=NXTIDK+4*(I-1)
    2 RECORD (IDK) SITECT
C
C     READ
      PRINT 100
    7 READ 101,  ICC, MTNUM, ISOIL, COST
      PRINT 103, ISOIL, MTNUM, COST
C
C     CHECK FOR END CODE
      IF(ICC-99) 4,3,4
    3 IDKCST=NXTIDK
      NXTIDK=NXTIDK+90*4
      RETURN
C
C     CHECK FOR CARD CODE
    4 IF(ICC-2) 5,6,5
C     WRONG CARD CODE                                                   35
    5 PRINT 102, ICC, MTNUM, ISOIL, COST
      CALL EXIT
C
C     PRINT
    6 IDK=NXTIDK+4*(MTNUM-1)
      IDKBCK=IDK
      FETCH(IDK)SITECT
      PRINT 103, ISOIL, MTNUM, COST
C
C     STORE
      SITECT(ISOIL)=COST
      RECORD (IDKBCK) SITECT
      GO TO 7
  100 FORMAT( 67H1 CLUSTER COMP INPUT --- MODULE TYPE - SOIL TYPE - SITE
     $ COST MATRIX// 42H  SOIL TYPE  MODULE TYPE          SITE COST)
  101 FORMAT(I2,I8,I5,E10.6)
  102 FORMAT( 38H1CARD ORDER ERROR --- SITE COST MATRIX/
     $  1H , I2,I8,I5,F18.8)
  103 FORMAT( 1H , I10, I13, E16.8)
      END


*DELETIN4


*LDISK
*LISTPRINTER
*ALLSTATEMENTMAP
*FANDK0804
      SUBROUTINE IN4
C                                                                       36
C     IN4 IS AN INPUT ROUTINE FOR PLACE COMP.                           37
C          THE NUMBER OF DIVISIONS IN THE PROBLEM                       38
C          THE CONNECTIVITY PRICE FOR EACH DIVISION                     39
C          THE PARENT DIVISION OF EACH DIVISION                         40
C          THE PARENT DIVISION HALF OF EACH DIVISION                    41
C          THE CELL LIST FOR EACH DIVISION                              42
C
      DIMENSION  LOCDIV(300)
      DIMENSION  IARAY(90),  ICEL1(200),  ICEL2(200)
      COMMON   NXTIDK, IDKML, IDKARE, IDKMTN,  IDKSOL,  IDKCST, NDIVC,
     $         LOCDIV, NOOFMT
      COMMON  IDKLNK, IDKFCT, NOOFLT, DIST
C                                                                       43
C     ZERO THE DIVISION HALF MODULE TYPE NUMBER BLANK OUT ARAY
      DO 1 I=1,90
    1 IARAY(I)=0
C                                                                       44
C     INITIALIZE DIVISION COUNTER
      NDIVC=0
      IDONE=0
C     PRINT HEADING
      PRINT 100
C                                                                       45
C     READ A DIVISION PRICE CARD
    2 READ 101, ICC, NODIV, PRICE,  IDVPNT,  IPNTHF,  NOCELS, DIST
C
C     CHECK FOR END CODE
      IF(ICC-99) 4,3,4
    3 RETURN
C
C     CHECK FOR CARD CODE
C     WRONG CARD CODE                                                   46
    4 IF(ICC-5) 5,6,5
    5 PRINT 102, ICC, NODIV, PRICE, IDVPNT, IPNTHF, NOCELS
      CALL EXIT
C
C     PRINT
    6 PRINT 103, NODIV, PRICE, IDVPNT, IPNTHF , DIST
C
C     STORE
      LOCDIV(NODIV)=NXTIDK
      RECORD (NXTIDK) NODIV, PRICE, IDVPNT, IPNTHF, NOCELS, IDONE,DIST
      NDIVC=NDIVC+1
C                                                                       47
C     READ THE CELL LIST
      ITESTC=0
      NTSTC =0
      DO11 I=1, NOCELS
      READ 106,  ICC,  IHALF,  ICELL, NODIVC
C
C     CHECK CARD CODE AND DIVISION NO.
      IF(ICC-4+NODIVC-NODIV)  7,12,7
    7 PRINT 104, ICC, IHALF, ICELL, NODIVC
C
C     PRINT
   12 PRINT 105, ICELL, IHALF
C
C     STORE IN ARRAY LISTS
      IF(IHALF-1)  9,8,9
    8 ITESTC=ITESTC+1
      ICEL1(ITESTC)=ICELL
      GO TO   11
    9 IF(IHALF-2) 7,10,7
   10 NTSTC=NTSTC+1
      ICEL2(NTSTC )=ICELL
   11 CONTINUE
C                                                                       48
C     STORE THE CELL LISTS AND BLANK OUT AN AREA FOR MODULE NOS.
      RECORD (NXTIDK) IARAY
      RECORD (NXTIDK) IARAY
      RECORD (NXTIDK)    ITESTC,( ICEL1(II),II=1,ITESTC)
     $                   NTSTC , (ICEL2(II),II=1,NTSTC)
      GO TO 2
  100 FORMAT( 43H1 CLUSTER COMP INPUT -- DIVISION CELL LISTS)
  101 FORMAT( I2, I8, F15.0, I10, 2I5, F10.0)
  102 FORMAT( 32H1 CARD ORDER ERROR -- CELL LISTS/ 1H ,I2,I8,F18.8,I10,
     $ 2I5)
  103 FORMAT( 13H0DIVISION NO.,I5/ 19H CONNECTIVITY PRICE, F18.8/
     $       16H PARENT DIVISION, I5/21H PARENT DIVISION HALF, I5//
     $ 10H DISTANCE ,  F20.8//
     $       24H CELL NO.  DIVISION HALF)
  104 FORMAT( 25H1ORDER ERROR -- CELL LIST/ 1H , I2,I1,I7,I8)
  105 FORMAT(1H I9,I15)
  106 FORMAT(I2,I1,2X,2I5)
      END


*DELETIN35


*LDISKIN35
*ALLSTATEMENTMAP
*LISTPRINTER
*FANDK0804
C     IN35 IS AN INPUT ROUTINE FOR PLACECOMP II
C          IT READS THE LINKAGE TYPE MATRIX AND THE
C          FIRST COST VECTOR AND SOTRES THESE VALUES ON DISK
      SUBROUTINE IN35
      DIMENSION LINK (30),FSTCST (30), LOCDIV(300)
      COMMON NXTIDK, IDKML, IDKARE, IDKMTN, IDKSOL, IDKCST, NDIVC,
     $       LOCDIV, NOOFMT
      COMMON  IDKLNK, IDKFCT, NOOFLT, DIST
    4 CONTINUE
      NXTIDK=NXTIDK+1
      IDKLNK=NXTIDK
      DO 1 I=1,90
      READ 100, ICC, MTN, LINK
      PRINT 101, ICC, MTN, LINK
C
C     TEST CARD CODE
      IF(ICC-8) 2,3,2
    2 IF(ICC-99)5,7,5
C     TYPE ERROR
    5 TYPE 102
      PAUSE
      GO TO 4
    3 IDK=NXTIDK+(MTN-1)*2
      RECORD(IDK) LINK
    1 CONTINUE
    7 CONTINUE
      NXTIDK=NXTIDK+ 62
      IDKFCT=NXTIDK
C      READ AND STORE FIRST COST CARDS
      DO 17 I=1,30
      FSTCST(I)=0
   17 CONTINUE
      DO 18 I2=1,30
C     READ A CARD
      READ 200, ICC, LTN, FC
      PRINT201, ICC, LTN, FC
C
C     TEST CARD CODE
      IF(ICC-9) 8, 10, 8
    8 IF (ICC-99) 9,99,9
    9 TYPE 102
      PAUSE
      GO TO 7
   99 NXTIDK=NXTIDK+5
      IDK=IDKFCT
      RECORD (IDK) FSTCST
      PRINT 114, NXTIDK, IDKFCT
      PRINT 115, FSTCST
      RETURN
   10 FSTCST(LTN)=FC
   18 CONTINUE
  100 FORMAT ( I2, 3X, I5, 10X, 30I2)
  101 FORMAT( 1H , I2, 3X, I5, 10X, 30I2)
```

```
102 FORMAT(     16H CARD CODE ERROR)
200 FORMAT (        I2, 3X, I5,          F10.0 )
201 FORMAT (1H ,   I2, 3X, I5,          F10.0 )
114 FORMAT (1H , 20 I5)
115 FORMAT (1H ,5F20.8)
    END


*DELETDVDIN


*LDISKDVDIN
*ALLSTATEMENTMAP
*LISTPRINTER
*FANDK0804
C
C
C      DVDIN, DVDSTT AND DIVIDE ARE THE MAINLINE ROUTINES FOR PLACECOMP II
C      DVDIN BEGINS EACH PARTITION BY FORMING A SOIL TYPE INVENTORY FOR        5
C      EACH OF THE PARTITION HALVES.  DVDSTT CONTINUES THE PROCESS BY          5
C      READING THE MODULES TO BE DIVIDED FROM DISK STORAGE.                   52
C      A PRELIMINARY PARTITION OF THE MODULES IS MADE AND THE SOIL TYPE        5
C      INVENTORIES ARE REDUCED ACCORDINGLY.  AT THE SAME TIME 2 VECTORS       54
C      ARE CREATED FOR EACH MODULE TYPE, ONE FOR EACH PARTITION HALF,          5
C      SHOWING HOW MODULES WERE DISTRIBUTED AMONG THE SOIL TYPES.  THE        56
C      TOTAL POSSIBLE LINKAGE COST IS COMPUTED.  THEN THE NUMBER OF           57
C      CONNECTIONS EACH MODULE TYPE HAS WITH EACH HALF OF THE                 58
C      PRELIMINARY PARTITION IS COMPUTED.  THE DIVIDE ROUTINE IS THEN          5
C      CALLED TO SELECT THE LEAST COST PARTITION.  THIS IS DONE BY TRYING      6
C      ALL THE POSSIBLE PARTITIONS THAT CAN BE ACCOMPLISHED BY MOVING         6
C      ONE MODULE FROM THE HALF IT IS IN TO THE OTHER HALF.  IF ANY OF       62
C      THESE PARTITIONS COSTS LESS THEN THE PRELIMINARY PARTITION, THEN THE
C      LEAST EXPENSIVE OF THESE PARTITIONS IS CHOSEN AS THE NEW
C      PRELIMINARY PARTITION.  THE MODULE IS MOVED TO THE OTHER HALF.
C      ONCE AGAIN ALL THE POSSIBLE PARTITIONS (ONE MODULE FROM ONE HALF        6
C      TO THE OTHER) ARE TRIED.  THE PROCEDURE CONTINUES UNTIL SOME
C      PARTITION IS FOUND WHICH CANNOT BE IMPROVED BY MOVING ONE MODULE.       6
C      THE COSTS USED TO JUDGE THE PARTITIONS ARE THE SITE COSTS PLUS THE      6
C      COST OF CONNECTIONS BETWEEN THE DIVISION HALVES.  WHEN THE LEAST       70
C      COST PARTITION HAS BEEN FOUND FOR THIS SET OF CELLS AND MODULES         7
C      IT IS RECORDED ON DISK AND DVDIN IS CALLED TO BEGIN WORK ON THE        72
C      NEXT SET.                                                              73
C                                                                             74
C      DEFINITIONS
C      AREA -------- A VECTOR CONTAINING THE AREA REQUIRED FOR EACH      AREA   1
C                    MODULE TYPE                                         AREA   2
C      CHEAP ------- THE SITE COST OF A PARTICULAR MODULE TYPE ON ITS    CHEAP  1
C                    CHEAPEST SOIL TYPE                                  CHEAP  2
C      CINTST ------ SOIL TYPE INVENTORY FOR NON-TEST                    CINTST
C      CITST ------- SOIL TYPE INVENTORY FOR TEST                        CITST
C      COSTAD        THE SITE COST OF ADDING A MODULE
C      FINFOL        THE LOWEST VALUE OF FINFO                           FINFOL
C                    THE PARTITION                                       FINL   2
C      FINV          THE SUM OF IV(I) I=1,90  ALL THE MODULES IN         FINV   1
C      FM ---------- NUMBER OF MODULES IN TEST                           FM
C      FMN           THE PRODUCT OF THE MODULES IN TEST TIMES THE        FMN    1
C                    MODULES IN NONTEST                                  FMN    2
C      FN ---------- NUMBER OF MODULES IN NONTST                         FN
C      FNSQ1         FINV*(FINV-1)/2  A NORMALIZING VARIABLE FOR FINFO   FNSQ1
C      FSTCST(N) --- FIRST COST PER UNIT LENGTH OF LINKAGE N             FSTCST
C      ICEL1 ------- CELL LIST FOR TEST                                  ICEL1
C      ICEL2 ------- CELL LIST FOR NON-TEST                              ICEL2
C      ICHEAP ------ THE CHEAPEST SOIL TYPE FOR A PARTICULAR MODULE TYPE ICHEAP
C      IDONE ------- A VARIABLE INDICATING THE DIVISION HAS BEEN MADE (1)IDONE  1
C                    OR HAS NOT BEEN MADE (0)                            IDONE  2
C      IDVPNT ------ THE PARENT DIVISION NUMBER                          IDVPNT
C      IEXPEN        THE MOST EXPENSIVE SOIL TYPE NOW OCCUPIED BY A      IEXPEN 1
C                    CERTAIN MODULE TYPE                                 IEXPEN 2
C      IFROM         THE SOIL TYPE A MODULE IS BEING MOVED FROM          IFROM
C      FINFO         THE NORMALIZED COST OF A DIVISION                   INFO
C      IPNTHF ------ THE PARENT PARTITION HALF  (1 OR 2)                 IPNTHF
C      ITEST ------- A VECTOR SHOWING HOW MANY OF EACH MODULE TYPE ARE   ITEST  1
C                    IN TEST                                             ITEST  2
C      ITESTA        THE LOWEST COST ADDITION  (MODULE TYPE) TO TEST     ITESTA
C      ITESTC ------ THE NUMBER OF CELLS IN TEST  (HALF OF THE DIVISION) ITESTC
C      ITESTS        THE LOWEST COST SUBTRACTION (MODULE TYPE) FROM TEST ITESTS
C      ITESTS ------ THE NUMBER OF SOIL TYPES USED IN TEST TO HOLD       ITESTS 1
C                    MODULES OF A PARTICULAR TYPE                        ITESTS 2
C      ITLIST ------ A MATRIX SHOWING THE DISTRIBUTION OF MODULES        ITLIST 1
C                    BY TYPE IN THE VARIOUS SOIL TYPES IN TEST           ITLIST 2
C      ITLT(N) ----- THE NO OF MODULES IN TEST THAT REQUIRE A LINKAGE  N ITLT
C      ITO           THE SOIL TYPE A MODULE IS BEING MOVED TO            ITO
C      IV ---------- A VECTOR CONTAINING THE NUMBER OF EACH MODULE TYPE  IV     1
C                    TO BE DIVIDED                                       IV     2
C      IVC --------- ONE HALF OF IV(I)                                   IVC
C      IVT --------- A VARIABLE THAT IS SET TO IV(I) AND IS REDUCED      IVT    1
C                    EVERY TIME A MODULE OF TYPE I IS PLACED             IVT    2
C      LOCDIV(N) --- LOCATION OF PARTITION N INFORMATION ON DISK         LODIV
C      ML ---------- MODULE LINKAGE MATRIX                               ML
C      NODIV ------- THE NUMBER OF THE PARTITION                         NODIV
C      NONTST ------ A VECTOR SHOWING HOW MANY OF EACH MODULE TYPE ARE   NONTST 1
C                    IN NONTST                                           NONTST 2
C      NOOFLT ------ THE NUMBER OF LINKAGE TYPES                         NOOFLT
C      NOOFMT ------ THE NUMBER OF MODULE TYPES IN THE PROBLEM           NOOFMT
C      NTLIST ------ A MATRIX SHOWING THE DISTRIBUTION OF MODULES        NTLIST 1
C                    BY TYPE IN THE VARIOUS SOIL TYPES IN NONTEST        NTLIST 2
C      NTLT(N) ----- THE NO OF MODULES IN NONTEST REQUIRING A LINKAGE  N NTLT
C      NTSTC ------- THE NUMBER OF CELLS IN NONTEST (HALF THE DIVISION)  NTSTC
C      NTSTS ------- THE NUMBER OF SOIL TYPES USED IN NONTEST TO HOLD    NTSTS  1
C                    MODULES OF A PARTICULAR TYPE                        NTSTS  2
C      PRICE ------- THE PRICE OF ONE CONNECTION BETWEEN DIVISION HALVES PRICE
C      REFUND        THE SITE COST OF A MODULE BEFORE IT IS MOVED.  WHEN REFUND 1
C                    THE MOVE IS MADE THIS VALUE REDUCES THE COST OF THE REFUND 2
C                    PARTITION                                           REFUND 3
C      RNTST         A VECTOR SHOWING THE LINKAGE COST BETWEEN EACH      RNTST  1
C                    MODULE IN THE PROBLEM (IV) AND ALL THE MODULES      RNTST  2
C                    IN NONTST AS A GROUP                                RNTST  3
C      RR            SITE AND LINKAGE COST FOR THIS PARTITION            RR
C      RRH           A HOLDING VARIABLE FOR THE LOWEST RRN               RRH
C      RRN           A TRIAL RR                                          RRN
C      RTST -------- A VECTOR SHOWING THE LINKAGE COST BETWEEN EACH      RTST   1
C                    MODULE IN THE PROBLEM  (IV) AND ALL THE MODULES IN  RTST   2
C                    ITEST AS A GROUP.                                   RTST   3
C      SITECT ------ A MATRIX CONTAINING THE SITE COST OF EACH           SITECT 1
C                    MODULE SOIL TYPE COMBINATION                        SITECT 2
C      SOILCL        SOIL TYPE INVENTORY FOR EACH CELL                   SOILCL
C      TLC --------- TOTAL POSSIBLE LINKAGE COST                         TLC
C      TSC --------- TOTAL SITE COST                                     TSC
C
C      DISK LAYOUT INFORMATION AND RESTART CONSTANTS
C                                                                        3
C      SECTOR ONE
C           NODIV --- PARTITION NUMBER IN PROCESS
C           IDKML --- SECTOR LOCATION OF THE MODULE LINKAGE MATRIX
C           IDKARE -- SECTOR LOCATION OF THE MODULE AREA VECTOR
C           IDKMTN -- SECTOR LOCATION OF THE MODULE TYPE NUMBER VECTOR
C           IDKSOL -- SECTOR LOCATION OF THE CELL - SOIL TYPE INVENTORY
C           IDKCST -- SECTOR LOCATION OF THE MODULE - SOIL SITE COST MATRIX
C           NDIVC --- THE NUMBER OF PARTITIONS IN THE PROBLEM
C           NOOFMT -- NO OF MODULE TYPES IN THE PROBLEM
C           LOCDIV(1 TO NDIVC) -- SECTOR LOCATION FOR INFORMATION THAT
C                       PERTAINS TO THE INDIVIDUAL PARTITIONS ONE TO NDIVC
C                                                                        4
C      SECTOR  IDKML
C           A 91 BY 90 MODULE LINKAGE MATRIX.  THE 91ST COLUMN OF EACH ROW
C           CONTAINS THE NO OF MODULES OF THE TYPE IN THE PROBLEM.  EACH
C           ROW REPRESENTS A TYPE AS DOES EACH COLUMN EXCEPT THE 91ST.
C           EACH ROW TAKES 4 SECTORS
C                                                                        5
C      SECTOR  IDKARE
C           A VECTOR CONTAINING THE AREA REQUIRED FOR EACH MODULE TYPE
C                                                                        6
C      SECTOR  IDKMTN
C           A VECTOR CONTAINING THE NO. OF MODULES OF EACH TYPE IN THE
C           PROBLEM.  SAME AS ML COLUMN 91
C                                                                        7
C      SECTOR  IDKSOL
C           A 369 COLUMN BY 30 ROW MATRIX CONTAINING THE SOIL OF EACH TYPE   8
C           AVAILABLE IN EACH CELL.  EACH ROW REPRESENTS A SOIL TYPE,
C           EACH COLUMN A CELL.  EACH ROW TAKES 37 SECTORS                   9
C                                                                           10
C      SECTOR  IDKCST
C           A 30 COLUMN BY 90 ROW MATRIX CONTAINING THE SITE COSTS FOR      11
C           EACH SOIL TYPE (COLUMN) AND MODULE TYPE (ROW) COMBINATION.      12
C           EACH ROW TAKES FOUR SECTORS                                     13
C                                                                           14
C      SECTOR LOCDIV
C           AT EACH LODIV SECTOR THERE IS A RECORD CONTAINING               15
C                NODIV -- THE PARTITION NUMBER
C                PRICE -- THE PRICE OF A SINGEL CONNECTION BETWEEN THE
C                          DIVISION HALFS.
C                IDVPNT - THE PARENT DIVISION NO.
C                IPNTHF - THE PARENT DIVISION HALF
C                NOCELS - NO OF CELS IN THE DIVISION
C               DIST --- THE DISTANCE BETWEEN PARTITION CENTERS              A
C                                                                           16
C      SECTORS WHICH FOLLOW SECTOR LOCDIV CONTAIN                           17
C           ITESTC--  NO OF CELLS IN FIRST HALF OF THE DIVISION
C           ICEL1 --  LIST OF CELLS IN FIRST HALF OF DIVISION
C           NTSTC --  NO OF CELLS IN 2ND HALF OF THE DIVISION
C           ICEL2 --  LIST OF CELLS IN 2ND HALF
C                     FOLLOWED BY TWO 90 POSITION ZERO VECTORS WHICH WILL   18
C                     CONTAIN THE NO. OF EACH MODULE TYPE ASSIGNED TO
C                     EACH HALF AFTER THE DIVISION IS MADE
C                                                                           19
C      SECTOR  IDKLNK
C           A 30 COLUMN BY 90 ROW MATRIX CONTAINING ZEROS AND ONES           B
C           TO INDICATE WHICH LINKAGE TYPES ARE REQUIRED BY WHICH
C           MODULE TYPES.  THE 30 COLUMNS ARE THE LINKAGE TYPES
C           AND THE 90 ROWS ARE THE MODULE TYPES. EACH ROW TAKES 2 SECTORS
C      SECTOR  IDKFCT
C           A VECTOR CONTAINING THE FIRST COST OR NEW COST PER UNIT          C
C           LENGTH OF EACH LINKAGE TYPE
C
C
C

      DEFINE DISK (10,19000)
      DIMENSION  ICEL1(369),     ICEL2(369),  SOILCL(369)
      DIMENSION  LOCDIV(300),    IV(90),    ITEST(90),    NONTST(90),
     $           AREA(90),       RTST(90), RNTST(90),    CITST(30),
     $           CINTST(30)
      COMMON  IDKMTN, LOCDIV, IV, ITEST, NONTST, AREA, TSC, FM, FN,
     $ IDKCST, TLC, RTST, RNTST, FNSQ1, FINV, NODIV,    FMN, NXTIDK,
     $ CITST,  CINTST , IDVPNT, IPNTHF, PRICE .
      COMMON  IDKLNK, IDKFCT, NOOFLT, DIST
C     READ DIVISION NO. AND DISK LOCATIONS FROM THE DISK
      IDK=1
      FETCH(IDK) NODIV, IDKML, IDKARE, IDKMTN, IDKSOL, IDKCST,
     $           NDIVC, NOOFMT, (LOCDIV(I),I=1,NDIVC), NXTIDK
     $ , IDKLNK, IDKFCT, NOOFLT
C
C
C     READ FROM THE DISK
C          DIVISION CONNECTIVITY PRICE
C          PARENT DIVISION NO. AND HALF
C          FIRST HALF (TEST) CELL LIST
C          2ND HALF (NONTST) CELL LIST
C
      IDK=LOCDIV(NODIV)
      FETCH(IDK) PRICE, PRICE, IDVPNT, IPNTHF, DIST,DIST,DIST
      IDK=IDK+8
      FETCH(IDK) ITESTC, (ICEL1(I),I=1,ITESTC), NTSTC, (ICEL2(I),I=1,
     $           NTSTC)
C
C     PRINT THE INFORMATION
      PRINT 100, NODIV, PRICE, IDVPNT, IPNTHF, (ICEL1(I),I=1,ITESTC)
      PRINT 101, (ICEL2(I),I=1,NTSTC)

C
C     READ THE CELL SOIL TYPE INVENTORY FROM THE DISK ONE ROW (SOIL
C     TYPE) AT A TIME.  COMPARE THE SOIL TYPE ROW WITH THE TEST AND
C     NONTEST CELL LISTS AND FORM 2 SOIL TYPE INVENTORIES.  ONE FOR TEST
C     AND ONE FOR NONTEST.

C
      DO 1  I=1,30
      CITST(I)=0
    1 CINTST(I)=0

C
      DO  4 I=1,30
      IDK= IDKSOL +(I-1)*37
      FETCH (IDK) SOILCL

C
      IPRINT=1
      DO  2 II=1, ITESTC
      III=ICEL1(II)
      CITST(I)=CITST(I)+SOILCL(III)
      IF(SENSE SWITCH 2) 5,2
    5 PRINT 102, IPRINT, ITESTC, I, II, III, CITST(I) , SOILCL(III)
    2 CONTINUE

C
      IPRINT = 2
      DO  3 II=1, NTSTC
      III=ICEL2(II)
      CINTST(I)=CINTST(I)+SOILCL(III)
      IF(SENSE SWITCH 2) 6,3
    6 PRINT 102, IPRINT, NTSTC, I, II, III, CINTST(I) , SOILCL(III)
    3 CONTINUE
    4 CONTINUE
      CALL LINK (DVDSTT)
  100 FORMAT(     16H1DIVISION NUMBER, I5/ 19H CONNECTIVITY PRICE, F20.8/
     $            16H PARENT DIVISION, I5,  9H      HALF,I5/
     $            17H FIRST HALF CELLS,  20( /1H ,20I5))
  101 FORMAT(     15H 2ND HALF CELLS,    20( /1H ,20I5))
  102 FORMAT(1H , 5I10,2F20.4)
      END
```

```
*DELETDVDSTT


*LDISKDVDSTT
*ALLSTATEMENTMAP
*LISTPRINTER
*FANDK0804
C
C
C
      DEFINE DISK (10,19000)
      DIMENSION  SITECT(30),    ITLIST(30), NTLIST(30), ML(91)
      DIMENSION  LOCDIV(300),    IV(90),    ITEST(90),    NONTST(90),
     $           AREA(90),       RTST(90), RNTST(90),    CITST(30),
     $           CINTST(30)
      DIMENSION FSTCST(30), ITLT(30), NTLT(30), LINK(30)
      COMMON  IDKMTN, LOCDIV, IV, ITEST, NONTST, AREA, TSC, FM, FN,
     $ IDKCST, TLC, RTST, RNTST, FNSQ1, FINV, NODIV,    FMN, NXTIDK,
     $ CITST,  CINTST , IDVPNT, IPNTHF, PRICE
      COMMON  IDKLNK, IDKFCT, NOOFLT, DIST
      COMMON ITLT, NTLT, FIRSTC
      IDK=1
      FETCH(IDK) NODIV, IDKML, IDKARE, IDKMTN, IDKSOL, IDKCST,
     $           NDIVC, NOOFMT, (LOCDIV(I),I=1,NDIVC), NXTIDK
     $ , IDKLNK, IDKFCT, NOOFLT
C
C     IF THIS IS DIVISION ONE READ THE SET (IV) OF MODULES TO BE DIVIDED
C     FROM THE TYPE NO. VECTOR.  IF THIS IS NOT DIVISION ONE READ IV
C     FROM THE PARENT DIVISION HALF DISK RECORD
C
      IDK=IDKMTN
      IF(NODIV-1)  6,6,5
    5 IDK=LOCDIV(IDVPNT)+1+(IPNTHF-1)*4
    6 FETCH (IDK) IV
      DO 90 I=1,90
      IF(IV(I)) 90,90,91
   90 CONTINUE
      PRINT 114
      GO TO 92
   91 CONTINUE
C
C
C     DIVIDE THE MODULES (IV) INTO A TRIAL DIVISION (ITEST AND NONTST).
C     AT THE SAME TIME REDUCE THE TEST (CITST) AND NON-TEST (CINTST)
C     SOIL TYPE INVENTORIES AND COMPUTE THE SITE COSTS.
C
      IDK=IDKARE
      FETCH (IDK) AREA
      TSC=0
      FIRSTC=0
      PRINT 103,  TSC, FIRSTC, CITST, CINTST
      IF(NODIV-1) 87,87,89
   89 CONTINUE
      IDK=LOCDIV(IDVPNT)
      FETCH (IDK) L1, F1, L2, L3, L4, IDONE
      IF(IDONE) 88,88,87
   88 CONTINUE
      PRINT 113
   92 CONTINUE
      IDK=1
      FETCH (IDK) NODIV,L1,L2,L3,L4,L5,L6,L7,L8,L9
      NODIV=NODIV+1
      IDK=1
      RECORD(IDK)NODIV,L1,L2,L3,L4,L5,L6,L7,L8,L9
      CALL LINK (DVDIN)
   87 CONTINUE
      FM=0
      FN=0
C     ZERO THE LINKAGE VECTORS
      DO 200  I200=1,30
      NTLT(I200)=0
      ITLT(I200)=0
  200 CONTINUE
C
      PRINT116,   NODIV, IDKML, IDKARE, IDKMTN, IDKSOL, IDKCST, NDIVC,
     $  NOOFMT ,  (LOCDIV(I),I=1,NDIVC), NXTIDK
     $ , IDKLNK, IDKFCT, NOOFLT
      IDK=IDKFCT
      FETCH (IDK) FSTCST
      PRINT 115, FSTCST
      DO 60 I=1,90
      ITEST(I)=0
      NONTST(I)=0
   60 CONTINUE
      DO 30 I=1,NOOFMT
      IVT=IV(I)
      IVC=IV(I)/2
   72 IDK=IDKCST+(I-1)*4
      NTSTS=0
      ITESTS=0
      ITEST(I)=0
      NONTST(I)=0
      FETCH (IDK) SITECT
      PRINT 115, SITECT
      IDK=IDKLNK+(I-1)*2
      FETCH (IDK) LINK
      PRINT 116, LINK
C
      DO 27 II=1,30
      ITLIST(II)=0
      NTLIST(II)=0
   27 CONTINUE
   71 IF(IVT-IVC)16,16,7
C
    7 CHEAP=9999999000000000000000000000000000000000000000000.0
      ICHEAP=0
      DO 9  I1=1,30
      IF(SITECT(I1)-CHEAP)  8,9,9
    8 CHEAP=SITECT(I1)
      ICHEAP=I1
    9 CONTINUE
C
      IF(ICHEAP)  16,16,10
C
   10 IF(AREA(I      )-CITST(ICHEAP))  12,12, 11
C
   11 SITECT(ICHEAP)=9999999000000000000000000000000000000000000000
     $000.0
      GO TO 7
C
   12 ITEST(I)=ITEST(I)+1
      FM=FM+1.0
      IVT=IVT-1
      TSC=TSC+SITECT(ICHEAP)
      CITST(ICHEAP)=CITST(ICHEAP)-AREA(I)
      ITLIST(ICHEAP)=ITLIST(ICHEAP)+1
      IF(SENSE SWITCH 2) 50,51
   50 PRINT 108, I, ITEST(I), FM, IVT, TSC, SITECT(ICHEAP), ICHEAP,
     $ CITST(ICHEAP), AREA(I), ITLIST(ICHEAP)
   51 CONTINUE
      DO 210 I210=1,30
      IF(LINK(I210)) 210,210,201
  201 IF(NTLT(I210)) 209,209,202
  202 IF(ITLT(I210))203,203,209
  203 FIRSTC=FIRSTC+FSTCST(I210)*DIST
  209 ITLT(I210)=ITLT(I210)+1
  210 CONTINUE
      GO TO 71
C
C
C
C
C
   16 IDK=IDKCST+(I-1)*4
      FETCH(IDK) SITECT
   17 IF(IVT)29,29, 18
C
   18 CHEAP=9999999000000000000000000000000000000000000000000.0
      ICHEAP=0
      DO 20 I1=1,30
      IF(SITECT(I1)-CHEAP) 19,20,20
   19 CHEAP=SITECT(I1)
      ICHEAP=I1
   20 CONTINUE
C
      IF(ICHEAP) 21,21,24
   21 IF(IVC) 22,22,23
   22 PRINT 102, I, AREA(I), CITST(I), CINTST(I), SITECT,
     $                ITESTS, (ITLIST(I4),I4=1,ITESTS),
     $                NTSTS,  (NTLIST(I4),I4=1,NTSTS)
      IDK=1
      FETCH (IDK) NODIV,L1,L2,L3,L4,L5,L6,L7,L8,L9
      NODIV=NODIV+1
      IDK=1
      RECORD(IDK)NODIV,L1,L2,L3,L4,L5,L6,L7,L8,L9
      CALL LINK (DVDIN)
C
   23 IVC=0
      GO TO 72
C
   24 IF(AREA(I      )-CINTST(ICHEAP))  26,26,25
C
   25 SITECT(ICHEAP)=9999999000000000000000000000000000000000000000
     $000.0
      GO TO 17
C
   26 NONTST(I)=NONTST(I)+1
      FN=FN+1.0
      IVT=IVT-1
      TSC=TSC+SITECT(ICHEAP)
      CINTST(ICHEAP)=CINTST(ICHEAP)-AREA(I)
      NTLIST(ICHEAP)=NTLIST(ICHEAP)+1
      IF(SENSE SWITCH 2) 52,53
   52 PRINT 109, I, NONTST(I), FN, IVT, TSC, SITECT(ICHEAP), ICHEAP,
     $ CINTST(ICHEAP), AREA(I), NTLIST(ICHEAP)
   53 CONTINUE
      DO 220  I220=1,30
      IF(LINK(I220)) 220,220,211
  211 IF(ITLT(I220)) 219,219,212
  212 IF(NTLT(I220)) 213,213,219
  213 FIRSTC=FIRSTC+FSTCST(I220)*DIST
  219 NTLT(I220)=NTLT(I220)+1
  220 CONTINUE
      GO TO 17
C
C
C
   29 IDK=NXTIDK+(I-1)*4
      IDKP=IDK
      RECORD(IDK) ITLIST, NTLIST
      PRINT 112, I,IDKP,  IV(I), ITLIST, NTLIST
   30 CONTINUE
C
C
C     PRINT THE SITE COST, THE SOIL INVENTORIES AND THE DIVISION
      PRINT 103 , TSC,  CITST, CINTST
      PRINT 104 , ITEST
      PRINT 110, NONTST
      PRINT 111, IV
C
C
C
C     COMPUTE THE TOTAL LINKAGE COST.  ALL LINKAGES TIMES PRICE
C
      TLC=0
C
      DO 33 I=1,NOOFMT
      IF(IV(I))33,33,31
   31 IDK=IDKML+(I-1)*4
      FETCH(IDK) ML
      FVI=IV(I)
      DO 32 II=1,NOOFMT
      FVII=IV(II)
      FML=ML(II)
      TLC=TLC+ FVI*FVII*PRICE*FML
   32 CONTINUE
   33 CONTINUE
      PRINT 105, TLC
C
C
C
C     COMPUTE 2 VECTORS
C       1. RTST, SHOWING THE LINKAGE COST BETWEEN EACH MODULE IN THE
C          PROBLEM (IV) AND ALL THE MODULES IN ITEST AS A GROUP.
C       2. RNTST, SHOWING THE LINKAGE COST BETWEEN EACH MODULE IN THE
C          PROBLEM (IV) AND ALL THE MODULES IN NONTST AS A GROUP
C
C
C
C
      DO 61 I=1,90
      RTST(I)=0
      RNTST(I)=0
   61 CONTINUE
      DO 37 I=1,NOOFMT
      IF(IV(I))37,37,35
   35 IDK=IDKML+(I-1)*4
      FETCH(IDK) ML
      DO 36 II=1,NOOFMT
      FTST=ITEST(II)
      FNTST=NONTST(II)
      FML=ML(II)
      RTST(I)=RTST(I)+FTST*FML*PRICE
      RNTST(I)=RNTST(I)+FNTST*FML*PRICE
   36 CONTINUE
   37 CONTINUE
C
       PRINT 106
```

```
      PRINT 107,  RTST, RNTST
C
C
C     COMPUTE THE INFO VARIABLES
      FINV=0
      DO 38 I=1,NOOFMT
      FVI=IV(I)
      FINV=FINV+FVI
   38 CONTINUE
      FMN=FN*FM
      FNSQ1=FINV*(FINV-1.0)/2.0
      CALL LINK (DIVIDE)
  102 FORMAT(      16H1RAN OUT OF AREA, 3E16.8,  6( /1H , 5E16.8),
     $               4 (/1H ,20I5))
  103 FORMAT (   17HO TOTAL SITE COST,  F20.8/
     $ 19H FIRST LINKAGE COST, F20.8/
     $              26HO TEST SOIL TYPE INVENTORY, 6 (/ 1H , 5F20.8)/
     $              29HO NONTEST SOIL TYPE INVENTORY, 6(/ 1H , 5F20.8))
  104 FORMAT (   6HO TEST, 5( /1H ,20I5))
  105 FORMAT(    19HOTOTAL LINKAGE COST, E16.8)
  106 FORMAT(    16HO RTST AND RNTST)
  107 FORMAT(  1H , 5F20.8)
  108 FORMAT( 6H ITEST, 2I10, F10.2, I10, 2F20.4/
     $ 1H , I10, 2F20.4, I10)
  109 FORMAT( 7H NONTST, 2I10, F10.2, I10, 2F20.4/
     $ 1H , I10, 2F20.4, I10)
  110 FORMAT(      9HO NONTEST,  5( / 1H , 20I5))
  111 FORMAT(  3H IV,              5( / 1H , 20I5))
  112 FORMAT(1HO, 20I5, 2(/1H ,20I5))
  113 FORMAT(32HOPARENT DIVISION NOT YET DIVIDED                       )
  114 FORMAT(25H NO MODULES TO DEVIDE                                  )
  115 FORMAT (1H , 5F20.8)
  116 FORMAT (1H , 20 I5)
      END


06    00010
031       1        12432113 714162977181416
032   00001
031       2         45413280931289834293132
032   00002
031       3          77 7 9 6   2 4  99
032   00003
031       4         3711431  31263131253131
032   00004
031       5          971628 226292825252525
032   00005
031       6          502998 431283127292528
032   00006
031       7         2007734  31252751263132
032   00007
031       8         13918299925252926282525
032   00008
031       9          201431  31252531253131
032   00009
033   000090000000001
031      10         45016320031252832253132
032   00010
033   000100000000001
05        1          7200000                    144
05        2          7500000          1     1    89
05        3          4930000          1     2    55
05        4          4730000          2     1    41
05        5          2860000          4     1    15
05        6          3400000          4     2    26
05        7          2550000          6     2    14
05        8          3315000          6     1    12
05        9          2950000          3     1    25
05       10          2550000          9     1    15
05       11          2950000          3     2    30
05       12          2330000         11     1     9
05       13          4120000         11     2    21
05       14          6000000          2     2    48
05       15          2950000         14     1    28
05       17          4020000         15     1    16
05       16          3050000         15     2    12
033       1
033       2
033       3
033       4
033       5
033       6
033       7
033       8


*DELETDIVIDE


*LDISKDIVIDE
*ALLSTATEMENTMAP
*LISTPRINTER
*FANDK0604
*ARITHMETICTRACE
*IFTRACE
C
C
C
      DEFINE DISK (10,19000)
      DIMENSION  ITLIST(30),  NTLIST(30), SITECT(30), ML(91)
      DIMENSION  LOCDIV(300),    IV(90),    ITEST(90),    NONTST(90),
     $           AREA(90),       RTST(90), RNTST(90),    CITST(30),
     $           CINTST(30)
      DIMENSION FSTCST(30), ITLT(30), NTLT(30), LINK(30)
      COMMON  IDKMTN, LOCDIV, IV, ITEST, NONTST, AREA, TSC, FM, FN,
     $ IDKCST, TLC, RTST, RNTST, FNSQ1, FINV, NODIV,    FMN, NXTIDK,
     $ CITST,  CINTST , IDVPNT, IPNTHF, PRICE
      COMMON  IDKLNK, IDKFCT, NOOFLT, DIST
      COMMON ITLT, NTLT, FIRSTC
C
      IDK=1
      FETCH(IDK) NODIV, IDKML, IDKARE, IDKMTN, IDKSOL, IDKCST,
     $           NDIVC, NOOFMT, (LOCDIV(I),I=1,NDIVC), NXTIDK
     $ , IDKLNK, IDKFCT, NOOFLT
      IDK=IDKFCT
      FETCH (IDK) FSTCST
C
C     SUM THE CONNECTIVITY COST FOR THE TRIAL DIVISION.  ADD IT TO
C     THE SITE COST AND CALL IT TOTAL COST  (RR).  THEN COMPUTE
C     THE DIVISION VALUE VARIABLE  INFO.  PUT INFO INTO INFOL
C
      RR=TSC+FIRSTC
      DO 1 I=1,NOOFMT
      FTST=NONTST(I)
      RR=RR+RTST(I)*FTST
    1 CONTINUE
C
      FINFOL=10.0E60
      IF(FMN*(FNSQ1-FMN)) 47,47,46
   46 CONTINUE
      STR=(RR-(TLC*FMN)/FNSQ1)/SQRT(FMN*(FNSQ1-FMN))
      FINFOL=STR*ABS(STR)
   47 CONTINUE
C******* A PATCH CARD TO AVOID NORMALIZATION **********************************
      FINFOL=RR
C
      PRINT 100, FINFOL, RR, FNSQ1, FMN, STR
C
C
C
C     ADDITIONS AND SUBTRACTIONS ROUTINE
C
C     TRY ALL POSSIBLE ADDITIONS TO AND SUBTRACTIONS FROM ITEST
C     TO SEE IF ANY OF THESE ADJACENT DIVISIONS COST LESS THEN THE
C     TRIAL DIVISION
C
C
   38 ITESTA=0
      ITESTS=0
C
      DO 29 I=1,NOOFMT
      IF(NONTST(I)+ITEST(I)) 29,29,2
C
    2 IDK=NXTIDK+(I-1)*4
      IDKP=IDK
      FETCH(IDK) ITLIST, NTLIST
      IDK=IDKCST+(I-1)*4
      PIDK=IDK
      FETCH(IDK) SITECT
      IF(SENSE SWITCH 3) 900,901
  900 CONTINUE
      PRINT 201, I, IDKP, IV(I), ITLIST, NTLIST
      PRINT 206, PIDK, SITECT
  901 CONTINUE
      IDK=IDKLNK+(I-1)*2
      FETCH(IDK) LINK
C
C     CAN ONE OF THE MODULES OF TYPE I BE MOVED FROM NONTEST TO ITEST
C
C     IS THERE A MODULE IN NONTEST TO MOVE
      IF(NONTST(I))13,13, 3
C
C     FIND THE CHEAPEST ITEST SOIL TO PUT THE NONTST MODULE INTO.
C     THERE MAY BE NO SOIL AVAILABLE AT ALL
C
    3 CHEAP=9999999990000000000000000000000000000000000000000000000.0
      ICHEAP=0
      DO  5 II=1,30
      IF(SITECT(II)-CHEAP)  4,5,5
    4 CHEAP=SITECT(II)
      ICHEAP=II
    5 CONTINUE
C
C
C     WAS A SOIL TYPE FOUND
      IF (ICHEAP)13,13,6
C
C     DOES THE CHEAPEST SOIL TYPE HAVE ENOUGH ROOM TO TAKE A
C     TYPE I MODULE INTO ITEST
    6 IF (AREA(I)-CITST(ICHEAP))7,7,19
C
C     NO ELIMINATE SOIL TYPE ICHEAP FROM CONSIDERATION AND FIND THE
C     NEXT CHEAPEST SITE
   19 SITECT(ICHEAP)=999999990000000000000000000000000000000000000000000
     $000.0
      GO TO 3
C
C     YES, WHAT IS THE COST OF ADDING THE MODULE TO ITEST
    7 COSTAD=SITECT(ICHEAP)
C
C     NOW FIND THE REFUND FROM THE REMOVAL OF THE MODULE FROM NONTEST
      IDK=IDKCST+(I-1)*4
      FETCH(IDK)SITECT
      REFUND=0
      IEXPEN=0
C
      DO 10 II=1,30
      IF(NTLIST(II))10,10,8
C
    8 IF(SITECT(II)-REFUND) 10,10,9
C
    9 IEXPEN=II
      REFUND=SITECT(II)
   10 CONTINUE
C
C     ARE THERE ANY FIRST LINKAGE COSTS INVOLVED IN THE MOVE (ADD)
      FC=0
      DO 800 I800=1,30
      IF(LINK(I800)) 800,800,801
  801 IF(ITLT(I800)+NTLT(I800)-1) 800, 800, 802
  802 IF(ITLT(I800)) 803,803,804
  803 FC=FSTCST(I800)*DIST+FC
  804 IF(NTLT(I800)-1) 805,805,800
  805 FC=-FSTCST(I800)*DIST+FC
  800 CONTINUE
C
C     COMPUTE THE NEW RR FOR FINFO
      RRN=RR+COSTAD-REFUND+RNTST(I)-RTST(I)+FC
      FINFO=10.0E60
C******* A PATCH CARD TO AVOID NORMALIZATION **********************************
      FINFO=RRN
      FMN=(FM+1.0)*(FN-1.0)
      IF(FMN*(FNSQ1-FMN)) 11,11,45
   45 STR=(RRN-(TLC*FMN)/FNSQ1)/SQRT(FMN*(FNSQ1-FMN))
      FINFO=STR*ABS(STR)
C******* A PATCH CARD TO AVOID NORMALIZATION **********************************
      FINFO=RRN
      IF(SENSE SWITCH 2) 902,903
  902 CONTINUE
      PRINT 204, I, ICHEAP, IEXPEN, FINFO, RR, COSTAD, REFUND, RNTST(I),
     $ RTST(I), RRN, FNSQ1, FMN, STR
  903 CONTINUE
      IF(SENSE SWITCH 3) 904,905
  904 CONTINUE
      PRINT 206, SITECT
  905 CONTINUE
C
C     IS THIS FINFO LOWER THEN FINFOL
   11 IF(FINFO-FINFOL) 12,13,13
C
   12 FINFOL=FINFO
      FCH=FC
      RRH=RRN
      IFROM=IEXPEN
      ITO=ICHEAP
      ITESTS=0
      ITESTA=I
C
C     NOW TRY A SUBTRACTION (IS THERE A MODULE IN ITEST TO SUBTRACT)
```

```
   13 IF(ITEST(I))29,29,17
   17 IDK=IDKCST+(I-1)*4
      PIDK=IDK
      FETCH(IDK) SITECT
      IF(SENSE SWITCH 3) 906,907
  906 CONTINUE
      PRINT 206, PIDK, SITECT
  907 CONTINUE
C
C     FIND THE CHEAPEST SOIL TYPE THAT HAS ROOM FOR A MODULE
   14 ICHEAP=0
      CHEAP=9999999000000000000000000000000000000000000000000000.0
      DO 16 II=1,30
      IF(SITECT(II)-CHEAP) 15,16,16
   15 CHEAP=SITECT(II)
      ICHEAP=II
   16 CONTINUE
C
C     WAS A SOIL TYPE FOUND
      IF(ICHEAP)29,29,18
C
C     DOES THE CHEAPEST SOIL TYPE HAVE ROOM
   18 IF(AREA(I)-CINTST(ICHEAP)) 21,21,20
C
C     NO ELIMINATE ICHEAP FROM CONSIDERATION
   20 SITECT(ICHEAP)=99999999.0E46
      GO TO 14
C
C     REMBER THE COST TO ADD THE MODULE TO NONTST
   21 COSTAD=SITECT(ICHEAP)
C
C     NOW FIND THE REFUND FOR REMOVING THE MODULE FROM ITEST
      IDK=IDKCST+(I-1)*4
      FETCH(IDK) SITECT
C
   22 IEXPEN=0
      EXPEN=0
      DO 25 II=1,30
      IF(ITLIST(II)) 25,25,23
   23 IF(EXPEN-SITECT(II)) 24,25,25
   24 IEXPEN=II
      EXPEN=SITECT(II)
   25 CONTINUE
      REFUND=EXPEN
C
C     ARE THERE ANY FIRST LINKAGES COSTS INVOLVED IN THE MOVE (SUB)
      FC=0
      DO 820 I820=1,30
      IF(LINK(I820)) 820, 820, 821
  821 IF(ITLT(I820)+NTLT(I820)-1) 820, 820, 822
  822 IF(NTLT(I820)) 823, 823, 824
  823 FC=FSTCST(I820)*DIST+FC
  824 IF(ITLT(I820)-1) 825, 825, 820
  825 FC=FC-FSTCST(I820)*DIST
  820 CONTINUE
C
C     COMPUTE THE NEW RR FOR FINFO
      RRN=RR+COSTAD-REFUND+RTST(I)-RNTST(I)+FC
      FINFO=10.0E60
C******* A PATCH CARD TO AVOID NORMALIZATION **********************************
      FINFO=RRN
      FMN=(FM-1.0)*(FN+1.0)
      IF(FMN*(FNSQ1-FMN))27,27,26
   26 STR=(RRN-(TLC*FMN)/FNSQ1)/SQRT(FMN*(FNSQ1-FMN))
      FINFO=STR*ABS(STR)
C******* A PATCH CARD TO AVOID NORMALIZATION **********************************
      FINFO=RRN
      IF(SENSE SWITCH 2) 908,909
  908 CONTINUE
      PRINT 205, I, ICHEAP, IEXPEN, FINFO, RR, COSTAD, REFUND, RNTST(I),
     $ RTST(I), RRN, FNSQ1, FMN, STR
  909 CONTINUE
      IF(SENSE SWITCH 3) 910,911
  910 CONTINUE
      PRINT 206, SITECT
  911 CONTINUE
C
C     IS FINFO LESS THRN FINFOL
   27 IF(FINFO-FINFOL)  28, 29, 29
C
C     YES
   28 FINFOL=FINFO
      RRH=RRN
      FCH=FC
      IFROM=IEXPEN
      ITO=ICHEAP
      ITESTS=I
C
   29 CONTINUE
C
C     WAS A SUBTRACTION BETTER THEN THE TRIAL DIVISION
      IF(ITESTS)33,33,30
C
C     ADJUST  ITEST,  NONTST,  CITST,  CINTST,  RTST, AND RNTST FOR
C     THE SUBTRACTION
C
   30 RR=RRH
      FIRSTC=FIRSTC+FCH
      FM=FM-1.0
      FN=FN+1.0
      ITEST(ITESTS)=ITEST(ITESTS)-1
      NONTST(ITESTS)=NONTST(ITESTS)+1
      IDK=NXTIDK+(ITESTS-1)*4
      IDKB=IDK
      IDKP=IDK
      FETCH(IDK)ITLIST, NTLIST
      ITLIST(IFROM)=ITLIST(IFROM)-1
      NTLIST(ITO)=NTLIST(ITO)+1
      RECORD(IDKB) ITLIST, NTLIST
      CINTST(ITO)=CINTST(ITO)-AREA(ITESTS)
      CITST(IFROM)=CITST(IFROM)+AREA(ITESTS)
      DO 32 I=1,90
      IF(IV(I))32,32,31
C
   31 IDK=IDKML+(I-1)*4
      FETCH(IDK) ML
      FML=ML(ITESTS)
      RTST(I)=RTST(I)-FML*PRICE
      RNTST(I)=RNTST(I)+FML*PRICE
   32 CONTINUE
      IDK=IDKLNK+(ITESTS-1)*2
      FETCH(IDK) LINK
      DO 830 I830=1,30
      IF(LINK(I830))  830, 830, 831
  831 NTLT(I830)=NTLT(I830)+1
      ITLT(I830)=ITLT(I830)-1
  830 CONTINUE
C
C     PRINT
      PRINT 207, NODIV
      PRINT 200, ITESTS, ITO, IFROM, RR
      PRINT 201, ITEST
      PRINT 201,         NONTST
      PRINT 202, CITST
      PRINT 202,           CINTST
      PRINT 201, IDKP, ITLIST
      PRINT 201, IDKP,            NTLIST
      PRINT 206, FINFOL
      PRINT 202, FIRSTC
      PRINT 201, LINK, ITLT, NTLT
      GO TO 38

C
C
C     WAS AN ADDITION BETTER THEN THE TRIAL DIVISION
   33 IF(ITESTA)37,37,34
C
C     YES, ADJUST THE DIVISION PARAMETERS
   34 RR=RRH
      FIRSTC=FIRSTC+FCH
      FM=FM+1.0
      FN=FN-1.0
      NONTST(ITESTA)=NONTST(ITESTA)-1
      ITEST(ITESTA)=ITEST(ITESTA)+1
      IDK=NXTIDK+(ITESTA-1)*4
      IDKP=IDK
      IDKB=IDK
      FETCH(IDK) ITLIST, NTLIST
      NTLIST(IFROM)=NTLIST(IFROM)-1
      ITLIST(ITO)=ITLIST(ITO)+1
      RECORD(IDKB) ITLIST, NTLIST
      CITST(ITO)=CITST(ITO)-AREA(ITESTA)
      CINTST(IFROM)=CINTST(IFROM)+AREA(ITESTA)

C
      DO 36 I=1,90
      IF(IV(I))36,36,35
   35 IDK=IDKML+(I-1)*4
      FETCH(IDK) ML
      FML=ML(ITESTA)
      RTST(I)=RTST(I)+FML*PRICE
      RNTST(I)=RNTST(I)-FML*PRICE
   36 CONTINUE
      IDK=IDKLNK+(ITESTA-1)*2
      FETCH(IDK) LINK
      DO 840 I840=1,30
      ITLT(I840)=ITLT(I840)+LINK(I840)
      NTLT(I840)=NTLT(I840)-LINK(I840)
  840 CONTINUE

C
C     PRINT
      PRINT 207, NODIV
      PRINT 203, ITESTA, ITO, IFROM, RR
      PRINT 201, ITEST
      PRINT 201,         NONTST
      PRINT 202, CITST
      PRINT 202,           CINTST
      PRINT 201, IDKP, ITLIST
      PRINT 201, IDKP,            NTLIST
      PRINT 206, FINFOL
      PRINT 202, FIRSTC
      PRINT 201, LINK, ITLT, NTLT
      GO TO 38

C
C     WE HAVE AN ANSWER
C     STORE TEST AND NONTST ON THE DISK AND PRINT
C
   37 IDK=LOCDIV(NODIV)
      ID=IDK
      FETCH(ID) L1,F1,L2,L3,L4,IDONE
      IDONE=1
      RECORD(IDK)L1,F1,L2,L3,L4,IDONE
      RECORD (IDK)  ITEST, NONTST
C
C     INCREMENT THE DIVISION NO
      IDK=1
      FETCH(IDK) NODIV, IDKML, IDKARE, IDKMTN, IDKSOL, IDKCST,
     $ NOIVC, NOOFMT, L1, L2
      PRINT 207, NODIV
      PRINT 208
      PRINT 209, (I, IV(I), ITEST(I), NONTST(I), I=1, NOOFMT)
      PRINT 206, FINFOL
      PRINT 202, FIRSTC
      PRINT 201, LINK, ITLT, NTLT
C
      PRINT 211, (I,I=1,30)
      DO  50 I=1,NOOFMT
      IDK=NXTIDK+(I-1)*4
      FETCH (IDK) ITLIST, NTLIST
      PRINT 210, I, IV(I), ITEST(I), ITLIST, NONTST(I), NTLIST
   50 CONTINUE
      NODIV=NODIV+1
      IDK=1
      RECORD(IDK)  NODIV, IDKML, IDKARE, IDKMTN, IDKSOL, IDKCST,
     $ NDIVC, NOOFMT, L1, L2

C
C
C     WAS THAT THE LAST DIVISION
      IF(NODIV-NDIVC)40,40,39
   39 CALL EXIT
   40 CALL LINK (DVDIN)
  100 FORMAT(     22H1 FIRST DIVISION VALUE, 5E16.8///////////////)
  200 FORMAT(     28H0 A SUBTRACTION, MODULE TYPE, I5/
     $            13H SOIL TYPE TO, I5,    19H     SOIL TYPE FROM, I5/
     $             3H RR, E16.8)
  201 FORMAT(1H , 20I5)
  202 FORMAT(1H ,        5F20.8)
  203 FORMAT(     27H0 AN ADDITION,  MODULE TYPE,  I5/
     $            13H SOIL TYPE TO, I5,    19H     SOIL TYPE FROM, I5/
     $             3H RR, E16.8)
  204 FORMAT(2H A, 3I5, 6E16.8/ 1H , 4E16.8)
  205 FORMAT(2H S, 3I5, 6E16.8/ 1H , 4 E16.8)
  206 FORMAT( 1H ,  7E16.8)
  207 FORMAT(12H1DIVISION NO, I5)
  208 FORMAT(60H0MODULE TYPE      TO DIVIDE     1ST HALF     2ND HALF
     $                          /)
  209 FORMAT(1H , I11, I14, 2I13)
  210 FORMAT( 1H0, 2I5, 5H    1, 16I5/ 1H , 20X, 15I5/
     $              1H , 13X, 2H 2,  16I5  / 1H , 20X, 15I5)
  211 FORMAT(41H0 TYPE  AVL HALF INHF SOIL TYPE PLACEMENT,
     $  2(/1H ,20X, 15I5))
      END
```

Appendix IV
PHASE III WORK PROGRAM

The emphasis in the third phase of the urban design model program will shift from model application to the preparation of training manuals and other aids for the education of planners and engineers in the use of the model in practical planning applications. If the design model is to have any real impact on urban planning, then it must be applied by large numbers of people; and, to be applied, it must first be understood. The Phase III work program has as its objective the initiation of this training program.

The Phase III program will be comprised of the following work elements:

1. The preparation of a user's manual containing all of the procedural information necessary for the application of the design model in both community-level and regional-level planning.

2. The documentation of all computer programs for general application on medium- and large-scale computers and for special application on a selected small-scale computer.

3. The preparation of a course outline for, and the initial presentation of, a three-day training course in the theory and application of the design model, which will be conducted for personnel selected by the Department of Housing and Urban Development.

4. The preparation of a policy statement and a work program for the nation-wide implementation of the design model by the Department of Housing and Urban Development.

Appendix V
GERMANTOWN INPUT DATA

Appendix V-1

PLACECOMP INPUT---MODULE TYPE AREA, AND CONNECTIVITY

TYPE	NO.	AREA	CONNECTIVITY TO MODULE TYPES																													
			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
			31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60
			61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90
1	36	126.100	12	9	17	99	29	10	6	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
			0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
			0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	23	62.700	9	8	14	89	26	1	5	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
			0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
			0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	2	6.400	17	14	7	15	10	7	5	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
			0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
			0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	1	28.200	99	89	15	40	19	17	12	13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
			0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
			0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5	1	45.000	29	26	10	19	14	17	7	9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
			0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
			0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6	3	64.000	10	1	7	17	17	8	5	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
			0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
			0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7	2	2.000	6	5	5	12	7	5	2	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
			0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
			0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Appendix V-2

PLACECOMP INPUT---SOIL INVENTORY

SOIL TYPE	CELL	AREA
1	32	64.00000000
1	101	43.00000000
1	102	99.00000000
1	103	38.00000000
2	14	87.00000000
2	21	217.00000000
2	22	54.00000000
2	31	36.00000000
2	32	9.00000000
2	33	194.00000000
2	34	302.00000000
2	41	102.00000000
2	42	78.00000000
2	43	523.00000000
2	44	519.00000000
2	52	219.00000000
2	53	191.00000000
2	54	102.00000000
2	61	1075.00000000
2	62	610.00000000
2	63	800.00000000
2	64	321.00000000
2	71	134.00000000
2	72	317.00000000
2	73	260.00000000
2	74	105.00000000
2	81	130.00000000
2	82	312.00000000
2	84	242.00000000
2	91	578.00000000
2	92	225.00000000
2	93	124.00000000
2	94	62.00000000
2	101	518.00000000
2	102	473.00000000
2	103	192.00000000
2	104	149.00000000
2	111	30.00000000
2	112	272.00000000
2	113	269.00000000
2	114	101.00000000
2	121	28.00000000
2	122	9.00000000
2	123	73.00000000
2	124	144.00000000
2	131	196.00000000
2	132	526.00000000
2	133	364.00000000
2	141	516.00000000
2	142	56.00000000
2	143	311.00000000
2	144	477.00000000
2	151	188.00000000
2	152	561.00000000
2	153	174.00000000
2	154	182.00000000
2	161	307.00000000
2	162	295.00000000
2	163	242.00000000
2	164	201.00000000
2	171	18.00000000
2	172	167.00000000
2	173	277.00000000
2	174	462.00000000
2	181	460.00000000
2	182	649.00000000
2	183	207.00000000
2	184	433.00000000
2	191	143.00000000
2	192	221.00000000
2	193	9.00000000
2	194	215.00000000
2	201	321.00000000
2	202	559.00000000
2	203	136.00000000
2	204	126.00000000
2	211	33.00000000
2	212	14.00000000
2	213	24.00000000
2	214	30.00000000
2	222	265.00000000
2	223	210.00000000
2	224	208.00000000
2	231	365.00000000
2	232	10.00000000
2	233	374.00000000
2	234	181.00000000
2	241	3.00000000
2	242	318.00000000

Appendix V-3

PLACECOMP INPUT---MODULE TYPE - SOIL TYPE - SITE COST MATRIX

SOIL TYPE	MODULE TYPE	SITE COST						
			2	3	.11247400E+06	4	5	.22544400E+06
1	1	.99999900E+30	3	3	.58793900E+05	5	5	.32710800E+06
2	1	.99999900E+30	4	3	.70529000E+05	6	5	.35216400E+06
3	1	.99999900E+30	5	3	.10159300E+06	7	5	.16376400E+06
4	1	.99999900E+30	6	3	.10924900E+06	8	5	.17888400E+06
5	1	.99999900E+30	7	3	.51363900E+05	9	5	.17623200E+06
6	1	.99999900E+30	8	3	.55983900E+05	10	5	.18076800E+06
7	1	.99999900E+30	9	3	.55492000E+05	11	5	.17902000E+06
8	1	.99999900E+30	10	3	.56878000E+05	12	5	.40220400E+06
9	1	.99999900E+30	11	3	.55760400E+05	13	5	.17620400E+06
10	1	.99999900E+30	12	3	.12453800E+06	14	5	.20303400E+06
11	1	.99999900E+30	13	3	.55112300E+05	15	5	.17623200E+06
12	1	.85983700E+06	14	3	.63204000E+05	16	5	.18203200E+06
13	1	.52285700E+06	15	3	.55492000E+05	17	5	.19110400E+06
14	1	.99999900E+30	16	3	.57051900E+05	18	5	.18604600E+06
15	1	.47544800E+06	17	3	.59824000E+05	19	5	.32086400E+06
16	1	.49391000E+06	18	3	.57801000E+05	20	5	.99999900E+30
17	1	.50827300E+06	19	3	.99579000E+05	1	6	.71560000E+06
18	1	.99999900E+30	20	3	.99999900E+30	2	6	.15223900E+06
19	1	.99999900E+30	1	4	.14880800E+06	3	6	.75623000E+06
20	1	.99999900E+30	2	4	.40456300E+06	4	6	.89577000E+06
1	2	.10021300E+07	3	4	.17280400E+06	5	6	.84576000E+06
2	2	.11504000E+07	4	4	.23329400E+06	6	6	.14484000E+06
3	2	.84784700E+06	5	4	.36319800E+06	7	6	.64619000E+06
4	2	.79455800E+06	6	4	.39521400E+06	8	6	.71213000E+06
5	2	.96964600E+06	7	4	.14960400E+06	9	6	.68115000E+06
6	2	.10127900E+07	8	4	.16892400E+06	10	6	.70093000E+06
7	2	.78890800E+06	9	4	.17041200E+06	11	6	.72891000E+06
8	2	.81494800E+06	10	4	.17620700E+06	12	6	.16666300E+06
9	2	.70980400E+06	11	4	.16503400E+06	13	6	.70369000E+06
10	2	.71761600E+06	12	4	.45915400E+06	14	6	.82716000E+06
11	2	.89899600E+06	13	4	.16468700E+06	15	6	.68115000E+06
12	2	.10989700E+07	14	4	.19734400E+06	16	6	.71939000E+06
13	2	.82709600E+06	15	4	.17041200E+06	17	6	.75895000E+06
14	2	.90682700E+06	16	4	.17457100E+06	18	6	.76602000E+06
15	2	.70980400E+06	17	4	.18616400E+06	19	6	.13183700E+06
16	2	.78684400E+06	18	4	.17238500E+06	20	6	.99999900E+30
17	2	.80246800E+06	19	4	.35359400E+06	1	7	.19558700E+06
18	2	.94462200E+06	20	4	.99999900E+30	2	7	.16963000E+06
19	2	.99241800E+06	1	5	.17077400E+06	3	7	.14523000E+06
20	2	.99999900E+30	2	5	.36393400E+06	4	7	.11680500E+06
1	3	.52869400E+05	3	5	.18825400E+06	5	7	.13092400E+06

Appendix V-4

PLACECOMP INPUT---DIVISION CELL LISTS

DIVISION NO. 1
CONNECTIVITY PRICE 923960.00000000
PARENT DIVISION 0
PARENT DIVISION HALF 0

DISTANCE 3.50000000

CELL NO.	DIVISION HALF
11	1
12	1
13	1
14	1
21	1
22	1
23	1
24	1
31	1
32	1
33	1
34	1
41	1
42	1
43	1
44	1
51	1
52	1
53	1
54	1
61	1
62	1
63	1
64	1
71	1
72	1
73	1
74	1
81	1
82	1
83	1
84	1
91	1
92	1
93	1
94	1
101	1
102	1
103	1
104	1
111	1
112	1
113	1
114	1
141	1
142	1
151	1
152	1
153	1
161	1
162	1
163	1
164	1
171	1
172	1
173	1
174	1
181	1
182	1
183	1
184	1
191	1
192	1
193	1
194	1
201	1
202	1
203	1
204	1
211	1
212	1
213	1
291	1
292	1
293	1
294	1
301	1
302	1
303	1
304	1
311	1
312	1
313	1
314	1
321	1
322	1
323	1
324	1
333	1
121	2
122	2
123	2
124	2
131	2
132	2
133	2
134	2
143	2
144	2
154	2
214	2
221	2
222	2
223	2
224	2
231	2
232	2
233	2
234	2
241	2
242	2
243	2
244	2
251	2
252	2
253	2
254	2
261	2

Appendix VI
DEVELOPMENT COSTS

Due to its large bulk all of the development cost data prepared under Phase I of the project could not be included in this report. It may be obtained at cost by writing to:

Administrative Officer
Southeastern Wisconsin Regional
Planning Commission
P. O. Box 769
916 N. East Avenue
Waukesha, Wisconsin 53196

The complete development cost data includes unit development cost for each site development or linkage development for each of the 224 soil categories in the model test area described in this report. The 141 cost development tables are listed below. Examples of eight of these tables have been included in this appendix for illustrative purposes.

LIST OF SUMMARY TABLES

1. Airport Runways, Asphalt
2. Airport Runways, Concrete
3. Electric Power Production Plant
4. Electric Power Transmission Lines
5. Foundations, Commercial Buildings
6. Foundations, Industrial Buildings
7. Foundations, Residences (See Following Example)
8. Laterals, Storm and Sanitary Sewers and Water Lines, Earth Backfill
9. Laterals, Storm and Sanitary Sewers, Earth Backfill
10. Laterals, Storm Sewers and Water Lines, Earth Backfill
11. Laterals, Sanitary Sewers and Water Lines, Earth Backfill
12. Laterals, Storm Sewers, Earth Backfill
13. Laterals, Sanitary Sewers, Earth Backfill
14. Laterals, Water Lines, Earth Backfill
15. Laterals, Storm and Sanitary Sewers and Water Lines, Gravel Backfill
16. Laterals, Storm and Sanitary Sewers, Gravel Backfill
17. Laterals, Storm Sewers and Water Lines, Gravel Backfill
18. Laterals, Sanitary Sewers and Water Lines, Gravel Backfill
19. Laterals, Storm Sewers, Gravel Backfill
20. Laterals, Sanitary Sewers, Gravel Backfill (See Following Example)
21. Laterals, Water Lines, Gravel Backfill
22. Parking Area, Automobiles
23. Parking Area, Trucks
24. Play Area, Paved
25. Railroad, Main Line (See Following Example)
26. Railroad, Spur Line
27. Sewage Disposal Units, On Site Septic Tanks
28. Sewage Sanitary Collection Lines, 8 Inch Diameter Main Only, Earth Backfill
29. Sewage Sanitary Collection Lines, 10 Inch Diameter Main Only, Earth Backfill (See Following Example)
30. Sewage Sanitary Collection Lines, 12 Inch Diameter Main Only, Earth Backfill
31. Sewage Sanitary Collection Lines, 15 Inch Diameter Main Only, Earth Backfill

32. Sewage Sanitary Collection Lines, 18 Inch Diameter Main Only, Earth Backfill
33. Sewage Sanitary Collection Lines, 21 Inch Diameter Main Only, Earth Backfill
34. Sewage Sanitary Collection Lines, 24 Inch Diameter Main Only, Earth Backfill
35. Sewage Sanitary Collection Lines, 8 Inch Diameter Main Only, Gravel Backfill
36. Sewage Sanitary Collection Lines, 10 Inch Diameter Main Only, Gravel Backfill
37. Sewage Sanitary Collection Lines, 12 Inch Diameter Main Only, Gravel Backfill
38. Sewage Sanitary Collection Lines, 15 Inch Diameter Main Only, Gravel Backfill
39. Sewage Sanitary Collection Lines, 18 Inch Diameter Main Only, Gravel Backfill
40. Sewage Sanitary Collection Lines, 21 Inch Diameter Main Only, Gravel Backfill
41. Sewage Sanitary Collection Lines, 24 Inch Diameter Main Only, Gravel Backfill
42. Sewage Sanitary Interceptor Lines, Larger Than 24 Inch Diameter, Gravel Backfill
43. Sewage Treatment Plant
44. Site Grading, Allowable Slope 0 Percent
45. Site Grading, Allowable Slope 1 Percent
46. Site Grading, Allowable Slope 2 Percent
47. Site Grading, Allowable Slope 3 Percent
48. Site Grading, Allowable Slope 4 Percent
49. Site Grading, Allowable Slope 5 Percent
50. Site Grading, Allowable Slope 6 Percent
51. Site Grading, Allowable Slope 7 Percent (See Following Example)
52. Site Grading, Allowable Slope 8 Percent
53. Site Grading, Allowable Slope 9 Percent
54. Site Grading, Allowable Slope 10 Percent
55. Site Grading, Allowable Slope 11 Percent
56. Site Grading, Allowable Slope 12 Percent
57. Site Grading, Allowable Slope 13 Percent
58. Site Grading, Allowable Slope 14 Percent
59. Site Grading, Allowable Slope 15 Percent
60. Site Grading, Allowable Slope 16 Percent
61. Site Grading, Allowable Slope 17 Percent
62. Site Grading, Allowable Slope 18 Percent
63. Site Grading, Allowable Slope 19 Percent
64. Site Grading, Allowable Slope 20 Percent
65. Site Grading, Allowable Slope 21 Percent
66. Site Grading, Allowable Slope 22 Percent
67. Site Grading, Allowable Slope 23 Percent
68. Site Grading, Allowable Slope 24 Percent
69. Site Grading, Allowable Slope 25 Percent
70. Site Grading, Allowable Slope 26 Percent
71. Site Grading, Allowable Slope 27 Percent
72. Site Grading, Allowable Slope 28 Percent
73. Site Grading, Allowable Slope 29 Percent
74. Site Grading, Allowable Slope 30 Percent
75. Site Grading, Allowable Slope 31 Percent
76. Site Grading, Allowable Slope 32 Percent
77. Site Grading, Allowable Slope 33 Percent
78. Site Grading, Allowable Slope 34 Percent
79. Site Grading, Allowable Slope 35 Percent
80. Site Grading, Allowable Slope 36 Percent
81. Site Grading, Allowable Slope 37 Percent
82. Storm Sewer Collection Lines, 8 Inch Diameter Main Only, Earth Backfill
83. Storm Sewer Collection Lines, 10 Inch Diameter Main Only, Earth Backfill
84. Storm Sewer Collection Lines, 12 Inch Diameter Main Only, Earth Backfill
85. Storm Sewer Collection Lines, 15 Inch Diameter Main Only, Earth Backfill
86. Storm Sewer Collection Lines, 18 Inch Diameter Main Only, Earth Backfill

87. Storm Sewer Collection Lines, 21 Inch Diameter Main Only, Earth Backfill
88. Storm Sewer Collection Lines, 24 Inch Diameter Main Only, Earth Backfill
89. Storm Sewer Collection Lines, 27 Inch Diameter Main Only, Earth Backfill
90. Storm Sewer Collection Lines, 30 Inch Diameter Main Only, Earth Backfill
91. Storm Sewer Collection Lines, 36 Inch Diameter Main Only, Earth Backfill
92. Storm Sewer Collection Lines, 42 Inch Diameter Main Only, Earth Backfill
93. Storm Sewer Collection Lines, 48 Inch Diameter Main Only, Earth Backfill
94. Storm Sewer Collection Lines, 54 Inch Diameter Main Only, Earth Backfill
95. Storm Sewer Collection Lines, 8 Inch Diameter Main Only, Gravel Backfill
96. Storm Sewer Collection Lines, 10 Inch Diameter Main Only, Gravel Backfill
97. Storm Sewer Collection Lines, 12 Inch Diameter Main Only, Gravel Backfill
98. Storm Sewer Collection Lines, 15 Inch Diameter Main Only, Gravel Backfill
99. Storm Sewer Collection Lines, 18 Inch Diameter Main Only, Gravel Backfill
100. Storm Sewer Collection Lines, 21 Inch Diameter Main Only, Gravel Backfill
101. Storm Sewer Collection Lines, 24 Inch Diameter Main Only, Gravel Backfill
102. Storm Sewer Collection Lines, 27 Inch Diameter Main Only, Gravel Backfill
103. Storm Sewer Collection Lines, 30 Inch Diameter Main Only, Gravel Backfill
104. Storm Sewer Collection Lines, 36 Inch Diameter Main Only, Gravel Backfill
105. Storm Sewer Collection Lines, 42 Inch Diameter Main Only, Gravel Backfill
106. Storm Sewer Collection Lines, 48 Inch Diameter Main Only, Gravel Backfill
107. Storm Sewer Collection Lines, 54 Inch Diameter Main Only, Gravel Backfill **(See Following Example)**
108. Storm Drainage Ditches, Surface
109. Telephone Transmission Lines
110. Thoroughfares, Rural Freeway 8 Lane
111. Thoroughfares, Rural Freeway 6 Lane
112. Thoroughfares, Rural Freeway and Expressway 4 Lane
113. Thoroughfares, Rural Standard Arterial (See Following Example)
114. Thoroughfares, Rural Collector Street
115. Thoroughfares, Rural Local Street
116. Thoroughfares, Urban Freeway 8 Lane
117. Thoroughfares, Urban Freeway 6 Lane
118. Thoroughfares, Urban Standard Arterial
119. Thoroughfares, Urban Collector Street
120. Thoroughfares, Urban Local Street
121. Thoroughfares, Urban Alley
122. Water Transmission Lines, 6 Inch Diameter Main Only, Separate
123. Water Transmission Lines, 8 Inch Diameter Main Only, Separate
124. Water Transmission Lines, 12 Inch Diameter Main Only, Separate
125. Water Transmission Lines, 16 Inch Diameter Main Only, Separate
126. Water Transmission Lines, 20 Inch Diameter Main Only, Separate **(See Following Example)**
127. Water Transmission Lines, 24 Inch Diameter Main Only, Separate
128. Water Transmission Lines, 30 Inch Diameter Main Only, Separate
129. Water Transmission Lines, 36 Inch Diameter Main Only, Separate
130. Water Transmission Lines, 42 Inch Diameter Main Only, Separate
131. Water Transmission Lines, 48 Inch Diameter Main Only, Separate
132. Water Transmission Lines, 54 Inch Diameter Main Only, Separate
133. Water Transmission Lines, 60 Inch Diameter Main Only, Separate
134. Water Transmission Lines, Hydrant Leads, Branches, Earth Backfill
135. Water Transmission Lines, Hydrant Leads
136. Water Transmission Lines, Hydrant Leads, Branches, Earth Backfill
137. Water Transmission Lines, Manholes Blowoff, 8 Inch Drain Pipe
138. Water Transmission Lines, Manholes, Inspection Used With 24 Inch Or Larger Mains
139. Water Transmission Lines, Manholes, Blowoff, 6 Inch Drain Pipe
140. Water Treatment Plant
141. Water Well

Table VI-7

LAND USE DESIGN MODEL
CONSTRUCTION COSTS

FOUNDATIONS - RESIDENCES

MULTIPLY ALL FIGURES BY 10**2
$ PER ACRE[c]

		LESS THAN 1 FT TO WATER TABLE			1 TO 5 FT TO WATER TABLE			MORE THAN 5 FT TO WATER TABLE		
	SLOPE[d]	LESS TN 2 TO BEDROCK	2-5 TO BEDROCK	MORE TN 5 TO BEDROCK	LESS TN 2 TO BEDROCK	2-5 TO BEDROCK	MORE TN 5 TO BEDROCK	LESS TN 2 TO BEDROCK	2-5 TO BEDROCK	MORE TN 5 TO BEDROCK
	A	78.54	362.40	659.40	63.40	171.40	302.90	48.47	107.40	166.20
FINE	B	227.80	584.80	952.80	146.85	225.65	434.65	67.77	116.00	166.20
	C1	392.40	826.40	1258.40	239.40	284.90	570.90	90.35	126.40	166.20
GRAINED	C2	426.60	853.40	1278.20	273.60	308.90	585.30	124.55	149.40	178.80
	D1	460.80	880.40	1298.00	307.80	332.90	599.70	158.75	173.10	191.40
SOILS[a]	D2	506.40	916.40	1324.40	353.40	365.90	618.90	204.35	204.40	208.20
	E	592.40	984.40	1373.90	439.40	426.90	654.90	290.35	266.40	239.70
	F	740.40	1101.40	1458.40	587.40	524.90	717.30	438.35	364.40	294.20
	A	78.54	682.40	1296.40	63.40	415.40	793.90	48.47	107.40	166.20
COARSE	B	227.80	984.80	1784.80	146.85	549.65	1079.65	67.77	116.00	166.20
	C1	392.40	306.40	2286.40	239.40	679.90	1364.90	90.35	126.40	166.20
GRAINED	C2	426.60	333.40	2306.20	273.60	703.90	1379.30	124.55	149.40	178.80
	D1	460.80	360.40	2326.00	307.80	727.90	1393.70	158.75	173.10	191.40
SOILS[b]	D2	506.40	396.40	2352.40	353.40	760.90	1412.90	204.35	204.40	208.20
	E	592.40	464.40	2401.90	439.40	821.90	1448.90	290.35	266.40	239.70
	F	740.40	581.40	2486.40	587.40	919.90	1511.30	438.35	364.40	294.20
	A	78.54	132.00	1410.90	63.40	565.00	1094.90	48.47	305.00	559.90
	B	227.80	244.40	1903.30	146.85	724.25	1433.15	67.77	364.60	661.90
ORGANIC	C1	392.40	366.00	2404.90	239.40	889.50	1783.40	90.35	425.00	762.90
	C2	426.60	406.00	2450.30	273.60	923.15	1816.50	124.55	456.50	791.70
SOILS	D1	460.80	446.00	2495.60	307.80	956.80	1849.60	158.75	488.00	820.60
	D2	506.40	498.50	2556.00	353.40	1001.50	1893.40	204.35	530.00	858.90
	E	592.40	598.50	2669.90	439.40	1086.00	1976.40	290.35	609.00	930.90
	F	740.40	771.00	2866.40	587.40	1232.00	2120.40	438.35	745.00	1055.90
	A							48.47		
	B							67.77		
	C1							90.35		
BEDROCK	C2							124.55		
	D1							158.75		
	D2							204.35		
	E							290.35		
	F							438.35		

[a] *This texture subclass is based on the unified classifications of CL, Ch, and ML as described in SEWRPC Planning Report No. 8, Soils of Southeastern Wisconsin.*

[b] *This texture subclass is based on the unified classifications of GP, SM, GW, GM, SP, and SC as described in SEWRPC Planning Report No. 8, Soils of Southeastern Wisconsin.*

[c] *Costs are in Hundreds of Dollars per Acre of Building Coverage.*

[d] *Slope categories A, B, C1, C2, D1, D2, E, and F have average slopes of 1, 5, 8, 11, 15, 19, 26, and 30 percent respectively.*

Source: SEWRPC.

Table VI-20

LAND USE DESIGN MODEL
CONSTRUCTION COSTS

LATERALS - SANITARY SEWERS

GRAVEL BACKFILL

$ PER FOOT[c]

		LESS THAN 1 FT TO WATER TABLE			1 TO 5 FT TO WATER TABLE			MORE THAN 5 FT TO WATER TABLE		
	SLOPE[d]	LESS TN 2 TO BEDROCK	2-5 TO BEDROCK	MORE TN 5 TO BEDROCK	LESS TN 2 TO BEDROCK	2-5 TO BEDROCK	MORE TN 5 TO BEDROCK	LESS TN 2 TO BEDROCK	2-5 TO BEDROCK	MORE TN 5 TO BEDROCK
	A	27.08	23.14	19.20	23.70	18.64	13.58	23.70	18.45	13.20
FINE	B	27.08	23.14	19.20	23.70	18.64	13.58	23.70	18.45	13.20
	C1	27.08	23.14	19.20	23.70	18.64	13.58	23.70	18.45	13.20
GRAINED	C2	27.08	23.14	19.20	23.70	18.64	13.58	23.70	18.45	13.20
	D1	27.08	23.14	19.20	23.70	18.64	13.58	23.70	18.45	13.20
SOILS[a]	D2	27.08	23.14	19.20	23.70	18.64	13.58	23.70	18.45	13.20
	E	27.08	23.14	19.20	23.70	18.64	13.58	23.70	18.45	13.20
	F	27.08	23.14	19.20	23.70	18.64	13.58	23.70	18.45	13.20
	A	27.08	25.39	23.70	23.70	21.45	19.20	23.70	20.33	16.95
COARSE	B	27.08	25.39	23.70	23.70	21.45	19.20	23.70	20.33	16.95
	C1	27.08	25.39	23.70	23.70	21.45	19.20	23.70	20.33	16.95
GRAINED	C2	27.08	25.39	23.70	23.70	21.45	19.20	23.70	20.33	16.95
	D1	27.08	25.39	23.70	23.70	21.45	19.20	23.70	20.33	16.95
SOILS[b]	D2	27.08	25.39	23.70	23.70	21.45	19.20	23.70	20.33	16.95
	E	27.08	25.39	23.70	23.70	21.45	19.20	23.70	20.33	16.95
	F	27.08	25.39	23.70	23.70	21.45	19.20	23.70	20.33	16.95
	A	27.08	25.39	23.70	23.70	22.58	21.45	23.70	19.20	14.70
	B	27.08	25.39	23.70	23.70	22.58	21.45	23.70	19.20	14.70
ORGANIC	C1	27.08	25.39	23.70	23.70	22.58	21.45	23.70	19.20	14.70
	C2	27.08	25.39	23.70	23.70	22.58	21.45	23.70	19.20	14.70
SOILS	D1	27.08	25.39	23.70	23.70	22.58	21.45	23.70	19.20	14.70
	D2	27.08	25.39	23.70	23.70	22.58	21.45	23.70	19.20	14.70
	E	27.08	25.39	23.70	23.70	22.58	21.45	23.70	19.20	14.70
	F	27.08	25.39	23.70	23.70	22.58	21.45	23.70	19.20	14.70

[a] *This texture subclass is based on the unified classifications of CL, CH, and ML as described in SEWRPC Planning Report No. 8, Soils of Southeastern Wisconsin.*

[b] *This texture subclass is based on the unified classifications of GP, SM, GW, GM, SP, and SC as described in SEWRPC Planning Report No. 8, Soils of Southeastern Wisconsin.*

[c] *Costs are in Dollars Per Lineal Foot.*

[d] *Slope categories A, B, C1, C2, D1, D2, E, and F have average slopes of 1, 5, 8, 11, 15, 19, 26, and 30 percent respectively.*

Source: SEWRPC.

Table VI-25

LAND USE DESIGN MODEL
CONSTRUCTION COSTS

RAILROAD MAIN LINE

$ PER FOOT [c]

		LESS THAN 1 FT TO WATER TABLE			1 TO 5 FT TO WATER TABLE			MORE THAN 5 FT TO WATER TABLE		
	SLOPE [d]	LESS TN 2 TO BEDROCK	2-5 TO BEDROCK	MORE TN 5 TO BEDROCK	LESS TN 2 TO BEDROCK	2-5 TO BEDROCK	MORE TN 5 TO BEDROCK	LESS TN 2 TO BEDROCK	2-5 TO BEDROCK	MORE TN 5 TO BEDROCK
FINE GRAINED SOILS [a]	A	20.38	20.30	20.22	20.38	20.27	20.16	20.38	20.26	20.14
	B	22.28	21.80	21.32	22.28	21.62	20.96	22.28	21.56	20.84
	C1	24.56	23.60	22.64	24.56	23.24	21.92	24.56	23.12	21.68
	C2	26.46	25.10	23.74	26.46	24.59	22.72	26.46	24.42	22.38
	D1	28.36	26.60	24.84	28.36	25.94	23.52	28.36	25.72	23.08
	D2	31.02	28.70	26.38	31.02	27.83	24.64	31.02	27.54	24.06
	E	36.34	32.90	29.46	36.34	31.61	26.88	36.34	31.18	26.02
	F	45.84	40.40	34.96	45.84	38.36	30.88	45.84	37.68	29.52
COARSE GRAINED SOILS [b]	A	20.38	20.30	20.22	20.38	20.27	20.16	20.38	20.26	20.14
	B	22.28	21.80	21.32	22.28	21.62	20.96	22.28	21.56	20.84
	C1	24.56	23.60	22.64	24.56	23.24	21.92	24.56	23.12	21.68
	C2	26.46	25.10	23.74	26.46	24.59	22.72	26.46	24.42	22.38
	D1	28.36	26.60	24.84	28.36	25.94	23.52	28.36	25.72	23.08
	D2	31.02	28.70	26.38	31.02	27.83	24.64	31.02	27.54	24.06
	E	36.34	32.90	29.46	36.34	31.61	26.88	36.34	31.18	26.02
	F	45.84	40.40	34.96	45.84	38.36	30.88	45.84	37.68	29.52
ORGANIC SOILS	A	20.38	20.44	20.50	20.38	20.37	20.37	20.38	20.35	20.32
	B	22.28	22.65	23.02	22.28	22.24	22.21	22.28	22.10	21.92
	C1	24.56	25.30	26.05	24.56	24.49	24.42	24.56	24.20	23.84
	C2	26.46	27.51	28.57	26.46	26.36	26.26	26.46	25.95	25.44
	D1	28.36	29.72	31.09	28.36	28.23	28.10	28.36	27.70	27.04
	D2	31.02	32.82	34.62	31.02	30.85	30.67	31.02	30.15	29.28
	E	36.34	39.01	41.67	36.34	36.08	35.82	36.34	35.05	33.76
	F	45.84	50.06	54.27	45.84	45.43	45.02	45.84	43.80	41.76

[a] *This texture subclass is based on the unified classifications of CL, CH, and ML as described in SEWRPC Planning Report No. 8, Soils of Southeastern Wisconsin.*

[b] *This texture subclass is based on the unified classifications of GP, SM, GW, GM, SP, and SC as described in SEWRPC Planning Report No. 8, Soils of Southeastern Wisconsin.*

[c] *Costs are in Dollar Per Lineal Foot.*

[d] *Slope categories A, B, C1, C2, D1, D2, E, and F have average slopes of 1, 5, 8, 11, 15, 19, 26, and 30 percent respectively.*

Source: SEWRPC.

Table VI-29
LAND USE DESIGN MODEL
CONSTRUCTION COSTS

SEWAGE SANITARY COLLECTION LINES 10 DIA MAIN ONLY EARTH BACKFILL

$ PER FOOT[c]

	SLOPE	LESS THAN 1 FT TO WATER TABLE			1 TO 5 FT TO WATER TABLE			MORE THAN 5 FT TO WATER TABLE		
		LESS TN 2 TO BEDROCK	2-5 TO BEDROCK	MORE TN 5 TO BEDROCK	LESS TN 2 TO BEDROCK	2-5 TO BEDROCK	MORE TN 5 TO BEDROCK	LESS TN 2 TO BEDROCK	2-5 TO BEDROCK	MORE TN 5 TO BEDROCK
	A	21.10	17.82	14.55	16.74	13.87	11.00	16.74	13.53	10.33
FINE	B	21.10	17.82	14.55	16.74	13.87	11.00	16.74	13.53	10.33
	C1	21.10	17.82	14.55	16.74	13.87	11.00	16.74	13.53	10.33
GRAINED	C2	21.10	17.82	14.55	16.74	13.87	11.00	16.74	13.53	10.33
	D1	21.10	17.82	14.55	16.74	13.87	11.00	16.74	13.53	10.33
SOILS[a]	D2	21.10	17.82	14.55	16.74	13.87	11.00	16.74	13.53	10.33
	E	21.10	17.82	14.55	16.74	13.87	11.00	16.74	13.53	10.33
	F	21.10	17.82	14.55	16.74	13.87	11.00	16.74	13.53	10.33
	A	21.10	21.10	21.10	16.74	18.92	21.10	16.74	15.64	14.55
COARSE	B	21.10	21.10	21.10	16.74	18.92	21.10	16.74	15.64	14.55
	C1	21.10	21.10	21.10	16.74	18.92	21.10	16.74	15.64	14.55
GRAINED	C2	21.10	21.10	21.10	16.74	18.92	21.10	16.74	15.64	14.55
	D1	21.10	21.10	21.10	16.74	18.92	21.10	16.74	15.64	14.55
SOILS[b]	D2	21.10	21.10	21.10	16.74	18.92	21.10	16.74	15.64	14.55
	E	21.10	21.10	21.10	16.74	18.92	21.10	16.74	15.64	14.55
	F	21.10	21.10	21.10	16.74	18.92	21.10	16.74	15.64	14.55
	A	21.10	21.10	21.10	16.74	18.92	21.10	16.74	14.12	11.50
	B	21.10	21.10	21.10	16.74	18.92	21.10	16.74	14.12	11.50
ORGANIC	C1	21.10	21.10	21.10	16.74	18.92	21.10	16.74	14.12	11.50
	C2	21.10	21.10	21.10	16.74	18.92	21.10	16.74	14.12	11.50
SOILS	D1	21.10	21.10	21.10	16.74	18.92	21.10	16.74	14.12	11.50
	D2	21.10	21.10	21.10	16.74	18.92	21.10	16.74	14.12	11.50
	E	21.10	21.10	21.10	16.74	18.92	21.10	16.74	14.12	11.50
	F	21.10	21.10	21.10	16.74	18.92	21.10	16.74	14.12	11.50

a. *This texture subclass is based on the unified classifications of CL, CH, and ML as described in SEWRPC Planning Report No. 8, Soils of Southeastern Wisconsin.*

b *This texture subclass is based on the unified classifications of GP, SM, GW, GM, SP, and SC as described in SEWRPC Planning Report No. 8, Soils of Southeastern Wisconsin.*

c *Costs are in Dollars Per Lineal Foot.*

d *Slope categories A, B, C1, C2, D1, D2, E, and F have average slopes of 1, 5, 8, 11, 15, 19, 26, and 30 percent respectively.*

Source: SEWRPC.

Table VI-51

LAND USE DESIGN MODEL
CONSTRUCTION COSTS

SITE GRADING ALLOWABLE SLOPE 7PCT

MULTIPLY ALL FIGURES BY 10**1
$ PER ACRE[c]

		LESS THAN 1 FT TO WATER TABLE			1 TO 5 FT TO WATER TABLE			MORE THAN 5 FT TO WATER TABLE		
	SLOPE[d]	LESS TN 2 TO BEDROCK	2-5 TO BEDROCK	MORE TN 5 TO BEDROCK	LESS TN 2 TO BEDROCK	2-5 TO BEDROCK	MORE TN 5 TO BEDROCK	LESS TN 2 TO BEDROCK	2-5 TO BEDROCK	MORE TN 5 TO BEDROCK
	A									
FINE	B									
	C1									
GRAINED	C2	342.00	270.00	198.00	342.00	243.00	144.00	342.00	234.00	126.00
	D1	684.00	540.00	396.00	684.00	486.00	288.00	684.00	468.00	252.00
SOILS[a]	D2	1140.00	900.00	660.00	1140.00	810.00	480.00	1140.00	780.00	420.00
	E	1995.00	1575.00	1155.00	1995.00	1417.50	840.00	1995.00	1365.00	735.00
	F	3477.00	2745.00	2013.00	3477.00	2470.50	1464.00	3477.00	2379.00	1281.00
	A									
COARSE	B									
	C1									
GRAINED	C2	342.00	270.00	198.00	342.00	243.00	144.00	342.00	234.00	126.00
	D1	684.00	540.00	396.00	684.00	486.00	288.00	684.00	468.00	252.00
SOILS[b]	D2	1140.00	900.00	660.00	1140.00	810.00	480.00	1140.00	780.00	420.00
	E	1995.00	1575.00	1155.00	1995.00	1417.50	840.00	1995.00	1365.00	735.00
	F	3477.00	2745.00	2013.00	3477.00	2470.50	1464.00	3477.00	2379.00	1281.00
	A									
	B									
ORGANIC	C1									
	C2	342.00	397.80	453.60	342.00	336.60	331.20	342.00	315.00	288.00
SOILS	D1	684.00	795.60	907.20	684.00	673.20	662.40	684.00	630.00	576.00
	D2	1140.00	1326.00	1512.00	1140.00	1122.00	1104.00	1140.00	1050.00	960.00
	E	1995.00	2320.50	2646.00	1995.00	1963.50	1932.00	1995.00	1837.50	1680.00
	F	3477.00	4044.30	4611.60	3477.00	3422.10	3367.20	3477.00	3202.50	2928.00
	A									
	B									
	C1									
BEDROCK	C2							342.00		
	D1							684.00		
	D2							1140.00		
	E							1995.00		
	F							3477.00		

[a] *This texture subclass is based on the unified classifications of CL, CH, and ML as described in SEWRPC Planning Report No. 8, Soils of Southeastern Wisconsin.*
[b] *This texture subclass is based on the unified classifications of GP, SM, GW, GM, SP, and SC as described in SEWRPC Planning Report No. 8, Soils of Southeastern Wisconsin.*
[c] *Costs are in Tens of Dollars per Acre Graded.*
[d] *Slope categories A, B, C1, C2, D1, D2, E, and F have average slopes of 1, 5, 8, 11, 15, 19, 26, and 30 percent respectively.*

Source: SEWRPC.

Table VI-107

LAND USE DESIGN MODEL
CONSTRUCTION COSTS

STORM SEWER COLLECTION LINES 54 DIA MAIN ONLY GRAVEL BACKFILL

$ PER. FOOT[c]

	SLOPE[d]	LESS THAN 1 FT TO WATER TABLE			1 TO 5 FT TO WATER TABLE			MORE THAN 5 FT TO WATER TABLE		
		LESS TN 2 TO BEDROCK	2-5 TO BEDROCK	MORE TN 5 TO BEDROCK	LESS TN 2 TO BEDROCK	2-5 TO BEDROCK	MORE TN 5 TO BEDROCK	LESS TN 2 TO BEDROCK	2-5 TO BEDROCK	MORE TN 5 TO BEDROCK
FINE GRAINED SOILS[a]	A	65.30	63.80	62.30	61.30	56.80	52.30	57.30	50.80	44.30
	B	65.30	63.80	62.30	61.30	56.80	52.30	57.30	50.80	44.30
	C1	65.30	63.80	62.30	61.30	56.80	52.30	57.30	50.80	44.30
	C2	65.30	63.80	62.30	61.30	56.80	52.30	57.30	50.80	44.30
	D1	65.30	63.80	62.30	61.30	56.80	52.30	57.30	50.80	44.30
	D2	65.30	63.80	62.30	61.30	56.80	52.30	57.30	50.80	44.30
	E	65.30	63.80	62.30	61.30	56.80	52.30	57.30	50.80	44.30
	F	65.30	63.80	62.30	61.30	56.80	52.30	57.30	50.80	44.30
COARSE GRAINED SOILS[b]	A	65.30	65.80	66.30	61.30	58.80	56.30	57.30	51.30	45.30
	B	65.30	65.80	66.30	61.30	58.80	56.30	57.30	51.30	45.30
	C1	65.30	65.80	66.30	61.30	58.80	56.30	57.30	51.30	45.30
	C2	65.30	65.80	66.30	61.30	58.80	56.30	57.30	51.30	45.30
	D1	65.30	65.80	66.30	61.30	58.80	56.30	57.30	51.30	45.30
	D2	65.30	65.80	66.30	61.30	58.80	56.30	57.30	51.30	45.30
	E	65.30	65.80	66.30	61.30	58.80	56.30	57.30	51.30	45.30
	F	65.30	65.80	66.30	61.30	58.80	56.30	57.30	51.30	45.30
ORGANIC SOILS	A	65.30	71.80	78.30	61.30	61.80	62.30	57.30	52.80	48.30
	B	65.30	71.80	78.30	61.30	61.80	62.30	57.30	52.80	48.30
	C1	65.30	71.80	78.30	61.30	61.80	62.30	57.30	52.80	48.30
	C2	65.30	71.80	78.30	61.30	61.80	62.30	57.30	52.80	48.30
	D1	65.30	71.80	78.30	61.30	61.80	62.30	57.30	52.80	48.30
	D2	65.30	71.80	78.30	61.30	61.80	62.30	57.30	52.80	48.30
	E	65.30	71.80	78.30	61.30	61.80	62.30	57.30	52.80	48.30
	F	65.30	71.80	78.30	61.30	61.80	62.30	57.30	52.80	48.30

[a] *This texture subclass is based on the unified classifications of CL, CH, and ML as described in SEWRPC Planning Report No. 8, Soils of Southeastern Wisconsin.*

[b] *This texture subclass is based on the unified classifications of GP, SM, GW, GM, SP, and SC as described in SEWRPC Planning Report No. 8, Soils of Southeastern Wisconsin.*

[c] *Costs are in Dollars Per Lineal Foot.*

[d] *Slope categories A, B, C1, C2, D1, D2, E, and F have average slopes of 1, 5, 8, 11, 15, 19, 26, and 30 percent respectively.*

Source: SEWRPC.

Table VI-113

LAND USE DESIGN MODEL
CONSTRUCTION COSTS

THOROUGHFARES URBAN STANDARD ARTERIAL

$ PER FT. ROW[c]

	SLOPE[d]	LESS THAN 1 FT TO WATER TABLE			1 TO 5 FT TO WATER TABLE			MORE THAN 5 FT TO WATER TABLE		
		LESS TN 2 TO BEDROCK	2-5 TO BEDROCK	MORE TN 5 TO BEDROCK	LESS TN 2 TO BEDROCK	2-5 TO BEDROCK	MORE TN 5 TO BEDROCK	LESS TN 2 TO BEDROCK	2-5 TO BEDROCK	MORE TN 5 TO BEDROCK
	A	52.22	52.22	52.22	52.22	52.22	52.22	52.22	52.22	52.22
FINE	B	52.22	52.22	52.22	52.22	52.22	52.22	52.22	52.22	52.22
	C1	52.27	52.26	52.25	52.27	52.25	52.24	52.27	52.25	52.24
GRAINED	C2	52.31	52.29	52.27	52.31	52.29	52.26	52.31	52.28	52.25
	D1	52.36	52.33	52.30	52.36	52.32	52.28	52.36	52.31	52.27
SOILS[a]	D2	52.42	52.37	52.33	52.42	52.36	52.30	52.42	52.35	52.29
	E	52.53	52.46	52.40	52.53	52.44	52.35	52.53	52.43	52.33
	F	52.72	52.62	52.51	52.72	52.58	52.43	52.72	52.56	52.40
	A	52.22	52.22	52.22	52.22	52.22	52.22	52.22	52.22	52.22
COARSE	B	52.22	52.22	52.22	52.22	52.22	52.22	52.22	52.22	52.22
	C1	52.27	52.26	52.25	52.27	52.25	52.24	52.27	52.25	52.24
GRAINED	C2	52.31	52.29	52.27	52.31	52.29	52.26	52.31	52.28	52.25
	D1	52.36	52.33	52.30	52.36	52.32	52.28	52.36	52.31	52.27
SOILS[b]	D2	52.42	52.37	52.33	52.42	52.36	52.30	52.42	52.35	52.29
	E	52.53	52.46	52.40	52.53	52.44	52.35	52.53	52.43	52.33
	F	52.72	52.62	52.51	52.72	52.58	52.43	52.72	52.56	52.40
	A	52.22	52.22	52.22	52.22	52.22	52.22	52.22	52.22	52.22
	B	52.22	52.22	52.22	52.22	52.22	52.22	52.22	52.22	52.22
ORGANIC	C1	52.27	52.27	52.28	52.27	52.26	52.26	52.27	52.26	52.26
	C2	52.31	52.32	52.34	52.31	52.31	52.31	52.31	52.30	52.30
SOILS	D1	52.36	52.38	52.40	52.36	52.35	52.35	52.36	52.34	52.33
	D2	52.42	52.45	52.48	52.42	52.41	52.41	52.42	52.40	52.38
	E	52.53	52.58	52.63	52.53	52.52	52.52	52.53	52.50	52.48
	F	52.72	52.80	52.89	52.72	52.71	52.71	52.72	52.68	52.64
	A							52.22		
	B							52.22		
	C1							52.27		
BEDROCK	C2							52.31		
	D1							52.36		
	D2							52.42		
	E							52.53		
	F							52.72		

[a] *This texture subclass is based on the unified classifications of CL, CH, and ML as described in SEWRPC Planning Report No. 8, Soils of Southeastern Wisconsin.*
[b] *This texture subclass is based on the unified classifications of GP, SM, GW, GM, SP, and SC as described in SEWRPC Planning Report No. 8, Soils of Southeastern Wisconsin.*
[c] *Costs are in Dollar Per Lineal Foot.*
[d] *Slope categories A, B, C1, C2, D1, D2, E, and F have average slopes of 1, 5, 8, 11, 15, 19, 26, and 30 percent respectively.*

Source: SEWRPC.

Table VI-126

LAND USE DESIGN MODEL
CONSTRUCTION COSTS

WATER TRANS LINES 20 IN DIA MAIN ONLY -SEPARATE

$ PER FOOT[c]

	SLOPE[d]	LESS THAN 1 FT TO WATER TABLE			1 TO 5 FT TO WATER TABLE			MORE THAN 5 FT TO WATER TABLE		
		LESS TN 2 TO BEDROCK	2-5 TO BEDROCK	MORE TN 5 TO BEDROCK	LESS TN 2 TO BEDROCK	2-5 TO BEDROCK	MORE TN 5 TO BEDROCK	LESS TN 2 TO BEDROCK	2-5 TO BEDROCK	MORE TN 5 TO BEDROCK
FINE GRAINED SOILS[a]	A	42.74	36.57	30.40	37.45	29.52	21.59	37.45	29.23	21.00
	B	42.74	36.57	30.40	37.45	29.52	21.59	37.45	29.23	21.00
	C1	42.74	36.57	30.40	37.45	29.52	21.59	37.45	29.23	21.00
	C2	42.74	36.57	30.40	37.45	29.52	21.59	37.45	29.23	21.00
	D1	42.74	36.57	30.40	37.45	29.52	21.59	37.45	29.23	21.00
	D2	42.74	36.57	30.40	37.45	29.52	21.59	37.45	29.23	21.00
	E	42.74	36.57	30.40	37.45	29.52	21.59	37.45	29.23	21.00
	F	42.74	36.57	30.40	37.45	29.52	21.59	37.45	29.23	21.00
COARSE GRAINED SOILS[b]	A	42.74	40.10	37.45	37.45	33.93	30.40	37.45	32.16	26.88
	B	42.74	40.10	37.45	37.45	33.93	30.40	37.45	32.16	26.88
	C1	42.74	40.10	37.45	37.45	33.93	30.40	37.45	32.16	26.88
	C2	42.74	40.10	37.45	37.45	33.93	30.40	37.45	32.16	26.88
	D1	42.74	40.10	37.45	37.45	33.93	30.40	37.45	32.16	26.88
	D2	42.74	40.10	37.45	37.45	33.93	30.40	37.45	32.16	26.88
	E	42.74	40.10	37.45	37.45	33.93	30.40	37.45	32.16	26.88
	F	42.74	40.10	37.45	37.45	33.93	30.40	37.45	32.16	26.88
ORGANIC SOILS	A	42.74	40.10	37.45	37.45	35.69	33.93	37.45	30.40	23.35
	B	42.74	40.10	37.45	37.45	35.69	33.93	37.45	30.40	23.35
	C1	42.74	40.10	37.45	37.45	35.69	33.93	37.45	30.40	23.35
	C2	42.74	40.10	37.45	37.45	35.69	33.93	37.45	30.40	23.35
	D1	42.74	40.10	37.45	37.45	35.69	33.93	37.45	30.40	23.35
	D2	42.74	40.10	37.45	37.45	35.69	33.93	37.45	30.40	23.35
	E	42.74	40.10	37.45	37.45	35.69	33.93	37.45	30.40	23.35
	F	42.74	40.10	37.45	37.45	35.69	33.93	37.45	30.40	23.35

[a] *This texture subclass is based on the unified classifications of CL, CH, and ML as described in SEWRPC Planning Report No. 8, Soils of Southeastern Wisconsin.*

[b] *This texture subclass is based on the unified classifications of GP, SM, GW, GM, SP, and SC as described in SEWRPC Planning Report No. 8, Soils of Southeastern Wisconsin.*

[c] *Costs are in Dollars Per Lineal Foot.*

[d] *Slope categories A, B, C1, C2, D1, D2, E, and F have average slopes of 1, 5, 8, 11, 15, 19, 26, and 30 percent respectively.*

Source: SEWRPC.

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