



A method for analyzing environmental effects of impacting activities
by Louis Theodore Egging

A thesis submitted in partial fulfillment of the requirements for the degree of MASTER OF SCIENCE
in Industrial and Management Engineering
Montana State University
© Copyright by Louis Theodore Egging (1976)

Abstract:

The public land manager is directed by law to manage for multiple use and sustained yield of goods and services. This must be accomplished without long term detriment to the environment. He must also analyze the environmental consequences of any proposed management action. These impacts might not only be short term effects, but may be long range as well.

The ecosystem, impacted by the activity, is a complex maze of relationships. An impact directed at one resource will influence not only that resource but others as well. Some effects are immediate, others are not apparent until after a considerable time period. This complexity requires the ecosystem to be analyzed as a whole. It must be perceived as a complete system.

A method is proposed to help the manager analyze the environmental impacts of an activity. Using systems analysis and computer simulation techniques, a two-phased simulation model is presented. This approach models the activity as the micro phase. If desired, this phase can be modeled in detail suitable for productivity optimization, or it can be modeled simply. The macro phase of the approach models the ecosystem. This phase simulates the dynamic response of the ecosystem to the impact.

STATEMENT OF PERMISSION TO COPY

In presenting this thesis in partial fulfillment of the requirements for an advanced degree at Montana State University, I agree that the Library shall make it freely available for inspection. I further agree that permission for extensive copying of this thesis for scholarly purposes may be granted by my major professor, or, in his absence, by the Director of Libraries. It is understood that any copying or publication of this thesis for financial gain shall not be allowed without my written permission.

Signature

Louis L. Eggen

Date

10/22/76

A METHOD FOR ANALYZING ENVIRONMENTAL EFFECTS
OF IMPACTING ACTIVITIES

by

LOUIS THEODORE EGGING

A thesis submitted in partial fulfillment
of the requirements for the degree

of

MASTER OF SCIENCE

in

Industrial and Management Engineering

Approved:

David F. Wilson

Chairman, Examining Committee

John A. Ritchey

Head, Major Department

Henry L. Parsons

Graduate Dean

MONTANA STATE UNIVERSITY
Bozeman, Montana

September, 1976

ACKNOWLEDGMENT

I wish to extend my appreciation to the U.S.D.A. Forest Service for supporting this effort. A special thanks goes to Dr. James E. Lotan, Program Manager and Dr. Richard J. Barney, my immediate supervisor for their continued support, not only financial, but professional and personal as well.

I acknowledge the clerical personnel at the Northern Forest Fire Lab for their efforts in preparing drafts of this thesis. For her typing of this final draft, a special thank you goes to Betty Lackey.

Dr. David F. Gibson, my major professor and advisor is gratefully recognized for his direction and guidance. I thank all those too numerous to mention who offered their support.

To my little wife, Gabriela, and my growing family, I apologize for the many hours I was absent when working on this study. I sincerely say thank you for your understanding and support.

TABLE OF CONTENTS

	Page
LIST OF TABLES	vi
LIST OF FIGURES	vii
ABSTRACT	x
Chapter	
1. INTRODUCTION	1
Multiple Use Management	1
Land Use Planning	4
The Problem	6
2. SYSTEMS AND SIMULATION: A METHOD	9
The Systems Approach	9
Systems and Simulation	14
Systems Dynamics	18
GASP IV	25
Approach to the Problem	27
3. MODEL DEVELOPMENT	30
The Systems Description	30
System Objectives	31
Environment	33
Resources and Components	34
System Manager	34
Ecosystem - Harvesting Productivity Model	36
Combining Model Types	39

	Page
4. MACRO-MODEL PHASE	42
Area Subsystem	43
Moisture-Water Subsystem	45
Timber Subsystem	48
Forage Subsystem	50
Wildlife Subsystem	52
Erosion Subsystem	54
5. MICRO-DISCRETE PHASE	56
Harvesting Subsystem	56
Fire Subsystem	60
Road Building and Closing Subsystem	62
6. SIMULATION RESULTS	65
Ecosystem Base Run	65
Combined Impacts	69
7. SUMMARY AND RECOMMENDATIONS	75
LITERATURE CITED	77
APPENDICES	80
APPENDIX A: Flow Charting Symbols	81
APPENDIX B: Ecosystem Model	83
APPENDIX C: Model Variables Defined	98
APPENDIX D: Model Output	112
APPENDIX E: Computer Listing of Selected Routines	125

LIST OF TABLES

Table	Page
1. Harvesting Subsystem Production and Cost Summaries	73
2. Area Subsystem Equations	85
3. Moisture-Water Subsystem Equations	88
4. Timber Subsystem Equations	91
5. Forage Subsystem Equations	93
6. Wildlife Subsystem Equations	95
7. Erosion Subsystem Equations	97
8. Area Subsystem Variables Defined	99
9. Moisture-Water Subsystem Variables Defined	101
10. Timber Subsystem Variables Defined	105
11. Forage Subsystem Variables Defined	107
12. Wildlife Subsystem Variables Defined	108
13. Erosion Subsystem Variables Defined	110
14. System Constants Defined	111
15. Production and Cost Summaries for Felling Activity	117
16. Production and Cost Summaries for Skidding Activity	118
17. Production and Cost Summaries for Loading Activity	119
18. Production and Cost Summaries for Hauling Activity	120

LIST OF FIGURES

Figure	Page
1. Resources and Resource Uses	3
2. The Influence of Timber Harvesting Activity on Resources and Uses	7
3. Classification of Simulation Languages	17
4. Decisions and Information Feedback	19
5. Forrester's Flowcharting Method	24
6. Ecosystem Diagram Showing Environment, Resources, and Components	35
7. Black Box Diagram of Ecosystem Response to Activity Impacts	37
8. Black Box Diagram of Harvesting Productivity Model	38
9. Time Scales of Combined Macro - Micro Simulation Model	41
10. Area Subsystem Flow Diagram	44
11. Moisture-Water Subsystem Flow Diagram	47
12. Timber Subsystem Flow Diagram	49
13. Forage Subsystem Flow Diagram	51
14. Wildlife Subsystem Flow Diagram	53
15. Erosion Subsystem Flow Diagram	55
16. Harvesting Subsystem Flow Diagram	57
17. Fire Subsystem Flow Diagram	61
18. Road Building and Closing Subsystem Flow Diagram	64

Figure	Page
19. Ecosystem Summary Plot for Base Simulation Run	67
20. Ecosystem Summary Plot for Combined Impact Run	70
21. Flowcharting Symbols Defined	82
22. Systems Diagram of Area Subsystem	84
23. Systems Diagram of Moisture-Water Subsystem	87
24. Systems Diagram of Timber Subsystem	90
25. Systems Diagram of Forage Subsystem	92
26. Systems Diagram of Wildlife Subsystem	94
27. Area/Erosion Subsystem Plot for Base Run	113
28. Moisture-Water Subsystem Plot for Base Run	114
29. Timber Subsystem Plot for Base Run	115
30. Forage/Wildlife Subsystem Plot for Base Run	116
31. Area/Erosion Subsystem Plot for Combined Impacts	121
32. Moisture-Water Subsystem Plot for Combined Impacts	122
33. Timber Subsystem Plot for Combined Impacts	123
34. Forage/Wildlife Subsystem Plot for Combined Impacts	124
35. FORTRAN Source of Initializing Routine, INTLC	126
36. FORTRAN Source of Ecosystem Routine, STATE	139
37. FORTRAN Source of Tree Volume Routine, VOLPT	149
38. FORTRAN Source of Time Conversion and Parameter Setting Routine, CTME	150
39. FORTRAN Source of Fire Routine, FIRE	151
40. FORTRAN Source of Roadbuilding and Closing Routine, ROADBLD	153

Figure	Page
41. FORTRAN Source of Harvest Starting Routine, STRTLOG	154
42. FORTRAN Source of Harvest Ending Routine, ENDLOG	157
43. FORTRAN Source of Output Plotting Routine, GPLOT	158

ABSTRACT

The public land manager is directed by law to manage for multiple use and sustained yield of goods and services. This must be accomplished without long term detriment to the environment. He must also analyze the environmental consequences of any proposed management action. These impacts might not only be short term effects, but may be long range as well.

The ecosystem, impacted by the activity, is a complex maze of relationships. An impact directed at one resource will influence not only that resource but others as well. Some effects are immediate, others are not apparent until after a considerable time period. This complexity requires the ecosystem to be analyzed as a whole. It must be perceived as a complete system.

A method is proposed to help the manager analyze the environmental impacts of an activity. Using systems analysis and computer simulation techniques, a two-phased simulation model is presented. This approach models the activity as the micro phase. If desired, this phase can be modeled in detail suitable for productivity optimization, or it can be modeled simply. The macro phase of the approach models the ecosystem. This phase simulates the dynamic response of the ecosystem to the impact.

Chapter 1

INTRODUCTION

Multiple Use Management

Society's growing concern for "conservation" and "ecology" has caused the U.S. Forest Service to pursue with renewed vigor, the directive of "multiple use" and "sustained yield" in its public land management. This policy was established by Congress in 1960 when Public Law 86-517 was handed down on June 12. This, the Multiple Use - Sustained Yield Act states in part:

It is the policy of the Congress that the national forests are established and shall be administered for outdoor recreation, range, timber, watershed, and wildlife and fish purposes.

The Secretary of Agriculture is authorized and directed to develop and administer the renewable surface resources of the national forests for multiple use and sustained yield of the several products and services obtained therefrom. (USDA, 1963).

The objective of multiple use management is to manage the resource complex for the most beneficial combination of both present and future uses. This idea of deriving maximum benefit from a given resource base is not new, but it becomes more important and complicated as the competition for limited and interrelated resources increases.

While the basic concept of multiple use is generally accepted, its application is still a difficult process. As outlined by Ridd (1964) the term "multiple use" may be applied to areas of land or to particular resources available on that land. When applied to land areas, it refers

to the production and management of the various resources or resource combinations on that land area. These managed resources may be competitive or complementary to one another. When applied to resources, "multiple use" refers to the various uses of those resources. For example, the water resource can be used for irrigation, municipal and industrial water, esthetics or recreation. Timber can be used for lumber, pulpwood, esthetics or recreation. Figure 1 (Ridd, 1964) provides an overview of possible relationships between resources and resource uses.

Multiple use land management involves both the multiple use of individual resources and the multiple use of the land areas. A demand for a particular resource for a specific use will place demands on a land area where that resource is produced.

When speaking of multiple use, the four resources; water, timber, forage, and wildlife, are generally discussed along with recreation. However, recreation is actually a use to which the resources are put. This recreational use is centered primarily on one resource; however, the "quality" of the recreation is influenced by several resources comprising the environmental complex.

In managing a land area, no resource or use can be isolated. Any management action, even when directed at one resource, is going to have an affect on the other resources and their uses. A logging operation started in any forest will affect not only the timber resource, but also

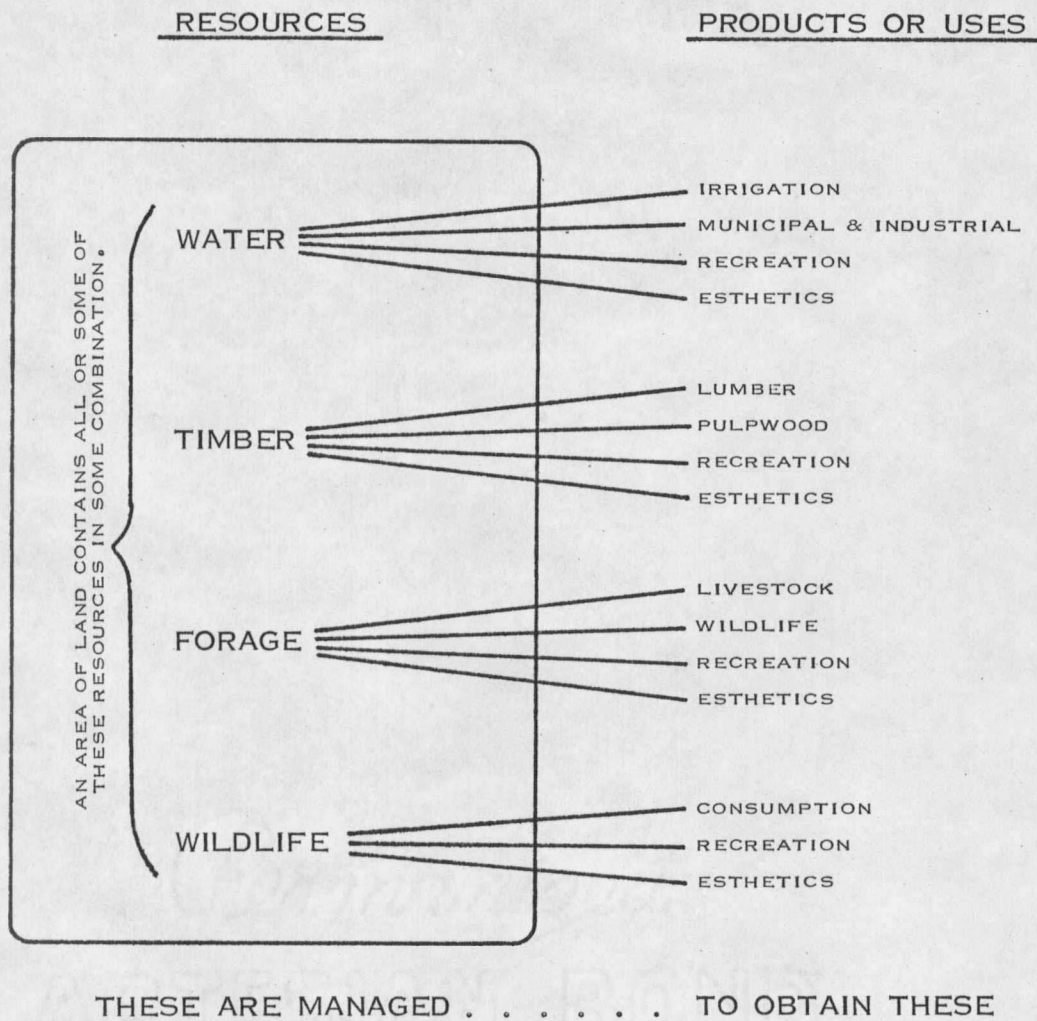


Figure 1. Resources and Resource Uses

the water, forage, and wildlife resources. For this reason, the overall area with all its resources must be viewed as a whole in making any management decisions on a proposed activity.

Land Use Planning

Over half the land area in the United States is in forest, brush, or rangeland. Of this area, the Forest Service has the responsibility for managing 187 million acres to obtain sustained flows of goods and services under the multiple use management concept. This philosophy requires the balancing of various land uses to minimize conflicts while providing for a sustained yield over an extended time period.

With growing pressures from timber and cattle interests for specific resource uses, the Forest Service became more and more production oriented in its management. This was at times accomplished to the long term detriment of the total environment. Timber and forage production increased to satisfy demand. Irreversible consequences to the ecosystem were not a prime consideration.

In 1968, Congress enacted into law the National Environmental Policy Act. This Act directs the land manager to assess his management activities from an environmental impact standpoint. The Act declared it "a national policy [to] encourage productive and enjoyable harmony between man and his environment; [and] to promote efforts which will prevent or eliminate damage to the environment" (USDA, 1974:243). "This policy is one of balancing the amenities or quality of life against the

continued use of renewable resources" (Leopold, 1975:609). Recognizing that man's activities do impact the interrelationships of the ecosystem components, the manager must prepare a detailed statement of the environmental impacts of any proposed action that might have an effect on the quality of the human environment.

The Forest Service has been preparing "Multiple Use" or "Land Use" Plans to implement these directives. A Land Use Plan is intended to be a planning document directed at a specific area of land. Resource capabilities are identified, demands and resource uses are estimated for the present and future, and management alternatives are identified and presented to the public for scrutiny. These documents are prepared and presented to the public soliciting and encouraging public involvement and participation in determining management direction. Coupled with the Land Use Plan is the Environmental Impact Statement which must be prepared for any proposed management action. This statement is an attempt to identify and quantify the environmental impacts of the activity. These impacts must include not only the short term immediate effects, but also the long range effects of the activity.

The public land manager is directed by law to manage on a multiple use and sustained yield basis. He must analyze and document the environmental consequences of proposed activities. This can be a difficult task as the system being impacted consists of numerous

interacting relationships. The area must be viewed as a whole in making management decisions.

The Problem

The problem is basically that of identifying the impacts or effects of a given activity upon an area's ecosystem. The impacts cannot be limited only to short term immediate effects, but must also include the long range time dependent effects. The system being impacted is a complex maze of interrelated interacting cause-effect relationships.

As an example of man's activities impacting the ecosystem, we might look at timber harvesting. The interactive influences of timber harvesting on the system might be illustrated as in Figure 2. For measurable impacts, we are primarily interested in the effects on the other resources and resource uses for the area. The harvesting of timber from a given area and the method used in harvesting will have a direct effect upon other resources such as water quality and quantity, timber availability now and in the future, forage quality and quantity, and the amount of type of wildlife present. These can be both short and long range effects.

In addition to these primary effects, the changes brought on by the primary influences in the available resources will also cause secondary changes in the resources and uses of the area. Recreation and esthetics will be influenced secondarily. Changes in the resources will change the recreational appeal of the area. There are also secondary

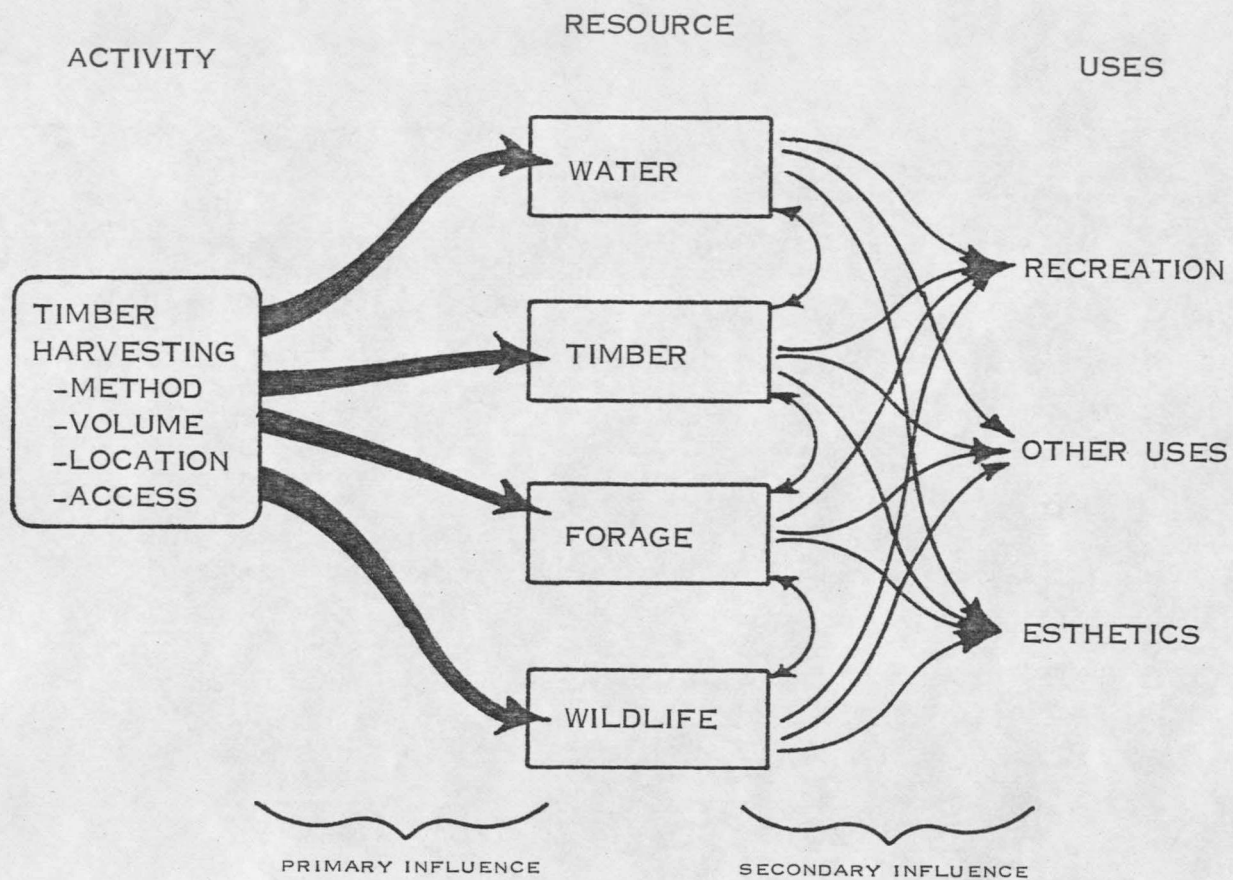


Figure 2. The Influence of Timber Harvesting Activity on Resources and Uses

influences between resources, that is, a change in water quality might affect timber or wildlife.

A natural force which will impact the system in a similar fashion might be fire. Fire will remove vegetation much like timber harvesting. The manager is interested in knowing how sensitive the ecosystem is to fire. How will the system respond to suppression activities: suppression road construction, fire breaks, etc? What happens if a major portion of a drainage burns? Once again there are both short and long range effects which must be evaluated.

It is this maze of complex, interacting influences which makes multiple use management such a difficult principle to practice in a "real" world situation. The resources of an area are affected over a period of time when a particular activity impacts the system. A change in one resource causes change in the other available resources and their uses.

In this study, a procedure and methodology is developed to aid the manager in analyzing the environmental effects of an impacting activity. The area is viewed as a whole with resource responses portrayed over extended time periods.

Chapter 2

SYSTEMS AND SIMULATION: A METHOD

With continued advances in computer technology and capabilities, insights are being gained into complex problems by the use of systems analysis and simulation. Major components of the system can be identified and the relationships between components quantified. These can then be organized in a manner allowing the designer and manager to monitor the dynamic responses of the modeled system for extended time periods. The sensitivity of the system to various inputs or decision criteria can be presented and evaluated.

The Systems Approach

Much has been written in recent literature on systems analysis. Its major impetus began with the success of military scientific teams during the second World War. After the war, much effort was put into applying this kind of thinking to nonmilitary problems. This school of thought was labeled "operations research" and was applied to rather small problems in production, marketing, and finance. Following these initial applications of science to management, the electronic computer grew in its capabilities.

As the computer grew, so did the scientist's ability to look at and solve larger and more complex problems. This increased ability led to the expansion of the scientist's perspective, out of which grew what is now commonly referred to as the systems approach. C. West Churchman

(1968) in his book, The Systems Approach, points out in the preface:

As the scientist's perspective widened, he began to think of his approach as the "systems approach". He saw that what he was chiefly interested in was characterizing the nature of the system in such a way that the decision making could take place in a logical and coherent fashion and that none of the fallacies of narrow-minded thinking would occur. Furthermore, using his scientific knowledge, he expected to be able to develop measures which would give as adequate information as possible about the performance of the system.

Throughout this growth process, the word "systems" has been defined in many different ways by people claiming to be "experts" in the field. No matter how it is defined, most people will agree that "a system is a set of parts coordinated to accomplish a set of goals" (Churchman, 1968:29). From this definition, anything that operates for a common purpose can be thought of as a system. A system can be simple or it can be extremely complex. This body of techniques and theories developed for analyzing systems has come to be known as systems analysis.

Churchman (1968:231) concludes his book by stating four principles of a deception-perception approach to systems:

1. The systems approach begins when first you see the world through the eyes of another.
2. The systems approach goes on to discovering that every world view is terribly restricted.
3. There are no experts in the systems approach.
4. (He presents his own bias) The systems approach is not a bad idea.

Though there is no universally right way to describe a system, a great

deal can be learned by a clear statement of the approach taken so that its opponents may state their opposition in as cognate a fashion as possible. Churchman concludes that the systems approach really consists of a continuing debate between various attitudes of mind with respect to society.

In looking at systems, Churchman stresses the importance of the scientific approach. For this approach, he identifies five basic considerations. These include the total system objectives; the systems environment; the resources of the system; the components of the system; and the management of the system. These considerations will be explored further in the next chapter on the development of the systems macro-model.

As noted by Bjerke (1973), Churchman's approach also implies the need for interdisciplinary study teams. When studying complex problems, each discipline with its specializations can contribute to a clearer understanding of the whole system. However, a truly worthwhile systems analysis can be developed only when each discipline begins to see the world through the eyes of the other, and recognizes that his world view might be terribly restricted.

The book by Kenneth E.F. Watt (1966), Systems Analysis in Ecology, is a collection of works done by nine writers. This work is a comprehensive account of the need for and the benefits of applying systems analysis to the field of ecology and environment. In an

ecological system, it is seen that everything affects everything else, and the complexity of interlocking cause-effect pathways confronts the analyst with a superficially baffling problem in scientific analysis.

It is this interlocking network which is the most identifying characteristic of the ecological system. For the ecologists, an operational definition of a system is "An interlocking complex of processes characterized by many reciprocal cause-effect pathways"

(Watt, 1966:2). A principal attribute of an ecological system is that we can only understand it by viewing it as a whole.

Watt identifies some of the most important concepts of systems thinking insofar as they can be applied in ecology. Perhaps the most basic component of this thinking is the operating maxim...extremely complex processes can be easier understood by dissecting them into a large number of very simple components. A second important notion is complex historical processes in which all variables change with time, can be dealt with in terms of recurrence formula that express the state of a system at time $t+1$ as a function of the state of the system at time t . Thus the understanding of the process is acquired not in terms of its entire history, but rather in terms of the cause-effect relationships that operate through a typical time interval.

Watt points out that another important tenet of systems analysis is that optimization of the process is the central aim of research. Combining this optimization aim and the notion of recurrence

relationships leads to the idea that "the central aim of systems analysis is that of making the optimal choice from among an array of alternative strategies at each of a sequence of times" (Watt, 1966:4). This leads to the idea of multistage decision process. The multistage decision process, due to its high degree of dimensionality and the need to use an iterative process for solution, indicates the use of an electronic computer and simulation for its analysis.

Watt points out three reasons for the prominence of simulation as a tool to the systems analyst. Most systems optimization problems are so complex they cannot be worked out in any straightforward fashion on paper. Therefore, a system of trial and error is used to solve them. Various combinations of variables are tried to determine how the system will react in given conditions. This could not be done with actual experiments in the real world because of the prohibitive costs. Secondly, apart from the cost, there is often not enough time available to follow the experiments through to completion especially if there are repeated experiments to be conducted. Finally, the actual experiments may not be feasible because the outcomes might have a "ruinous" effect on the system being experimented with.

The book goes on to discuss such subjects as the organization and management of complex systems studies, the acquisition of data, and the building of models. These subjects are presented by the individual authors in the light of their individual experiences. Much of the

discussion is built from actual studies which were conducted on ecologically related problems.

Systems and Simulation

Simulation is an important tool of the systems analyst. However, it should be kept in mind that systems analysis does not mean you must use simulation, and systems analysis is not equated to simulation. There is much knowledge and understanding to be gained about the system merely by studying it from the systems point of view, without carrying the study through to simulation. For this research, simulation is used so systems simulation in general will be discussed here.

James R. Emshoff and Roger L. Sisson (1970) introduce the reader to simulation models in their book, Design and Use of Computer Simulation Models. This book takes the reader step-by-step through the background and technical skills required to learn and use simulation. The reader is introduced to simulation as a management aid and how it is used in decision making processes. There is discussion of the technical aspects of using simulation and general discussions of the nature and uses of various types of simulations. Much of the discussion centers around detailed examples explaining basic techniques.

In Chapter 6, the authors review some of the popular simulation languages. The advantages and disadvantages of the various languages are compared by a review of the process of translating a problem into a simulation program. It should be noted that though the use of an

established language is not necessary for simulation, it does have some definite advantages to the user. Probably the major advantage in using a canned simulation language is user time saved in preparing and debugging the simulator. As noted by Emshoff and Sisson (1970:117), "It is not uncommon for this reduction to be a factor of ten". The simulator resulting from the use of an established language is also generally easier to modify than one written in a multipurpose language such as FORTRAN.

There are other dramatic changes which occur as a result of using specially designed simulation languages. As the authors note, "Some of these are actually languages in the more general sense; that is, they are useful in describing a situation independent of the fact that they can be translated by a computer into machine language" (Emshoff, 1970:117). These languages have a "syntax" and a "vocabulary" which can be quite descriptive. It is often the case that the user, after becoming experienced with a simulation language, will begin to think in that language. Thus the language becomes useful in the actual problem formulation.

The languages considered by the authors include:

- | | |
|------|--|
| GASP | a set of subroutines in FORTRAN that performs functions useful in simulations. |
| GPSS | a complete language oriented toward problems in which items pass through a series of processing and/or storage functions (latest version: GPSS/360). |

SIMSCRIPT	a complete language oriented toward event-to-event simulations in which discrete logical processes are common (latest version: SIMSCRIPT II).
CSMP	a complete language oriented toward the solution of problems stated as nonlinear, integral-differential equations with continuous variables (CSMP permits a digital computer to simulate an analog computer).
DYNAMO	a complete language oriented toward expressing macro-economic models of firms by means of difference equations.
JOB-SHOP SIMULATOR	a program package that can be set up to represent a variety of job shops by means of parameters (Emshoff, 1970:139).

These languages can be classified in terms of orientation and scope or generality of application as illustrated in Figure 3.

FORTRAN is included in Figure 3 as an example of a multipurpose computer language which can be used to write simulation programs.

Though it is not a simulation language in itself, FORTRAN is a widely used language and has the capability of representing any sort of state-change process. GASP and SIMSCRIPT are simulation languages that are very general. Both are written in FORTRAN and have the capability of doing anything that FORTRAN can.

On the other end of the graph, DYNAMO and the JOB-SHOP SIMULATOR are much more problem oriented. In fact, the JOB-SHOP SIMULATOR is so specific that it is not really a simulation language at all. It is actually a simulation program that is written general enough to adequately describe various job-shop situations and sizes. DYNAMO as a language is oriented toward problems formulated in terms of nonlinear

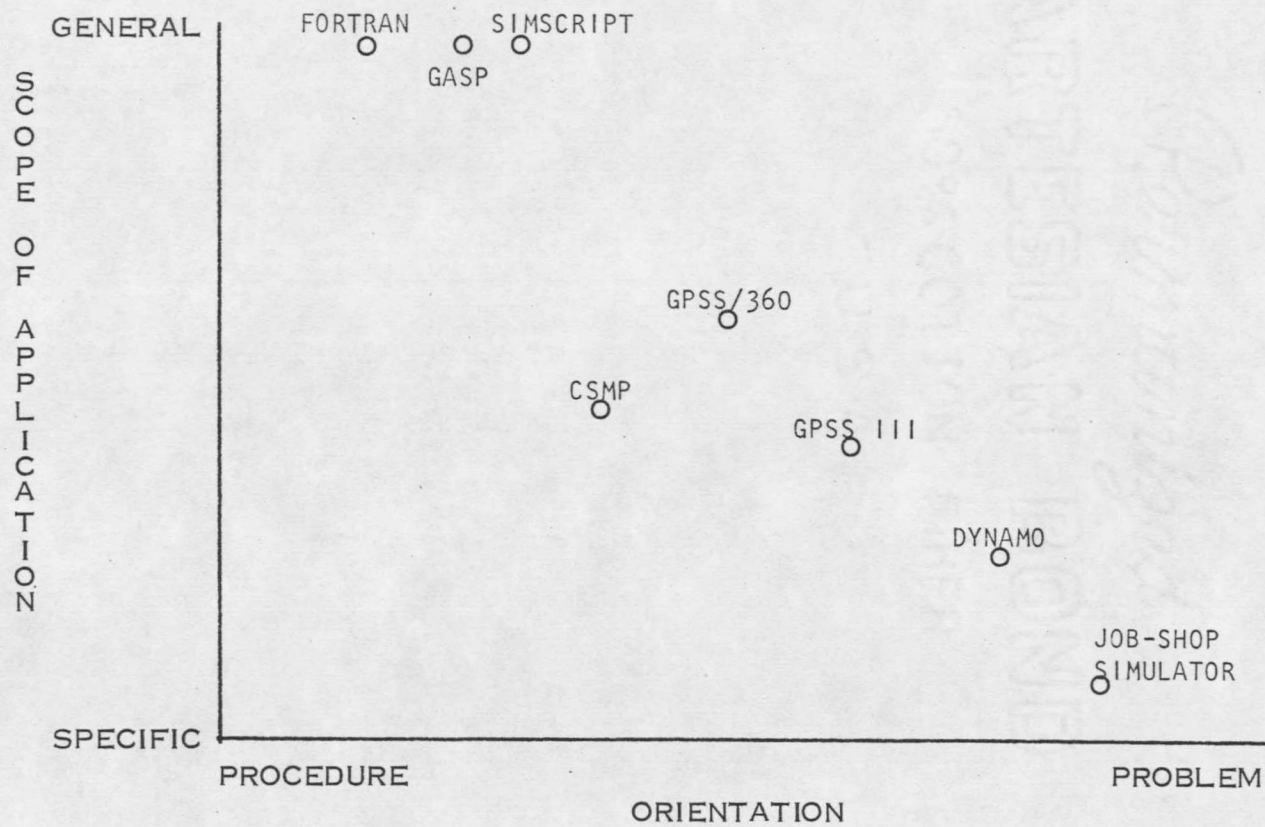


Figure 3. Classification of Simulation Languages (Relative Location Only)

differential or difference equations. It handles variables that are continuous or nearly so over their entire range.

One distinction that should be made is how a simulation language perceives the problem. As Emshoff and Sisson point out, the variables in a simulation may change in any of four ways:

1. In a continuous fashion, but at any point in time.
2. In a discrete fashion, but at any point in time.
3. In a discrete fashion and only at certain points in time.
4. In a continuous fashion, but only at discrete points in time.

GASP II can be thought of as a discrete simulation language where the variables can change at any point in time or at specific points in time depending upon the discretion of the user. DYNAMO is primarily a language where the variables change in a continuous fashion but only at certain points in time. A newly revised version of GASP, GASP IV, combines both the continuous and discrete possibilities of variable changes. In fact, with GASP IV the variables can change either discretely, continuously, or both discretely and continuously. The variables can be changed at specific points in time or at variable points in time. GASP IV will be discussed in greater detail in a later section.

Systems Dynamics

J. W. Forrester (1961; 1968) has done much to improve the "art" of describing and simulating large scale macro-economic problems. He has named his form of analysis and simulation "Industrial Dynamics". One

might begin by looking at some concepts about organization, decision making, and the relationship between information and managing. Management then can be thought of as "...the process of converting information into action" (Forrester, 1961:93). The conversion process is what we generally recognize and define as decision making. The success of the manager depends upon what information is available to him and how he converts it into action. Forrester (1961:38) has made this observation:

The manager sets the stage for his accomplishments by his choice of which information sources to take seriously and which to ignore. After choice has been made of certain classes of information and certain information sources to carry the highest priority, managerial success depends on what use is made of this information. How quickly or slowly is it converted to action? What is the relative weight given to different information sources in the light of desired objectives? How are these desired objectives created from the information available?

Forrester sees the modern manager not as converting the information himself into action, but rather he outputs a stream of information or decisions which directs the efforts of the human or nonhuman elements of the organization towards some goal. This might be illustrated as the information flow and feedback process as in Figure 4.

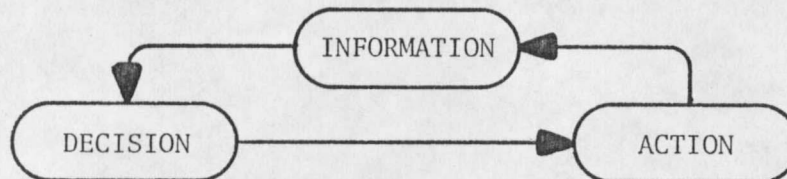


Figure 4. Decisions and Information Feedback

This illustrates an important characteristic of the information network in a firm. The decision that leads to control over a physical process is based on information about the prior state of that process. Information about the state of the system is said to be fed back through the information network to the decision point. Forrester (1961:14) defines the information-feedback system in the following manner. "An information-feedback system exists whenever the environment leads to a decision that results in action which affects the environment and thereby influences future decisions."

In studying feedback processes, the investigator deals with the way information is used for the purpose of control. The information-feedback control process is a continuous regenerative process with new results leading to new decisions. This cycling keeps the system in continuous motion. These systems as pointed out by Forrester need not behave in a predictable and satisfactory manner. In fact, a complex information-feedback system designed by happenstance or in accordance with what may be intuitively obvious will usually be unstable or ineffective.

There are three factors or characteristics of a system that result in the system's behavior. These include structure, delays, and amplification. As might be expected, the structure of the system tells how the parts are interrelated. Delays exist in the generation and transmission of information. Delays are further encountered in the

information conversion or decision making process and in taking action on the decisions. Amplification as noted by Forrester usually exists throughout such systems, especially in the decision making process of our industrial and social systems. "Amplification is manifested when an action is more forceful than might at first seem to be implied by the information inputs to the governing decisions" (Forrester, 1961:16).

This concept of servomechanisms or information-feedback systems is one of the most important foundations for industrial dynamics. Until recently, the effect of time delays, amplification and structure on the behavior of systems was of little concern. Only now are investigators becoming aware of the fact that the interactions between system components can be more important than the components themselves.

A second foundation on which industrial dynamics was developed is a better understanding of the decision making process gained during the 1950's with the automation of military tactical operations. A third foundation is the development of experimental approaches to understanding complex systems. This has been accomplished through the use of models. The fourth foundation to the development of industrial dynamics has been the growth of the electronic computer and its computative capabilities.

From these foundations, Forrester has developed the industrial dynamics approach to enterprise design. This approach progresses through the following steps:

1. Identify the problem.

2. Isolate the factors that appear to interact to create the observed symptoms.
3. Trace the cause-and-effect information-feedback loops that link decisions to action to resulting information changes and to new decisions.
4. Formulate acceptable formal decision policies that describe how decisions result from the available information streams.
5. Construct a mathematical model of the decision policies, information sources, and interactions of the system components.
6. Generate the behavior through time of the system as described by the model (usually with a digital computer to execute the lengthy calculations).
7. Compare results against all pertinent available knowledge about the actual system.
8. Revise the model until it is acceptable as a representation of the actual system.
9. Redesign, within the model, the organizational relationships and policies which can be altered in the actual system to find the changes which improve system behavior.
10. Alter the real system in the directions that model experimentation has shown will lead to improved performances (Forrester, 1961:13).

Probably the most important step of this approach as with any other is the definition of the problem. Once the problem is defined, the manner in which it is defined will affect how it is perceived and studied by any investigating team.

The last two steps of this approach are worth mentioning. Any conceptual model of a system, be it computerized or not, is only as good as it helps the user gain a fuller understanding of the operation of the

system. The objective of building the model should be to gain this understanding and hopefully apply this understanding to the system and thereby improve its performance.

To help gain an understanding of the structure of any feedback system, Forrester (1968:7-1) suggests the use of the flow diagram.

Feedback systems are elusive. Their structure and dynamic implications are hard to grasp and to keep in mind. One needs as many viewpoints as possible. From each viewpoint he may see something that was missed in a different exposure. A verbal description is one approach to a system; equations describing behavior of the separate parts is another. But to show the relationship between the parts and to accentuate the loop structure of a system, the flow diagram is best.

The flow diagram is not intended to show minute details of the system's workings but rather give broader perspective of the problem. The flow diagram should show how the cause-effect interactions of the system are interconnected to produce the feedback loops and how these loops are interlocked to create the system.

A simplified summary of this flowcharting method is represented in Figure 5. This summary illustrates the representation of levels; flows that transport the contents of one level to the next; decision functions that control the rates of flow between levels; and information channels that connect the decision functions to the levels. Also represented are auxiliaries which transform the information obtained from levels to a workable form for decision making.

Using this basic scheme of charting, complex systems can be

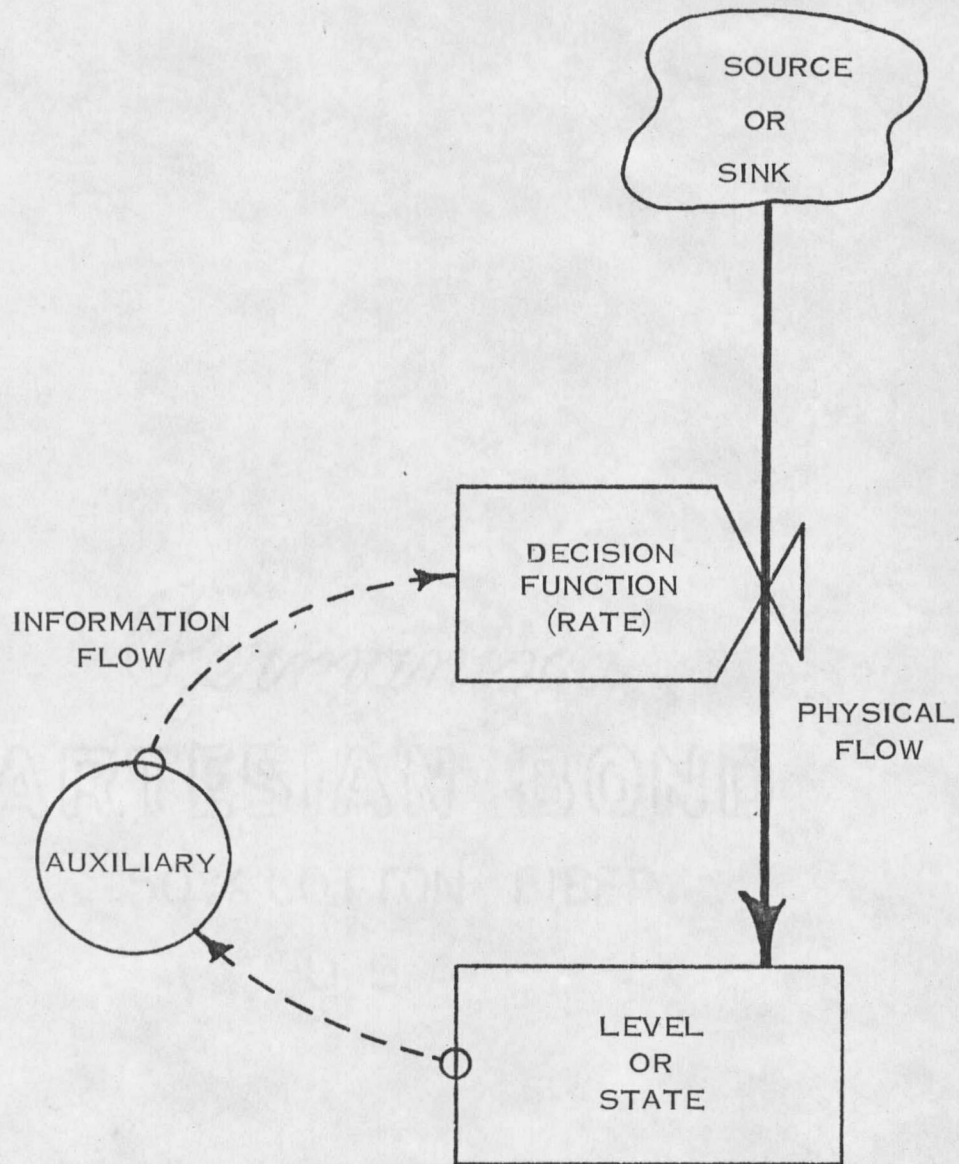


Figure 5. Forrester's Flowcharting Method

represented. This method will be used in the model development portion of this thesis.

GASP IV

GASP IV is a FORTRAN based simulation language designed for modeling a system in two dimensions: time and state-space. The language was developed by Alan B. Pritsker and Nicolas R. Hurst at Purdue University as an extension of the simulation structure of the discrete event language, GASP II (Pritsker and Kiviat, 1969; Pritsker and Hurst, 1973; Pritsker, 1974).

As outlined by Pritsker (1974) in his book GASP IV, a necessary first step in building a GASP IV simulation model is breaking down time and state-space into manageable elements. For the time dimension, this decomposition involves defining events and changes that will result when the event occurs. The user must specify the mathematical-logical relations that transpire at an event occurrence and the casual mechanism by which events occur. He is relieved, however, from the need for sequencing events or modeling the timing of events during the simulation. This is provided by the GASP IV routine.

In the state-space dimension, the system model is broken down into entities, which can be described by their attributes. These attributes can be further classified as discrete or continuous. The discrete attributes are characterized by their static nature between event times. That is, their values remain constant between event occurrences. The

value of a continuous attribute is dynamic, for its value changes over the time span between event occurrences. These attributes represent the dynamic behavior of the system being modeled and are referred to as state variables. These state variables can be thought of as levels in Forrester's Industrial Dynamics model. The user is compelled to specify only the relationships whereby these values change. This can be done in terms of difference or differential equations. GASP IV provides the mechanism for integrating these relationships over time and thereby updating the values of the state variables.

The philosophy of GASP IV grows out of a broader definition of event than is normally attributed to a discrete-event language. An event is defined as:

A point in time beyond which the status of a system cannot be projected (Pritsker, 1974:13).

Though events generally cause change in the status of the system, they can also occur at decision points where the decision is made not to change the status.

It is useful to describe events in terms of the mechanism by which they are scheduled. There are those that occur at a specified point in time which has been projected by the user. This type of event is referred to as a time-event and is commonly thought of when working with "next event" or "discrete" simulation models. Another type, referred to as state-events, occur when the system reaches a specified state. These events are not scheduled to occur at a specified point in time, as

events, but occur when state variables meet predetermined conditions. In GASP IV, time events can initiate state events, and state events can initiate time events. This is left to the discretion of the user.

As a GASP IV simulation run progresses, the values of the state variables are computed at small time steps. The values of the discrete variables are computed at scheduled event times. When an event, either state or discrete, occurs, the status of the system can change: by altering the values of state or discrete variables; by altering the relationships that exist between variables; and by changing the number of entity variables that exist. Between event times, only the values of the continuous state variables can change.

The formalized world view of GASP IV can be summarized as follows:

The world view specified that the status of a system be described in terms of a set of entities, their associated attributes, and state variables. The GASP IV simulation philosophy is that a dynamic simulation can be obtained by modeling the events of the system and by advancing time from one event to the next (Pritsker, 1974).

The fact that GASP IV is a FORTRAN based simulation language makes it attractive to the experienced user. GASP provides the framework for analyzing a complex problem but gives the user complete control of the system and with programming expertise, the extended capabilities of the FORTRAN language.

Approach to the Problem

The land manager is faced with the problem of identifying and

evaluating the effects of a given activity upon an area's ecosystem. This study, using the systems approach and systems simulation, focuses on an approach to aid the manager analyze these dynamic effects over extended time periods. The basic model will be developed with timber harvesting as the impacting activity. This will be expanded to include fire as an impacting force and road building as an impacting activity. These latter impacts are included to demonstrate the flexibility of this modeling approach.

In looking at harvesting and how it effects the ecosystem from the multiple use viewpoint, two distinct simulation approaches are indicated. The logging system can be thought of as a micro-system which is production oriented. The manager is interested in productivity at least cost. The area or ecosystem is time oriented and can be thought of as the macro-system. In this case, the manager is interested in responses over an extended time frame.

For the micro-phase of this model, extensive work has been done by Johnson (Biller and Johnson, 1972; Johnson, 1970; Johnson et al., 1972) in simulating the harvesting system. The approach taken was event oriented GASP II simulation language. The model contains minute details of the harvesting activity. Effectiveness of the system is measured in terms of man and machine productivity and cost. No attempt is made to measure the impacts on other resources.

For the macro-phase of this systems model, the effectiveness measure will be the availability or levels of all resources over time. This phase will be designed based on the continuous modeling approach. The ecosystem will be represented as levels with flows that transport the contents of one level to another with decision functions controlling the rate of flow between levels and information channels that connect the decision functions to the levels. This approach is described by Forrester (1961; 1968) as Industrial Dynamics.

GASP IV, based on the traditional FORTRAN programming language with the capability of combining both discrete and continuous elements of a system into one simulation model, offers a good approach to analyzing complex problems. The language has been used to analyze the chemical electroplating process for production efficiency with environmental considerations (Sigal, 1973). Using GASP IV, Sigal was able to effectively analyze environmental factors, cost factors, and various aspects of the production process in evaluating the recovery process.

This thesis is directed at designing the macro-phase of the model and the linking of the two phase concept into a working model. The GASP IV simulation language will be used. It is hoped that this thesis will demonstrate the usefulness of such a modeling approach in analyzing such complex problems.

Chapter 3

MODEL DEVELOPMENT

The public land manager is directed by law to evaluate the environmental impacts of proposed activities. These activities must be planned with due consideration for "multiple use" and "sustained yield". Systems simulation is an approach which allows the manager to test the dynamic responses of an ecosystem to activity impacts.

For this study, an ecosystem impact model is presented. This model will be developed from a general description of the system, followed by the development of general relationships and then lastly the regimentation of these relationships into a mathematical model which will be computerized and simulated. The model will be based on general cause-effect relationships, many of which are gross assumptions on the author's part. The modeling approach is presented here.

The Systems Description

In developing the system model, the five step scientific approach suggested by Churchman (1968) will be used. This approach begins with the imperative first step of identifying the total system objectives. This might also be stated as identifying the measures of performance of the whole system. This first step is worthy of considerable attention as all subsequent thinking about the system is influenced by how the true objectives are perceived.

The second step of this approach is to identify the environment or the fixed constraints of the system. The environment of the system is that over which the system, as it is defined, has no control. In addition to lying outside the control of the system, the environment or fixed constraints also influence how the system performs.

The next step in the scientific approach is to identify the resources of the system. In contrast to the environment, resources lie within and can be changed by the system. In fact, the resources are used by the system to obtain its objectives.

The fourth step of this approach is to identify the components of the system. The components are those parts that use the resources to contribute to the overall operations of the system. The components have a specific job to perform in the system.

The final step in the scientific approach to study systems as presented by Churchman is to identify the management of the system. Management is that function which sets the goals of the components, allocates all of the resources, and has direct control over the systems performance. The management is the decision maker in the system.

System objectives. Defining the objectives of an ecosystem is a problem. If left to its own design the ecosystem will continue to cycle and function as it has since the beginning of time following the natural laws of growth, death, recovery, and succession. Like it or not, man is also a very important part of that ecosystem. With more and more people

inhabiting the same land area, there is bound to be more pressures placed on the land and its uses. But man is the one component of the ecosystem who has the ability to choose his role and decide how he will interact with his environment. He has the ability to influence his own destiny if you will.

So what is the role of our forested lands? What is the objective used to manage these lands? For our National Forests this goal, derived from the interpretation of all legislation that applies to Forest Service operations, might be stated as follows:

To optimize public benefits from the National Forests while maintaining the long term productivity of the land (Brown and Dane, 1974:1-6).

The above goal is limited by the following constraints:

Land Capability - No activity may be allowed if it will result in the destruction, depredation, or diminishment of the land's long term productivity;

Sustained Yield Management - All resources are to be managed on a sustained yield basis;

Funding - The intensity of local management is constrained by the level of funding and the manner in which these funds are allocated (Brown and Dane, 1974:1-6).

The responsibility of National land management is awesome. Public inputs are required. Within the Forest Service a Land Use Planning process is evolving which is directed at making land use decisions. Research is continually conducted to improve this process (Barney, 1976; Brown and Dane, 1974).

With this overall land management objective in mind we can now look at the specific objective toward which this thesis is directed. One important element of the management objective is to test any proposed management action against the lands "long term productivity" and "sustained yield capability". Another element is to "optimize public benefits from the National Forest land".

The planner must evaluate the proposed activity not only against its optimization, but also against its impacts on the area in general. In the case of timber harvesting, the planner wishes to remove a given quantity of timber by the most efficient means possible while minimizing the impacts on other resources. Therefore, the objective of this systems model might be stated:

To represent the impacts of an activity on an area's ecosystem in terms of the dynamic responses of the area's resources over time while optimizing the activity.

Environment. The environment or fixed constraints of the system are primarily related to the area's location in time and space. This includes such elements as climatology, geography, physiography, and existing cultural forces. Climatological elements include moisture received in the form of rain and snow, temperature, and length of growing season. The form of the land and its relation to surrounding areas are part of its geography. The soil characteristics and production potential are elements of physiography. Cultural forces of the area

include existing timber harvested areas, existing roads and any developments.

The environment consists of those elements which fall outside the system's boundary, but which influence the workings of that system.

This might be presented as shown in Figure 6.

Resources and components. In this model the resources and components as defined by Churchman are intermixed. Area, timber, forage, wildlife, moisture, and existing roads would be classified as resources. They are consumed or used by the system and lie within the system boundaries. At the same time timber, forage, wildlife, and roads would be classified as components as they each use other resources; timber uses the area and moisture resource; wildlife consumes forage, etc.

In addition to those already listed, the activities of timber harvesting, road construction, and fire would be components. The decision maker has direct control over harvesting and road construction. He also has some control over fire.

System manager. The manager of this system is assumed to be the Forest Service. The Forest Service is responsible to the public for the management of lands entrusted to it. It has control over allowable timber cuts and harvesting practices. The Forest Service sets road construction standards and allowable access routes and is also

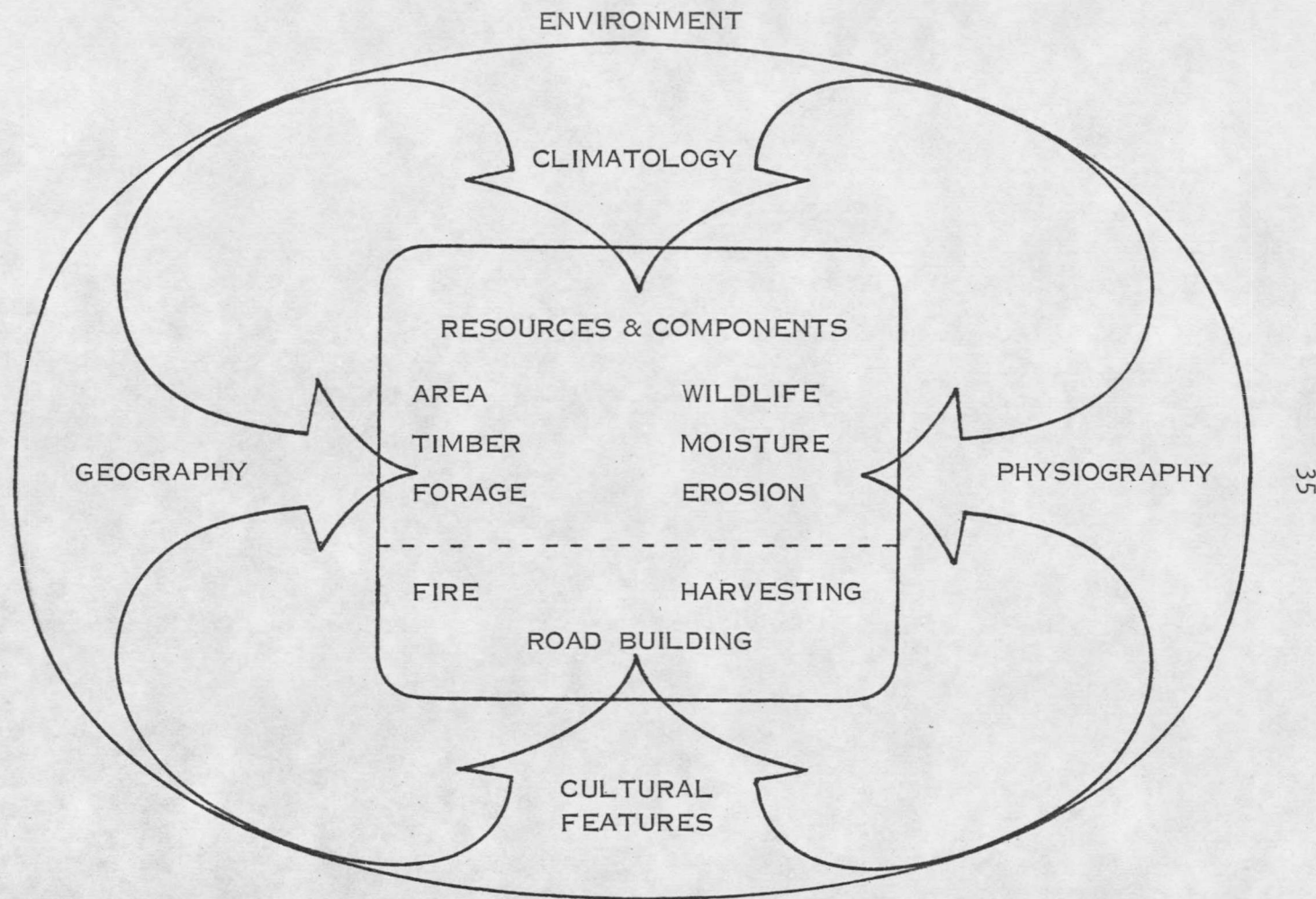


Figure 6. Ecosystem Diagram Showing Environment, Resources, and Components

responsible for fire protection on the National Forests and Grasslands.

Ecosystem - Harvesting Productivity Model

With the previous discussion as background, we will now look at the model developed to portray ecosystem impacts. Because of the two phased objective we are addressing; namely (a) ecosystem response to activity, and (b) optimization of activity productivity, it is logical to divide the model into two phases. The black box diagram of these phases is shown in Figure 7.

In the ecosystem phase, time is the key element. The planner is interested in changes in the system over extended time periods such as one to three hundred years. This phase of the model is represented by combinations of recurrence formula. These equations are written:

$$SS(t) = SS(t-1) + (RATE_i - RATE_d) \times DELTA_t.$$

$SS(t)$ is the calculated systems status at time t . $SS(t-1)$ is systems status at time $t-1$ or the last update time. Change in status is represented by $RATE_i$, the rate of increase, and $RATE_d$, the rate of decrease. This change rate is then multiplied by the time increment between updates, $DELTA_t$. These equations represent a continuous flow mechanism which can be written in terms of differential equations as $DELTA_t$ approaches zero. However, for this general model, $DELTA_t$ is set to one month.

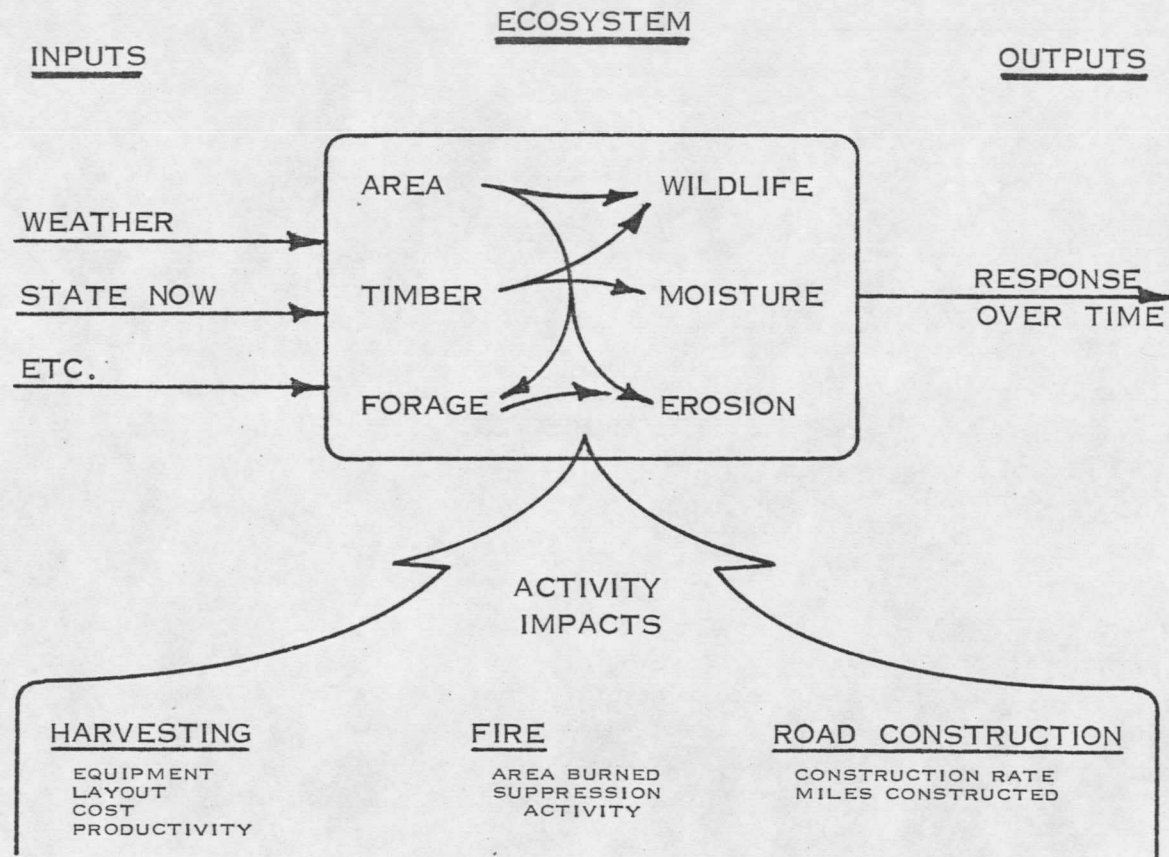


Figure 7. Black Box Diagram of Ecosystem Response to Activity Impacts

Inputs to the ecosystem phase of the model are controlled by the user to represent the environment. These inputs include such factors as weather, the state of the system now, and the physiography of the system. With these inputs, the systems resources and components interact by specified recurrence formula to provide output in terms of the response of given levels or state variables over time.

The activity impact phase of the model is of two types. The first type is represented by the harvesting model. This model is directed at activity production and is presented in Figure 8. This phase requires considerably more detail than the ecosystem phase as internal activities are occurring on a much smaller time scale than months.

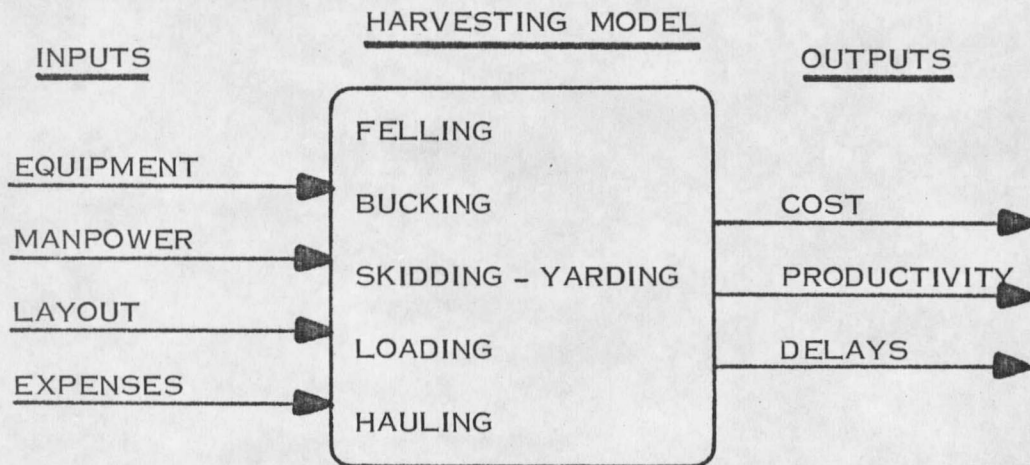


Figure 8. Black Box Diagram of Harvesting Productivity Model

This phase of the model is analyzed by the discrete simulation method. Detailed analysis of this phase is provided by an existing timber harvesting system simulation called SAPLOS. A refined version of this package is utilized to represent in great detail the interrelationships and productivity of logging operations. This simulator is a next-event type model where each event is scheduled at some future time based on the status of the system now. The time scale used in this model is minutes.

Utilizing this detailed simulator, the planner has the capability of looking at the harvesting system in great detail. He can design and lay out the logging operation for optimal efficiency. Inclusion of the macro-phase of this model allows him to also look at environmental responses of the proposed layout.

The second type of activity impact is represented by fire and road construction. These impacts can be thought of as discrete for they are scheduled at a specified point in time. They directly influence state variables in the macro-phase model as specified by input parameters. These impacts are not simulated in great detail and no productivity optimization capability is provided. The user is merely interested in determining how the ecosystem will respond to the impacts.

Combining Model Types

The mechanism for combining these various model types is provided by GASP IV. Being a generalized FORTRAN based simulation language

combining both discrete and continuous variables, GASP IV is ideally suited to the task at hand, with several coding changes in its output plotting subroutine. These coding changes were made, varying the time increment, to improve output presentation.

The model progresses through the two phases as depicted in Figure 9. Starting at "time now", the macro-phase operates in the steady state. This represents the ecosystem as it might be before harvesting. At a specified point in time, say 1990, harvesting begins. At this point, the simulation model shifts to the micro-phase with its operation controlled by the discrete events of harvesting. System status is recorded weekly during this phase. At the completion of harvesting, the model once again returns to the macro-phase monitoring the responses of the ecosystem. During this phase, system status is recorded yearly.

Options are provided allowing the user to request status reporting on a monthly basis. This is particularly useful if the system is subjected to a fire or road building impact. The systems immediate response to these activities can be monitored over a given time period. Seasonal trends can also be observed at any time. This capability gives the user considerable control of the model.

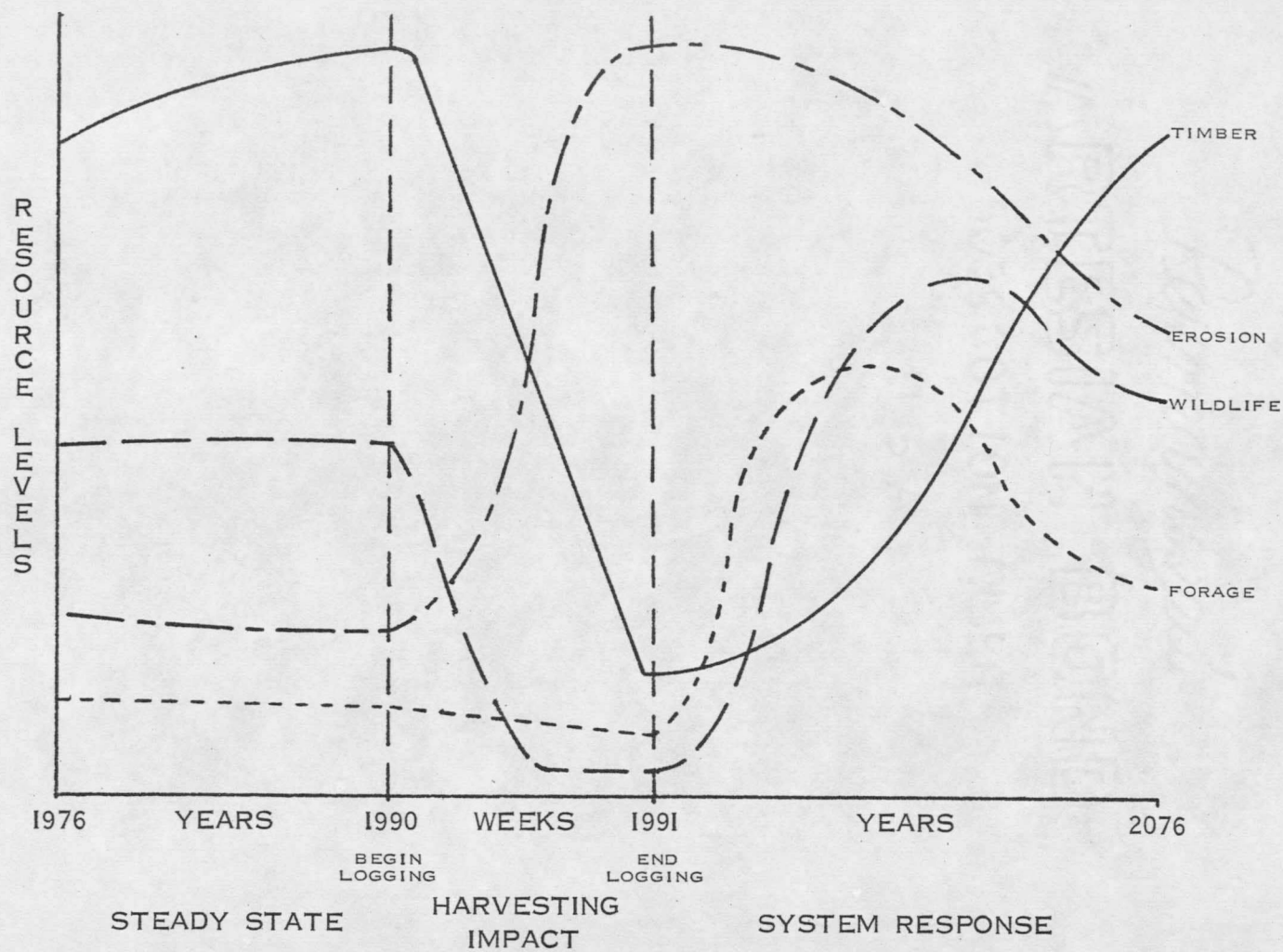


Figure 9. Time Scales of Combined Macro - Micro Simulation Model

Chapter 4

MACRO-MODEL PHASE

The ecosystem model is divided into six subsystems: 1) area, 2) moisture-water, 3) timber, 4) forage, 5) wildlife, and 6) erosion. This was done to facilitate understanding from an interdisciplinary perspective. The climatologist is primarily interested in the moisture-water subsystem. The silviculturalist and timber specialist function within the timber subsystem. Range specialists are concerned with the forage subsystem. Wildlife and its interactions are portrayed in the wildlife subsystem. The hydrologist would be concerned with both the erosion and moisture-water subsystem.

In dividing the macro phase into these segments, physical flows are contained entirely within a subsystems boundary. However, information about a state variable is used to influence the rates of flow in other subsystems. These information links represent the interactions of the ecosystem.

The remainder of this chapter is devoted to describing each subsystem of the macro phase in detail. The basic flow charting scheme used is derived from that used by Forrester (1968). The symbols and their intended meanings are discussed in Appendix A. Complete systems diagrams and model equations for each subsystem are provided in Appendix B.

Area Subsystem

The area subsystem provides the sizes of major area classes for the ecosystem model. The generalized flow diagram for this subsystem is shown in Figure 10. This complex is represented by five distinct area classes. For modeling purposes, these categories are assumed to be mutually exclusive. Each class is identified depending on the dominant use or influence of the area.

Burned area includes all which has recently been subjected to fire. This area is characterized by little or no vegetation with patches of exposed mineral soil. The assumption is made that this area has production potential and will eventually return to range and finally forest production. The major influence of this area on the system is in terms of moisture holding capacity and erosion. There is also the immediate effect of removing the area from biomass production.

Range area is dominated by its forage production. This classification includes all biomass productive area that is not producing timber. Though forage does grow under standing timber, this area is not included in the range classification.

The state variable, forest area, is that whose major influence to the system is timber production. This area includes all with growing timber. The last area classes presented as state variables are for roads. This road area is subdivided into two classes, open and closed. Open

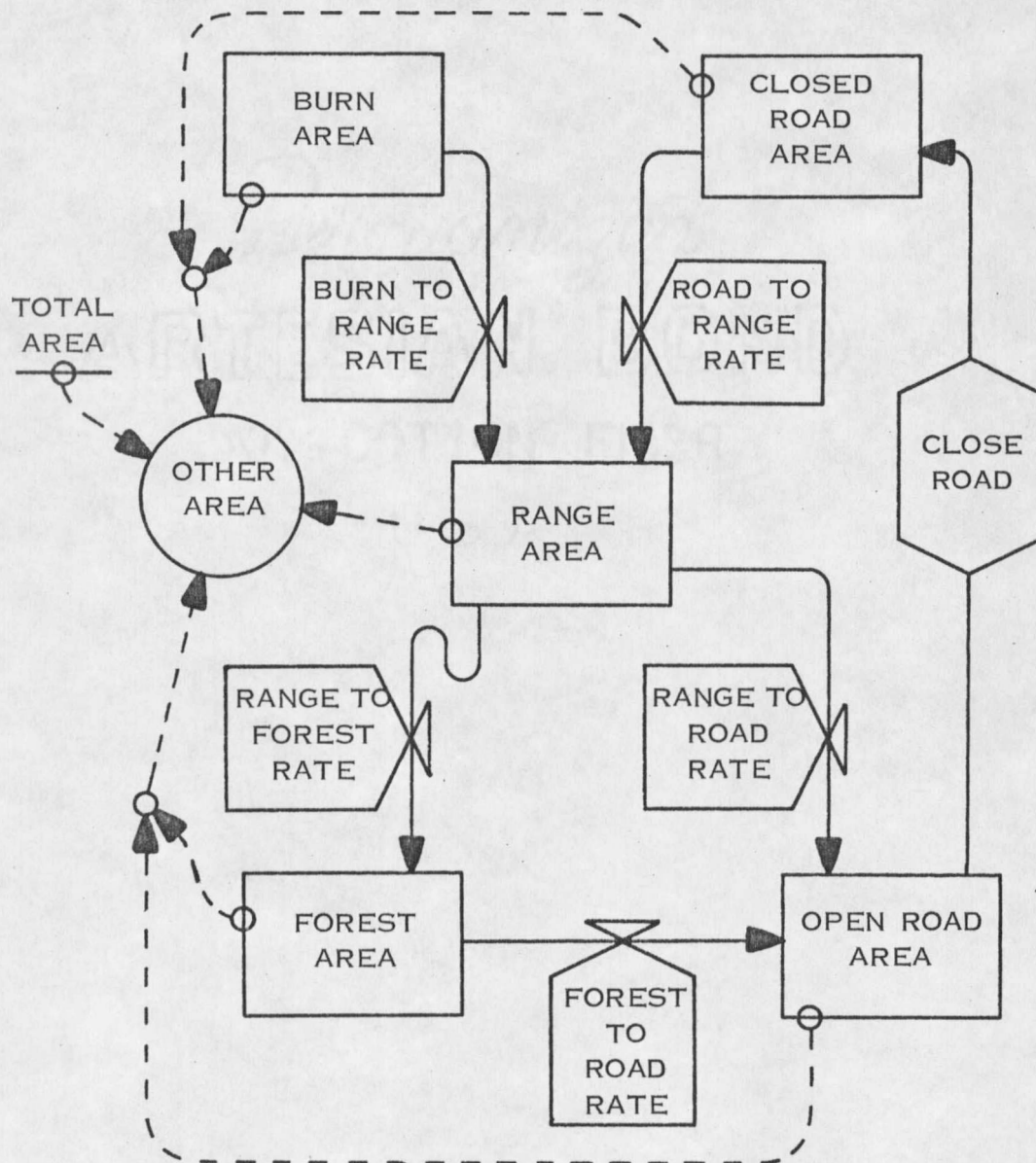


Figure 10. Area Subsystem Flow Diagram

roads are maintained in such a condition that, vegetation is not allowed to become established in the area. Closed roads on the other hand are allowed to return to their natural state of biomass production.

Provisions are made in this subsystem to classify the unproductive area in the ecosystem. This is identified in the model as auxiliary information and is represented in the diagram as a circle. The size of this area is calculated by subtracting from total area all biomass productive area, burned area, and road area.

Flows of area within this subsystem are assumed to follow the natural progression from burned or closed road area to range area and finally forest area. Provisions are included in the model for converting range and forest area to road area. The rates of these flows are controlled by road construction and are explained further in the next chapter.

The rates of flow, burn to range and closed road to range, are set up in the model as inverse decay functions. The magnitude of these decays is specified by the user. The flow from range to forest is dependent upon area sizes and average tree height. The distance seeds will travel depends on tree height and the assumption is made that timber encroachment into range results from this seed travel. This distance-height relationship is derived from user inputs.

Moisture-Water Subsystem

The moisture-water subsystem is the primary driving component of

the ecosystem model. All vegetation growth is dependent upon the available moisture which in turn affects wildlife capacity. In addition to this, erosion is caused directly by the amount of runoff occurring. The generalized flow chart of this regime is given in Figure 11. For more detail, the specific flow chart and accompanying equations are provided in Appendix B.

The moisture-water subsystem receives two primary inputs; snow and rain. Snow is allowed to accumulate as snow pack and is stored until spring runoff. This runoff plus any rain which might be received contributes to the available surface water.

The surface water that accumulates is dispersed by three modes: absorption into the soil, runoff over the surface, and evaporation back into the atmosphere. Surface water absorption and runoff are dependent upon the area class on which the moisture is received. The three area classes, burn, range, and forest, are assumed to have different moisture absorption capabilities. These values are determined by the surface water available and the area's field capacity or soil moisture holding capacity.

Once the moisture becomes trapped by the soil, there are two ways provided for its consumption. One is the use of the moisture in the soil by the area's biomass. This consumption is determined by the biomass load being supported by the site. The other method of soil moisture loss is through percolation. The percolation rate for each land area

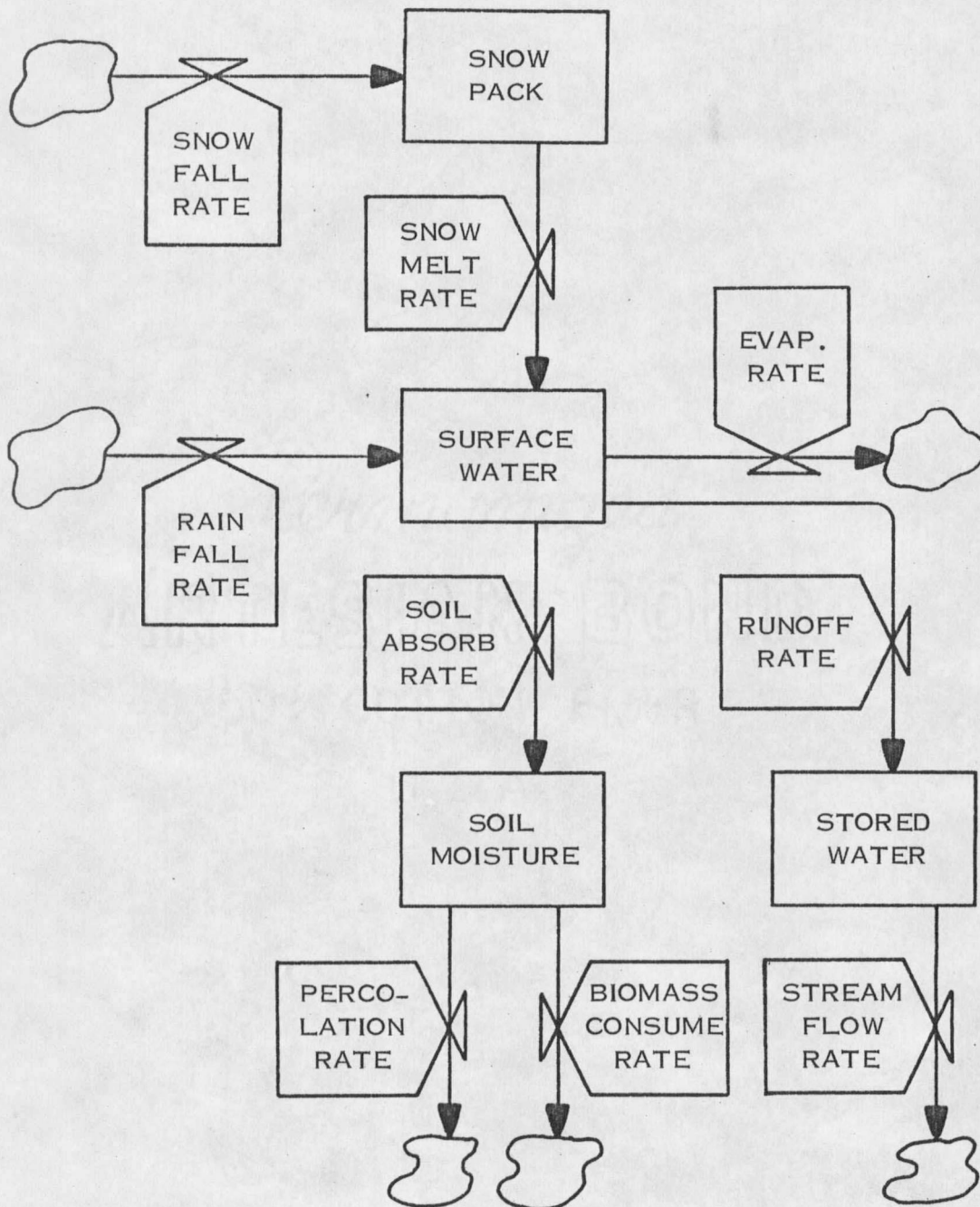


Figure 11. Moisture-Water Subsystem Flow Diagram

type is provided by the user as input.

A second use of available surface water is evaporation back into the atmosphere. This rate is provided by the user in the form of a 12 month array specifying the percent evaporated per month.

The last available route for surface water to take is in the form of runoff. This rate is crucial in determining the amount of soil erosion produced. This runoff is accumulated in streams, and lakes if applicable, and is referred to by the model as stored water.

Finally, the level of stored water is reduced by the stream flow rate which is provided by the user.

Timber Subsystem

The timber subsystem is represented in the model by four level or state variables. The flow diagram for this subsystem is shown in Figure 12. A detailed diagram with all equations is included in Appendix B.

The first state variable in the timber regime is the number of growing stems. This level is increased by seedling establishment and decreased by timber mortality. Timber death increases the level of standing dead trees. After a period of time, the standing dead trees fall to the forest floor adding to accumulated litter and debris. This function is identified as the topple rate.

Average stand diameter is influenced by a growth rate and a decrease rate. The growth rate is determined by assuming a constant

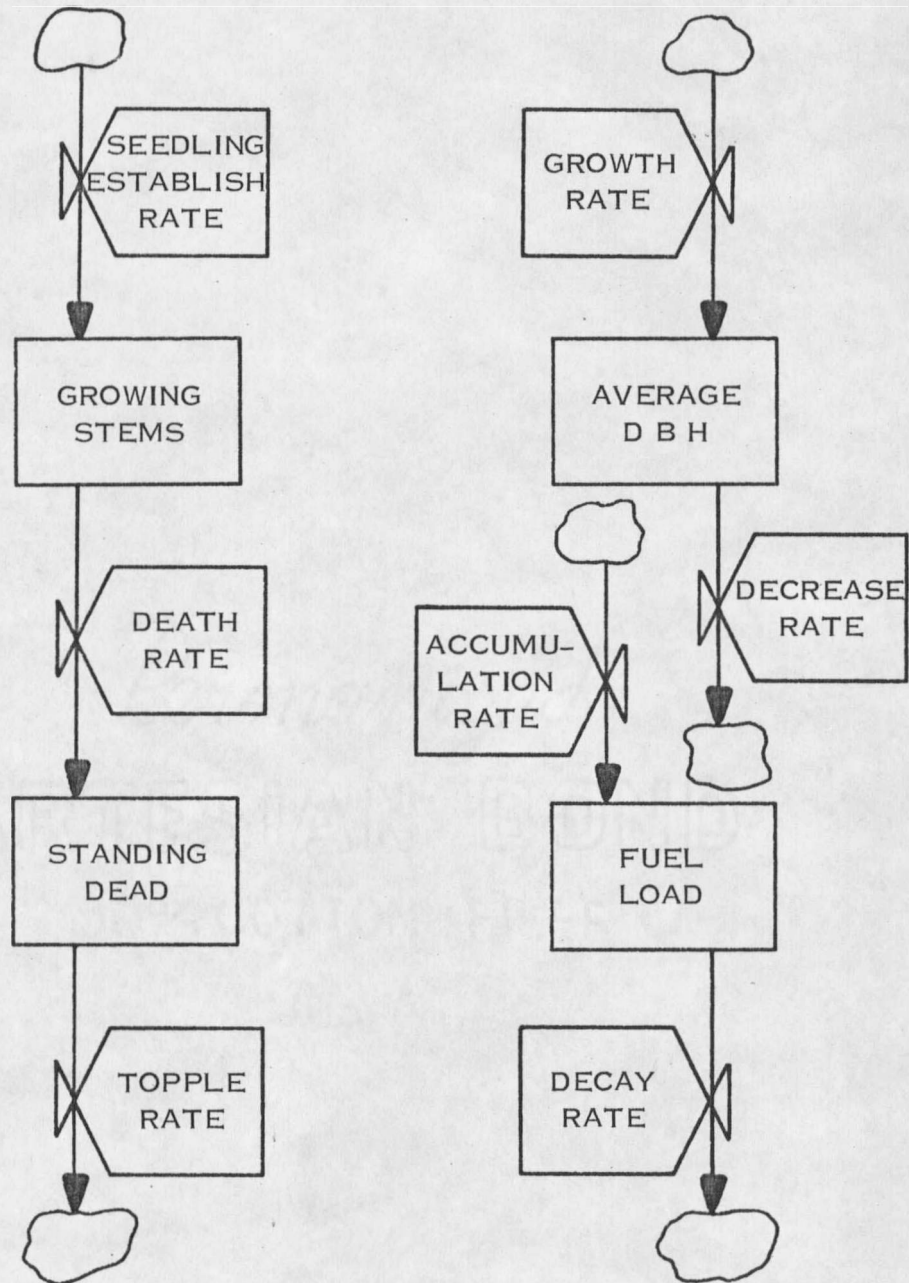


Figure 12. Timber Subsystem Flow Diagram

basal area increase per year. This increment is determined from the one hundred year site index for the area. This relation seems reasonable as a tree tends to grow faster when small and its growth slows down as size increases.

The final state variable in the timber subsystem is fuel loading. This includes all fallen woody material, litter, twigs, and branches. The rate of fuel accumulation is assumed to be a function of the average tree size, the number of growing stems, and the number of standing dead stems. It is assumed that a percentage of the growing tree volume is lost every year to falling branches and needle cost. This percentage is input to the model by the user. In a similar fashion, it is assumed that a percentage of the standing dead timber volume is also lost every year.

The magnitude of fuel load is decreased by a decaying function. This rate is assumed to be related to the amount of surface water available in the system. It is recorded as a percentage value input by the user.

Forage Subsystem

The forage subsystem is represented in the model by two state variables with their accompanying flows. These levels and flows are diagrammed in Figure 13. The complete systems diagram with equations is provided in Appendix B.

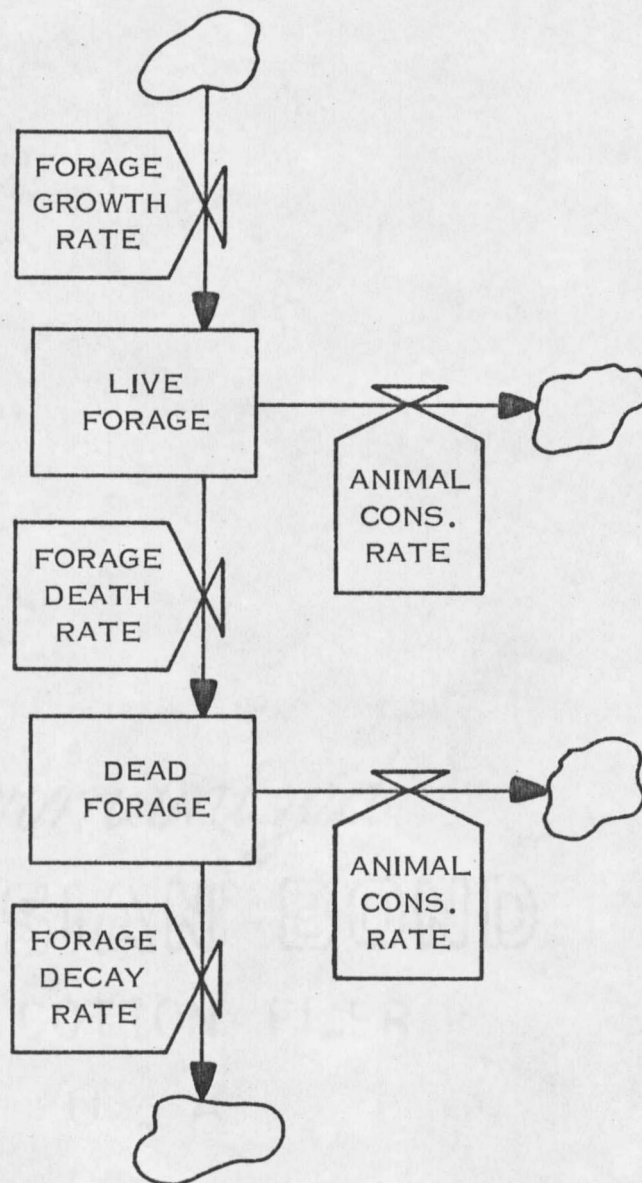


Figure 13. Forage Subsystem Flow Diagram

The first state variable in this subsystem is live forage. Forage growth increases while forage death and animal consumption decreases this level. Forage growth is dependent upon the area of forage production, the soil moisture available and the rate at which forage consumes the moisture. The area of forage production includes the area of range as defined by the Area Subsystem and the effective area of forage production in timber. This latter value is assumed to be a function of tree height, density, and fuel loading.

Forage death occurs on a seasonal basis at the end of a growing season. It will also occur when the available soil moisture is not sufficient to support the existing load. This death transfers load from live to dead forage. Decay and animal consumption decrease dead forage load. In the model, decay is assumed dependent upon the amount of surface water available. The percent forage decay per inch of surface water is provided by the user.

Animal consumption of forage is calculated from the number of animals in the system and the forage available. It is assumed that animals will eat live forage over dead. The amount consumed by both large herbivores and small animals is controlled by the user.

Wildlife Subsystem

The wildlife subsystem of the model is depicted by three state variables; carnivore number, small animal number, and herbivore number. These levels and the accompanying flows are shown in Figure 14. Each

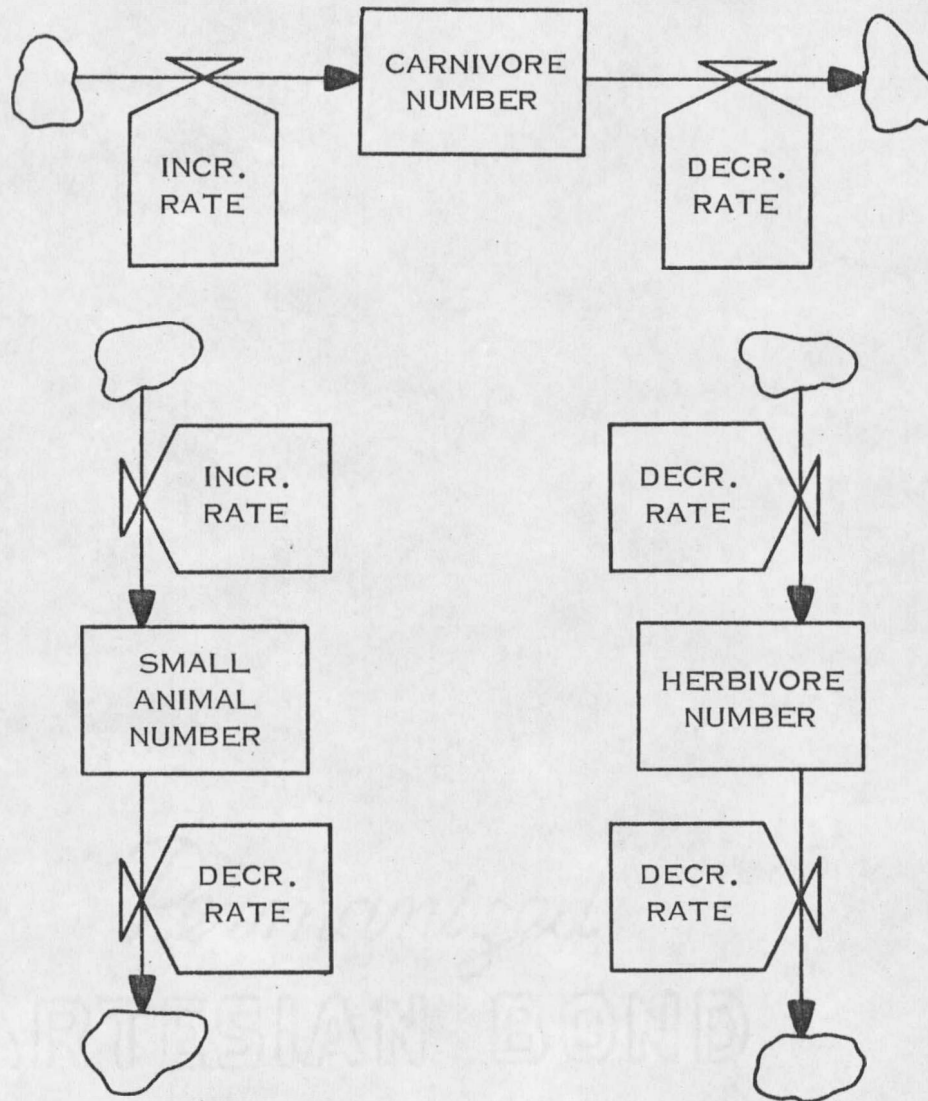


Figure 14. Wildlife Subsystem Flow Diagram

level can increase or decrease by a calculated rate. The increase in animal numbers can occur by two means: one is the natural birth rate associated with the animal type, and the other is by migration into the modeled area.

The rate at which animal numbers decrease is caused primarily by two factors; natural death and migration out of the area. In addition to these, small animal and herbivore numbers are reduced by carnivore kill and consumption. Provisions are made to allow for a hunter kill of large herbivore in October of each year.

A more detailed flow diagram with equations is presented in Appendix B.

Erosion Subsystem

Erosion is recorded by the model as total sediment load. Sedimentation accumulates from four primary sources; 1) burn area, 2) forest area, 3) range area, and 4) road area. These areas contribute to the total load at differing rates depending upon the water runoff rate for each area. The amount of erosion carried per inch of runoff for each area is provided by the user. The flow diagram for this Subsystem is shown in Figure 15.

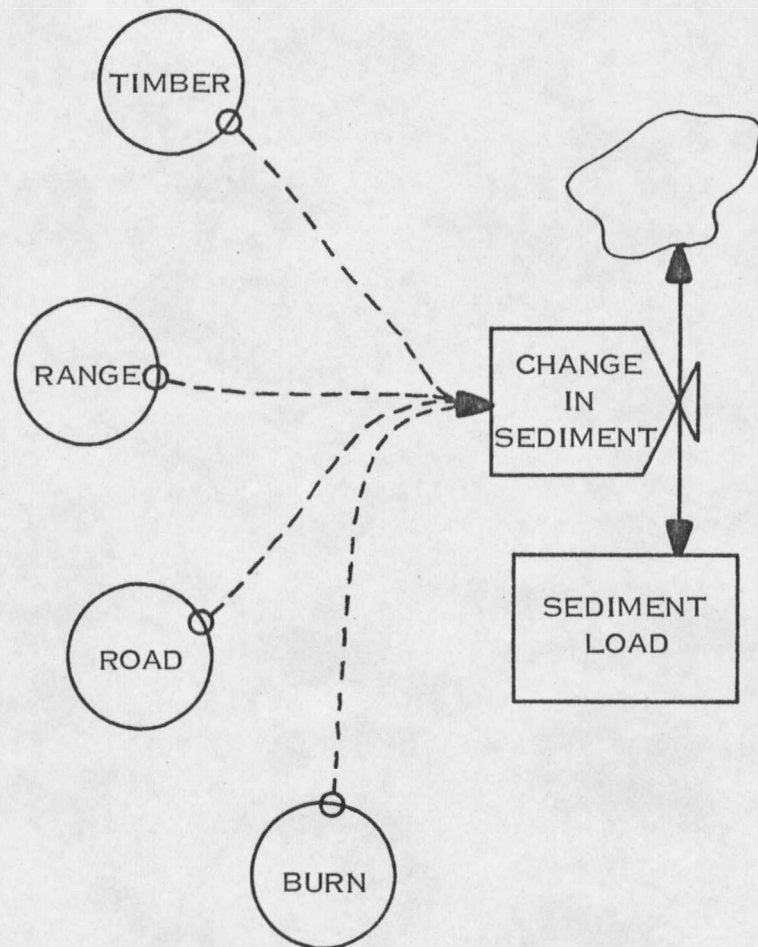


Figure 15. Erosion Subsystem Flow Diagram

Chapter 5

MICRO-DISCRETE PHASE

The micro-phase of the model is divided into three types of discrete subsystems. These are represented by: 1) the harvesting subsystem, 2) the fire subsystem, and 3) the road building subsystem. The three discrete subsystems were chosen to illustrate the modeling flexibility available by the two-phase modeling approach. In this chapter, each of these subsystems is described. Other subsystems could be added to model impacts desired by the user.

Harvesting Subsystem

The harvesting subsystem represents a detailed model directed at analyzing the productivity of an activity. For this subsystem, the logging simulation model, SAPLOS, developed by Johnson (1970; Johnson et al., 1972) is utilized. This model, originally written for the discrete-event GASP II language, was modified and updated to GASP IV.

The flow of timber through the harvesting model is diagramed in Figure 16. As shown, up to nine logging tasks or operations can be represented by the model. Each of these operations is divided into its components and these are scheduled at specific points in time. These scheduled components are defined as discrete events and the time between event occurrences is determined by the model at completion of the preceeding event. Thus the model steps through the harvesting operation event by event until harvesting is completed.

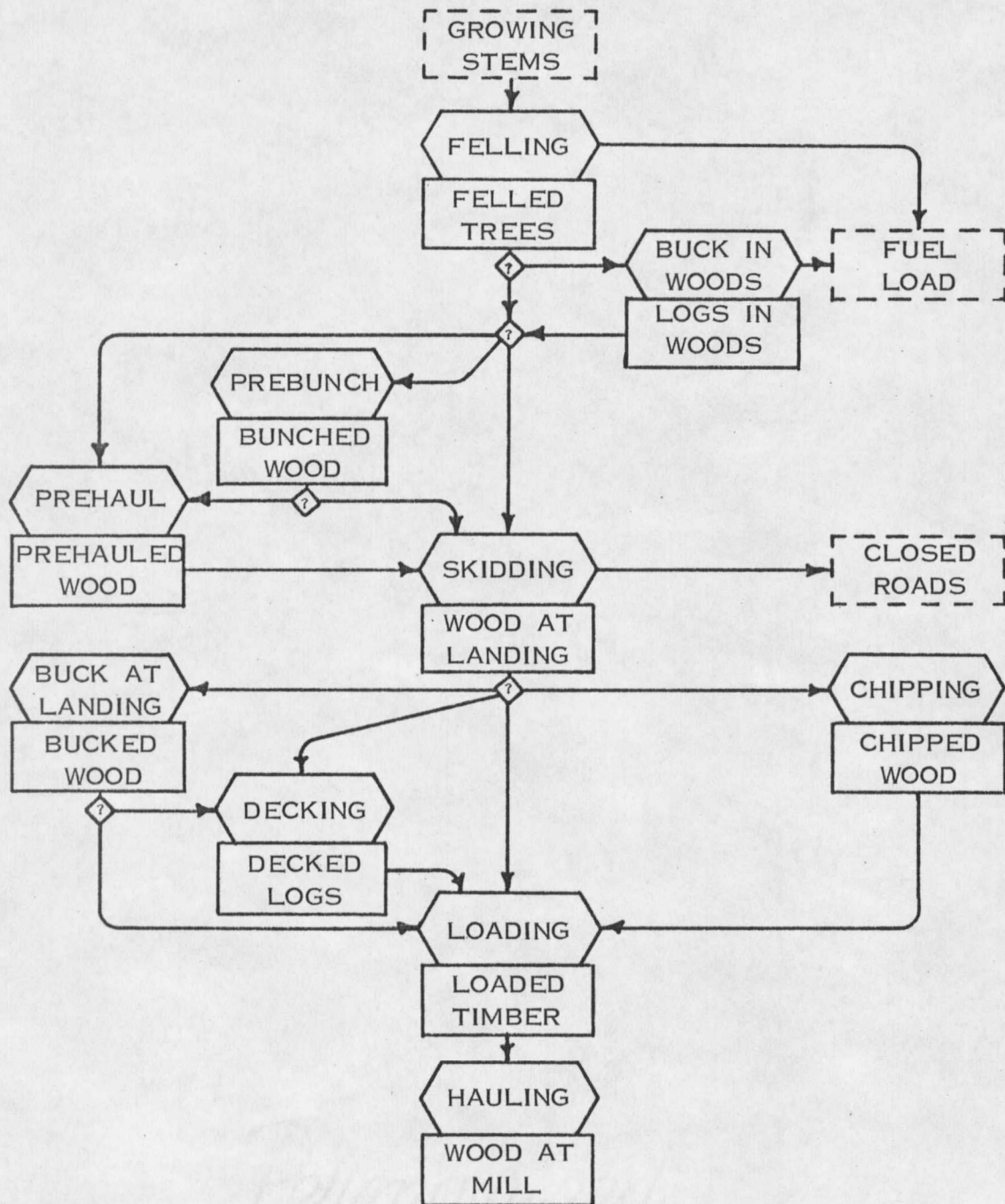


Figure 16. Harvesting Subsystem Flow Diagram

Felling a tree reduces the macro-phase state variable, growing stems, by one. At the same time, this increases the inventory of felled trees by one. The felling operation also increases fuel loading in the area because of breaking limbs and tops, etc. After felling, the user can specify bucking in woods. If layout design calls for this task, felled trees become logs in woods and more is added to the state variable fuel loading.

At this point, logs may follow one of three pathways through the system. The model allows for prehauling, prebunching or skidding. In the prehauling activity, the logs are skidded from the tree to a prehaul dock. From there, they are skidded to the landing over established skid roads. If prebunching is selected, logs in the woods are bunched together before prehauling or skidding. This makes it easier for the transporting equipment to acquire a load in the woods. In the skidding operation, logs are transported from the woods or prehaul dock to the landing. The skidding operation causes soil disturbance depending on the type of skidding employed. This disturbance is represented in the macro-model by an increase in the state variable, area of closed roads.

With the logs skidded to the landing, there are four possible next activities. The logs, if they have not been bucked already, can be bucked at the landing. They are then decked or loaded directly. The decking activity is merely a piling operation where logs are stacked in piles or decks before loading. Another choice, chipping, is also provided by the

model. At this point, the logs are loaded and then transported or hauled to the mill.

Throughout this stepping operation, various information about the working of the system is recorded. For each machine in the logging system, statistics are recorded on the following:

1. Total time in the system.
2. Time spent on each of its assigned activities.
3. Time spent moving between setups.
4. Time delayed because of waiting on other machines.
5. Time delayed because of waiting for logs to process.
6. Time delayed because of breakdown, maintenance or personal delays.
7. Total volume of timber handled.
8. Total number of pieces handled.
9. Production rate in cubic feet per hour.
10. Production costs in dollars per hour and dollars per cubic foot.

In addition to this, costs and production averages for each of the nine possible harvesting tasks are recorded.

This detailed picture of harvesting system operations gives the designer a valuable tool in analyzing the system layout. He is able to design the harvesting system for "peak" efficiency and productivity.

Fire Subsystem

The fire subsystem depicts discrete changes in continuous state variables at a scheduled point in time. When a fire occurs, it will impact directly 11 continuous state variables.. These impacts are depicted in the fire subsystem flow diagram, Figure 17. These level changes are assumed to be instantaneous at the time fire occurs. The magnitude of these changes are calculated from inputs provided by the user.

As a fire burns in the ecosystem, it directly impacts four of the macro model subsystems defined earlier: area, timber, forage, and wildlife. These impacts change specific state levels within each subsystem. These changes in turn cause secondary effects within the ecosystem model. The primary or immediate changes in each subsystem are explained below.

When a fire burns through an area, it converts biomass productive area to unproductive burned area. For simplicity, the model assumes that the ratio of range to forest area burned is equal to the ratio of range to forest levels in the macro model at the time of fire occurrence. The biomass productive area is also converted to closed road area if suppression roads are constructed.

The levels of number of growing stems, number of standing dead stems, and timber fuel load are reduced when fire burns through the

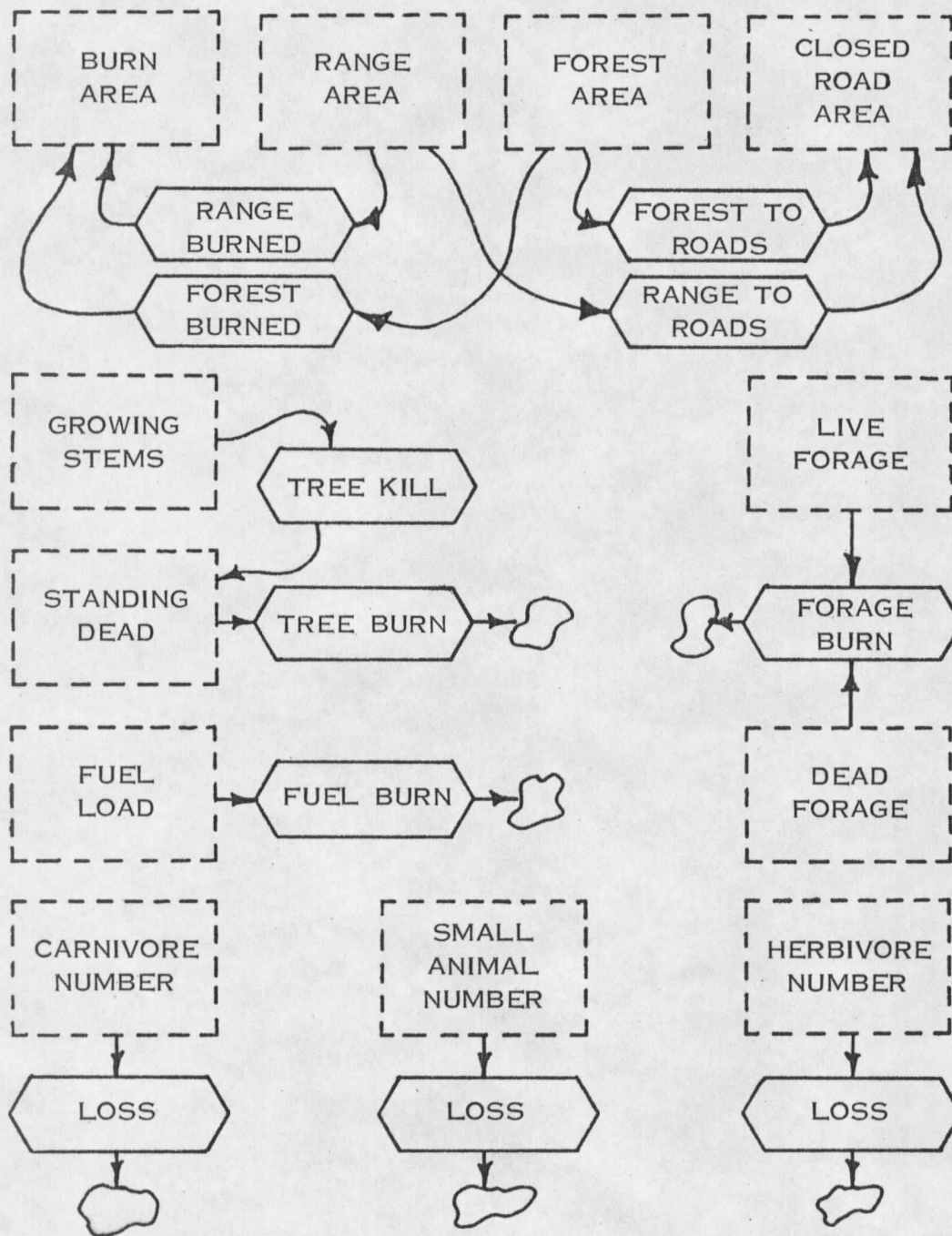


Figure 17. Fire Subsystem Flow Diagram

forest. In addition to these level reductions, the number of standing dead stems is increased by live tree kill.

In the forage subsystem, both live and dead forage loads are reduced by fire. These loads are reduced assuming that all forage is removed from burned area be it range land or forest land.

The impact of fire on the wildlife subsystem of the macro model is to reduce the number of animals in the system. Animals are either killed or driven out of the modeled area by fire and suppression activities. The number of animals lost is dependent upon the size of the area, the size of the fire, and whether the fire was suppressed or not.

Road Building and Closing Subsystem

The road building subsystem causes a discrete change in the flow rate for a continuous state variable. When a prescribed magnitude is reached by the state variable the rate returns to its former value. In this case, the rate is road construction as defined in the area subsystem of the macro model. This rate is set at the indicated level when construction activities begin. From this point the level of open roads is monitored until it reaches a preset level, indicating all roads have been constructed. At this point in time, the rate of roadway construction is reset to zero, its initial value.

A second portion of this subsystem allows the user to schedule the closing of roads. When the scheduled time arrives in the simulation,

the level of open roads is decreased and the level of closed roads is increased by the given amount. Figure 18 is the flow diagram for this subsystem.

Though this is a simplistic representation of road construction, it does illustrate modeling options available. The user can gain much information about the ecosystem with unsophisticated impact models. Only two state variables and one flow rate are affected by this subsystem, yet when linked to the macro model, the ecosystem's response can be monitored.

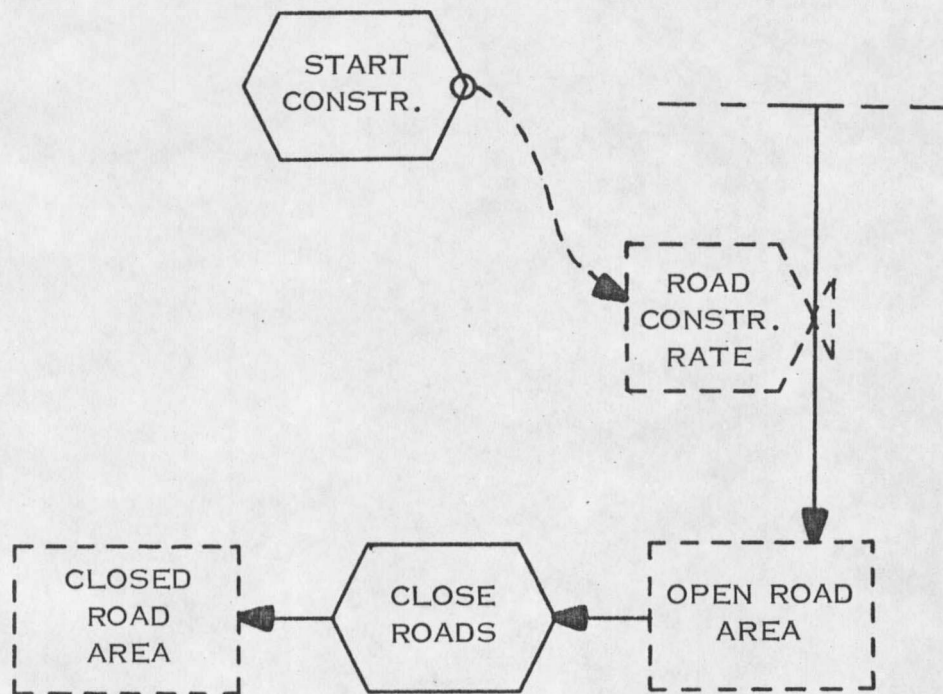


Figure 18. Road Building and Closing Subsystem Flow Diagram

Chapter 6

SIMULATION RESULTS

To help the land manager evaluate the environmental impacts of an activity, an ecosystem response model has been developed. This model, using a two-phase approach, simulates the dynamic responses of the ecosystem to the specific impacts of an activity. The ecosystem is modeled as the macro-phase. In this phase, generalized cause-effect relationships are quantified and state variables change in a continuous fashion. The impacting activity is modeled by the micro-phase. The activity can be modeled in considerable detail as done in the harvesting model or very generally as represented by the road building and fire models. In either case, the impacts occur at specific points in time and are modeled in a discrete fashion.

This two-phased modeling approach with the variations presented is demonstrated here by two simulation runs. The first is a base run simulating the ecosystem with no outside activity impacts. This is the macro-phase of the model. The second run combines the impacts of road building, harvesting, and fire with the ecosystem model. This run combines the two phases, modeling the impacts of the activities on the ecosystem over an extended time period.

Ecosystem Base Run

The first example is a simulation run of the ecosystem with no outside impacts. For the sake of illustration, the model is run for

a 10,000 acre drainage. Sixty percent of this area is assumed to be in timber. The remaining area is open with approximately 3,000 acres supporting grass or forage production. Close to 1,000 acres is unproductive land in the form of rock outcroppings, washes and stream beds. There is a short spur road in the area which accounts for ten acres.

The model was run to simulate 100 years. Figure 19 shows the ecosystem summary plot provided by the model. This output might be thought of as a series of snapshots taken of the ecosystem at successive points in time. For the first 30 years, the ecosystem is plotted once a year in June. In the year 2000, the time axis shifts from yearly increments to monthly increments. By this shift, the investigator is able to view the seasonal trends occurring in the system. After two years, the plotting frequency returns to a yearly basis.

In the ecosystem summary plot, six state variables are monitored: 1) area of open roads, 2) volume of stored water, 3) volume of timber, 4) live and dead forage load, 5) total number of animals in the system, and 6) the accumulated volume of erosion. In addition to the summary plot, the model produces four other plots providing more detail on each of the macro-phase subsystems. These plots are provided in Appendix D.

In the base run, the area of roads remains constant. It is assumed that these roads are used but that there is no road construction or road closures during the simulation.

PLOT NUMBER 5
ECOSYSTEM SUMMARY

SCALES OF PLOT

1000E+02	1000E+02	1000E+02	1000E+02	1000E+02
8328E+05	5522E+05	5522E+05	5522E+05	5522E+05
6038E+08	4025E+08	4025E+08	4025E+08	4025E+08
9194E+05	7325E+05	7325E+05	7325E+05	7325E+05
1405E+05	1179E+05	1179E+05	1179E+05	1179E+05
3170E+04	2377E+04	2377E+04	2377E+04	2377E+04

TIME 0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100 DUPLICATES
M YR
W+.....

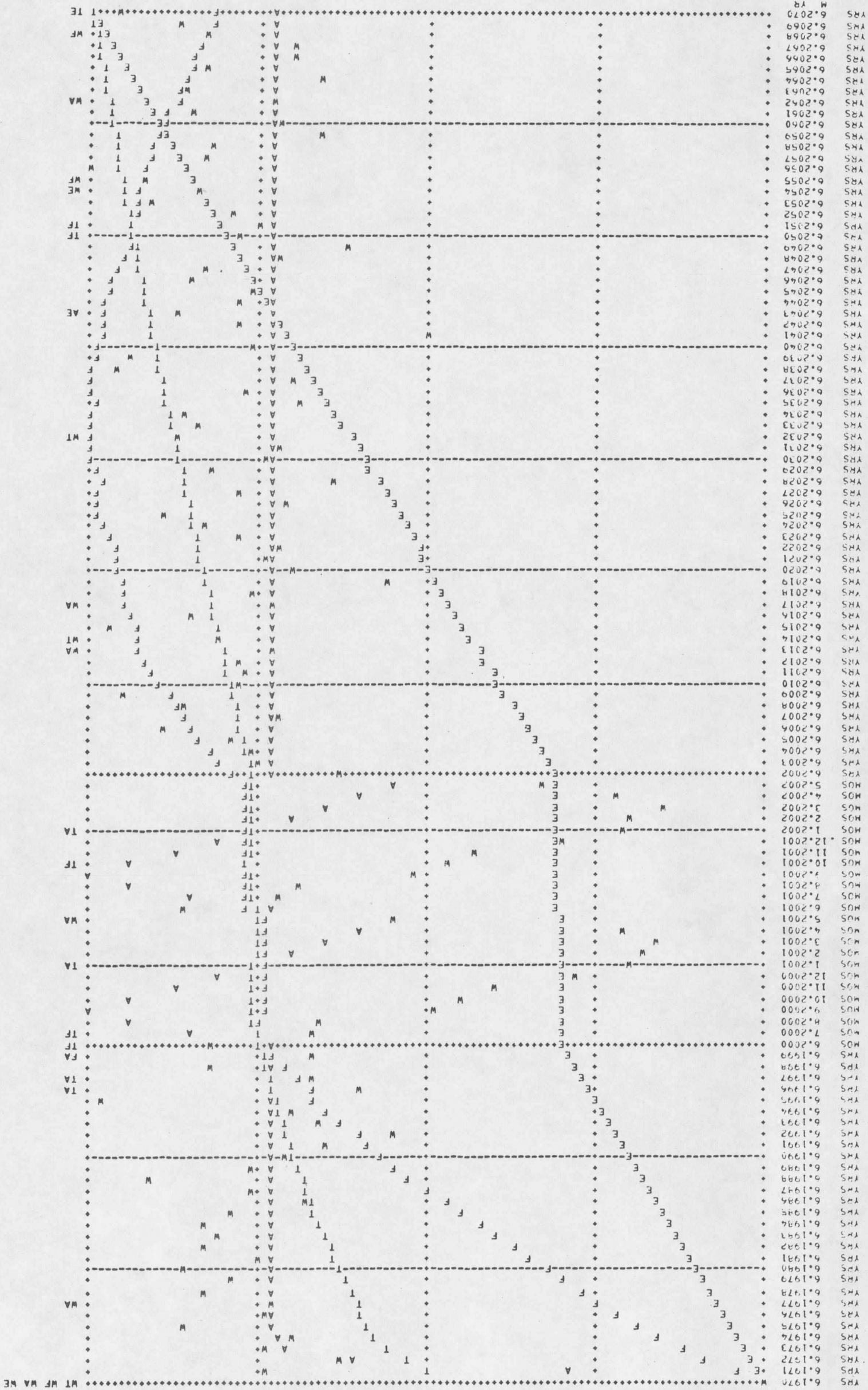


Figure 19. Ecosystem Summary Plot for Base Stimulation Run

The volume of stored water fluxuates from year to year. This fluxuation reflects the yearly variations in amount and timing of moisture received by the area. The model also portrays a strong seasonal trend in stored water. Volume is highest in June and July with spring runoff and lowest in February and March when stored in the form of snow with little moisture available to the system.

Timber volume rises sharply at the beginning of the simulation run as initial conditions balance themselves. After this initial rise, timber volume continues to increase, but at a slower and slower rate. This increase is due to the natural growth of timber and the encroachment of the stand into the range area.

The total forage load increases steadily until the year 2030. At this point, it levels off and finally begins to decline. This decline is caused primarily by the advancement of timber into the forage production area and the decrease in forage production under growing trees.

The number of animals in the area remains fairly constant throughout the model run. However, a strong seasonal trend is shown when system status is plotted monthly. The trend is to increase in the spring and summer and decrease during the fall and winter.

The last variable shown in the ecosystem summary plot is the accumulated volume of erosion. This is shown to increase steadily over the simulated period. This increase indicates that the rate of erosion

is fairly constant throughout the simulated time period.

Combined Impacts

The second run simulates the combined impacts of road construction, harvesting, and fire on the ecosystem model. The simulation begins in the macro-phase. After 20 years, road construction begins. Ten years later, harvesting begins, at which point the model shifts into the micro-phase for detailed analysis. At harvest completion, the macro-phase takes over and the model is run to completion. In 2020, 75 percent of all open roads in the area are closed. Finally, a fire occurs in 2030 which burns 2000 acres.

The ecosystem summary plot for this combined simulation is presented in Figure 20. Additional subsystem plots are provided in Appendix D. The output from this run is identical to the base run until 1990 when the ecosystem is subjected to its first impact.

The first impact is imposed on the ecosystem in late 1990. Ten miles of roads are constructed. This road construction represents a discrete change in the rate at which a state variable is increased or decreased. This change occurs when road construction begins. The rate of construction effects the levels of range area, forest area and roaded area. Road construction rate returns to zero when the level of roads reaches a predetermined value (i.e. all roads have been constructed). The system is allowed to respond over time to the changes.

##PLOT NUMBER 5##
ECOSYSTEM SUMMARY

```
R=ROADS .5993E+01
W=WATER 0
T=TIMBER VOL 0
F=FORAGE LD. .1718E+05
A=ANIMALS .2449E+02
E=EROSION 0
```

.1049E+02
 .2816E+05
 .1729E+08
 .4145E+05
 .3480E+04
 .1206E+04

SCALES OF PLOT

- 149HE+02
- 5632E+05
- 3458E+08
- 6572E+05
- 6935E+04
- 2412E+04

.1948E+02
 .8447E+05
 .5186E+08
 .9000E+05
 .1039E+05
 .3618E+04

.2397E+02
 .1126E+06
 .6915E+08
 .1143E+06
 .1384E+05
 .4824E+04

[illegible]

This road construction increases the area of roads in the system. It also decreases slightly the total number of animals. This is caused by the assumption that increased access will increase usage of the area. Increased usage disturbs animals causing them to migrate out of the area. Erosion is increased slightly by the new roads. No other major impacts are apparent following road construction. This is probably due to the relatively large size of the area being modeled.

The harvesting impact begins in July of the year 2000. It continues until 4000 trees are removed. The harvesting system presented consists of: two men with chainsaws for felling; one rubber tired skidder for moving logs from the woods to the landing; one heelboom loader with tongs and setter for loading logs; and three hauling trucks with standard pole trailers for transporting logs to the mill. The system is assumed to be a tree length operation with no bucking in the woods.

The harvesting subsystem combines the micro and macro simulation phases of the models. The harvesting or micro-phase is simulated in minute detail in determining system productivity. This activity produces change in the state variables of the macro-phase. The ecosystem is monitored to determine how it responds to the changes imposed by the harvesting activity.

To harvest the 4000 trees with this configuration, the micro model ran for 13 weeks. Production and cost summaries for each component of

the harvesting subsystem are presented in Table 1. The complete output for this subsystem is presented in Appendix D. Upon completion of harvesting, the model shifts back into the macro-phase to simulate the ecosystems response to the activity.

Harvesting reduces the volume of timber available in the system. It also increases the rate of erosion slightly. The area of closed roads is increased because the harvesting layout uses rubber tired skidders which require skid trails to transport logs from the woods to the ecosystem. This is due primarily to the size of the area being modeled. The area harvested is much smaller than the total.

After harvesting, 75 percent of all open roads are closed. This occurs in the year 2020, 20 years after harvest. Closing roads merely changes the status of the area involved from open to closed road. The closed road area is then allowed to return to a natural state of biomass production. The rate of erosion is decreased slightly by this action.

Finally, in August of 2030, the ecosystem is subjected to a fire impact. The fire burns 2000 acres of timber and range land. Ten acres of ground are disturbed in the construction of suppression roads.

The fire impact represents the capability to impose on the macro model change in selected state levels at a discrete point in time. There is no fire modeling done. All level changes are calculated from

Table 1. Harvesting Subsystem Production and Cost Summaries

ACTIVITY	VOLUME PROCESSED (1000 cu ft)	TOTAL TIME (hr)	PRODUCTION (cu ft / hr)	COST (\$ / cu ft)
Felling #1	132	533.8	247.4	.0316
Felling #2	134	540.7	249.1	.0315
Skidding	266	524.3	508.1	.0193
Loading	266	515.8	516.5	.0216
Hauling #1	97	422.9	230.3	.0581
Hauling #2	96	477.4	200.3	.0672
Hauling #3	73	522.6	140.5	.0962
TOTALS	266			.3255

inputs provided by the user. These changes are imposed upon the continuous state variables at a predetermined point in time. The ecosystem model is then allowed to respond to these changes.

Fire causes a reduction in the levels of timber, forage, and wildlife. Erosion increases rapidly following the fire, but then gradually returns to its prefire rate of increase. As the burned area returns to range, the number of animals in the system increases to its former level. Total timber volume increases at a much slower rate than forage.

Of all the impacts presented, fire is the most significant. It directly affects the largest area, 2000 acres. If more roads were constructed or a larger area harvested, the impacts of these activities would be more severe.

Chapter 7

SUMMARY AND RECOMMENDATIONS

The public land manager is directed by law to manage the land on a "multiple use" and "sustained yield" basis. This directive becomes more difficult to implement as land use pressures increase. The manager is also directed to assess the environmental impacts of proposed activities. Both the short term immediate impacts and the long range time dependent impacts must be analyzed. This can be difficult to accomplish as the system being impacted is a complex maze of interacting cause-effect relationships.

Using computer technology and systems simulation, an approach has been presented to aid the manager analyze the environmental effects of a proposed activity. The approach combines the continuous and discrete simulation techniques in a two-phased simulation model. The continuous phase simulates the ecosystem response in the macro scale, while the discrete phase models the activity and it's impacts in the micro scale..

The macro or ecosystem model is developed from generalized flow relationships. The author stresses that these relationships are based on limited experience and often gross assumptions.. It should be kept in mind that the process of developing a systems dynamics model is cyclical. This work provides a basis from which to build. The ecosystem has been divided into six subsystems which allow for study along disciplinary lines. An interdisciplinary team could be formed to evaluate and

improve the relationships defined in each subsystem. The activity can be modeled in considerable detail as done by the harvesting model. This gives the planner the ability to design the activity for peak efficiency and productivity. At the same time, he is able to monitor the ecosystem responses to the activity.

To gain insight into the response of the ecosystem, the simple impact model is useful. The impact need not be modeled in the detail provided by the harvesting model. The fire and road building models illustrate this.

The land use planner and activity designer must broaden their perspective in evaluating management activities. Their analysis must include the components of the larger system over longer time periods. This systems model helps them do just that.

LITERATURE CITED

LITERATURE CITED

1. Barney, Richard J., Land Use Planning - Fire Management, Relationships and Needs in the U.S. Forest Service. Unpublished Ph.D. dissertation, Michigan State University. 1976. 244 p.
2. Biller, Cleveland J. and Leonard R. Johnson. Comparing Logging Systems Through Simulation. Winter Meeting ASAE, Chicago, Illinois. Dec. 1972. No. 72-654.
3. Bjerke, Ardine L. Systems Analysis of the Environmental Impacts of Recreation: The Dynamics of the Fishing Ecosystem. Master's thesis, Montana State University, Bozeman, Montana. 1973. 168 p.
4. Browne, William G. and Charles W. Dane. Analytical Methods and Computer Applications in USFS planning and Decision Making. School of Business and Technology, Oregon State University, Corvallis, Oregon. June 1974.
5. Churchman, C. West. The Systems Approach. New York; Dell Publishing Company, Inc. 1968.
6. Emshoff, James R. and Rodger L. Sisson. Design and Use of Computer Simulation Models. The MacMillan Company, Collier-MacMillan Limited, London. 1970.
7. Forrester, Jay W. Industrial Dynamics. Massachusetts; The M.I.T. Press. Massachusetts Institute of Technology. 1961.
8. _____. Principles of Systems. Massachusetts; Wright-Allen Press, Inc. 1968.
9. Johnson, Leonard R. Simulation of the Loading and Hauling Subsystems of a Logging System. Master's thesis, Montana State University, Bozeman, Montana. 1970. 350 pp.
10. _____, D.L. Gochenour, Jr., and C.J. Biller. Simulation Analysis of Timber Harvesting Systems. 23rd Ann. Conf. AIIE Tech. Pap. Anaheim, California. 1972. 353-361 p.
11. Leopold, Aldo. The National Forest Service and the Forest and Rangeland Renewable Resources Planning Act. Natural Resources Journal, Vol. 15, July 1975. 603-628 p.
12. Pritsker, A.A.B. and P.J. Kiviat. Simulation With GASP II, Englewood Cliffs, New Jersey; Prentice-Hall, Inc. 1969.

13. _____, Nicholas R. Hurst. GASP IV: A Combined Continuous-Discrete For ran-Based Simulation Language. Simulation, Vol. 21, September 1973. 65-70 p.
14. _____. The GASP IV Simulation Language. John Wiley & Sons, New York. 1974.
15. Ridd, Merrill K. Area-Oriented Multiple Use Analysis. U.S. Forest Service Research Paper INT-21, Intermountain Forest and Range Experiment Station, USDA, Ogden, Utah. 1965.
16. Sigal, C.E. Designing a Production System with Environmental Considerations. Proceedings of the AIIE Tall Institute Conference, New York. 1973. 31-39 p.
17. U.S. Department of Agriculture Forest Service Manual. 2102, Amendment No. 10. January 1963.
18. Watt, Kenneth E.F., ed. Systems Analysis in Ecology. Academic Press, Inc. New York. 1966.

APPENDICES

APPENDIX A

Flow Charting Symbols

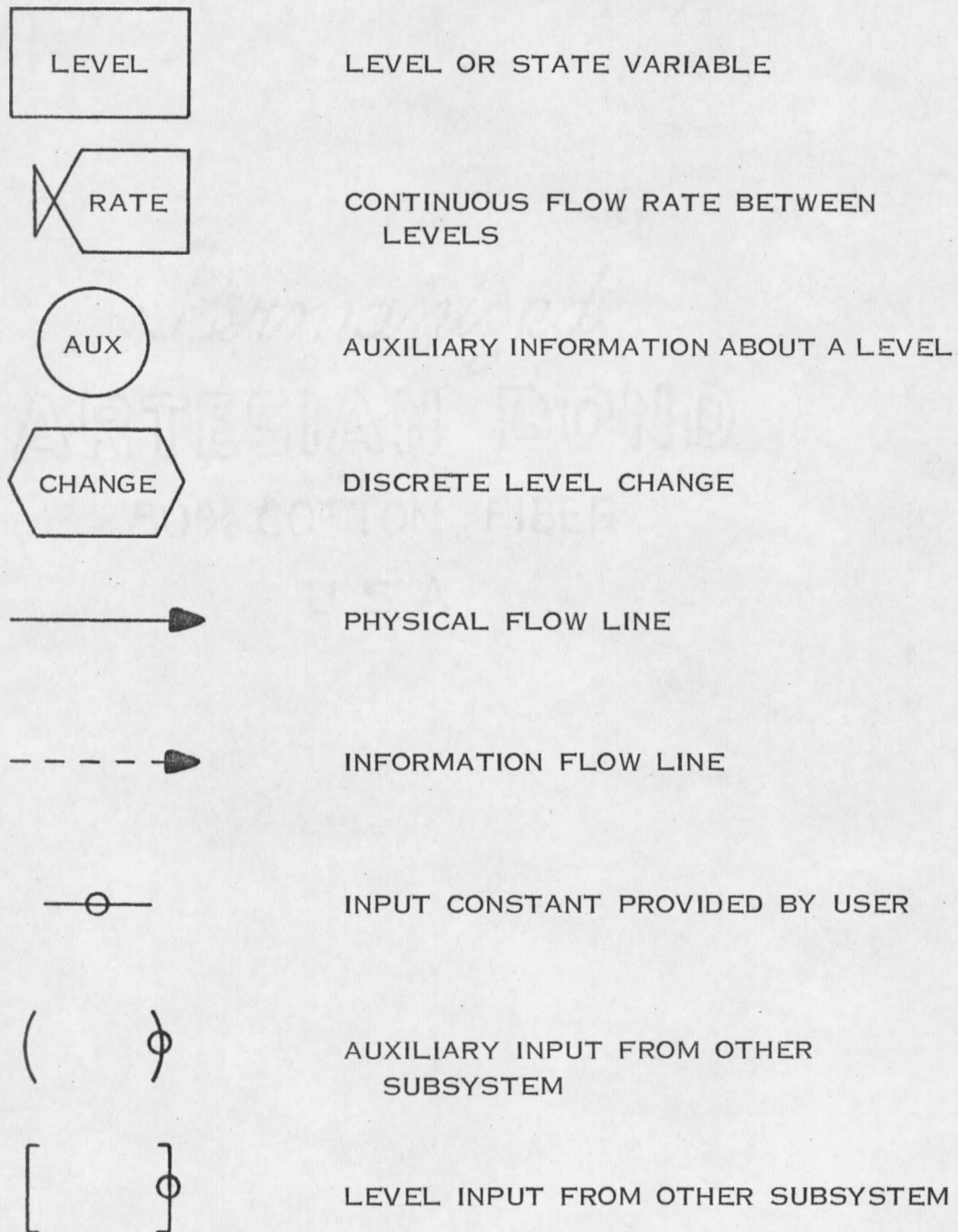


Figure 21. Flowcharting Symbols Defined

APPENDIX B

Ecosystem Model

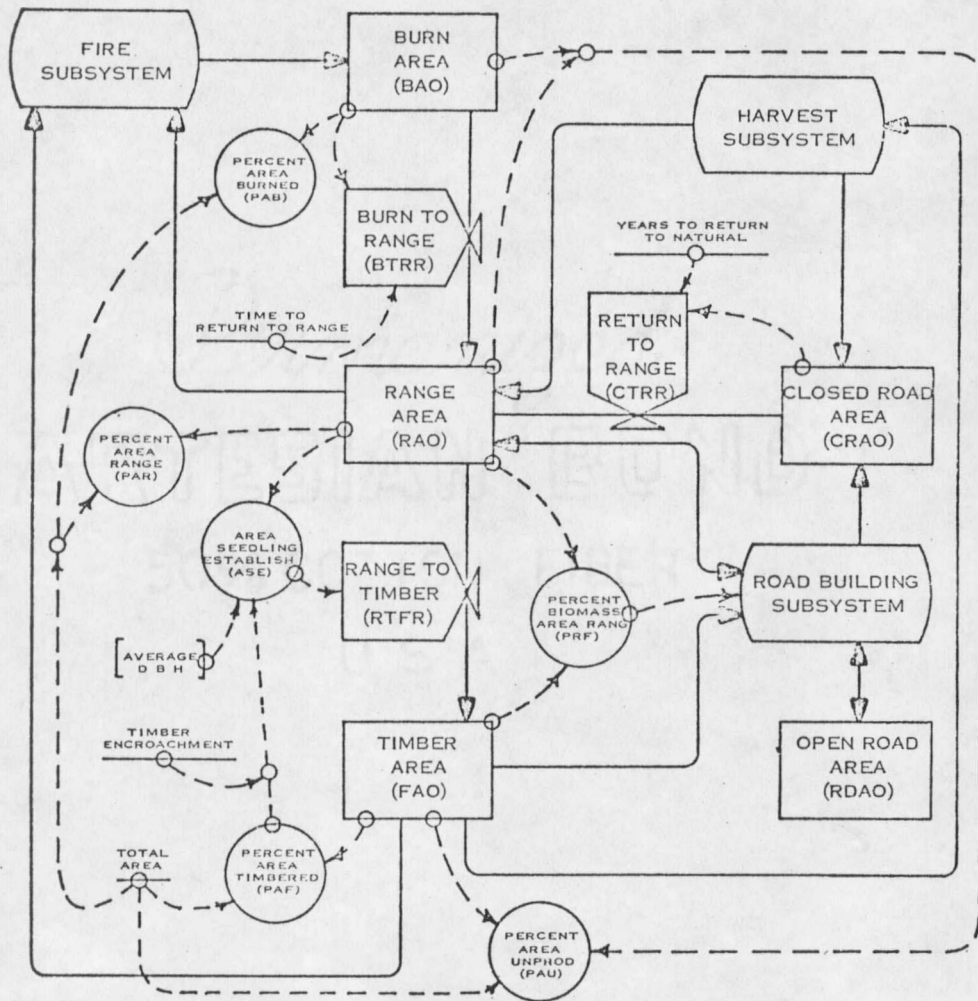


Figure 22. Systems Diagram of Area Subsystem

Table 2. Area Subsystem Equations^aAuxiliary Equations

$$\begin{aligned}
 PAB &= BAO/TA \\
 PAR &= RAO/TA \\
 PAF &= FAO/TA \\
 PAU &= 1.0 - (BAO + RAO + FAO)/TA \\
 AER &= AHT * APHE \\
 TBPA &= FAO + RAO \\
 PRF &= RAO/TBPA
 \end{aligned}$$

During the growing season

$$\begin{aligned}
 ASE &= PAF * PI * (AER / GRMO) * (2.0 * SQRT(RAO * ACRE / PI) \\
 &\quad - AER * AER / GRMO) / ACRE * DTNOW
 \end{aligned}$$

otherwise

$$ASE = 0.0$$

Rate Equations

$$\begin{aligned}
 RTFR &= ASE / DTNOW \\
 RTRR &= PRF * RCR \\
 FTRR &= PRF * RCR
 \end{aligned}$$

During the growing season

$$\begin{aligned}
 BTRR &= BAO / (TTR * GRMO) \\
 CTRR &= CRAO / (YRN * GRMO)
 \end{aligned}$$

otherwise

$$\begin{aligned}
 BTRR &= 0.0 \\
 CTRR &= 0.0
 \end{aligned}$$

Table 2. (continued)

State Equations

$$SS(1) = BAO - BTRR * DTNOW$$

$$SS(2) = RAO + (BTRR - RTFR - RTRR + CTRR) * DTNOW$$

$$SS(3) = FAO + (RTFR - FTRR) * DTNOW$$

$$SS(4) = RDAO + (RTRR + FTRR) * DTNOW$$

$$SS(5) = CRAO - CTRR * DTNOW$$

^a Variables are defined in Appendix C.

Figure 23. Systems Diagram of Moisture-Water Subsystem

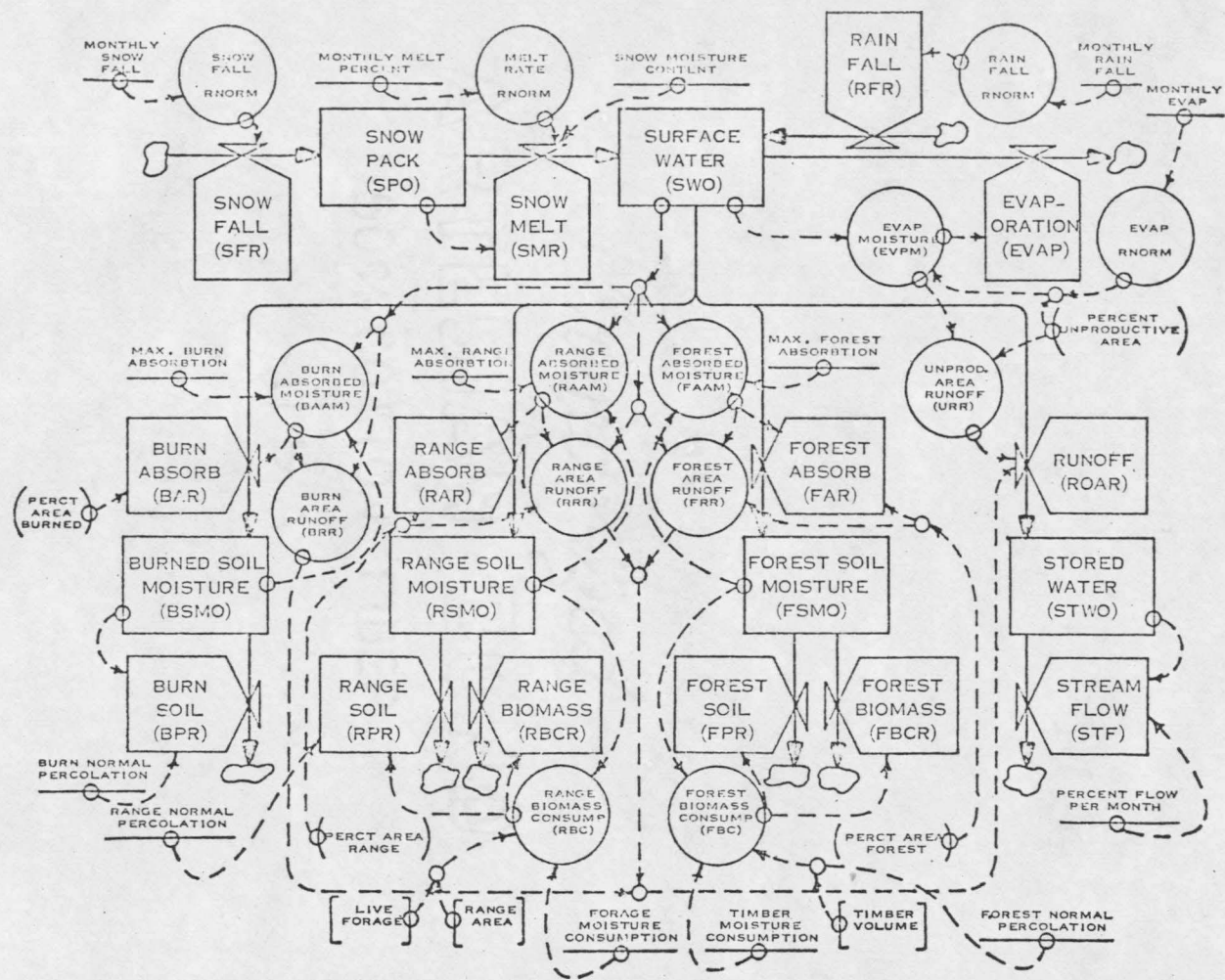


Table 3. Moisture - Water Subsystem Equations^aAuxiliary Equations

BAAM = AMAX1(0.0, AMIN1(BSMX, SWO) - BSMO)
 RAAM = AMAX1(0.0, AMIN1(RSMX, SWO) - RSMO)
 FAAM = AMAX1(0.0, AMIN1(FSMX, SWO) - FSMO)
 EVAP = RNORM(17, 3)
 EVPM = AMAX1(0.0, AMIN1(EVAP*DTNOW, SWO))
 EARF = AMAX1(0.0, FAO-GSO*PI/ACRE*((AHT*0.1)**2.0))
 EXP(-0.5(AFLO/FAO)**2.0)
 PFFA = EARF/(EARF+RAO)
 RBC = AMIN1(RSMO, (XLFO*(1.0-PFFA)*FMCR/RAO)*DTNOW)
 TTV = VPT*GSO
 FBC = AMIN1(FSMO, TMCN*TTV*DTNOW+PFFA*XLFO*FMCR)

Rate Equations

SFR = RNORM(14, 4)
 SMR = RNORM(15, 5)*SPO
 RFR = RNORM(16, 6)
 SMWR = SMR*SMC
 BAR = BAAM/DTNOW
 BRR = (SWO-BAAM)/DTNOW
 RAR = RAAM/DTNOW
 RRR = (SWO-RAAM)/DTNOW
 FAR = FAAM/DTNOW
 FRR = (SWO-FAAM)/DTNOW
 EVR = EVPM*PAU/DTNOW
 URR = (SWO-EVPM)/DTNOW
 ROR = BRR*PAB+RRR*PAR+FRR*PAF+URR*PAU
 SAR = BAR*PAB+RAR*PAR+FAR*PAF
 BPR = AMIN(BNPR, BSMO/DTNOW)
 RBCR = RBC/DTNOW
 RPR = AMIN(RNPR, (RSMO-RBC)/DTNOW)
 FBCR = FBC/DTNOW
 FPR = AMIN(FNPR, (FSMO-FBC)/DTNOW)
 ROAR = ROR*TA
 STF = STWO*PFPM

Table 3. (continued)

State Equations

$$SS(6) = SPO + (SFR - SMR) * DTNOW$$

$$SS(7) = SWO + (SMWR + RFR - SAR - EVR - ROR) * DTNOW$$

$$SS(8) = BSMO + (BAR - BPR) * DTNOW$$

$$SS(9) = RSMO + (RAR - RBC - RPR) * DTNOW$$

$$SS(10) = FSMO + (FAR - FBCR - FPR) * DTNOW$$

$$SS(11) = STWO + (ROAR - STF) * DTNOW$$

^aVariables are defined in Appendix C.

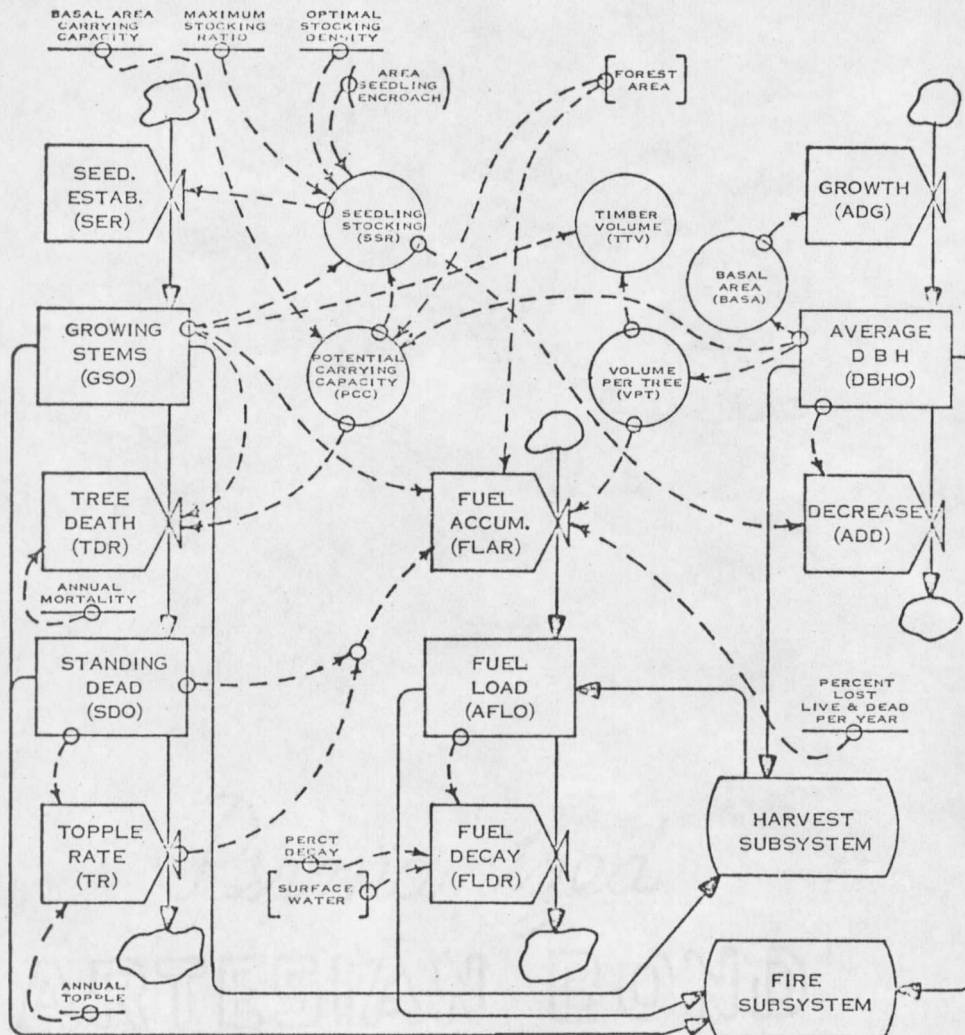


Figure 24. Systems Diagram of Timber Subsystem

Table 4. Timber Subsystem Equations^aAUXILIARY EQUATIONS

$$\begin{aligned} \text{BASA} &= \text{PI} * \text{DBHO} * \text{DBHO} / 4.0 \\ \text{PCC} &= \text{BACC} * 144.0 * \text{FAO} / \text{BASA} \end{aligned}$$

During the growing season

$$\text{SSR} = \text{OSSD} * \text{ASE} / \text{GSO} + \text{AMIN1}(\text{XSSR} / \text{GRMO}, \text{AMAX1}(0.0, ((\text{PCC} - \text{GSO}) / (\text{GRMO} * 5.0) / \text{GSO})) * \text{DTNOW})$$

otherwise

$$\text{SSR} = 0.0$$

Rate Equations

$$\begin{aligned} \text{SER} &= \text{SSR} * \text{GSO} / \text{DTNOW} \\ \text{TDR} &= \text{AMRT} / \text{XMPY} * \text{GSO} + \text{AMAX1}(0.0, (\text{GSO} - \text{PCC}) / 2.0) \\ \text{TR} &= \text{SDO} * \text{ATPL} / \text{XMPY} \\ \text{ADD} &= (\text{DBHO} - (\text{DBHO} + \text{SSR}) / (1.0 + \text{SSR})) / \text{DTNOW} \\ \text{FTR} &= \text{FLTR} / \text{FAO} * \text{AFLO} \end{aligned}$$

During the growing season

$$\begin{aligned} \text{ADG} &= \text{SQRT}((\text{BASA} + \text{DBA} / \text{GRMO}) / \text{PI}) * 2.0 - \text{DBHO} \\ \text{FLDR} &= \text{AFLO} * \text{PDPY} * \text{SWO} / \text{GRMO} \\ \text{FLAR} &= \text{SDO} * \text{PVDL} / \text{XMPY} * \text{VPT} * \text{WPCF} + \text{TR} * \text{VPT} \end{aligned}$$

otherwise

$$\begin{aligned} \text{ADG} &= 0.0 \\ \text{FLDR} &= 0.0 \\ \text{FLAR} &= (\text{GSO} * \text{PVLL} / (\text{XMPY} - \text{GRMO}) + \text{SDO} * \text{PUDL} / \text{XMPY}) * \text{VPT} * \text{WPCF} + \text{TR} * \text{VPT} \end{aligned}$$

State Equations

$$\begin{aligned} \text{SS}(12) &= \text{GSO} + (\text{SER} - \text{TDR}) * \text{DTNOW} \\ \text{SS}(13) &= \text{SDO} + (\text{TDR} - \text{TR}) * \text{DTNOW} \\ \text{SS}(14) &= \text{DBHO} + (\text{ADG} - \text{ADD}) * \text{DTNOW} \\ \text{SS}(15) &= \text{AFLO} + (\text{FLAR} - \text{FLDR} - \text{FTR}) * \text{DTNOW} \end{aligned}$$

^a Variables are defined in Appendix C.

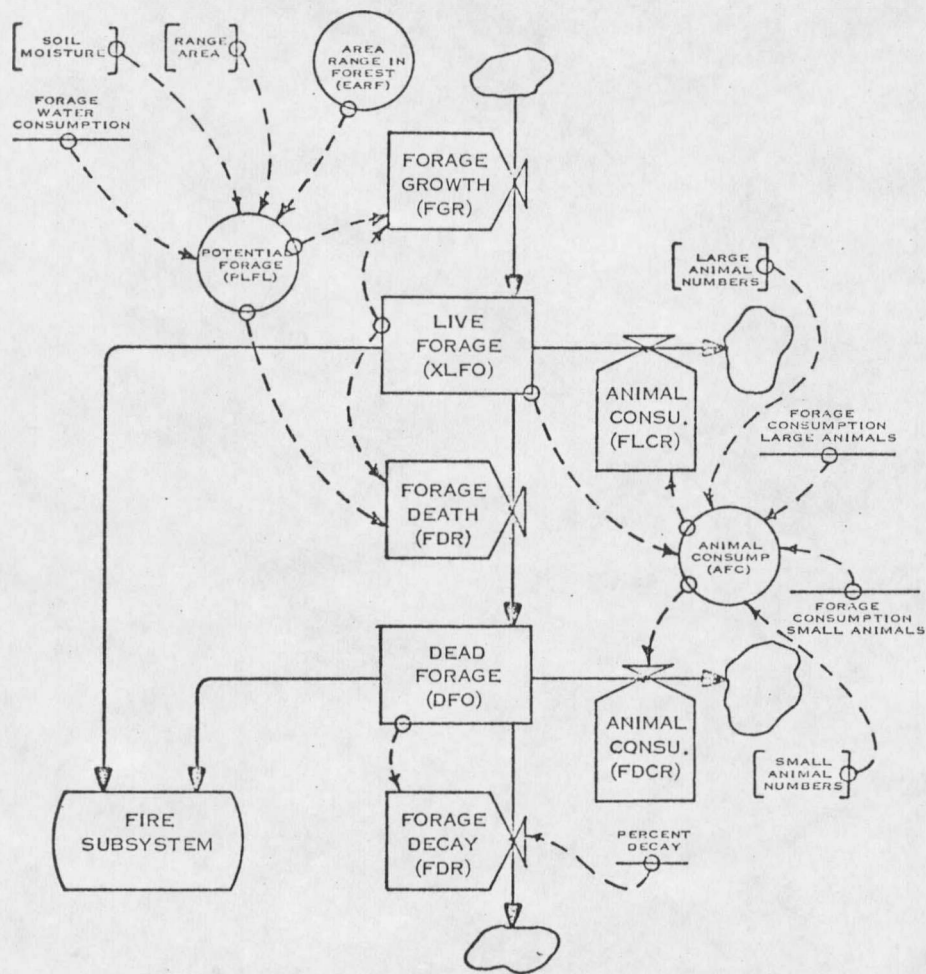


Figure 25. Systems Diagram of Forage Subsystem

Table 5. Forage Subsystem Equations^aAuxiliary Equations

$$AFC = FCLM * HANO + FCSM * SANO$$

During the growing season

$$PLFL = (RSMO * RAO / FMCR + EARF * FSMO / FMCR) * DTNOW$$

otherwise

$$PLFL = 0.0$$

Rate Equations

$$FDR = \text{AMAX1}(0.0, (XLFO - PLFL) / DTNOW)$$

$$FLCR = \text{AMIN1}(AFC, XLFO / DTNOW - FDR)$$

$$FDCR = \text{AMIN1}((AFC - FLCR), DFO / DTNOW)$$

During the growing season

$$FGR = \text{AMAX1}(0.0, (PLFL - XLFO) / (TFRP * GRMO))$$

$$XNDR = (DFO - FDCR * DTNOW) * PFDY * SWO / GRMO$$

otherwise

$$FGR = 0.0$$

$$XNDR = 0.0$$

State Equations

$$SS(16) = XLFO + (FGR - FDR - FLCR) * DTNOW$$

$$SS(17) = DFO + (FDR - FDCR - XNDR) * DTNOW$$

^aVariables are defined in Appendix C.

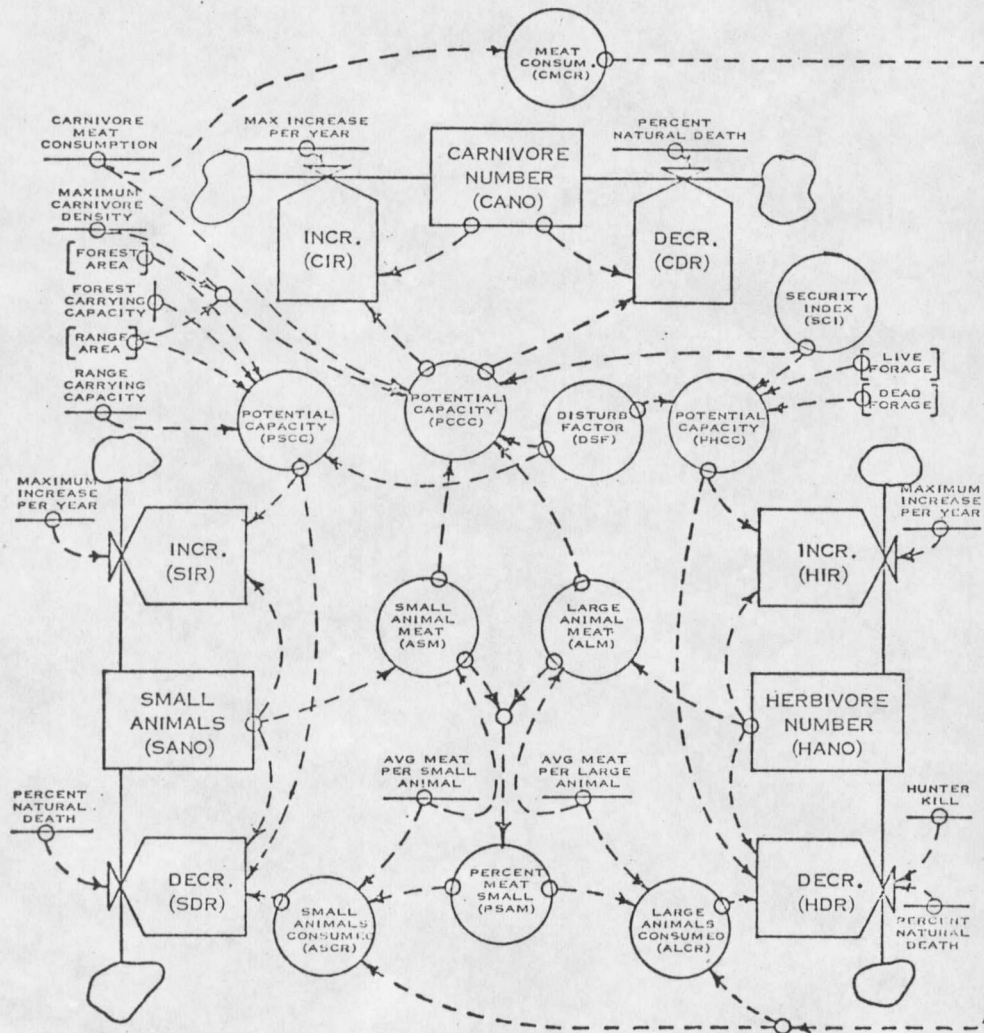


Figure 26. Systems Diagram of Wildlife Subsystem

Table 6. Wildlife Subsystem Equations^aAuxiliary Equations

$ASM = SANO * AMPS$
 $ALM = HANO * AMPL$
 $PSAM = ASM / (ASM + ALM)$
 $TFA = XLFO + DFO$
 $SCI = 1.0 - (1.0 - PAF) ** 2.0$
 $PSCC = AMIN1(TBPA / SDM, (TFA / 2.0 - HANO * FCLM * DTNOW) / (FCSM * DTNOW)) * DSF$
 $PCCC = AMIN1(TBPA / CDM, (ASM + ALM) * 0.5 / (CMC * DTNOW)) * DSF * SCI$
 $PHCC = AMIN1(TBPA / HDM, (TFA / 2.0 - SANO * FCSM * DTNOW) / (FCLM * DTNOW)) * DSF * SCI$
 $CMCR = CMC * CANO$
 $ASCR = CMCR * PSAM / AMPS$
 $ALCR = CMCR * (1.0 - PSAM) / AMPL$
 $DSF = (1.0 - RDAO / (RDAO + FAO))$

With any outside activity

$$DSF = DSF * (1.0 - \exp(-0.5 * (FAO / 2400.0) ** 2.0))$$

Rate Equations

$CIR = AMAX1(PCCC * 0.001, AMIN1(CANO * PCIR, PCCC - CANO) / XMPY)$
 $CDR = CANO * PCDR / XMPY + AMAX1(0.0, (CANO - PCCC) / XMPY)$
 $SDR = AMAX1(0.0, (SANO - PSCC) / XMPY) + AMAX1(SANO * PSDR / XMPY, ASCR)$
 $HIR = AMAX1(PHCC * 0.01, AMIN1(HANO * PHIR, PHCC - HANO) * 0.15)$
 $HDR = AMAX1(0.0, (HANO - PHCC) / XMPY) + AMAX1(HANO * PHDR / XMPY, ALCR)$

During hunting season

$$HDR = HDR + (HANO - HDR * DTNOW) * PHHK / 2.0$$

During the growing season

$$SIR = AMAX1(PSCC * 0.001, AMIN1(SANO * PSIR, PSCC - SANO) / GRMO)$$

otherwise

$$SIR = 0.0$$

Table 6. (continued)

State Equations

$$SS(18) = CANO + (CIR - CDR) * DTNOW$$

$$SS(19) = SANO + (SIR - SDR) * DTNOW$$

$$SS(20) = HANO + (HIR - HDR) * DTNOW$$

^aVariables are defined in Appendix C.

Table 7. Erosion Subsystem Equations^a

Auxiliary Equations

$$\text{FAE} = \text{FRR} * \text{EFF} * \text{FAO}$$

$$\text{RAE} = \text{RRR} * \text{EFR} * \text{RAO}$$

$$\text{BAE} = \text{BRR} * \text{EFB} * \text{BAO}$$

$$\text{RDE} = \text{URR} * \text{EFRD} * (\text{RDAO} + \text{CRAO})$$

Rate Equations

$$\text{ERR} = \text{FAE} + \text{RAE} + \text{BAE} + \text{RDE} + \text{RCR}$$

State Equations

$$\text{SS}(21) = \text{SLO} + \text{ERR} * \text{DTNOW}$$

^a Variables are defined in Appendix C.

APPENDIX C

Model Variables Defined

Table 8. Area Subsystem Variables Defined

Variable	Description	Type
AER	Timber encroachment into range (ft/yr)	Aux.
APHE	Average timber encroachment into range (.% stem ht/yr)	Const.
ASE	Area of seedling establishment (acres)	Aux.
BAO	Burn area (acres)	State
BTRR	Burned to range rate (acres/mo)	Rate
CRAO	Closed road area (acres)	State
CTRR	Closed road to range rate (acres/mo)	Rate
FAO	Forest area (acres)	State
FTRR	Forest to road rate (acres/mo)	Rate
PAB	Percent area burned (.%)	Aux.
PAF	Percent area forest (.%)	Aux.
PAR	Percent area range (.%)	Aux.
PAU	Percent unproductive area (.%)	Aux.
PRF	Percent of biomass area range (.%)	Aux.
RAØ	Range area (acres)	State
RCR	Road construction rate (acre/mo)	Const.
RDAØ	Open road area (acres)	State
RTFR	Range to forest rate (acres/mo)	Rate

Table 8. (continued)

Variable	Description	Type
RTRR	Range to road rate (acres/mo)	Rate
TA	Total system area (acres)	Const.
TBPA	Total biomass productive area (acres)	Aux.
TTR	Time for burned area to return to range (yrs)	Const.
YRN	Time for closed roads to return to normal (yrs)	Const.

Table 9. Moisture - Water Subsystem Variables Defined.

Variable	Description	Type
BAAM	Burned area absorbed moisture (in)	Aux.
BAR	Burned area soil absorption rate (in/mo)	Rate
BNPR	Burned area normal percolation rate (in/mo)	Const.
BPR	Burned soil percolation rate (in/mo)	Rate
BRR	Burned area runoff rate (in/mo)	Rate
BSMO	Burned soil moisture (in)	State
BSMX	Burned area field capacity (in)	Const.
EARF	Effective area of range in forest (acres)	Aux.
EVAP	Evaporation rate (in/mo)	Aux.
EVPM	Evaporation moisture (in)	Aux.
EVR	Unproductive area evaporation rate (in/mo)	Rate
FAAM	Forest area absorbed moisture (in)	Aux.
FAR	Forest area soil absorption rate (in/mo)	Rate
FBCR	Forest biomass consumption rate (in/mo)	Rate
FBC	Forest biomass consumption (in)	Aux.
FMCR	Forage moisture consumption rate (in/ton/mo)	Const.
FNPR	Forest area normal percolation rate (in/mo)	Const.
FPR	Forest percolation rate (in/mo)	Rate

Table 9. (continued)

Variable	Description	Type
FRR	Forest area runoff rate (in/mo)	Rate
FSMO	Forest soil moisture (in)	State
FSMX	Forest area field capacity (in)	Const.
PFFA	Percent of forage in forest area (%)	Aux.
PFFM	Percent of stored water in streamflow (%/mo)	Const.
RAAM	Range area absorbed moisture (in/mo)	Aux.
RAR	Range area soil absorbtion rate (in/mo)	Rate
RBCR	Range biomass consumption rate (in/mo)	Rate
RBC	Range biomass moisture consumption (in)	Aux.
RFR	Rainfall rate (in/mo)	Rate
RNPR	Range area normal percolation rate (in/mo)	Const.
ROAR	Runoff rate (acre-in/mo)	Rate
ROR	Total runoff rate (in/mo)	Rate
RPR	Range percolation rate (in/mo)	Rate
RRR	Range area runoff rate (in/mo)	Rate
RSMO	Range soil moisture (in)	State
RSMX	Range area field capacity (in)	Const.
SAR	Soil absorbtion rate (in/mo)	Rate
SFR	Snowfall rate (in/mo)	Rate

Table 9. (continued)

Variable	Description	Type
SMC	Snow moisture content (in-water/in-snow)	Const.
SMR	Snow melt rate (in/mo)	Rate
SMWR	Snow melt rate (in-water/mo)	Rate
STF	Stream flow (acre-in/mo)	Rate
SPO	Snow pack (in)	State
STWO	Stored water (acre-in)	State
SWO	Surface water (in)	State
TMCR	Timber moisture consumption rate (in/cu-ft/mo)	Const.
TRFM	Mean rainfall by months (in/mo)	Const.
TRFN	Minimum rainfall by months (in/mo)	Const.
TRFX	Maximum rainfall by months (in/mo)	Const.
TRFS	Standard deviation of rainfall by month	Const.
TSFM	Mean snowfall by months (in/mo)	Const.
TSFN	Minimum snowfall by months (in/mo)	Const.
TSFX	Maximum snowfall by months (in/mo)	Const.
TSFS	Standard deviation of snowfall by month	Const.
TSM	Mean percent snowmelt by month (./mo)	Const.
TSMX	Maximum percent snowmelt by month (./mo)	Const.

Table 9. (continued)

Variable	Description	Type
TSMS	Standard deviation of percent snowmelt by month	Const.
TTV	Total timber volume (cu-ft)	Aux.
TUEM	Mean evaporation rate per month	Const.
URR	Unproductive area runoff rate (in/mo)	Rate

Table 10. Timber Subsystem Variables Defined

Variable	Description	Type
ADD	Average diameter decrease rate (in/mo)	Rate
ADG	Diameter growth rate (in/mo)	Rate
AFLO	Total timber fuel load (tons)	State
AHT	Average stem height (ft)	Aux.
AMRT	Percent annual timber mortality (./yr)	Const.
ATPL	Percent annual dead stem topple rate (./yr)	Const.
BACC	Basal area carrying capacity (sq ft/acre)	Const.
BASA	Average basal area (sq in/tree)	Aux.
DBHO	Average stand d.b.h. (in)	State
DBA	Average basal area growth increment (sq-in/yr)	Aux.
DMX	Maximum tree diameter (in)	Const.
FLAR	Fuel accumulation rate (ton/yr)	Rate
FLDR	Fuel decay rate (ton/yr)	Rate
FLTR	Acres of fuel treated per month (acres/mo)	Const.
FTR	Fuel treatment rate (ton/yr)	Rate
GSO	Number of growing stems (stems)	State
OSSD	Optimal stocking stand density (tree/acre)	Const.
PCC	Potential tree carrying capacity (stems)	Aux.

Table 10. (continued)

Variable	Description	Type
PDPY	Percent timber decay per in surface water per year (.%/yr)	Const.
PVDL	Percent volume of dead tree lost per year (.%/yr)	Const.
PVLL	Percent volume of live tree lost per year (.%/yr)	Const.
SER	Seedling establishment rate (stems/mo)	Rate
SDO	Number of standing dead stems (stems)	State
SSR	Seedling stocking ratio	Aux.
TDR	Tree death rate (stems/mo)	Rate
TR	Tree topple rate (stems/mo)	Rate
TTV	Total timber volume (cu-ft)	State
VPT	Average volume per tree (cu-ft)	Aux.
WPCF	Weight of wood (lb/cu-ft)	Const.
XSSR	Maximum seedling stocking ratio (seed trees/tree/yr)	Const.

Table 11. Forage Subsystem Variables Defined

Variable	Description	Type
AFC	Animal forage consumption (ton/mo)	Aux.
DFO	Dead forage (tons)	State
FCLM	Large animal forage consumption (lb/animal/mo)	Const.
FCSM	Small animal forage consumption (lb/animal/mo)	Const.
FDCR	Animal dead forage consumption rate (ton/mo)	Rate
FDR	Forage death rate (ton/mo)	Rate
FGR	Forage growth rate (ton/mo)	Rate
FLCR	Animal live forage consumption rate (ton/mo)	Rate
PFDY	Percent forage decay per in surface water per year (.%/yr)	Const.
PLFL	Potential live forage load (ton)	Aux.
TFRP	Time for forage load to reach potential (yr)	Const.
XLFO	Live forage load (tons)	State
XNDR	Forage decay rate (ton/mo)	Rate

Table 12. Wildlife Subsystem Variables Defined

Variable	Description	Type
ALCR	Large animals consumed (animals)	Aux.
ALM	Large animal meat (lb)	Aux.
AMPL	Average meat per large animal (lb/animal)	Const.
AMPS	Average meat per small animal (lb/animal)	Const.
ASCR	Small animals consumed (animals)	Aux.
ASM	Small animal meat (lb)	Aux.
CANO	Carnivore number (animals)	State
CDM	Maximum carnivore density (acres/animal)	Const.
CDR	Carnivore decrease rate (animals/mo)	Rate
CIR	Carnivore increase rate (animals/mo)	Rate
CMCR	Carnivore meat consumption (lb/mo)	Aux.
CMC	Carnivore meat consumption (lb/animal/mo)	Const.
DSF	Disturbance factor	Aux.
HANO	Herbivore number (animals)	State
HDM	Maximum herbivore density (acres/animal)	Const.
HDR	Herbivore decrease rate (animals/mo)	Rate
HIR	Herbivore increase rate (animals/mo)	Rate
PCCC	Potential carnivore carrying capacity (animals)	Aux.
PCDR	Carnivore death rate (./yr)	Const.

Table 12. (continued)

Variable	Description	Type
PCIR	Maximum carnivore birth rate (./yr)	Const.
PHCC	Potential herbivore carrying capacity (animals)	Aux.
PHDR	Herbivore death rate (./yr)	Const.
PHHK	Percent hunter kill (./yr)	Const.
PHIR	Maximum herbivore birth rate (./yr)	Const.
PSAM	Percent of meat in small animals (%)	Aux.
PSCC	Potential small animal carrying capacity (animals)	Aux.
PSDR	Small animal death rate (./yr)	Const.
PSIR	Small animal birth rate (./yr)	Const.
SANO	Small animal number (animals)	State
SCI	Security index	Aux.
SDM	Maximum small animal density (acres/animal)	Const.
SDR	Small animal decrease rate (animals/mo)	Rate
SIR	Small animal increase rate (animals/mo)	Rate
TFA	Total forage available (ton)	Aux.

Table 13. Erosion Subsystem Variables Defined

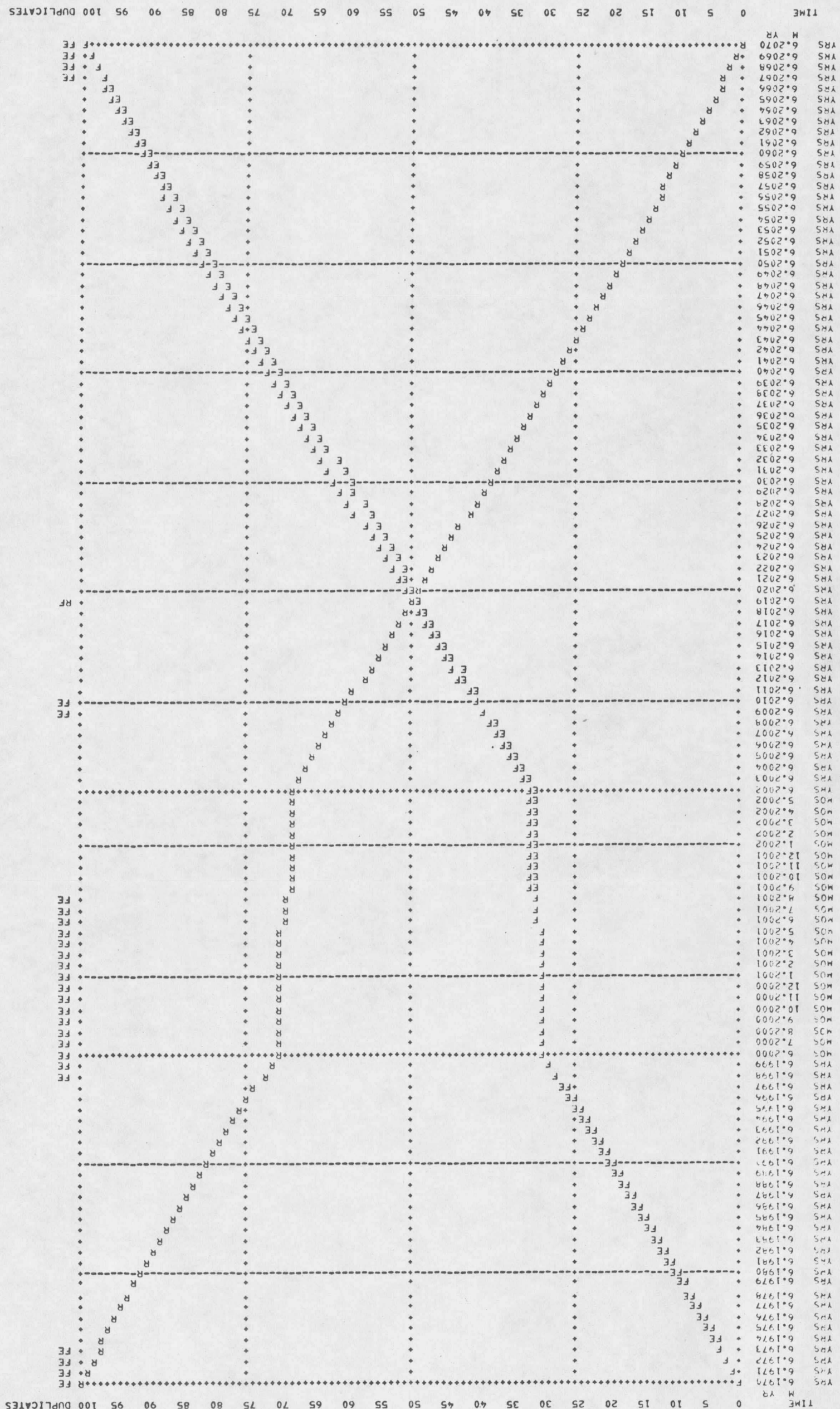
Variable	Description	Type
BAE	Burn area erosion rate (acre-in/mo)	Aux.
EFB	Erosion factor for burned area (in-soil/ in-runoff)	Const.
EFF	Erosion factor for forest area (in-soil/ in-runoff)	Const.
EFRD	Erosion factor for roaded area (in-soil/ in-runoff)	Const.
EFR	Erosion factor for range area (in-soil/ in-runoff)	Const.
ERR	Erosion rate (acre-in/mo)	Rate
FAE	Forest area erosion rate (acre-in/mo)	Aux.
RAE	Range area erosion rate (acre-in/mo)	Aux.
RDE	Road area erosion rate (acre-in/mo)	Aux.
SLO	Soil loss or accumulative erosion (acre-in)	State

Table 14. System Constants Defined

Variable	Description
ACRE	Constant sq-ft per acre (43,560)
GRMO	Number of months in growing season
IACT	Switch set .True. when activity occurs
IBM	Beginning month of growing season
IEM	Ending month of growing season
PI	Constant (3.14)

APPENDIX D

Model Output

[illegible]

TIME

0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100 DUPLICATES

MOISTURE-WATER SUBSYSTEM

SCALES OF FLOT

[illegible]

114

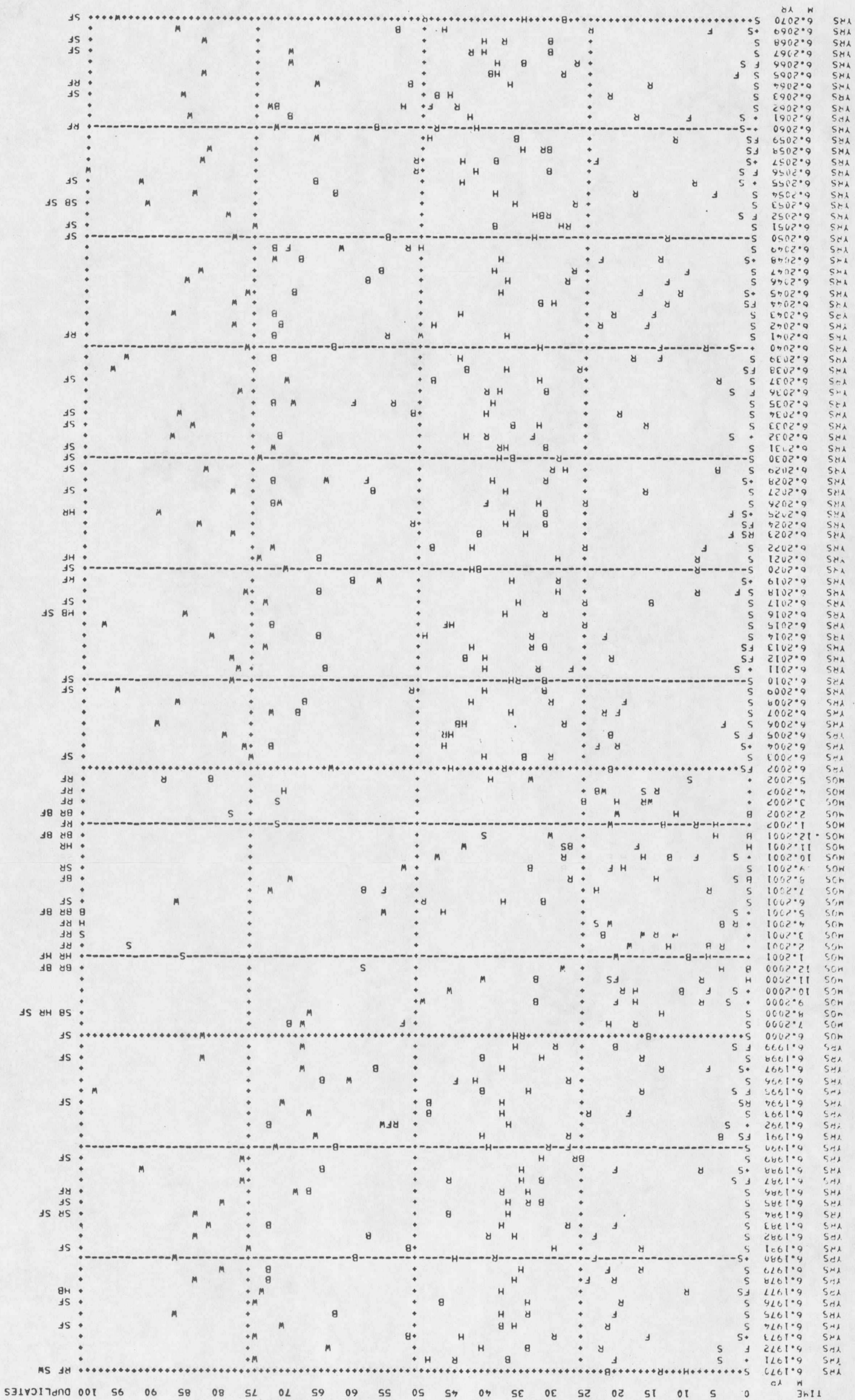


Figure 28. Moisture-Water Subsystem Plot for Base Run

TIME 0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100 DUPLICATES

SCALES OF PLOT

- 1226E+07
- 1704E+06
- 1446E+02
- 1476E+07
- 2013E+08

SCALES OF PLOT

.1A06E+07
 .4912E+06
 .1938E+02
 .4425E+07
 .6038E+08

.2095E+07
 .6516E+06
 .2184E+02
 .5900E+07
 .8051E+08



Figure 29. Timber Subsystem Plot for Base Run

PLOT NUMBER 4
 FORAGE/WILDLIFE SUBSYSTEMS

[illegible]

Figure 30. Forage/Wildlife Subsystem Plot for Base Run

Table 15. Production and Cost Summaries for Felling Activity

 : FELLING :
 :

***** PRODUCTION *****

EQUIPMENT NUMBER	TOTAL PRODUCTION (IN CU.FT. & NUMBER)				TOTAL TIME (IN HOURS)			PRODUCTION RATES (IN CU.FT. PER HOUR)		
FELLER NUMBER	VOLUME CUT	TREES CUT	PULP BUCKED	SAWLOGS BUCKED	CUTTING TIME	BUCKING TIME	TOTAL TIME	FELLING RATE	BUCKING RATE	PRODUCTION RATE
2	132104	2003	-0	-0	482.82	0	533.88	273.61	999.99	247.44
3	134696	1997	-0	-0	489.03	0	540.73	275.43	999.99	249.10

***** TIME IN EACH ACTIVITY *****

EQUIP NUM	TOTAL TIME	CUTTING TIME	BUCKING TIME	MOVING TIME	WAIT FOR MACHINE	WAIT FOR TREES	HELP WITH SKIDDING	BKDN DELAY	MAINT DELAY	PERSONAL DELAY	QUOTA FILLED
2	533.884	482.822	0	2.780	0	0	0	48.282	0	0	0
% OF TOTAL	100.00%	90.436%	0%	.521%	0%	0%	0%	9.044%	0%	0%	0%
3	540.734	489.034	0	2.796	0	0	0	48.903	0	0	0
% OF TOTAL	100.00%	90.433%	0%	.517%	0%	0%	0%	9.044%	0%	0%	0%

***** COSTS --- GROSS COSTS FOR TOTAL SIMULATION RUN *****

EQUIP NUM	TOTAL COST IN \$	TOTAL TIME IN HRS	PRODUCTION IN CU FT	PROD RATE CUFT/HOUR	COST \$/HOUR	COST \$/CUFT
2	4169.062	533.884	132104	247.4394	7.8071	.0316
3	4245.586	540.734	134696	249.0985	7.8515	.0315
0	8413.648	1074.618	266800	496.5378	15.6586	.0315

***** COST AND PRODUCTION AVERAGES ---- AVERAGE OF ALL DAYS *****

EQUIP NUM	NUMBER OF DAYS	AVG PROD RATE IN CUFT/HR	STD DEV OF PROD RATE	AVG COST IN \$/ CUFT	STD DEV OF COST	PERCENT OF TOTAL COST
2	65.0	247.9426	44.7434	.0359	.0078	44.798
3	65.0	249.3711	41.5479	.0354	.0066	44.198
0	65.0	497.3136	0	.0357	0	44.498

Table 16. Production and Cost Summaries for Skidding Activity

 • SKIDDING •

***** PRODUCTION *****

EQUIPMENT NUMBER	TOTAL PRODUCTION (IN CU.FT. ^ NUMBER)	HOOKING TIME	UNHOOK TIME	TOTAL TIME (IN HOURS)	HOOKING RATE	UNHOOK RATE	MOVING RATE	PRODUCTION RATE
SKIDDER NUMBER	VOLUME SKIDDED	PULP SKIDDED	SAWLOGS SKIDDED	MOVING TIME	UNHOOK TIME	HOOKING RATE	UNHOOK RATE	MOVING RATE
4	266401	0	3999	19.85	12.19	24.58	524.32	13423.95
								21852.80
								10838.23
								508.09

***** TIME IN EACH ACTIVITY *****

EQUIP NUM	TOTAL TIME	HOOKING TIME	UNHOOK TIME	MOVING TIME	WAIT FOR LOGS	WAIT FOR MACHINE	WAIT FOR OTHER	BKDN DELAY	MAINT DELAY	PERSONAL DELAY	QUOTA FILLED	SETUP TIME
4	524.319	19.845	12.191	24.580	433.020	0	0	2.183	32.500	0	0	0
% OF TOTAL	100.00%	3.785%	2.325%	4.688%	82.587%	0%	0%	.416%	6.199%	0%	0%	0%

DISTANCE TRAVELED BY NUMBER 4 = 521.72 MILES

***** COSTS --- GROSS COSTS FOR TOTAL SIMULATION RUN *****

EQUIP NUM	TOTAL COST IN \$	TOTAL TIME IN HRS	PRODUCTION IN CU FT	PROD RATE CUFT/HOUR	COST \$/HOUR	COST \$/CUFT
4	5130.942	524.319	266401	508.0900	9.7859	.0193
0	5130.942	524.319	266401	508.0900	9.7859	.0193

***** COST AND PRODUCTION AVERAGES ---- AVERAGE OF ALL DAYS *****

EQUIP NUM	NUMBER OF DAYS	AVG PROD RATE IN CUFT/HR	STD DEV OF PROD RATE	AVG COST IN \$ / CUFT	STD DEV OF COST	PERCENT OF TOTAL COST
4	65.0	510.2264	69.3706	.0212	.0029	26.496
0	65.0	510.2264	0	.0212	0	26.496

Table 17. Production and Cost Summaries for Loading Activity

 * LOADING *

***** PRODUCTION *****

EQUIPMENT NUMBER	TOTAL PRODUCTION (IN CU.FT. & NUMBER)			TOTAL TIME (IN HOURS)		PRODUCTION RATES (IN CU.FT. PER HOUR)	
LOADER NUMBER	VOLUME LOADED	PULP LOADED	SAWLOGS LOADED	LOADING TIME	TOTAL TIME	LOADING RATE	PRODUCTION RATE
1	266401	0	3999	123.86	515.83	2150.83	516.45

***** TIME IN EACH ACTIVITY *****

EQUIP NUM		TOTAL TIME	LOADING TIME	MOVING TIME	WAIT FOR TRUCKS	WAIT FOR WOOD	BLOCKED BY MACHINE	BKDN DELAY	MAINT DELAY	PERSONAL DELAY	QUOTA FILLED
1	TIME IN HRS	515.830	123.860	0	332.731	14.354	0	12.386	32.500	0	0
	% OF TOTAL	100.00%	24.012%	0%	64.504%	2.783%	0%	2.401%	6.301%	0%	0%

***** COSTS --- GROSS COSTS FOR TOTAL SIMULATION RUN *****

EQUIP NUM	TOTAL COST IN \$	TOTAL TIME IN HRS	PRODUCTION IN CU FT	PROD RATE CUFT/HOUR	COST \$/HOUR	COST \$/CUFT
1	5757.057	515.830	266401	516.4507	11.1608	.0216
0	5757.057	515.830	266401	516.4507	11.1608	.0216

***** COST AND PRODUCTION AVERAGES ----- AVERAGE OF ALL DAYS *****

EQUIP NUM	NUMBER OF DAYS	AVG PROD RATE IN CUFT/HR	STD DEV OF PROD RATE	AVG COST IN \$/ CUFT	STD DEV OF COST	PERCENT OF TOTAL COST
1	65.0	520.3981	97.4859	.0240	.0054	30.012
0	65.0	520.3981	0	.0240	0	30.012

Table 18. Production and Cost Summaries for Hauling Activity

 *
 * HAULING *
 *

***** PRODUCTION *****

EQUIPMENT NUMBER	TOTAL PRODUCTION (IN CU.FT. & NUMBER)				TOTAL TIME (IN HOURS)		PRODUCTION RATES (IN CU.FT. PER HOUR)					LOD
TRUCK NUMBER	VOLUME LOADED	PULP LOADED	SAWLOGS LOADED	LOADING TIME	UNLOAD TIME	MOVING TIME	TOTAL TIME	LOADING RATE	UNLOAD RATE	MOVING RATE	PRODUCTION RATE	MNT
5	97382	0	1523	50.02	65.00	243.42	422.91	1946.97	1498.18	400.05	230.26	0
6	95617	0	1456	51.39	65.00	239.40	477.45	1860.79	1471.03	399.40	200.27	0
7	73402	0	1020	34.84	65.00	239.40	522.60	2106.62	1129.26	306.61	140.46	0

***** TIME IN EACH ACTIVITY *****

EQUIP NUM	TOTAL TIME	LOADING TIME	UNLOAD TIME	MOVING TIME	WAIT FOR LOADING	WAIT TO RET WOODS	SELF LOADER WAITS LOG	BKOWN DELAY	MAINT DELAY	PERSONAL DELAY	QUOTA FILLED
5 TIME IN HRS	422.915	50.017	65.000	243.425	.123	0	0	31.850	32.500	0	0
% OF TOTAL	100.00%	11.827%	15.370%	57.559%	.029%	0%	0%	7.531%	7.685%	0%	0%
6 TIME IN HRS	477.445	51.385	65.000	239.400	53.285	0	0	35.875	32.500	0	0
% OF TOTAL	100.00%	10.762%	13.614%	50.142%	11.161%	0%	0%	7.514%	6.807%	0%	0%
7 TIME IN HRS	522.601	34.844	65.000	239.400	114.983	0	0	35.875	32.500	0	0
% OF TOTAL	100.00%	6.667%	12.438%	45.809%	22.002%	0%	0%	6.865%	6.219%	0%	0%

DISTANCE TRAVELED BY NUMBER 5 = 5200.00 MILES

DISTANCE TRAVELED BY NUMBER 6 = 5200.00 MILES

DISTANCE TRAVELED BY NUMBER 7 = 5200.00 MILES

***** COSTS --- GROSS COSTS FOR TOTAL SIMULATION RUN *****

EQUIP NUM	TOTAL COST IN \$	TOTAL TIME IN HRS	PRODUCTION IN CU FT	PROD RATE CUFT/HOUR	COST \$/HOUR	COST \$/CUFT
5	5655.794	422.915	97382	230.2638	13.3734	.0581
6	6426.419	477.445	95617	200.2679	13.4600	.0672
7	7064.560	522.601	73402	140.4551	13.5181	.0962
0	19146.772	1422.962	266401	570.9868	40.3514	.0719

***** COST AND PRODUCTION AVERAGES ---- AVERAGE OF ALL DAYS *****

EQUIP NUM	NUMBER OF DAYS	AVG PROD RATE IN CUFT/HR	STD DEV OF PROD RATE	AVG COST IN \$/ CUFT	STD DEV OF COST	PERCENT OF TOTAL COST
5	65.0	230.4949	7.6388	.0650	.0021	81.060
6	65.0	200.5479	26.5344	.0887	.1379	110.744
7	65.0	138.5654	60.8365	.2723	.7836	339.818
0	65.0	569.6082	0	.1420	0	177.207

SCALES OF PLOT

121

Figure 31. Area/Erosion Subsystem Plot for Combined Impacts



##PLOT NUMBER 4##
FORAGE/WILDLIFE SUBSYSTEMS

L=LIVE FORG.	0
D=DEAD FORG.	.1615E+05
C=CARNIVORES	.4791E-02
S=SMALL ANM.	.2362E+02
H=HERBIVORES	.8597E+00

- 6602E+03
- 4030E+05
- 1728E+01
- 3476E+04
- 3145E+01

SCALES OF PLOT
 .1320E+04
 .6445E+05
 .3452E+01
 .6929E+04
 .5430E+01

.1980E+04
 .8860E+05
 .5175E+01
 .1038E+05
 .7715E+01

.2641E+04
.1127E+06
.6899E+01
.1383E+05
.1000E+02

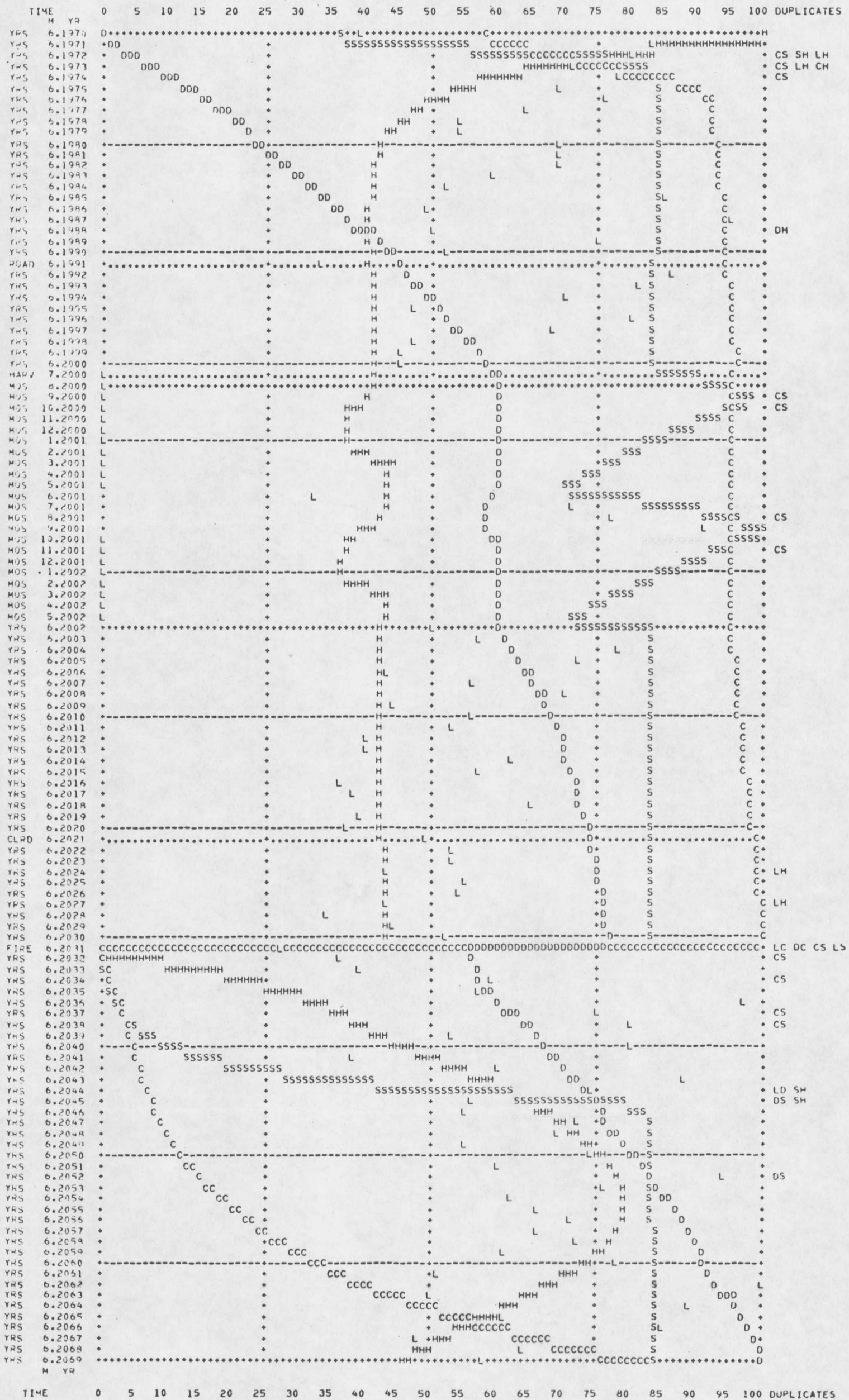


Figure 34. Forage/Wildlife Subsystem Plot for Combined Impacts

APPENDIX E

Computer Listing of Selected Routines

```

SUBROUTINE INTLC
DIMENSION NSET(1),ITL(3,5),LARP(6,5),LSYM(6,5)
COMMON OSET(1)
COMMON /GCOM1/ ATRIB(6),JEVNT,MFA,MFE(6),MLE(6),MSTOP,NCRDR,NINTL
INAP0,NNAPT,NNATR,NNFIL,NQ(6),NNTRY,NPRNT,PARAM(25,4),TNOW,TBEG,TINTL
2TCLR,TFIN,TTRI(6),TTSET
COMMON /GCOM2/ DD(25),DDL(25),DTFUL,DTNOW,ISEES,LFLAG(1),NFLAG,INTL
1NNEQD,NNEWS,NNEUT,SS(25),SSL(25),TTNEX
COMMON /GCOM3/ AAERR,DTMAX,DTMIN,DTSAV,IITES,LLERR,LLSAV,LLSEV,RREINTL
1RR,TTLAS,TTSAV,RESLS
COMMON /GCOM4/ DTPLT(10),HHLOW(25),HHWID(25),IICRD,ITAP(10),JJCEL(INTL
11),LLABC(25,2),LLABH(25,2),LLABP(11,2),LLABT(25,2),LLPHI(10),LLPINTL
2LO(10),LLPLT,LLSUP(15),LLSYM(10),MMPTS,NNCEL(25),NNCLT,NNHIS,NNPLTINTL
3,NNPTS(10),NNSTA,NNVAR(10),PPHI(10),PPLO(10),IISUB(10,10)
COMMON /GCOM5/ IIEVT,IISED(6),JJBEG,JJCLP,MMNIT,MON,NNAME(3),NNCFIINTL
1,NDAY,NNPT,NNSET,NPROJ,NNPRM,NNRNS,NNRUN,NNSTR,NYR,SSEED(6)
COMMON /GCOM6/ EENO(6),IINN(6),KKRNK(6),MMAQ(6),QQTIM(6)
1),SUMA(25,5),SSUMA(25,6),VVNO(6)
EQUIVALENCE (NSET(1),OSET(1))
COMMON /UGCM1/ W,X,Y,Z,I,J,K,L,M,N
COMMON /UGCM2/ NLOAD,NFEL,NBUCK,NPBCH,NSKD,NSTK,NPTK,IBUCK,ITREE,IINTL
10SYS,LDSYS,ILHLP,IFHLP,IWAIT,IFILL,IVLWD,ISIWD,IPWID,TPULP,TSAW,TPINTL
2ROD,WPROD,TIDAY,QUOTA,QUOTA1,PLPLN,LCRTK(10),IVLG(10),ISW(10),IPW(INTL
310),TMTM(10),THTM(10),TUTM(10),XMLE(10),DLTIM(10,7),LSTUS(10),LODINTL
4MX(10)
COMMON /UGCM3/ PMNLD,NALD(2),NBLKL(2),LGBLK(2),NMLBK(2),IPLPC(2),IINTL
1PILE(2),ISIBK(2),IVLRK(2),IVLLD(2),ISILD(2),IPILD(2),KSYS,ITW(10)
COMMON /UGCM4/ XMIPI,XMIPR,XMIS,SDIST,SPED(10,2),NSKL,IBHLP,MAINT(INTL
110),JSWBK(10),NCREW(10),WFCTR(10),TRIPS(10),TSTP(10),PRFRE,SRFRE,PINTL
2RFRF,SRFRF,JUHVR,JDHVR,UHSD,OHSD,OBSTP,CDIST,SLAND,LNDNO,NSOLD,AINTL
3DIAP,ADIA8,ADJAT,HGHTM,MCHUB,TPDST,MNSKD,MXSKD,TDIST(10),ASTIM,SLOINTL
4PE,CHSP1,CHSP2,NCHST,NARD,NBLKR,IVLRD,ISIRD,PIRD
COMMON /UGCM5/ TENDY,CSNEW(10),CSLVG,USLFE(10),EYOH,CFUEL(10),FLCMINTL
1P(10),CSRPR(10),WAGE1(10),WAGE2,CMANT(10),CSINS,CSINT,CSTAX,CSOWN(INTL
210),CTIRE(10),CSOPR(10),TMMNT(10),IFELL,CXTRA(10),ITRUK,TAMIL,LNGWINTL
3K,OVRAI,PRDLY(10),IVLG2(10),THTM2(10),TUTM2(10),DLTM2(10)INTL
4,7),XMTL2(10),NEXSW,NFM,LCAI,NORPT,NWRPT
COMMON /AREAS/ TTR,APHE,YRN,RCR,TA,PAF
COMMON /MOIST/ SMC,BSMX,RSMX,FSMX,BNPR,FNCR,RNPR,TMCR,FNPR,PFPM,TSINTL
1FM(12),TSFN(12),TSFX(12),TSFS(12),TSM(12),TSMX(12),TSM5(12),TRFM(INTL
212),TRFN(12),TRFX(12),TRFS(12),TUEM(12)
COMMON /FORST/ BACC,OSSD,XSSP,DBA,DMX,PVLL,WPCF,PVDL,PDPY,FLTR,AMRINTL
1T,ATPL
COMMON /RANGE/ TFRP,FCLM,FCSM,PFDY
COMMON /WDLDF/ AMPS,AMPL,SDM,CMC,CDM,PCIR,PCDR,HDM,PHIR,PHHK,PHOR,INTL
1PSIR,PSDR
COMMON /EROSN/ EFF,EFR,EFB,EFRD
COMMON /STVBL/ IACT,IBM,IEM,GRMO,PI,ACRE

```

Figure 35. FORTRAN Source of Initializing Routine, INTLC


```

C      COMMON /DATE/ BYR,BMO,XPY,XPM,XPW,XPD,XPH,IYR,IMO,ITP      INTL 56
C      COMMON /FIRES/ ABRN,ASPR,PTLS      INTL 57
C      COMMON /ROADS/ XMRD,AWTH,ACRT,PRTC      INTL 58
C      LOGICAL IACT      INTL 59
C      DATA IACT/.FALSE./      INTL 60
C      INTL 61
C      INTL 62
C      INTL 63
C      INTL 64
C      INTL 65
C      INTL 66
C      INTL 67
C      *** SET UP THE PLOTTING ARRAYS      INTL 68
C      DATA LSYM,1HB,1HR,1HF,1HO,1HC,1HE,1HS,1HH,1HB,1HR,1HF,1HW,1HG,1HD      INTL 69
C      1,1HA,1HF,1HV,1H,1HL,1HD,1HC,1HS,1HH,1H,1HR,1HW,1HT,1HF,1HA,1HE/      INTL 70
C      DATA LABP/10HBURN AREA,10HRANGE AREA,10HFOREST A.,10HO,ROAD A.      INTL 71
C      1,10HCLD.RD.A.,10HEROSION,10HSNOW PACK,10HSURF.WATER,10HBURN SINTL 72
C      2,M.,10HRANGE S.M.,10HFST.S.M.,10HSTORED WT.,10HNO.G.STEMS,10HNOINTL 73
C      3,D.STEMS,10HAVG.DRH,10HFUEL LOAD,10HTIMBER VOL,10H,1INTL 74
C      40HLIVE FORG.,10HDEAD FORG.,10HCARNIVORES,10HSMALL ANM.,10HHERBIVORINTL 75
C      SES,10H,10HROADS,10HWATER,10HTIMBER VOL,10HFORAINTL 76
C      6GE LD.,10HANIMALS,10HEROSION /      INTL 77
C      DATA ITLE/10H AREA/ER,10HOSION SUB,10HSYSTEMS,      INTL 78
C      1 10H MOISTUR,10HE-WATER SU,10HBSYSTEM,      INTL 79
C      2 10H TIM,10HBER SUBSYS,10HTEM,      INTL 80
C      3 10H FORAGE/W,10HILDLIFE SU,10HBSYSTEMS,      INTL 81
C      4 10H ECOS,10HYSTEM SUM,10HMARY /      INTL 82
C      J=0      INTL 83
C      NNPLT=5      INTL 84
C      DO 5 I=1,NNPLT      INTL 85
C      REWIND I      INTL 86
C      WRITE (I) J,(ITLE(K,I),K=1,3),(LSYM(K,I),K=1,6),(LABP(K,I),      INTL 87
C      1 K=1,6)      INTL 88
C      5 CONTINUE      INTL 89
C      ITP=1      INTL 90
C      INTL 91
C      INTL 92
C      INTL 93
C      INTL 94
C      INTL 95
C      INTL 96
C      INTL 97
C      ----- STATE VARIABLES -----      INTL 98
C      IYR - BEGINNING YEAR OF SIMULATION      INTL 99
C      IMO - BEGINNING MONTH OF SIMULATION      INTL 100
C      IBM - BEGINNING MONTH OF GROWING SEASON      INTL 101
C      IEM - ENDING MONTH OF GROWING SEASON      INTL 102
C      IBRD - BEGINNING MONTH AND YEAR FOR ROAD BUILDING (MYYYYY)      INTL 103
C      MYRC - MONTH AND YEAR FOR CLOSING ROADS (MYYYYY)      INTL 104
C      IBHR - BEGINNING MONTH AND YEAR FOR HARVESTING (MYYYYY)      INTL 105
C      IFRE - MONTH AND YEAR OF FIRE (MYYYYY)      INTL 106
C      INTL 107
C      READ (NCRDR,20) IYR,IMO,IBM,IEM,IBRD,MYRC,IBHR,IFRE      INTL 108
C      BYR=IYR      INTL 109
C      BMO=IMO      INTL 110

```

Figure 35. (continued)


```

C      GRMO=IEM-IBM+1
C
C      ----- AREA SYSTEM -----
C
C *** AREA CONSTANTS
C      TTR - TIME FOR BURNED AREA TO RETURN TO RANGE (YRS)
C      APHE - AVERAGE TIMBER ENCROACHMENT INTO RANGE (.% STEM HT/YR)
C      YRN - TIME FOR CLOSED ROADS TO RETURN TO NORMAL (YRS)
C      TA - TOTAL SYSTEM AREA (ACRES)
C      RCR - ROAD CONSTRUCTION RATE (ACRE/MO)
C
C      READ (NCRDR,30) TTR,APHE,YRN,TA
C      RCR=0.0
C
C *** STATE VALUES
C
C      ( 1) - BURNED AREA (ACRES)
C      ( 2) - RANGE AREA (ACRES)
C      ( 3) - FOREST AREA (ACRES)
C      ( 4) - ROAD AREA (ACRES)
C      ( 5) - CLOSED ROAD AREA (ACRES)
C
C      READ (NCRDR,30) (SS(I),I=1,5)
C
C      ----- MOISTURE SYSTEM -----
C
C *** MOISTURE CONSTANTS
C
C      SMC - SNOW MOISTURE CONTENT (IN-WATER/IN-SNOW)
C      BSMX - BURNED AREA FIELD CAPACITY (IN)
C      RSMX - RANGE AREA FIELD CAPACITY (IN)
C      FSMX - FOREST AREA FIELD CAPACITY (IN)
C      BNPR - BURNED AREA NORMAL PERCOLATION RATE (IN/MO)
C      FMCR - FORAGE MOISTURE CONSUMPTION RATE (IN/TON/MO)
C      RNPR - RANGE AREA NORMAL PERCOLATION RATE (IN/MO)
C      TMCR - TIMBER MOISTURE CONSUMPTION RATE (IN/CU-FT/MO)
C      FNPR - FOREST AREA NORMAL PERCOLATION RATE (IN/MO)
C      PFPM - PERCENT OF STORED WATER IN STREAMFLOW (.%/MO)
C      TSFM, TSFN, TSFX, TSFS - SNOW FALL PER MONTH MEAN,MIN,MAX,STD.DEV.
C      TSMH, TSMX, TSMS - PERCENT SNOW MELT PER MONTH MEAN,MAX,STD.DEV.
C      TRFM, TRFN, TRFX, TRFS - RAIN FALL PER MONTH MEAN,MIN,MAX,STD.DEV.
C      TUEM - MEAN EVAPORATION RATE PER MONTH
C
C      READ (NCRDR,25) SMC,BSMX,RSMX,FSMX,BNPR,FMCR,RNPR,TMCR,FNPR,PFPM,
C      TSFM,TSFN,TSFX,TSFS,TSMH,TSMX,TSMS,TRFM,TRFN,TRFX,TRFS,TUEM
C      25 FORMAT (2(I5F10.0,/),12(I2F6.0,/))
C
C *** STATE VALUES
C
C      ( 6) - SNOW PACK (IN)
C      ( 7) - SURFACE WATER (IN)
C      ( 8) - BURNED SOIL MOISTURE (IN)

```

```

INTL 111
INTL 112
INTL 113
INTL 114
INTL 115
INTL 116
INTL 117
INTL 118
INTL 119
INTL 120
INTL 121
INTL 122
INTL 123
INTL 124
INTL 125
INTL 126
INTL 127
INTL 128
INTL 129
INTL 130
INTL 131
INTL 132
INTL 133
INTL 134
INTL 135
INTL 136
INTL 137
INTL 138
INTL 139
INTL 140
INTL 141
INTL 142
INTL 143
INTL 144
INTL 145
INTL 146
INTL 147
INTL 148
INTL 149
INTL 150
INTL 151
INTL 152
INTL 153
INTL 154
INTL 155
INTL 156
INTL 157
INTL 158
INTL 159
INTL 160
INTL 161
INTL 162
INTL 163
INTL 164
INTL 165

```

Figure 35. (continued)

C	(9) - RANGE SOIL MOISTURE (IN)	INTL 166
C	(10) - FOREST SOIL MOISTURE (IN)	INTL 167
C	(11) - STORED WATER (ACRE-IN)	INTL 168
C		INTL 169
C	READ (NCRDR,30) (SS(I),I=6,11)	INTL 170
C		INTL 171
C		INTL 172
C	----- FOREST SYSTEM -----	INTL 173
C		INTL 174
C	*** FOREST CONSTANTS	INTL 175
C		INTL 176
C	BACC - BASAL AREA CARRYING CAPACITY (SQ FT/ACRE)	INTL 177
C	OSSD - OPTIMAL STOCKING STAND DENSITY (TREE/ACRE)	INTL 178
C	XSSR - MAXIMUM SEEDLING STOCKING RATIO (SEED TREES/TREE/YR)	INTL 179
C	FSI - FOREST AREA 100 YR SITE INDEX (TREE HEIGHT IN FT)	INTL 180
C	DMX - MAXIMUM TREE DIAMETER (IN)	INTL 181
C	PVLL - PERCENT VOLUME OF LIVE TREE LOST PER YEAR (.%/YR)	INTL 182
C	WPCF - WEIGHT OF WOOD (LB/CU-FT)	INTL 183
C	PVDL - PERCENT VOLUME OF DEAD TREE LOST PER YEAR (.%/YR)	INTL 184
C	PDPY - PERCENT TIMBER DECAY PER IN SURFACE WATER PER YEAR (.%/YR)	INTL 185
C	FLTR - ACRES OF FUEL TREATED PER MONTH (ACRES/MO)	INTL 186
C	AMRT - PERCENT ANNUAL TIMBER MORTALITY (.%/YR)	INTL 187
C	ATPL - PERCENT ANNUAL DEAD STEM TOPPLE RATE (.%/YR)	INTL 188
C	DBA - BASAL AREA GROWTH INCREMENT PER YEAR (SQ IN/YR)	INTL 189
C		INTL 190
C	READ (NCRDR,30) BACC,OSSD,XSSR,FSI,DMX,PVLL,WPCF,PVDL,PDPY,FLTR,AM	INTL 191
C	IRT,ATPL	INTL 192
C	R=0.5*(((FSI+38.4256)/37.0809)**2.3998)	INTL 193
C	DBA=PI*R*R/100.0	INTL 194
C		INTL 195
C	*** STATE VALUES	INTL 196
C		INTL 197
C	(12) - NUMBER OF GROWING STEMS (TREE)	INTL 198
C	(13) - NUMBER OF STANDING DEAD STEMS (TREE)	INTL 199
C	(14) - AVERAGE STEM DIAMETER (IN)	INTL 200
C	(15) - TOTAL TIMBER FUEL LOAD (TON)	INTL 201
C		INTL 202
C	READ (NCRDR,30) (SS(I),I=12,15)	INTL 203
C		INTL 204
C		INTL 205
C	----- RANGE SYSTEM -----	INTL 206
C		INTL 207
C	*** RANGE CONSTANTS	INTL 208
C		INTL 209
C	TFRP - TIME FOR FORAGE LOAD TO REACH POTENTIAL (YR)	INTL 210
C	FCLM - LARGE ANIMAL FORAGE CONSUMPTION (LB/ANIMAL/MO)	INTL 211
C	FCSM - SMALL ANIMAL FORAGE CONSUMPTION (LB/ANIMAL/MO)	INTL 212
C	PFDY - PERCENT FORAGE DECAY PER IN SURFACE WATER PER YEAR (.%/YR)	INTL 213
C		INTL 214
C	READ (NCRDR,30) TFRP,FCLM,FCSM,PFDY	INTL 215
C		INTL 216
C	*** STATE VALUES	INTL 217
C		INTL 218
C	(16) - TOTAL LIVE FORAGE LOAD (TON)	INTL 219
C	(17) - TOTAL DEAD FORAGE LOAD (TON)	INTL 220

Figure 35. (continued)

C	READ (NCRDR,30) (SS(I),I=16,17)	INTL 221
C		INTL 222
C		INTL 223
C	----- WILDLIFE SYSTEM -----	INTL 224
C		INTL 225
C	*** WILDLIFE CONSTANTS	INTL 226
C		INTL 227
C		INTL 228
C	AMPS - AVERAGE MEAT PER SMALL ANIMAL (LB/ANIMAL)	INTL 229
C	AMPL - AVERAGE MEAT PER LARGE ANIMAL (LB/ANIMAL)	INTL 230
C	SOM - MAXIMUM SMALL ANIMAL DENSITY (ACRES/ANIMAL)	INTL 231
C	CMC - CARNIVORE MEAT CONSUMPTION (LB/ANIMAL/MO)	INTL 232
C	CDM - MAXIMUM CARNIVORE DENSITY (ACRES/ANIMAL)	INTL 233
C	PCIR - MAXIMUM CARNIVORE BIRTH RATE (.%/YR)	INTL 234
C	PCDR - CARNIVORE DEATH RATE (.%/YR)	INTL 235
C	HDM - MAXIMUM HERBIVORE DENSITY (ACRES/ANIMAL)	INTL 236
C	PHIR - MAXIMUM HERBIVORE BIRTH RATE (.%/YR)	INTL 237
C	PHHK - PERCENT HUNTER KILL (.%/YR)	INTL 238
C	PHDR - HERBIVORE DEATH RATE (.%/YR)	INTL 239
C	PSIR - SMALL ANIMAL BIRTH RATE (.%/YR)	INTL 240
C	PSDR - SMALL ANIMAL DEATH RATE (.%/YR)	INTL 241
C		INTL 242
C	READ (NCRDR,30) AMPS,AMPL,SOM,CMC,CDM,PCIR,PCDR,HDM,PHIR,PHHK,PHDR	INTL 243
C	1,PSIR,PSDR	INTL 244
C		INTL 245
C	*** STATE VALUES	INTL 246
C		INTL 247
C	(18) - NUMBER OF CARNIVORE (ANIMALS)	INTL 248
C	(19) - NUMBER OF SMALL ANIMALS (ANIMALS)	INTL 249
C	(20) - NUMBER OF HERBIVORE (ANIMALS)	INTL 250
C		INTL 251
C	READ (NCRDR,30) (SS(I),I=18,20)	INTL 252
C		INTL 253
C		INTL 254
C	----- EROSION SYSTEM -----	INTL 255
C		INTL 256
C	*** EROSION CONSTANTS	INTL 257
C		INTL 258
C	EFF - EROSION FACTOR FOR FOREST AREA (IN-SOIL/IN-RUNOFF)	INTL 259
C	EFR - EROSION FACTOR FOR RANGE AREA (IN-SOIL/IN-RUNOFF)	INTL 260
C	EFB - EROSION FACTOR FOR BURNED AREA (IN-SOIL/IN-RUNOFF)	INTL 261
C	EFRD - EROSION FACTOR FOR ROADED AREA (IN-SOIL/IN-RUNOFF)	INTL 262
C		INTL 263
C	READ (NCRDR,30) EFF,EFR,EFB,EFRD	INTL 264
C		INTL 265
C	*** STATE VALUES SET TO ZERO	INTL 266
C		INTL 267
C	(21) - SEDIMENT LOAD (ACRE-IN)	INTL 268
C	(22) - TOTAL TIMBER VOLUME (CU-FT)	INTL 269
C	(23) - VOLUME OF TREES FELLED (CU-FT)	INTL 270
C	(24) - VOLUME OF TREES AT LANDING (CU-FT)	INTL 271
C	(25) - VOLUME OF TREES AT MILL (CU-FT)	INTL 272
C		INTL 273
C	DO 4 I=21,25	INTL 274
C	SS(I)=0.0	INTL 275

Figure 35. (continued)

C	4 CONTINUE	INTL 276
C		INTL 277
C	----- FIRE SYSTEM -----	INTL 278
C		INTL 279
C	*** FIRE CONSTANTS	INTL 280
C		INTL 281
C	ABRN - TOTAL AREA BURNED (ACRES)	INTL 282
C	ASPR - AREA OF SUPPRESSION ROADS CONSTRUCTED (ACRES)	INTL 283
C	PTLS - PERCENT OF BURNED STEMS LEFT STANDING (.)	INTL 284
C		INTL 285
C	ATRIB(3)=ATRIB(4)=ATRIB(5)=ATRIB(6)=0.0	INTL 286
C	IF (IFRE.LE.0) GO TO 7	INTL 287
C	READ (NCRDR,30) ABRN,ASPR,PTLS	INTL 288
C		INTL 289
C	*** SCHEDULE THE FIRE	INTL 290
C		INTL 291
C	I=IFRE/10000	INTL 292
C	J=IFRE-I*10000	INTL 293
C	X=(J-IYR)*XPY	INTL 294
C	Y=(I-IMO)*XPM	INTL 295
C	ATRIB(1)=INOW*X*Y	INTL 296
C	ATRIB(2)=15.0	INTL 297
C	CALL FILEM(1)	INTL 298
C		INTL 299
C	----- ROAD BUILDING SYSTEM -----	INTL 300
C		INTL 301
C	*** ROAD BUILDING CONSTANTS	INTL 302
C		INTL 303
C	XMRD - MILES OF ROADS TO BE CONSTRUCTED	INTL 304
C	AWTH - AVERAGE ROAD WIDTH (FT)	INTL 305
C	ACRT - AVERAGE CONSTRUCTION RATE (MILES/DAY)	INTL 306
C	PRTC - PERCENT OF ROADS CLOSED (.)	INTL 307
C		INTL 308
C	7 IF (IBRD.LE.0.AND.MYRC.LE.0) GO TO 8	INTL 309
C	READ (NCRDR,30) XMRD,AWTH,ACRT,PRTC	INTL 310
C		INTL 311
C	*** SCHEDULE CONSTRUCTION BEGINNING	INTL 312
C		INTL 313
C	IF (IHRD.LE.0) GO TO 9	INTL 314
C	I=IBRD/10000	INTL 315
C	J=IBRD-I*10000	INTL 316
C	X=(J-IYR)*XPY	INTL 317
C	Y=(I-IMO)*XPM	INTL 318
C	ATRIB(1)=INOW*X*Y	INTL 319
C	ATRIB(2)=16.0	INTL 320
C	CALL FILEM(1)	INTL 321
C		INTL 322
C	*** SCHEDULE ROAD CLOSURES	INTL 323
C		INTL 324
C	9 IF (MYRC.LE.0) GO TO 8	INTL 325
C	I=MYRC/10000	INTL 326
C	J=MYRC-I*10000	INTL 327
C	X=(J-IYR)*XPY	INTL 328
		INTL 329
		INTL 330

Figure 35. (continued)

Y=(I-IMO)*XPM	INTL 331
ATRI(1)=INOW*X+Y	INTL 332
ATRI(2)=20.0	INTL 333
CALL FILEM (1)	INTL 334
C	INTL 335
C	INTL 336
C ----- HARVEST MICRO-SYSTEM -----	INTL 337
C	INTL 338
C *** SYSTEM INPUTS	INTL 339
C	INTL 340
C B IF (IBHR.LE.0) GO TO 1000	INTL 341
C	INTL 342
C *** SCHEDULE START OF LOGGING	INTL 343
C	INTL 344
I=IBHR/10000	INTL 345
J=IBHR-I*10000	INTL 346
X=(J-IYR)*XPY	INTL 347
Y=(I-IMO)*XPM	INTL 348
ATRI(1)=INOW*X+Y	INTL 349
ATRI(2)=17.0	INTL 350
CALL FILEM (1)	INTL 351
C	INTL 352
C*****INPUT CRITERION VARIABLES THAT SET NUMBERS EACH EQUIPMENT TYPE	INTL 353
C*****AND TYPE LOGGING SYSTEM	INTL 354
C	INTL 355
MON=1	INTL 356
NDAY=1	INTL 357
READ (NCRDR,20) NLOAD,NFEL,NBUCK,NPBCH,NSKD,NSTK,NPTK	INTL 358
20 FORMAT (14I5)	INTL 359
READ (NCRDR,20) IDSYS,KSYS,LDSYS,MCHUB,NSKL,NDEC	INTL 360
READ (NCRDR,20) IFELL,IFHLP,IBUCK,IBHLP,ILHLP,NEXSW	INTL 361
READ (NCRDR,20) IWAIT,ITRUK,ITREE,LCAT,NFM,NORPT,NWRPT	INTL 362
C	INTL 363
C	INTL 364
C	INTL 365
C*****INPUT VARIABLES THAT SPECIFY CONDITIONS AT THIS PARTICULAR SITE	INTL 366
C	INTL 367
READ (NCRDR,30) XMIPA,XMIPR,XMIS,SDIST,DBSTP,SLAND	INTL 368
30 FORMAT (8F10.3)	INTL 369
READ (NCRDR,30) SLOPE,UHSD,DHSD,QUOTA1	INTL 370
READ (NCRDR,30) PRFRE,SFRF,PRFRF,SFRF	INTL 371
READ (NCRDR,30) ADIAP,ADIAB,ADIAT,HGHTM,PMNLD,PLPLN	INTL 372
C	INTL 373
C*****INPUT VARIABLES THAT DESCRIBE LOGGING SYSTEM COMPONENTS AND AREAS	INTL 374
C	INTL 375
READ (NCRDR,30) ASTIM,CHSP1,CHSP2,TAMIL,TIDAY,EYOH	INTL 376
READ (NCRDR,20) MNSKD,MXSKD,LNGWK,NARD,NBLKR	INTL 377
DO 40 J=1,2	INTL 378
40 READ (NCRDR,20) NBLKL(J),LGBLK(J),NMLBK(J)	INTL 379
C	INTL 380
C*****INPUT COST VARIABLES ASSOCIATED WITH ALL EQUIPMENT	INTL 381
C	INTL 382
READ (NCRDR,30) CSLVG,WAGE2,CSINS,CSINT,CSTAX,OVRRAT	INTL 383
C	INTL 384
C*****INPUT VARIABLES ASSOCIATED WITH INDIVIDUAL PIECES OF EQUIPMENT	INTL 385

Figure 35. (continued)

```

C                                     INTL 386
      IJ=NLOAD*NFEL*NBUC*NPBCH*NSKD*NSTK*NPTK          INTL 387
      DO 50 I=1,IJ                                     INTL 388
      READ (NCRDR,20) LODMX(I),NCREW(I)                INTL 389
      READ (NCRDR,30) SPED(I,1),SPED(I,2),TMMNT(I),PRDLY(I),WFCTR(I) INTL 390
      READ (NCRDR,30) CSNEW(I),USLFE(I),CFUEL(I),FLCMP(I),CSRPR(I)  INTL 391
      READ (NCRDR,30) WAGE1(I),CMANT(I),CTIRE(I),CXTRA(I)          INTL 392
C                                     INTL 393
C*****NOW INITIALIZE THOSE VARIABLES CONNECTED WITH INDIVIDUAL MACHINES INTL 394
C                                     INTL 395
      READ (NCRDR,20) IVLG(I),ITW(I),ISW(I),IPW(I),JSWRK(I),MAINT(I),IVL INTL 396
      IG2(I)                                              INTL 397
      READ (NCRDR,30) TUTM(I),TMTM(I),THTM(I),XMILE(I),TUTM2(I),TMTM2(I) INTL 398
      1,THTM2(I),XMIL2(I)                                INTL 399
      READ (NCRDR,30) TSTP(I)                            INTL 400
      READ (NCRDR,30) (DLTIM(I,J),J=1,7)                 INTL 401
      READ (NCRDR,30) (DLTM2(I,J),J=1,7)                 INTL 402
      50 CONTINUE                                         INTL 403
      READ (NCRDR,30) (TRIPS(I),I=1,8)                   INTL 404
      READ (NCRDR,30) TRIPS(9),TRIPS(10)                 INTL 405
      READ (NCRDR,30) (TDIST(I),I=1,8)                   INTL 406
      READ (NCRDR,30) TDIST(9),TDIST(10)                 INTL 407
C                                     INTL 408
C                                     INTL 409
C                                     INTL 410
C*****INPUT TRUCK - LOADER COMBINATION
      IJ=NSTK*NPTK                                       INTL 411
      READ (NCRDR,20) (LDRTK(I),I=1,IJ)                 INTL 412
C                                     INTL 413
C*****NOW INITIALIZE OTHER DATA COLLECTION AND CONTROL VARIABLES
C                                     INTL 414
      READ (NCRDR,30) TPROD,TSAW,TPULP,WPROD,CDIST,TPDST,DIST,TENDY  INTL 415
      READ (NCRDR,20) IFILL,IVLWD,ISIWD,IPIWD,IVLRD,ISIRD,IPIRD,NCHST,JU INTL 417
      IHVR,JDHVR,LNDNO,NSOLD                             INTL 418
      DO 60 I=1,2                                         INTL 419
      60 READ (NCRDR,20) IPLPC(I),IPILE(I),ISIBK(I),IVLBK(I),NALD(I),IVLLD( INTL 420
      II),ISILD(I),IPILO(I)                             INTL 421
C                                     INTL 422
C*****NOW INPUT DATA THROUGH THE GASP SUBROUTINE --- DATAN
C                                     INTL 423
      QUOTA=QUOTA1                                       INTL 424
C                                     INTL 425
C                                     INTL 426
C*****NOW CALCULATE OWNING AND OPERATING COST FOR THE SYSTEM COMPONENTS
C                                     INTL 427
      L=NLOAD*NFEL*NBUC*NSKD*NPBCH                     INTL 428
      N=L*NSTK*NPTK                                       INTL 429
      DO 130 I=1,N                                        INTL 430
C                                     INTL 431
C                                     INTL 432
C*****FIRST CALCULATE OWNING COST
C                                     INTL 433
      X=(CSNEW(I)*(1.-CSLVG))/(USLFE(I)*EYOH)           INTL 435
      Y=(((((CSNEW(I)*(1.-CSLVG))*(USLFE(I)+1.))/(2.*USLFE(I)))+(CSNEW(I) INTL 436
      I)*CSLVG))*(CSINS+CSTAX+CSINT))/EYOH              INTL 437
      CSOWN(I)=X*Y                                         INTL 438
      IF (I.LE.NLOAD) GO TO 70                             INTL 439
      IF (I.GT.(NLOAD*NFEL)) GO TO 70                    INTL 440

```

Figure 35. (continued)


```

      CSOWN(I)=(((X+Y)*NEASW)/NFEL)+CSOWN(I)                                INTL 441
C                                                                              INTL 442
C*****NOW CALCULATE OPERATING COST                                       INTL 443
C                                                                              INTL 444
70 W=FLCMP(I)*CFUEL(I)                                                    INTL 445
   IF (FLCMP(I).LE.0.0) W=CFUEL(I)                                         INTL 446
   IF (I.GT.L) GO TO 80                                                    INTL 447
   CSOPR(I)=W*(CMANT(I)*W)+(CSRPR(I)*X)+(CTIRE(I)/EYOH)                   INTL 448
   GO TO 90                                                                INTL 449
80 Z=XMIPA+XMIPR+XMIS                                                    INTL 450
   T=XMIS/Z                                                                INTL 451
   V=XMIPR/Z                                                                INTL 452
   Z=XMIPA/Z                                                                INTL 453
   T=(((SPED(I,1)+SPED(I,2))/2.0)*Z)+((((SPED(I,1)*PRFRE)+(SPED(I,2)*INTL 454
   IPRFRF))/2.0)*V)+((((SPED(I,1)*SRFRE)+(SPED(I,2)*SRFRF))/2.0)*T)      INTL 455
   CSOPR(I)=W*(CMANT(I)*W)+((CSRPR(I)*X)/T)+(CTIRE(I)/(T*EYOH))          INTL 456
C                                                                              INTL 457
C*****NOW ROUND THE COSTS TO THE DESIRED NUMBER OF DECIMAL              INTL 458
C                                                                              INTL 459
90 M=CSOWN(I)*(10.**NDEC)                                                 INTL 460
   M=M*10                                                                  INTL 461
   J=CSOWN(I)*(10.**NDEC+1)                                                INTL 462
   J=J-5                                                                    INTL 463
   IF (J.GE.M) GO TO 100                                                  INTL 464
   CSOWN(I)=M/(10.**NDEC+1)                                                INTL 465
   GO TO 110                                                                INTL 466
100 CSOWN(I)=(M+10)/(10.**NDEC+1)                                          INTL 467
110 M=CSOPR(I)*(10.**NDEC)                                                 INTL 468
   M=M*10                                                                  INTL 469
   J=CSOPR(I)*(10.**NDEC+1)                                                INTL 470
   J=J-5                                                                    INTL 471
   IF (J.GE.M) GO TO 120                                                  INTL 472
   CSOPR(I)=M/(10.**NDEC+1)                                                INTL 473
   GO TO 130                                                                INTL 474
120 CSOPR(I)=(M+10)/(10.**NDEC+1)                                          INTL 475
130 CONTINUE                                                                INTL 476
C                                                                              INTL 477
C*****PRINT OUT THE INITIAL CONDITIONS AND COSTS                        INTL 478
WRITE (NPRNT,140)                                                         INTL 479
140 FORMAT (1H1)                                                           INTL 480
   WRITE (NPRNT,150)                                                       INTL 481
150 FORMAT (40X,30H***** )                                               INTL 482
   WRITE (NPRNT,160)                                                       INTL 483
160 FORMAT (40X,2H** ,26X,2H**)                                           INTL 484
   WRITE (NPRNT,170) NPKO.J                                               INTL 485
170 FORMAT (40X,*** SAPLOS STUDY NO. #,I4,# ***)                        INTL 486
   WRITE (NPRNT,160)                                                       INTL 487
   WRITE (NPRNT,150)                                                       INTL 488
   WRITE (NPRNT,180) NFM                                                  INTL 489
180 FORMAT (/15X,*SIMULATION OF TIMER HARVESTING ON FOREST MODEL NUMBINTL 490
   IBER *,I4//)                                                           INTL 491
   WRITE (NPRNT,190)                                                       INTL 492
190 FORMAT (15X,*LOGGING SYSTEM BEING TESTED --- IDENTIFICATION OF SYSINTL 493
   ITEM VARIABLES//)                                                       INTL 494
   IF (NFEL.GT.0) GO TO 210                                               INTL 495

```

Figure 35. (continued)

```

WRITE (NPRNT,200)                                INTL 496
200 FORMAT (20X,*FELLING - FELLING NOT STUDIED*,21X,* NUMBER OF FELINTL 497
1LERS = 0*/)                                       INTL 498
GO TO 250                                          INTL 499
210 IF (IFELL.GT.0) GO TO 230                     INTL 500
WRITE (NPRNT,220) NFEL                           INTL 501
220 FORMAT (20X,*FELLING - MANUAL FELLING -- MAN WITH CHAINSAW*,5X,*INTL 502
1 NUMBER OF FELLERS =*,13/)                       INTL 503
GO TO 250                                          INTL 504
230 WRITE (NPRNT,240) NFEL                        INTL 505
240 FORMAT (20X,*FELLING - MECHANICAL HARVESTERS*,19X,* NUMBER OF FINTL 506
1ELLERS =*,13/)                                   INTL 507
250 IF (IBUCK-2) 260,280,300                     INTL 508
260 WRITE (NPRNT,270)                             INTL 509
270 FORMAT (20X,*BUCKING - BUCKING IN WOODS BY FELLER*,14X,* NUMBERINTL 510
1 OF BUCKERS = 0*/)                               INTL 511
GO TO 320                                          INTL 512
280 WRITE (NPRNT,290) NBUCK                       INTL 513
290 FORMAT (20X,*BUCKING - BUCKING AT THE LANDING*,18X,* NUMBER OF INTL 514
1BUCKERS =*,13/)                                  INTL 515
GO TO 320                                          INTL 516
300 WRITE (NPRNT,310)                             INTL 517
310 FORMAT (20X,*BUCKING - BUCKING AT MILL -- HAUL LONG LENGTH*,5X,*INTL 518
1 NUMBER OF BUCKERS = 0*/)                         INTL 519
320 IF (NPBCH.GT.0) GO TO 340                     INTL 520
WRITE (NPRNT,330)                                 INTL 521
330 FORMAT (20X,*PREBUNCHING - NOT USED IN THIS SYSTEM*,15X,* NUMBER INTL 522
1OF PREBUNCHERS = 0*/)                           INTL 523
GO TO 380                                          INTL 524
340 IF (MCHUB.LE.0) GO TO 360                     INTL 525
WRITE (NPRNT,350) NPBCH                          INTL 526
350 FORMAT (20X,*PREBUNCHING - WHEELED OR TRACKED VEHICLES*,11X,* NUMINTL 527
1BER OF PREBUNCHERS =*,13/)                       INTL 528
GO TO 380                                          INTL 529
360 WRITE (NPRNT,370) NPBCH                       INTL 530
370 FORMAT (20X,*PREBUNCHING - CHUBALL SERVES AS PREBUNCHER*,5X,* NUMBINTL 531
1ER OF PREBUNCHERS =*,13/)                       INTL 532
380 IF (NSKD.GT.0) GO TO 400                      INTL 533
WRITE (NPRNT,390)                                 INTL 534
390 FORMAT (20X,*SKIDDING - NOT USED IN THIS SYSTEM*,17X,* NUMBER OFINTL 535
1 SKIDDERS = 0*/)                                 INTL 536
GO TO 490                                          INTL 537
400 IF (NSKL-1) 410,430,450                      INTL 538
410 WRITE (NPRNT,420) NSKD                        INTL 539
420 FORMAT (20X,*SKIDDING - SKYLINE OR HIGH LEAD SYSTEM*,13X,* NUMBEINTL 540
1R OF SKIDDERS =*,13/)                           INTL 541
GO TO 490                                          INTL 542
430 WRITE (NPRNT,440) NSKD                        INTL 543
440 FORMAT (20X,*SKIDDING - ROLLING STOCK SKIDDERS*,18X,* NUMBER OF INTL 544
1SKIDDERS =*,13/)                                INTL 545
GO TO 490                                          INTL 546
450 IF (MCHUB.GT.1) GO TO 470                    INTL 547
WRITE (NPRNT,460) NSKD                           INTL 548
460 FORMAT (20X,*SKIDDING - CHUBALL ACTS AS SKIDDER*,17X,* NUMBER OFINTL 549
1 SKIDDERS =*,13/)                               INTL 550

```

Figure 35. (continued)


```

GO TO 490
470 WRITE (NPRNT,480) NSKD
480 FORMAT (20X,%SKIIDDING - CHUBALL ACTS AS HIGH LEAD*,15X,* NUMBER
1OF SKIDDERS =*,13/)
490 IF (NLOAD.GT.0) GO TO 510
WRITE (NPRNT,500)
500 FORMAT (20X,%LOADING - NO SELF CONTAINED LOADER IN THIS SYSTEM
1 NUMBER OF LOADERS = 0*/ )
GO TO 660
510 GO TO (520,540,560,580,600,620,640),LCAT
520 WRITE (NPRNT,530)
530 FORMAT (20X,%LOADING - FULLY ARTICULATED, HYDRAULIC LOADER*,5X,*
1NUMBER OF LOADERS = 1*/ )
GO TO 660
540 WRITE (NPRNT,550)
550 FORMAT (20X,%LOADING - LOADER WITH AIR OR HYDRAULIC PINCHERS
1 NUMBER OF LOADERS = 1*/ )
GO TO 660
560 WRITE (NPRNT,570)
570 FORMAT (20X,%LOADING - HEELBOOM LOADER WITH GRAPPLE*,12X,* NUMB
1ER OF LOADERS = 1*/ )
GO TO 660
580 WRITE (NPRNT,590)
590 FORMAT (20X,%LOADING - HEELBOOM LOADERS WITH TONGS AND SETTER
1 NUMBER OF LOADERS = 1*/ )
GO TO 660
600 WRITE (NPRNT,610)
610 FORMAT (20X,%LOADING - FRONT-END LOADER*,24X,* NUMBER OF LOADER
1S = 1*/ )
GO TO 660
620 WRITE (NPRNT,630)
630 FORMAT (20X,%LOADING - LONG-BOOM LOADER WITH GRAPPLE*,11X,* NUM
1BER OF LOADERS = 1*/ )
GO TO 660
640 WRITE (NPRNT,650)
650 FORMAT (20X,%LOADING - LONG-BOOM LOADER WITH TONGS*,13X,* NUMB
1R OF LOADERS = 1*/ )
660 IF ((NSTK+NPTK).GT.0) GO TO 680
WRITE (NPRNT,670)
670 FORMAT (20X,%HAULING - HAULING NOT CONSIDERED IN THIS STUDY
1 NUMBER OF TRUCKS = 0*/ )
GO TO 860
680 N=NSTK+NPTK
GO TO (690,710,730,750,770,790,810),KSYS
690 WRITE (NPRNT,700) N
700 FORMAT (20X,%HAULING - TRACTOR WITH STANDARD POLE TRAILER
1 NUMBER OF TRUCKS =*,13/)
GO TO 830
710 WRITE (NPRNT,720) N
720 FORMAT (20X,%HAULING - TRACTOR WITH PREHAUL TRAILER*,12X,* NUMB
1ER OF TRUCKS =*,13/)
GO TO 830
730 WRITE (NPRNT,740) N
740 FORMAT (20X,%HAULING - TRACTOR WITH FLATBED TRAILER*,12X,* NUMB
1ER OF TRUCKS =*,13/)

```

Figure 35. (continued)

```

      GO TO 830
750 WRITE (NPRNT,760) N
760 FORMAT (20X,'HAULING - SINGLE AXLE TRUCK',23X,' NUMBER OF TRUCK
      IS =',I3/)
      GO TO 830
770 WRITE (NPRNT,780) N
780 FORMAT (20X,'HAULING - TANDEM AXLE TRUCK',23X,' NUMBER OF TRUCK
      IS =',I3/)
      GO TO 830
790 WRITE (NPRNT,800) N
800 FORMAT (20X,'HAULING - SINGLE AXLE TRUCK WITH TRAILER',10X,' NU
      IMBER OF TRUCKS =',I3/)
      GO TO 830
810 WRITE (NPRNT,820) N
820 FORMAT (20X,'HAULING - TANDEM AXLE TRUCK WITH TRAILER',10X,' NU
      IMBER OF TRUCKS =',I3/)
830 J=0
      DO 840 I=1,N
840 IF (LDRTK(I).GT.0) J=J+1
      WRITE (NPRNT,850) J,N
850 FORMAT (25X,'TRUCK MOUNTED LOADERS USED ON ',I2,' OF ',I2,' TRUCKS
      1*//)
C
C*****NOW PRINT OUT OWNING AND OPERATING COSTS OF EQUIPMENT
C
860 WRITE (NPRNT,870)
870 FORMAT (////15X,'INITIAL COSTS ASSOCIATED WITH THIS SYSTEM#//)
      WRITE (NPRNT,880)
880 FORMAT (22X,'EQUIP ORIGINAL SALVAGE USEFUL
      1 OWNING OPERATING EXTRA',22X,'NUMBER',9X,'COST',9X,'
      2VALUE',10X,'LIFE',10X,'COST',10X,'COST',10X,'COST'//)
      N=NLOAD*NFEL*NBUCK*NPBCH*NSKD*NSTK*NPTK
      DO 890 I=1,N
      X=CSNEW(I)*CSLVG
890 WRITE (NPRNT,900) I,CSNEW(I),X,USLFE(I),CSOWN(I),CSOPR(I),CXTRA(I)
900 FORMAT (23X,I3,9X,'$',F9.2,' $',F7.1,5X,F5.1,'YRS $',F9.3,'/IN
      1HR $',F9.3,'PER',3X,'$',F9.3,'PER')
C
C*****NOW PRINT OUT INITIAL CONDITIONS IN THE LOGGING SYSTEM
C
      WRITE (NPRNT,910)
910 FORMAT (////15X,'SYSTEM DESCRIPTION IN TERMS OF SYSTEM CODES#//)
      WRITE (NPRNT,920) IDSYS,ILHLP,LDSYS,IWAIT,IBHLP,ITRUK
920 FORMAT (20X,'TYPE LOGGING SYSTEM = IDSYS =',I2,15X,'LOADINGIN
      1 HELP FROM BUCKER = ILHLP =',I2/20X,'TYPE LANDING SYSTEM
      2= LDSYS =',I2,15X,'DOES SKIDDER WAIT BUCKING = IWAIT =',I2/20X,'B
      3UCKER DELAY AT LANDING = IBHLP =',I2,15X,'TRUCK DOING OTHER HAULIN
      4LING = ITRUK =',I2/4//)
      WRITE (NPRNT,930)
930 FORMAT (15X,'SYSTEM STATE AT START OF SIMULATION#//)
      WRITE (NPRNT,940) ITREE,QUOTA1
940 FORMAT (20X,'NUMBER OF STANDING TREES = ITREE =',I5,15X,'INITIAL W
      1EEKLY QUOTA =QUOTA1 =',F7.1)
      WRITE (NPRNT,950) IVLWD,IVLRD,ISIWD,ISIRO,IPIWD,IPIRO
950 FORMAT (20X,'VOLUME READY FOR SKIDDING= IVLWD =',I5,15X,'VOLUME ATIN

```

Figure 35. (continued)

```

1 SKID ROAD      = IVLRD =*,15/20X,*TREES READY FOR SKIDDING = ISIWINTL 661
2D =*,15,15X,*TREES(SAWLOGS) AT ROAD = ISIRD =*,15/20X,*PULPWOOD INTL 662
3READY FOR SKID = IPIWD =*,15,15X,*PULPWOOD AT SKID ROAD = IPIRINTL 663
4D =*,15) INTL 664
WRITE (NPRNT,960) IVLHK(1),IVLHK(2),ISIRK(1),ISIRK(2) INTL 665
960 FORMAT (20X,*VOLUME TO BE BUCKED-LND 1= IVLHK =*,15,15X,*VOLUME TOINTL 666
1 BE BUCKED-LND 2= IVLHK =*,15/20X,*TREES TO BE BUCKED -LND 1= ISIBINTL 667
2K =*,15,15X,*TREES TO BE BUCKED -LND 2= ISIRK =*,15) INTL 668
WRITE (NPRNT,970) IPILE(1),IPLPC(1),IPILE(2),IPLPC(2) INTL 669
970 FORMAT (20X,*VOLUME TO BE PILED -LND 1= IPILE =*,15,15X,*VOLUME TOINTL 670
1 BE PILED -LND 2= IPILE =*,15/20X,*PIECES TO BE PILED -LND 1= IPLPINTL 671
2C =*,15,15X,*PIECES TO BE PILED -LND 2= IPLPC =*,15) INTL 672
WRITE (NPRNT,980) IVLLD(1),IVLLD(2),ISILD(1),ISILD(2),IPILD(1),IPIINTL 673
1LD(2) INTL 674
980 FORMAT (20X,*VOLUME TO BE LOADED-LND 1= IVLLD =*,15,15X,*VOLUME TOINTL 675
1 BE LOADED-LND 2= IVLLD =*,15/20X,*TREES TO BE LOADED -LND 1= ISILINTL 676
2D =*,15,15X,*TREES TO BE LOADED -LND 2= ISILD =*,15/20X,*PULPWD TOINTL 677
3 BE LOADED/LND 1= IPILD =*,15,15X,*PULPWD TO BE LOADED-LND 2= IPILINTL 678
4D =*,15///) INTL 679
C INTL 680
C INTL 681
1000 RETURN INTL 682
END INTL 683

```

Figure 35. (continued)

1	COMMON /SUBROUTINE STATE	1
2	COMMON /GCOM1/ ATTRIB(6) ,JEVNT,MFA,MFE(6) ,MLE(6) ,MSTOP,NCRDR,NSTAT	2
3	INAP0,NNAPT,NNATR,NNFIL,NNQ(6) ,NNTRY,NPRNT,PPARM(25,4),TNOW,ITHEG,STAT	3
4	2,TTCLR,TTFIN,TTIB(6) ,TTSET	4
5		5
6	COMMON /GCOM2/ DD(25),DDL(25) ,DTFUL,DTNOW,ISEES,LFLAG(1) ,NFLAG,STAT	6
7	1NNEQD,NNEQS,NNEQT,SS(25),SSL(25),TTNEX	7
8		8
9	COMMON /DATE/ BYR,BMO,XPY,XPM,XPW,XPD,XPH,IYR,IMO,ITP	9
10		10
11	----- . AREA CONSTANTS -----	11
12		12
13	TTR - TIME FOR BURNED AREA TO RETURN TO RANGE (YRS)	13
14	APHE - AVERAGE TIMBER ENCROACHMENT INTO RANGE (.% STEM HT/YR)	14
15	YRN - TIME FOR CLOSED ROADS TO RETURN TO NORMAL (YRS)	15
16	RCR - ROAD CONSTRUCTION RATE (ACRE/MO)	16
17	TA - TOTAL SYSTEM AREA (ACRES)	17
18		18
19	COMMON /AREAS/ TTR,APHE,YRN,RCR,TA,PAF	19
20		20
21	----- WATER CONSTANTS -----	21
22		22
23	SMC - SNOW MOISTURE CONTENT (IN-WATER/IN-SNOW)	23
24	BSMX - BURNED AREA FIELD CAPACITY (IN)	24
25	RSMX - RANGE AREA FIELD CAPACITY (IN)	25
26	FSMX - FOREST AREA FIELD CAPACITY (IN)	26
27	BNPR - BURNED AREA NORMAL PERCOLATION RATE (IN/MO)	27
28	FMCR - FORAGE MOISTURE CONSUMPTION RATE (IN/TON/MO)	28
29	RNPR - RANGE AREA NORMAL PERCOLATION RATE (IN/MO)	29
30	TMCR - TIMBER MOISTURE CONSUMPTION RATE (IN/CU-FT/MO)	30
31	FNPR - FOREST AREA NORMAL PERCOLATION RATE (IN/MO)	31
32	PFFM - PERCENT OF STORED WATER IN STREAMFLOW (.%/MO)	32
33	TSFM,TSFN,TSFX,TSFS - SNOW FALL PER MONTH (MEAN,MIN,MAX,STD.DEV.)	33
34	TSMH,TSMX,TSMS - PERCENT SNOW MELT PER MONTH (MEAN,MAX,STD.DEV.)	34
35	TRFM,TRFN,TRFX,TRFS - RAIN FALL PER MONTH (MEAN,MIN,MAX,STD.DEV.)	35
36	TUEM - MEAN EVAPORATION RATE PER MONTH	36
37		37
38	COMMON /MOIST/ SMC,BSMX,RSMX,FSMX,BNPR,FMCR,RNPR,TMCR,FNPR,PFFM,TS	38
39	1FM(12),TSFN(12),TSFX(12),TSFS(12),TSMH(12),TSMX(12),TSMS(12),TRFM	39
40	2(12),TRFN(12),TRFX(12),TRFS(12),TUEM(12)	40
41		41
42	----- FOREST CONSTANTS -----	42
43		43
44	BACC - BASAL AREA CARRYING CAPACITY (SQ FT/ACRE)	44
45	OSSD - OPTIMAL STOCKING STAND DENSITY (TREE/ACRE)	45
46	XSSR - MAXIMUM SEEDLING STOCKING RATIO (SEED TREES/TREE/YR)	46
47	DBA - AVERAGE BASAL AREA GROWTH INCREMENT (SQ-IN/YR)	47
48	DMX - MAXIMUM TREE DIAMETER (IN)	48
49	PVLL - PERCENT VOLUME OF LIVE TREE LOST PER YEAR (.%/YR)	49
50	WPFC - WEIGHT OF WOOD (LB/CU-FT)	50
51	PVOL - PERCENT VOLUME OF DEAD TREE LOST PER YEAR (.%/YR)	51
52		52
53		53
54		54
55		55

Figure 36. FORTRAN Source of Ecosystem Routine, STATE

C	PDPY - PERCENT TIMBER DECAY PER IN SURFACE WATER PER YEAR (.%/YR)	STAT 56
C	FLTR - ACRES OF FUEL TREATED PER MONTH (ACRES/MO)	STAT 57
C	AMRT - PERCENT ANNUAL TIMBER MORTALITY (.%/YR)	STAT 58
C	ATPL - PERCENT ANNUAL DEAD STEM TOPPLE RATE (.%/YR)	STAT 59
C		STAT 60
C	COMMON /FORST/ BACC,OSSD,XSSR,DBA,DMX,PVLL,WPCF,PVDL,PDPY,FLTR,AMR	STAT 61
C	IT,ATPL	STAT 62
C		STAT 63
C		STAT 64
C	----- RANGE CONSTANTS -----	STAT 65
C		STAT 66
C	TFRP - TIME FOR FORAGE LOAD TO REACH POTENTIAL (YR)	STAT 67
C	FCLM - LARGE ANIMAL FORAGE CONSUMPTION (LB/ANIMAL/MO)	STAT 68
C	FCSM - SMALL ANIMAL FORAGE CONSUMPTION (LB/ANIMAL/MO)	STAT 69
C	PFDY - PERCENT FORAGE DECAY PER IN SURFACE WATER PER YEAR (.%/YR)	STAT 70
C		STAT 71
C	COMMON /RANGE/ TFRP,FCLM,FCSM,PFDY	STAT 72
C		STAT 73
C		STAT 74
C	----- WILDLIFE CONSTANTS -----	STAT 75
C		STAT 76
C	AMPS - AVERAGE MEAT PER SMALL ANIMAL (LB/ANIMAL)	STAT 77
C	AMPL - AVERAGE MEAT PER LARGE ANIMAL (LB/ANIMAL)	STAT 78
C	SDM - MAXIMUM SMALL ANIMAL DENSITY (ACRES/ANIMAL)	STAT 79
C	CMC - CARNIVORE MEAT CONSUMPTION (LB/ANIMAL/MO)	STAT 80
C	CDM - MAXIMUM CARNIVORE DENSITY (ACRES/ANIMAL)	STAT 81
C	PCIR - MAXIMUM CARNIVORE BIRTH RATE (.%/YR)	STAT 82
C	PCDR - CARNIVORE DEATH RATE (.%/YR)	STAT 83
C	HDM - MAXIMUM HERBIVORE DENSITY (ACRES/ANIMAL)	STAT 84
C	PHIR - MAXIMUM HERBIVORE BIRTH RATE (.%/YR)	STAT 85
C	PHHK - PERCENT HUNTER KILL (.%/YR)	STAT 86
C	PHDR - HERBIVORE DEATH RATE (.%/YR)	STAT 87
C	PSIR - SMALL ANIMAL BIRTH RATE (.%/YR)	STAT 88
C	PSDR - SMALL ANIMAL DEATH RATE (.%/YR)	STAT 89
C		STAT 90
C	COMMON /WLDLF/ AMPS,AMPL,SDM,CMC,CDM,PCIR,PCDR,HDM,PHIR,PHHK,PHDR,	STAT 91
C	1PSIR,PSDR	STAT 92
C		STAT 93
C		STAT 94
C	----- EROSION CONSTANTS -----	STAT 95
C		STAT 96
C	EFF - EROSION FACTOR FOR FOREST AREA (IN-SOIL/IN-RUNOFF)	STAT 97
C	EFR - EROSION FACTOR FOR RANGE AREA (IN-SOIL/IN-RUNOFF)	STAT 98
C	EFB - EROSION FACTOR FOR BURNED AREA (IN-SOIL/IN-RUNOFF)	STAT 99
C	EFRD - EROSION FACTOR FOR ROADED AREA (IN-SOIL/IN-RUNOFF)	STAT 100
C		STAT 101
C	COMMON /EROSN/ EFF,EFR,EFB,EFRD	STAT 102
C		STAT 103
C		STAT 104
C	----- STATE VARIABLES -----	STAT 105
C		STAT 106
C	IACT - SWITCH SET .TRUE. WHEN ACTIVITY OCCURES	STAT 107
C	IBM - BEGINNING MONTH OF GROWING SEASON	STAT 108
C	IEM - ENDING MONTH OF GROWING SEASON	STAT 109
C	GRMO - NUMBER OF MONTHS IN GROWING SEASON	STAT 110

Figure 36. (continued)

C	PI - CONSTANT (3.14)	STAT 111
C	ACRE - CONSTANT SQ-FT PER ACRE (43560)	STAT 112
C		STAT 113
C	COMMON /STVBL/ IACT,IBM,IEM,GRMO,PI,ACRE	STAT 114
C		STAT 115
C	EQUIVALENCE (SSL(1),BAO),(SSL(2),RAO),(SSL(3),FAO),(SSL(4),RDAO),(SSL(5),CRAO)	STAT 116
C		STAT 117
C	EQUIVALENCE (SSL(6),SPO),(SSL(7),SWO),(SSL(8),RSMO),(SSL(9),RSMO),	STAT 118
C	1(SSL(10),FSMO),(SSL(11),STWO)	STAT 119
C		STAT 120
C	EQUIVALENCE (SSL(12),GSO),(SSL(13),SDO),(SSL(14),DBHO),(SSL(15),AF	STAT 121
C	ILO)	STAT 122
C		STAT 123
C	EQUIVALENCE (SSL(16),XLFO),(SSL(17),DFO)	STAT 124
C		STAT 125
C	EQUIVALENCE (SSL(18),CANO),(SSL(19),SANO),(SSL(20),HANO)	STAT 126
C		STAT 127
C	EQUIVALENCE (SSL(21),SLO)	STAT 128
C		STAT 129
C	EQUIVALENCE (SS(22),TTV)	STAT 130
C		STAT 131
C	DATA PI,ACRE,XMPY/3.14159265358979,43560.0,12.0/	STAT 132
C		STAT 133
C		STAT 134
C	LOGICAL IGRO,IACT	STAT 135
C		STAT 136
C		STAT 137
C	IF (DTNOW.LE.0.0) RETURN	STAT 138
C	TEMP=DTNOW	STAT 139
C	DTNOW=DTNOW/XPM	STAT 140
C	CALL CTME	STAT 141
C	IGRO=.FALSE.	STAT 142
C	IF (IMO.GE.IBM.AND.IMO.LE.IEM) IGRO=.TRUE.	STAT 143
C		STAT 144
C	*** DETERMINE TIMBER CHARACTERISTICS	STAT 145
C		STAT 146
C		STAT 147
C	DBHO - AVERAGE STAND DBH (IN)	STAT 148
C	AHT - AVERAGE STEM HEIGHT (FT)	STAT 149
C	VPT - AVERAGE VOLUME PER TREE (CU-FT)	STAT 150
C		STAT 151
C	VPT=VOLPT(DBHO,AHT)	STAT 152
C		STAT 153
C		STAT 154
C	***** AREA SYSTEM *****	STAT 155
C	=====	STAT 156
C		STAT 157
C	*** AUXILARY EQUATIONS	STAT 158
C		STAT 159
C	PAB - PERCENT AREA BURNED (.)	STAT 160
C	PAR - PERCENT AREA RANGE (.)	STAT 161
C	PAF - PERCENT AREA FOREST (.)	STAT 162
C	PAU - PERCENT UNPRODUCTIVE AREA (.)	STAT 163
C	AER - TIMBER ENCROACHMENT INTO RANGE (FT/YR)	STAT 164
C	ASE - AREA OF SEEDLING ESTABLISHMENT (ACRES)	STAT 165

Figure 36. (continued)

C	TBPA - TOTAL BIOMASS PRODUCTIVE AREA (ACRES)	STAT 166
C	PRF - PERCENT OF BIOMASS AREA RANGE (.%)	STAT 167
C		STAT 168
	PAB=BAO/TA	STAT 169
	PAR=RAO/TA	STAT 170
	PAF=FAO/TA	STAT 171
	PAU=1.0-(BAO*RAO+FAO)/TA	STAT 172
	AER=AHT*APHE	STAT 173
	ASE=0.0	STAT 174
	IF (IGRO) ASE=PAF*PI*(AER/GRMO)*(2.0*SQRT(RAO*ACRE/PI))-AER*AER/GRM	STAT 175
	10)/ACRE*DTNOW	STAT 176
	IF (ASE.GT.RAO) ASE=RAO	STAT 177
	TBPA=FAO+RAO	STAT 178
	PRF=RAO/TBPA	STAT 179
C		STAT 180
C	*** RATE EQUATIONS	STAT 181
C		STAT 182
C	BTRR - BURNED TO RANGE RATE	STAT 183
C	RTFR - RANGE TO FOREST RATE (ACRES/MO)	STAT 184
C	RTRR - RANGE TO ROAD RATE (ACRES/MO)	STAT 185
C	CTRR - CLOSED ROAD TO RANGE RATE (ACRES/MO)	STAT 186
C	FTRR - FOREST TO ROAD RATE (ACRES/MO)	STAT 187
C		STAT 188
	BTRR=0.0	STAT 189
	IF (IGRO) BTRR=BAO/(TTR*GRMO)	STAT 190
	RTFR=ASE/DTNOW	STAT 191
	RTRR=PRF*RCR	STAT 192
	CTRR=0.0	STAT 193
	IF (IGRO) CTRR=CRAO/(YRN*GRMO)	STAT 194
	FTRR=PRF*RCR	STAT 195
C		STAT 196
C	*** STATE EQUATIONS	STAT 197
C		STAT 198
C	(1) - BURNED AREA (ACRES)	STAT 199
C	(2) - RANGE AREA (ACRES)	STAT 200
C	(3) - FOREST AREA (ACRES)	STAT 201
C	(4) - ROAD AREA (ACRES)	STAT 202
C	(5) - CLOSED ROAD AREA (ACRES)	STAT 203
C		STAT 204
	SS(1)=RAO-BTRR*DTNOW	STAT 205
	SS(2)=RAO*(BTRR-RTFR-RTRR+CTRR)*DTNOW	STAT 206
	IF (SS(2).LT.0.0) SS(2)=1.0	STAT 207
	SS(3)=FAO*(RTFR-FTRR)*DTNOW	STAT 208
	SS(4)=RDAO*(RTRR+FTRR)*DTNOW	STAT 209
	SS(5)=CRAO-CTRR*DTNOW	STAT 210
C		STAT 211
C		STAT 212
C	***** MOISTURE-WATER SYSTEM *****	STAT 213
C	=====	STAT 214
C		STAT 215
C	*** AUXILIARY EQUATIONS	STAT 216
C		STAT 217
C	BAAM - BURNED AREA ABSORBED MOISTURE (IN)	STAT 218
C	RAAM - RANGE AREA ABSORBED MOISTURE (IN)	STAT 219
C	FAAM - FOREST AREA ABSORBED MOISTURE (IN)	STAT 220

Figure 36. (continued)

C	EVAP - EVAPORATION RATE (IN/MO)	STAT 221
C	EVPM - EVAPORATION MOISTURE (IN)	STAT 222
C	EARF - EFFECTIVE AREA OF RANGE IN FOREST (ACRES)	STAT 223
C	PFFA - PERCENT OF FORAGE IN FOREST AREA (%)	STAT 224
C	RBC - RANGE BIOMASS MOISTURE CONSUMPTION (IN)	STAT 225
C	TTV - TOTAL TIMBER VOLUME (CU-FT)	STAT 226
C	FBC - FOREST BIOMASS CONSUMPTION (IN)	STAT 227
C		STAT 228
	BAAM=AMAX1(0.0,AMIN1(BSMX,SWO)-BSMO)	STAT 229
	RAAM=AMAX1(0.0,AMIN1(RSMX,SWO)-RSMO)	STAT 230
	FAAM=AMAX1(0.0,AMIN1(FSMX,SWO)-FSMO)	STAT 231
	EVAP=RNORM(17,3)	STAT 232
	EVPM=AMAX1(0.0,AMIN1(EVAP*DTNOW,SWO))	STAT 233
	EARF=AMAX1(0.0,FAO-GSO*PI/ACRE*((AHT*0.1)**2.0))*EXP(-0.5*(AFLO/	STAT 234
	1 FAO)**2.0)	STAT 235
	PFFA=EARF/(EARF+RAO)	STAT 236
	RBC=AMIN1(RSMO,(XLFO*(1.0-PFFA)*FMCR/RAO)*DTNOW)	STAT 237
	TTV=VPT*GSO	STAT 238
	FBC=AMIN1(FSMO,TMCR*TTV*DTNOW+PFFA*XLFO*FMCR)	STAT 239
		STAT 240
C	*** RATE EQUATIONS	STAT 241
C		STAT 242
C	SFR - SNOW FALL RATE (IN/MO)	STAT 243
C	SMR - SNOW MELT RATE (IN/MO)	STAT 244
C	RFR - RAIN FALL RATE (IN/MO)	STAT 245
C	SMWR - SNOW MELT RATE (IN-WATER/MO)	STAT 246
C	BAR - BURNED AREA SOIL ABSORPTION RATE (IN/MO)	STAT 247
C	BRR - BURNED AREA RUNOFF RATE (IN/MO)	STAT 248
C	RAR - RANGE AREA SOIL ABSORPTION RATE (IN/MO)	STAT 249
C	RRR - RANGE AREA RUNOFF RATE (IN/MO)	STAT 250
C	FAR - FOREST AREA SOIL ABSORPTION RATE (IN/MO)	STAT 251
C	FRR - FOREST AREA RUNOFF RATE (IN/MO)	STAT 252
C	EVR - UNPRODUCTIVE AREA EVAPORATION RATE (IN/MO)	STAT 253
C	URR - UNPRODUCTIVE AREA RUNOFF RATE (IN/MO)	STAT 254
C	ROR - TOTAL RUNOFF RATE (IN/MO)	STAT 255
C	SAR - SOIL ABSORPTION RATE (IN/MO)	STAT 256
C	BPR - BURNED SOIL PERCOLATION RATE (IN/MO)	STAT 257
C	RBCR - RANGE BIOMASS CONSUMPTION RATE (IN/MO)	STAT 258
C	RPR - RANGE PERCOLATION RATE (IN/MO)	STAT 259
C	FBCR - FOREST BIOMASS CONSUMPTION RATE (IN/MO)	STAT 260
C	FPR - FOREST PERCOLATION RATE (IN/MO)	STAT 261
C	ROAR - RUNOFF RATE (ACRE-IN/MO)	STAT 262
C	STF - STREAM FLOW (ACRE-IN/MO)	STAT 263
C		STAT 264
	SFR=RNORM(14,4)	STAT 265
	SMR=RNORM(15,5)*SPO	STAT 266
	RFR=RNORM(16,6)	STAT 267
	SMWR=SMR*SMC	STAT 268
	BAR=BAAM/DTNOW	STAT 269
	BRR=(SWO-BAAM)/DTNOW	STAT 270
	RAR=RAAM/DTNOW	STAT 271
	RRR=(SWO-RAAM)/DTNOW	STAT 272
	FAR=FAAM/DTNOW	STAT 273
	FRR=(SWO-FAAM)/DTNOW	STAT 274
	EVR=EVPM*PAU/DTNOW	STAT 275

Figure 36. (continued)

URR=(SWO-EVPM)/DTNOW	STAT 276
ROR=BRR*PAB+RRR*PAR+FRF*PAF+URR*PAU	STAT 277
SAR=BAR*PAB+RAR*PAR+FAF*PAF	STAT 278
BPR=BNPR	STAT 279
IF (BSMO-BNPR*DTNOW.LT.0.0) BPR=BSMO/DTNOW	STAT 280
RBCR=RBC/DTNOW	STAT 281
RPR=(RSMO-RBC)/DTNOW	STAT 282
IF (RPR.GT.RNPR) RPR=RNPR	STAT 283
FBCR=FBC/DTNOW	STAT 284
FPR=(FSMO-FBC)/DTNOW	STAT 285
IF (FPR.GT.FNPR) FPR=FNPR	STAT 286
ROAR=ROR*TA	STAT 287
STF=STWO*PFPM	STAT 288
C *** STATE EQUATIONS	STAT 289
C	STAT 290
C (6) - SNOW PACK (IN)	STAT 291
C (7) - SURFACE WATER (IN)	STAT 292
C (8) - BURNED SOIL MOISTURE (IN)	STAT 293
C (9) - RANGE SOIL MOISTURE (IN)	STAT 294
C (10) - FOREST SOIL MOISTURE (IN)	STAT 295
C (11) - STORED WATER (ACRE-IN)	STAT 296
C	STAT 297
SS(6)=SPO*(SFR-S*MR)*DTNOW	STAT 298
SS(7)=SWO*(SMWR+RFR-SAR-EVR-ROR)*DTNOW	STAT 299
SS(8)=BSMO*(BAR-BPR)*DTNOW	STAT 300
IF (PAB.LE.0.0) SS(8)=0.0	STAT 301
SS(9)=RSMO*(RAR-RAC-RPR)*DTNOW	STAT 302
SS(10)=FSMO*(FAR-FBCR-FPR)*DTNOW	STAT 303
SS(11)=STWO*(ROAR-STF)*DTNOW	STAT 304
C	STAT 305
C	STAT 306
C ***** TIMBER SYSTEM *****	STAT 307
C =====	STAT 308
C	STAT 309
C *** AUXILIARY EQUATIONS	STAT 310
C	STAT 311
C BASA - AVERAGE BASAL AREA (SQ-IN/TREE)	STAT 312
C PCC - POTENTIAL TREE CARRYING CAPACITY (STEMS)	STAT 313
C SSR - SEEDLING STOCKING RATIO	STAT 314
C	STAT 315
BASA=PI*DBH0*DBH0/4.0	STAT 316
PCC=BACC*144.0*FA0/BASA	STAT 317
SSR=0.0	STAT 318
IF (IGR0) SSR=OSS0*ASE/GS0+AMIN1(XSSR/GRMO*AMAX1(0.0,((PCC-GS0)/(GSTAT	STAT 319
1RMO*5.0)/GS0))*DTNOW)	STAT 320
C	STAT 321
C *** RATE EQUATIONS	STAT 322
C	STAT 323
C SER - SEEDLING ESTABLISHMENT RATE (STEMS/MO)	STAT 324
C TDR - TREE DEATH RATE (STEMS/MO)	STAT 325
C TR - TREE TOPPLE RATE (STEMS/MO)	STAT 326
C ADG - DIAMETER GROWTH RATE (IN/MO)	STAT 327
C ADD - AVERAGE DIAMETER DECREASE RATE (IN/MO)	STAT 328
C FLAR - FUEL ACCUMILATION RATE (TON/YR)	STAT 329
C	STAT 330

Figure 36. (continued)

C	FLDR - FUEL DECAY RATE (TON/YR)	STAT 331
C	FTR - FUEL TREATMENT RATE (TON/YR)	STAT 332
C		STAT 333
	SER=SSR*GSO/DTNOW	STAT 334
	TDR=AMRT/XMPY*GSO*AMAX1(0.0,(GSO-PCC)/2.0)	STAT 335
	TR=SDO*ATPL/XMPY	STAT 336
	ADG=0.0	STAT 337
	IF (IGRO) ADG=SQRT((BASA+DBA/GRMO)/PI)*2.0-DBHO	STAT 338
	ADD=(DBHO-(DBHO+SSR)/(1.0+SSR))/DTNOW	STAT 339
	FLAR=0.0	STAT 340
	IF (.NOT.IGRO) FLAR=GSO*PVLL/(XMPY-GRMO)	STAT 341
	FLAR=(FLAR+SDO*PVDL/XMPY)*VPT*WPCF+TR*VPT	STAT 342
	FLDR=0.0	STAT 343
	IF (IGRO) FLDR=AFLO*PDY*SWO/GRMO	STAT 344
	FTR=FLTR/FAO*AFLO	STAT 345
C		STAT 346
C	*** STATE EQUATIONS	STAT 347
C		STAT 348
C	(12) - NUMBER OF GROWING STEMS (STEMS)	STAT 349
C	(13) - NUMBER OF STANDING DEAD STEMS (STEMS)	STAT 350
C	(14) - AVERAGE STEM DIAMETER (IN)	STAT 351
C	(15) - TOTAL TIMBER FUEL LOAD (TONS)	STAT 352
C	(22) - TOTAL TIMBER VOLUME (CU-FT)	STAT 353
C		STAT 354
	SS(12)=GSO*(SER-TDR)*DTNOW	STAT 355
	SS(13)=SDO*(TDR-TR)*DTNOW	STAT 356
	SS(14)=DBHO*(ADG-ADD)*DTNOW	STAT 357
	SS(15)=AFLO*(FLAR-FLDR-FTR)*DTNOW	STAT 358
C		STAT 359
C	***** RANGE-FORAGE SYSTEM *****	STAT 360
C	=====	STAT 361
C		STAT 362
C		STAT 363
C	*** AUXILIARY EQUATIONS	STAT 364
C		STAT 365
C	PLFL - POTENTIAL LIVE FORAGE LOAD (TON)	STAT 366
C	AFC - ANIMAL FORAGE CONSUMPTION (TON/MO)	STAT 367
C		STAT 368
	PLFL=0.0	STAT 369
	IF (IGRO) PLFL=(RSMO*HAO/FMCR+EARF*FSMO/FMCR)*DTNOW	STAT 370
	AFC=FCLM*HANO+FCSM*SANO	STAT 371
C		STAT 372
C	*** RATE EQUATIONS	STAT 373
C		STAT 374
C	FGR - FORAGE GROWTH RATE (TON/MO)	STAT 375
C	FDR - FORAGE DEATH RATE (TON/MO)	STAT 376
C	FLCR - ANIMAL LIVE FORAGE CONSUMPTION RATE (TON/MO)	STAT 377
C	FDCR - ANIMAL DEAD FORAGE CONSUMPTION RATE (TON/MO)	STAT 378
C	XNDR - FORAGE DECAY RATE (TON/MO)	STAT 379
C		STAT 380
	FGR=0.0	STAT 381
	IF (IGRO) FGR=AMAX1(0.0,(PLFL-XLFO)/(TFRP*GRMO))	STAT 382
	FDR=AMAX1(0.0,(XLFO-PLFL)/DTNOW)	STAT 383
	FLCR=AMINI(AFC,XLFO/DTNOW-FDR)	STAT 384
	FDCR=AMINI((AFC-FLCR),DFO/DTNOW)	STAT 385

Figure 36. (continued)

	XNDR=0.0	STAT 386
	IF (IGRO) XNDR=(DFO-FDCR*DTNOW)*PFDY*SWO/GRMO	STAT 387
C	*** STATE EQUATIONS	STAT 388
C		STAT 389
C	(16) - LIVE FORAGE LOAD (TON)	STAT 390
C	(17) - DEAD FORAGE LOAD (TON)	STAT 391
C		STAT 392
	SS(16)=XLFO*(FGR-FDR-FLCR)*DTNOW	STAT 393
	SS(17)=DFO*(FDR-FDCR-XNDR)*DTNOW	STAT 394
C		STAT 395
C		STAT 396
C	***** WILDLIFE SYSTEM *****	STAT 397
C	=====	STAT 398
C		STAT 399
C	*** AUXILIARY EQUATIONS	STAT 400
C		STAT 401
C	ASM - SMALL ANIMAL MEAT (LB)	STAT 402
C	ALM - LARGE ANIMAL MEAT (LB)	STAT 403
C	PSAM - PERCENT OF MEAT IN SMALL ANIMALS (%)	STAT 404
C		STAT 405
C	DSF - DISTURBANCE FACTOR	STAT 406
C	TFA - TOTAL FORAGE AVAILABLE (TON)	STAT 407
C	SCI - SECURITY INDEX	STAT 408
C	PSCC - POTENTIAL SMALL ANIMAL CARRYING CAPACITY (ANIMALS)	STAT 409
C	PCCC - POTENTIAL CARNIVORE CARRYING CAPACITY (ANIMALS)	STAT 410
C	PHCC - POTENTIAL HERBIVORE CARRYING CAPACITY (ANIMALS)	STAT 411
C	CMCR - CARNIVORE MEAT CONSUMPTION (LB/MO)	STAT 412
C	ASCR - SMALL ANIMALS CONSUMED (ANIMALS)	STAT 413
C	ALCR - LARGE ANIMALS CONSUMED (ANIMALS)	STAT 414
C		STAT 415
	ASM=SANO*AMPS	STAT 416
	ALM=HANO*AMPL	STAT 417
	IF (ASM+ALM.EQ.0.0) GO TO 10	STAT 418
	PSAM=ASM/(ASM+ALM)	STAT 419
	GO TO 20	STAT 420
10	PSAM=0.0	STAT 421
20	DSF=(1.0-RDAO/(RDAO+FAO))	STAT 422
	IF (IACT) DSF=DSF*(1.0-EXP(-0.5*(FAO/2400.0)**2.0))	STAT 423
	TFA=XLFO+DFO	STAT 424
	SCI=1.0-(1.0-PAF)**2.0	STAT 425
	PSCC=AMINI(TBPA/SDM,(TFA/2.0-HANO*FCLM*DTNOW)/(FCSM*DTNOW))	STAT 426
1	*DSF	STAT 427
	IF (PSCC.LT.0.0) PSCC=0.0	STAT 428
	PCCC=AMINI(TBPA/CDM,(ASM+ALM)*0.5/(CMC*DTNOW))*DSF*SCI	STAT 429
	IF (PCCC.LT.0.0) PCCC=0.0	STAT 430
	PHCC=AMINI(TBPA/HDM,(TFA/2.0-SANO*FCSM*DTNOW)/(FCLM*DTNOW))*DSF	STAT 431
1	*SCI	STAT 432
	IF (PHCC.LT.0.0) PHCC=0.0	STAT 433
	CMCR=CMC*CANO	STAT 434
	ASCR=CMCR*PSAM/AMPS	STAT 435
	ALCR=CMCR*(1.0-PSAM)/AMPL	STAT 436
	IF (ALCR.LE.HANO*PHDR/XMPY) GO TO 30	STAT 437
	ALCR=AMINI(ALCR,HANO*(PHIR-PHHK)/XMPY)	STAT 438
	ASCR=(CMCR-ALCR*AMPL)/AMPS	STAT 439
30	CONTINUE	STAT 440

Figure 36. (continued)

```

C
C *** RATE EQUATIONS
C
C   CIR - CARNIVORE INCREASE RATE (ANIMALS/MO)
C   CDR - CARNIVORE DECREASE RATE (ANIMALS/MO)
C   SIR - SMALL ANIMAL INCREASE RATE (ANIMALS/MO)
C   SDR - SMALL ANIMAL DECREASE RATE (ANIMALS/MO)
C   HIR - HERBIVORE INCREASE RATE (ANIMALS/MO)
C   HDR - HERBIVORE DECREASE RATE (ANIMALS/MO)
C
C   CIR=AMAX1(PCCC*0.001,AMINI(CANO*PCIR,PCCC-CANO)/XMPY)
C   CDR=CANO*PCDR/XMPY+AMAX1(0.0,(CANO-PCCC)/XMPY)
C   IF (CDR*DTNOW.GT.CANO) CDR=CANO/DTNOW
C   SIR=0.0
C   IF (IGRO) SIR=AMAX1(PSCC*0.001,AMINI(SANO*PSIR,PSCC-SANO)/GRMO)
C   SDR=AMAX1(0.0,(SANO-PSCC)/XMPY)+AMAX1(SANO*PSDR/XMPY,ASCR)
C   IF (SDR*DTNOW.GT.SANO) SDR=SANO/DTNOW
C   HIR=AMAX1(PHCC*0.01,AMINI(HANO*PHIR,PHCC-HANO)*0.15)
C   IF (IMO.LT.2.OR.IMO.GT.3) HIR=HIR*0.1333333333
C   HDR=AMAX1(0.0,(HANO-PHCC)/XMPY)+AMAX1(HANO*PHDR/XMPY,ALCR)
C   IF (IMO.GE.9.AND.IMO.LE.10) HDR=HDR*(HANO-HDR*DTNOW)*PHHK/2.0
C   IF (HDR*DTNOW.GT.HANO) HDR=HANO/DTNOW
C
C *** STATE EQUATIONS
C
C   (18) - NUMBER OF CARNIVORE (ANIMALS)
C   (19) - NUMBER OF SMALL ANIMALS (ANIMALS)
C   (20) - NUMBER OF LARGE HERBIVORE (ANIMALS)
C
C   SS(18)=CANO*(CIR-CDR)*DTNOW
C   SS(19)=SANO*(SIR-SDR)*DTNOW
C   SS(20)=HANO*(HIR-HDR)*DTNOW
C
C
C   *****      EROSION SYSTEM      *****
C   =====
C
C *** AUXILIARY EQUATIONS
C
C   FAE - FOREST AREA EROSION RATE (ACRE-IN/MO)
C   RAE - RANGE AREA EROSION RATE (ACRE-IN/MO)
C   BAE - BURN AREA EROSION RATE (ACRE-IN/MO)
C   RDE - ROAD AREA EROSION RATE (ACRE-IN/MO)
C
C   FAE=FRR*EFF*FAO
C   RAE=RRR*EFR*RAO
C   BAE=BBR*EFB*BAO
C   RDE=URR*EFRD*(KDAO+CRAO)
C
C *** RATE EQUATION
C
C   ERR - EROSION RATE (ACRE-IN/MO)
C
C   ERR=FAE+RAE+BAE+RDE+RCH
C

```

```

STAT 441
STAT 442
STAT 443
STAT 444
STAT 445
STAT 446
STAT 447
STAT 448
STAT 449
STAT 450
STAT 451
STAT 452
STAT 453
STAT 454
STAT 455
STAT 456
STAT 457
STAT 458
STAT 459
STAT 460
STAT 461
STAT 462
STAT 463
STAT 464
STAT 465
STAT 466
STAT 467
STAT 468
STAT 469
STAT 470
STAT 471
STAT 472
STAT 473
STAT 474
STAT 475
STAT 476
STAT 477
STAT 478
STAT 479
STAT 480
STAT 481
STAT 482
STAT 483
STAT 484
STAT 485
STAT 486
STAT 487
STAT 488
STAT 489
STAT 490
STAT 491
STAT 492
STAT 493
STAT 494
STAT 495

```

Figure 36. (continued)

C *** STATE EQUATION	STAT 496
C	STAT 497
C (21) - EROSION (ACRE-IN)	STAT 498
C	STAT 499
SS(21)=SLO*ERR*DTNOW	STAT 500
C	STAT 501
C	STAT 502
DTNOW=TEMP	STAT 503
C	STAT 504
RETURN	STAT 505
C	STAT 506
END	STAT 507

Figure 36. (continued)

```
FUNCTION VOLPT(DBH,HT)
  IF (DBH.LT.2.0) GO TO 20
  HT=-38.4256+37.0809*(DBH**0.4167)
  GO TO 30
20 HT=5.0
30 VOLPT=(0.001714*DBH+0.003865)*DBH*HT
  RETURN
END
```

VOLP	1
VOLP	2
VOLP	3
VOLP	4
VOLP	5
VOLP	6
VOLP	7
VOLP	8

Figure 37. FORTRAN Source of Tree Volume Routine, VOLPT


```

SUBROUTINE CTME
C
COMMON /GCOM1/ ATRIB(6) ,JEVNT,MFA,MFE(6) ,MLE(6) ,MSTOP,NCRDR,NCTME
INAPD,NNAPT,NNATR,NNFIL,NNQ(6) ,NNTRY,NPRNT,PPARM(25,4),TNO*,TTREGCTME
2,TTCLR,TTFIN,TTIRH(6) ,TTSET
C
COMMON /MOIST/ SMC,B54X,RSMX,FSMX,BNPR,FMCR,RNPR,TMCR,FNPR,PFPN,TSC
IFM(12),TSFN(12),TSFX(12),TSFS(12),TSMH(12),TSMX(12),TSM5(12),TRFM(
212),TRFN(12),TRFX(12),TRFS(12),TUEM(12)
C
COMMON /DATE/ BYR,BMO,XPY,XPM,XPW,XPD,XPH,IYR,IMO,ITP
C
DATA XPY,XPM,XPW,XPD,XPH/525960.0,43830.0,10080.0,1440.0,60.0/
C
DATA IML/0/
C *** DETERMINE YEAR AT TIME TNOW
C
X=TNOW*(BMO-1.0)*XPM
IYR=BYR+X/XPY
C
C *** DETERMINE MONTH AT TIME TNOW
C
IMO=(X-(FLOAT(IYR)-BYR)*XPY)/XPM+1.01
C
IF (IMO.EQ.IML) RETURN
IML=IMO
C *** SET SNOW FALL PARAMETERS
C
PPARM(14,1)=TSFM(IMO)
PPARM(14,2)=TSFN(IMO)
PPARM(14,3)=TSFX(IMO)
PPARM(14,4)=TSFS(IMO)
C
C *** SET SNOW MELT PARAMETERS
C
PPARM(15,1)=TSMH(IMO)
PPARM(15,2)=0.0
PPARM(15,3)=TSMX(IMO)
PPARM(15,4)=TSM5(IMO)
C
C *** SET RAIN FALL PARAMETERS
C
PPARM(16,1)=TRFM(IMO)
PPARM(16,2)=TRFN(IMO)
PPARM(16,3)=TRFX(IMO)
PPARM(16,4)=TRFS(IMO)
C
C *** SET EVAPORATION PARAMETERS
C
PPARM(17,1)=TUEM(IMO)
PPARM(17,2)=0.0
PPARM(17,3)=2.0*TUEM(IMO)
PPARM(17,4)=TUEM(IMO)
C
RETURN
C
END

```

Figure 38. FORTRAN Source of Time Conversion and Parameter Setting Routine, CTME

	SUBROUTINE FIRE	FIRE 1
C	COMMON /GCOM2/ DN(25),DOL(25), DTFUL,DTNOW,ISEES,LFLAG(1),NFLAG,FIRE	FIRE 2
	INNEQD,NNEUS,NNEQT,SS(25),SSL(25),TTNEX	FIRE 3
C	COMMON /AREAS/ TTR,APHE,YRN,RCR,TA,PAF	FIRE 4
	COMMON /STVBL/ IACT,IBM,IEM,GPMO,PI,ACRE	FIRE 5
C	COMMON /DATE/ BYR,BMO,XPY,XPM,XPW,XPD,XPH,IYR,IMO,ITP	FIRE 6
	----- FIRE CONSTANTS -----	FIRE 7
C	ABRN - TOTAL AREA BURNED (ACRES)	FIRE 8
C	ASPR - AREA OF SUPPRESSION ROADS CONSTRUCTED (ACRES)	FIRE 9
C	PTLS - PERCENT OF BURNED STEMS LEFT STANDING (.%)	FIRE 10
C	COMMON /FIRES/ ABRN,ASPR,PTLS	FIRE 11
	***** FIRE SYSTEM *****	FIRE 12
C	=====	FIRE 13
C	*** AUXILIARY EQUATIONS	FIRE 14
C	PRF - PERCENT OF BIPRODUCTIVE AREA RANGE (.%)	FIRE 15
C	ARGB - AREA OF RANGE BURNED (ACRES)	FIRE 16
C	ARTR - AREA OF RANGE TO SUPPRESSION ROADS (ACRES)	FIRE 17
C	AFSB - AREA FOREST BURNED (ACRES)	FIRE 18
C	AFTR - AREA FOREST TO SUPPRESSION ROADS (ACRES)	FIRE 19
C	TPAL - TREES PER ACRE LIVE (TREE/ACRE)	FIRE 20
C	TPAD - TREES PER ACRE DEAD (TREE/ACRE)	FIRE 21
C	FLPA - TIMBER FUEL LOAD PER ACRE (TON/ACRE)	FIRE 22
C	VPT - VOLUME PER TREE (CU-FT/TREE)	FIRE 23
C	AHT - AVERAGE TREE HEIGHT (FT)	FIRE 24
C	EARF - EFFECTIVE AREA OF RANGE IN FOREST (ACRES)	FIRE 25
C	PFAL - PERCENT EFFECTIVE FORAGE AREA LOST (.%)	FIRE 26
C	PANL - PERCENT ANIMALS LOST (.%)	FIRE 27
C	PRF=SS(2)/(SS(2)+SS(3))	FIRE 28
	ARGB=ABRN*PRF	FIRE 29
	ARTR=ASPR*SS(2)/TA	FIRE 30
	PRF=SS(2)/(SS(2)+SS(3))	FIRE 31
	AFSB=ABRN*(1.0-PRF)	FIRE 32
	AFTR=ASPR*PAF	FIRE 33
	TPAL=SS(12)/SS(3)	FIRE 34
	TPAD=SS(13)/SS(3)	FIRE 35
	FLPA=SS(15)/SS(3)	FIRE 36
	VPT=VOLPT(SS(14),AHT)	FIRE 37
	EARF=AMAX1(0.0,SS(3)-SS(12)*PI/ACRE*((AHT*0.1)**2.0))*	FIRE 38
	1 EXP(-0.5*(SS(15)/SS(3))**2.0)	FIRE 39
	PFAL=(ARGB+ARTR+EARF/SS(3))*(AFSB+AFTR)/(EARF+SS(2))	FIRE 40
	PANL=1.0-EXP(-(3.5*ABRN+ASPR/TA)**2.0)	FIRE 41
C		FIRE 42
		FIRE 43
		FIRE 44
		FIRE 45
		FIRE 46
		FIRE 47
		FIRE 48
		FIRE 49
		FIRE 50
		FIRE 51
		FIRE 52
		FIRE 53
		FIRE 54
		FIRE 55

Figure 39. FORTRAN Source of Fire Routine, FIRE

C *** STATE EQUATIONS	FIRE 56
C	FIRE 57
C (1) - BURNED AREA (ACRES)	FIRE 58
C (2) - RANGE AREA (ACRES)	FIRE 59
C (3) - FOREST AREA (ACRES)	FIRE 60
C (5) - CLOSED ROAD AREA (ACRES)	FIRE 61
C (8) - BURNED SOIL MOISTURE (IN)	FIRE 62
C (12) - NUMBER OF GROWING STEMS (TREES)	FIRE 63
C (13) - NUMBER OF STANDING DEAD STEMS (TREES)	FIRE 64
C (15) - TIMBER OF FUEL LOAD (TONS)	FIRE 65
C (16) - LIVE FORAGE LOAD (TONS)	FIRE 66
C (17) - DEAD FORAGE LOAD (TONS)	FIRE 67
C (18) - NUMBER OF CARNIVORE (ANIMALS)	FIRE 68
C (19) - NUMBER OF SMALL ANIMALS (ANIMALS)	FIRE 69
C (20) - NUMBER OF HERBIVORE (ANIMALS)	FIRE 70
C (21) - EROSION (ACRE-IN)	FIRE 71
C	FIRE 72
SS(1)=SS(1)+ABRN	FIRE 73
SS(2)=SS(2)-ARGB-ARTR	FIRE 74
SS(3)=SS(3)-AFSB-AFTR	FIRE 75
SS(5)=SS(5)+ASPR	FIRE 76
SS(8)=(SS(9)*ARGB+SS(10)*AFSB)/ABRN	FIRE 77
SS(12)=SS(12)-TPAL*(AFSB+AFTR)	FIRE 78
SS(13)=SS(13)-TPAD*(AFSB+AFTR)+(TPAL+TPAD)*AFSB*PTLS	FIRE 79
SS(15)=SS(15)-FLPA*AFSB	FIRE 80
SS(16)=SS(16)-SS(16)*PFAL	FIRE 81
SS(17)=SS(17)-SS(17)*PFAL	FIRE 82
SS(18)=SS(18)-SS(18)*PANL	FIRE 83
SS(19)=SS(19)-SS(19)*PANL	FIRE 84
SS(20)=SS(20)-SS(20)*PANL	FIRE 85
SS(21)=SS(21)+ABRN*0.1+ASPR	FIRE 86
C	FIRE 87
ITP=4	FIRE 88
C	FIRE 89
RETURN	FIRE 90
C	FIRE 91
END	FIRE 92

Figure 39. (continued)


```

SUBROUTINE ROADBLD
COMMON /GCOM1/ ATRIB(6) ,JEVNT,MFA,MFE(6) ,MLE(6) ,MSTOP,NCRDR,NROAD
1NAPO,NNAPT,NNATR,NNFIL,NNQ(6) ,NNTRY,NPRNT,PPARM(25,4),TNOW,TTREGROAD
2,TTCLR,TTFIN,TTIRI(6) ,TTSET
COMMON /GCOM2/ DD(25),DDL(25) ,DTFUL,DTNOW,ISEES,LFLAG(1) ,NFLAG,ROAD
1NNEQD,NNEQS,NNEQT,SS(25),SSL(25),TTNEX
COMMON /GCOM3/ AAERR,DTMAX,DTMIN,DTSAV,IITES,LLERR,LLSAV,LLSEV,RREROAD
1RR,TTLAS,TTSAV,RESLS
C
COMMON /ROADS/ XMRD,AWTH,ACRT,PRTC
C
COMMON /AREAS/ TTR,APHE,YRN,RCR,TA,PAF
C
COMMON /DATE/ BYR,RMO,XPY,XPM,XPW,XPD,XPH,IYR,IMO,ITP
C
COMMON /STVBL/ IACT,IBM,IEM,GRMO,PI,ACRE
C
LOGICAL IACT
C *** DETERMINE AREA OF CONSTRUCTION AND SET CONSTRUCTION RATE
C
ACON=XMRD*AWTH*.12121212
RCR=ACRT*16.0*ACON/XMRD
C *** SCHEDULE END OF CONSTRUCTION
C
ATTRIB(1)=TNOW+ACON/RCR*XPM
ATTRIB(2)=19.0
ATTRIB(3)=ATTRIB(4)=ATTRIB(5)=ATTRIB(6)=0.0
CALL FILEM (1)
C
ITP=5
IACT=.TRUE.
C
RETURN
C *** CLOSE ROADS
C
ENTRY ROADCLD
ACON=SS(4)*PRTC
SS(4)=SS(4)-ACON
SS(5)=SS(5)+ACON
C
ITP=6
C
RETURN
C
END

```

Figure 40. FORTRAN Source of Roadbuilding and Closing Routine, ROADBLD

```

SUBROUTINE STRTLOG                                STRT 1
DIMENSION NSET(1)                                STRT 2
COMMON OSET(1)                                    STRT 3
COMMON /GCOM1/ ATRIB(6),JEVNT,MFA,MFE(6),MLE(6),MSTOP,NCRDR,NSTRT 4
1NAPQ,NNAPT,NNATR,NNFIL,NNQ(6),NNTRY,NPRNT,PPARM(25,4),TNOW,TTBEGSTRT 5
2,TTCLR,TTFIN,TTIRH(6),TTSET                    STRT 6
COMMON /GCOM2/ DD(25),DDL(25),DTFUL,DTNOW,ISEES,LFLAG(1),NFLAG,STRT 7
1NNEQD,NNEQS,NNEQT,SS(25),SSL(25),TTNEX        STRT 8
COMMON /GCOM3/ AAERR,DTMAX,DTMIN,DTSAV,IITES,LLERR,LLSAV,LLSEV,RRESTRT 9
1RR,TTLAS,TTSAV,RESLS                            STRT 10
COMMON /GCOM4/ DTPLT(10),HHLOW(25),HHWID(25),IICRD,IITAP(10),JJCELSTRT 11
1(1),LLABC(25,2),LLABH(25,2),LLABP(11,2),LLABT(25,2),LLPHI(10),LLSTRT 12
2PLO(10),LLPLT,LLSUP(15),LLSYM(10),MMPTS,NNCEL(25),NNCLT,NNHIS,NNPLSTRT 13
3T,NNPTS(10),NNSTA,NNVAR(10),PPHJ(10),PPLO(10),IISUB(10,10) STRT 14
COMMON /UGCM1/ W,X,Y,Z,I,J,K,L,M,N              STRT 15
COMMON /UGCM2/ NLOAD,NFEL,NBUCK,NPBCH,NSKD,NSTK,NPTK,IBUCK,ITREE,ISTRT 16
1DSYS,LDSYS,ILHLP,IFHLP,IWAIT,IFILL,IVLWD,ISIWD,IPIWD,TPULP,TSAW,TPSTRT 17
2ROD,WPROD,TIDAY,QUOTA,QUOTA1,PLPLN,LDRTK(10),IVLG(10),ISW(10),IPW(STRT 18
310),TMTM(10),THTM(10),TUTM(10),XMILE(10),DLTIM(10,7),LSTUS(10),LODSTRT 19
4MX(10)                                           STRT 20
COMMON /UGCM3/ PMNLD,NALD(2),N3LKL(2),LG3LKL(2),NMLBK(2),IPLPC(2),ISTRT 21
1PILE(2),ISIBK(2),IVLBK(2),IVLLO(2),ISILD(2),IPILO(2),KSYS,ITW(10) STRT 22
COMMON /UGCM4/ XMIPA,XMIPR,XMIS,SOIST,SPEL(10,2),NSKL,IBHLP,MAINT(STRT 23
110),JSWBK(10),NCREW(10),WFCTR(10),TRIPS(10),TSTP(10),PRFRE,SRFRE,PSTRT 24
2RFRF,SRFRE,JOHVR,JOHVR,UHSD,UHSD,DBSTP,CDIST,SLAND,LNDNO,NSDLO,ASTRT 25
3DIAP,ADIAF,ADIAF,HGHTM,MCHUB,TPDST,MNSKD,MXSKD,TOIST(10),ASTIM,SLOSTRT 26
4PE,CHSP1,CHSP2,NCHST,NARD,NBLKR,IVLRO,ISIRD,IPIRD STRT 27
COMMON /UGCM5/ TENDY,CSNEW(10),CSLVG,USLFE(10),EYOH,CFUEL(10),FLCMSTRT 28
1P(10),CSRPR(10),WAGE1(10),WAGE2,CMANT(10),CSINS,CSINT,CSTAX,CSOWN(STRT 29
210),CTIRE(10),CSOPR(10),TMMNT(10),IFELL,CXTRA(10),ITRUK,TAMIL,LNGWSTRT 30
3K,OVRAI,PRDLY(10),IVLG2(10),TMTM2(10),THTM2(10),TUTM2(10),DLTM2(10)STRT 31
4,7),XMIL2(10),NEXSW,NFM,LCAT,NDRPT,NWRPT STRT 32
C                                                    STRT 33
COMMON /DATE/ BYR,BMO,XPY,XPM,XPW,XPD,XPH,IYR,IMO,ITP STRT 34
C                                                    STRT 35
COMMON /STVBL/ IACT,IBM,IEM,GRMO,P1,ACRE STRT 36
C                                                    STRT 37
EQUIVALENCE (NSET(1),OSET(1)) STRT 38
C                                                    STRT 39
LOGICAL IACT STRT 40
C                                                    STRT 41
IACT=.TRUE. STRT 42
IF (ITREE.LE.0) ITREE=SS(12) STRT 43
C                                                    STRT 44
C                                                    STRT 45
C*****NOW SCHEDULE INITIAL SIMULATION EVENTS --- INCLUDED IN THIS TIME STRT 46
C*****WILL BE INITIAL MORNING MAINTENANCE STRT 47
C                                                    STRT 48
TTBEG=TNOW STRT 49
C                                                    STRT 50
C*****STORE LOADER IN FILE WAITING FOR TRUCKS STRT 51
C                                                    STRT 52
IF (NLOAD.LE.0) GO TO 10 STRT 53
ATRIB(1)=TNOW STRT 54
ATRIB(2)=0.0 STRT 55

```

Figure 41. FORTRAN Source of Harvest Starting Routine, STRTLOG

LSTUS(NLOAD)=0	STRT 56
ATRI(3)=TMMNT(NLOAD)+TNOW	STRT 57
ATRI(4)=0.0	STRT 58
ATRI(5)=0.0	STRT 59
ATRI(6)=NLOAD	STRT 60
CALL FILEM (2)	STRT 61
DLTIM(NLOAD,5)=TMMNT(NLOAD)	STRT 62
C	STRT 63
C*****SCHEDULE FELLERS ARRIVAL AT THE TREE	STRT 64
C	STRT 65
10 MM=NLOAD+1	STRT 66
NN=MM*NFEL-1	STRT 67
IF (NFEL.LE.0) GO TO 30	STRT 68
DO 20 IJ=MM,NN	STRT 69
CALL TRIPT (IJ,21,TIM,DIST,0)	STRT 70
ATRI(1)=TNOW+TIM+TMMNT(IJ)	STRT 71
ATRI(2)=9.0	STRT 72
ATRI(3)=TIM	STRT 73
ATRI(4)=0.0	STRT 74
ATRI(5)=DIST	STRT 75
ATRI(6)=IJ	STRT 76
CALL FILEM (1)	STRT 77
LSTUS(IJ)=2	STRT 78
20 DLTIM(IJ,5)=TMMNT(IJ)	STRT 79
C	STRT 80
C*****SCHEDULE BUCKERS ARRIVAL AT THE LANDING	STRT 81
C	STRT 82
30 MM=MM*NFEL	STRT 83
NN=NN*NBUCK	STRT 84
IF (NBUCK.LE.0) GO TO 50	STRT 85
DO 40 IJ=MM,NN	STRT 86
ATRI(1)=TNOW+TMMNT(IJ)	STRT 87
ATRI(2)=1.0	STRT 88
ATRI(3)=10**4	STRT 89
ATRI(4)=-5.0	STRT 90
ATRI(5)=1.0	STRT 91
ATRI(6)=IJ	STRT 92
CALL FILEM (1)	STRT 93
LSTUS(IJ)=4	STRT 94
40 DLTIM(IJ,5)=TMMNT(IJ)	STRT 95
C	STRT 96
C*****SCHEDULE PREBUNCHERS OR SKIDDERS ARRIVAL AT THE TREE	STRT 97
C	STRT 98
50 MM=MM*NBUCK	STRT 99
NN=NN*NPBCH+NSKD	STRT 100
JJ=NN-NSKD	STRT 101
IF (NPBCH.GT.0) GO TO 60	STRT 102
IF (NSKD.LE.0) GO TO 130	STRT 103
60 DO 120 IJ=MM,NN	STRT 104
IF (IJ.LE.JJ) GO TO 90	STRT 105
IF (NSKL-1) 70,80,100	STRT 106
70 CALL TRIPT (IJ,24,TIM,DIST,0)	STRT 107
ATRI(2)=9.0	STRT 108
GO TO 110	STRT 109
80 IF (NPBCH.LE.0) GO TO 90	STRT 110

Figure 41. (continued)

CALL TRIPT (IJ,14,TIM,DIST,0)	STRT 111
ATRI(2)=13.0	STRT 112
GO TO 110	STRT 113
90 CALL TRIPT (IJ,11,TIM,DIST,0)	STRT 114
ATRI(2)=9.0	STRT 115
GO TO 110	STRT 116
100 IF (MCHUB.LT.2) GO TO 90	STRT 117
CALL TRIPT (IJ,19,TIM,DIST,0)	STRT 118
ATRI(2)=9.0	STRT 119
110 ATRI(1)=TNOW+TIM+TMMNT(IJ)	STRT 120
ATRI(3)=TIM	STRT 121
ATRI(4)=0.0	STRT 122
ATRI(5)=DIST	STRT 123
ATRI(6)=IJ	STRT 124
CALL FILEM (1)	STRT 125
DLTIM(IJ,5)=TMMNT(IJ)	STRT 126
120 LSTUS(IJ)=6	STRT 127
C	STRT 128
C*****SCHEDULE TRUCK ARRIVALS TO LANDING	STRT 129
C	STRT 130
130 MM=MM+NPBCH+NSKD	STRT 131
NN=NN+NSTK+NPTK	STRT 132
IF ((NSTK+NPTK).LE.0) GO TO 190	STRT 133
DO 180 IJ=MM+NN	STRT 134
IF (KSYS.EQ.2) GO TO 140	STRT 135
CALL TRIPT (IJ,3,TIM,DIST,0)	STRT 136
GO TO 160	STRT 137
140 J=NN-NPTK	STRT 138
IF (IJ.LE.J) GO TO 150	STRT 139
CALL TRIPT (IJ,6,TIM,DIST,0)	STRT 140
ATRI(2)=3.0	STRT 141
GO TO 170	STRT 142
150 CALL TRIPT (IJ,5,TIM,DIST,0)	STRT 143
160 ATRI(2)=1.0	STRT 144
170 ATRI(1)=TNOW+TIM+TMMNT(IJ)	STRT 145
ATRI(3)=10**4+TIM	STRT 146
ATRI(4)=0.0	STRT 147
ATRI(5)=DIST	STRT 148
ATRI(6)=IJ	STRT 149
CALL FILEM (1)	STRT 150
DLTIM(IJ,5)=TMMNT(IJ)	STRT 151
180 LSTUS(IJ)=3	STRT 152
C	STRT 153
C*****NOW SCHEDULE THE END OF THE FIRST DAY	STRT 154
C	STRT 155
190 ATRI(1)=TNOW+TIDAY	STRT 156
ATRI(2)=8.0	STRT 157
ATRI(3)=0.0	STRT 158
ATRI(4)=0.0	STRT 159
ATRI(5)=0.0	STRT 160
ATRI(6)=0.0	STRT 161
CALL FILEM (1)	STRT 162
C	STRT 163
ITP=7	STRT 164
C	STRT 165
RETURN	STRT 166
END	STRT 167

Figure 41. (continued)


```

SURROUTINE ENDLOG                                ENDL 1
COMMON /GCOM1/ ATRIB(6) ,JEVNT,MFA,MFE(6) ,MLE(6) ,MSTOP,NCRDR,NENDL 2
1NAPO,NNAPT,NNATR,NNFIL,NNQ(6) ,NNTRY,NPRNT,PPARM(25,4),TNOW,ITBEGENDL 3
2,TTCLR,TTFIN,TTIRI(6) ,TTSET                      ENDL 4
COMMON /GCOM2/ DD(25),DDL(25) ,DTFUL,DTNOW,ISEES,LFLAG(1) ,NFLAG,ENDL 5
1NNEQD,NNEQS,NNEQT,SS(25),SSL(25),ITNEX           ENDL 6
COMMON /GCOM3/ AAERR,DTMAX,DTMIN,DTSAV,IITES,LLERR,LLSAV,LLSEV,RREENDL 7
1RR,ITLAS,ITSAV,RESLS                             ENDL 8
COMMON /GCOM4/ DTPLT(10),HHLOW(25),HHWID(25),ITCRD,IITAP(10),JJCELENDL 9
1(1) ,LLABC(25,2),LLABH(25,2),LLABP(11,2),LLABT(25,2),LLPHI(10),LLENDL 10
2PLO(10),LLPLT,LLSUP(15),LLSYM(10),MMPTS,NNCEL(25),NNCLT,NNHIS,NNPLENDL 11
3T,NNPTS(10),NNSTA,NNVAR(10),PPHI(10),PPLO(10),IISUB(10,10) ENDL 12
C                                                    ENDL 13
COMMON /STVBL/ IACT,IBM,IEM,GRMO,PI,ACRE           ENDL 14
C                                                    ENDL 15
LOGICAL IACT                                       ENDL 16
C                                                    ENDL 17
IACT=.FALSE.                                       ENDL 18
C                                                    ENDL 19
IINN=NNPLT                                         ENDL 20
NNPLT=0                                             ENDL 21
CALL SOTPUT                                         ENDL 22
NNPLT=IINN                                          ENDL 23
C                                                    ENDL 24
C*****CLEAN UP FILE #1                           ENDL 25
C                                                    ENDL 26
10 IF (NNQ(1).LE.0) GO TO 20                       ENDL 27
CALL RMOWE (MFE(1),1)                             ENDL 28
IJ=ATRIB(2)                                         ENDL 29
IF (IJ.GT.0.AND.IJ.LT.15) GO TO 10                 ENDL 30
CALL FILEM (6)                                     ENDL 31
GO TO 10                                            ENDL 32
20 IF (NNQ(6).LE.0) GO TO 30                       ENDL 33
CALL RMOWE (MFE(6),6)                             ENDL 34
IJ=ATRIB(2)                                         ENDL 35
IF (IJ.GT.0.AND.IJ.LT.15) GO TO 20                 ENDL 36
CALL FILEM (1)                                     ENDL 37
GO TO 20                                            ENDL 38
30 CONTINUE                                         ENDL 39
RETURN                                              ENDL 40
C                                                    ENDL 41
END                                                ENDL 42

```

Figure 42. FORTRAN Source of Harvest Ending Routine, ENDLOG

	SUBROUTINE GPLOT (ITL,XX,T,IPLT)	GPLO	1
	DIMENSION XX(6), PLOG(6), PHIG(6), NOUT(117), RANGE(6), ITTL(7)	GPLO	2
	DIMENSION NNPTS(6),LLSYM(6),LLABP(6),IPCT(6),NNVAR(5),ITL(3)	GPLO	3
	COMMON /GCOM1/ ATRIB(6),JEVNT,MFA,MFE(6),MLE(6),MSTOP,NCRDR,NGPLO	GPLO	4
	1NAPD,NNAPT,NNATR,NNFIL,NNQ(6),NNTRY,NPRNT,PPARM(25,4),TNOW,ITREG	GPLO	5
	2,ITCLR,ITFIN,ITRIH(6),ITSET	GPLO	6
	DATA IPLUS,IBLNK,IAST,IPRD,IMIN/1H,1H,1H,1H,1H-/	GPLO	7
C	DATA ITTL/3HYRS,3HMOS,3HWKS,4HFIRE,4HROAD,4HCLRD,4HHARV/	GPLO	8
C		GPLO	9
	DATA NNVAR/6,6,5,5,6/	GPLO	10
	DATA NNPLT/5/	GPLO	11
	DATA LLABT/8HTIME /	GPLO	12
	DATA NNPTS/6*0/	GPLO	13
	IF (IPLT) 100,110,10	GPLO	14
	10 IT=IPLT	GPLO	15
	NVAR=NNVAR(IPLT)	GPLO	16
	80 WRITE (IT) ITL,T,(XX(I),I=1,NVAR)	GPLO	17
	90 NNPTS(IPLT)=NNPTS(IPLT)+1	GPLO	18
	GO TO 760	GPLO	19
	100 IFP=-IPLT	GPLO	20
	ILP=IFP	GPLO	21
	GO TO 120	GPLO	22
	110 IFP=1	GPLO	23
	ILP=NNPLT	GPLO	24
	120 DO 750 N=IFP,ILP	GPLO	25
	IT=N	GPLO	26
	NVAR=NNVAR(N)	GPLO	27
	130 REWIND IT	GPLO	28
	READ (IT) LLPLT,ITL,LLSYM,LLABP	GPLO	29
	140 NPT=NNPTS(N)	GPLO	30
	IF (LLPLT.LE.0) GO TO 150	GPLO	31
	WRITE (NPRNT,830) N,ITL	GPLO	32
	WRITE (NPRNT,810) LLABT,(LLABP(I),I=1,NVAR)	GPLO	33
	150 DO 160 I=1,NVAR	GPLO	34
	PLOG(I)=1.E20	GPLO	35
	160 PHIG(I)=-1.E20	GPLO	36
	DO 290 J=1,NPT	GPLO	37
	230 READ (IT) ITL,TSN,(XX(I),I=1,NVAR)	GPLO	38
	DO 270 IP=1,NVAR	GPLO	39
	IF (XX(IP)-PLOG(IP)) 240,250,250	GPLO	40
	240 PLOG(IP)=XX(IP)	GPLO	41
	250 IF (XX(IP)-PHIG(IP)) 270,270,260	GPLO	42
	260 PHIG(IP)=XX(IP)	GPLO	43
	270 CONTINUE	GPLO	44
	IF (LLPLT.LE.0) GO TO 290	GPLO	45
	280 WRITE (NPRNT,820) ITTL(ITL),TSN,(XX(I),I=1,NVAR)	GPLO	46
	290 CONTINUE	GPLO	47
	IF (LLPLT.LE.0) GO TO 295	GPLO	48
	WRITE (NPRNT,840) (PLOG(I),I=1,NVAR)	GPLO	49
	WRITE (NPRNT,850) (PHIG(I),I=1,NVAR)	GPLO	50
	295 IF (LLPLT.EQ.1) GO TO 720	GPLO	51
	300 WRITE (NPRNT,770) N,ITL	GPLO	52
	DO 410 I=1,NVAR	GPLO	53
	400 RANGE(I)=PHIG(I)-PLOG(I)	GPLO	54
		GPLO	55

Figure 43. FORTRAN Source of Output Plotting Routine, GPLOT

QR=RANGE(I)*.25	GPLU 56
Q1=PLOG(I)*QR	GPLU 57
Q2=Q1*QR	GPLU 58
Q3=Q2*QR	GPLU 59
410 WRITE (NPRNT,780) LLSYM(I),LLARP(I),PLOG(I)*Q1,Q2,Q3,	GPLU 60
IPHIG(I)	GPLU 61
WRITE (NPRNT,790) LLABT	GPLU 62
WRITE (NPRNT,800)	GPLU 63
440 REWIND IT	GPLU 64
READ (IT) LLPLT	GPLU 65
READ (IT) ITL,TSN,(XX(I),I=1,NVAR)	GPLU 66
IPT=1	GPLU 67
GO TO 480	GPLU 68
460 ITL=ITX	GPLU 69
IF (IPT.EQ.NPT) GO TO 480	GPLU 70
IF (ITL.GT.3) GO TO 465	GPLU 71
IF (ITL.NE.ITLL) GO TO 480	GPLU 72
IY=TSN*10000.0+0.5	GPLU 73
IF (ITL.NE.1) GO TO 461	GPLU 74
IF (IY.EQ.IY/10*10) GO TO 463	GPLU 75
GO TO 469	GPLU 76
461 IM=TSN	GPLU 77
IF (IM.NE.1) GO TO 469	GPLU 78
463 DO 464 J=2,100	GPLU 79
464 NOUT(J)=IMIN	GPLU 80
GO TO 474	GPLU 81
465 DO 466 J=2,100	GPLU 82
466 NOUT(J)=IPRD	GPLU 83
GO TO 474	GPLU 84
469 DO 470 J=2,100	GPLU 85
470 NOUT(J)=IBLNK	GPLU 86
474 DO 475 J=1,101,25	GPLU 87
475 NOUT(J)=IPLUS	GPLU 88
GO TO 486	GPLU 89
480 DO 484 J=1,101	GPLU 90
484 NOUT(J)=IPLUS	GPLU 91
ITLL=ITL	GPLU 92
486 DO 487 J=102,117	GPLU 93
487 NOUT(J)=IBLNK	GPLU 94
NCOUN=103	GPLU 95
DO 620 IP=1,NVAR	GPLU 96
PLIP=XX(IP)	GPLU 97
IF (PLIP-PLOG(IP)) 620,490,490	GPLU 98
490 IF (PLIP-PHIG(IP)) 500,500,620	GPLU 99
500 IF (RANGE(IP)) 620,620,510	GPLU 100
510 NPCT=(PLIP-PLOG(IP))*100./RANGE(IP)+1.5	GPLU 101
IF (IPT.LE.1) GO TO 515	GPLU 102
IF (N.EQ.2) GO TO 515	GPLU 103
IF (N.EQ.4.AND.IP.EQ.1) GO TO 515	GPLU 104
IF (N.EQ.5.AND.IP.EQ.2) GO TO 515	GPLU 105
I1=MIN0(IPCT(IP),NPCT-1)+1	GPLU 106
I2=MAX0(IPCT(IP),NPCT+1)-1	GPLU 107
GO TO 516	GPLU 108
515 I1=I2=NPCT	GPLU 109
516 IPCT(IP)=NPCT	GPLU 110

Figure 43. (continued)

DO 615 I=11,12	GPL0 111
NONP=NOUT(I)	GPL0 112
IF (NONP.EQ.LLSYM(IP)) GO TO 615	GPL0 113
IF (NONP.EQ.IBLNK.OR.NONP.EQ.IPLUS.OR.NONP.EQ.IPRD.OR.	GPL0 114
1 NONP.EQ.IMIN) GO TO 600	GPL0 115
560 IF (NCOUN-117) 570,610,610	GPL0 116
570 DO 590 J=103,NCOUN,3	GPL0 117
IF (NOUT(J+1)-LLSYM(IP)) 590,580,590	GPL0 118
580 IF (NOUT(J)-NONP) 590,615,590	GPL0 119
590 CONTINUE	GPL0 120
NOUT(NCOUN)=NOUT(I)	GPL0 121
NOUT(NCOUN+1)=LLSYM(IP)	GPL0 122
NCOUN=NCOUN+3	GPL0 123
GO TO 615	GPL0 124
600 NOUT(I)=LLSYM(IP)	GPL0 125
GO TO 615	GPL0 126
610 NOUT(117)=IAST	GPL0 127
615 CONTINUE	GPL0 128
620 CONTINUE	GPL0 129
TSL=TSN	GPL0 130
IF (IPT-NPT) 660,710,710	GPL0 131
660 READ (IT) ITX,TSN,(XX(I),I=1,NVAR)	GPL0 132
IPT=IPT+1	GPL0 133
IF (TSN.EQ.TSL) GO TO 460	GPL0 134
WRITE (NPRNT,800) ITTL(ITL),TSL,NOUT	GPL0 135
GO TO 460	GPL0 136
710 WRITE (NPRNT,800) ITTL(ITL),TSL,NOUT	GPL0 137
WRITE (NPRNT,880)	GPL0 138
WRITE (NPRNT,790) LLABT	GPL0 139
720 I=NPT*NVAR	GPL0 140
WRITE (NPRNT,860) NPT,I	GPL0 141
NNPTS(N)=0	GPL0 142
740 REWIND IT	GPL0 143
IF (IPLOT) 760,750,760	GPL0 144
750 CONTINUE	GPL0 145
760 RETURN	GPL0 146
C	GPL0 147
770 FORMAT (1H1,56X,13H**PLOT NUMBER,I3,2H**/51X,3A10//59	GPL0 148
1X,14HSCALES OF PLOT)	GPL0 149
780 FORMAT (1X,A1,1H=, A10 ,E11.4,4(14X,E11.4))	GPL0 150
790 FORMAT (1H0,3X, A8,3X,1H0,4X,1H5,3X,2H10,3X,2H15,3X,2H20,3X,2H25,3X,2H30,3X,2H35,3X,2H40,3X,2H45,3X,2H50,3X,2H55,3X,2H60,3X,2H65,3X,2H70,3X,2H75,3X,2H80,3X,2H85,3X,2H90,3X,2H95,2X,3H100,1X,10HDOUPLICATES)	GPL0 151
800 FORMAT (1X,A4,F8.4,2X,117A1)	GPL0 152
810 FORMAT (2X,A9 ,10(2X,A10)/)	GPL0 153
820 FORMAT (1X,A4,F8.4,10(E12.4))	GPL0 154
830 FORMAT (1H1,48X,14H**TABLE NUMBER,I3,2H**/44X,3A10/)	GPL0 155
840 FORMAT (/4X,7HMINIMUM,10E12.4)	GPL0 156
850 FORMAT (4X,7HMAXIMUM,10E12.4)	GPL0 157
860 FORMAT (///5X,21HOUTPUT CONSISTS OF ,I6,13H POINT SETS (,I6,8H POINTS))	GPL0 158
870 FORMAT (5X,21HSTORAGE ALLOCATED FOR,I6,13H POINT SETS (,I6,8H WORDS))	GPL0 159
15)/5X,21HSTORAGE NEEDED FOR,I6,13H POINT SETS (,I6,8H WORDS)	GPL0 160
880 FORMAT (7X,5HM YR)	GPL0 161
C	GPL0 162
END	GPL0 163
	GPL0 164
	GPL0 165
	GPL0 166
	GPL0 167

Figure 43. (continued)



3 1762 10013668 6

N378 Egging, Louis T
Eg35 A method for analyzing
cop.2 environmental effects of
impacting activities

DATE	ISSUED TO
3-1-78	LIBRARY LOAN
4-26	Hold H
MAY 1978	Stemmer
MAR 4 1980	Gray
1981	
1982	

N378
Eg35
cop 2