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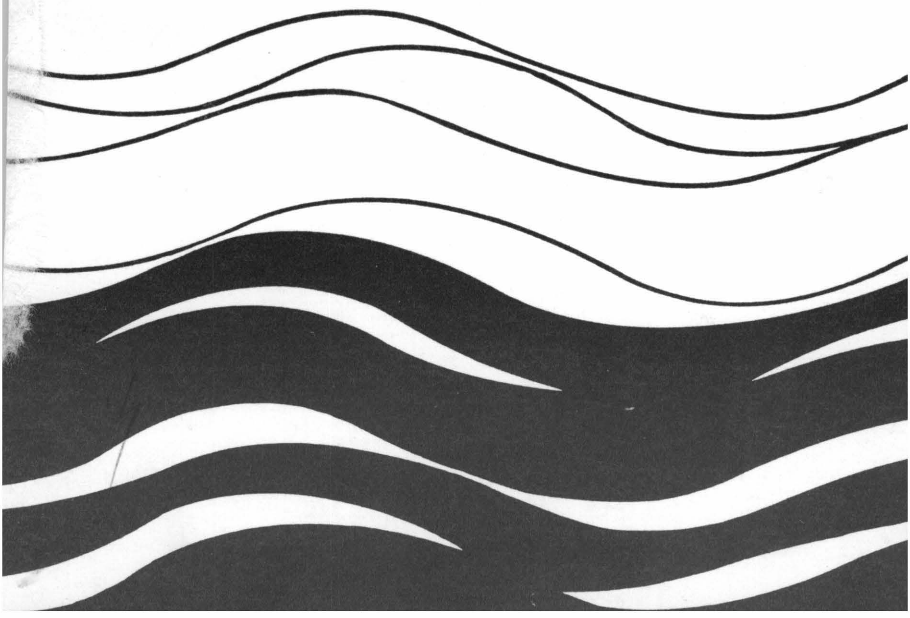
A Watershed Planning And Management System: Design and Synthesis

Robert H. Giles, Jr.



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A Watershed Planning And Management System: Design and Synthesis

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ABSTRACT

This research develops a blueprint for a watershed management system, conceived for the South River Watershed in Virginia, that could be used in making decisions about the future development of any similar large (950 km^2 or 350 mi^2) urbanizing watershed. The investigation first analyzes the complex problem of land-use planning and management, particularly the need for a comprehensive system providing long-term rational management and allowing achievement of complex human goals and objectives. Twenty-two tenets of land-use management are cited as fundamental to the design and implementation of such a system, and major phenomena that have obscured or halted comprehensive management efforts in the past are analyzed. One part of this report discusses the "taking issue" and how it relates to the proposed system. Existing institutions, particularly the law, that influence land use are also analyzed. One new institution, a "watershed guidance center," is proposed. The study then describes an objective function that can be used as the basis for decisionmaking concerning a watershed. This complex expression is based on over 300 citizen-weighted objectives, each having a production function. Each production is expressed in net energy, for the total management system is energy-based and is related to probable change in physical and ecological systems. A computer program, Goal-1, is described which would integrate citizens' expressions of preferred management goals. A modified form of goal programming is proposed as the solution alogrithm. Many of the inputs necessary for operation of the total management system already are available in the "State Information System," also described in this report. It was conceived for the South River Watershed but could be adapted for use in other watersheds.

Key Words: Planning, Watershed Management, Computers, Models, Optimization, Decisionmaking, Urban Ecosystems.

ACKNOWLEDGMENTS

I am grateful for the support of the Virginia Water Resources Research Center which allowed me to explore the use of an existing environmental information system adapted to land use planning. The Center funded a graduate student, Mr. Stephen W. Hoecker, for one year, enabling him to develop further the present system, to create a computer program for the citizens' objectives, and to aid in collecting data.

I am particularly grateful to Dr. James E. Hackett for ideas and advice throughout this design development. Of course, I take full responsibility for the concepts. I also request that readers engage in conversations about the design, for there remain some omissions, points of disagreement, and ideas not expressed clearly.

Special acknowledgment is accorded the following who generously gave their time to review the manuscript: Charles D. Buffington, Division of Forestry, Fisheries, and Wildlife Development, Tennessee Valley Authority, Norris, Tennessee, and Demetres A. Vlatas, Office of Water Research and Technology, U.S. Department of the Interior. Acknowledgment is made also to Victoria C. Esarey for editorial processing and typesetting, and to Pat Nickinson for layout and paste-up.

THE ASSUMPTIONS AND CONTEXT

This is the final report of a research project undertaken to determine whether a planning model could be created for the South River Watershed in Virginia. Since a past legislature looked upon this watershed as a pilot watershed, the results were expected to be transferable to other watersheds throughout the state. The project was limited to the *design* of a system for planning and aiding decisionmakers in the watershed and therefore did not include implementation of that system. The test of the design is expected in careful studies of the design, critiques of this document, and in evaluations, years hence, of the results of implementation. In part, the power of the design will be measured in the time required for its development and first use.

Design is a human activity; designs are not discovered through the scientific process. They are statements of perceived natural and social laws, various processes and interactions, and a concept of an actual or hoped-for future. To design is to model the future. All designs have a human element and therefore some will call them subjective. The objective here was to create a decision-aiding system that will perfectly match a future watershed with the needs and expectations of the citizens living there and in adjacent watersheds. That is an elaborate and high goal, but it would seem less than desirable to set a lower one. It is a goal that can be objectively tested in the future by physiological, psychological, and sociological instruments.

As in developing an architectural design for a client, assumptions and constraints must be established. The better articulated the assumptions, the better can be the tests of whether the design matches these assumptions. Following are the assumptions, definitions, and working rules (called tenets) used in this design of a computer-based system for aiding decisionmakers in the South River Watershed.

Tenet 1. An effective land use planning and guidance system is needed very soon, probably within the next decade.

Since problems arise at a rate faster than they are solved, even man's best solutions to watershed problems seem to result in a net loss. There are new needs for more sophistocated planning than ever before. The general dimensions of the overall problem, each dimension a major problem in itself, are:

a. Human population growth continues. Even though increase rates are reduced, total populations increase. Even if births equal deaths, the total population will increase for many years.

b. Each individual consumes an average amount of resources. U.S. citizens consume 1 to 25 times more food resources than citizens of other countries, and 1 to 50 times the total resources.

c. With each per capita consumption of resources, a per capita amount of pollution is produced. As this total amount increases, the toxicity or severity of impact on natural systems increases. Biological species are not equipped to overcome sudden, totally new chemicals added to their environment. There is no time for behavioral adaptations or evolution.

d. Pollution control costs time, resources, and energy. In a resource-scale environment, more and more resources must be used for pollution control, security, and maintenance.

e. Pollution problems increase with crowding. A simple air pollution effect (e.g. emphesyma) is magnified in densely populated areas.

f. Some say there is no environmental crisis, only distribution and spatial problems. There are interacting reasons why this claim is untrue, notably that all lands are not equally fertile, not all have water, transportation costs in some areas are excessive, and people need the proper juxtaposition of services (e.g. medical), resources, and markets. Distribution of people and various land uses is a major problem, whether it is termed an environmental problem or not. It is interactive with and a part of the previous five problems.

g. There are many cumulative phenomena in human and natural systems. A little lead or mercury may not be noticed, but cumulative effects become evident. Problems do not grow conspicuously; they grow, hidden, then appear. Knowledge of such cumulative processes is usually available. It is poorly used.

h. Some writers have expressed theological roots to environmental and land-use problems. How one perceives his present god and his after-life surely influences his value system and risk-taking behavior. If "God will take care of me" is a valid belief statement, then it will surely result in less concern for (i.e., lower value attached or lower risk assigned) a future resource than a personal belief statement that "the fate of the world is in my hands." How a person synthesizes ideas of life after death, his life expectancy, the importance of passing along the family name, and the utility of physical resources as influenced by dogma and derived belief, influences his preferences and therefore resource utility. Resource utility, by definition, is inversely related to disutility and externalities.

The theological basis for value is apparent, inseparable from economic theory, and from environmental decisionmaking.

i. Some political scientists see the so-called environmental crisis as a failure of institutions and administration. Aspects of the institutional problem are variously listed as (1) resource agency incompetence or yielding to various pressures; (2) failures of lawmakers; (3) insufficient laws or their interpretation; (4) failures in accountability and regulation; (5) delays at all levels (with associated costs, failures, and continual disutilities and risks); (6) duplication of effort and waste; (7) counter-productive actions among governments and their agencies, and (8) inadequate citizen expression and representation in institutional decision processes.

j. The watershed problem now being faced may be due to a lack of planning. More to the point, it may be due to a lack of highly competent planners. Kaiser et al. [1976] found planning efforts followed rather than lead national environmental awareness. Croke et al. [1972, p. 36] observed that "many environmental planners are not as accustomed to developing and adhering to grand regional strategies as are their colleagues in the socioeconomic planning agencies and may find it difficult to adapt to this mode (broadly based strategies for regionwide control activities) of activity." The lack of planning expertise is a conclusion of an analysis of the past, though, and reflection yields the lesson: practices and planning methods and theory have been inadequate for they have never created an image that captured the aspirations of government or landowners nor have they produced conspicuous benefits.

k. A malaise grips society. Toffler [1970] called it future shock. The citizen's paradox is that he must spend more thoughtful time on certain problems, when those are the very problems that are crying for immediate answers.

l. It is very difficult to see the whole of anything, much less an entity as large as a watershed, and to be able to organize it meaningfully for solution. A systems approach is the only conceivable good approach.

m. No matter how perfectly we develop present planning and guidance systems, not all environmental problems created by past decisions about land use or development processes are solvable by technology or vast amounts of money. We are victims of history.

n. The environmental impact of present economic development decisions will often be of a prolonged nature and may be irreversible [Croke et al., no date, p. 70].

o. Even though precedents are numerous, Virginians have not internalized that their government has the right and responsibility to control private land and its use. At issue in a democracy is the question: are the best interests, health and welfare of all the people served by a laissez faire use policy, one that accepts that the private owner really knows best and acts accordingly? The evidence is overwhelming: The private good is not the public good. When most citizens seem bent upon getting their share of a limited resource supply, the end results are neither pleasant nor healthy.

p. Who are the proper decisionmakers? The greatest problem of designing any system is one of specifying the user. Clear lines of authority and responsibility must be created for enforcing land use, pollution control, and site development laws. Present unintegrated approaches will not suffice, partially because the risks that are associated with such problems make it seem very desirable for "someone else" to take the responsibility for a decision. Who is that someone else has yet to be agreed upon. Suggestions are provided herein; the decision should be made soon.

q. Highly competent technical and professional personnel are needed to serve as assistants for decisionmakers. The small community faced with rapid growth finds the problem most critical. New intensified educational programs, new funds, computer assistance and various task force approaches seem possible solutions.

r. Virginia must do its land use planning and decisionmaking within an ambiguous national context. Personnel, agencies, policy statements, governor involvement, and civil suits are needed to shape the environment of Virginia's (and other states') legislation.

s. The land-use problem is largely interpretable as an economic problem in the broad sense, it being a search for that mix of uses which provides an optimum allocation of land. The thresholds or limits (constraints) must be specified as well as the objectives. The parallels that exist with a systems approach are unmistakable. The corollary problem is that of convincing people that ecological problems are economic problems. Land use problems can be solved on strictly economic grounds. Virtually every land characteristic can be valued by some means, if not explicitly in monetary or energetic terms, at least in acceptable pragmatic terms. The problem is to see and understand the ecological costs. Every cost reduces man's opportunities, his freedom. Everyman's command is thus: Do not tamper with my freedom; hold back on how you handle my humanity!

t. "Time preference" is a poorly understood concept. Society can place a much greater value on future uses of resources than can an individual. Few citizens value a promissory note which can be called 100 years from now. But, communities may well highly value such a note. The environmental consequences of land development [the costs or benefits] are not fully perceived when decisions are made [Croke et al., no date, p. 70]. Lower rates of resource returns are more acceptable to the public than to individuals. There is less need for the public to "get while the getting is good." For most land use, the longer the resource lasts, the greater will be the total yield as well as the average annual yield.

u. Few Virginia communities have written, precise goals. Therefore it can be assumed that most communities have poorly conceived goals. This is a primary problem, but since so few citizens seem to recognize it as such, it is presented down in the list. Governments grope with the land use and related questions because they do not really know what it is they are trying to do. Until governments know, they cannot tell if they are winning at the land-use game.

v. There are no algorithms for forcing land to its highest and best use. The luxuries of mere personal desire, extravagance, or under-utilization were permissable when land was plentiful. After sophisticated analyses are made, taxation, regulation, licensing, and zoning provide some of the means to assure that land may be used optimally.

w. The specific problems of land use and the environment of man include economic, physical, ecological, social and a host of interrelated problems. There are a group of problems specific to public lands. Aspinall [1973, p. 4] spoke of a hodgepodge of laws, regulations, and practices relating to public lands, such as the Mining Law of 1872. "This 100-year-old statute," he said, "though it played a significant role both in the settlement of the West and in providing the needs for an expanding industrial economy, was clearly not in accordance with many current concepts."

Regional problems of inequitable resource allocation among regions and people have been real. Resource management policy differs significantly between the eastern and western United States. There are areas water rich, others, water poor. Grant [1973, p. 15] reported on a 1931 conference on land utilization in which Secretary of Agriculture Hyde spoke of "over-production, serious maladjustments in taxation and credit, a radical transformation in the geography of production, a greatly changed outlook with regard to population increase and land requirements, and . . . the widespread human stress growing out of these dislocations. . . ."

Perhaps nothing has changed and problems are as they always have been. It seems unlikely that they will always be the same. Curtis [1974] said, "We are now reaping the harvest of earlier, indiscriminate land-use patterns. We are coming to realize that our ability to deal with the symptoms of today's environmental crisis is shackled by yesterday's land use practices." We also are beginning to realize that our children will reap the same or greater "harvest" unless we do something that overcomes past mistakes while establishing beneficial patterns within the same areas. Sussna [1970, p. 70] acknowledged the likelihood of "broadcast pessimism" in the face of such obstacles, but reasserted the need for regenerative action.

Tenet 2. The needs for planning are neither clear nor universally agreed upon.

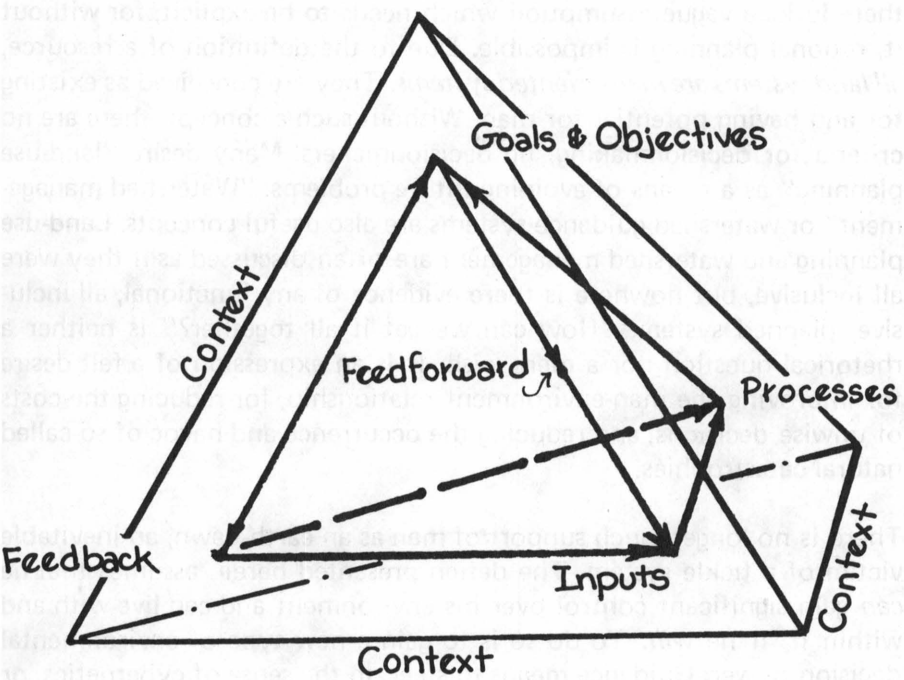
Only one-third of the counties, two-thirds of the cities, and one-fourth of Virginia towns have comprehensive plans [Virginia Division of State Planning and Community Affairs, 1973]. Resistance to land planning stems from individuals who think: (1) their decisionmaking perogatives (freedom) will be removed; (2) their opportunities for maximizing personal or corporate profit or an inheritance estate may be jeopardized; (3) they will experience significant embarrassment or loss-of-face when yields from old land uses are compared with new uses and management; (4) some governmental mandate will require actions that are absurd, demeaning, dispiriting, or counter to a life's work (e.g., plant a field back into trees; channelize a stream).

There is a growing awareness that environmental protection is not inconsistent with individual property rights; that government at all levels has an essential role to play in such protection; and, that planning for and the actual renewal of natural resources is in the individual's as well as the public's general best interest.

It is one thing to recognize a problem, quite another to solve it. The land use and environmental solutions are not always clear, feasible, economical, or unanimous. These environmental and human problems seem to be expressions of apparent failure of the present system to achieve human goals. A problem exists in the gap between perceived present condition and one or more real but poorly articulated goals. "The situation is bad," must be qualified with the question: "Compared to what?" In the final analysis, the answer will be: human goals.

Tenet 3. A reasonable basis for a guidance system for how the lands of Virginia will be used is general systems theory (symbolized in Figure 1).

FIGURE 1
General Systems Theory [Von Bertalanffy, 1968]
As Symbolized in Three Dimensions as a Tetrahedron



The remainder of the text and design attempts to be compatible with that theory.

Tenet 4. Planning is beneficent cybernetics.

Planners can help man create a near-perfect, environment-man interaction, indefinitely. There are some who quibble about whether a perfect environment-man interaction is possible. The concept of "perfection," perhaps utopian, must be defined, but when it is, then it becomes a goal. A simple question is revealing: "Perfect, as compared to what?" Perfection will be elaborated in general phrases like stable, productive, safe, and efficient, but these, too, need to be made explicit. Unless a concept of perfection or of any ultimately good environment-man interaction is set, there is no basis for measuring the degree of failure, or the impossibility of achievement (due, for example, to various bio-physical laws).

Not too surprising, within some natural resource and land use literature there lurks a vague assumption which needs to be explicit, for without it, rational planning is impossible. Due to the definition of a resource, *all land systems are man-oriented systems.* They are conceived as existing for and having potential for man. Without such a concept, there are no criteria for decisionmaking, no decisionmakers. Many desire "land-use planning" as a means of avoiding future problems. "Watershed management" or watershed guidance systems are also useful concepts. Land-use planning and watershed management are often discussed as if they were all inclusive, but nowhere is there evidence of any functional, all inclusive, planned system. "How can we get it all together?" is neither a rhetorical question nor a mere wish. It is an expression of a felt desire for improving the man-environment relationship, for reducing the costs of unwise decisions, and reducing the occurrence and havoc of so-called natural catastrophies.

There is no longer much support of man as an earth-pawn, an inevitable victim of a fickle system. The design presented herein assumes that he *can* gain significant control over his environment and can live with and within it, if he *will.* To do so is to gain a new type of environmental decision power. Guidance means to steer, in the sense of cybernetics, or as in the finest sense of management.

Herein, design is the first in a series of attempts to create a means for controlling and guiding at a reasonable level a dynamic human habitat. The concept of this habitat should include: (a) the watershed as the best conceivable subsystem for management and design, (b) spatial concepts of area, points, layers, and zones, (c) time concepts of dynamics, sequence, convergence, interruptions, and relevant investment periods, (d) energy and water as profoundly dominant environmental factors, (e) man as decisionmaker, user, and as both influencing and being influenced by the environment, (f) planning as the act of suggesting likely future alternatives, (g) planning as action to cause things to occur in their proper sequence, (h) aids for decisionmaking and conflict resolution today, (i) governmental rules, authority and action programs, (j) citizen benefits, responsibility, and actions, and (k) man-man interactions, such as stresses of crowding.

Tenet 5. Man is rational.

Man's apparent irrationality, often observed and used as the basis for counter claims, is due to: (a) dissimilar objectives of the observer and the person(s) being observed, (b) lack of information, (c) inadequate or untimely retrieval or recall of essential information, (d) faulty or improper comparison, aggregation, or other processes, (e) improper analyses of risks, (f) failure to observe historical inadequacies in data, processes, goals, and feedback processes, (g) misweighted objectives, (h) failure to attempt to predict or to project trends, and (i) in short, failure of the decisionmaking system.

"Rationality" is like "efficiency;" it is a theoretical concept. The value 1.0 exists for efficiency but is never achieved. Likewise, 1.0 can be an expression of an ultimate state of rationality that never seems to be reached. Man, situation by situation, varies in his relative rationality. The better designed the systems to aid decisionmaking, the greater will be man's rationality. A corollary: it is illogical to attempt to design a system or plan for irrational or capricious man.

The so-called irrational forces at work in society (except for people exhibiting genetic or other brain pathology which are not being discussed), are (a) those whose value systems conflict, who seek local or group goals over those of the larger group, or those imperceptive of the greater long-term social "good," or (b) those victimized by the "counterintuitive" [Forrester, 1971; Bauer, 1973, p. 163].

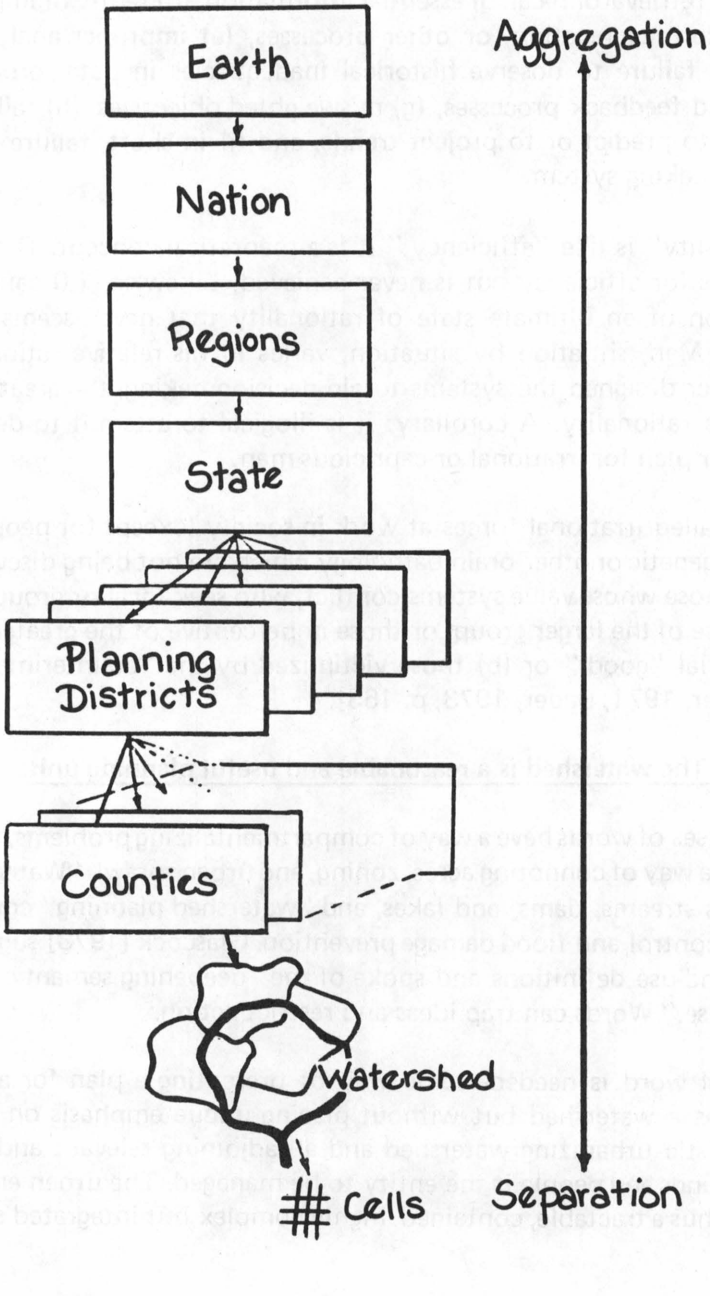
Tenet 6. The watershed is a reasonable and useful planning unit.

Special uses of words have a way of compartmentalizing problems. "Land use" has a way of connoting acres, zoning, and urban sprawl. "Watershed" connotes streams, dams, and lakes, and "watershed planning" connotes erosion control and flood damage prevention. Glascock [1973] suggested many land-use definitions and spoke of the "deepening semantic jungle in land use." Words can trap ideas and restrict action.

A special word is needed—some way of presenting a plan for an area known as a watershed but without placing undue emphasis on water. The holistic urbanizing watershed and all adjoining relevant and interrelated lands and people is the entity to be managed. The urban environment is thus a tractable, contained, highly complex but integrated system

FIGURE 2

A System for Dealing with Watersheds as Described Herein Enables Regional Aggregation or Further Separation of Data For Decisionmaking That Is International or Cell Specific.



of natural and manmade elements in various mixes. It is also a set of publics, each with the same goals but with quite different weights or priorities associated with each. Both complicated and complex, the spatial thing which is to be designed is not isolated. It influences adjacent watersheds and is influenced by them. The spatial hierarchy of the watershed is shown in *Figure 2.*

What is implied by urbanizing? Nothing more than (a) a relatively large size (about 300 square miles or 77,700 hectares), (b) that wilderness or forested watersheds, while they may be included, are not the focus, and that development and land-use changes are very much a part of the situation; and (c) the situation is dynamic. The plan must be for the whole life-space of the average human population.

Why choose the watershed as the management unit? Why not the region, the county, the enumeration district, or some geographic cell? There is no best unit; the watershed is the least bad. Its advantages are that all of its area is subject to many of the same profound environmental factors; water control and supply are major human needs as well as costs; wind, air pollution, and water all function as a unit within watersheds; the ridge crests are energy barriers—it costs energy to move out of watersheds; the ridge crests and the three-dimensional space they embrace determine the volume of water received, the velocity of that water and its ultimate ability to do work on the land or to produce electricity for other uses. Political boundaries not related to such boundaries may cause land-use problems, e.g. citizens of the uphill county pollute the downhill county. Alternative boundaries are needed for decisionmaking when natural forces do not recognize such artificial boundaries. Multi-county regions seem too large for detailed planning or control; natural factors usually vary widely over such large areas. Virginia contains about 40,000 mi^2 (over 10 million hectares). Watersheds averaging 400 mi^2 (104,000 hectares) would result in 100 watershed units, about the same as the number of counties for which data are now available and readily processed. Cells (e.g., 27 acres or 1/9 km^2) seem too small since variables in adjacent cells often seem as important as those in the cell itself. The watershed is a natural land unit; streams can be viewed as independent; some farms are isolated within watersheds and thus largely subject to the factors within the watershed. Water is such a critical element in the lives of man and other animals that it is essential to focus on the unit that "produces" that resource. The results of many of the natural and sociological processes and managerial decisions made on a piece of land converge at the mouth of each watershed. The pulse of the condition and activities of the land may be taken from the waters at the lower reaches of a watershed. In the land-health analogy of Leopold [1949], the watershed is the land patient. A land-use guidance system is for diagnosis and prescription for the whole patient, both man and environment.

Tenet 7. All land units, including the urbanizing watershed, are open systems. The degree of closedness is critical to planning.

As part of Earth, Virginia or any of its watersheds is an open system. The biogeochemical cycles are interconnected on a global basis. Water, air, and, to some extent, nutrients are exchanged freely with the atmosphere. The human sector imports and exports resources, various goods and services, and people with other watersheds, states, and countries of the world. However, accumulating evidence suggests that such free exchanges of goods and services may not be feasible for long into the future. Because of shortages, institutions, and wars, it is likely that countries, states, and watersheds will become less open.

World supplies of high-quality mineral resources and energy are limited. Given present resource consumption rates and the projected increase in these rates, the great majority of the currently important non-renewable resources will be extremely costly 100 years from now [Meadows et al., 1972, p. 66]. This means that presence of a mineral is much less important than availability or accessibility as a measure of human usefulness in support of a desirable life style. High-quality resources are likely to become very expensive, therefore less accessible, much sooner than 100 years. Cost of mineral resources will be a function of rapidly increasing demands and decreasing availability.

As costs of providing adequate resources increase with relative scarcity, governments will be engaged in the difficult business of maintaining material living standard for those governed. Political realities might literally force a nation and, in turn, lesser governmental units to strive for self-sufficiency. The results are not isolation, but an elimination of or reduction in dependency.

In a closed system with constant technological potential, the renewable resources required to feed, clothe, and house each person are less available on a per capita basis as population grows. Demand on food and fiber will increase dangerously. Growing population and increased materials consumption will, for the foreseeable future, cause food and fiber demand to increase rapidly. Each nation, state, or governmental unit strives, usually by charter, if not out of concern, to supply its residents with food, fiber, and other basic needs. Failure to do so results in increased reliance upon balanced trade, which will become more and more difficult due to differences in distribution of resource supplies and demands.

A concept of relative closedness of governmental units becomes intuitively realistic under the previous scenarios. A closedness value of 0.70 would mean that an area must supply, from within, 70 percent of its needs for a particular resource. The recent past is characterized by almost all large governmental units and societies operating ecologically, as linear, open systems described by Commoner [1971, p. 12].

One might say that mankind has now entered a transitional period with respect to resource usage. In the near future many governments and societies will realize the value of ever-scarcer, high quality, natural resources as prices rise and competition increases. The social response to high costs for foreign resources will be group self-interest, and a trend toward self-sufficiency. (This response, of course, assumes that agressive, destructive actions will be held in check by a clear view of the consequences of such action . . . a tenuous assumption, indeed!.) The state or governmental unit which can provide the necessary resources for its citizens will be in the best position to survive increased competition for scarce resources. That state or its subunit will also be less dependent on "risky" resource supplies and less vulnerable to political and ideological instability.

Eventually, under an optimistic scenario, each state will strive for as much self-sufficiency and mutuality as possible. The level of closedness of a state will be determined, in part, by the commitment of each state to insuring adequate resources for the future. Other factors will be the material standard of living sought by citizens, the availability of resources (a function in part of how soon the state acknowledged resource "scarcity" and took remedial action), and the innovative capacity of social, economic, and technological institutions. The most successful systems—watersheds, states, and nations—in this period will be those that have control of their resource supplies, are using those resources with minimum waste and degradation, and are seeking capacities for resource renewal.

Tenet 8. The people of a watershed are pluralistic.

Planning must and can achieve maximally the diverse, differentially weighted, disproportionately held interests or values of the many publics within a watershed and relevant region. It is possible to arrive at useful statistics by which various watersheds can be compared, thus giving the unwarranted appearance of a centralist planning approach.

Tenet 9. Planning must deal with the optimum allocation of time, space, diversity, and mass (Figure 3).

Within the concept of diversity and energy are embodied many institutional and human factors of the watershed.

Tenet 10. Master planning can be done for a watershed.

Contrary to the present form of such plans, master plans should be computer-generated documents, easily edited, updated, and revised as various human needs are met. Master planning is long-range, comprehensive, and emphasizes (a) goals, (b) assessed present conditions, (c) constraints and restrictions, and (d) needs.

Tenet 11. One or more centralized governmental planning centers are needed within a state.

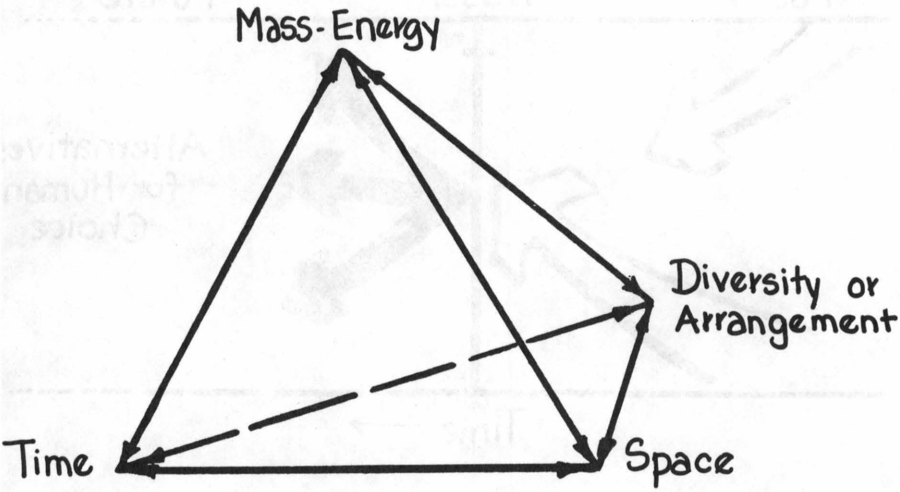
The work of such centers is (a) to provide information, (b) to operate monitoring and feedback systems, and (c) to run analyses of private and public proposals and requests for permission to build certain facilities or implement certain policies or laws in the watershed.

The usual service of the planning center which will operate general purpose computer programs, given project-specific data, will be: (a) a report that the proposed project is within a reasonable (or unacceptable) limit of the optimum solution, (b) a list of consequences, (c) an optimum solution, which can be used as a basis for project design.

Planners in these centers will : (a) operate and improve the systems, (b) assure citizen inputs, as will be specified later, (c) educate the people of the watershed about the planning action and its meaning, (d) mediate apparent planning conflicts, (e) develop prognostic aids, and (f) collect data as needed to improve the computer models.

FIGURE 3

All Man-Environment or Resource Systems Can Be Conceived As a Tetrahedron of Four Interactive General Concepts. Specifying the Optimum Allocation of these Four Primary Resources is a Major Planning Function.



Tenet 12. Achievement of a complex set of weighted goals, expressed in energetic terms, is the dependent variable in the planning equation.

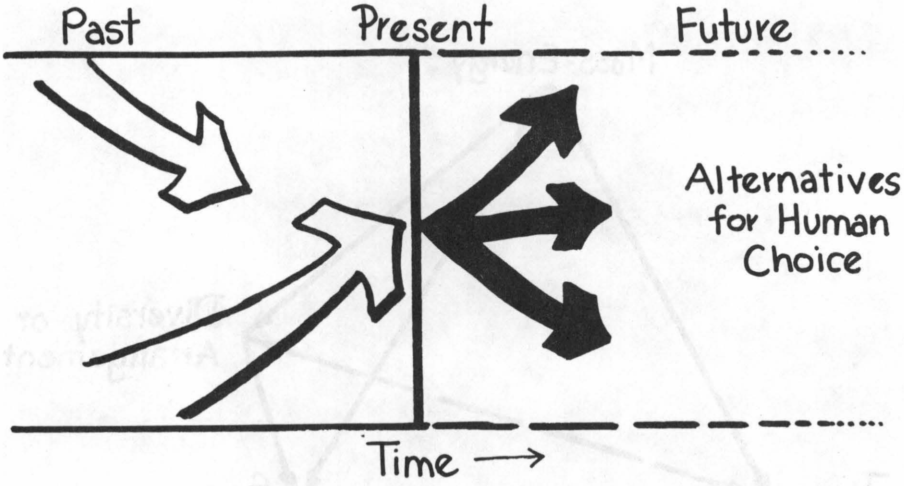
Population is an independent factor in a watershed. It is *not* an objective. Growth in population may result from the recommendations that are followed; stability or decreases may also result.

Tenet 13. Economic or physical growth of a community may result from decisions, but growth does not necessarily occur.

The system should include concepts of planned growth or reductions. A hands-off policy is untenable, since it virtually assures very serious economic and ecological problems in every Virginia watershed in a few years. It assures the loss of most of the present desirable qualities of every community. A planned growth concept is depicted in *Figure 4.*

FIGURE 4

Planned Growth Is a Human Decision That Is Made (or Allowed to Happen) in Watersheds. Desired Direction and Rate Can Be Determined and Actions Taken to Achieve Them.



The system does not present several unique strategies for watershed development and require a choice be made among them. A document and multiple choices are too much like advanced conventional planning [UCLA Regents, 1972]. Some plans present one alternative and become "that book on the shelf." Larger volumes with more alternatives will likely join them on the shelf.

Planning documents are needed. However, the moot questions of "this industry or that?," and the imponderables of "three little developments or one large one?" are usually unanswered by such documents.

Goals established by means described later and an energetic objective function provide the initial component of a guidance system. The market largely determines major physical changes in a community. Federal or state funds and human populations may also cause major change. These forces must be accommodated when they occur within the system.

Tenet 14. With computer technology, all feasible alternatives in a decision-making situation can be examined and the best selected, as defined.

Close-at-hand alternatives can be presented to establish relation, suggest risks, and demonstrate the likelihood of suboptimization if the decision-maker deviates from the stated optimum (as he may rationally decide to do). A solution is presented which is optimum and alternatives which might be considered are presented to serve other purposes. The approach is significantly different from that of Zube [1974,p. 14] and others who perceive the role of the planner not as a decisionmaker but "rather an illuminator for decisionmakers of potential courses of action and of the probable consequences attendant to the adoption of each of the alternative plans." Zube's [1974, p. 14] statement is not believed to be valid: "To be of value in this context, it is axiomatic that the alternatives should represent significantly different choices with significantly different consequences." With computer assistance, the pre-specified weighted goals, and a massive energy-related data system, these extreme choices are nearly useless and resemble a restatement of the fact that a problem exits. The subtle differences and the great choice for suboptimization make computer solutions necessary.

Contrary to searching for the mythical "highest and best use" of land, planning is approached from at least two perspectives, simultaneously. First, from a particular proposal, the system can evaluate a site on the basis of how well it can satisfy the needs of a particular development or type of use, both in terms of production and constraints. There are an infinite number of uses and interactive uses of a site. To attempt to select one best option from an infinite set (even if it could be done), without considering cost or existing supplies, is silly. The other perspective is that of the watershed. The answer to what is the best use of a piece of land can only be answered after such questions have been asked and answered as: "What are the needs?" "What have been the past decisions?" "What are the constraints within the watershed and adjacent units?"

Tenet 15. The approach should be consistent with (and some erroneously say identical to) the multiple use objective of the U.S. Forest Service and some other agencies.

The multiple-use literature is voluminous, with most of the phrasing supportive of various political stances. The Forest Service or other agencies have not yet devised a process agreeable to most that will accomplish the articulated need.

Tenet 16. "Disjointed incrementalism" occurs with or without planners or planning and is to be eschewed as a planning approach.

Tenet 17. As citizens, planners may advocate certain projects, but advocacy has no place in the professional activities of the planner.

The whole, public, long-term good is the quest of the planner in operating a highly effective urbanizing watershed planning system.

The planner is *not* the watershed decisionmaker (though of course everyone makes decisions at all stages of planning). The planner is seen to be in a staff role, as if serving an industrial board. When performing best, he has analyzed community goals, examined all feasible alternatives for achieving those goals, presented the top-candidate strategies and their likely benefits, costs, and externalities, and shown where the industry is likely to be, over time, if each alternative is taken. The planner does not make the decision. After some analyses, it may appear that he has done so because one alternative is superior to all the rest. Nevertheless, *he does not decide;* he does not take the responsibility for the decision. Responsible for the analyses, certainly, he provides the environment in which are brought to bear the evaluations of risk, the nuances of citizen desires and expectations, the diverse experience of the board members, and alternative concepts of an unpredictable future.

Tenet 18. Without exception, watershed planning must begin with the articulation of citizen goals.

Bauer [1973, p. 163] said that planning is "a rational process for formulating and meeting objectives (goals)." The creation of goals is not a scientific process. They are invented by the minds of men, and must be articulated by and written for the citizens of the watershed and the relevant region. Data gathering or other typical actions done prior to goal setting are likely to be wasteful. Without goals, there is no basis to judge whether ample or excessive data have been gathered and whether the costs are appropriate.

Problems represent unfulfilled goals; the extent of the problem is an interaction between the goal's importance and the gap between the present condition and the desired condition of goal achievement. There has been emphasis in the past on problem analysis preceeding goal articulation. Insistence upon problem analysis by some writers has the same meaning as does the admonition to "establish the system context." For the watershed planner, the context is given; no one can describe how to manage or plan for an unspecified or unknown entity. The place to start planning is with goals.

Tenet 19. When goals are well established, crises are reduced and thus the need for adaptive or contingency planning is reduced.

A major function and thus a measure of planning effectiveness is the reduction in number and magnitude of crises. A typical master plan provides a list of needs without specifying how those needs will be met. When proposals are offered, or other events arise, they are accepted as healthful responses to the needs of citizens and are evaluated against the goals and constraints. Rather than daily crises, daily opportunities arise for achieving goals in the recast planning system.

Tenet 20. Education and learning is a part of a vital life but it cannot be called planning.

Inputs are needed for decisionmaking. Some call such inputs knowledge. Real planning knowledge is of the interactions and processes as well as goals, information, feedback, and feedforward of a watershed system. In the same way that the medical doctor does not expect the patient to master his knowledge of the human body, the professional planner does not expect all citizens to master his knowledge of the urbanizing watershed system. Man can know, can model, can predict, and can decide about taking actions in the watershed. The planner must teach planning groups the basics of decisionmaking—identical to those components of general systems theory *(Figure 1)*.

Tenet 21. Planning recommendations must be consistent with legal tradition, but this does not mean they must be legal under the present law, or demonstrably approved.

Suggestions for legal changes and new laws are needed to accommodate future environmental management. Legislative and institutional arrangements can eventually be created if compelling arguments are made.

Tenet 22. Much of what planners and planning staffs now do has no relation to planning.

This is not to say that what they do is unimportant. The statement is made (a) to answer the planner's objection that he has no time or funds to do what is specified in this text, (b) to suggest to governments they may be misallocating their planning funds and human planning resource, and (c) to suggest to agencies and universities that if the planners needed for achieving this design are not available, then there are options available other than to continue on course.

The approach detailed herein, to the author's knowledge, has not been used. There is thus hope. The practices of the past have led to the current mess. There is little evidence that older, simplistic methods are likely to work in the future.

"Land use" is a phrase that is almost meaningless due to its diverse use and interpretations. How a farmer plows or what crops he plants are both land uses. How lands are taxed or taken are land-use issues. Land means "all resources" to a growing number of writers. How regions are formed and how lands are administered are also called land-use issues. There is now more land-use literature than can be read by a person in a lifetime. How to make sense out of it all is a major problem, for there is much knowledge for solving the problems that have been listed in the previous section.

This book is about land use and it, too, is likely to seem to many readers to have just another point of view of what now is almost one word: the-complex-issue-of-land-use. The book attempts to provide a valid organizational method for accommodating the many problems and perspectives of modern land-use discussion.

The outline of the premises is as follows:

1. Land encompasses all of the actual and potential resources of an area.
2. Land, as resources, is influenced by (or is statistically dependent upon) other forces such as human actions, climate, and geological forces.
3. Man is both an environmental factor as well as the primary recipient of land benefits.
4. Land, by definition, exists for man.
5. Land has potential for meeting many of the goals of man.
6. Depending on many factors, human, biological, and physical, man may not achieve the potential long-term benefits from land.
7. A 50-year planning horizon is reasonable for planners of the urbanizing watershed. This is an unfortunately short period but some will still argue that it is too long to be reasonable. They argue retrospectively. Longer periods are needed. Cities have hundred-year-old structures; museums display thousand-year histories of man; million-year stories are writ large in the geological strata. Countering these pressures for the long term are desires to meet the needs of the immediate family, to adjust to short-term changes in markets and interest rates. The planner can now adopt a 50-year period, operate as if planning at two-year intervals, but every two years push the 50-year horizon ahead by two years.

Thereby, the planner can secure the relative confidence of the short run and the perspective of the long run.

8. Land benefits are best evaluated as net benefits, since land can have both positive and negative utility to man.

9. Man can decide on goals, weight them, and assign risks to them.

10. Land systems are primary potential means for achieving these goals.

11. Lands are used, that is held (owned); employed as reservoirs or material "sinks" or storage areas; extracted from; changed in structure, relation, and their dynamics; or maintained in a near-stable stage.

12. Use of (or failure to use) land is done to achieve complex, often conflicting, objective sets for the owner, often by his agent.

13. The owner may be public or private, singular or plural. All U.S. lands now have major dimensions of public ownership, especially in restrictions on rights of use.

14. Land management is a decision science. Rational decisions can be made about all of the above by applying general systems theory. The land management quest is to design and implement an environment, e.g., the urbanizing watershed, in which man may achieve his highest humanity. How land is used is a major determinant of that opportunity.

15. Such management is not now within the purview of any one profession [Parker, 1974, p. 8]. One such profession is emerging—the quantitative general systems ecologist and planner. The name is irrelevant; the needs are great.

16. Institutions are involved in land-use issues because of the overlapping public-private nature of land, the extensiveness of some holdings into more than one jurisdiction, and because of the off-site consequences of site-specific decisions. Decisions are thus both a professional and an institutional problem.

17. Land-use policy is a set of constraints, assumptions, concepts of the future, and criteria of performance for any actions taken. Policies are not goals. They are the guides and limits to actions by which goals may be achieved. They are criteria for choosing among alternatives and for implementing a chosen strategy, such as safety, preservation of options for the future, and for reflecting high-quality workmanship. Policy may be enacted into regulations and laws.

18. "Critical area planning" is wholly insufficient as a basis for statewide planning, specifies only what not to do (or what areas to which little may be done), and provides no goalthrust for the inter-spaces.

19. Zoning was an advance over the absence of goals or criteria as a viable basis for land-use planning. It worked poorly and incompletely.

Relatively few communities have zoning ordinances (5,000 out of 60,000 jurisdictions). Sussna [1970, p. 8] observed that ". . . . qualitative zoning ordinance devices as setback, side yard, height limitation and lot coverage requirements are too often inimical to architectural beauty." With goals, a large informational system, and sophisticated computer programs, it is now feasible to do facility-by-facility, proposal-by-proposal analyses of the total consequences (impacts, plus or minus) of each site-specific or area-wide decision to be reached. Planning, with computer assistance, can now advance beyond the grossness of zones and overcome the great loss of information and detail required by such aggregation.

20. It is now possible to achieve total, integrated planning and guidance systems for managing the watersheds of the state to achieve, as best possible, the goals of the citizens of the state.

... devices as setback, side yard, height limitation and lot cove requirements are too often inimical to architectural beauty.[5] With a large informational system and sophisticated computer program is now feasible to do facility-by-facility, proposal-by-proposal analysis of the total consequences (impacts), plus or minus, of each site decision or area-wide decision to be reached. Planning with computer assistance can now advance beyond the grossness of zones and district zones to the level of information and detail required by such management.

It is now possible to achieve total, integrated planning, and guidelines for managing the watersheds of the state to achieve ... the goals of the citizens of the state.

While society may grant fee simple titles to land, this is not a complete domaine. Clawson [1973, p. 25] observed that "fee simple ownership became the dominant form of land title. A man could use his land as he chose, bequeath it to anyone of his choice, and sell or rent it as he chose. The doctrine that he owned the land from the center of the earth to the zenith of the sky became dominant." Smith [1959, p. 454] says, however, that "by reserving the right of escheat, eminent domaine, taxation, and the police power, we have established the fact that there is a public interest inherent in private land." (Similarly there are private interests in public lands.) Even though social perceptions of resource and land values are changing, it is necessary to establish a balanced concept of appropriate public and private interest in all land. Two-thirds of the U.S. is in private ownership. Increasingly, controls in limited ownership rights have been seen necessary in: (1) coastal developments; (2) building construction (by codes and inspections); (3) subdivision developments; (4) planning and scheduling public roads and utilities; (5) critical areas protection (scenic, historic, endangered wildlife); (6) public health (by codes and inspections); (7) strip mining; (8) farm land as open space; (9) irrigation allotments; (10) weed control; (11) where houses can be built or bought; (12) zoning (upheld since 1926), and (13) Land Sales Full Disclosure Act of 1968.

Clawson [1973, p. 26] observed that "as a people, we have gradually concluded that private rights in land must be restricted or limited in the general public interest." The concept of land as a commodity, an entity to be bought and sold, is changing to that of land as a national resource in which all citizens have a rightful interest. As regulations increase, the desire for ownership is likely to decrease as will the price (value) of land. The stake the public at large has in any land use includes the availability of low-income housing, open space, and the community real estate or other tax base. The shift in ownership is likely to be toward more strategic public ownership and thus acquisition and land banking [Anon., 1973]. Clawson [1973, p. 35] speculated that new forms of public land ownership would be developed with the government acquiring land and then serving as the means by which use and control could be transferred to new owners and users.

Gibson [1974] said, "We cannot hope to establish an adequate land settlement policy until our people acquire a better understanding of public rights in land and the relation of these rights to the goods they wish to achieve. . . ."

Increasingly, "private ownership no longer grants total immunity from public review" [Welch, 1973], as many forest industries in Oregon and elsewhere have discovered. It now seems clear, although myths abound, that governments can regulate use of lands for public purposes. Where regulation is not possible, land can be taken from an owner by government. Both by law and by taking, government now regulates use of land. The latter is most extreme, and the law requires compensation for it. It is not true, however, that courts will overturn regulations that do not provide compensation for losses experienced from such regulation [Bosselman et al., 1973]. Batie and Long [1974, p. 43] made the pertinent observation:

> . . . why should the state compensate for those values lost by landowners which were created by the state's action? The availability of publicly provided services may be the chief component of the purchase price of development rights. Should the state create values and then be expected to repurchase them?"

No compensation is generally required by courts in situations where some reasonable and profitable use of property is left after regulations are applied.

Ruled a Supreme Court Justice in 1887, "Appropriate regulation of the use of property is not taking property. . . ." The Virginia colonial legislatures long regulated the type and amount of crops that could be grown. Courts generally sustain regulations that reduce private land values by as much as two-thirds. Two-thirds seemed to quantify as "too far" in 1922 when the court ruled "that while property may be regulated to a certain extent, if regulation goes too far, it will be recognized as a taking." Smith [1959, p. 455] observed that "in any case, private ownership is not permitted to hold land against the welfare of the group." How to define and attempt to achieve the welfare of the people of a watershed is the topic of this book.

INSTITUTIONS

The realization is becoming clear that there are no good answers for improving the quality of life in a situation of scarce land, increasing human populations, and increasing expectations. All answers are only more or less bad. This superficially negative concept is an admission that land-use guidance is extremely difficult and that it is unrealistic to search for a perfect answer. Such a search reaps only interminable frustrations. Students reading this paper have claimed in it the emergence of realities of *1984;* others have suspected it to be undemocratic. Careful readers will see that it is responsive to what the author believes are massive environmental problems demanding unconventional and massive solutions. The specter of *1984* was, when Wells wrote it, an extrapolation of trends as he perceived them, not an advocacy of them. If the present trends can be reversed or the problems articulated herein solved by other means than war, famine, or pestilence, then those means should be adopted. Even then, the guidance center recommended is likely to be useful. To counter claims that the system is undemocratic or "big brotherish," attention is requested (1) to the section on participatory democracy; (2) to the ability of citizens to input their objectives and to weight them; (3) to reduction in the complete control of such systems by experts, as presently practiced; (4) to the statements that present governmental forms are *not* changed; (5) to the non-compulsory nature of the center, it providing *opportunities* for gaining guidance; (6) to the ability to restate or articulate new goals to reduce "big brotherism," and (7) to the ability of the system to provide citizens more information than ever before about the consequences of possible decisions and decisions actually made. Not a *control* system, but a *guidance* system is operated by the staff of a center, now to be described.

It seems reasonable to take a systems approach to the problem and to design goal-oriented systems with abundant corrective feedback mechanisms. One component of such an approach must be the processors, the means by which the various inputs are converted into goods and services desired and needed by the citizens of the watershed.

Taxation has been called an "institutional means" of land-use control, but this seems an unwarranted use of that phrase. There are two major institutions that can be created and shaped to achieve citizen's goals. These are the *law,* including legislature, courts, and enforcement, and a watershed agency called the *watershed guidance center.*

I. The Law

Like public works that are authorized but never funded, environmental laws are passed but rarely reach full implementation or the maturity of their intent. Similarly, laws attack large, complex, and interrelated problems piecemeal and simplistically.

Zigler [1974, p. 80] listed environmental laws affecting Virginia and asked, "What more do we need?" He listed many and admitted there were likely others. A representative list includes:

- —The cooperative soil survey legislation
- —The forestry laws
- —Critical Environmental Areas Act (1972, *Virginia Code,* Sect. 10-187.)
- —The game and fish laws
- —The health department regulations
- —The air pollution control laws
- —The statewide building code
- —The marine resources laws
- —The Open Space Act (1966 *Virginia Code,* Sect. 10-152.)
- —The Outdoors Plan
- —The Reforestation Act
- —The Scenic Highway Act
- —The Scenic Rivers Act
- —The Erosion and Sediment Control Act (1973, *Virginia Code,* Sect. 21-89.1, 21-89.15.)
- —Soil and water conservation district laws
- —The strip mine laws
- —The water quality laws (e.g. Water Pollution Control Act Amendments of 1972, P.L. 92-500).
- —The water resources laws
- —The Wetlands Act (1972, *Virginia Code,* Sect. 62.1-13.4)
- —The State Constitution (1971, Article XI, Sect. 1.)
- —State master planning (*Virginia Code,* Sect. 2.1-63.3.)
- —Virginia zoning enabling legislation (1927 and 1950 *Virginia Code,* Sect. 15.1-486.)
- —Special Real Estate Taxation Act (1971, *Virginia Code,* Sect. 58-769.4.)
- —High voltage electric transmission review (1972, *Virginia Code,* Sect. 56-46.1.)

—Subdivision Control Ordinance (1973, *Virginia Code,* Sect. 15.1-465, Sect. 15.1-466.)

Horkan [1974, p. 69] said that ". . . it must be recognized that effective land-use control is primarily a political and not a legal matter." Most people will interpret "political" too narrowly and negatively. Horkan said further:

> If the people are satisfied with the present land-use practices in their jurisdictions, they must concentrate their efforts on electing new political leaders who share their common objectives in land-use control. A legalistic interpretation of an ordinance is no substitute for an informed and determined electorate in bringing about improvements in land-use control in the Old Dominion.
>
> Local government must be persuaded to utilize fully the legal tools now available to protect irreplaceable agricultural lands and open spaces. The state government must be persuaded to develop new legal tools to protect critical environmental areas—particularly our mountain ranges and historic sites—perhaps using the recent wetlands legislation as a model. The basic problem is not with the laws, but rather with our will to achieve better land-use control. Once we develop a clear consensus on the kind of county in which we want to live, I am confident the law will find a means to provide it on an equitable basis.

Sussna [1970, p. 10] noted the American Bar Association's statement in 1940: "The broad reaches of 'public purpose,' 'public use,' 'public power,' 'due process,' 'reasonableness,' and so on can be expected eventually to provide authority for all that needs to be done." He also quoted [1970, p. 39] the lawyer-planner, Alfred Bellman, as saying:

> Be sure you are right, *then go ahead.* There is nothing in the nature of American constitutional law which should produce timidity or the palsying of effort by fear of constitutional difficulties. The American Constitution is sufficiently beneficient and wide-armed to receive within its protection whatever is morally and intellectually justifiable and really needed for the public welfare.

A substantial legal basis now seems to exist for much of what must be done. Imaginative use of present laws can achieve much of man's desired environment. How much will depend upon later court rulings. Planning is needed to prepare for these later court cases to assure they are brought by useful types, in sequence, into the courts. Appeals and subsequent legislative action must also be planned.

There is new environmental law to be written, particularly that relating to planning, taxation, building codes, health, open space, recycling, and energy conservation and consumption.

II. The Watershed Guidance Center

New legislation may be needed to clarify the legal environment within which a watershed guidance center may operate. There exists an optimum planning institution for Virginia's urbanizing watersheds now and for the immediate future. There are major needs to invent an alternative social institution and that need is combined with evidence that present institutions are not working, that present institutions are ponderous, and that some institutions exercise a monopolistic hold.

The citizens of the South River watershed could band together and, with sacrifice, create the system and center described herein. However, there are 90 similar watersheds in Virginia alone. Each cannot create its own system; there is not the expertise or resources available. Even with unlimited resources the effort would be folly. The system proposed herein is appropriate for the South River, and in the opinion of the author, would pay off if they alone created it. Once created, however, should not other watersheds be enabled to use it? Perhaps the guidance center, as a non-profit organization, could achieve the collective ends of citizens for which governments are usually created. Normal social change proceeds during periods in excess of 50 years. Such a rate of change cannot meet the immediate challenges of a family of widely recognized crises.

Bauer [1973, p. 169] observed that:

> A national land use policy that simply shifts the present irrational way of making land use decisions to a higher level of government will produce ad hoc decisions that are little better and perhaps worse than those that are being produced by the present arrangements, decisions that may negate themselves or, what is worse,

that may cause irreparable damage to the underlying and sustaining natural resource base.

National policy, guidance, and services are needed as the context of a local guidance center. An overview is needed to prevent the "diseconomies of scale," the wastes and abuses that result from taking the small view. Torheim and Harlan [1973, p. 470] demonstrated the problem of planning scale for national forest lands. They said:

> Obviously, we can no longer limit land planning to national forest lands. In the future there will be as much concern for lands outside national forest boundaries as for these within. Concerned agencies are moving rapidly to combine their skill in a unified effort. The mobility of the nation and changes in population patterns— aggravated by a shrinking resource base—make a modern and common base for land-use planning essential.

National guidance is badly needed, for such outside forces as other countries now virtually are specifying how thousands of United States agricultural and forest acres will be used and how lands will be managed. An optimum watershed guidance system is not created within a watershed nor can it exist in a geographic vacuum. Forces within the United States can be organized and directed so all future land use is not exclusively the result of outside forces. Within the United States, federal, state, and corporate action now dictate local policy as a result of the hidden policy built into various programs, largely in the patterns of expenditure, highway and utility construction, public works activities, and various regulatory and fiscal acts.

State and federal overview must be present, and a watershed guidance center can assure it, advocating such overview while simultaneously remaining fearful of and taking actions to avoid heavy-handed, centralized power. Such overview can be provided, as is now evolving in the U.S. Environmental Protection Agency and the President's Council on Environmental Quality. Like most other land-use concepts, such overview systems have potential for good *and* evil.

Presently, federal and state land-use law are expressions of abdication of such overview since they typically deal only with critical environmental areas, and key facilities. Advocates of sticking to these issues either do not perceive the total, interactive land-use issue, or are fearful of being unable to control a centralized overview function.

Such overview as now envisioned will be directed at Earth, the nation, and regional areas, but reported to citizens in the watershed. These are the users, though they now have little or no identity. Goodman [1964] spoke of the new intermediate levels of government that were being created "to bridge gaps in the present structure or to provide an umbrella for dispersed units." Bauer [1973, p. 168] spoke of guidance for "multi-jurisdictional regions having essentially a single community interest." As Barrow [1973, p. 119] said, plans and new agencies are needed because

> one prime weakness of existing land use systems is the inability of various levels of government to get together in attacking the problems. Literally scores of federal organizations have responsibility over some aspect of land resource management. Each of these organizations was established to discharge a relatively narrow, specific responsibility and cannot act beyond the scope of its enabling legislation.
>
> On the state and local level the situation is even more fragmented. State level organizations are widely supplemented by city and county-level bodies, together with an overabundance of special purpose groups.
>
> A broad variety of private interests adds to the decision-making mix. So although a great many people in both public and private sectors are concerned with land use, this concern does not necessarily add up to a total management of land that is in the public's best interests. In many cases we find *de facto* systems that each effectively control.

It is essential to analyze such problems and see them clearly. However, it is nearly impossible to see workable solutions to the problems once they are identified. At the national, state, intermediate or local levels, the problems are conspicuous. Gibson [1974, p. xii] perceptively added the personal level to this list. He said:

> *The question is no longer one of whether we shall have greater restraints on property rights in natural resources in the future.*

> *Rather, the question is what institutional arrangements shall be used to restrict property rights, and what procedures shall we use to determine and implement trade-offs between conflicts?* Again, the real danger lies in whether the American people will accept institutional arrangements that can be formulated to reduce the deterioration of our environment."

There is fairly uniform agreement that land use planning and management must be done at the local level. Healy [1975, p. 2] said that "by virtue of not only tradition, but efficiency and political responsiveness, there is a strong case for local control of land use." Croke et al. [1971, p. 21] said that state enabling legislation in all 50 states had delegated the powers of land-use regulation to local city and county governments. Otte [1973, p. 84] said that "most of the acute problems of land use will have to be tackled, as they always have, at the local level. However, many of their problems do extend over more than one local unit of government and need either regional or state coordination." In Virginia the possibilities are very great for conflicts, disagreements, and simple misunderstanding that can require jurisdictional dispute and result in delayed benefits from land or even in its abuse. There are in Virginia 99 counties, 38 independent cities, 196 towns, 22 planning districts, and a myriad of state and federal agencies with different regional boundaries. Healy [1975, p. 2] observed:

> There is a pervasive feeling that local control of land use, which in practice means local zoning and subdivision regulation, has been a failure. However, it is important to separate the failure of specific local controls from the shortcomings of the concept of 'local control.' If local zoning has failed, the fault may lie with the tool rather than with the level of government that wields it. Given new policy instruments, new property tax laws, and prodded by an environmentally aware citizenry, local governments can go far in improving the quality of their land use.

The problems with local controls, as Healy [1973, p. 3] observed, are lack of land controls (due to the generally small size of localities), lack of resources, and lack of expertise of local government. Over and over must be stated the general inability of local groups to solve readily the many cross-border problems they encounter, to coordinate programs, and to stabilize a community in an otherwise dynamic system. Local organizations often have narrow scope and a single purpose, thus failing to see larger regional or economic changes. Their limited resources or expertise prevent them from securing information for decisions. Industries, businesses, developers, and some government agencies seem to have the answer before local regulatory or governing boards can formulate the questions. Kaiser et al. [1974, p. ii] observed that "local government is currently the weak link in the intergovernmental environmental policy framework mainly because it lacks technical capacity and is under-utilized by higher levels of government."

The concepts of Watt [1973, p. 196-197] are compelling in analyzing alternative institutions. He said:

> Many economists have pointed out the importance of separating the intelligence or data gathering and interpretation function, the regulatory function, and the action function in government and other organizations. . . . Galbraith [1967] has pointed out the types of symbiotic relations between government and industry that have come to characterize what he calls the new industrial state. Too often, we have a highway industry and highway departments with a community of interest. . . . Can one imagine a highway agency in government deciding that the highway industry should slow down on its rate of building highways? . . . The point is that in order to make our political system work effectively, and ensure the most rational, objective possible system of selecting optimal management strategies for resources, including watersheds, we must separate administratively the functions of collecting and interpreting data, action, and regulation. Each of these three functions must be under entirely separate control, so that collection and interpretation of data and regulation are negative feedback control loops regulating the action agencies, rather than being easily overruled adjunctions to the action agencies.

Croke et al. [1972, p. 25] used the concept of land-use guidance systems. The watershed guidance center proposed herein for the South River watershed and similar units in the future are to be composed of a paid professional director and his staff (of size determined by the nature of the watershed and community). Its primary function is largely intelligence gathering and interpretation for watershed decision guidance. Its interactive functions are: (1) assisting citizens in articulating goals and obtaining citizens' weights for these goals; (2) organizing and coordinating organizations for improved goal achievement; (3) collecting, storing and retrieving information; (4) prescribing and advising, and (5) educating. (This is a design document only and the use of such phrases as "the center will . . ." are not based in any law or mandate. The author, however, is of the opinion that the design can and will be implemented one day.)

A. Articulating and Weighting Goals

The center will solicit, in the most sophisticated way possible, public goal statements, quantify them, and seek updated expressions of public value and acceptable risk-levels for these goals. A new methodology is outlined later, and its further development will be a center and state responsibility.

B. Organizing and Coordinating

The watershed guidance center can guide and direct the orderly, cooperative growth of watershed sections of counties. The centers would be in a position to remove many of the massive, onerous tasks from existing agencies and citizen commissions and assist them in their decisionmaking by providing information, plans, and suggested policy.

The center would not replace the councils, boards of supervisors, or other established decisionmaking groups within counties or planning districts. It is unrealistic to think that they could be replaced or drastically changed. They remain the decisionmaking units of government. County boards of supervisors, city councils, and similar decisionmaking groups had, years ago, only limited responsibility and power. Much of their responsibility was once associated with local roads and utilities. Now they have power to establish police and security forces; organize a planning commission; make building, zoning, and housing regulations; regulate parking; construct and maintain sewage and solid waste disposal systems; provide and operate parks and other recreational facilities; and perform many other functions.

The center would not replace local planning commissions. In their current organization and practice, commissions now perform many essential functions, few of which are planning. Their planning role can be enhanced and aided by the center, and information supplied that allows them to see better "the whole picture" and to include adjacent county or city factors in their decisions.

The center would not replace the state planning districts. Where a watershed and its adjacent watersheds lie entirely within a district, it is conceivable that a section of a district staff may perform the function of the center. The districts are conceived along county boundaries and these are a root cause of problems the center is conceived in design to alleviate.

State planning agencies may participate in the watershed center with carrot and stick. It could provide (1) advice, (2) computer assistance, (3) partial staff support, (4) grants, (5) general public incentive funds to be allocated to accelerate the watershed planning processes, (6) a data bank, (7) educational materials, (8) special influence in allocations of federal local assistance funds, and (9) assistance in securing goal-specified and highly compatible developments. The state as well as planning districtsmay render assistance to enable the watershed authorities to develop their own policies and potentials. The state planning agencies may also participate by not recommending highway, utility, hospital, airport, or energy funds to areas not actively and effectively participating in the watershed guidance center process.

Welch [1973] noted a major problem "that bedevils the whole rush to comprehensive land-use planning; not enough planners are experienced in full-spectrum planning." There is no way this deficiency can be overcome in the short run. Therefore highly integrated computer systems of the type to be outlined and operated at the state level, constantly improved and updated by the best knowledge available and most efficient and realistic processes of the time, can reduce this need at the local level. The expertise to provide the guidance system will remain in short supply. Universities should not stop trying to educate such people. However, the center should rely heavily upon capturing present-day wisdom as it is discovered, and build it into the stystem with corrective feedback.

C. Collecting and Storing Data

A computer-based information system is described later. A type of data collection that is called monitoring is needed and this must be input or relayed to various enforcement agencies (including new ones). The center will provide analyses of just how far removed from a predetermined optimum decision each alternative is in order (a) to communicate this difference to the public and (b) to refine the system and operative variables. The guidance center will monitor watershed changes as reported by existing agencies. It will monitor and report regional and national resource supplies which potentially threaten the ability of the watershed to achieve its objectives. It will analyze and report how past decisions impair the ability of present societies to achieve their objectives.

D. Prescribing and Advising

A major responsibility of the authority will be to make available prescriptions and design recommendations for proposed developments and land-use changes. These will be made to existing decisionmaking groups. Based on all presently available data, computer analyses will provide the likely influences which a development or change would have, if completed, both locally and within the watershed.

When land use is specified by the computer system operated by the guidance center and the owner feels his use is better, then he can require the authority to prove their use is better in 30 days. This represents a need for a system "dump" of a somewhat costly (but not exorbitantly so), lengthy report showing the factors in the decision and the consequences of allowing the alternative land use. This places the burden of proof on the quidance center where it is and should stay. Where past designations of land use have been made and a developer wishes to challenge them, then the burden of proof is upon him to show the improperness of the zoning or other regulation. This is somewhat like requiring an environmental impact statement (EIS) from a developer (or having the developer pay for a computer run, an equivalent of an excellent EIS). The prescription by the guidance center should not be binding. Like advice from a doctor, the patient may take it or not. Eventually, however, the political process, an informed citizenry, and the prescriptive system are likely to become balanced. Information tends to hasten such balancing, i.e., to reduce the entropy of the system.

E. Education

The guidance center will provide education for decisionmakers and the public by providing maps and other analyses of decisions and possible consequences. An important function of the center will be to help decisionmakers to see the interconnectedness of things—of the effects of apparently simple decisions on many factors of the environment.

It is clear why Watt [1973] said separation of intelligence gathering and interpretation is needed. Education must include an interpretation of how well the other two elements of the political process are performing—how well decisions are made and how well regulation and enforcement are carried out. These interpretations are the feedback necessary to create and keep a system vital. Roberts [1970] discussed large basin authorities with heavy federal investments.

The major legal underpinning for the watershed guidance center proposed is Title 15.1, Section 427 of the *Virginia Code.* A watershed guidance center is a special "local planning commission" created by county or municipality and operating under the intent of the code which reads:

> *Creation of local and regional planning commissions authorized declaration of legislative intent.*—The governing body of any county or municipality may by resolution or ordinance create a local planning commission in order to promote the orderly development in such political subdivisions and its environs. This chapter is intended to encourage local governments to improve public health, safety, convenience or welfare and to plan for the future development of communities to the end that transportation systems be carefully planned; that new community centers be developed with adequate highway, utility, health, education, and recreational facilities; that the needs of agriculture, industry and business be recognized in future growth; that residential areas be provided with healthy surroundings for family life; and that the growth of the community be consonant with the efficient and economic use of public funds.

It may take one state agency to implement the guidance center concept. It can be done (a) within a planning district, (b) by a state planning agency, (c) the Governor's Council on the Environment, (d) a new unit of the state energy office, or (e) by a temporary section of the State Extension Service (see *Figure 5).*

Figure 6 is a flow diagram of the work of the center in a land-use decision. Note that the final decision is made by one or more pre-existing decision-making groups.

FIGURE 5

A Diagram of the Major Concepts and Disciplines for Use in Creating a Guidance System for Improving the Quality of Life for Man in the Watershed Environment

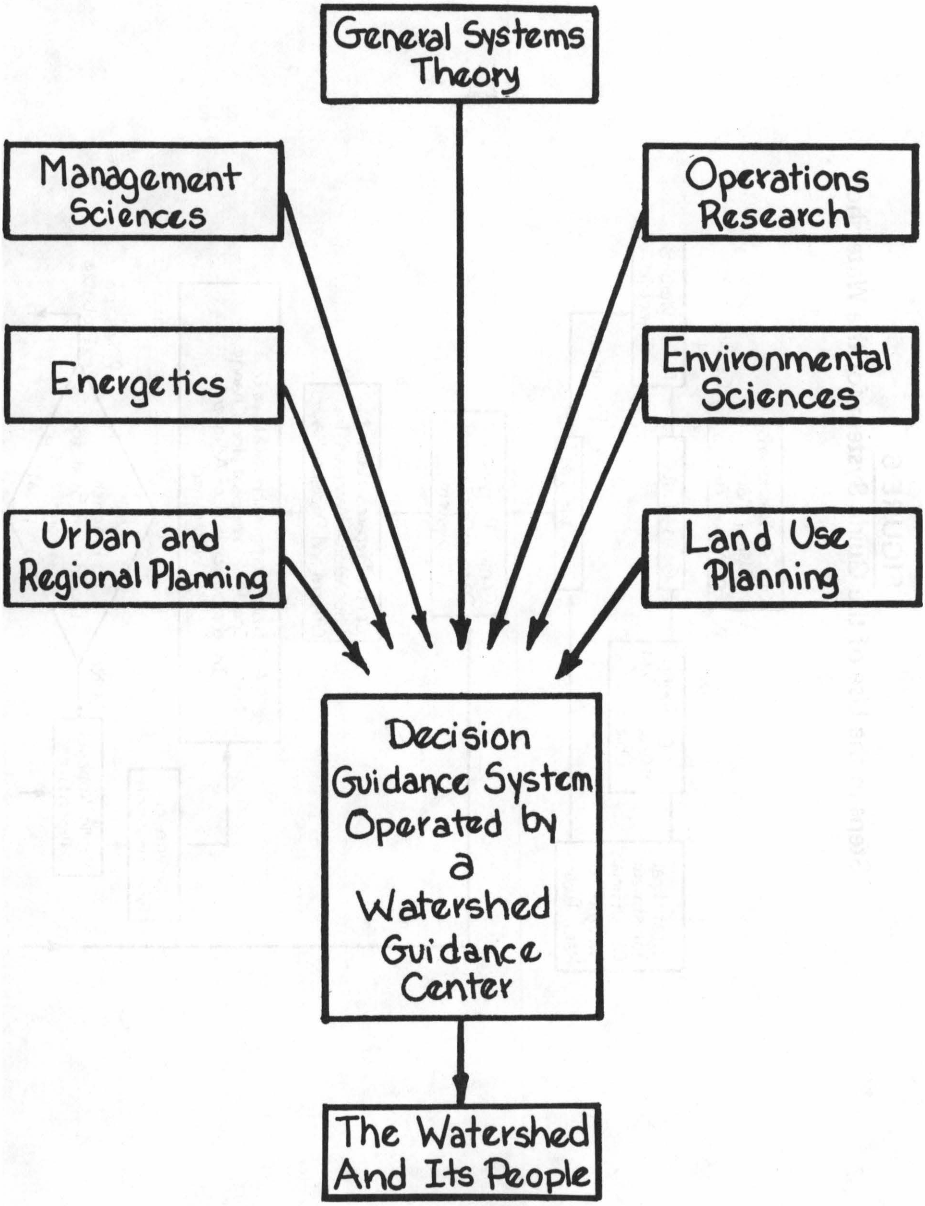
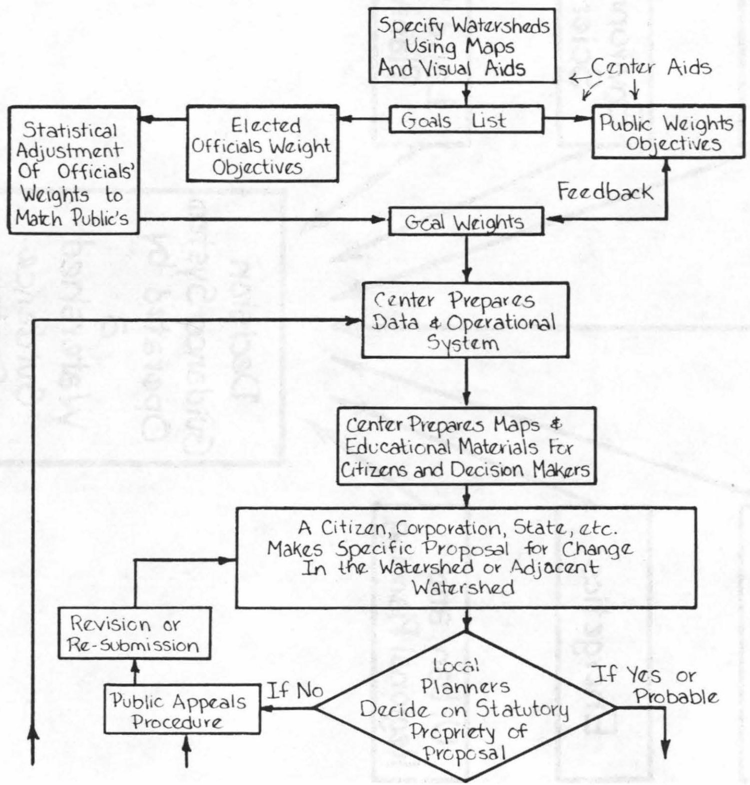
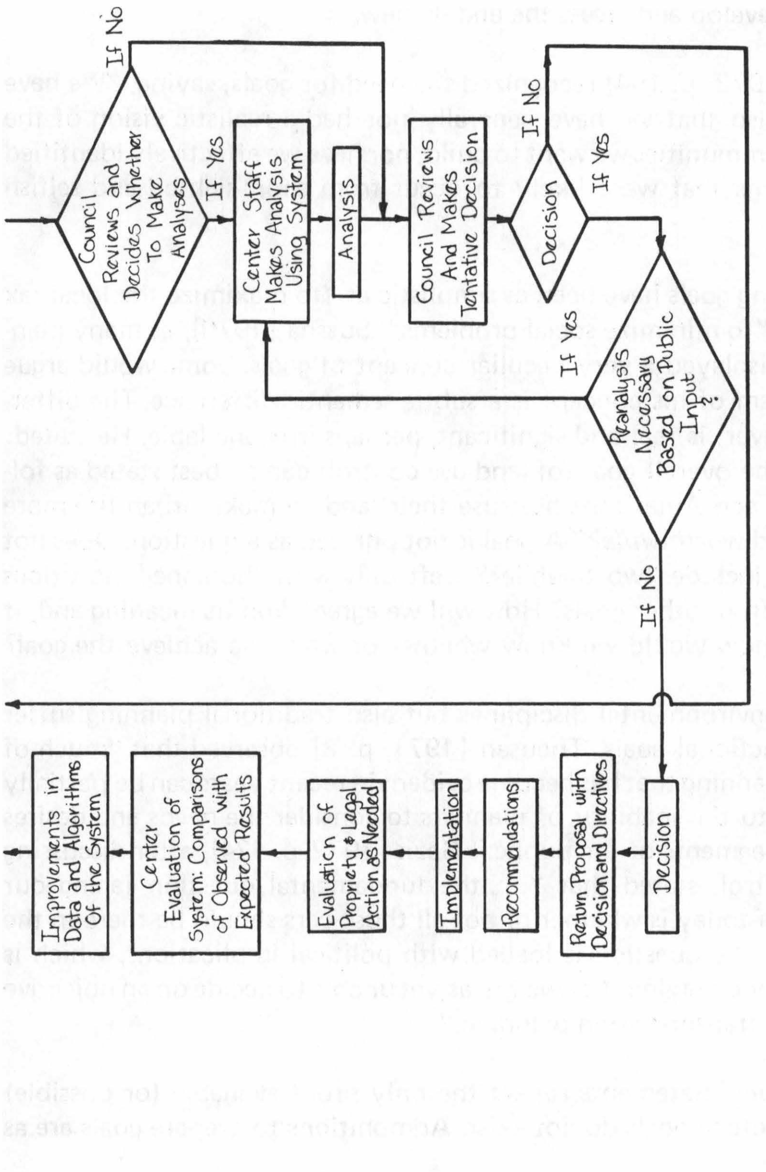


FIGURE 6
Steps in the Use of the Guide System for the Watershed




Council Reviews and Decides Whether To Make Analyses
If No
If Yes
Center Staff Makes Analysis Using System
Analysis
Council Reviews And Makes Tentative Decision
Decision
If No
If Yes
Reanalysis Necessary Based on Public Input ?
If Yes
If No
Decision
Return Proposal with Decision and Directives
Recommendations
Implementation
Evaluation of Propriety & Legal Action as Needed
Center Evaluation of System: Comparisons of Observed with Expected Results
Improvements in Data and Algorithms Of the System

F. The Watershed Guidance Objective

All valid systems design begin with the clear statement of a goal. Complex systems have a complex goal statement. Such a statement for the urbanizing watershed has eluded past workers. There is no physical ideal of good land that can guide man or one that will reflect on his progress or wanderings. Vlasin [1973, p. 54] said that "if the planning, guidance, and use of land is a means to an end, then we need institutional arrangements to develop and assess the end in view."

Wengert [1973, p. 154] recognized the need for goals, saying, "We have to admit also that we have generally not had a realistic vision of the kinds of communities we want to build, nor have we effectively identified the problems that were likely to occur from short-sighted and selfish decisions."

Past planning goals have been as simplistic as "to maximize the local tax base" and "to minimize social problems." Sussna [1970], as many planners, has displayed a very peculiar concept of goals. Some would argue that criticism of his concept is a subtle semantic difference. The difference, however, is real and significant, perhaps irreconcilable. He stated: "Perhaps the overall goal (of land-use control) can be best stated as follows: How can Americans best use their land to make urban life more *humane* and *worthwhile?"* A goal is not phrased as a question. Does not "humane" include "worthwhile?" Left only with "humane," how does this differ from other goals? How will we agree upon its meaning and, if we could, how would we know whether or when we achieve the goal?

Not only environmental disciplines but also traditional planning suffer lack of functional goals. Theusen [1971, p. 3] observed that "much of the poor planning that has become evident in recent years can be partially attributed to the inability of planners to consider the needs and desires of certain segments of the public." Gazis [1972, p. 424], after discussing traffic control, stated that ". . . the fundamental question facing our urban areas today is whether or not all those cars should be there in the first place. The question is loaded with political implications, which is another way of saying that we are as yet unable to decide on an objective function in transportation planning."

In total, such statements reflect the only proof available (or possible) that satisfactory goals do not exist. Admonitions to prepare goals are as old and abundant as are such claims. The odds *against* developing adequate goals and making them functional are extremely great.

Batie and Long [1974, p. 40] can be discouraging as they add further odds against a successful system.

> The public interest is indeed a moving target, continually being rearticulated, redefined, and reassessed.
>
> The really difficult task, then, will not be the formation of an elitist plan to be forced on any so uneducated as to not recognize its wisdom. The hard part will be performing balancing acts between conflicting objectives while chasing that elusive goal of public interest.

Batie and Long [1975, p. 44] suggested that the public interest in land use is some ill-defined composite of the interests of individuals and groups perceiving private gain or loss: "How to weigh these interests is unknown, although it is known that the political processes will weigh them." The problem is clear; a way to improve that weighing process is presented below.

The concept of participatory democracy characterized the urban-renewal, model cities, and anti-poverty programs of the 1960's [Appleby, 1971]. In the natural resource area, Edward Cliff, Chief of the U.S. Forest Service, perceptively observed that current criticism of the forester and the Forest Service did not focus on the technical ability of foresters. What is challenged is the ability of foresters to recognize and meet the public's needs. An unhealthy polarization has arisen between resource men and planners and those who advocate public involvement. The resource person has typically seemed to adopt an elitist stance: "The public pays me to tell them what is right; I know best: I am the expert." Some segments of the public want full control, review, and decision power. Although public opinion should become an important part of watershed management decisions, it would be unfortunate for management to rely solely on public opinion [Lime and Stankey, 1971; Lansing and Morgan, 1971]. Public participation at hearings and through other media is largely (1) articulating goals, (2) expressing weights and importance, (3) suggesting alternative goal-achievement strategies, and (4) suggesting consequences. The manager's job is to capture the above and to provide advice and aids for selecting among alternatives.

The most difficult and often forgotten aspect of decisionmaking is that ultimately a decision must rest with those accountable to the public [Appleby, 1971]. Those accountable, because they are accountable, are reluctant to turn over any decisionmaking power to the public. In a critical session on his accountability, the resource manager sees that "the public told me to do it" will be a vacuous defense. Defense will be less necessary if watershed guidance center staffs obtain specific, quantified value expression such as shall be described herein. Resource management and urban decisions are often based on flimsy assumptions about what the public wants. Many studies now support the view that natural resource managers often do not know or do not have the same attitudes or preferences as those held by their clients [Kasperson, 1969; Hendee and Harris, 1970; Bultena and Hendee, 1972; Kennedy, 1970, and Hampton, 1975].

Participation by citizens in decisionmaking in much more operational form is essential. All too frequently, the view is expressed that public hearings are perfunctory. They are held, the public views are "considered," and afterwards the agencies seem to go ahead and do what they proposed to do anyway. From public meetings, powerholders gain evidence that they have involved the people [Arnstein, 1971, p. 78].

In the future, improved, functional citizen participation is necessary, at a minimum, to guide the decisions. Citizen participation is ". . . the process by which citizens influence or control these who make major decisions affecting them" [Verba, 1969, p. 126]. Studies on citizen participation in water resource and related problems include Kasperson [1969], Fulton, [1971], Thuesen [1971], Warner [1971], Friedmann [1973], and Grigsley and Campbell [1972].

The recommended approach to citizen participation as an essential part of a watershed guidance system is based on (1) substituting "the probability of satisfying all the people" for "the greatest good to the most people," (2) the emergency of systems ecology, and (3) new computer aids for obtaining and analyzing citizen inputs. Sussna [1970, p. 38] observed, "With our vaunted pragmatism and all of our simulative electronic gear . . . the proper mix of controls to attain more precise objectives might be amenable to analytic processes that far surpass our current crude conjectures." The methods described herein are designed to aid in establishing more precise objectives as well as a proper mix of controls. Goal statement is not a scientific procedure, but a human activity requiring the synthesis of desires, preferences, and expectations. It is a risk-taking activity, for it is possible that goals may be imprecisely articulated, that what is obtained is not exactly what was desired, and that perhaps changes in desires and preferences, which have occurred in the past, may occur in the future. The following design, not likely to be perfect, is at least as good as and probably much better than the system now in operation. It offers opportunities for improvement where the present system seems to be deteriorating. A systems approach to goal formation requires continual feedback to that subsystem.

In *Table 1* is presented a list of 340 goals in 28 categories likely to be those of Virginians, statewide. Highly precise goal statements are prepared. In *Table 2* are the criteria used in developing them. The goals are likely to be reworded for various reasons. They have been developed largely by the author, revised and tested in a two-year involvement by citizen committees and a local planning commission, and scrutinized and edited by students of a Resource Evaluation Studio at Virginia Polytechnic Institute and State University, 1974. It is the author's opinion that the rate of addition of goals to the list has plateaued, and all goals "important" to citizens have been listed (by definition of importance). Additions will be of the nature of afterthought and will be either of low preference or low risk. Such undefined goals are unlikely to have impact on the systems design, the resulting computer programs, or the computed optimal solutions.

Giles and Lee [1975] argued that, while the appropriate source of goals for the public is each citizen, the systems analyst's job is to help the public articulate these goals, especially the hidden goals, and to express goals in useable, precise terms. Historically, goals have been listed and just as well could have been an appendix as the first section of planning documents. The systems man's job is to express goals in prose readily translatable into a mathematical or computer statement so that some operations can be performed with them. Goals must be stated in a particular way if they will be useful for such purposes.

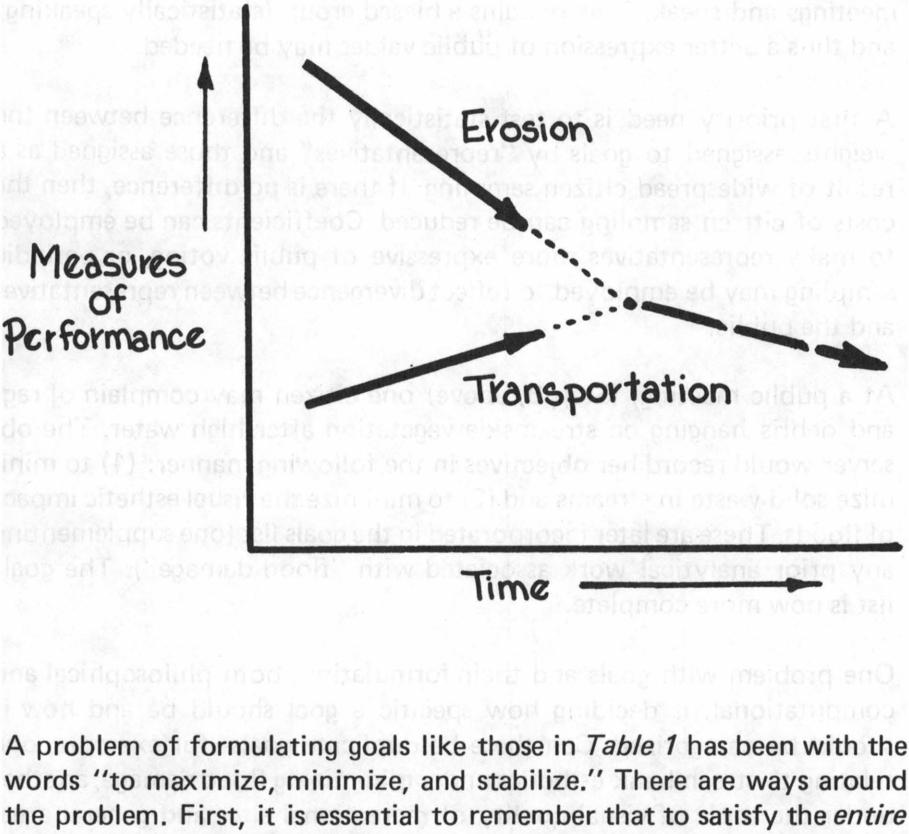
In WRAP [Giles, 1974], a TVA system for aiding landowners in achieving their wildland goals, there is the means for expressing 37 private wildland goals and then, by heuristic and goal programming, to present guides for achieving these goals.

Goals are those higher-order, precisely stated, final ends or conditions desired by man. They tend to be unreachable, something for which man strives, more directions of travel than destinations. After working toward a goal there always seems to remain at least one more step which can be taken to achieve it. *Objectives* mean discrete, potentially attainable activities which, when completed, will partially attain or fulfill the goals. *Policy* means the quality of performance in achieving goals and objectives. Policies operate as constraints or sideboards. Some call policies "criteria of performance" and include concepts like safety, efficiency, and concern for the future. These definitions are made here in recognition of the vast, ambiguous literature on their meaning. (If more time were spent on discussing the goals and objectives themselves and less on whether something was a "goal" or an "objective," society would be the better for it.) If a particular use or a special format is required for the ideas to become functional (as is the case herein), then some discussion of the differences is needed. Whatever the reader's past preferences, the author encourages little further argument over definition, and suggests the reader look at the examples, call them what he wishes, and then proceed to substantive discussions of omissions, increased precision, or alternative means for achieving the needs.

The most problematic aspect of the goal-formulation process with citizens or their leaders is the ease with which conversations revert to techniques and methods. The expressions of desires to achieve particular acts are called objectives. These objectives all lead to goal achievement. Discussions tend to be directed toward objectives which, if achieved, would tend to satisfy the goals. This occurs often enough to suspect it is natural and thus should be recognized as an inevitable part of the process. Only the greatest of effort and perseverence can return critical thought to goals. Once goals are articulated, agreed upon, and weighted, then it is believed that the creative intellect can be unleashed for achieving them in new, efficient, effective systems of action programs, projects, and individual action. Goals are the only bases for rationally allocating limited funds and manpower. They are the bases for evaluating supply and demand. They specify the production analyses that enable citizens to see what they get "free," or what they get as the result of past investments, and how much more must be produced and at what frequency or amount. The future will bring absolutely new events, techniques, and ideas at an increasing rate [Toffler, 1971]. Typically these innovations will be ways to achieve goals. The goals themselves are not likely to change very much. They provide the fundamental basis for decisionmaking now and in the reasonable future.

FIGURE 7

To Minimize Erosion and Maximize Transportation System Effectiveness Are Both Desirable Though Often Conflicting Goals. The Slope of the Line May Be Related to Values or to the Natural Limits of the System, the Dashed Line Represents the Simultaneous Solution



A problem of formulating goals like those in *Table 1* has been with the words "to maximize, minimize, and stabilize." There are ways around the problem. First, it is essential to remember that to satisfy the *entire* list of goals is the goal of the government (as aided by the comprehensive watershed planner). The government may not be able to do so, but that does not change the goals. (They need only seek alternative means or delays.) Thus, the list in *Table 1* is a *set*. Equations related to each goal are not developed in isolation. They operate as a system of equations and operations. A simple example of this operation together is shown in *Figure 7*. The reader must remember as he reads "to maximize *x*," that there is an implicit statement that each goal is ". . . subject to achieving all of the other goals."

The sequence of events in the goal formulation process is: (1) The first draft of the goals is prepared by an analyst, typically a representative of the guidance center. (2) The list is taken to representative decisionmakers (such as the South River Flood Commission) and changes made, based upon their suggestions. (3) Public meetings are held to gain insight into citizen objectives. (4) The revised list is then prepared. The list reflects both elected and appointed representatives and the public that will attend meetings and speak. This remains a biased group (statistically speaking) and thus a better expression of public values may be needed.

A first priority need is to test statistically the difference between the weights assigned to goals by "representatives" and those assigned as a result of widespread citizen sampling. If there is no difference, then the costs of citizen sampling can be reduced. Coefficients can be employed to make representatives more expressive of public voting, or periodic sampling may be employed to reflect divergence between representatives and the public.

At a public meeting, (Step 3, above) one citizen may complain of rags and debris hanging on streamside vegetation after high water. The observer would record her objectives in the following manner: (1) to minimize solid waste in streams and (2) to minimize the visual esthetic impact of floods. These are later incorporated in the goals list (one supplementing any prior analytical work associated with "flood damage"). The goals list is now more complete.

One problem with goals and their formulation, both philosophical and computational, is deciding how specific a goal should be and how it should be categorized. Can there be duplicate goals—for example, one relating to streambank esthetics under minimizing flood damage, another under the topic of visual quality of recreational sites and general areawide appearance of order and concern? Work to date suggests that if people state a goal in a particular way it should be included, even though double-counting may occur. The effort of the entire guidance system is to satisfy man over the long run. His satisfaction is derived from how he sees his universe. Rags on trees may not be very important to tree growth or streambank erosion control and may not have high removal costs. However, they may reduce the quality of solitary, infrequent, high-intensity and high-cost recreational experiences, *and* the visual beauty of highways, *and* the probability of his participation in areawide citizen action. One event can influence the achievement of many goals. In part, this concept of having many weighted goals explains why simple things seem to "get blown out of all proportion" (a frequent statement by politicians), or why more citizens appear at public meetings about some topics than about others. One event affecting one goal (A) may result in 10 units of dissatisfaction, but another event may create three units of dissatisfaction for Goal B, six for Goal C, seven for D, five for E, and two for F. The resulting 23 units of dissatisfaction are enough to cause great public turmoil though no one objective is compromised nearly as much as it is by the event affecting Goal A.

In addition, there appears to be a threshold of response, perhaps 12 units of dissatisfaction. A citizen, offended by some event causing seven units of dissatisfaction in Goal D, then experiencing an extra five units associated with E, may well experience "the straw that broke the camel's back" and swing into action.

Based on careful study and critical review, it is believed that the list in *Table 1* is likely to represent most (> 90 %) of the goals of populations of Virginia citizens and all (> 90%) of the highly-valued goals of the citizens. The list is likely to be identical in many other states, perhaps nationwide, but such a study has not been made. The list is the *structure* of a general goal system for citizens.

Unless the goals are clearly identified, systems will not be designed to achieve them, or if they are poorly stated, suboptimal systems will be designed. An example of the problem of clearly identifying goals is the goal: (1) to prevent flood damage. Another similar goal held by society is (2) to minimize public costs of flooding. Obviously that is not all that is implied by recognizing a flood damage problem. Other likely flood-related goals include: (3) to minimize mean per capital losses to flood victims; (4) to minimize the total present-discounted annual estimated flood damage over 50 years; (5) to minimize loss of life in floods; (6) to minimize crop and agricultural land productivity loss resulting from flooding. There are others.

Major dimensions of the goal-formulation process, especially related to energy, are as follows [Cottrell et al., no date; Environmental Information Center, 1974; Herendeen, 1973ab; Hirst, 1973; Koenig and Tumala, 1972; Macrakis, 1974; Rickles, 1973; and Searl, 1973]:

1. Goals are human statements. Stating goals is one of the most human of activities.

2. Goals are not discovered, as by using the scientific method. They are created by man.

3. Scientific analysis can aid in stating goals precisely.

4. Goals may be poorly perceived, thus merely identifying desirable goals can influence the outcome of goal-oriented decisions. Equally, problems may be poorly perceived. They may not even exist or they may be hidden, awaiting maturity before emerging into human awareness. The interaction of these two perceptions is critical for designing the watershed.

5. Goals are plural. Man is too complex to have *a* simple desire. He has a set of goals. Goals can be added or deleted. The structure of a goals list or weights or risk levels may be dynamic. Except for increasing editorial and quantifying precision, a goals list will soon stabilize, probably reflecting a near-universal list of wishes and desires of mankind.

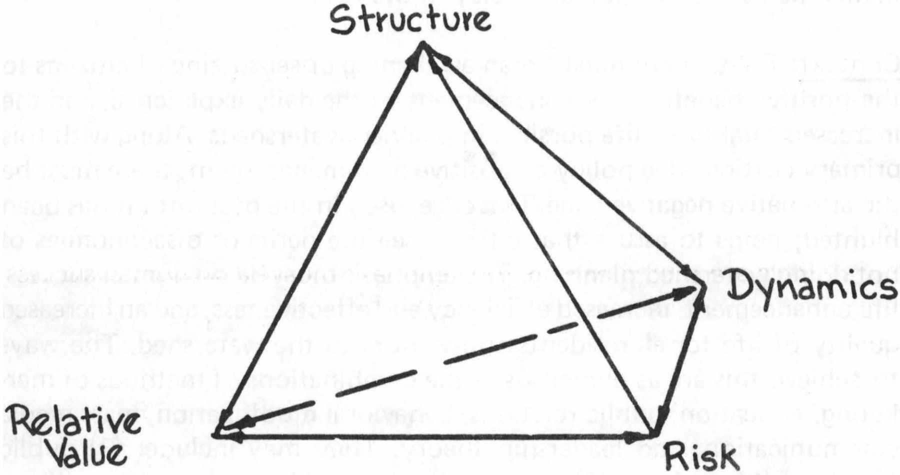
Before the reader rushes to join in refuting the concept of "universal" desires, let it be recognized that goals are multi-dimensional as shown in *Figure 8.* They have ***structure, dynamics, relative value,*** and ***risk levels.***

Different populations of citizens have what appear to be different goals. It is believed that they all have virtually the same *structure* but that each population attaches a different relative value to these goals. The goals are the same; the levels of preference or importance differ. Other phrases used to connote this same idea are that citizens "have different priorities," or that "they have a different value system than . . . ," that "they perceive a stimulus differently," or even "their tastes are different." Citizens' utility resulting from a decision about an action depends upon which of their goals are achieved by such acts and the preference they attach to each. Pressure groups form; citizens are irrate or apathetic depending on the effects of a proposed or actual event upon their highly-valued objectives.

The word "weight" implies the estimate of the relative importance or the utility an individual assigns to each objective. A citizen has many goals, each of which is a perceived "best condition," one in which his desire could be satisfied. This level may change, but that change can be accounted later. Desire is seen as a continuous state between deprivation and satisfaction. When a person is satisfied, $S = 1.0$, there is no further desire (D). Therefore where $S = 1.0 - D$, then $S = 1.0 - 0 = 1.0$. Satis-

FIGURE 8

Goals are Multidimensional Having Four Major Interactive Elements



faction, like the concept of potential, is a theoretical maximum and unlikely ever to be achieved, but it represents an operational and realistic limit which most people are at least willing to accept as a basis for fruitful discussion.

The literature of natural resource management is replete with discussions about the difficulty of multiple-use management, the resolution of conflicting goals, and the tradeoffs necessary between often near-irreconcilable objectives. The large watershed presents such a problem for system design. How does one optimize for 340 objectives for thousands of people over 50 years? This section presents a functional answer to how to formulate the objective function for this persistent problem.

Weights are assigned to each goal. Citizen involvement is essential. The length of the goals list is ominous. Many modern problems are due largely to citizens' (or their agents') unwillingness to face up to the extremely difficult task of writing objectives and weighting them. Man has simplified, grouped, and euphemized goals into functionless platitudes and quaint statements. Goals must be very particular and measurable if they are to be useful and worthy of time spent upon them. Few modern goal-statements can be so categorized. Any short cuts taken in developing goals will require lengthy discussion, arguments, and delays in the future. The time and pain invested early in goal statement (as *Table 1*) will eliminate much cost, conflict, and delay in the future.

Context: First, there must be an awakening or sensitizing of citizens to the positive benefits, the enhancement of the daily experience, and the increased quality of life possible in planned watersheds. Along with this primary cutting-edge policy of positive man-management, there must be the alternative negative edge. This edge, used in the past until it has been blunted, helps to assure that citizens see the perils or diseconomies of not doing watershed planning. The emphasis must be on human success, life enhancement, increased efficiency and effectiveness, and an increased quality of life for all residents and visitors to the watershed. The ways to achieve this are as numerous as the combinations of methods of marketing, education, public relations, behavioral modification, mass media communication, and leadership theory. They may include: (1) public meetings, (2) seminars, (3) mass media releases, (4) brochures, pamphlets, and newsletters, (5) special maps, including those that are historical, present, and some of the likely future, (6) demonstration and experimental projects, (7) presentation of future scenarios, (8) workshops, (9) game or simulation sessions, and (10) field trips.

Planning, expanding and coordinating existing efforts, and initiating new sensitizing efforts may require the work of a volunteer or paid advocate. This advocate can develop and maintain the context within which effective watershed planning can exist.

Of course planning must have other lines of communication with citizens. From such lines are obtained inputs to decision processes of both the citizens and planners. The techniques found useful in many communities include: (1) socio-economic analyses and background studies, (2) newspaper ballots, (3) interviews with key people, (4) analyses of past plans, (5) analyses of key political issues, (6) maintenance of an open office and open telephone, (7) task forces and brainstorm sessions, (8) progress reports, (9) employed arbitrators where necessary, (10) advisory committees and councils, (11) media rehearsals and previews to minimize poor communication, and (12) computer-based information systems. The design of an input system for watershed planning is fully as important as that for any other subsystem. The above dozen major alternatives provide the structural components for such systems. How to choose among them and how to allocate time and funds among the choices is a problem that is likely to be solvable analogously to other systems which will be described later in this paper. The communication process is so influenced by personal idiosyncracies and local conditions that generalized optimal solutions are impossible. However, general solution models can be developed and, if responsibly used, can result in significantly improved watershed planning.

There is an ambivalence among politicians and citizens about participatory democracy. Some elected decisionmakers wonder what a completely citizen-specified set of goals might mean: would they no longer "decide," but merely count votes on issues and report them? The citizen wonders how his vote on issues will be used, if at all. Interpretations of ballots are difficult when well done; the meaning of a simple yes or no vote can be misread or twisted. The politician and public both have misgivings about serious and elaborate citizen involvement methodologies. Both are united in questioning whether the costs will be justified.

Presently there seems no way to "prove" at any stated level of certainty that the method outlined will overcome the above tensions. The assumptions behind it are:

1. It is unacceptable to have no citizen involvement.
2. Present systems are limited and usually judged to be poorly functioning.
3. Significant environmental or planning changes have not occurred in the past 10 years even as a result of significantly increased efforts to incorporate citizen inputs.
4. Citizen meetings are a biased sample of the population and can easily result in unnecessary schisms among publics and between people and their agencies. There are few situations in which followups are made to present data, to clarify points, or to correct misstatements or errors.
5. Rarely can the personal preference of an agent be separated from an agency or from agency policy.

The method outlined has the following traits:

1. It is expandable or contractable within a dictatorial, one-man input to a totally democratic input from every willing or able citizen. The maximum expansion is expected.

2. The analytical results from citizens can be employed by a decisionmaker, whether dictatorial or a large commission or board, as *one* major basis for decisions. Such citizen expressions will probably be a heavily-weighted component of the decision, even more so than in the past, but it will be only one component, among others which will typically be risks, political competition, data not available to citizens, and projections of how citizen value systems will change over the time when the results of the decisions are being felt.

3. Most important, the decisionmaker takes the responsibility and thus the *accountability* for decisions. No automatic action, based on citizen inputs, has this dimension. The decisionmaker is asked by election or employment to do the synthesis of citizen utility, risk, time and discounting, natural and catastrophic change, and the dynamics of human population and their preference in his watershed. He is required to make decisions upon which he will bet his job, resources, reputation, life, or the quality of life for his children. He has the right, therefore, to make his own decisions. The system proposed herein *does not make decisions. It provides guidance only.*

4. A majority of citizens will weight the goals—and willingly. The goal list is too long, relative to past use of such lists. It is not too long relative to modern use and sophisticated citizen input to goals and means to achieve them. If the list contributes to improving the watershed for man in a cost-effective manner, then its length should hardly be considered. Future studies will probably suggest that some goal weights are highly correlated and the time spent by citizens reading and weighting the list can be shortened.

Some contend that large bodies of citizens will not weight the objectives. So be it. Based on that argument, or the penchant for representative government, the small group vote may be realistic. The method outlined will accommodate 500,000 or five "voters." In a county, for example, each of five commissioners assigns weights to each goal based on how he perceives the general public would make such entries. He is assumed to be representing the public.

Method: An interviewer uses an optical scan sheet (to reduce keypunching time) or a reproduced form can be used. Later, citizens may be able to complete such evaluations without an interviewer. Considering the sweeping importance of this activity and the long-term consequence, it seems inappropriate to contest the relatively small costs of such an operation.

The councilmen assign values, ranging from zero to 100, to each goal. A value of 100 is first assigned to the single most important goal (or goals, if there are several of equal utmost importance). All others are weighted relative to this (these) objective(s). Experience has shown that citizens *are* willing to assign such ranks (1) if they can compare and discuss them, (2) if they have an ample range of values (at least 0 to 100), (3) if they do not have to justify each weight to an audience, special-interest or otherwise, (4) if they will have the opportunity to reevaluate later after experiencing feedback. They fear to be "locked-in." There must be feedback; the system must be dynamic.

It is possible but doubtful that the range of values (0 to 100) to be employed is too narrow. One goal is unlikely to be 10,000 times more important than another, although public speeches may suggest such weights. None of the goals in the suggested list of *Table 1* is trivial. Most people seem to have trouble discriminating between the goals. "All are important," is a frequent comment. The instruction to express importance for groups of people tends to damp the extreme value expressions. Goals can have equal importance; they need not be placed in an order of "ranked" preference.

One aspect of the value problem involved the meaning of a zero weight assigned to a goal. Computational problems led to the conceptual problem. Conceivably a negative weight could be assigned, expressive of net loss of benefits but this was not allowed, largely due to the inherent problems of relative values, great enough with positive entities. To seek positive-to-negative comparisons among many citizens was thought to be an insurmountable problem. Also, most negative concepts can be rewritten as a positive goal. Where zero weights are assigned, it is interpreted that for the person doing the weighting, such objectives were non-objectives, and did not exist within his value system. Within the computer program, such valuations were ignored as irrelevant to the group value system. All computations tended toward ascertaining relative group desires. Zeroes, by definition, are not expressive of desires. Goals for which there is no desire for achievement are not goals and therefore do not exist.

When a person assigns a goal a weight of 100, the assumption is made that if this goal is achieved it will probably produce for the citizen the maximum possible satisfaction that can be perceived by him. It is likely to achieve for him the most important ends he identifies for life support and enhancement. Of course, the context of this goal analysis system is the total watershed and it therefore emphasizes the less personal, broader, and usually more social and environmental goals. Personal and social goals, however, are largely inseparable. A social goal is defined as the summation of all the personal goals in society. The weight of 100 is assigned a value of 1.0 and is assumed, roughly, to be a probability estimate. A weight of 80 is transformed to 0.80. Later, weights of relative importance of a select portion of the objectives will be studied. The results may prevent each citizen from having to weight each item on the very long list of goals.

To compute the probability of satisfying all of the people, the multiplication rule is employed, that is, the probability of satisfaction of goals (A) A_1 *and* A_2 *and* A_3 . . . is the multiplication of $A_1 \times A_2 \times A_3$ . . . .

These numbers become very small very quickly (e.g., $0.01 \times 0.02 \times 0.03 = 0.000006$). The convention of using the logarithm to the base 10 of these numbers was adopted. The frequency (f) of each weight (W_i) was tallied and a percentage was computed and displayed for the analyst. The equation for the maximum probability of satisfying all of the people for a particular goal, D_j, was:

$$D_j = \log_{10} \prod_{i\,=\,0.10}^{n\,=\,100} W_i^{f_i}$$

where each of the n weight classes is studied (1 to 100, i.e., 0.01 to 1.00), and a frequency tallied. An alternative expression is:

$$D = \log_{10} \left(0.10^{f_{0.10}} \times 0.20^{f_{0.20}} \times 0.30^{f_{0.30}} \times \ldots\right)$$

Recall that D is computed only for non-zero weights.

To compute D^* the maximum probability of satisfying all of the goals of all of the citizens of the watershed, the multiplication rule (expressed as the sum of logarithms) is again employed as:

$$D^* = \sum_{j=1}^{n} \log_{10} D_j$$

In one case, five people weighted 200 goals. The value of D ranged from $1 \times 10^{5.61091}$ to $1 \times 10^{9.57623}$.

D* was 176.91540 which is the exponent in the expression $1 \times 10^{176.91540}$. An alternate expression is 8.23010×10^{176}.

Computer results of the above analyses are available with the program from the author at cost. The concept, as simple as it is, previously has been suppressed due to computational difficulties (now surmountable) and to the problem of the zero weight for a goal (now resolved).

The uses of D and D* are evident:

1. for comparative purposes between groups, areas, and times;
2. as feedback from educational and other efforts to change expressions of citizen values;
3. as the basis for allocating resources to achieve goals; and
4. as a basis for comparing how well a community is achieving (or might achieve as the result of a decision) an optimum level (i.e., its effectiveness as a system).

Values change. How they are likely to change is mere conjecture, but thoughtful decisionmakers are prone to make such conjectures. The computer system developed provides a mechanism by which a perception of the future can be made without significant costs or without any risks. A supplemental program has been developed that allows a decisionmaker to assign a likely rate of change in values to each goal. For some objectives the decisionmaker may assume rates will be stable, others (due to shortages, perhaps) will increase, others may decline. The system makes computations based on these assumptions given to it and recalculates D and D*. The program provides a feedforward tool.

There remains to be defined a difficult aspect of the goal concept: risk. A farmer, for example, may attach a very high preference or weight to a goal of maximizing his profit. However, he realizes that consistent achievement of this goal is unlikely. He therefore internalizes, somehow, that he must secure a good profit about 80 percent of the time (or some other number unique for each citizen) in order to survive in farming. He must operate at or above the 0.80 level or, in other words, he can tolerate a risk level no greater than 0.20. A person who, for example, weights wilderness areas as very high, but never takes any action or advocates any action in wilderness preservation, is likely to be demonstrating an assigned risk of 0.50. He may not have articulated his level of acceptable risk but behaviorally he says that there is no real consequence of having or not having wilderness.

At a risk level of 0.50, benefit will occur about half the time anyway, no matter what anyone does. Deciding by using a fair coin is a rational decisionmaking procedure to achieve this person's goal, and no sophisticated computer system or team of experts is needed. One way to phrase the question of risk is to ask: how many times out of a hundred can I not achieve this goal before I find my life style and its quality intolerable? It is assumed that no goals will receive a zero-risk answer. Thus the risk level will range from 0.001 to 0.999. Alternative ways to phrase the risk question are: (1) As a government official, how many times can I afford to bypass this objective before the consequence will be the loss of my position? (2) What level of achievement of this goal (roughly, efficiency) must I secure each year to be judged publically successful? Thus, whether failure is tolerable only one year out of 10 or 10 percent failure per year is tolerable, the risk level is still 0.10. In later studies it will be possible to investigate the effects of changing risk rates, a very likely phenomenon as per capita resources become more scarce and supportive system interactions less dependable.

Citizens or their representatives will be requested to assign such risk estimates and they will be employed in straight-forward risk-benefit computations to achieve an expression of relative utility or probably desired satisfaction.

To this point attention has been given citizen goals. These can be seen as desired life benefits. The efficiency and effectiveness of all systems are measured in benefits *and* costs. The goal of the watershed center, with its prescriptive and interpretative responsibilities, is to synthesize these two concepts into one that is meaningful and functional—one that will provide a practical basis for watershed guidance.

Based on modeling experiences, literature review, and analysis, an *energetics* or net energy budgeting theme for a computer system has been selected. That theme is predisposed by the goals as formulated above, by the realities of energy economics as a basis for costing, and by the universal idiom provided by energy for the diverse goals of watershed citizens. The next section deals with energetics in detail.

The rationale for the systems objective function is now to follow. The risks of deciding are great. Poor selection can be impeding, costly, and wasteful; the proper selection can be liberating. One possible objective function is *to minimize the entropy within the watershed* (subject to and directed toward achieving the set of goals). It falls short in that to pursue such a goal is to encourage the natural and man-influenced ecosystem to progress toward an ecological climax stage and to stabilize there. No use, return to nature, maximum conservation, and increased controls are all consistent with such an objective. Accelerated use of low entropy systems could result. No use and minimum human intervention would be the most likely embodiment of such a goal and thus it is judged unsuitable for the urbanizing watershed.

Alternative simple objective functions were tested like: *to minimize the energy dependence of the watershed.* To do this while others adopted a growth philosophy would result in major economic and taxation problems. Emigration would be likely if these differences occurred. Likewise, *to minimize the fossil energy-to-other energy consumption per capita,* almost a restatement of the above, requires major land-use changes and could not deal with the problem of planning scale, i.e. what is the appropriate management unit? All units are interdependent when energy-based modeling is done (in fact, most modeling). The concept of watershed "closedness," previously defined, is used and computer outputs of solutions will show four levels of energy and material closedness as decision criteria.

To maximize the non-fossil fuel energy available per capita within the watershed was not a satisfactory objective function for it did not accommodate the limited context of the watershed and required significant local investments (in money and energy) in nuclear, solar, wind, and organic energy sources.

An alternative objective function is *to maximize the energy efficiency of the watershed.* This is a desirable goal but efficiency is difficult to quantify. It does not specify or provide insight into the proper role of fossil or other fuels. It puts no constraints on the amounts to be used. Maximum consumption could be encouraged . . . so long as it is efficient. In terms of energetics, it requires the system to grind to a halt.

Another alternative is *to maximize the total production of weighted* *goods and services per unit of adjusted energy consumed.* This is an expansion of the above objective function with the same inadequacies.

An alternative is *to maximize the likely, citizen-weighted present-discounted worth of the components of the watershed over a decided planning horizon, while simultaneously minimizing fossil fuel energy consumption per capita.* This objective has many desirable dimensions.

Another alternative studied in the evolution of the objective function was: *to maximize the positive difference (within z percent) between the computed long term (y years) potential aggregate energetic support capacity of the watershed and the actual energetic demand within the watershed.* The subtle shifts in emphasis and the testing of alternative approaches are evident.

A final objective formulation was chosen which has the following characteristics:

1. It has energetic, spatial, and temporal dimensions.
2. The complex goal set requires no special computation of a diversity index.
3. Consequences of various decision alternatives are evaluated, based primarily upon their effects on an energetic index of life-quality within the watershed.
4. The existing watershed with all of its topographic and other characteristics is the context for decisionmaking. Decisions are all based on likely change from the present condition.
5. The same index can be used, only slightly modified, as the basis for new city design.

The objective function recommended as the fundamental criterion for deciding among alternatives is that any decision made to be implemented should *minimize the difference over the long run between the energy costs of products of the natural watershed without man's presence, and the energy costs of the urbanizing watershed system in producing desired goods and services for man.*

The assumptions and mathematical formulation of this index are:

1. The long term is 50 years. Since the system will be run year after year, the period analyzed extends further and further into the future.

2. An extra-watershed observer is assumed in order that an appropriate computation can be made of all potential human benefits from a watershed, it having, throughout, the characteristics of the most advanced (climax) ecological community likely for each cell. No humans are, theoretically, present within the watershed. The construct provides a theoretical basis for comparison, the recognized condition of maximum natural energy efficiency, and it clearly reflects nature's best evolutionary strategy. All changes from this condition cost man money and energy. Any cessation of "payment" results, eventually, and in predictable manner, in a return to this community climax state.

3. There are certain human benefits potentially immediately derived from the above climax conditions, even though man is theoretically not present. These include wood, wildlife, runoff adjustments, erosion control, and others.

4. A condition of complete closedness is assumed for the natural watershed, that is: $C_1 = 1.0$. Other comparative hypothetical conditions of closedness include: C_2 - 0.8, $C_3 = 0.5$, and $C_4 = 0.1$.

5. The extra-watershed human population, $P_{S,A}$ is defined for purposes of computation as needed, to be one of average-weight males (S), age 40 (A).

6. The concept of energy cost or input to the system was adopted over efficiency, entropy, or other measures because all systems require energy. Cost tends to reflect efficiency as well as price, availability, and substitutability.

7. Since much work is provided "free" by natural systems, the difference between that system and a man-guided system reflects the result of human intervention and that for which man may take credit or blame. The difference is human production (or lost production).

8. In that all weighted goals will be sought, these represent a type of agreed-upon willingness to pay. The goal-set represents a type of constraint set that implies that man will take what energy nature provides free and add to it the energy required to achieve just the right amount (and no more) of goods and services (i.e. goal satisfactions).

9. Because only one watershed is being examined, and the planning horizon is set at 50 years, no averaging or other statistics seem justified. *Relative differences* caused in the watershed system by the proposed alternatives (e.g. shopping centers, airports) are sufficient for making most decisions.

One day, perhaps, the entire state may be the area for decision, not just the watershed. This will be as it should be, but the watershed is the place to begin. It is this author's estimate that three-forths of decisions to be made have detectable effects that are only intra-watershed.

10. Where relative differences among alternatives are nearly identical (less than three percent), the variance in the differences over 50 years will be reported so that decisionmakers may compare fluctuations over time. At present, it is likely that the best among otherwise equal alternatives is the one that minimizes the variance-to-mean ratio in system performance over time.

11. Given that change will be made within a watershed by a proposal requiring a decision, then the most desirable alternative for change will be the one with the minimum computed value of Q_C, given that an estimate can be made of relative desired or reasonable closedness.

The equation expressing the above concepts is:

$$\text{Min}\,Q_c = \overbrace{\sum_{t=1}^{50}\sum_{m=1}^{n}}^{\text{Time and space}} \overbrace{\overbrace{\sum_{a=1}^{n}\sum_{s=1}^{2}\sum_{j=1}^{n} G_{jmt}\, P_{sat}\, W_{jsat}\,(1.0+F_{jt})\, R_{jsat}}^{\text{Man}} \;\overbrace{X_{jmt}\, C_{ij}}^{\text{Physical}}}^{\text{Man-guided system}} \;\overbrace{-\,G_{kmt}\, X_{kmt}}^{\text{Computed natural watershed system}}$$

The watershed guidance criterion is Q, given a choice among four states of closedness, C. It is to be minimized.

It is computed as the sum over 50 years, t, of the sum over all cells, m, having horizontal and vertical coordinates, within the watershed boundary, of the sum of all citizens, P, of age a and sex s, for each jth goal G, weighted by their desires W, and risks R, that can be potentially produced from each map cell, at a cost of X units of work from which, during each year, has been subtracted the goals potentially satisfied by a completely natural climax community and its requisite energy costs in each cell of the system. The definitions are:

G_{jmt} = potential achievement or yield of the jth desired system goal in cell m, in year t,

P_{sat} = the citizen population of sex s, age a, in year t,

W_{jsat} = the citizen weights expressed or estimated for G_j given subpopulation s, a, in year t. Weights may be estimated to be dynamic over time.

$(1.0 + F_{jt})$ = the rate of change in W_j over time. F_{jt} is usually assigned a value of 0 because of scant knowledge. Assumed rates may be tested.

R_{jsat} = the minimum risks or degree of requirement and surety expressed by citizens for each goal G_j by citizens of subpopulation s, a, in year t;

X_{jmt} = the energy inputs, in kcal, required to obtain one potential unit of goal G_j in cell m in year t;

C_{ij} = the closedness index (initially C_1 = 1.0, C_2 - 0.8, C_3 = 0.5, C_4 - 0.1), the potential availability of inputs of X and related resources to achieve the jth goal.

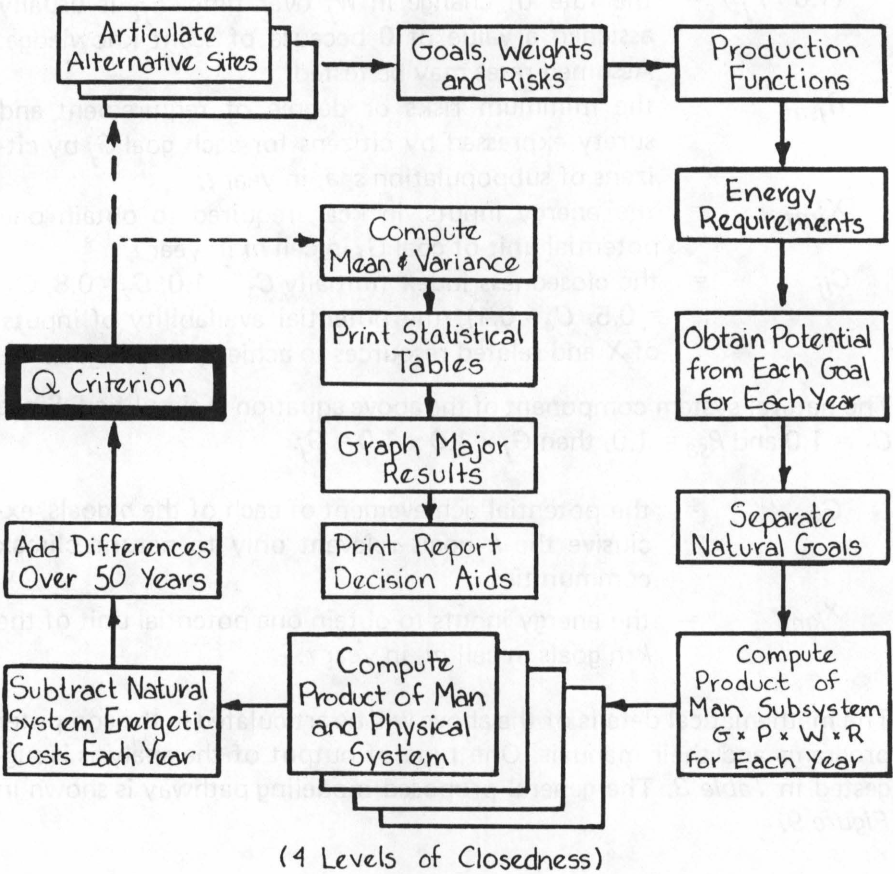
The natural system component of the above equation is simplified. Since $C_1 = 1.0$ and $P_{sa} = 1.0$, then $G_j \times 1.0 \times 1.0 = G_j$.

G_{kmt} = the potential achievement of each of the n goals, exclusive the k goals relevant only to natural climax communities.

X_{kmt} = the energy inputs to obtain one potential unit of the kth goals in cell m, in year t.

The mathematical details of the above will be articulated in the computer programs and their manuals. One type of output of the analysis is suggested in *Table 3.* The general proposed modeling pathway is shown in *Figure 9.*

FIGURE 9
General Overview of Computer Procedure for Arriving at the *Q* Criterion for Varying Choices Among Changes to be Made Within a Watershed. The Alternative with the Minimum Reported *Q* Value Will Typically be Preferred.



Hafele [1974, p. 438] said:

> In the past, the demand for energy was the primary driving force in the development of energy technology and the evolution of an energy economy. Other considerations were secondary, and it was therefore possible to deal only with gross parameters in the energy field, such as the increase in the demand for electric energy, which doubled every 10 years. Now the situation has changed. In the short range, the supply of certain fuels cannot easily meet demand, and ecological and other constraints can no longer be ignored. The need for more detailed evaluations of parameters and their components leads to the mathematical modeling of energy supply and demand.

This book is a "leap of faith" past the statement of need for energy modeling into the assumption that enough now is known to do more than study energy or to develop descriptive models of energy systems. It seems the whole urban watershed systems can be designed and operated on the basis of energetic effectiveness. What I propose is new, from at least one point of view. Odum [1972] cited the work of Zimmerman in 1933 having diagrams which portray the fate of energy in converging and branching networks. The later [1942] work of Linderman in a community energetic approach [see Williams, 1971], and then work of Odum and a host of other ecologists (particularly those working with the International Biological Program) have advanced the analysis of the structure of systems and how energy flows, is transformed, becomes stored, or is lost within them.

Heretofore energetic models have been few, have tended to deal with a small subsystem, or have been descriptive. The increasing rate of use represents the growth of scientific interest in energy and the accumulation of knowledge in ecology. Thus, previously there has been neither the concept of, nor the data for, a decisionmaking system based on energy. For example, the National Science Board [1971, p. viii] said:

> Environmental science today, is unable to match the needs of society for definitive information, predictive capability, and the analysis of environmental systems as systems. Because existing data and current theoretical models are inadequate, environment-

> al science remains unable in virtually all areas of application to offer more than qualitative interpretations or suggestions of environmental change that may occur in response to specific actions.

Some contend the situation has not changed. That remains to be seen—or judged. There are enough problems unsolved to make the effort attractive.

There is evidence that a total system can be analyzed or designed from the viewpoint of energetics. Odum [1971] made clear that such a viewpoint is useful because it can provide a broad "understanding of seemingly unrelated aspects of society and the resources that sustain it, the costs and benefits that will result from individual decisions" and it can provide a means for predicting the changes that may occur throughout the system as other changes rapidly occur. Energy itself is universal and will never change as a system fundamental.

One of the peculiar characteristics of an energetics approach to understanding and designing systems is that it "counts" the free services provided by natural systems that are rarely included in standard economic analyses. It also counts or attempts to count all of the costs. It provides insights into the outer limits or maximum yields of systems and basic system constraints. It seems likely that energy constraints on man's systems may be the most limiting of all. Thus precise knowledge of them is essential. An energetic approach has been adopted for the above reasons. It is not likely to be an all-embracing, impeccable theory, but it seems a sensible or appropriate approach to human affairs. It will include an heuristic attitude and a tentativeness that is unsatisfying to many workers, and will require the continuing feedback needed for any properly functioning general system.

An energetic approach has been called energy budgeting, energy accounting, energy cost evaluation, and net energy analysis. The phrase *urban watershed energetics* is used to denote the study of the storage, flow, and transformations of energy from one form to another within watersheds. While *analysis* is an essential aspect of such an approach, the emphasis is on *design.* All design is shaped by the objective function. In this case an objective function is now available for the urbanizing watershed. An energetics approach is within the context of "system theory" [von Bertalanffy, 1968], therefore, wholistic. The ideas herein are strongly influenced by H. T. Odum [1971] and Odum and Odum [1976].

Mankind's understanding of the world and the way it works is grounded in the first and second laws of thermodynamics:

1. Energy may be transformed from one form to another but it is neither created nor destroyed. You cannot do more work than the energy you have that is available for such work.
2. All transformation processes are *entropic,* that is, they change in energy from a non-random to a random form. Waste of energy is inevitable. Entropy is the tendency of all systems toward randomness or maximum dispersion. Entropy is a decrease in the ability to do work.

It is assumed here that the present solar radiation reaching the earth's atmosphere at the rate of 15.3×10^5 kilocalories (1,000 calories equal one kilocalorie) per square meter (m^2) per year has continued for a long time. Deposits of coal, oil, and gas are concentrated energy, the results of geological compaction of years of green plant collection and energy storage. The energy from a forest is no different from that of its fossils. Only time is significantly different. The amounts of fossil fuels are variously estimated. All estimates suggest that at current use rates (or likely accelerating rates) the supply will be exhausted in less than a few hundred years. A host of other major problems of energy including availability, supply, costs, technology, and transportation are poorly recognized by society but well documented and will not be recited here. The guidance system is based on the conclusion that a massive energy problem already exists and that it is likely to get much worse. Energy for citizens to achieve their many goals will be in increasingly short supply over the long run. Therefore it seems likely that a system which is based on a resource in short supply, thus highly prized (and priced), will be beneficial. It will be demanded as decisons at the new economic margin (expressed as energy, not money) become more difficult.

All of the arguments of the impending energy problems will not be recounted but, based on them, planning for use of energy and alternatives to such use seems like a good idea. There is no overriding concern evident in land-use planning for fossil fuels. The recent oil and gas shortage has had little influence on this modeling effort. Hopefully, the reader will adopt a reasonable time scale and focus his attention on the dominance of the sun's energy, manifest in the fossil fuels. Phillipson [1966] said, "The biological capacity of the earth depends ultimately on the energy received from the sun, and man, to satisfy amongst other things his need for food, depends on the use to which this energy is put by living organisms." *Use* may be interpreted broadly, not simply in the sense of food but for manufacture, transportation, and other needs of people.

Lotka's principle is that systems that can tap the most energy sources and that can maximize the flow of energy to do the most useful work will survive and expand over other systems. It operates within the limits of the first and second law stated above. This principle is true for the omnivore (in contast to the herbivore or carnivore) or for the industrial conglomerate. In the process of gaining power, systems build structure and add new occupations or specialists in order to tap better any available energy sources. The structures gained in biological systems are analogous to those in ecological and social systems. The feedback and maintenance processes all cost energy. The problem, already discussed under "the guidance center," is whether efficient enough social and governmental systems can be created that will maintain systems stability. They must not cost more energy than they are worth, that is, in achieving system goals.

The costs, C, of maintenance are a function of the interactions, I, within a system between all of its components, N. Where $I = N(N-1)$, $C = [N(N-1)]/2$. Odum and Odum [1972] said that because this relationship between maintenance costs and size is poorly understood, *"developed systems have an inherent tendency to grow beyond optimum size and at the expense of natural systems."*

Any system that does less than possible is likely to lose in competition. Effective systems maximize energy returns on energy investments over the short run, diversify energy returns over the long run.

Useful work in Lotka's principle may not be a self-evident phrase. It means those activities that continue to enhance survival by improving the efficiency of wasteful processes, by creating an output, or by bringing in more energy from another source. "Useful" implies goal-oriented, and in biological or human systems may mean "meaningful survival." Since Lotka's principle operates over time, it is evident that successful systems store energy. Countries store grain, industries stockpile materials, people save money, animals store fat or seeds, and plants store sugars in their root system. Pritchard and Palmer [1974] said that under present economic conditions it is possible to make an apparent cash gain while making a net energy loss. "In such cases as extracting oil in the North

Sea, it would have been better to leave the fossil fuel where nature will store it free until needed."

A corollary to Lotka's principle is that some energy must be spent on new alternatives for the system so that it may evolve as external conditions change. Uncountable tree seeds, thousands of fish eggs, exploring parties, market ventures for companies, conference attendance for individuals, all constitute the act of increasing choices to the next bigger system. Lotka's principle, said Kylstra [1974], implies that each person or organization should try to have available as many sources of fossil fuel, natural energies, material, buildings, information, labor pools, and machinery, as can be obtained and are likely to be used.

Pritchard and Palmer [1974] reported Odum's belief that man should use remaining fossil fuel reserves, not to accelerate consumption (as is now the case) toward some final systems collapse, but to invest it in a complex of support systems for man that will not require fossil fuels for their operation.

Concentrated energy, like gasoline, has a greater capacity to do work than dilute energy, like sunlight. An energetics awareness causes one to resist losses in concentrated energy and to recognize concentration as the basis for achieving work. It explains in part why solar and wind energy technologies have not been further developed. Concentrating such energy is costly of energy.

Over the past few years *information* has come to be recognized as energy. It is the most concentrated form of energy. Very great amounts of energy have been spent in getting knowledge and there is very little heat produced on transfer (entropy). It can unlock new energy sources or improve the use of old sources. Thus, it is the highest quality or most concentrated form of energy [Kylstra, 1974].

Odum and Odum [1972] said that "frequently, it is not energy itself that becomes the limiting factor—but some basic natural resource required to maintain the high rate of energy flow." This is the general system's concept of constraints and the biologist's law of the minimum. They are unified in energetics. They said:

> It is a sad situation when cities grow beyond their means and can no longer pay for their own maintenance. They borrow

> money or demand federal grants in order to grow even larger and more demanding of their life support system when they ought to be diverting more of their energy to maintaining the quality and efficiency of the environment already developed, and to reducing the stress on vital life supporting natural environment.

The emphasis in managerial energetics is on net, not gross, energy. Typical is the situation of counting gains from industrial processes or a building without counting costs to the environment or human life. Pritchard and Palmer [1974] suggested that profit could be turned into loss if manufacturers had to pay the medical bills of people affected by SO_2 pollution from their mills.

As a result of the studies outlined in this book, there has been developed a concept of a computer model that can provide guidance for urbanizing watersheds in Virginia (or elsewhere) based on a goal of the energetic effectiveness of the total watershed system.

The proposed system resembles that proposed by Odum [1971], developed by Forrester [1971], and Lyle and von Wodtke [1974]. The latter authors identified needs much like those expressed in this work:

> Given any two of these factors [location, development action, environmental effects], it is presumed that the third can be determined with some degree of accuracy by applying the hypothesis that particular developmental actions in given locations will bring about certain predictable environmental impacts. Given the actions and the location, the impacts may be predicted in general qualitative terms, thus providing a basis for evaluating the acceptability of those actions in that location. Or given certain developmental actions to be carried out and specified environmental effects to be controlled, one can show the most and least suitable locations for those actions. Finally, given a specified location and environmental effects to be controlled, one can determine the most acceptable developmental actions.

It seems that their system, while useful to these ends, is not dependent upon or designed to account such decisions in energetic terms.

A problem with the energetics approach is that people are not attuned to the energetic market. They are poorly aligned in the monetary marketplace—often buying irrationally. Given this weakness, it is not surprising that they should not "think energy." Because of severe energy limitations and general benefits from people being more closely in balance with their environment, it is not too late to begin redefining the marketplace.

There are imperfections in knowledge. People do not know how much things cost and therefore, even though willing, cannot make rational decisions between certain acts—for example, in energy conservation. They have equal difficulty in deciding which system is best in terms of energetics—mass transit or a shift to smaller cars.

There are likely to remain different values to commodities, no matter what their energy costs or potential yields. Ten kilocalories of eagle are not worth ten kilocalories of vulture. A recreational fisherman will spend many times the value of a fish on equipment, travel, and action to catch it. There is a high energy value on fish. The watershed objectives seek to approximate relative energy values on outputs of the watershed.

The translation of energy into economics is best done through the well established economic concept of opportunity cost. In general, it means the amount of energy required to do the same work by an alternative method. There is no explicit monetary value to the kilocalories in wind but the energy cost of technology to produce equivalent energy is known. Thus, a temporary monetary value, expressed as "worth at least . . . ," can be placed on wind.

A difficult aspect of energy analysis, but the basis of its analytical benefits, is that it tends to be universal. There is no appropriate place to stop or start an analysis. In computing auto costs, do you count the calories in gasoline? The calories required to manufacture the car? The calories in the gasoline used by all of the assembly linemen? As with the general systems concept previously outlined, the context must be carefully specified. That the question is real and must be answered may cause, of itself, significant improvements in decisionmaking.

Klystra [1974] discussed the important concept that maximum energetic efficiency is not really desirable. The highest energetic efficiency (100 percent) of a watershed occurs when it grinds to a halt. It sits there. This is the old community, the status quo industry, the climax eastern deciduous forest. Inputs exactly equal outputs. The production-to-respiration ratio is 1.0. No maintenance or other costs of running the system are incurred to man. The lowest efficiency is zero percent, corresponding to the system running fast with all energies going into friction, disorder, and waste. There is no optimum between the two. When a community (or people of a watershed) lose their energy sources, they enter a declining phase. They have not changed, or diversified, or sought new energy sources to match changing external environments (energy sources) or citizen desires (valued energy). Declining watersheds disassemble in the reverse order to that in which they were formed. Technologists, researchers, and educators go, then administrative and government staffs, then some less profitable enterprises. The watershed stabilizes at the agrarian or early urban level or proceeds to bankruptcy. It follows the Lotka law of species survival. By understanding the law and its first- and second-law constraints, watersheds can insure their chances for continued survival as resource entities producing opportunities for man to achieve his potential.

Hafele [1976, p. 446] said:

> *Figure . . . [10]* is an attempt to illustrate what the term *energy systems* means. The traditional understanding of the relationship of fuel, energy, and the GNP is presented in the dashed lines. The boxes* indicate constraints, each of which refers also to acceptability and therefore to the sociological aspect of the constraint. Within these constraints, energy can be produced. An optimization process should lead to the adjustment of densities for risk, power, and pollution. The means to that end are technological development, the dispersal of installations, and the transport of energy and water over longer distances. A generalized objective function will be employed in such an optimization. Econometry thus becomes a more general discipline than previously. Of course, other factors must be taken into account in considering long-range policies—for example, communications, data processing, and general transport requirements. But the result of such an optimization turns out to be a scheme for land use, which becomes one of the major points of contact between energy systems and other large systems of the infrastructure of modern civilization.

FIGURE 10

This Schematic Representation of an Energy System Depicts Some Relationships of Energy, Land Use, and Gross National Product. (from Hafele, 1974)

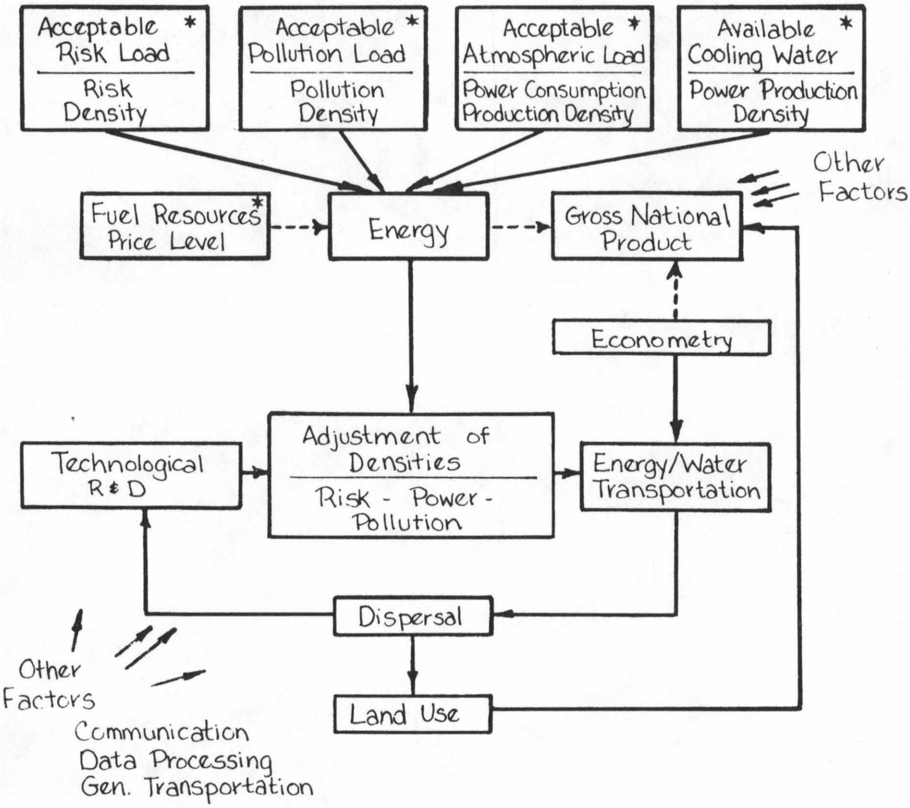


FIGURE 10

This Schematic Representation of an Energy System Depicts the Relationships of Energy, Land Use, and Gross National Product (from Hafele, 1974)

ENERGY FOR THE WATERSHED

The primary input to all watersheds is energy. It is easy to direct attention to the readily observable aspects of life and ignore the less conspicuous. Energy is not conspicuous and therefore few people understand or sense its overriding importance in every life process and every function within the watershed. As with a coal-driven electric blanket, we lose sight of the source because electricity is delivered in wires. Matter, of course, can also be limiting. A shortage in a mineral or a type of energy can halt a watershed system. The models include both matter and energy but are unified by the singular energy component. Energy is the "services" of "goods and services" of economic theory; it is the driving force of life processes and the transformer of both the nature and location of the physical reality of things in the watershed.

Energy for driving the watershed machinery must come from somewhere. These sources are reviewed in many places and will not be duplicated here. It seems important to make six summary observations that are critical to watershed planning:

1. Energy supplies, sources, and reserves are *finite* either due to supply, limitations on their accessibility, or counter productive aspects of their use (e.g., ionizing radiation.)
2. There are multiple energy sources *(Table 4)*, most of which are interchangeable, but all of which are influenced by ownership, use rates, price, and a host of factors such as technology and transportation.
3. All processing, transportation, and conversions of energy from one form to another cost energy. It is rational to count such costs and compute the net energy available to do work resulting from each decision.
4. Competition for energy will increase. Political bodies will become more defensive about energy supplies. More difficult bargains will be struck in the future between energy and desired commodities.
5. Because of complex population, pollution, economic, and governmental interactions (including the very concepts of freedom and life in a republic), the solutions, if they come, will be ponderous and implementation tediously slow. Many "good" solutions will be implemented so late they will be non-solutions. To plan for a quality life for citizens in such an environment seems reasonable; pessimistic perhaps, but not unreasonable.
6. Optimism is unwarranted for levels of energy continuing as in the past due to reduced supply, increased cost of acquisition, reduced

amounts suitable for use, health and social cost constraints on certain types of removal and use, the high-energy costs of technological "fixes," and unforeseen undesirable interactions of the natural system.

Miller [1973] agreed with John Muir in his observation that "when we try to pick out anything by itself, we find it hitched to everything else in the universe." Miller said, "You can't talk about coal without talking about energy. You can't talk about energy without talking about oil. You can't talk about oil without talking about politics." Meyer [1974], advocating western energy development, said: "So in a broad but very real sense, Americans all prosper together." Of course, he neglected to mention that they also falter together. How energy is used will determine the fate of man in the watershed.

In the watershed, energy can come from many sources, many of which are now or may be substituted for each other. Where the watershed's energy comes from is a vastly complex question at the very pinnacle of planning for the entire system. It must be answered. The difficulty of answering it suggests the critical importance of planning for the energy-short watershed in the future.

Developing new or existing energy sources, substituting more abundant for less abundant fuels, reducing demand and conserving energy are means for assuring energy for a quality life in the future. Such acts will also reduce problems associated with foreign petroleum imports. "By far the most effective action we could take now is conservation," said Abelson [1973]. It is not the only step; alone it will not work (but it could solve as much as 50 percent of the California need for electricity) [Hammond, 1972]. The Office of Emergency Preparedness [1972] said that energy conservation measures could reduce United States energy demands in 1980 by as much as the equivalent of 7.3 million barrels of oil a day. Other steps are taken slowly and many create environmental problems. Conservation is equally slow in coming. It is unfortunate how little attention is paid conservation of energy—unfortunate but explainable. Darmstadter [1975, p. 99] gave an energy example of the now well known "tragedy of the commons."

> But even where regional energy conservation succeeds (irrespective of what triggered it), in the absence of a national commitment to conservation, savings in the New York region may simply be dissipated elsewhere by additional consumption of the freed

resources. That being the case, the impulse to conserve on the part of the regional energy user may quickly flag. This happens because energy products move within a national, not a local, market. The exception is electric power capacity, where regional retrenchment in demand can confer visible benefits to New York region, if only in the form of reduced claims on power-plant sites. In this respect, less regional consumption is beneficial even where the overall resource saving is cancelled.

Conservation of energy seems straightforward. The admonition to conserve is easy to accept. The concept of net good, however, dominates a decision to conserve. For example, the more safe a car, the larger becomes its gross weight; the less polluting a car, the lower the gasoline mileage. Thus energy saving is in direct conflict with safety, pollution, and health considerations. The question then becomes: how much increased energy consumption is the crash-safety and smog control worth? Turning off lights conserves energy but reduces bulb life. Energy required to produce bulbs is very great. What is the appropriate tradeoff? Bever [1974] said:

> Very little is known about the energy consumed by the collection, transportation, physical separation, and mechanical processing of secondary raw materials. The nature and location of old (or post user) scrap determine the amount of energy expended in collection and transport.

These types of questions have only begun to be asked; they can only be answered by far-reaching studies of the interactions within large human and environmental systems.

Energy may be conserved by reducing the basic *consumption* rate, by increasing the *efficiency* of its production (conversion), and by minimizing *transmission* losses. Conservation is not a sole solution, any more than a decision about what is the best energy source. The solution is another question: What is the optimum mix? One source of inaction is that there seem to be innumerable solutions. Systems can be designed to screen from among them and determine a desirable mix. Such systems must be developed and used. There are macro- and micro-conservation activities that can be implemented. Examples of the micro approach include lowering home thermostats, adding insulation, and conserving hot water. Macro approaches [Ford Foundation, 1974, Darmstadter, 1975] include improving design of buildings, providing low interest loans for home improvements designed for energy conservation, and modifying power rates to reduce peak loads.

All conservation activities cost energy. Each act to reduce energy consumption may increase costs in time, dollars, or health (therefore longevity). For example, air travel, which is expensive of fossil energy, is conserving of time. Frost-free refrigerators, also expensive of electrical energy, are conservative of human muscle energy and time. There are legitimate value systems to be considered; diversity of opportunities is desirable. Eventually, however, the allocation of virtually finite fossil fuel resources to mankind now and over the future requires foregoing efficiencies, safety, and health to experience the known world. A number of writers suggest, and the potential exists within the system as designed, that rules not be fixed in these murky areas in which tradeoffs must be made among time, diversity, energy, and locations. Instead, the system should provide guidance for the increasingly difficult and more risk-filled task of the decisionmaker.

THE SOUTH RIVER EMPHASIS

Throughout this design document, the South River watershed in Virginia has been in mind but the design has not been exclusively oriented to that watershed. To optimize how one watershed performs is to suboptimize a state. The design has been oriented to all watersheds within the state. Watershed guidance must be interactive with and within the context of other watersheds. A start must be made, however.

The South River Watershed was designated as a pilot watershed study of the State of Virginia by action of the 1973 session of the General Assembly on House Joint Resolution No. 205. The resolution was consistent with a Constitutional amendment two years prior: "It shall be the Commonwealth's policy to protect its atmosphere, lands and waters from pollution, impairment, or destruction, for the benefit, enjoyment, and welfare of the people of the Commonwealth" [Article XI, section 1 of 1971 Constitution]. All appropriate state agencies were directed by the legislation to cooperate in the study program with primary responsibility assigned to the State Division of Planning and Community Affairs. No funds were allocated in response to the directive of the legislature. The South River Flood Control Commission Task Force was formed to direct the role of the Commonwealth in the pilot study. The task force consists of representatives of the State Water Control Board, the Commission of Outdoor Recreation, and the Soil and Water Conservation Commission.

Responsibility for planning the total social, economic and physical improvement of the watershed area was assigned to the South River Flood Control Commission whose members represent the local jurisdictional units in the watershed, the City of Waynesboro, Augusta County, and Rockingham County.

Technical aspects of the planning study were assigned to the Central Shenandoah Regional Planning District Commission. Independent research projects to study the relationship between the natural environment, man's use of the land, and the social and economic factors which affect a model watershed were recognized as a proper function of the Colleges and Universities of the Commonwealth. Such projects were to be coordinated by the Planning District Commission with the assistance of the South River Flood Control Commission Task Force. The project reported herein is one such effort.

The South River watershed, an area of about 350 mi^2 (906 km^2) is part of the Shenandoah River watershed, a part of the Potomac River Basin. The basin itself is 14,670 mi^2 (37,990 km^2) and includes portions of Maryland, West Virginia, Pennsylvania, Virginia, and all of the District of Columbia. There are five physiographic regions in the basin; the South River is in the Blue Ridge Province.

The Potomac River basin has a mean annual temperature of 59° F (15° C) in Tidewater, to 50° F (10.5° C) in the Appalachian Highlands. Annual precipitation varies from 30 to 35 inches (76.2 to 88.9 cm) at the foothills of the Allegheny Mountains to 50 inches (127 cm) on the western divide and 45 inches along the crest of the Blue Ridge.

In the Verona-Staunton area on the edge of the South River area, ground water yields are expected to be almost 200 gpm per well.

The South Fork of the Shenandoah River has been reported to have below standard water quality, low BOD, and high coliform densities. There were no excessive nutrients, pesticides, acid mine drainage, thermal discharges, or excessive heavy metals.

The basin easily is judged to be urbanized since 74 percent or 2.9 million of the population is concentrated in the Washington Metropolitan area. The concentration is typical of the watershed planning situation in which so many are so concentrated on so few acres. "Urbanizing" has connotations of creeping concrete and physical expansion of the city. Some urban acreage increases or urban sprawl does occur, but the immenseness of the total basin dwarfs such spatial change.

Scale of change is a major problem in any planning activity. Deciding what is significant and how precise the data should be is a problem for which there are no answers other than: (1) as precise as possible, (2) as precise as is justified by the collection methods and base data, and (3) as precise as can be afforded in terms of collection, storage, retrieval, processing, and results print-out time. Costs increase by at least the square of data precision increases. To halve a cell width is to create four cells where there was one. To divide a cell into thirds is to create nine cells. The planner typically wants great precision but he quickly finds precision is the Midas touch. Once he has it, he is not likely to know what to do with it.

An example of the problem is in the geology of the watershed. David Barnum, executing an undergraduate project at VPI&SU, compiled materials on the geology of the South River watershed. The area has not been mapped as a single unit and knowledge about it is dependent upon the following publications:

1. Brent, William B., 1960. "Geology and Mineral Resources of Rockingham County," Bulletin 76, Virginia Division of Mineral Resources, Charlottesville, Virginia.
2. Butts, Charles, 1940. "Geology of the Appalachian Valley in Virginia, Parts I and II." Virginia Geological Survey, Bulletin 52, University of Virginia,
3. Cooper, Byron N., 1960. "The Geology of the Region Between Roanoke and Winchester in the Appalachian Valley in Western Virginia." Study No. 18, Johns Hopkins University.
4. Fara, Mark, 1971. "The Burketown and Associated Klippen of the Staunton Thrust, Harrisonburg Quadrangle, Virginia." In *Contrast in Style of Deformation of the Southern and Central Appalachians of Virginia.* W. D. Lowry, Editor. Guidebook No. 6, Department of Geology, Virginia Polytechnic Institute and State University.
5. Rader, Eugene K., 1967. "Geology of the Staunton, Churchville, Greenville, and Stuarts Draft Quadrangles, Virginia." Report of Investigations No. 12, Virginia Division of Mineral Resources, Charlottesville, Virginia.
6. Werner, H. J., 1966. "Geology of the Vesuvius Quadrangle, Virginia." Report of Investigations No. 7, Virginia Division of Mineral Resources, Charlottesville, Virginia.

Information on the geology is important for knowledge of soils, ground water, highway and other construction, and, of couse, potential mining. The geological complexity of this small region of Virginia is implicit in *Table 5.* While it is possible to enter the surface geology into the "State Information System" described in the next section, in the categories of *Table 5,* the question remains: should it be entered? There are areas of the state for which no geological map exists! The answer, at present, is to enter broad geological groups that are known to have (or should have) influence on land-use decisions and to omit the others. Feedback, constantly applied to the total system, will cause improvements in the system where data are available and the benefits-to-costs ratio are subjectively estimated to be high.

...entered as a single unit and knowledge about the geology ... the following publications:

Brent, William B., 1960. "Geology and Mineral Resources of ... ingham County." Bulletin 76, Virginia Division of Mineral Resources, ...esville, Virginia.

Butts, Charles, 1940. "Geology of the Appalachian Valley in ... art ... Virginia Geological Survey, Bulletin 52, Univer... ...ia.

Cooper, Byron N., 1960. "The Geology of the Region Betw... ...e and Winchester in the Appalachian Valley in Western Virgini... No. 18, Johns Hopkins University.

Fara, Mark, 1970. "The Brocktown and Associated ... Queen ... Thrust, Harrisonburg Quadrangle, Virginia." in Conti... ...s of Deformation of the Southern and Central Appalachians ... W. B. Lowry, Editor, Guidebook No. 6, Department of Ge... ...rginia Polytechnic Institute and State University.

Rader, Eugene K., 1967. "Geology of the Staunton, Churchvi... ...le, and Stuarts Draft Quadrangles, Virginia." Report of Inve... No. 12, Virginia Division of Mineral Resources, Charlottesvi... ...

Werner, H. J., 1966. "Geology of the Vesuvius Quadrangle, V... Report of Investigations No. 7, Virginia Division of Mineral ... Charlottesville, Virginia.

...ation on the geology is important for knowledge of soils, grou... ...ighway and other construction, and, of course, potential mine... ...logical complexity of this small region of Virginia is implici... ...While it is possible to enter the surface geology into the "Sta... ...tion System" described in the next section, in the categorie... ...the question remains: should it be entered? There are areas ... ...for which no geological map exists! The answer, at present, ...based geological groups that are known to have (or should hav... ...on land use decisions and to omit the others. Feedback, ...pplied to the total system, will cause improvements in the sy... ...data are available and the benefits-to-costs ratio are subjective... ...d to be high.

INPUTS

A computerized information base for Virginia, called the "State Information System" (SIS), is being developed by the author and others in the Department of Fisheries and Wildlife Sciences at Virginia Polytechnic Institute and State University. This is a multi-level system with data for cells, census enumeration districts, watersheds, counties, and planning districts.

The data come from many sources. Cell-level data are manually read from U.S. Geological Survey topographic maps *(Table 6)* through a transparent grid overlay. Other data sources include enumeration district tapes, county level reports, and remotely sensed land-use data from the U.S. LANDSAT satellite system. Examples of such data or maps available for the South River watershed are listed in *Table 7*.

Through the use of computer programs, raw data can be transformed into useful information that can be funneled into the decisionmaking process. Before the implementation of this system some information, such as "viewscapes," were infeasible to collect or develop. To process one standard map (30 cells by 30 cells) for a visual analysis of where power line towers will be most conspicuous requires 2.7 million iterations. Putting this 2.7 million iterations into perspective, a man executing one iteration per minute, working an eight-hour day, five days a week, would not have completed processing that one map 20 years later. At a salary of $10,000 a year, such information would exceed $200,000. Clearly the constraints of time and money make the manual computations of these data infeasible.

In general, the use of the computer in SIS is essential for three reasons. First is the ability of the computer to store large amounts of data in a relatively small space. In the South River study area alone, there are 27,000 cells with approximately 40 peices of data per cell or about one million bits of data. This amount of data can be stored easily on a single disk pack, 18 inches in diameter by 12 inches in height. The second reason is the speed with which the computer can access and retrieve this data. Just to count the South River data at a rate of one bit of data per second would require in excess of 11 days. Some operations of the computer are executed in a billionth of a second. Computer programs can be written that assimilate this vast amount of data into useable information.

An example of a type of input now available for the South River but not available statewide is a soil survey. This situation shows the overlapping nature of inputs and processes.

Detailed soil data are available from the soil survey maps of Augusta County on a scale of one inch to 1,320 feet. Soils data will be critical for the guidance system. The determination of a variety of factors and indexes will be based on the assumption of such accurate soils data as soil moisture capacity, infiltration, runoff, vegetation potential, and construction site suitability. The soil types and series are coded on soil survey maps. Characteristics associated with the soil type include:

1. Drainage class
2. Stream flood hazard
3. Depth (in feet) to seasonal high water table
4. Bedrock depth (in feet)
5. Depth from surface (in inches) of typical profiles
6. USDA texture
7. Permeability
8. Shrink-swell potential

Also suitability for development of a particular soil type is rated slight, moderate, or severe based upon the following factors:

1. Depth to water table
2. Soil permeability
3. Flooding frequency
4. Steepness of slope
5. Depth to bedrock
6. Shrink-swell potential
7. Amount of stoniness, rockiness, etc.
8. Texture of soil surface and thickness
9. Unified grouping or classification
10. Traffic supportability

A rating of slight shows that on-site study would find that only minor problems exist. A moderate rating indicates that one or more problems exist, and an on-site study should be made to determine the seriousness and extent of the problem. Finally, a rating of severe dictates an on-site study to determine the extent of the problem and the feasibility of corrective measures.

It is reasonable to use the best data available and to use the power of the computer to calculate precise indices to land performance such as flooding potentials, traffic supportability, and suitability for septic fields. This can only be done where general guidelines are desirable (because the present data system is set for a one-third-kilometer cell width) and where soil maps (like that for Augusta County) are available. They are available for less than half the state. Facility-siting decisions are now made without the benefits of soil maps of any type. Currently, a computer-generated soils map of the state is being developed. Preliminary soil-use indices are to be created for each cell as a function of geology, slope, aspect, position on slope, rainfall, and proximity to water. The results will not replace the need for soil maps or for field inspection and detailed studies by soil scientists and engineers. The computer-generated soil maps will reduce the costs incurred by making such studies in "impossible" areas. It will prevent a first-order approximation to county or watershed land-use potentials; it will allow between-area comparisons of many types; and, it can provide a format for future studies that can supply corrective feedback and new equations for making soil indices in each cell of the state more precise and multi-dimensional.

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by soil scientists and engineers. The computer-generated soil maps
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[illegible] present a first-order approximation to [illegible] or water-related
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and it can provide a format for future studies [illegible] supply
ive feedback and new equations for making soil indices in each
the state more precise and multi-dimensional.

PROCESSES: AN OVERVIEW OF THE COMPUTER SYSTEM

Computer simulation of environmental systems is now well known and there are many practitioners [e.g., Van Dyne, 1969; Watt, 1966, 1968, 1973]. Such simulations have been helpful in analyzing systems, in directing research, and in actual land-use decisionmaking. Most models, because of the interests of the users, have been of relatively small systems [O'Neill et al., 1970; Newell and Newton, 1968]. The other conspicuous reasons have been the evolving nature of simulation and the tendency of users to lose confidence in models as they become large.

Very large systems (developed for a specific purpose) have been simulated for NASA space flight. The world system simulated by Forrester [1971] has stimulated others working along parallel lines. Smith [1973] has developed a model of Virginia and has used both an "index of stability" and a synthetic "environmental quality index" to evaluate the performance of Virginia as an environmental system. It is possible now to model very large systems. These models can achieve their intended use when design criteria or limitations are clearly specified. Such models, when developed with strong feedback loops, can be useful at any stage as *part* of a decisionmaking process—and they can be improved.

Many simulations focus on analysis, attempting the valuable task of describing the structure, dynamics, and relations within systems. Others sacrifice "complete" description and attempt to produce aids to man's complex decisionmaking capability. The South River modeling effort has the latter orientation. The very large system—a state, a region, a series of different estuaries—cannot be described totally. How far along the description must be before it becomes useful is a philosophical question answered variously from "in the first moment of effort to create such a model" all the way to "only when the model is completely realistic and true." There are many present needs for decisionmaking power. The need is for powerful analytical and processing tools to help high-level executive and legislative decisionmakers make hard choices among competing alternatives for allocation or for action [Kadanoff, 1972]. Such decisions are made under uncertainty. More information reduces these decisionmaking risks. But, increasingly, the problem becomes less risky at the cost and burden of too much information. New integrative, synthetic aids are needed therefore. Large systems have too many components, too many interactions, too many conflicting values among users, influences over too many years, and too much variance or fluctuation for the modern decisionmaker to comprehend a problem and make decisions. Educated guesses about facilities placement, tax allocation, or resources use are no longer likely to suffice in a modern, highly competitive urbanizing environment.

Computers, armed with data about watersheds throughout the state (Virginia or any other state, once the basic model is developed) can allow planners and decisionmakers to experiment with alternative solutions before making a final determination. Simulations have proven particularly valuable where the system being simulated is too complex to be represented by classical optimization techniques (e.g., linear programming) or where interactions are abundant. With the computer's output, decisionmakers can see the consequences of various decisions or mixes of decision as if they were made and implemented. They then can add the "political" or subjective elements of such decisions and arrive as least bad or best choices.

There is evidence that models of large systems can be developed. It is necessary that these models be made relevant to major social and environmental problems. Relevance is highest at the point of decisionmaking. By designing systems (1) for a specific class of decisionmaker, (2) for a specific class and scale of decision, and (3) for a specific set of consequences (to the watershed), then use and thereby improved environments can likely be achieved.

Modeling efforts are extremely difficult to describe. In past work, the pattern can only be described as heuristic. Nevertheless, there are major aspects of the work which can be described. The methods will be outlined under the major concepts of a general system: context, outputs, inputs, processes, feedback, and feedforward.

I. Context

The size, scope, and general design criteria of the proposed system are herein described.

1. The watersheds of Virginia are of primary interest. The models we develop will likely be useful for other east-central U.S. areas, but success will be judged only for Virginia.

2. The emphasis of the project will be on the watershed and adjacent watersheds.

3. The perceived decisionmaker is the board of the watershed guidance center. Outputs will be designed to communicate to these people.

4. The time frame of the model will be 50 years.

5. The response time of the system to a request will be approximately two weeks. An interactive or computer-terminal format is not feasible for such large-scale models. Rarely, if ever, would such large decisions be "forced" in less than several weeks.

6. The operation of the completed system is planned for a new or modified state-level agency, each planning district, or as a service function of a branch of Virginia Polytechnic Institute and State University. Use of the system would be on demand.

7. It seems desirable that user costs be borne by a central public agency so that there are no impediments to asking for information, to encouraging multi-use of data, and to discouraging duplication of efforts.

II. Outputs

A computer-generated report is now planned. The report, a multi-page book, would contain:

1. Problem description, including (a) time of request, (b) requesting personnel, and (c) requirements;
2. Primary inputs special to this request;
3. Computer generated maps relevant to the project;
4. Computer graphics relevant to the project;
5. A numbered list of major feasible tactics or strategies to be considered, and
6. Consequence tables with alternative project tactics or strategies listed horizontally and environmental impact categories or synthetic variables listed vertically.

Alternative strategies for a proposed livestock pasture subsidy and a new town might include:

Pasture

1. Pasture subsidy A—one percent change in pasture,
2. Pasture subsidy B—five percent change in pasture,
3. Pasture subsidy C—25 percent change in pasture,
4. Pasture subsidy D—78 percent change in pasture, or

New Town

1. New town at site A,
2. New town at site B,
3. New town at site C.

III. Inputs

Example contents of the "State Information System" were listed in *Table 7*. The system is based on the universal transverse mercator projection and the cell size is one-ninth square kilometer or about 27 miles. Within every 27-acre cell are stored over 150 variables. The 27-acre grid is perfectly suited, perhaps even more refined than necessary, to achieve the scale specified under "Context."

Data quality is always a matter of concern. The system is designed to enable use of the best data presently available to decisionmakers. It is desirable that improved information sources be examined. Waltz et al. [1970] described remote sensing of hydrologic resources. Remote sensing seems likely to enable inputs and updates to the information system and LANDSAT will be used. Land-use data are processed by LARSYS, now operational at VPI&SU.

IV. Processes

The program will be developed in FORTRAN. Portions of the information system, file management, and map preparation may be written in PL-1.

Major efforts will be made to unify existing computer programs. The concepts of Hufschmidt and Fiering [1966] will be used, as will those of Van Dyne [1969], who describes a broad computer-based approach to the ecosystem. In this model must be unified forest, agricultural, urban, river, and estuary models.

Many computer subsystems will be employed outright. There is an abundance of modeling work on watershed topics. These include Chen and Orlob [1972] on physical water movements, Walsh [1972] and Park et al. [1974] on biological nutrients and interactions, Kitchel et al. [1974] and Bauman et al. [1974] on fish production. Martin and Sendak [1973] reviewed forestry operations research literature and Thomas et al. [1963] reviewed operations research in water-quality management. Other sources to be used are: Water Resources Engineers Inc. [1968] on temperature, Huff et al. [1973] on urban development, Jacques and Huff [1972] on channel hydraulics, Ivarson et al. [1972] on impoundment effects, Goldstein and Mankin [1972] on evapotranspiration, and Hett [1974] on land-use change.

Sinha [1970] has developed a watershed model, as have Holtan and Lopez [1971], Dunn [1970], and Monroe [1971]. Elements of these will be employed. D'Arge [1970] has described water resource planning and provided guidance for large basins. As in many such studies, translation of the concepts into a functional, interactive system for "real-world" application is not made. In this modeling effort we shall locate additional models, examine their characteristics, assumptions, data needs, and outputs, and employ them where suitable. The output of one system will typically become input to another. Where systems exist, such as for "air quality implementation planning" [TRW Systems Group, 1970; Croke et al., 1972, p. 34], they will be studied for use. Typically their data requirements are enormous because of the problem for which they were specifically designed and their scale. They will be judiciously used with clearly specified data sets representing, for example, a typical new town to built. Population is likely to be the only variable that can be readily specified by the user. The model, given a new town decision of 30,000 people in area X, would compute likely air quality problems in such an area, and, through changes in climate [Frisken, 1973; Olgyay, 1963], evapotranspiration, évaporation, and albedo of plants soil and structures, produce three to five feasible consequences, say in runoff, silt, and energy budget shifts, that would be fed to the river subsystem. This in turn after computations, would supply results to the estuary subsystem. Interactions are accommodated by loops in the program that may, after a particular estuary change which modified climate, cause the program to recalculate the air subsystem and in effect start the entire process over again.

An optimization system for location [Lasdon, 1970] will be developed using heuristic and modified goal programming. The theme throughout will be energetics.

V. Feedback

1. As described above, there are many feedback loops within the system itself.

2. Feedback to *Inputs* can allow reductions in data collection and storage costs and are likely to lead to a minimum set of highly useful planning data. Meyers [1970] described this in his paper. The effort can thus contribute to the broad field of environmental information systems.

3. Provisions must be made for access to necessary hardware and to the use of programs at reasonable costs with appropriate return times for response. Procedures also must be established to maintain an updated information system. A further and highly important requirement is that an institutional structure be developed with adequate authority to implement management decisions on a watershed scale that effectively applies use of the computer system.

The close coordination in activities between the research effort and those directly responsible for the planning of the management program for the watershed is designed to facilitate the realization of those needs. Continuous interaction during the implementation with a conscious instructional attitude on the part of the investigators is also essential to these accomplishments. State planning agencies will have a role in determining the potential utilization of the South River watershed study project to other urban watershed areas within the state.

Built into the final system of people-and-computer must be personnel responsible for improving, checking, and testing the algorithms and computational efficiency.

VI. System Flow Diagram

The *foldout flow diagram* depicts the major subsystems of the system that has been designed in this bulletin. Each box is described by a detailed flow diagram. Most of these now have been detailed but are beyond the scope of this publication. Virtually every box within the entire system will have to be further detailed. Where entire systems already exist, and many do, further detailing is not necessary. Many other subsystems require only the most rudimentary decisionmaking. The final report generator will evolve as subsystems are detailed and as potentials are creatively explored. The foldout diagram is developed to suggest the organization and orientation of the programming, the direction toward the objective function, and the well known components of watershed planning that will be translated into energy-based functions.

Until there are further signs that more detailed diagrams are needed and that they may represent more than an interesting exercise, further diagramming seems unjustified.

VII. Subsystems

The solar subsystem was developed in a master of science thesis by Lawrence [1976]. The soil moisture subsystem was developed by Prince [1977]. These subsystems are essential for water and energy-related modeling. Their systems require climatological data such as that available in the HISARS system of the Virginia Water Resources Research Center. The parameters from this data base include daily information on temperature, precipitation, evapotranspiration, and wind. Because of the problems involved in coding the plethora of climatological data recorded each day, this is probably as detailed a statewide weather data base as could be expected. The only major omission is cloud cover data.

Lawrence [1976] contacted the Virginia Weather Reporting Stations for the South River area, then visited the National Climatic Service in Asheville, North Carolina to which he was referred. They have a vast data collection, some on tape, but most in an uncoded and unusable form. Subsequently, he was able to obtain sufficient solar and cloud cover data to develop an operational model for computing net solar radiation at any time for each cell of the state. These data and those from HISARS will be used to develop cell-specific climatological profiles, statewide.

Edmund Saunders, a graduate student at Virginia Polytechnic Institute and State University, is presently developing a computer system for modeling the hydrology of a small watershed based on a significantly revised Haan model. Minimum inputs is a fundamental design criterion. By focusing on *relative* changes in runoff and peak flow likely from siting a facility at various places in a watershed, the model provides guidance for minimizing such phenomena.

Hett [1971] developed a model for describing and predicting land-use changes for three counties in Tennessee. By combining LARSYS interpretations of land-use data and employing the methods of Hett, general changes in watersheds can be predicted and siting decisions made with these inputs. Given knowledge of large area change, it will then be possible, given the slope, elevation, aspect, soil moisture and type, of any cell, to estimate the consequences (in terms of vegetative change and runoff) of any cell and that cell's influence on the watershed.

In order to illustrate a fairly detailed subsytem analysis, to demonstrate how relatively subtle components of the watershed can be modeled, and to illustrate an application of energetics, John Hamill, a graduate student at Virginia Polytechnic Institute and State University, has developed the description iterated below.

Based on the work of Kerr [1966], Johnston and Odum [1956], Dambach and Good [1940], Warbach [1958], and Geis [1974], it is possible to estimate the relative abundance and species diversity of birds for several successional stages and land-use types. The successional classes used by Kerr or Johnston and Odum could provide a basis for assembling all the above data. Relative bird abundance (total number of birds/successional stage) can be determined by assigning a value of 100 to the successional stage having the greatest number of birds and assigning values for the remaining stages on a proportional basis. These data could be incorporated into a production function, assigned a citizen value, and then extrapolated into a weighted-production function.

A similar approach could be used to calculate species diversity. By knowing the total bird population per given sized area, the number of pairs of each bird species and the total number of bird species in aggregation (all of which are available from the above references), species diversity can be calculated using the formula:

$$H' = 1/N \left(N \log N - \sum_{i=1}^{s} n_i \log n_i\right)$$

where:

N = total population/area/successional class,

n_i = number of pairs of species i,

s = number of species in aggregation.

Since citizens may be more concerned about seeing many species of birds instead of just large numbers of birds, it becomes important to incorporate this calculation into a weighted production function. For example, seeing only one or two members of four or five species may have a greater esthetic significance than seeing 10,000 starlings and nothing else. However, to the hunter, large numbers of just a few game species are probably more important than seeing hundreds of various songbirds.

By more of the above calculation, the total kilocalories of energy consumed by birds in each successional stage can be calculated by:

$$\log M = (0.306 + 0.633 \log W)\, N$$

where:

M = kcal's consumed by a given bird population/successional stage,
N = total population/given-sized area/successional stage,
W = average bird weight/successional stage.

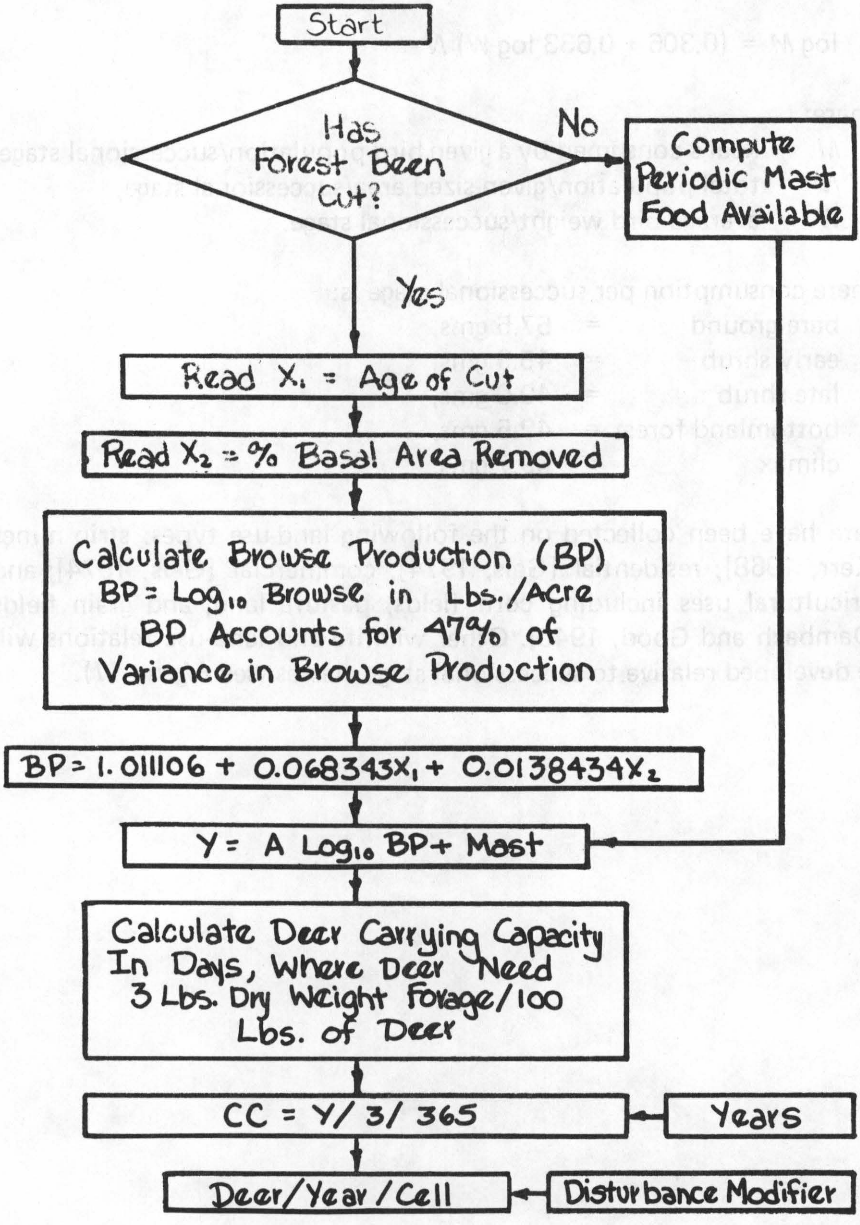
where consumption per successional stage is:

bare ground	=	57.5 gms,
early shrub	=	45.9 gms,
late shrub	=	49.0 gms,
bottomland forest	=	49.5 gms,
climax	=	59.7 gms.

Data have been collected on the following land-use types: strip mines [Kerr, 1968]; residential [Geis, 1974]; commercial [Geis, 1974]; and agricultural uses including corn fields, pasture land, and grain fields [Dambach and Good, 1940]. Other wildlife and land-use relations will be developed relative to successional stage classes (see *Figure 11*).

FIGURE 11

Example of Detailed Flow Diagram of a Wildlife Subsystem. Calculation of Changes in Deer Forage Production and Subsequent Changes in Deer-Carrying Capacity (from Patton and McGinnes, 1964)



CONCLUSION

This document is a blueprint for future watershed architects and developers. It displays the orientation, concerns, and constraints of time and other factors essential for watershed design for the citizens of tomorow. The context of the problem has been developed in detail, for the problem surely will not yield to simple solutions.

With better and more creative use of existing environmental laws and improved use-taxation law, significant problems can be reduced. However, such action will be insufficient and, therefore, an administrative or institutional arrangement called a guidance center has been proposed and described in detail.

Problem reduction is desirable and must be achieved. However, creative design is needed. The future environment of man can be conceived and guided into a system dynamically responsive to the needs of citizens. Not problem reduction, but creative guidance is the objective of the system proposed herein.

The proposed system is a general system, with initial focus on citizen goals and the weights or priorities attached by them to each. It denies those who prefer to see first "what you get" from a decision, but asks first "what do you desire as a human?" Using the alternatives provided by creative people, the system proceeds to evaluate the consequences of making a choice among these alternatives.

It is a simulator of the best possible decision, employing the best data and relations available. It has inherent checks and feedback mechanisms to keep such data as relevant and "good" as is appropriate.

It employs a long planning period, argued to be highly responsible. It is based on and responsive to the human population, computing energy necessary for satisfying each population subclass, each often having unique sets of needs as well as desires.

It evaluates production from land units in terms of useful energy, stored energy, and waste energy to air or water. By computing energy costs, a type of second-law system efficiency is implicit. The objective function of the entire watershed is to minimize Q_c, where an appropriate level of closedness, c, is decided by the people of the watershed. The system is designed to provide a criterion for the effect of any major decision on the value of Q. This becomes the decision criterion and since incremental, project-by-project decisionmaking is likely to continue in most urbanizing watersheds, the system can provide guidance to improved system effectiveness. System effectiveness, though elaborate mathematically, is an expression of the minimum costs of achieving a set of interactive, citizen-weighted goals.

The system designed can be implemented. It will be a massive task, but one for which the benefits over a few years in even one watershed will very likely exceed the present-day costs of developing the system. With energy costs likely to rise, with a 50-year planning horizon, and with 100 watersheds in Virginia, the benefits likely to result can be immense. It is the author's opinion that the system should be implemented soon.

After multiple runs of the completed system, it may be possible to develop general guides for types of decisions so that a run of the system need not be made for each proposed project. The system can be simplified; variables to which solutions are not sensitive can be removed. This is a type of system feedback which well-designed systems have in generating their own expansion, efficiencies, and further development by computer scientists as well as subsystem researchers and students.

It is important that this document be evaluated and used as that for which it was intended—a design document. Like the latter-stage drawings of the architect, it can be redone and modified as seems appropriate. Hopefully, what will result is a superior guidance system for the future environmental systems of Virginians. At least, it will be useful for the citizens of the South River watershed.

LITERATURE CITED

Abelson, P. H., 1973. "Increasing World Energy Supplies." *Science* 182 (4117): Editorial.

Alich, J. A., Jr., and Inman, R. E., 1973. *Effective Utilization of Solar Energy to Produce Clean Fuel.* National Science Foundation. 161 p.

Anonymous, 1973. "Pressures Mount to Limit Use of Private Land." *Conservation Foundation Letter.* Washington, D.C. 8 pp.

Appleby, T., 1971. "Citizen Participation in the '70's, the Need to Turn to Politics." *City* 5(3):52-55.

Arnstein, S. R., 1971. "Eight Rungs on the Ladder of Citizen Participation." *Citizen Participation: Effecting Community Change.* Preger Publishers. p. 69-91.

Aspinall, W. N., 1973. "Turns and Curves on a Well-Travelled Road: The Vicissitudes of Establishing Land Use Planning Policy." In *National Land Use Policy: Objectives, Components, Implementation.* Proceedings of a Conference, Soil Conservation Society of America. pp. 3-12.

Barrow, T. D., 1973. "Industry Cools at Land Use." In *National Land Use Policy: Objectives, Components, Implementation.* Proceedings of a Conference, Soil Conservation Society of America. pp. 118-124.

Batie, S. S., and Long, B. F., 1974. "Roles, Approaches, and Problems of Developing a State Land-Use Planning Process." In *Land Use Issues: Proceedings of a Conference.* Publication 629, Cooperative Extension Service, Virginia Polytechnic Institute and State University. pp. 41-49.

Bauer, K. W., 1973. "National Land Use Policy and the Need for Land-Use Plans." In *National Land Use Policy: Objectives, Components, Implementation.* Proceedings of a Conference, Soil Conservation Society of America. pp. 161-172.

Baumann, P. C.; Kitchell, J. F.; Magnuson, J. J., and Kayes, T. B., 1974. "Lake Wingra 1837-1973—A Case History of Human Impact." *Transcript of the Wisconsin Academy of Science, Arts and Letters, 1974.*

Bever, M. B., 1974. "Raw Materials: Energy and Environmental Constraints." *Science* 185:99 (Letters).

Bosselman, F., Callies, D., and Banta, J., 1973. *The Taking Issue: An Analysis of the Constitutional Limits of Land Use Control.* Council on Environmental Quality. 329 p.

Bultena, G. L., and Hendee, J. C., 1972. "Forester's Views of Interest Group Positions on Forest Policy." *Journal of Forestry* 70(6):337-342.

Chen, C. W., and Orlob, G. T., 1972. *Ecological Simulation for Aquatic Environments.* Office of Water Resources Research, U.S. Department of the Interior. 156 pps.

Clawson, M., 1973. "A Look to the Past and a Look to the Future." In *National Land Use Policy: Objectives, Components, Implementation.* Proceedings of a Conference, Soil Conservation Society of America. pp. 23-27.

Clawson, M., and Held, B., 1957. *The Federal Lands: Their Use and Management.* Johns Hopkins University Press.

Commoner, B., 1971. *The Closing Circle.* Alfred A. Knopf. 326 pps.

Cottrell, W. F., Kwee, S. L., and Mullender, J. S. R.,Editors, No date. *Growing Against Ourselves: the Energy Environment.* 268 pps.

Croke, E. J.; Croke, K. G.; Kennedy, A. S., and Hoover, L. J., 1972. *The Relationship between Land Use and Environmental Protection.* Available from National Technical Information Service. PB-209-642. 61 pps.

———, No date. "The Relationship Between Land Use and the Environmental Protection." *Land Use and the Environment: An Anthology of Readings.* V. Curtis, Editor. Office of Research and Monitoring, U. S. Environmental Protection Agency. pp. 69-88.

Curtis, V., Editor, 1974. *Land Use and the Environment: An Anthology of Readings.* Office of Research and Monitoring, U. S. Environmental Protection Agency. 200 pp.

Dambach, C. A. and Good, E. E., 1940. "The Effects of Certain Land Use Practices on Populations of Breeding Birds in Southwestern Ohio." *Journal of Wildlife Management* 4(1):63-76.

D'Arge, R. C., 1970. *Quantitative Water Resource Basin Planning: An Analysis of the Pecos River Basin, New Mexico.* Water Resources Research Institute, New Mexico State University. 116 pp.

Darmstadter, J., 1975. *Conserving Energy: Prospects and Opportunities in the New York Region.* Johns Hopkins Press.

Division of State Planning and Community Affairs, 1973. *Status of Local Planning in Virginia.* Richmond, Virginia.

Dunn, D. E., 1970. *Computer Simulation of the Hydrology System of Mountain Watersheds.* Water Resources Research Center, Montana State University. 55 pp.

Environmental Information Center, Inc., 1974. *The Energy Index, 1973.* Environmental Information Center, New York, N.Y. 603 pp.

Ford Foundation, 1974. *The Art of Managing the Environment.* 42 pp.

Forrester, J. W., 1971. *World Dynamics.* Wright-Allen Press Inc. 147 pp.

Friedmann, J., 1973. "The Public Interest and Community Participation: Toward a Reconstruction of Public Philosophy." *Journal of American Institute of Planners* 39(1):12.

Frisken, W. R., 1973. *The Atmospheric Environment.* Johns Hopkins University Press. 68 pp.

Fulton, J. K., 1971. *Development and Evaluation of Citizen Participation Techniques for Inland Lake and Shoreland Management.* Office of Water Resources, U. S. Department of the Interior. 43 pp.

Gazis, D. C., 1972. "Traffic Flow and Control Theory: Theory and Applications." *American Scientist* 60:414-424.

Geis, A. D., 1974. *Effects of Urbanization and Type of Urban Development on Bird Populations.* Wildlife in an Urbanizing Environment. J. H.

Noyes, and D. R. Progulske, Editors. Cooperative Extension Service, University of Massachusetts. 184 pp.

Gibson, W. L., Jr., 1974. Foreword. In *Land-Use Issues: Proceedings of a Conference.* J. P. Marshall and P. M. Ashton, Editors. Publication 629. Cooperative Extension Service, Virginia Polytechnic Institute and State University.

Giles, R. H., Jr., 1974. "WRAP: A Wildland Resource Allocation Procedure for TVA Landowners." Manuscript report. TVA, Norris, Tenn.

Giles, R. H., Jr., and Lee, J. M., Jr., 1975. "When to Hunt Eastern Gray Squirrels." *Forest Resource Management: Decision Making Principles and Cases.* W. A. Duerr et al., Editors. Chapter 49.

Glascock, H. R., Jr., 1973. "Time for Land-Use Definitions." *Journal of Forestry* 71(7):392-393.

Goodman, W. I., 1964. "The New Look in American Planning." *Bureau of Community Planning Illinois Newsletter,* University of Illinois 4(3):1-4.

Goldstein, R. A., and Mankin, J. B., 1972. "PROSPER: A Model of Atmosphere-Soil—Plant Water Flow." In *Proceedings, 1972 Summer Computer Simulation Conference, AIAA/AIChE/AMS/ISA/SCi/SHARE.* pp. 1176-1181.

Grant, K. E., 1973. "Land Use: Past and Present." In *National Land-Use Policy: Objectives, Components, Implementation.* Proceedings of a Conference, Soil Conservation Society of America. 220 pp.

Grigsley, J. E., III, and Campbell, B., 1972. "A New Role for Planners: Working with Community Residents in Formulating Alternative Plans for Street Patterns—Before Decisionmaking." *Transportation* 1(2):125-150.

Hafele, W., 1974. "A Systems Approach to Energy." *American Scientist* 62:438-447.

Hammond, A. L., 1972. "Conservation of Energy: The Potential for More Efficient Use." *Science* 178:1079-1081.

Hampton, E. L., 1975. "Managerial Implications of Angler Preferences and Fisheries Management Objectives." Master's thesis. Virginia Polytechnic Institute and State University.

Healy, R. G., 1975. *Controlling the Uses of Land, Resources.* No. 50. Resources for the Future, Washington, D. C.

Hendee, J. C., and Harris, R. W., 1970. "Foresters' Perception of Wilderness-User Attitudes and Preferences." *Journal of Forestry* 68(12):759-762.

Herendeen, R. A., 1973. *Use of I/O for the United States, 1963: User's Guide.* Center for Advanced Computation. University of Illinois. Urbana.

Hett, J. M., 1971. *Land Use Changes in East Tennessee and a Simulation Model Which Describes These Changes for Three Counties.* Report No. ORNL-IBP-71-8. Oak Ridge National Laboratory. 56 pp.

———, 1973. *Energy Implications of Several Environmental Quality Strategies.* Report No. ORNL-NSF-EP-53. Oak Ridge National Laboratory. 34 pp.

Hett, J. M., and Herendeen, R. A., 1973. "Total Energy Demand for Automobiles." Society of Automotive Engineers, presented at the International Automotive Engineering Congress, Detroit.

Holtan, H. F., and Lopez, N. C., 1971. *USDAHL-70 Model of Watershed Hydrology.* U. S. Department of Agriculture Research Service. Technical Bulletin No. 1435. 84 pp.

Horkan, G. A., Jr., 1974. "Legal and Related Problems in Existing Land-Use Controls." In *Land-Use Issue: Proceedings of a Conference.* Publication 629, Cooperative Extension Service, Virginia Polytechnic Institute and State University. p. 63-69.

Huff, D. D., et al., 1973. "Simulation of Urban Runoff, Nutrient Loading and Biotic Response of a Shallow Eutrophic Lake." In *Modeling the Eutrophication Process.* Utah Water Resources Laboratory, Utah State University. p. 33-55.

Hufschmidt, M. M., and Fiering, M. B., 1966. *Simulation Techniques for Design of Water Resource Systems.* Harvard University Press.

Ivarson, W. R., Jacques, J. E., and Huff, D. D., 1972. "Report on Implementation of Lake and Reservoir Flow Routing into the HTM." Eastern Deciduous Forest Biome Memo Report 72-135, University of Wisconsin, 31 pp.

Jacques, J., and Huff, D. D., 1972. "Open Channel Flow Simulation with the Hydrologic Transport Model." Eastern Deciduous Forest Biome Memo Report 72-134. University of Wisconsin. 19 pp.

Johnston, D. W., and Odum, E. P., 1956. "Breeding Populations of Birds in Relation to Plant Succession on the Piedmont of Georgia." *Ecology* 37:50-62.

Kadanoff, L. P., 1972. "From Simulation Model to Public Policy." *American Scientist* 60:74-79.

Kaiser, E. J., et al., 1974. *Promoting Environmental Quality through Urban Planning and Controls.* EPA-600/5-73-015, Office of Research and Development. U. S. Environmental Protection Agency. 441 pp.

Kasperson, R. E., 1969. "Political Behavior and the Decision-Making Process in the Allocation of Water Resources Between Recreation and Municipal Use." *Natural Resources Journal* 9(2):176-211.

Kennedy, J. J., III, 1970. "A Consumer Analysis Approach to Recreational Decisions: Deer Hunters Area Case Study." Doctorial dissertation. Virginia Polytechnic Institute and State University. 182 pp.

Kerr, J. R., 1968. "Habitat and Avian Diversity on Strip Mined Land in East Centeral Illinois." *Condor* 70:348-357.

Kitchell, J. F., et al., 1974. "Model of Fish Biomass Dynamics." *Transactions of American Fisheries Society* 103(4):786-798.

Koening, H. E., and Tummala, R. L., 1972. "Principles of Ecosystem Design and Management." *Institute of Electrical and Electronics Engineers Transactions on Systems, Man and Cybernetics.* SMC-2. pp. 449-459.

Kylstra, C. D., 1974. "Energy Analysis as a Common Basis for Optimally Combining Man's Activities and Nature." Paper presented to the National

Symposium on Corporate Social Policy. Department of Nuclear Engineering Sciences. University of Florida. 37 p.

Lansing, J. B., and Morgan, J. N., 1971. *Economic Survey Methods.* University of Michigan. 430 pp.

Lasdon, L. S., 1970. *Optimization Theory for Large Systems.* Macmillan Company. 523 pp.

Lawrence, G. E., Jr., 1976. "A Computer-Based Isolation Mapping Algorithm for Large Areas." Master's thesis. Virginia Polytechnic Institute and State University. 95 pp.

Leopold, A., 1949. *A Sand County Almanac and Sketches Here and There.* Oxford University Press. 226 pp.

Lime, D. W., and Stankey, G. H., 1971. "Carrying Capacity: Maintaining Outdoor Recreation Quality." In *Recreation Symposium Proceedings.* Northeastern Forest Experiment Station, Upper Darby, Pennsylvania. pp. 184-194.

Lyle, J., and von Wodtke, M., 1974. "An Information System for Environmental Planning." *AIP Journal* 40(6):394-413.

Martin, A. J., and Sendak, P. E., 1973. *Operations Research in Forestry: A Bibliography.* U.S. Department of Agriculture Forest Service General Technical Report NE-8. Upper Darby, Pennsylvania. 90 pp.

Meadows, D. H., et al., 1972. *The Limits to Growth.* Universe Books, New York. 205 pp.

Meyer, R., 1974. "Developing Western Energy Reserves." An address to the Federation of Rocky Mountain States. Exxon Company, Public Affairs Department, Houston, Texas.

Meyers, C. F., 1970. *Using Experimental Models to Guide Data Gathering.* National Technical Information Service, PB 195 669. 38 pp.

Miller, A. 1973. " The Energy Crisis as a Coal Miner Sees It." *Center Magazine* (Nov.-Dec.):35-45.

Monroe, J. C., 1971. *Direct Search Optimization in Mathematical Modeling and a Watershed Model Application.* National Technical Information Service, COM 71-00616. 59 pp.

National Science Board, 1971. *Environmental Science: Challenge for the Seventies.* National Science Foundation. 50 pp.

Newell, W. T., and Newton, J., 1968. "Annotated Bibliography on Simulation in Ecology and Natural Resource Management." Quantification Science Paper No. 1, Center for Quantification Science in Forestry, Fisheries, and Wildlife. University of Washington. Mimeographed. 22 pp.

Odum, H. T., 1971. *Environment, Power, and Society.* Wiley-Interscience. 331 pp.

———, 1972. "An Energy Circuit Language for Ecological and Social Systems: Its Physical Basis." In *Systems Analysis and Simulation in Ecology.* Vol. II. Academic Press. pp. 139-211.

Odum, H. T., and Odum, E. C., 1976. *Energy Basis for Man and Nature.* McGraw-Hill Book Company. 297 pp.

Office of Emergency Preparedness, 1972. *The Potential for Energy Conservation: A Staff Study.* Executive Office of the President. 250 pp.

Olgyay, V., 1963. *Design with Climate.* Princeton University Press. 190 pp.

O'Neill, R. V.; Hett, J. M., and Sollins, N. F., 1970. *A Preliminary Bibliography of Mathematical Modeling in Ecology.* Oak Ridge National Laboratory, Tennessee. 97 pp.

Otte, R. C., 1973. "Human considerations in Land Use." In *National Land Use Policy: Objectives, Components, Implementation—Proceedings of a Conference.* Soil Conservation Society of America. pp. 68-85.

Park, R. A., et al., 1974. "A Generalized Model for Simulating Lake Ecosystems." *Simulation* 23(2):33-50.

Parker, F. H., 1974. "Emerging Trends in State Land-Use Planning." In *Proceedings of the 53rd Annual Meeting, Society of American Foresters.* pp. 8-13.

Phillipson, J., 1966. *Ecological Energetics.* Edward Arnold Publishers, Ltd., London.

Prince, G. R., 1977. "A Computer Based Algorithm to Determine Soil Moisture Index." Master's thesis. Virginia Polytechnic Institute and State University. 119 pp.

Pritchard, P. C, and Palmer, C., 1974. "Thoughts on Energy, Energetics, and Energese." *The Florida Naturalist* December: 7-11.

Rickles, R. N., 1973. *Energy in the City Environment.* Noyes Press. 240 pp.

Roberts, M. J., 1970. "River Basin Authorities: A National Solution to Water Pollution." *Harvard Law Review* 83: 1527-1556.

Scientific American, 1971. *Energy and Power.* W. H. Freeman and Co., San Francisco, 143 pp.

Searl, M. F., Editor, 1973. *Energy Modeling: Art, Science, Practice—Conference Proceedings.* Resources for the Future, Washington, D. C. 436 pp.

Sinha, L. K., 1970. " An Operational Watershed Model: General Considerations, Purposes, and Progress." Paper 70-231 before the American Society of Agricultural Engineers.

Smith, A. D., 1959. "Whose Space and For What?" *Transactions of the Conference of North American Wildlife Conference* 24:449-456.

Smith, J. L., 1973. "An Analysis of the Environmental Stability of Virginia." Master's thesis, Virginia Polytechnic Institute and State University. 229 pp.

Sussna, S., 1970. "Land Use Control: More Effective Approaches." *Resource Management* 17. Urban Land Institute. 52 pp.

Thomas, H. A., Jr., et al., 1963. *Operations Research in Water Quality Management.* National Technical Information Service, AD 673 779. 208 pp.

Thuesen, G. J., 1971. *A Study of Public Attitudes and Multiple Objective Decision Criteria for Water Pollution Control Projects.* Georgia Institute of Technology. 70 pp.

Toffler, A., 1970. *Future Shock.* Random House. 505 pp.

Torheim, R. H. and Harlan, W. T., 1973. "Comprehensive Land-Use Planning." *Journal Forestry* 71(8)468-470.

TRW Systems Group, 1970. *Air Quality Implementation Planning Program.* Vol. 1, "Operator's Manual." National Technical Information Service, PB 198 299. 344 pp.

UCLA Regents, 1972. *Facing the Future: Five Alternatives for Mammoth Lakes.* School of Architecture and Urban Planning. University of California. 243 pp.

Van Dyne, G. M., Editor, 1969. *The Ecosystem Concept in Natural Resources Management.* Academic Press. 383 pp.

Verba, S., 1969. "Democratic Participation." In *Social Intelligence for America's Future: Explorations in Societal Problems.* B. M. Gross, Editor. Allyn and Bacon, Inc. 541 pp.

Vlasin, R. D., 1973. "National Economic Considerations in Land Use." In *National Land Use Policy: Objectives, Components, Implementation—Proceedings of a Conference.* Soil Conservation Society of America. 220 pp.

Von Bertalanffy, L., 1968. *General System Theory.* Geo. Braziller Co. 289 pp.

Walsh, J. J., 1972. "Implications of a Systems Approach to Oceanography." *Science* 176:969-975.

Waltz, F. A., et al., 1970. *Remote Sensing of Hydrologic Resources in the Great Plains.* Remote Sensing Institute, South Dakota State University. National Technical Information Service, PB 195 451. 108 pp.

Warbach, O., 1958. "Bird Populations in Relation to Changes in Land Use." *Journal Wildlife Management* 22(1):24-28.

Warner, K. P., 1971. *Public Participation in Water Resources Planning.* Environmental Simulation Lab, University of Michigan. National Technical Information Service, PB 204 245. 243 pp.

Water Resources Engineers, Inc., 1968. "Prediction of Thermal Energy Distribution in Streams and Reservoirs." Final report to California Department of Fish and Game.

Watt, K. E. F., 1966. *Systems Analysis in Ecology.* Academic Press. 276 pp.

———, 1968. *Ecology and Resource Management: A Quantitative Approach.* McGraw-Hill Book Co. 450 pp.

———, 1973. *Principles of Environmental Science.* McGraw-Hill Book Co. 319 pp.

Welch, J. G., 1973. "Comprehensive Land Use Planning." *Journal Forestry.* 71(6):331-332.

Wengert, N., 1973. "Legal Aspects of Land Use Policies, Plans, and Implementation." In *National Land Use Policy: Objectives, Components, Implementation—Proceedings of a Conference.* Soil Conservation Society of America. 220 pp.

Williams, R. B., 1971. "Computer Simulation of Energy Flow in Cedar Bog Lake, Minnesota, Based on the Classical Studies of Lindeman." In *Systems Analysis and Simulation in Ecology.* B. C. Patten, Editor. Vol. 1. Academic Press. 607 pp.

Zigler, J. H., 1974. "Urban Land Use in Rural Areas: Conflicts and Suggestions." In *Land-use Issues: Proceedings of a Conference.* J. P. Marshall and P. M. Ashton, Editors. Publication 629, Cooperative Extension Service, Virginia Polytechnic Institute and State University. 113 pp.

Zube, E. H., 1974. "An Alternative Strategy for Land Use Planning." In *Proceedings of the 53rd Meeting.* Society of American Foresters. 31 pp.

TABLES

TABLE 1

Goals for Citizens of the Watersheds of Virginia.

(Goals, once listed, will be assigned preference or importance weights by citizens. No goals are independent; all constitute a set of goals to be achieved simultaneously.)

Community Identity

1. To publish a list of citizen's goals for themselves and their watershed, revised within five years.
2. To employ effective systems of citizen involvement in goal formation, weighting, and risk assignment.
3. To report how well decisions and actions of citizens and their government achieve goals or are consistent with them.
4. To quantify trends in changes in goals, weights, and perceived risks and report them to decisionmakers.

History

1. To develop a complete written and pictorial history of the watershed and to preserve those documents.
2. To develop statistics and equations expressive of all aspects of the watershed and its people.
3. To achieve at least 75 percent mastery of knowledge of the relevant watershed history by at least 75 percent of the citizens of the watershed.
4. To preserve all historically significant documents, stuctures, and ecological communities.
5. To minimize change in formally-designated historic buildings and sites.

Cultural Development

1. To provide or assure that space is available for opportunities for major cultural functions.
2. To assure that diverse cultural opportunities are available to citizens at reasonable costs.

Religion

1. To provide spaces within which opportunity exists for religious statement and practice consistent with the opportunities, amenities, and environmental quality of non-participants.
2. To minimize the average citizen indebtedness in church structures.
3. To minimize the variance of such annual indebtedness (2 above) within the watershed.
4. To minimize travel costs to such structures.
5. To minimize public costs to service such structures.

Esthetics and Beautification

1. To implement an effective system of street graphics and sign control.

2. To minimize the conspicuousness of utilities to residents and travelers in the watershed.
3. To maximize the wild or agrarian scenes visible from recreational sites and facilities.
4. To maximize the visual quality of lands adjacent to public recreational lands.
5. To minimize the number of existing structures judged by a citizens' committee to be ugly, in disrepair, or defaced with grafitti.
6. To minimize the number of proposed structures which would likely be judged by a representative citizens' committee to be ugly or incompatible with the esthetic evolution of the watershed.
7. To provide opportunity for architectural diversity within the watershed.

Landscaping and Vegetation

1. To maximize the diversity of species and the number of large landscape trees within the watershed.
2. To minimize the time that any soil area remains unvegetated.
3. To maximize the number and acreage of parcels of land (e.g., lots) in the watershed judged by a trained committee to exceed a minimum landscape quality index.
4. To maximize the sum of the quality weights of landscapes within the watershed over 10 years, each year being weighted by the number of actual or potential viewers.
5. To develop as public resources an appropriate number of spots that are uniquely landscaped.
6. To provide landscaping leadership on public lands for citizens.
7. To minimize change in desirable landscape features publicly recognized as special or unique.
8. To maximize the acres of green or open space of the watershed calculated as needed for such purposes.
9. To maximize the opportunities for all citizens to garden.

Open Space

1. To protect and preserve those areas which have significant recreational, scenic, cultural, scientific and natural resource potential from encroachment by urban uses.
2. To maximize the amount of land in open space around standing or running water, in floodplains, near geological fault zones, on soils highly erosive, and in areas having steep slopes.
3. To preserve and protect resources such as water, forests, or prime agricultural land uniquely suited for open space purposes.
4. To preserve and restore sites which have particular historic or architectural significance.
5. To maximize the linkage of the scenic resources of the watershed.
6. To provide, by roads and trails, open space recreational facilities that are appropriately distributed and readily accessible for all groups of citizens.
7. To acquire high quality open space in order to fulfill present needs and be adaptable to future demands.
8. To utilize public and private facilites, parks, schools, and existing open space

within the watershed jointly to avoid unnecessary duplication of costs and services.

9. To protect existing noise screens, visual screens, and green belts.
10. To minimize duplication of open spaces preserved and the undesirable location of open space between contiguous watersheds.

Ownership

1. To maximize local ownership of property.
2. To maximize local control over standards, quality, and uses of property which is owned by those living outside the watershed.
3. To maximize understanding of public rights associated with all lands and the relations of such rights to ownership.
4. To maximize the benefits of adjacency ownership.
5. To maximize public ownership or control over right-of-way, open space, recreational areas, landscaped and historical sites, and other sites of public value or use.
6. To minimize public ownership of commercial, business, or revenue-producing property.
7. To maximize on the watershed and contiguous watersheds the sum of the citizen benefits resulting from each ownership decision.

Organization and Operation

1. To maximize the benefits received by citizens as a result of activities they could not accomplish alone or in families.
2. To maximize citizen participation, registration and voting in governmental questions and elections.
3. To minimize the difference between citizen-expressed desires and the consequences of government-made decisions.
4. To minimize the costs of government and administration.
5. To maximize the cost effectiveness of the watershed as a managed system.
6. To evaluate watershed government and administration at least every 10 years to assure that it is consistent with goals and values of the citizens of the watershed.
7. To minimize capital investments and permanent labor forces consistent with providing desired benefits from the watershed.
8. To maximize the stability of the watershed governance.

The People

1. To predict accurately the population changes in terms of sex, ethnicity, age, birth, death, migration, education, and income resulting from changes within the watershed.
2. To minimize the difference between the actual population and the ability of the watershed and contiguous watersheds to support it.
3. To maximize the opportunities for every citizen to achieve his or her genetic potential.
4. To maximize educational and counseling opportunities for expectant mothers and their families within the watershed.
5. To maximize the educational and counseling opportunities for the mothers and families of pre-teenaged children within the watershed.

6. To maximize opportunities for families for high quality nursery service.
7. To minimize child-beating, trauma, and poisoning.
8. To provide adequate counseling opportunities for youth and their families.
9. To minimize juvenile delinquency.
10. To maximize housing for the elderly for whom it is not otherwise available.
11. To maximize constructive interactions of the elderly with other groups and subunits within the watershed.
12. To make available to the elderly sufficient space-heating energy to enable them to achieve a daytime winter temperature at or above 70° F.

Health

1. To maximize the life expectancy of the population.
2. To minimize in the watershed population the probabilities of occurrence of genetic phenomena judged by a panel of experts to be abnormal or unhealthy.
3. To minimize premature births.
4. To maximize the nutritional regime for prenatal mothers.
5. To maximize the number of wanted children born to vital families.
6. To minimize the births of abnormal, retarded, handicapped, defective, or diseased (genetic or otherwise) children.
7. To maximize the number of vital family units, having children amply supported, having children spaced for appropriate recovery of the mother and care of the child, and encouraged in healthful living.
8. To minimize infant mortality rates.
9. To minimize the ratio of mortality of aged (q_a) to infants (q_i) (i.e. q_a/q_i).
10. To maximize accuracy of citizens' perceptions of disease incidence, rate of spread, intensity of effects, risks, and reversibility.
11. To achieve enhanced citizen satisfaction from knowledge of the absence of detectable disease.
12. To minimize disease susceptibility of all age classes and sexes.
13. To achieve the earliest possible diagnosis of disease.
14. To minimize the duration of all disease.
15. To maximize the speed, accuracy, and reliability of diagnosis.
16. To reduce the mean duration and intensity of effect of the major infectious and communicable diseases.
17. To minimize the probability of disability resulting from disease.
18. To minimize the number of citizens unable to obtain legal employment due to physical disability.
19. To equip the largest number of disabled people with devices allowing the greatest amount and range of action per dollar invested in equipment.
20. To minimize the number of people requiring high quality long-term care and support during illness or disability.
21. To stabilize or reduce morbidity rates from the major infectious and communicable diseases.
22. To maximize recovery rates, minimize relapses and recurrences, and minimize second-disease occurrence within 365 days after recovery.
23. To provide treatment for all pathogenic states at the lowest costs sufficient to

enable body structure and processes to recover to within 90 percent or greater of the pre-disease efficiency.

24. To maximize allocation of resources toward treating diseases for which the probable differences in the patient between treatment and non-treatment are greater.
25. To maximize the rate of treating diseases for which there are the lowest probability of altering the cause of the disease.
26. To maximize the ratio of the actual population health to a conceptual optimum population health.
27. To minimize tuberculosis.
28. To minimize the total and mean dental caries per age-weighted person in the population.
29. To maximize the accessibility of the most effective known generic drugs or medicines for the lowest cost.
30. To maximize the number of post-treatment mental patients returning to a normal home environment.
31. To minimize both treatment time and recovery time for mental patients.
32. To minimize return of discharged citizen patients to mental hospitals.
33. To maximize citizen satisfactions and direct benefits experienced from the knowledge of having physical and mental health, equal to or above the 19-- norm, from completing disease- and accident-free years, and from achieving levels of an individual, complex, health-status index.
34. To minimize the incidence of alcoholism.
35. To minimize the incidence of drug addiction.
36. To minimize the duration of alcoholism.
37. To stabilize or reduce rates of occurrence of major accidents.
38. To minimize health problems associated with natural disaster, military operations, or significant socio-political change.
39. To minimize the time from trauma to treatment.
40. To minimize the number of institutionalized elderly citizens.
41. To minimize the occurrence and probability of highway, industrial, and home accidents.
42. To provide within three hours, emergency response to 90 percent of the needs of ten or more people experiencing (or likely to experience) major natural catastrophy.
43. To minimize chronic and acute poisoning.
44. To minimize in foods sold within the watersheds pathogens, tetratogens, carcinogens, toxicants and other substances known to be or highly probable to be detrimental to health.
45. To minimize heavy metal accumulations in citizens of the watershed.
46. To minimize the key indices of the effects of air pollution on citizens.
47. To minimize key indices to noise pollution effects on citizens.
48. To minimize the volume of solid waste disposed.
49. To reduce the probability of disease transmission associated with sewage and garbage.
50. To maximize the use of ideal solid waste disposal acreages.

51. To reduce pathogens in ground water and other water supplies, both public and private.
52. To reduce the probability of disease or dysfunction resulting from drinking water.
53. To prevent settlement and development where ample supplies of high quality water are unavailable.
54. To minimize disease and dysfunction resulting from eating in public or semi-public places.
55. To minimize human exposure to microwave, nuclear, x-ray, and other harmful radiation.
56. To minimize the number of habitations that are disease vector-free over most of the year.
57. To maximize a set of indices expressive of the nutritional indices for the population.
58. To minimize the variance among watersheds in the nutritional indices for the population.
59. To maximize acceptability of health care programs and treatment by citizens and members of the medical community.
60. To recruit, provide educational opportunities for, and maintain performance competency of doctors and other medical workers at or above the 1975 level.
61. To maximize the diversity of and fail-safeness of biomedical technology available within six hours for every citizen.
62. To maintain at least one program or treatment alternative where benefit-to-cost ratios are equal or do not exceed five percent of the primary program or treatment.
63. To minimize undesirable secondary consequences, externalities, and counter-intuitive aspects of programs and treatments.
64. To minimize the time between when research results are published in reviewed medical and health journals and when justified application is made to citizens of the watershed.
65. To develop the needed legal codes and atmosphere within which these health objectives can be achieved.

Education

1. To maximize the number and diversity of opportunities for citizens of the watershed to participate in educational and training experiences.
2. To provide cost-effective physical environments for teaching and learning for all people of the watershed.
3. To maximize the alternative uses of school buildings, consistent with their educational function.
4. To maximize teachers', staffs', and learners' involvement with the community at large.
5. To provide children within the watershed schools that are dynamically developed to enable them to achieve their full potential in every area of their interest, including basic competence in language and mathematics.
6. To make available diverse educational materials, modules, and services to meet the expressed desires of at least 70 percent of the citizens.
7. To maximize the citizen-learners' expressions and selections of their educational goals.

8. To maximize the number of citizens above age 18 that hold a high school diploma or its equivalent.
9. To provide counseling and aids for citizens to enhance their perception of their potential.
10. To minimize the time required per student to achieve indices of desired, lasting behaviors or competencies.
11. To minimize the public cost per unit of desired changed behavior.
12. To provide needed tutoring as well as educational aid and enhancement programs.
13. To employ and retain the best educated, most student-oriented, and most highly motivated teachers available.
14. To develop and operate an effective system of teacher evaluation, education, and incentives.
15. To develop effective governance and management of the educational systems for the people of the watershed.
16. To provide a suitable continuous means by which all citizens of the watershed may articulate their satisfaction with the quantity, quality, and costs of the educational system.
17. To provide information to the citizens about their watershed—achievement of goals, benefits experienced, opportunities, and needs.
18. To maximize information storage and retrieval services for all citizens.
19. To provide children of the watershed a school curriculum that enables them to become involved, contributing, and reasonably fulfilled members of the community.
20. To develop cost-effective systems of education for students and citizens having learning disabilities and exceptional learning talents.
21. To develop a cost-effective system including facilities, of special education for the handicapped for ensuring continued student growth and improvement.

Security and Justice

1. To conduct a cost-effective crime prevention program.
2. To minimize the number of committed crimes.
3. To achieve a "crime solution rate" equal to or superior to the mean rates of contiguous watersheds.
4. To minimize the number of crimes committed that are harmful to individuals.
5. To minimize the annual sum of mean property loss from reported crimes and annual law enforcement retention and court costs.
6. To provide counseling, psychological services, and training for citizens with high potential for committing crimes and for those having been convicted.
7. To predict occurrence of crimes and develop demonstrably optimum patrol and surveillance strategies.
8. To develop a law enforcement system for the watershed with internal checks and balances, high professionalism, fail-safe and back-up forces.
9. To maximize law enforcement, medical, emergency, and security communication among contiguous watersheds.
10. To minimize repeat rates for those convicted of crimes.
11. To minimize the modal time between arrest and conviction, dismissal, or acquital.
12. To minimize penal confinement while maximizing alternative opportunities for recreation or other activities, particularly for juveniles.

13. To maximize the comfort, consistent with security, of citizens between the time of arrest and court action on their cases.
14. To maximize the opportunity for all citizens to secure high quality legal advice.
15. To minimize for citizens convicted of a crime, the time from conviction to rehabilitation and a normal life.
16. To minimize the difference between convictions and the number of crimes reported as committed.
17. To support ongoing law enforcement research efforts, utilize latest cost-effective discoveries, and contribute descriptions of local advances to others.
18. To maximize the return of, replacement of, or restitution for stolen or damaged property by the person responsible or by the citizens of the watershed.
19. To maximize an index of the average citizen's perception of personal and property security.

Recreation and Leisure

1. To provide diverse recreational opportunities throughout the watershed.
2. To provide recreational opportunities for large-group and competitive activities.
3. To provide recreational opportunities for individuals and small groups.
4. To provide recreational opportunities that are used to within five percent of their capacity.
5. To provide a sufficient basic set of free recreational opportunities in each urban neighborhood and in each rural community of the watershed.
6. To provide facilities uniquely designed for and largely used only by citizens of the age classes of very young, youth, middle-aged, and elderly.
7. To provide temporary and experimental recreational opportunities.
8. To provide high-risk and adventurous recreational and leisure time opportunities.
9. To minimize public costs per unit of quality-ranked use of the recreational opportunities of the watershed.
10. To provide education, publicity, and counseling about leisure-time activities.
11. To provide space and opportunities for citizens of the watershed to display their creative works, talents, and activities.
12. To provide recreational areas for the very young with maximum ease of access and safety.
13. To provide adequate, healthful, year-round recreational opportunities for 90 percent of the youth living within the watershed.

Employment

1. To achieve at least 75 percent employment of the working population in activities they find at least 75 percent satisfying.
2. To assure work opportunities for at least 50 percent of the youth of the watershed.
3. To achieve diverse employment opportunities such that no more than 40 percent of the employment in the watershed and contiguous watersheds is by one employer.
4. To maximize opportunities for advances in employment in responsibility, required knowledge or skills, and satisfaction.
5. To minimize the five-year variance in unemployment.

6. To maximize the number of citizens amply protected by medical and unemployment insurance.
7. To minimize both number and duration of work stoppages among public employees.
8. To maximize the number of citizens employed within the watershed.
9. To maximize the meaningful work and service opportunities for the elderly citizens of the watershed.

Safety

1. To minimize hazardous roads, road conditions, and intersections.
2. To minimize the total number and variance of insurance claims for personal and property loss over a sliding five-year period of analysis.
3. To maximize safety of pedestrians and bicyclists.
4. To minimize total accidents to citizens and property within the watershed.
5. To maximize the predictability of accidents and hazard potentials of sites.
6. To maximize safety for all travelers within the watershed.

Fire

1. To minimize the injury, loss of life, and damage caused by fires within the watershed.
2. To minimize the number of fires.
3. To minimize the costs of fire prevention and suppression.
4. To maximize the ease of fire suppression in buildings.
5. To minimize the mean time between fire and emergency reports and arrival of needed assistance.

Civil Defense

1. To maximize current citizens' knowledge of defense plans.
2. To minimize the response time in aiding victims of natural or manmade catastrophe.
3. To minimize the difference between the needs and the responses made by public agencies to victims of enemy attacks or natural or manmade catastrophe.
4. To minimize the cost of emergency preparedness.
5. To minimize radiological hazards to all citizens of the watershed.
6. To coordinate defense needs of citizens of the watershed with needs and services at state and national levels.
7. To maintain a civil defense command network.
8. To maintain a civil defense communication network.

Industry, Commerce, and Finance

1. To maximize the availability of required commercial services for citizens of the watershed.
2. To stabilize or increase relative land or property values.
3. To provide opportunities for a maximum number of business owners to make profits equal to or greater than the mean annual profits in contiguous watersheds.
4. To maximize industrial diversity.
5. To minimize bankruptcy suits.

6. To minimize an index of the number, duration of vacancy, and per-month income foregone from unoccupied business spaces within the watershed.
7. To encourage ingress of energy-efficient industries.
8. To maximize the energy efficiency of industry existing within the watershed.
9. To maximize the export of goods from the watershed.
10. To minimize industrial impacts on the environment.
11. To minimize industrial use of agricultural land and open space.
12. To minimize industrial and commercial damage from floods.
13. To maximize the taxable property and income base of the watershed.
14. To maximize at least one major index of citizen satisfaction with the industrial and commercial complex of the watershed.
15. To minimize land "speculation."
16. To minimize citizen complaints to their government about industrial air and water pollution.

Food and Nutrition

1. To maximize the probability that all citizens can secure a continuous supply, or have the opportunity to secure abundant, high-quality foods year around.
2. To minimize food costs to citizens.
3. To maximize the mean nutritional status of all citizens.
4. To minimize malnutrition within the watershed.
5. To minimize disease or dysfunction resulting from improper quantities or quality of foods.
6. To maximize the nutritional levels for all prenatal children and mothers and all children through age seven.

Social Services

1. To maximize the awarenss of citizens of availability, scope, purpose, budget, and impact and evaluations of all social services within the watershed.
2. To maximize within contiguous watersheds the mean rate of change of families out of a "subsistence level" status.
3. To provide a cost-effective system of housing, tax relief, transportation, medical and dental care, and legal services to meet the needs of families on low or fixed incomes.
4. To mobilize resources and personnel of the watershed in an effective system of preventing welfare need, providing adequate services as needed, and enabling those receiving welfare to achieve viable, self-respecting life styles.
5. To minimize, within the watershed, the costs per unit of desired and needed services delivered.
6. To minimize the sliding three-year mode of the time citizens are on welfare.
7. To maximize the flexibility of programs in meeting citizen needs.
8. To minimize the difference between mean citizen need and mean public agency response.
9. To maximize the self-sufficiency of citizens receiving welfare.
10. To provide support and services reflecting as nearly as possible the purchasing power of the dollar and cost of living.

11. To provide opportunities for meaningful employment of citizens by public agencies within the watershed.
12. To maximize the availability of suitable housing at equitable prices.

Communications

1. To maximize the number of citizens voting in local and state elections.
2. To maximize the precision and representativeness of citizens' inputs to local decisions.
3. To maximize the information communicated to citizens on government achievements of watershed goals.
4. To assure a diversity of government and private radio and TV information for citizens.
5. To provide to all prospective citizens information on the watershed and expectations of citizens.
6. To maximize communication of rules, regulations, plans, and opportunities for citizens within the watershed.
7. To maximize citizen involvement in problems caused by not knowing rules, regulations, and ordinances.
8. To minimize the time between citizen requests for information and answers received.
9. To achieve diversity in mass media content within the watershed.

Taxation and Finance

1. To minimize the median governmental costs within contiguous watersheds.
2. To maximize citizen knowledge of tax fund expenditures and services received within the watershed.
3. To maximize avenues for citizen expression of the desires from tax expenditures.
4. To minimize interest monies paid by public governance and other agencies.
5. To maximize the bonding capability of the watershed.
6. To seek and utilize income sources that are alternatives to taxes.
7. To maximize the effectiveness of a long-term operating and capital budgeting system for the watershed, providing optimal managerial control, accountability and predictability.
8. To maximize efficiencies at all levels of operation.
9. To maximize the currency of the tax base reflection of fair market value of property.
10. To equalize citizen payments for services received.
11. To minimize tax, bill and assessment collection costs and losses.
12. To execute purchasing efficiencies consistent with cash flow estimates.

Transportation

1. To provide for ease of movement within the watershed community by developing a road, street, and trail system.
2. To develop a balanced transporation system with appropriate emphasis on mass transportation.
3. To minimize the impact of roads, highways, streets, and trails on existing and future land uses.

4. To provide convenient access to and from high frequency land uses within the watershed.
5. To encourage desired development patterns by means of the transportation system.
6. To preserve the integrity of villages and neighborhoods within the watershed by appropriate traffic direction.
7. To improve the aesthetic environment of the watershed through the landscaping of transportation arteries.
8. To minimize road accidents, injuries, and fatalities.
9. To provide for safe and convient movement of pedestrian and bicycle traffic throughout the watershed.
10. To protect existing and proposed rights-of-way.
11. To maximize use of transporation corridors for utilities.
12. To minimize future highway modifications.
13. To minimize highway and road maintenance costs.
14. To maximize accessibility to long-distance travel means.
15. To minimize traffic congestion, automotive standing time, and associated human stresses.
16. To maximize the mean comfort index of all roads within the watershed.

Utilities and Energy

1. To assure for all citizens a power supply at least 99 percent reliable.
2. To achieve alternative power supplies or sources for 50 percent of the 1975 energy needs for homes, business, and industry.
3. To maximize the 10-year total tax returns per 1,000 linear feet of utility provided.
4. To maximize the number of people served per 1,000 linear feet of utility provided.
5. To minimize disruptions in transportation, landscaping, and esthetic quality caused by utility construction and maintenance.
6. To provide abundant, high-quality water for all citizens, indefinitely.
7. To minimize total long-term utility maintenance costs.
8. To minimize the costs of water treatment.
9. To maximize energy conservation throughout the watershed.
10. To minimize conspicuousness and visual impact of all utilities.
11. To maximize the efficiency of generation, transmission, and use and conservation of energy throughout the watershed by government and citizens.
12. To maximize the use of solar energy, both passive and active.
13. To utilize maximally non-fossil fuel energy sources.
14. To minimize heat, radiation, and nuclear hazards to citizens of the watershed associated with nuclear power generation.
15. To minimize urban heat island effects.

Waste

1. To minimize solid waste.
2. To minimize litter.
3. To maximize recycling of solid waste.
4. To minimize secondary undesirable effects of solid waste disposal.

5. To minimize public costs of solid waste disposal.
6. To maximize public returns from solid waste recycling or use.
7. To minimize the area required for solid waste disposal.
8. To maximize solid waste separation at the source.
9. To maximize use of sewer plant and liquid chemical wastes.
10. To minimize storm sewer runoff.
11. To maximize the amount of sewer water from the watershed undergoing tertiary treatment.

Living Spaces

1. To stabilize or increase the quality of living spaces throughout the watershed.
2. To provide diversity of housing type and settlement configurations throughout the watershed.
3. To provide opportunities for every individual to aquire high quality living spaces.
4. To maximize the number of "decent physical shelters" defined as:
   a. not deteriorating,
   b. not needing major structural repairs,
   c. being safe,
   d. having hot and cold running water,
   e. having an indoor toilet,
   f. having at least reasonable light and air,
   g. not being overcrowded (i.e., greater than 700 sq. ft. per person),
   h. within a range that eighty percent of the citizens can afford,
   i. being away from major sources of noise or pollution,
   j. compatible with all relevant building codes.
5. To minimize the mean time per unit that rental space units are unoccupied.
6. To minimize noise in residential areas.
7. To minimize structural damage from earthquakes, hurricanes, winds, floods, and other natural or man-caused disasters.
8. To minimize the mean total travel time and travel time per mile between home and shopping areas.
9. To minimize the mean travel time between home and places of doing business.
10. To minimize one-way travel time for citizens from home to work.
11. To maximize the life expectancy of structures within the watershed.
12. To minimize slums and delapidated structures.
13. To prevent the formation of ghettos or ghetto-like conditions.
14. To maintain viable city centers.
15. To minimize the variance in the percent change in buildings within the watershed.
16. To minimize urban sprawl.
17. To minimize developments of existing or planned roads that are removed from utilities.

Land Use

1. To maximize land use diversity.
2. To so use land as to maximize alternatives for future decisions on land use.
3. To minimize runoff.

4. To maximize percolation and ground water recharge.
5. To minimize water table losses.
6. To minimize erosion.
7. To minimize developments in floodplains, or near geologically hazardous areas.
8. To minimize the use of agricultural land for production or use other than agricultural.
9. To minimize dust, air, water, surface water, and ground water pollution.
10. To minimize noise pollution.
11. To minimize the introduction of exotic or non-native plants and animals.
12. To minimize heat loss effects of winds in winter and unpleasant or damaging gustiness in all seasons.
13. To preserve unique land features, areas of great visual importance, and areas of biological or historical importance.
14. To acquire public lands or land control so as to have recreational areas and open or green space within reasonable walking distance of every resident.
15. To report land use inventory at least every 10 years.

TABLE 2

Criteria for Developing and Evaluating Statements of Goals

(Few stated goals will meet all of the criteria, suggesting need for continual rewriting, editing, and refinements.)

1. It has been written for the proper audience.
2. It is grammatically correct.
3. It is brief.
4. It can be understood to at least three peoples' mutual satisfaction.
5. There is at least one way imagined or known by which it can be achieved.
6. Progress toward it can be measured.
7. Acceptable units of measure of attainment can be agreed.
8. It expresses as a production function what to obtain or to retain.
9. It attains at a level beyond presently known capabilities of use or benefit.
10. It is flexible, allowing for adjustment to new directions or conditions.
11. It is not a step to a higher objective.
12. It contains no methodology.
13. It cannot be combined with another objective on the basis of the participant.
14. It goes beyond preventing deleterious effects.
15. It has no hidden objective.
16. It tends to be long term.

TABLE 3

Sample Output to be Accompanied by Computer Graphics.
Major Decision Criteria and Supportive Statistics and Decision Criteria are Provided.

South River Response

Date: June 10, 1977

You have requested information for construction of a factory of 40,000 sq. ft. in cells R 236 U 107

Your name for the project is A. W. Fuller Place

The achievement of watershed objectives if the project is completed is:

Decision Alternative	Difference by closedness	Mean difference per year	Variance	Years in which Q will be within 10% of mean	Index of variation S/Q bar	Mean percent natural to total difference
	1.0 0.8 0.5 0.1	1.0 0.8 0.5 .01	1.0 0.8 0.5 0.1	1.0 0.8 0.5 0.1	1.0 0.8 0.5 1.0	1.0 0.8 0.5 0.1
A						
B						
C						
.						
.						
N						

Continued	D*	Total cells population projection used
	1.0 0.8 0.5 0.1	
A		____
B		____
C		____
.		____
.		____
N		____
		____

TABLE 4
Major Dimensions of the Earth Energy System
(All energy is of solar origin. Electricity is a primary means of energy transmission, although direct physical transportation of coal, gas, oil, or hydrogen are other means.

Production
- Coal
- Natural gas
- Oil
- Coal gasification
- Nuclear power
  - Fission
  - Fusion
- Laser fusion
- Synthetic fuel from waste
- Waste incineration
- Biological matter (waste and energy forests)
- Firewood
- Peat
- Hydroelectric power
- Wind
- Hydrogen
- Ocean currents and the osmotic process
- Tidal power
- Geothermal energy
- Solar energy

Transmission

Storage

Conservation
- Macro
- Micro

TABLE 5
Geologic Formations of the South River Watershed, Virginia

Age	Name	Map Symbol	Character	Thickness (in feet)
Ordovician	Beekmantown formation	Ob	Thick-bedded, gray, medium-grained dolomite, some blue limestone, much chert.	2,000
	Chepultepec limestone	Och	Blue and gray limestone, some dolomite. Some nodular black chert.	500
Cambrian	Conococheaque limestone	Ꞓco	Thick-bedded, bluish limestone, some dolomite, thin sandstone beds.	2,500
	Elbrook dolomite	Ꞓe	Thin- and thick-bedded dolomite, limestone, and some shale.	2,000
	Rome formation	Ꞓr	Red and brown shale, calcareous shale, siltstone, some limestone.	1,700
	Shady dolomite	Ꞓs	Argillaceous dolomite, some limestone, some shale. Poorly exposed, commonly concealed by residual clay.	1,000
	Erwin quartzite (Antietam)	Ꞓa	Upper member: Brown sandstone and some quartzite. Lower member: white, thick-bedded quartzite, with *Scolithus* tubes	400 400
	Hampton formation (Harpers)	Ꞓh	Thin-bedded, dark gray to greenish siltstone. Micaceous shale or phyllite at base.	900
	Unicoi formation	Ꞓu	Ferruginous quartzite, thin-bedded greenish siltstone, and gray slate.	900
	Catoctin greenstone	Ꞓp-Ꞓc	Altered basaltic lava, some amygdaloidal, some epidotized: interlayered tuffaceous sedimentary materials.	0-1,000
Pre-Cambrian	Pedlar	p-Ꞓp	Chiefly granodiorite-hypersthene. Predominantly green, medium to coarse-grained. Some porphoritic.	?

TABLE 6
USGA Topographic Maps Depicting Portions of the South River Study Area

1. Fort Defiance	7. Vesuvius
2. Crimora	8. Big Levels
3. Grottoes	9. Stuarts Draft
4. Waynesboro, West	10. Mount Sidney
5. Sherando	11. Waynesboro, East
6. Greenville	12. Brown's Cove

TABLE 7
Examples of Computer Maps Containing Data Available for the South River Watershed

1. Watershed boundary	11. Soils
2. Elevation	12. Roads
3. Slope	13. Enumeration districts
4. Land use	14. Precipitation
5. Parkway	15. Transmission
6. Aspect	16. Visual analysis from secondary and primary roads
7. Lakes, rivers, streams	17. Visual analysis from scenic parkway
8. Power lines	18. Visual analysis from all cells
9. Utilities	
10. County boundaries	

The Virginia Water Resources Research Center is a federal-state partnership agency attempting to find solutions to the state's water resource problems through careful research and analysis. Established at Virginia Polytechnic Institute and State University under provisions of the Water Resources Research Act of 1964 (P.L. 88-379), the Center serves five primary functions:

- It studies the state's water and related land-use problems, including their ecological, political, economic, institutional, legal, and social implications.
- It sponsors and administers research investigations of these problems.
- It collects and disseminates information about water resources and water resources research.
- It provides training opportunities in research for future water scientists enrolled at the state's colleges and universities.
- It provides other public services to the state in a wide variety of forms.

More information on programs and activities may be obtained by contacting the Center at the address below.

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