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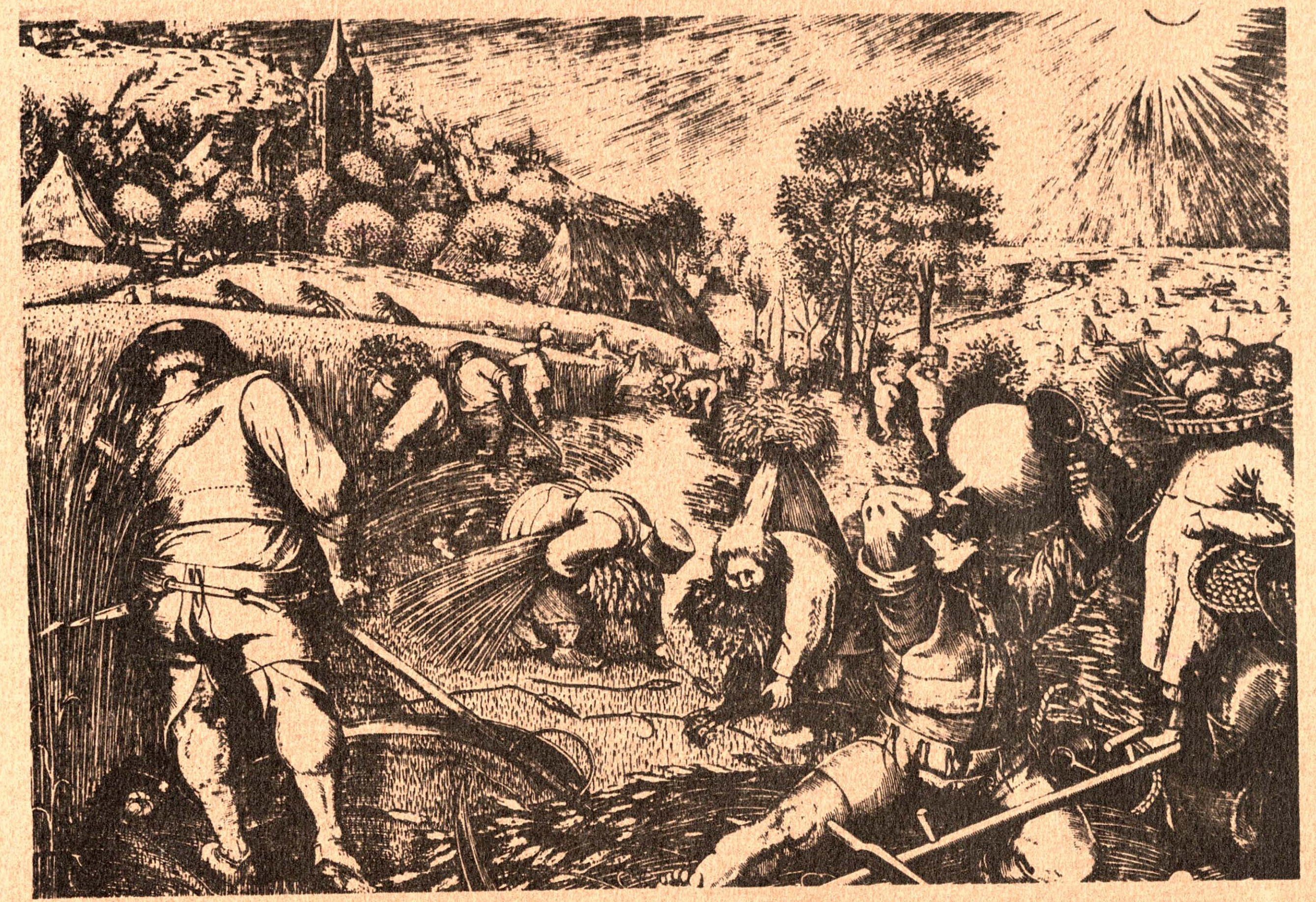

HEXE BARGER: DESIGN OF A SELF-SUSTAINING COMMUNITY

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Spring 1975

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INTRODUCTION: THE PROJECT

Background

Rural self-sustenance--in which people rely upon their own labor and local materials in securing life's necessities (growing their own food, constructing and maintaining their own shelter and water supply systems)--is both a contemporary lifestyle option and, possibly, a future necessity for society as a whole.

The growing "back-to-the-land" movement as a lifestyle choice is well documented by such publications as The Mother Earth News and the multitude of recent how-to-homestead and produce-your-own-power books. And, indeed, the most recent U.S. census figures confirm that, for the first time in many years, the rural population is no longer losing ground to the cities or suburbs.

Back-to-the-landers cite a complex assortment of negative and positive motives: their disenchantment with contemporary urban life and its black-outs, garbage strikes, and random violence; their weariness with being "consumers" prey to layoffs and "double-digit inflation"; their desire for greater independence and self-reliance in supplying their own needs; and their conviction that the natural and man-modified rural environment can offer at least as stimulating a context for daily life as the more exclusively man-modified and man-made urban environment.

Such rural self-sustenance is rich in historical American precedents, including the colonists of the eighteenth century and the homesteaders or utopians of the nineteenth century, who drew directly, in turn, upon a rural European tradition extending back to the small farming villages of the Middle Ages.

Even within the twentieth century, this lifestyle option is neither exclusively characteristic of the United States (given the Seymours in England) nor of the late 1960's and early 1970's (given M. G. Kains and the Nearings who sought rural self-sustenance as a refuge from international economic collapse and political insanity during the 1930's).

Some such back-to-the-landers have sought and still seek absolute autonomy on a small farm plot separated from the rest of mankind by a national forest and a glacier or active volcano. But some, such as those recently involved in planning Oregon's Cerro Gordo village, seek life within a structured rural community shared by others similarly determined to limit population and land uses according to the site's natural carrying capacity and to enhance the community's capacity for long-term self-sustenance by emphasizing use of renewable material and energy resources.

Others view rural self-sufficiency not only as a current lifestyle option, but also as a possible future necessity for society in general.

Shortages of conventional resources, such as petroleum, copper, and aluminum, seem to multiply in frequency and magnitude as population and demand grow exponentially and supplies simultaneously dwindle exponentially.

If the long-distance supply systems which now meet society's needs through intensive consumption of these non-renewable resources should ever collapse, society's component individuals would starve and freeze only if they lacked the potential of turning to their own renewable local resources for self-sustenance in the absence of support from the system.

For the United States the most traumatic period of depleted conventional resources and severed supply lines may still lie far in the future. But the potential for long-term future self-sustenance must be preserved now against local resource destruction for short-term gain.

Such maintenance of an area's self-sustenance potential requires definition of viable population limits, identification of essential local resources upon which the population may some day depend, and design for efficient employment of those resources in support of that population.

These planning and design decisions are the responsibilities of landscape architects.

Project Definition

The project had two over-all goals:

1. Development of a replicable method for determining:
   a. How a given land area's resources can be employed most efficiently toward a population's "self-sustenance" (i.e., the population's maximum possible long-term reliance upon local resources to meet specified human needs)
   b. What maximum population can the given area support under the specified conditions of self-sustenance (i.e., what is the area's "self-sustaining carrying capacity")
2. Design of a self-sustaining community of that population for a small rural watershed site in southwestern Pennsylvania according to the method developed

Given these project goals, we found that several guiding principles for project planning and design decisions followed closely. Such decisions should emphasize:

- Use of on-site material and energy resources (e.g., local timber, sandstone, and shale vs. imported steel and plastics) according to the goal stipulation of maximum reliance upon local resources
- Use of renewable material and energy resources (e.g., sun, wind, and cordwood vs. petroleum) according to the goal stipulation of long-term reliance upon local resources
- Conservation and re-cycling of non-renewable resources (e.g., nutrients) according to the goal stipulation of long-term reliance upon local resources

Within the general trade-off between maximizing an area's human population and minimizing environmental disturbance, the project seeks a definable middle ground. The site's self-sustaining carrying capacity (and hence the community's population) will be maximized within the environmental limits (expressed as the second and third principles above) set by the project's goal of that population's long-term reliance upon local resources. For example, wooded areas may be cleared for agricultural use (increasing the population which the site can feed), and the resulting cordwood may be burned for household space heating (increasing the population which the site can shelter) unless the areas to be cleared are so steeply sloping and their soils so erodible that the resulting loss of soil nutrients and stream water quality degradation threaten the population's long-term use of that soil and water.

Project Limits

We found that such an ambitious project required several explicit limits to allow its thorough completion within an acceptable length of time. We decided:

- to consider the population's needs for food, shelter, and water only (since these needs are most basic and most pertinent to the knowledge of landscape architecture) in determining the site's self-sustaining carrying capacity (leaving an additional land area allowance factor for satisfaction of any other material human needs which may be satisfied locally)
- to acknowledge that absolute self-sufficiency is neither feasible nor necessarily advisable and therefore, while maximizing the population's reliance upon local resources, to assume some minimal importation of goods essential in providing for food, shelter, water and any other needs not considered (leaving a further land area allowance factor for production of goods to export in trade)
- to consider only the community's long-term needs as an ongoing system in determining the site's self-sustaining carrying capacity, with concern neither for the initial capital investment required nor for the political feasibility of the design's implementation
- to use "low-flow" site productivity data in calculating the site's self-sustaining carrying capacity, providing for the population's continued support through below average months and years, but not through a major disaster (such as a tornado) which would require a massive new capital investment
- to make reasonable and explicit assumptions as necessary (based upon the best information immediately obtainable) and then to move forward with the project's work

Project Contribution

Thus defined and limited, our project contributes, to the best of our knowledge, a new and unique method for determining a small and specific land area's self-sustaining carrying capacity as an input to design of a self-sustaining community for that area.

Several previous and well-known models deal with similar issues on scales much larger than our project's. The Limits to Growth model functions at the global scale. Odum's work and Peterson's work in Florida and Oregon apply to the regional scale.

One previous project with which we are familiar deals with similar issues at the same scale as our project's. But, due at least partially to the widely differing natural resources of its Oregon site as compared with our Pennsylvania one, the Cerro Gordo project's method diverges significantly from ours.

Rather than basing their carrying capacity calculations simultaneously upon quantified human needs for food, shelter, and water, the Cerro Gordo planners dealt only with the water demand, evidently the single limiting factor on their site. They began with a generalized guess at their 1200-acre site's carrying capacity and then estimated the reservoir storage area required to supply that population with water through the site's characteristic two month summer drought. But it became apparent to them that reservoir areas of the required extent probably would cause significant changes in the site's physical environment (through greatly increased surface water evaporation). By some means (not clear in their published reports) the planners finally decided upon a smaller optimum reservoir area for the site and reduced their original carrying capacity guess accordingly.

Project Site

Our 1500-acre project site is known locally as "Hexe Barger"- "Hexed Valley" - because of its early blessing by a witch grateful for exceptionally fine treatment by the inhabitants.

The site consists of the watershed of Mose King Run, a tributary to Laurel Hill Creek. Located in Somerset County, it lies just east of Laurel Hill (recently the subject of a Regional Planning thesis), ten miles southeast of Wright's "Fallingwater," and sixty miles southeast of Pittsburgh.

Predominantly rural, the region now exports dairy, maple, and timber products. It is gaining importance as a location for recreational development and coal strip-mining.

We chose the project site itself for a variety of reasons, including its rural character, its reasonable size for study and community design, the diversity of its natural resources and the strength of their indications about land use potentials and limitations, the availability of on-site facilities for use during extensive field observation periods, and one team member's previous familiarity with the area and its residents.

Project Structure

Figure 1 outlines the project's overall structure, which is also the structure of this report. Reading from top to bottom, the project proceeded through three initial inventories (of the site's natural features, human needs, and appropriate technology) to three major design inputs (the site's self-sustaining carrying capacity, land use suitabilities, and social program) and, finally, to design of the site's self-sustaining community. The nature of each project component and its relation to other components which preceded and followed it are explained in detail within the report section bearing its name.

PROJECT STRUCTURE

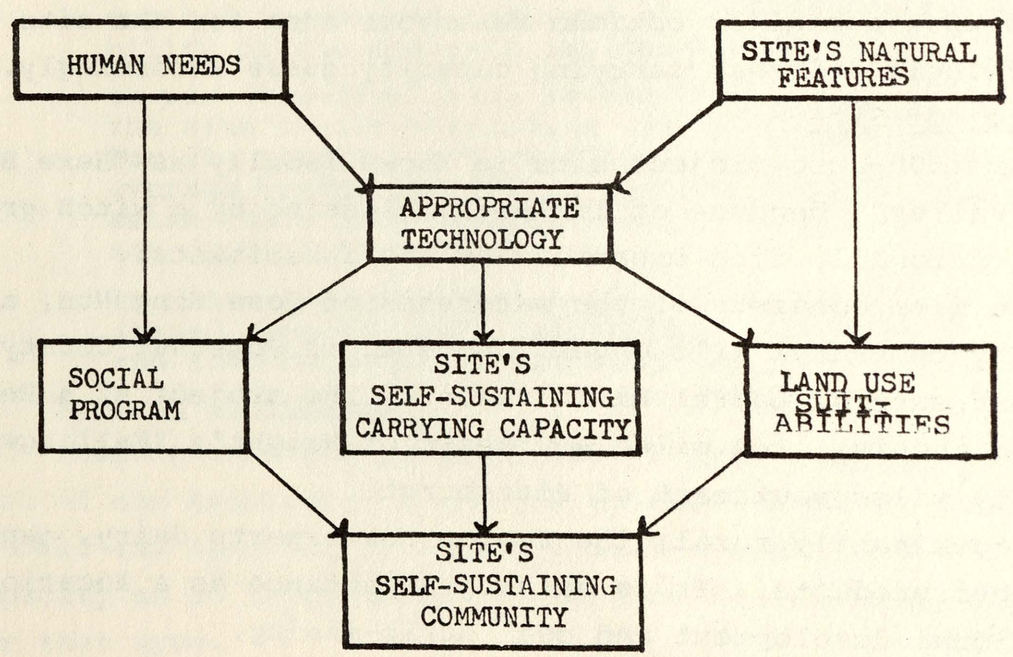

Figure 1

INVENTORIES:

SITE'S NATURAL FEATURES

Our first project inventory consisted of a complete spatial and, where appropriate and possible, statistical description of the watershed's natural features, including their present degree of human modification, their existing and potential productivity (especially for food, shelter and water), and their capacity to sustain further human intervention without long-term damage to non-renewable resources. Published sources, interviews, and on-site surveys contributed to this description.

Only the briefest summary of qualitative inventory findings is possible here. Some further qualitative productivity data (e.g., the potential of sandstone strata to yield water and building stone) is, however, included below in report Section IC's discussion of assumed technology; some quantitative productivity data (e.g., per-acre forest cordwood yield by vegetative association) is included in Section IIA's carrying capacity calculations; and some data regarding non-renewable resource vulnerability to use (e.g., erodibility as a function of slope and soil type) is included in Section IIB's land use suitabilities.

Visual Character

Topography strongly determines our site's overall visual character, both directly and indirectly.

Ridge lines directly divide the site into "Topographic Visual Units" (Slide 1). These include several "major" enclosures along the mainstream and its largest tributary. "Accessory" enclosures along the smaller stream tributaries face onto these major ones.

By influencing land use patterns topography also has additional indirect input to the composite "Existing Visual Character" (Slide 2) of any site area as "level" or "sloping" and "open field" or "forested." This overall visual character is most readily seen in the series of site "Cross Sections" (Slide 3).

The level open ridge tops, which rim the site on the upstream side, belong to the more prosperous dairy farms. Except where they are entirely enclosed by the tree line of the adjacent steep and forested side slopes, these ridgetops offer long views of both the valley bottom below and of other ridges across the valley and beyond (as shown in Section B-B' taken at the stream's headwaters and in Section C-C' taken further downstream). Smaller and less prosperous farms, houses, and trailers dot the valley bottom. Spur ridges extend from the peripheral ridgeline into the valley, forming the "accessory" enclosed units about smaller stream tributaries, as noted above (and shown in Section D-D').

Downstream to the west, the valley widens out into a broad terrace, enclosed by a forested ridge wall only on the upstream side (as shown in Section A-A'). This terrace includes the site's most extensive parcels of flat open land and its only large pond.

Finally the stream cuts down through the terrace on its fall into Laurel Hill Creek. Although this forested ravine is not large enough to merit its own cross-section, it is the show place of the watershed, including sandstone outcrop waterfalls and slopes shaded by hemlock, oak, and rhododendron.

Geology

Located within the mountainous portion of the Allegheny Plateau, the site consists of thin, nearly level alternating strata of sandstone and shale, occasionally interbedded with limestone, as shown on the map of "Geology" (Slide 4), which we drew from a published source (Flint, 1965) and verified by on-site surveys. There are no faults or other major distortions of this basic structure.

Slope Gradient and Orientation

As is evident from our "Slope Gradient" map (Slide 5), the sandstone's resistance produces very steep slopes, exceeding thirty percent on most of the ridge walls, but few real cliffs. Narrow and winding stretches of flat land follow the ridge tops

and valley bottom. The most substantial flat areas belong to the terrace.

Mose King Run and its valley generally run east to west. But the stream's frequently oblique path and the spur ridges projecting from the periphery into the valley result in a fairly even aspect distribution on our map of "Slope Orientation" (Slide 6).

Flood Hazard

Using Luna Leopold's method of floodplain delineation, we outlined the stream's ten-year innundation area on our "Flood Hazard" map (not included here). This necessitated use of published flood frequency data (U.S.G.S., Flood Frequency: Ohio River Basin), on-site stream discharge measurements, and on-site sections and mapping of stream-side terraces.

Soils

Lacking a complete Soil Conservation Service survey of the site, we compiled our own "Soils" map (Slide 7). Since our method of mapping soils represents, to the best of our knowledge, a new approach, we shall describe it in some detail here.

We began by overlaying individual site maps of the major soil-forming factors in combinations such that the resulting site areas could be assigned the soil series designations used in published S.C.S. surveys of adjacent counties (Westmoreland County, Pa., 1968; Fayette County, Pa., 1973).

Soil-forming factors which were mapped include parent material (from the maps of geology and flood hazard) and relief (from the maps of slope gradient and shape).

Several other soil-forming factors were not explicitly mapped for various reasons. The action of organisms was not mapped separately because vegetative association is already closely correlated with bedrock type on the site and because vegetative land use (e.g., hay field or forest) only affects the surficial soil horizons, not the S.C.S. series designation. Climate (more precisely regarded as "micro-climate" at the site scale) was not mapped because on-site investigations showed no conclusive influence by slope orientation or any other comparable micro-climatic factor upon the soil profile and because S.C.S. series definitions do not note micro-climatic distinctions. Time, the final soil-forming factor, was considered only in the general recognition of areas likely to be subject to relatively recent colluvial or alluvial parent material deposition.

We then verified these theoretically assigned S.C.S. series designations and their boundaries on our site by pits and augur borings and by reference to that small portion of the site previously mapped by the S.C.S. in preliminary form.

As an example of the method: A site area which is mapped as a lower concave side slope or slope bottom of gradient less than fifteen percent and subject to colluvial deposition matches the published S.C.S. description of "Ernest silt loam" and was given that series designation on our map after on-site confirmation by pits or borings that the actual profile also matched that typical of the Ernest.

Assigning S.C.S. series designations to the soil-areas on our site map allowed us to use published data (e.g., regarding productivity and erodibility) issued by series name.

Vegetation

Using aerial photographs, extensive on-site observations, and quantitative sampling, we produced a "Vegetation" map (Slide 8). It distinguishes forested areas from cultivated fields and pastures and further divides the forests into two general vegetative associations, maple-beech-birch and upland oak.

The maple forest, in both successional and mature stages, is lush, closed, and rapidly growing. The oak in comparable stages is relatively drier, thornier, more open and slower growing.

The distribution of the oak, as opposed to the maple, forest appears to be most closely correlated with the site's sandstone parent material.

Climate

The site's regional climate is cool--6633 heating degree days annually--and wet--50 inches of precipitation annually (U.S. N.O.A.A., 1971). The prevailing winter wind comes from the west, and the prevailing summer wind from the southwest. The area is subject to daily fog and to occasionally heavy snow storms.

Significant micro-climatic variations are largely based upon the site's topography. Steep slopes of northern aspect receive considerably less solar heat energy than those of southern aspect (as evidenced in their greatly differing rates of winter snow melt). And cold air drainage causes earlier, later, and more frequent frosts in the valley than on the upper side slopes and tops of ridges.

The deciduous forest offers considerable diurnal and seasonal micro-climatic moderation. Areas of surface water and high groundwater table also might be expected to promote such moderation, but are so small in extent on the site that they are unlikely to have much impact.

Water Quality

We sampled stream water at ten stations within the site, measured its chemical quality in the student laboratory at the Academy of Natural Sciences, and recorded the results on maps of "Organic Water Quality" and "Inorganic Water Quality" (not included here).

Overall site water quality is good. The major sources of discernable pollution are agricultural fields and pastures (contributing nitrates) and several small coal shafts worked during the Depression of the 1930's and subsequently by local farmers, primarily for their personal use (contributing acidity).

Human Use

The area is now, and has always been since its settlement, devoted to farming, supplemented by timbering, maple sugaring, and mining.

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Of secondary agricultural value due to the relatively wide dispersement of flat tillable ridge tops and valley bottoms among steep and stony slopes, the area was largely by-passed in the initial American rush west for the flat and fertile prairies. Subsequently, the area was occupied by Scotch-Irish, and then by German, settlers. Now it serves primarily as a dairy production area for Pittsburgh.

There are few "Existing Structures" now on the site (map not included here). None of the houses and only two or three of the barns were built much prior to the twentieth century.

The more substantial barns and the roadway system, which often follows the only logical route around and up the steep valley walls, promised to be of most value in our design of the site community.

HUMAN NEEDS

Our second project inventory assessed the proposed population's demands for food, shelter, and water. According to the project assumptions, these needs determine the site's self-sustaining carrying capacity (with an additional land allowance added cover to all other material human needs not considered).

For calculation purposes we quantified these human needs as much as possible, arriving at a specified "standard of living," defined as the kind and amount of goods to be supplied annually to the population's "average" household. The greater this standard of living, the smaller the number of such households which can be supplied by the site's natural resources and the lower the site's self-sustaining carrying capacity.

Given the project goal of maximizing this carrying capacity, we attempted to minimize the standard of living while setting it high enough (according to the best available opinion) to maintain the population's physical well-being and capacity for participation in a full range of human pursuits.

Life in such a community designed for long-term self-sustenance at a minimal but sufficient material standard of

living would certainly differ from that of contemporary American society in general, but need not be dull or degrading, as indicated in this excerpt from Limits to Growth (p. 175):

> Population and capital are the only quantities that need be constant in the equilibrium state. Any human activity that does not require a large flow of irreplaceable resources or produce severe environmental degradation might continue to grow indefinitely. In particular, those pursuits that many people would list as the most desirable and satisfying activities of man--education, art, music, religion, basic scientific research, Athletics, and social interactions--could flourish.

As opposed to our current society which includes a few professional performing artists and many spectators who work to support them, the proposed community would likely include more individuals who both work in the fields to support themselves during the day and paint or sing at night.

Finally it should be remembered that our carrying capacity calculations were based on "low-flow" site productivity data for below average periods. At most times there would be a surplus of goods beyond those necessary to supply the population at the calculations' specified standard of living. These could go toward material support of any additional human activities desired by the population.

Our first step toward actually defining and quantifying the population's standard of living was to understand the character of the site's proposed population itself.

Population Character

We began by assuming that community members would be willing to limit their population to a stationary level at or below the site's self-sustaining carrying capacity, either due to voluntary choice (viewing the design as a contemporary lifestyle option) or due to their desire for survival (viewing the design as a possible future necessity for more of society during "hard-times"). For such a "stationary" population both the total number of people within the community and the number of people within any given age/sex class would remain constant.

We constructed the age/sex pyramid (figure 2) which would evolve and continue if a representative sample of contemporary Americans decided upon "stationary" population status (thus assuming the most current U.S. mortality rates obtainable--U.S. Dept. of H.E.W., Vital Statistics of the U.S.--1969).

Using this pyramid and two other assumptions (noted in figure 3) about the character of a site population composed of contemporary Americans we arrived at the community's "average" household of specified size and fully representative age/sex composition (also shown in figure 3). This "average" household served as a convenient population unit for use in all calculations leading to determination of the site's carrying capacity. (A variety of "household types" later evolved to replace the single mathematical abstraction of this "average" household for actual community design purposes.)

We then specified the "average" household's standard of living relative to the human needs for food, shelter, and water.

Food

We researched nutritional requirements for individuals by age/sex category and summed them for the "average" household (figure 4) according to its assumed age/sex composition.

In addition to requiring foods of this overall nutritional content, the household would require food storage facilities of several types: warm and dry, cool and dry, cool and moist, and frozen. (Exact spatial and energy requirements depend upon the technology chosen and will be described in the self-sustaining carrying capacity section below.)

Cooking for the "average" household would demand about 7 million Btus/year (Spielvogel, February 1975).

Shelter

We defined the shelter need in terms of spatial and energy requirements. First we estimated the areas of land coverage per "average" household for built human shelter:

POPULATION'S ASSUMED AGE/SEX COMPOSITION

(Source: * "Stationary" Population Projection. U.S. Dept. of H.E.W. Vital Statistics of the U.S. - 1969 Vol.II Part.A Sect.5) * Assumes constant number within any given age/sex class

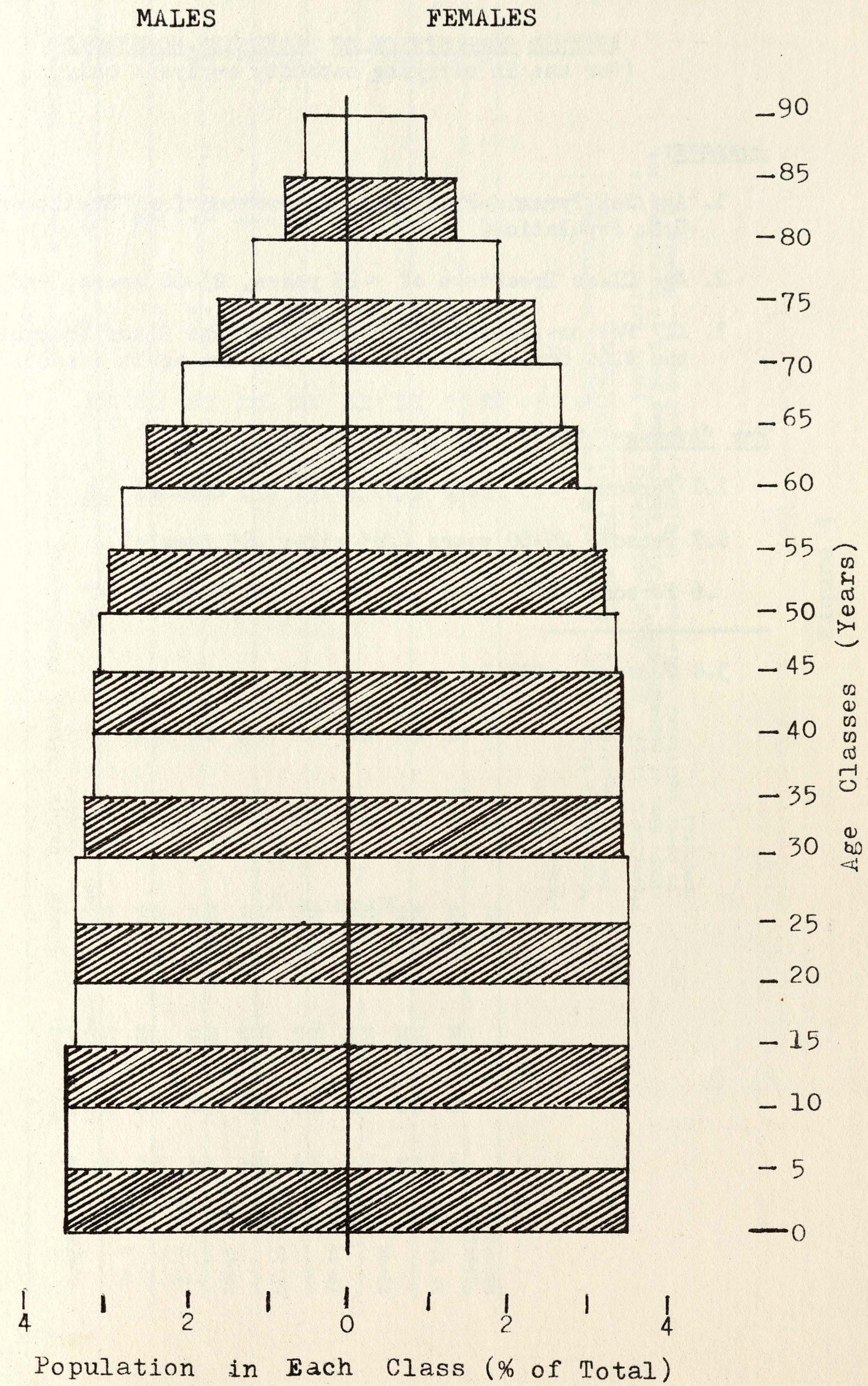


Figure 2

ASSUMED COMPOSITION OF "AVERAGE" HOUSEHOLD
(for use in carrying capacity analysis only)

Assumes:

1. Age/Sex Pyramid Previously Determined for "Stationary" U.S. Population.
2. Age Class Breakdown of <25 years, 25-60 years, and >60 years.
3. 1.7 Persons/Household in the 25-60 Age Class (because now in the U.S. 86% of all families have two adult heads).

Per "Average" Household:

1.1 Persons <25 years (.55 male; .55 female)
1.7 Persons 25-60 years (.85 male; .85 female)
.6 Persons >60 years (.23 male; .37 female)

3.4 Persons TOTAL

Figure 3

NUTRITIONAL REQUIREMENTS FOR INDIVIDUALS AND FOR "AVERAGE" HOUSEHOLD (per day)

Age/Sex Class		*Avg. Ht. (Inc.)	*Avg. Wt. (Lbs.)	*Energy (Calories)	**Usable Protein (gm.)	*Vitamin A	*Ascorbic Acid (gm.)	*Calcium (gm.)	*Iron (mg.)	*Thiamine (mg.)	*Riboflavin (mg.)	*Niacin Equivalent (mg.)	*Cobalamin (μg.)
0- 5 Years	M	33	26	1300	8	2000	40	0.6	15	0.6	0.6	10	2.0
	F	33	26	1300	8	2000	40	0.6	15	0.6	0.6	10	2.0
5-10 Years	M	48	51	2000	15	3500	40	0.9	10	1.0	1.1	14	4.0
	F	48	51	2000	15	3500	40	0.9	10	1.0	1.1	14	4.0
10-15 Years	M	57	86	2600	24	4800	43	1.3	14	1.4	1.4	21	5.0
	F	59	87	2300	25	5000	43	1.3	18	1.2	1.4	17	5.0
15-20 Years	M	68	138	2900	39	5000	57	1.1	14	1.4	1.6	25	5.0
	F	63	119	2300	34	5000	55	0.8	18	1.0	1.5	16	5.0
20-35 Years	M	69	154	2800	44	5000	60	0.8	10	1.4	1.7	21	5.0
	F	64	128	2000	36	5000	55	0.8	10	0.9	1.5	17	6.0
35-55 Years	M	68	154	2600	44	5000	60	0.8	10	1.3	1.7	19	5.0
	F	63	128	1850	36	5000	55	0.8	10	0.9	1.5	17	6.0
55 Years+	M	67	154	2400	44	5000	60	0.8	10	1.2	1.7	18	6.0
	F	62	128	1700	36	5000	55	0.8	10	0.9	1.5	17	6.0
"Average" Household				7387	111	16062	185	2.8	38	3.7	5.1	63	17.8

SOURCES:

*Generalized from: Natural Academy of Sciences--National Research Council, Food and Nutrition Board. Recommended Dietary Allowances. (Rev. 1968.)

**Francis M. Lappé. Diet for a Small Planet. New York: Ballantine, 1971. (Rep. Avg. of NAS-NRC, U.N.'s F.A.O. and Canadian Board of Nutrition + 30% to cover individual variances.) (= 0.28 g./lb. of body wt. "usable" protein)

Figure 4

Dwelling.........1200 sq. ft. (but may be several stories)
Workshed.........150 sq. ft.
Fenced "yard" (for children and pets).......... 1600 sq. ft.
Community Facilities.........15 sq. ft.
Roadways (assuming existing road system as a skeleton, 20 ft.-wide paving for major roads, and two 2-1/2 ft.-wide paving strips for minor roads).........700 sq. ft.

(Additional built shelter areas for animal housing, equipment and animal feed storage, and energy generation and storage were calculated later after determination of the appropriate technology and are included under Self-Sustaining Carrying Capacity below.)

We then quantified the energy component of the "average" household's shelter need. The largest single requirement is that for space heating. This was estimated at 10,000 Btus/degree day/year assuming average residential heat loss values (Shelton, February 17, 1975) or 66,330,000 Btus/year on our site. Careful design of the built shelter (as described in the Appropriate Technology section below) can avoid any energy demand for space cooling on the site.

Further miscellaneous energy requirements related to the need for built shelter (e.g., for lighting and the operation of appliances) are considered in the Appropriate Technology and Self-Sustaining Carrying Capacity sections which follow.

Water

We estimated the "average" household's water demand assuming a number of specified water conservation devices (figure 5). Most important of these is the composting toilet (explained further under Appropriate Technology) which eliminates water transport of wastes and alone cuts the overall water demand by almost half.

WATER DEMAND
PER "AVERAGE" HOUSEHOLD

Item	Current U.S. Use Rate * ** (gal./day)	Assumed Use Rate (and why different from current U.S. rate) (gal./day)
Toilet	100	0 (composting toilet - no water-borne waste)
Lavatory	8	5 (pedal valves**)
Shower	80	56 (limiting flow valve***)
Laundry	35	15 (front loading washer**)
Utility sink	5	5
Kitchen	27	20 (pedal valves**)
TOTALS	255	101

Sources:

*Pennsylvania State University. Water Conservation and Wasteflow Reduction in the Home. ("Special Circular 184") University Park, n.d.

**Tom Bender. University of Minnesota. Living Lightly: Energy Conservation in Housing. October, 1973.

***James F. Bailey, et al. A Study of Flow Reduction and Treatment of Waste Water from Households. Federal Water Quality Administration. December, 1969.

Figure 5

APPROPRIATE TECHNOLOGY

Our third project inventory resulted in specification of the technology most appropriate for utilizing local resources (surveyed in our first inventory of the Site's Natural Features) to meet each of the proposed population's human needs (assessed in our second inventory).

We based each such choice of technology upon: (1) results of the Site's Natural Features and Human Needs inventories, (2) the project's guiding principles, which emphasize use of local resources, use of renewable resources, and conservation and recycling of non-renewable resources (as discussed in the Introduction's section on Project Definition), and (3) within the limits of the above general criteria -- efficiency, in accord with the project goal of maximizing the population supportable by local resources, and durability, in accord with the project goal of the population's long-term support (also discussed in the Introduction's Project Definition section).

Most of the resulting choices fall within that category often termed "intermediate" technology. These choices do not constitute a full reversion to the eighteenth or nineteenth centuries, although they are in some cases reminiscent of the agricultural technology of these and even earlier periods, from which much can be learned about self-sustenance. Frequently they consist of very traditional devices recently improved (e.g., modern windmills which, due to the contributions of aerodynamic engineering, operate at efficiencies many times those of their older counterparts).

The technology assumed in carrying capacity calculations and in community design is discussed below for each of the previously established human need categories of food, shelter, and water.

Food

Foods differ greatly in the efficiency with which they utilize land resources in providing calories, protein, and nutrients for human use. For example, plants are significantly

more efficient than livestock in terms of protein produced per acre: cereals are five times more efficient, legumes are ten times more efficient, leafy vegetables are fifteen times more efficient, and spinach is twenty-six times more efficient (Lappé, p. 10). There is even a considerable variation in protein-production efficiency among livestock types:

	Pounds of Protein Fed to Yield One Pound of Protein for Human Consumption
Beef-Veal	21.4
Pork	8.3
Poultry	5.5
Milk	4.4
Eggs	4.3

(Lappé, p. 11).

Because of such differing food efficiencies, we needed to specify a diet for our "average" household, its standard of living with respect to food, for use in the carrying capacity calculations.

This diet (shown in figure 6) was designed to satisfy all of the caloric, protein, and nutrient needs outlined previously in the Human Needs section (figure 4), while emphasizing plant sources over animal sources and more efficient animal sources over less efficient ones (in the interests of maximizing per acre food production and therefore the site's carrying capacity). The animal sources were included because the necessary nutrient cobalamin, as well as trace elements not yet fully understood as to need or supply, is almost exclusively limited to such sources (Lappé, p. 55). Milk was also included as by far the most plentiful source of the required calcium.

The quantitative diet was necessitated by demand for reasonable and specific input to the carrying capacity calculations. It could be varied extensively by community members within the overall nutritional and acreage requirements (discussed in the Self-Sustaining Carrying Capacity report section below). Similarly, the diet represents a "low-flow" input to

ASSUMED DIET FOR "AVERAGE" HOUSEHOLD
(per year)

Food Sources Assumed	Energy (Calories)	"Usable" Protein (gm.)	Vitamin A (I.U.)	Ascorbic Acid (mg.)	Calcium (gm.)	Iron (mg.)	Thiamine (mg.)	Riboflavin (mg.)	Niacin Equivalent (mg.)	Cobalamin (µg.)
Total Required	2696073*	40612**	5862484*	67386*	1015*	13713*	1331*	1865*	23141*	6485*
Total Supplied	2696073***	75178**	14215610***	68160***	1022***	23117***	2428***	2255***	31273***	7170****
Maple Sugar 39.6 kg.	137813	--	--	--	57	554	--	--	--	--
Cabbage 31.3 kg.	5936	313	40443	14622	16	125	15	15	132	
Spinach 31.3 kg.	7194	467	2533680	8758	30	689	22	44	263	
Asparagus 10.0 kg.	2040	184	11800	2652	3	61	16	19	196	
Green peas 20.7 kg.	8912	622	126514	2904	12	104	46	23	667	
Green beans 20.7 kg.	5185	415	111996	2489	12	124	14	19	145	
Lettuce 20.7 kg.	2904	207	201178	1659	8	415	13	13	87	
Lima beans 19.4 kg.	21606	1947	--	3280	10	525	35	20	353	
Summer squash 17.7 kg.	2475	177	6895	1768	5	71	9	14	198	
Winter squash 17.7 kg.	11138	265	742560	2298	5	141	9	23	173	
Sweet Corn 35.4 kg.	29349	1061	141440	248	2	213	39	36	694	
Carrots 25.5 kg.	10710	255	2805000	2040	10	179	15	13	214	
Tomatoes 93.2 kg.	19564	47	838440	15837	13	466	47	28	913	
White potatoes 48.0 kg.	44663	576	--	9605	5	337	48	20	1008	
Oats 33.3 kg.	129817	3328	--	--	18	1498	200	47	599	100
Barley 12.4 kg.	43187	827	--	--	5	335	26	6	692	
Whole Wheat Flour 149.0 kg.	496244	12419	--	--	62	4917	815	179	11533	298
Soy Flour 81.0 kg.	319234	15748	6208	--	162	5850	629	229	3062	162
Rye Flour 12.5 kg.	40744	1885	--	--	7	561	76	28	563	
Milk 367.8 kg.	243451	1441	76340	--	430	22	111	625	3604	2427
Butter 75.3 kg.	547462	--	3490312	--	16	--	--	--	--	2733
Chicken meat 41.4 kg.	120060	6210	39744	--	5	787	29	91	5813	167
Chicken eggs 214.3 kg.	446385	26784	3043060	--	129	5143	214	763	364	1283

SOURCES:
*Nat. Acad. Sci. - Nat. Res. Council Food & Nutrition Board. Recommended Dietary Allowances (rev. 1968)
**F. M. Lappe'. Diet For A Small Planet. NY: Ballantine, 1967.
***U.S.D.A. AG. Res. Service. Composition of Foods. ("AG. Handbook. No. 8") Washington: GPO (rev. 1963).
****R. W. Vilter. "Vitamin B_{12}," Modern Nutrition in Health and Disease, ed. M. G. Wohl & R. S. Goodhart. Phila.: Lea & Febiger, 1968.

Figure 6

the carrying capacity analysis, meant to guarantee that at least enough food production land would be set aside to insure a minimal but adequate diet. Many additional food sources would likely be available to the population.

Fruit trees, nut trees, and vines, which can overlap other food production areas such as permanent pastures or shade-tolerant row crops, could provide additional fruits, ciders, and wines according to the individual desires of community residents. Fish, fowl, game, and wild fruits and nuts could likewise add quantity and seasonal variety.

Food production would depend upon the recycling of human and animal wastes to the soil upon which their food was grown, in proportion to the nutrients withdrawn from each land area. Human wastes would be collected and composted by the Clivus Multrum (illustrated in figure 7) for annual distribution.

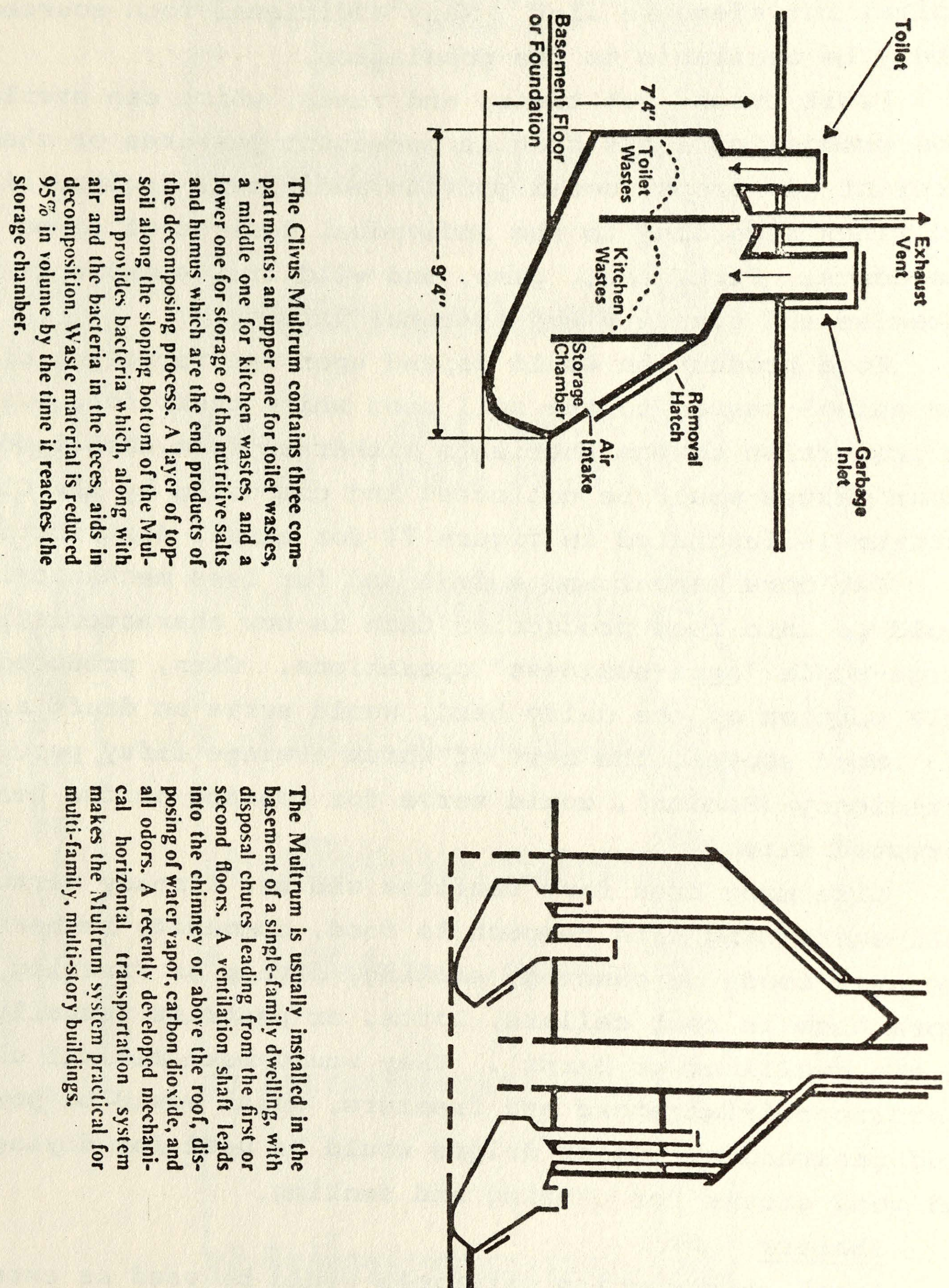
Far more manual and animal and far less mechanical labor would go into food production than is now characteristic of large-scale "agri-business" operations. Oxen, produced as the male portion of the dairy herd, would serve as draft animals.

Wood stoves, the best of which average fifty percent in efficiency (Bender), could serve for cooking on the heavily forested site.

Like many area farm families who are already virtually self-sustaining with respect to food, community members could preserve foods by canning, smoking, drying or freezing and could store them in root cellars, lofts, or pantries (usually included within dwellings or barns). They would make minimal use of electric refrigerators and freezers, which would be powered by wind generators. Solar driers would be used for drying foods and wood stoves for canning and smoking.

Shelter

Local construction materials would be used as extensively as possible to facilitate long-term maintenance and repair.



SOURCE: CLIVUS MULTRUM USA, 14A ELIOT STPEET, CAMBRIDGE, MASS. 02138

Figure 7

The site's sandstone, commonly found in the hand-laid foundations of older buildings, could be used for walls, its shale could be crushed for roadway surfacing, and its oak and maple timber could be cut for beams and roofing.

Among the local resources available for space heating, solar energy, which is the most rapidly renewable, would be the primary choice, supplemented as necessary by the more slowly renewable cord wood. Coal, as a non-renewable resource, would be unreliable on the long-term basis specified in the project goals.

Such solar space heating would function by architectural means such as careful siting and orientation (e.g., moderately sloping southern orientations rather than steeply sloping northern ones), proper choice and placement of materials with respect to their thermal properties (e.g., glass to admit light and stone to store heat on the south, bermed earth to insulate against heat loss on the north), and manually moveable elements (e.g., reflective shutters to hold in heat at night and to reflect light on summer days). More complex mechanical systems of solar space heating (e.g., those relying on forced air or pumped water) would be avoided due to their increased maintenance demands and greater energy consumption.

Comparison with our solar space heating prototype (England's St. George School) with respect to such factors as heating degree days and insolation suggested that solar energy could supply approximately eighty percent of the heating demand for site shelters built according to the above criteria.

Wood-burning stoves, the best of which average fifty-percent in efficiency as opposed to only eight percent for most open fireplaces, would meet the remaining twenty percent of the space heating requirement.

Space cooling would depend upon maximizing natural ventilation (by carefully orienting openings to take advantage of prevailing summer breezes) and upon minimizing summer heat gains (by using reflective surfaces, overhangs, and deciduous vegetative species).

Our built shelter prototypes, designed according to all of the above space heating and cooling criteria for three slope conditions, "optimum," "good," and "possible," appear in figures 8-10.

Further miscellaneous energy demands related to the provision of shelter (e.g., for lighting, appliances, communications equipment) would be met by wind and water sources, which are more appropriate than wood or solar sources for the generation of electricity.

Water

Water would be supplied by springs and shallow wells (now most common among site residents), by deeper wells drilled into the sandstone beds, and by cisterns collecting the plentiful precipitation.

Wind energy would be used to pump and distribute the water, and solar energy would be used for heating it.

The technology of water consumption would be that specified in the Human Needs Inventory's assessment of water demand (figure 5), including the Clivus Multrum (figure 7), which is the major means of water conservation.

II.A. DESIGN INPUTS:

SELF-SUSTAINING CARRYING CAPACITY

The first major community design input to result from the three project inventories was determination of the site's self-sustaining carrying capacity.

The size of the population which any given land area can support varies inversely with the kind and amount of goods to be supplied annually to the population's "average" household (specified for our site's population above in the Human Needs section), directly with the land's productivity of raw materials (quantified above in the section on the Site's Natural Features and below in this section), and directly with the chosen technology's efficiency in utilizing these raw materials to supply

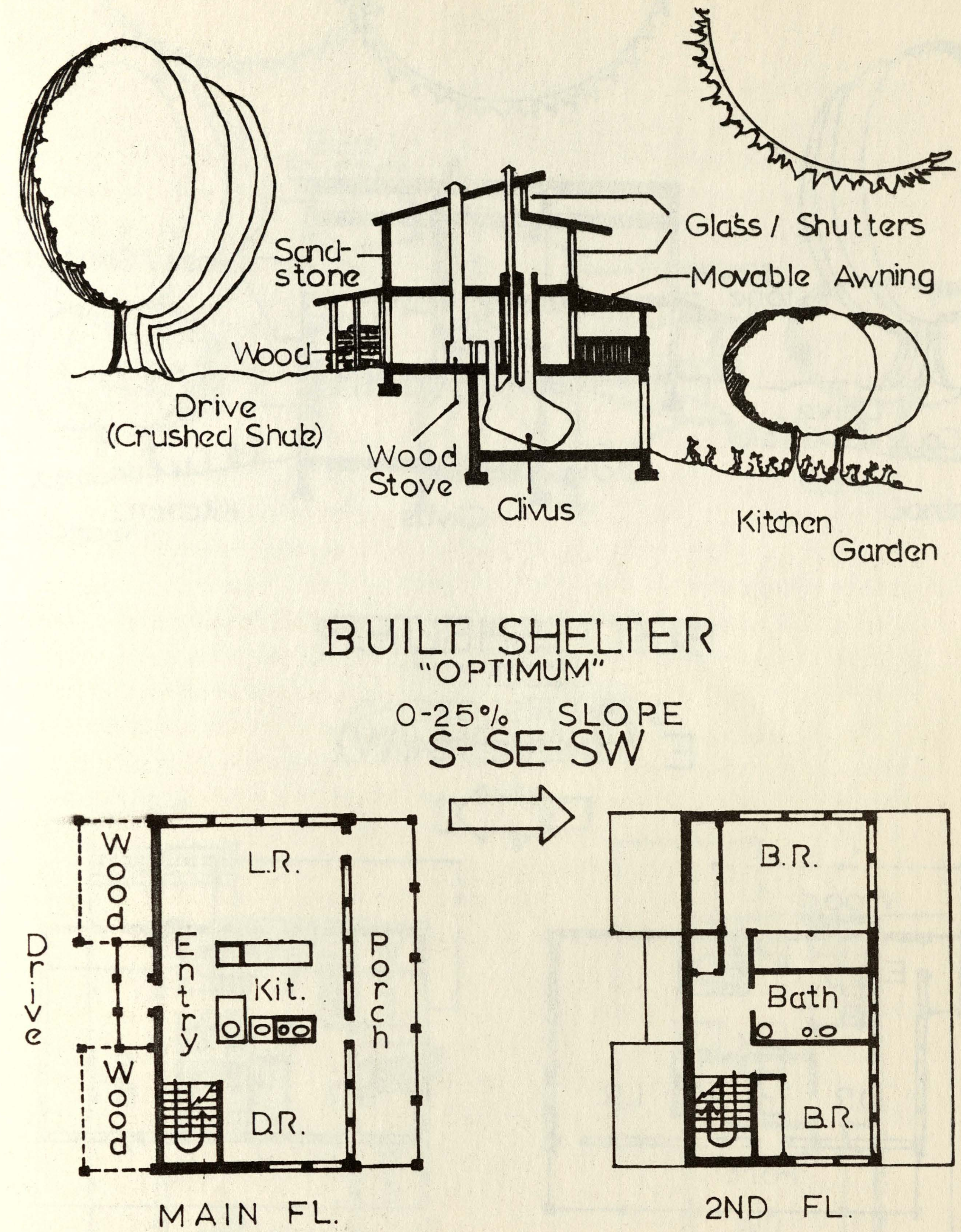


Figure 8

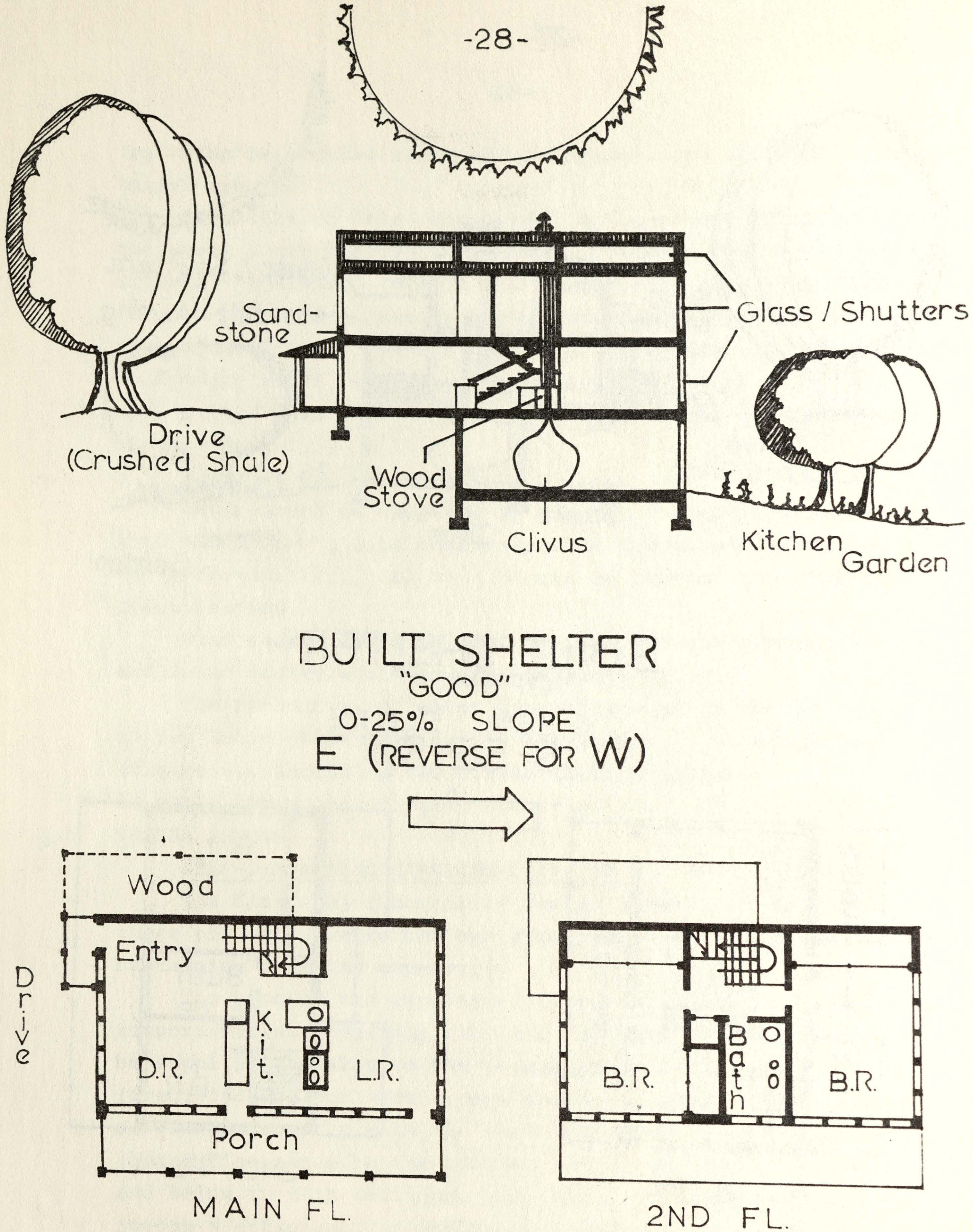


Figure 9

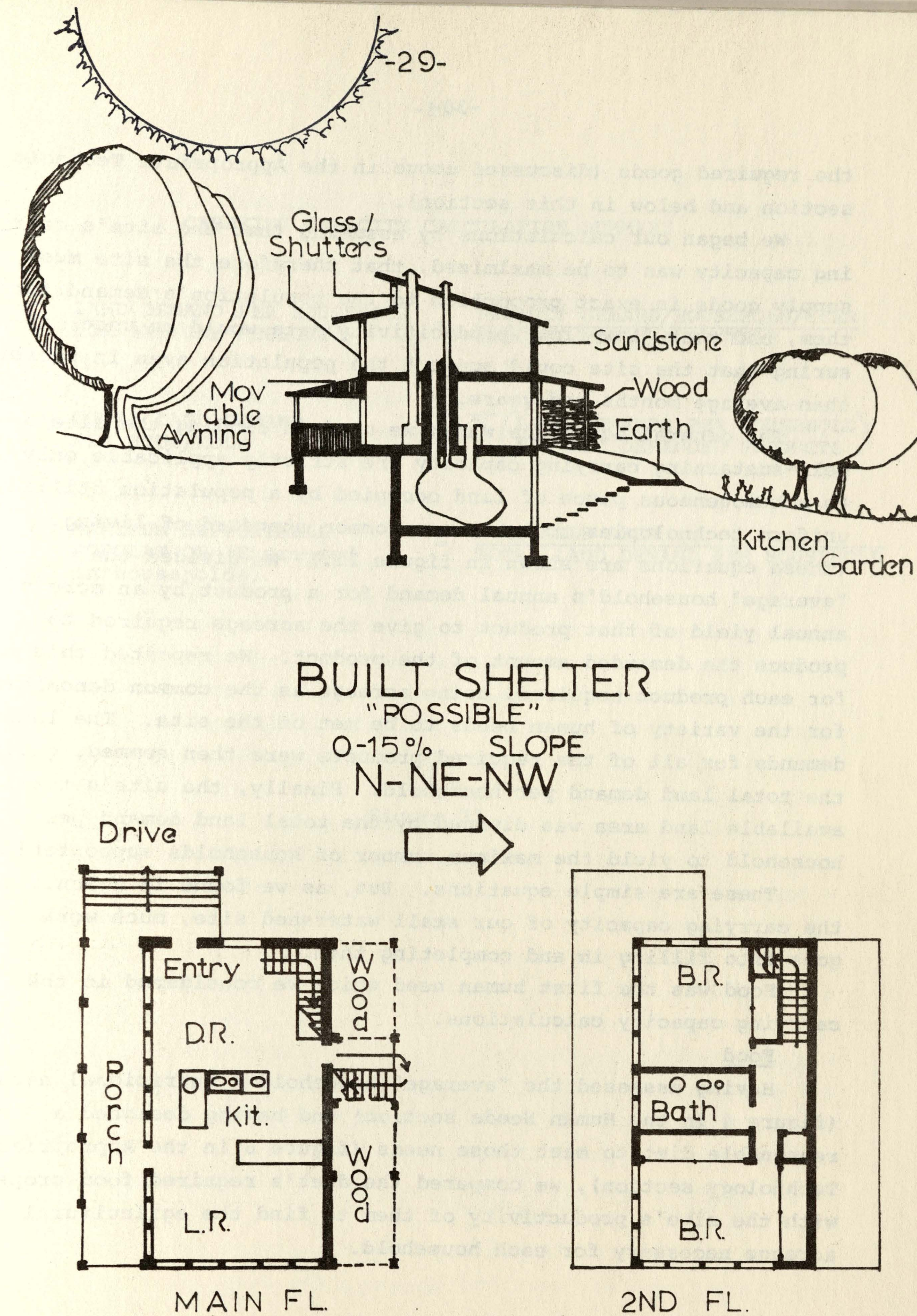


Figure 10

the required goods (discussed above in the Appropriate Technology section and below in this section).

We began our calculations by assuming that the site's carrying capacity was to be maximized, that therefore the site must supply goods in exact proportion to the population's demand for them, and that "low-flow" producitivity data would be used, insuring that the site could support the population even in poorer than average months and years.

The general equations which we used in finding the site's self-sustaining carrying capacity are strictly applicable only to a homogeneous piece of land occupied by a population utilizing uniform technologies to achieve a common standard of living. (These equations are shown in figure 11.) We divided the "average" household's annual demand for a product by an acre's annual yield of that product to give the acreage required to produce the demanded amount of the product. We repeated this for each product required, using acreage as the common denominator for the variety of human needs to be met on the site. The land demands for all of the required products were then summed, giving the total land demand per household. Finally, the site's total available land area was divided by the total land demand per household to yield the maximum number of households supportable.

These are simple equations. But, as we found in calculating the carrying capacity of our small watershed site, much work goes into filling in and completing them.

Food was the first human need which we considered in the carrying capacity calculations.

Food

Having assessed the "average" household's nutritional needs (figure 4 in the Human Needs section) and having designed a reasonable diet to meet those needs (figure 6 in the Appropriate Technology section), we compared the diet's required food crops with the site's productivity of them to find the agricultural acreage necessary for each household.

CARRYING CAPACITY CALCULATION SUMMARY

$$\text{LAND DEMAND PER HOUSEHOLD FOR ANY ONE PRODUCT} = \frac{\text{PRODUCT DEMAND/HOUSEHOLD/YEAR}}{\text{PRODUCT YIELD/ACRE/YEAR}}$$

$$\text{TOTAL LAND DEMAND PER HOUSEHOLD} = \sum\left(\text{LAND DEMANDS PER HOUSEHOLD FOR ALL DEMANDED PRODUCTS}\right)$$

$$\text{MAXIMUM SUPPORTABLE POPULATION (Expressed in households)} = \frac{\text{AVAILABLE AREA}}{\text{TOTAL LAND DEMAND PER HOUSEHOLD}}$$

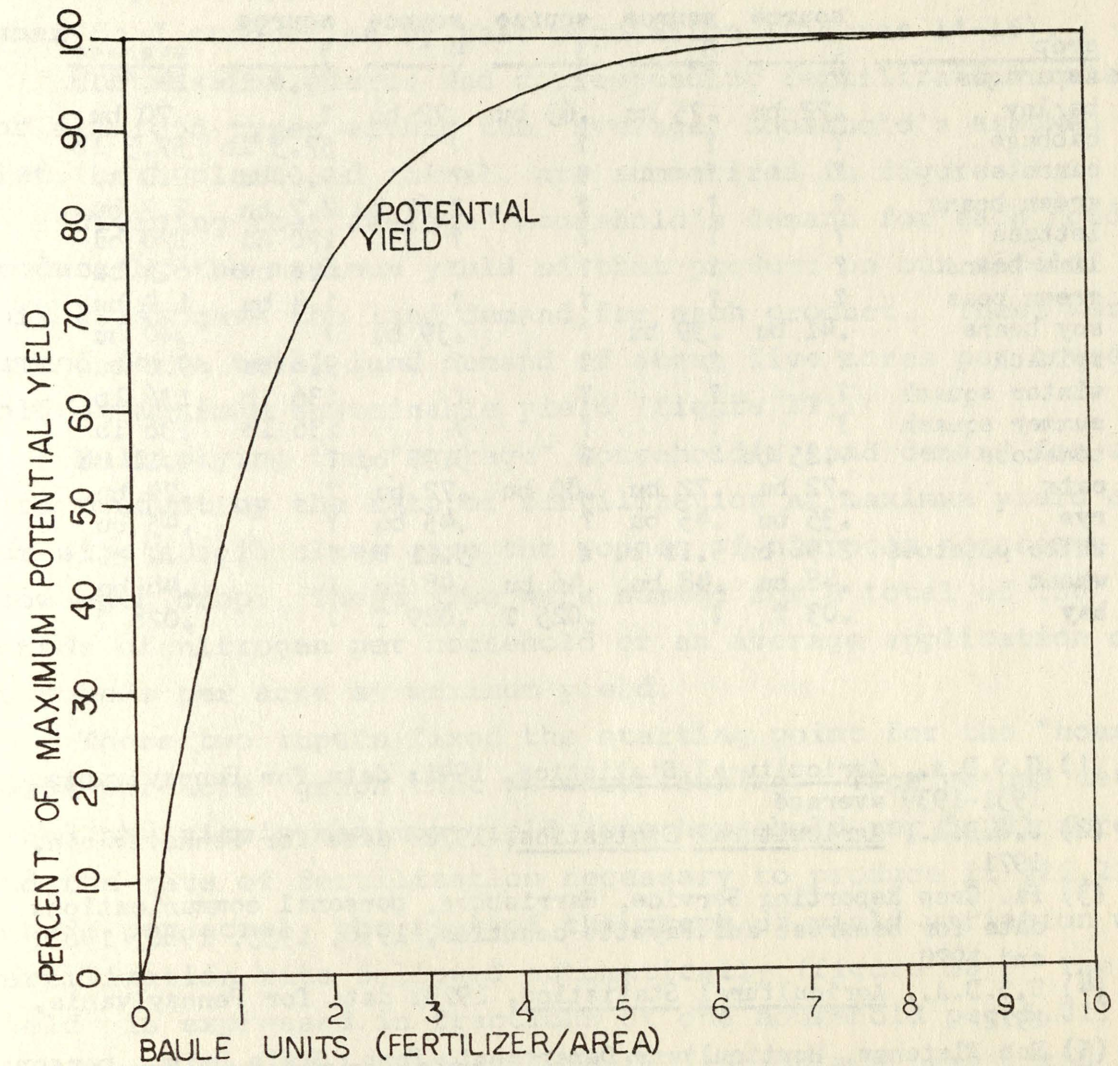
Figure 11

The average productivity of any food crop varies with the species, the soil type, and the fertilizer rate. Figure 12 shows a general graph relating the per acre yield of any crop to the per acre application of fertilizer (Tisdale & Nelson, 1966). One such graph can be drawn for each soil type and each crop species. The maximum potential yield is assigned a value of 100 percent and the quantity of fertilizer necessary to produce that yield is assigned a value of ten "Baule Units." The remainder of the graph can be drawn from this one known point by generating a logarithmic curve: the first Baule unit producing 50 percent of the maximum yield, the second producing 75 percent, the third producing 87.5 percent, and so on.

Since the size of the population supportable varies directly with the land's productivity of food crops, we could draw such a graph with human population as the "crop," with "yield" expressed in households per acre, and with applied fertilizer measured in some convenient unit such as pounds of nitrogen per acre per year. Once we have determined our site's maximum population yield and the amount of fertilizer required to produce it, the remainder of the graph could be generated automatically in the manner described above. Following is the determination of that point for our site's dominant soil capability class and for our "average" household's assumed diet of food crops.

The maximum sustainable yields on our site's dominant soil class (S.C.S. Capability Class 3) and the necessary fertilization rate for several grain crops, including corn, were available from Penn State (Hinish, February 27, 1965). Corresponding figures for the remaining required plant crops were found through establishing the yield ratios between these crops and corn (given the same general intensity of management) and then multiplying by the known yields of corn on our site's dominant soil class (figure 13).

Finally the yield and fertilization rates for animal products were found as functions of the plant crop quantities



POTENTIAL AGRICULTURAL YIELD PER FERTILIZATION RATE (1)

(1) TISDALE AND NELSON, FERTILITY AND FERTILIZERS, 1966

Figure 12

RATIOS OF CROP YIELDS TO CORN YIELDS
in bushels of corn

crop	source 1	source 2	source 3	source 4	source 5	average
asparagus	?	?	?	?	24.6 lb	24.6 lb
barley	.72 bu	.75 bu	.63 bu	.72 bu	?	.70 bu
cabbage	?	?	?	?	57.3 lb	57.3 lb
carrots	?	?	?	?	9.0 bu	9.0 bu
green beans	?	?	?	2.67 bu	2.7 bu	2.7 bu
lettuce	?	?	?	?	170 hd	170 hd
lima beans	?	?	?	?	6.1 bu	6.1 bu
green peas	?	?	?	?	1.4 bu	1.4 bu
soy beans	.41 bu	.39 bu	?	.39 bu	?	.40 bu
spinach	?	?	?	?	9.6 bu	9.6 bu
winter squash	?	?	?	?	136 lb	136 lb
summer squash	?	?	?	?	136 lb	136 lb
tomatoes	4.25 bu	?	?	3.97 bu	?	4.11 bu
oats	.72 bu	.72 bu	.80 bu	.72 bu	?	.74 bu
rye	.35 bu	.45 bu	?	.45 bu	?	.45 bu
white potatoes	2.98 bu	5.11 bu	?	5.11 bu	?	4.4 bu
wheat	.48 bu	.48 bu	.46 bu	.48 bu	?	.48 bu
hay	.03 T	?	.025 T	.029 T	?	.028 T

(1) U.S.D.A., Agricultural Statistics, 1941: data for Pennsylvania, 1931-1939 average
(2) U.S.D.A., Agricultural Statistics, 1972: data for Pennsylvania, 1971
(3) Pa. Crop Reporting Service, Harrisburg, personal communication: data for Somerset and Fayette counties, 1950, 1955, 1960, 1965, and 1970
(4) U.S.D.A., Agricultural Statistics, 1973: data for Pennsylvania, 1972
(5) Bob Fletcher, Horticulture Department, Penn. State Univ., personal communication, Feb. 28, 1975: data for U.S., 1970

Figure 13

necessary to support the animal population and the rate of human food production by that population (figures 14-16).

The maximum yields and corresponding fertilization rates for all food types within the "average" household's assumed diet, both plant and animal, are summarized in figure 17.

Dividing the "average" household's demand for each food product by the maximum yield of that product on our site's soil class gave the land demand for each product. These were summed for a total land demand of about five acres per household at maximum sustainable yield (figure 17).

Multiplying the "average" household's land demand for each food product by the rate of fertilization at maximum yield on our site's soil class gave the pounds of nitrogen necessary to grow each crop. These also were summed for a total of 130 pounds of nitrogen per household or an average application of 26 pounds per acre at maximum yield.

These two inputs fixed the starting point for the "households-per-acre" graph that we were seeking. Once we had determined the site's maximum yield (one household per 5.021 acres) and the rate of fertilization necessary to produce it (26.22 pounds per acre), the rest of the graph of yield variation with fertilization rate followed automatically (figure 18). The yield is expressed in fractions of one household per 5.021 acres, and the Baule units of fertilization are translated into tenths of 26.22 pounds of nitrogen per acre.

Which point on this curve would be the actual yield for our site community remained to be determined as a function of how much fertilizer could be applied. As noted above in the Appropriate Technology section, the sole source of fertilization would be the recycling of human and animal wastes to the soil upon which their food was grown, in proportion to the nutrients withdrawn from each land area. Figure 19 shows the resulting total quantity (22.2 pounds) of nitrogen produced and returned to the soil by the "average" household. This quantity is shown

EGG PRODUCTION RATE (MAXIMUM)

Feed Demand

col. 1 bird type	col. 2 birds per population unit	col. 3 corn demand per year per bird	col. 4 total corn demand per year (col. 2Xcol. 3)	col. 5 oat demand per year per bird	col. 6 total oat demand per year (col. 1Xcol. 4)
layer	100	.7 bu	70 bu	2.3 bu	230 bu
chick	100	.07 bu	7 bu	.42 bu	42 bu
total			77 bu		272 bu

Acreage and Fertilizer Demands

col. 1 feed crop	col. 2 nitrogen per acre at max. yield (1)	col. 3 maximum per acre yield (1)	col. 4 total demand per year	col. 5 acres per population unit at maximum yield (col. 4/col. 3)	col. 6 total nitrogen (col. 2Xcol. 5)
corn	120 lb	100 bu	77 bu	.77 ac	92.4 lb
oats	30 lb	60 bu	272 bu	4.53 ac	135.9 lb
total				5.30 ac	228.3 lb

Production Rate

Egg Production = (232 eggs/layer/year)X(100 layers/population unit)
= 23200 eggs/year/population unit

Maximum Egg Yield = (23200 eggs/year/pop'n unit)X(5.30 ac/pop'n unit)
= 4377 eggs/ac/year

Net Nitrogen at Maximum Yield = (228.3 lb)/(5.30 ac)
= 43.1 lb/ac

Manure Production

Nitrogen Production = (1.12 Tons manure/200 birds)X(29.9 lb N/Ton)
= 33.5 lb/population unit/year

(1) Wayne Hinisch, Agronomy Extenshion, University Park, Pa., personal communication, Feb. 27, 1975; and crop ratio table

Figure 14

CHICKEN MEAT PRODUCTION RATE (MAXIMUM)

Production

Pounds per Bird = (3 lb/bird at maturity) X (5.2 maturities/year)
= 15.6 lb/bird/year

Total pounds = (100 birds/population unit) X (15.6 lb/bird/year)
= 1560 lb meat/population unit/year

Feed Demand

Corn Demand = (.02 bu corn/lb meat) X (1560 lb meat/year)
= 31 bu/year/population unit

Oat Demand = (.08 bu oats/lb meat) X (1560 lb meat/year)
= 125 bu/year/population unit

Acreage and Fertilizer Demands

col. 1 feed crop	col. 2 nitrogen per acre at maximum yield (1)	col. 3 maximum per acre yield (1)	col. 4 total demand per year	col. 5 acres per population unit at maximum yield (col. 4/col. 3)	col. 6 total nitrogen (col. 2Xcol. 5)
corn	120 lb	100 bu	31 bu	.31 ac	37.2 lb
oats	30 lb	60 bu	125 bu	2.08 ac	62.4 lb
total				2.39 ac	99.6 lb

Production Rate

Maximum Meat Yield = (1560 lb/population unit) X (1 pop'n unit/2.39 ac)
= 653 lb meat/ac

Net Nitrogen at Maximum Yield = (99.6 lb)/(2/39 ac)
= 41.7 lb/ac

Manure Production

Nitrogen Production = (.56 Tons manure/100 birds) X (29.9 lb N/Ton)
= 16.7 lb/population unit/year

(1) Wayne Hinisch, Agronomy Extension, University Park, Pa., personal communication, Feb. 27, 1975; and crop ratio table

Figure 15

MILK PRODUCTION RATE (MAXIMUM)

Production

Production = (8,000 lb/cow/yr) X (30 cows/population unit)
= 240,000 lb/population unit/yr

Feed Demand (1)

col. 1 cow type	col. 2 corn	col. 3 oats	col. 4 legume hay	col. 5 pasture
30 milkers	600 bu	1500 bu	90 tons	60 ac
1 bull, 2 steers	36 bu	87 bu	7.5 tons	6 ac
15 heifers	135 bu	315 bu	30 tons	30 ac
total	771 bu	1902 bu	127.5 tons	96 ac

Acreage and Fertilizer Demands

col. 1 feed crop	col. 2 nitrogen per acre at max. yield (1)	col. 3 maximum per acre yield (1)	col. 4 total demand per year	col. 5 acres per population unit at maximum yield (col. 4/col. 3)	col. 6 total nitrogen (col. 2Xcol. 5)
corn	120 lb	100 bu	771 bu	7.7 ac	924 lb
oats	30 lb	60 bu	1902 bu	31.7 ac	951 lb
hay	33 lb	2.8 T	127.5 T	45.5 ac	1501.5 lb
pasture	recycle	.5 cow	96 ac	96 ac	recycle
total				180.9 ac	3376.5 lb

Production Rate

Maximum Milk Yield = (240,000 lb/pop'n unit) X (1 pop'n unit/180.9 ac)
= 1327 lb/ac

Net Nitrogen at Maximum Yield = (3376.5 lb)/(180.9 ac)
= 18.7 lb/ac

Manure Production

col. 1 cow type	col. 2 body weight (1,000 lb)	col. 3 nitrogen per 1,000 lb (lb/yr)	col. 4 number of animals	col. 5 nitrogen per year (lb) (col. 2Xcol. 3Xcol. 4)
milker	1.3	151.2	30	5897
heifer	.6	151.2	15	1361
male	1.5	151.2	3	681
total				7939

(1) Wayne Hinisch, Agronomy Extension, University Park, Pa., personal communication, Feb. 27, 1975; and crop ratio table

Figure 16

AGRICULTURAL LAND DEMAND PER "AVERAGE" HOUSEHOLD (AT MAXIMUM YIELD)

Acreage and Fertilizer Demands

col. 1 food crop	col. 2 nitrogen per acre at max. yield (1)	col. 3 maximum per acre yield (1)	col. 4 total demand per year	col. 5 acres per household at maximum yield (col. 4/col. 3)	col. 6 total nitrogen (col. 2Xcol. 5)
cabbage	16 lb	41400 lb	70 lb	.00169 ac	.0270 lb
spinach	16 lb	774 bu	3.7 bu	.00478 ac	.0765 lb
asparagus	16 lb	7000 lb	23 lb	.00329 ac	.0526 lb
green peas	16 lb	272 bu	2.6 bu	.00956 ac	.1530 lb
green beans	16 lb	285 bu	1.7 bu	.00596 ac	.0954 lb
lettuce	16 lb	11000 head	55 head	.00500 ac	.0800 lb
shelled sweet corn	120 lb	31800 ear	347 ear	.01090 ac	1.308 lb
winter squash	16 lb	22500 lb	36 lb	.00160 ac	.0256 lb
summer squash	16 lb	18400 lb	36 lb	.00196 ac	.0314 lb
carrots	16 lb	620 bu	1.1 bu	.00177 ac	.0283 lb
tomatoes	16 lb	411 bu	5.9 bu	.01440 ac	.2304 lb
wheat	20 lb	40 bu	7.7 bu	.19300 ac	3.860 lb
milk	18.7 lb	1327 lb	4372 lb	3.222 ac	60.25 lb
soybeans	80 lb	30 bu	4.2 bu	.1400 ac	11.20 lb
white potatoes	16 lb	440 bu	1.8 bu	.00409 ac	.0654 lb
rye	16 lb	45 bu	.6 bu	.0133 ac	.2128 lb
chicken meat	41.7 lb	653 lb	92 lb	.1409 ac	5.876 lb
oats	30 lb	60 bu	2.3 bu	.0383 ac	1.149 lb
eggs	43 lb	4377 eggs	4464 e.	1.020 ac	43.86 lb
barley	16 lb	50 bu	.6 bu	.012 ac	.1920 lb
maple sugar	(from forest land..................................)				
lima beans	16 lb	610 bu	1.1 bu	.00180 ac	.0288 lb
total				5.021 ac	131.66 lb

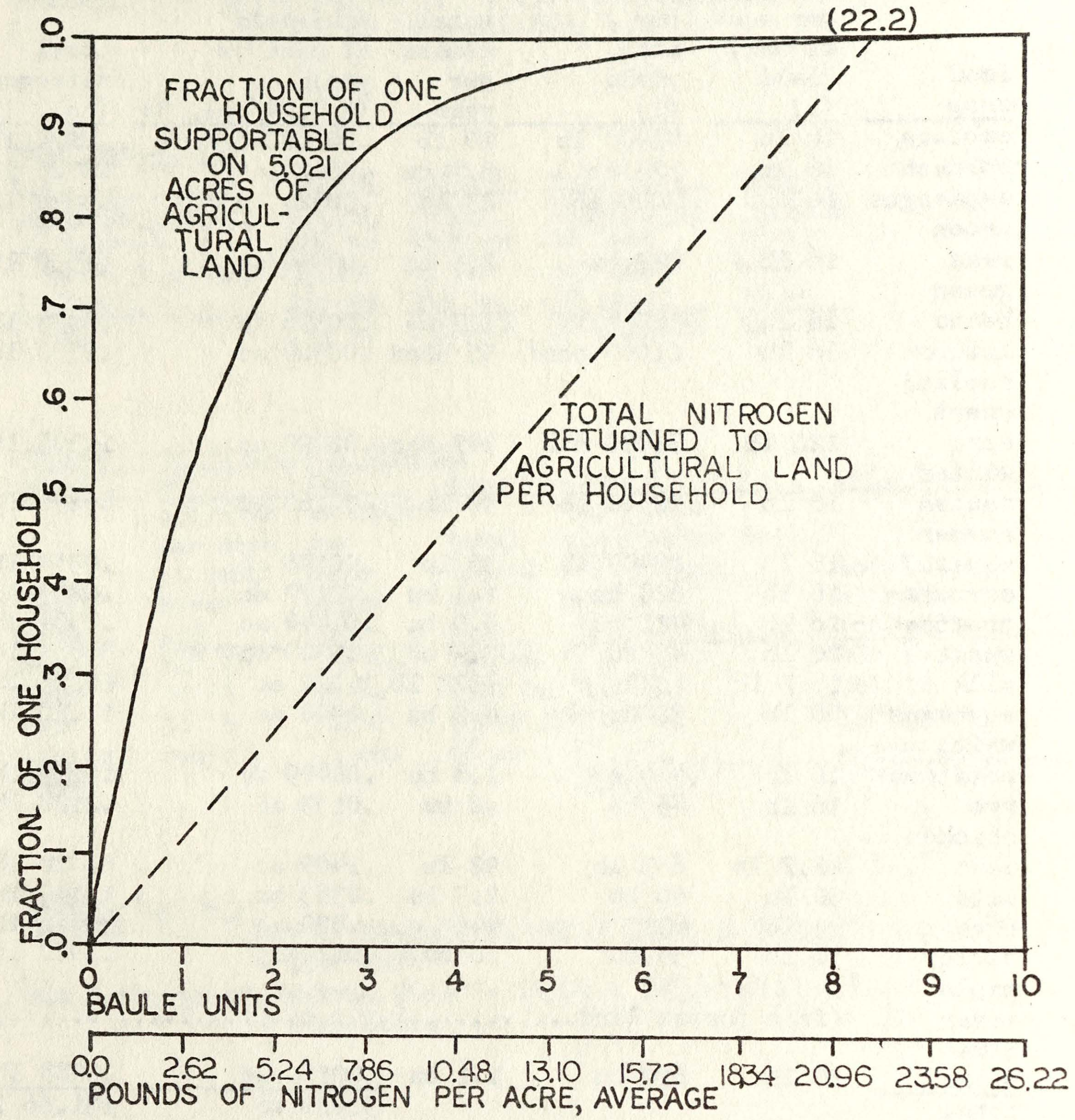
Production Rate

Minimum Agricultural Land Demand = 1 household/5.021 ac

Net Nitrogen at Minimum Demand = (131.7 lb)/(5.021 ac)
= 26.22 lb/ac

(1) Wayne Hinisch, Agronomy Extension, University Park, Pa., personal communication, Feb. 27, 1975; and crop ratio table

Figure 17



ACTUAL AGRICULTURAL LAND DEMAND PER AVERAGE HOUSEHOLD

Figure 18

NITROGEN RECYCLED PER "AVERAGE" HOUSEHOLD PER YEAR

col. 1 source	col. 2 food use per house	col. 3 food production per population unit	col. 4 nitrogen production per population unit	col. 5 nitrogen production per food production (col. 4/col. 3)	col. 6 nitrogen production per household (col. 5Xcol. 2)
dairy population	4372 lb	240,000 lb	7,939 lb	.033 lb/lb ÷2 for pasture loss = .0165	72.1 lb
broiler population	92 lb	1,560 lb	16.7 lb	.011 lb/lb	1.0 lb
layer population	4464 egg	23,200 egg	33.5 lb	.001 lb/lb	4.5 lb
human	(5.79 lb N/individual X 3.4 individuals........)				33.9 lb
					111.5 lb

Average Nitrogen Application = 111.5 lb/household
÷ 5.021 acres/household
= 22.2 lb/ac

Figure 19

on the yield graph (figure 18), at the top of the straight line representing nitrogen produced by fractions of an "average" household ranging from .0 to 1.0. This line intersects the supportable population curve nearly at the maximum yield, implying that the maximum sustainable yield could be achieved in our recycling system, and that 5.021 acres would be the actual agricultural land demand per "average" household.

As noted in the Human Needs section, the "average" household would require approximately 7 million Btus annually in cooking energy, to be supplied by a wood stove as specified in the Appropriate Technology section. This would easily be incorporated within that 20 percent of the "average" household's space heating demand (20% of 66,330,000 Btus = 13,266,000 Btus) also to be supplied by a wood stove. The consequent forest land demand for cord wood production is tallied below under the Shelter section's discussion of space heating.

Food storage areas, root cellars, lofts, and pantries, were assumed to have no specific land requirement of their own, but instead to be included within other built areas, such as dwellings and barns.

Shelter

The spatial component of the population's need for shelter was expressed in terms of the requirement for built land coverage, land therefore not productive of food or timber products. The land demand for built human shelter (dwelling, workshed, fenced yard, community facilities and roadways) as estimated in the Human Needs section totaled 3665 square feet for the "average" household. To this we added the built land required for animal housing, equipment, and feed storage (figure 20) and the built land required for timbering equipment and wood storage to arrive at a total of 3920 sq. ft. or .09 acre of built land coverage per "average" household (figure 21).

The second major component of the human need for built shelter, the requirement for space heating energy, was determined

BUILT LAND FOR ANIMALS

Built Land for Cattle per Household

Area for Milkers = 4372 lb milk/average household/yr
÷ 8,000 lb/milker/yr
= .55 milkers/household
X 130 sq ft/milker
= 71.5 sq ft/household

Area for Heifers = .55 milkers/household
X .5 heifer/milker
X 70 sq ft/heifer
= 19.3 sq ft/household

Total = 19.3 + 71.5 = 90.8 sq ft/household

Built Land for Poultry per Household

Area for Broilers = 92 lb chicken meat/household/yr
÷ 3.5 lb/broiler
X .192 yr lifetime/broiler
= 5.05 broilers/household standing crop
X 2. sq ft/broiler
= 10.1 sq ft/household

Area for Broiler Chicks = 5.05 chicks/household
X .8 sq ft/chick
= 4.04 sq ft/household

Are for Layers = 4464 eggs/household/yr
÷ 232 eggs/layer/yr
= 19.2 layers/household
X 2. sq ft/layer
= 38.4 sq ft/household

Areafor Layer Chicks = 19.2 chicks/household
X .8 sq ft/chick
= 15.4 sq ft/household

Total = 15.4 + 38.4 + 4.04 + 10.1 = 67.9 sq ft/household

Figure 20

BUILT LAND DEMAND PER "AVERAGE" HOUSEHOLD
(land not productive of food or timber)

Built Area Type	Location	Land Area Required (sq. ft.)
Dwelling	Household	1200
Workshed	Household	150
Chicken coop	Household	70
Wood storage (for 1 year)	Household	60
Windmill	Household	(overlaps other built areas)
Yard	Household	1600
Food and water storage	Household	(overlaps other built areas)
Dairy barn	Shared	90
Timber shed	Shared	35
Community facilities	Shared	15
Roadways (assuming 20 ft. exclusive use for major roads; 5 ft. for minor roads)	Shared	700
TOTAL		3920 (.09 acre)

Figure 21

in the Appropriate Technology section to consist of 80 percent solar energy plus 20 percent wood energy provided by stoves operating at an efficiency of 50 percent. The input to the carrying capacity calculations will therefore appear as a forest land demand for cord wood production.

We took quantitative samples within the existing forested areas of the site and found the average non-fertilized rate of energy storage for both the oak areas (figure 22) and maple areas (figure 23). The rate of energy storage was virtually the same for both of the site's major forest types and for a variety of slope positions and orientations. Combining this rate of wood energy storage with the "average" household's wood heat energy requirement at the stove's efficiency of 50 percent yielded a total forest land demand of 2.31 acres per "average" household (figure 24). This would easily absorb the land area required for production of the maple syrup (figure 25) included within the "average" household's assumed diet (figure 6).

Further miscellaneous energy demands related to the provision of built shelter (e.g., for lighting, appliances, communications equipment) would be met, as specified in the Appropriate Technology section, by water and wind sources.

We first considered energy generation by water. Water power is a function of the stream's discharge and the vertical distance through which the water falls. Since a stream falls at a certain gradient (at a specific rate relative to its horizontal movement), we could, given knowledge of this gradient and of the stream discharge (commonly represented as "Q"), map water power per 100 feet of horizontal flow (by the equation in figure 26).

The Stream Gradient for our site's Mose King Run was calculated and mapped (Slide 9) directly from the topographic map.

Low-flow stream discharge was then determined by correlating direct measurements with U.S.G.S. records. Such records

OAK FUEL YIELD

Site Index
Average Site Index = 75 (1,2,3)

Cordage Yield

col. 1 sampling station	col. 2 basal sq. ft. per acre (4)	col. 3 average dbh (in) (4)	col. 4 average age (yr) (5)	col. 5 cords per acre (5)	col. 6 average yield (cords/ac/year) (col. 5/col. 4)
11	94.4	9.3	60	32.0	0.5
12	70.5	6.6	40	19.5	0.5
13	72.5	5.1	30	14.0	0.5
average					0.5

Energy per Cord

col. 1 species	col. 2 BtuX10^6 per cord (6)	col. 3 BtuX10^6 per cord (7)	col. 4 BtuX10^6 per cord average
black and white oak	22.7	25.2	24.0
yellow birch	21.3	15.75	18.5
beech	(eliminated by cutting..)		
weighted average			22.0

Fuel Yield
Maximum Fuel Yield = 22,000,000 Btu/cord
X 0.5 cord/ac/yr
= 11,300,000 Btu/ac/yr

(1) Benjamin A. Roach and Samuel F. Gingrich, "Even-Aged Silviculture for Upland Central Hardwoods", Agri. Handbook 355, U.S.D.A., 1968
(2) Somerset County Interim Soil Survey Report, U.S.D.A., 1969
(3) Slope Shape Map
(4) on-site sample
(5) Martin E. Dale, "Growth and Yield Predictions for Upland Oak Stands", Forest Research Paper NE-241, U.S.D.A., 1972
(6) Tom Bender, "Living Lightly", U. of Minnesota, 1973
(7) Paul Kelsey, "Firewood and the Fuel Shortage", in The Conservationist, Apr/May, 1974

Figure 22

MAPLE FUEL YIELD

Growth per Tree

col. 1 species	col. 2 age (3)	col. 3 cu. ft. per tree (1)	col. 4 cu. ft./yr per tree (col. 3/col. 2)
sugar maple	30	6.0	0.2
black birch	80	14.2	0.17
yellow birch	40	4.1	0.1
beech	(eliminated by cutting...)		
weighted average			0.19

Cordage Yield
Cordage Yield = 0.19 cu.ft./yr/tree
X 350 trees/ac (2)
X .009 cord/cu. ft. (4)
= .61 cord/ac/yr

Energy per Cord

col. 1 species	col. 2 BtuX10^6 per cord (5)	col. 3 BtuX10^6 per cord (6)	col. 4 BtuX10^6 per cord average
sugar maple	21.3	16.8	19.1
black birch	21.3	18.6	20.0
yellow birch	21.3	15.75	18.5
beech	(eliminated by cutting...)		
weighted average			19.3

Fuel Yield
Maximum Fuel Yield = 19,300,000 Btu/cord
X 0.61 cord/ac/yr
=11,800,000 Btu/ac/yr

(1) Brian J. Turner, Board-Foot and Cubic-Foot Volume Tables for the Commercial Forest Species of Pa., Pa. State Univ., 1972
(2) on-site sample
(3) Silvics of Forest Trees of the U.S., Agri Handbook 271, U.S.D.A., 1965
(4) Martin Dale, Growth and Yield Predictions..., Forest Research Paper NE-241, U.S.D.A., 1972
(5) Tom Bender, "Living Lightly", U. of Minnesota, 1973
(6) Paul Kelsey, "Firewood and the Fuel Shortage", in The Conservationist, Apr-May, 1974

Figure 23

FOREST LAND DEMAND PER "AVERAGE" HOUSEHOLD

Heat Energy Demand
Total Gross Heat Demand = 10,000 Btu/degree day/household (1)
X 6,633 degree days/yr at Ebensburg, Pa. (2)
= 66,330,000 Btu/yr/household

Cooking Energy Demand
Gross Cooking Demand = 7,000,000 Btu/yr/household (3)

Cordwood Demand
Gross Cordwood Heat Demand = 100% - 80% heat from sun
= 20% of Total Gross Heat Demand
= 13,270,000 Btu/yr/household
(Gross Cordwood Heat Demand thus absorbs Gross Cooking Demand)
Net Cordwood Demand = 13,270,000 Btu/yr/household
X 50% wood stove efficiency (1)
= 26,540,000 Btu/yr/household

Acreage Demand
Forest Land Demand = 26,540,000 Btu/yr/household demand
/ 11,500,000 Btu/ac/yr yield
= 2.31 ac/household

(1) Dr. Jay Shelton, Physics Dept., Williams College, personal communication, Feb. 17, 1975
(2) N.O.A.A., "Climates of the States: Pennsylvania"
(3) Lawrence Spielvogel, Dept. of Architecture, University of Pennsylvania, personal communication, Feb., 1975

Figure 24

MAPLE FOREST LAND DEMAND

Yield = .33 gal syrup/tree (1)
X 20 trees/ac (2)
= 6.6 gal/ac
Land Demand = 11 gal/average household
÷ 6.6 gal/ac
= 1.67 ac/average household

(1) U.S.D.A., Agricultural Statistics, 1941
(2) Scott Nearing, The Maple Sugar Book

Figure 25

WATER POWER PER HORIZONTAL DISTANCE

$$\text{Horsepower}/100\text{ ft} = \frac{62.4 \times Q \times \text{head}}{33{,}000} / 100\text{ ft}$$

$$= \frac{62.4}{33{,}000} \times Q \times \frac{\text{head}}{100\text{ ft}}$$

$$= .00189 \times Q \times \text{stream gradient}$$

Figure 26

for a nearby gaging station established the ratios of the 50-year, 30-day low flow to the Mean Annual Flood (figure 27). Since we had previously established the Mean Annual Flood at several Mose King Run sampling stations while determining the site's Flood Hazard zone, each station's low flow could be found by simple multiplication (figure 28). A map of Stream Low Flow (Slide 10) then resulted from adding the flows at tributary junctions.

Overlaying the discharge (Slide 10) and gradient (Slide 9) maps and employing the previously noted equation (figure 26), we produced the site map of Gross Water Power (Slide 11).

It is readily apparent that the greatest concentration of water power lies in the ravine near the mouth of Mose King Run, where a large flow drops rapidly over the sandstone waterfalls. We therefore added up the full water power along this reach, as if a dam had been placed at the head of the ravine and a mill race extended over the length of the ravine. The total energy produced at low flow was only one-half of one horse power (figure 29). This implies that, while potentially of value for seasonal tasks at periods of higher flow, available water power at low flow would be small despite a large structural investment.

Wind was the other potential power source assessed for the site. Wind power is a function of the generator's propellor size and of the wind velocity cubed. We took a low monthly average wind speed from climatic records as the regional average low flow and found site variations from this average according to the likely interaction of the west-southwest wind with site topography (figure 30). We then mapped the site locations for above-average wind speeds at low flow (Slide 12).

Assuming 500 feet as the spacing between banks of windmills and defining "efficient" windmills as those located where wind speed is at or above the average, we laid out the site's maximum efficient windmill array and added up the total power

STREAM LOW FLOW AT LAUREL HILL CREEK AT URSINA (1)

30 Day Low Flows

Q (cfs)	Rank	RI	Q (cfs)	Rank
4.78	1	54	22.30	28
5.59	2	27	23.60	29
5.73	3	18	24.40	30
6.61	4	13.5	25.00	31
7.04	5		25.30	32
7.12	6		25.90	33
7.51	7		27.50	34
7.61	8		29.50	35
9.16	9		32.60	36
9.66	10		32.90	37
9.90	11		33.10	38
10.00	12		33.70	39
10.60	13		34.40	40
10.90	14		34.70	41
11.50	15		35.20	42
11.90	16		35.40	43
12.00	17		36.50	44
12.20	18		40.80	45
14.60	19		41.10	46
14.70	20		42.70	47
17.10	21		44.90	48
18.70	22		47.60	49
19.90	23		52.40	50
20.00	24		52.40	51
21.00	25		53.90	52
21.40	26		59.90	53
21.90	27			

$$RI = \frac{\text{Years of Record} + 1}{\text{Rank}} = \frac{54}{\text{Rank}}$$

50 Year Low Flow = 4.80 cfs
Mean Annual Flood = 5393. cfs
Ratio to Mean Annual Flood = .00089

(1) unpublished tabulation, U.S.G.S, Pittsburgh

Figure 27

STREAM LOW FLOW AT SAMPLING STATIONS

30 Day, 50 Year Low Flow = .00089 X Mean Annual Flood

sampling station	mean annual flood (1)	low flow
upper tributary	52 cfs	.05 cfs
middle tributary	63 cfs	.06 cfs
lower tributary	54 cfs	.05 cfs
headwater	73 cfs	.06 cfs
main between middle and upper tributaries	170 cfs	.15 cfs
main between middle and lower tributaries	240 cfs	.21 cfs
main between mouth and lower tributary	310 cfs	.28 cfs

(1) U.S.G.S., Flood Frequency, Ohio River Basin

Figure 28

TOTAL GROSS WATER POWER AT RAVINE
at 30 day, 50 year at low flow

col. 1 length (feet)	col. 2 horsepower per 100 feet	col. 3 horsepower (col. 1Xcol. 2)
700	.029	.203
670	.012	.080
450	.029	.130
250	.050	.125
total		.538

Figure 29

ABOVE AVERAGE WIND SPEEDS

Potential Miles per Hour Above Mean Monthly Wind Speed

relative elevation	head of WSW-facing bowl	top of NNW-SSE ridge	top of other ridge	plateau or terrace	other topography
high	3	2	1	1	<0
average	2	1	0	0	<0

All wind speeds are less if any trees, houses, windmills, or other obstructions are within 500 feet in any direction.

Figure 30

available from that array (figure 31). The total is as much as one thousand times the water power available in the ravine at stream low flow (depending upon the assumed propellor radius). Because of this potentially high performance, even at low flow, and because wind power is ubiquitous, we assumed wind-generated electricity to be the site population's supplemental power, usable for a variety of purposes according to the desires of the individual households to which the windmills would be assigned. These windmills would overlap other built areas, requiring no specific land coverage allotment of their own.

Water

Water was the third and final need category considered. Given the significant reductions in the "average" household's water demand through various conservation mechanisms (figure 5), the plentiful quantity of water provided by the site's fifty inches of annual precipitation, and the good quality of surface and shallow ground waters sampled, it was assumed that sufficient good quality water would be available from the site's surface waters, cisterns, springs, shallow wells, and deep wells to supply any population which the site could feed and shelter. It was likewise assumed that no land would be required exclusively for water treatment or storage.

These assumptions are confirmed by the experience of current site residents, who depend almost entirely upon spring and shallow well water, finding these sources dependable even on the ridge tops and even during the site's rare periods of drought.

Conclusion

We summed all of the land demands resulting from our assessments of the human needs for food, shelter, and water (figure 32). We then added a forest land allotment of 20 percent for production of exportable goods (such as lumber and maple sugar) to trade for necessary goods not producable on site. A further 10 percent overall land allowance was finally added for the

POTENTIAL POWER FROM MAXIMUM EFFICIENT WINDMILL ARRAY

Kilowatts = .00000806 x wind velocity^3 x length of array x rotor radius

Wind Velocity (V) = from Above Average Wind Speed map

Length of Array = from Above Average Wind Speed map

Rotor Radius (r) = varies

Number of Windmills = length of array/3r

V (mph)	V^3 (mph)^3	length (feet)	kilowatts at r= 3 ft.	kilowatts at r= 6 ft.	kilowatts at r= 12 ft.
7.0	343	2,650	22.0	44.0	88.0
8.0	512	12,700	158.0	316.0	632.0
9.0	729	1,800	31.9	63.8	127.6
10.0	1,000	2,950	71.7	143.4	286.8
total kilowatts			283.6	567.2	1134.4
number of windmills			2,233	1,117	558

Figure 31

TOTAL LAND DEMAND PER "AVERAGE" HOUSEHOLD
AND MAXIMUM SUPPORTABLE POPULATION

Agricultural Land: Total: 5.021 ac
Dairy: 3.222 ac
Pasture: 1.710 ac
Cattle Crop: 1.512 ac
Kitchen Garden: 1.799 ac

Forest Land: 2.77 ac
Cordwood: 2.31 ac
Maple Forest: 1.67 ac
Additional Cordwood: .64 ac
20% Trading Factor: .46 ac

Built Land: Total: .09 ac

Energy Generation Land: overlaps compatibly with agricultural and built land

Water Storage Land: absorbed by built land

Subtotal: 7.88 ac

10% Allowance Factor: .79 ac

Total: 8.67 ac

Maximum Supportable Population = 1518.89 ac/site
× 8.67 ac/household
= 175.2 households/site

Figure 32

satisfaction of human needs not considered within the categories of food, shelter, and water.

A summary of land demands by type is shown graphically in figure 33. Agriculture, dominated by dairy production land, is the largest of the three land use types. And the built land use is negligible compared to agricultural and forest uses.

The total is then a little over eight-and-one-half acres per "average" household or two-and-one-half acres per person. Our site of approximately 1500 acres could then support 175 households or 600 people (figure 32).

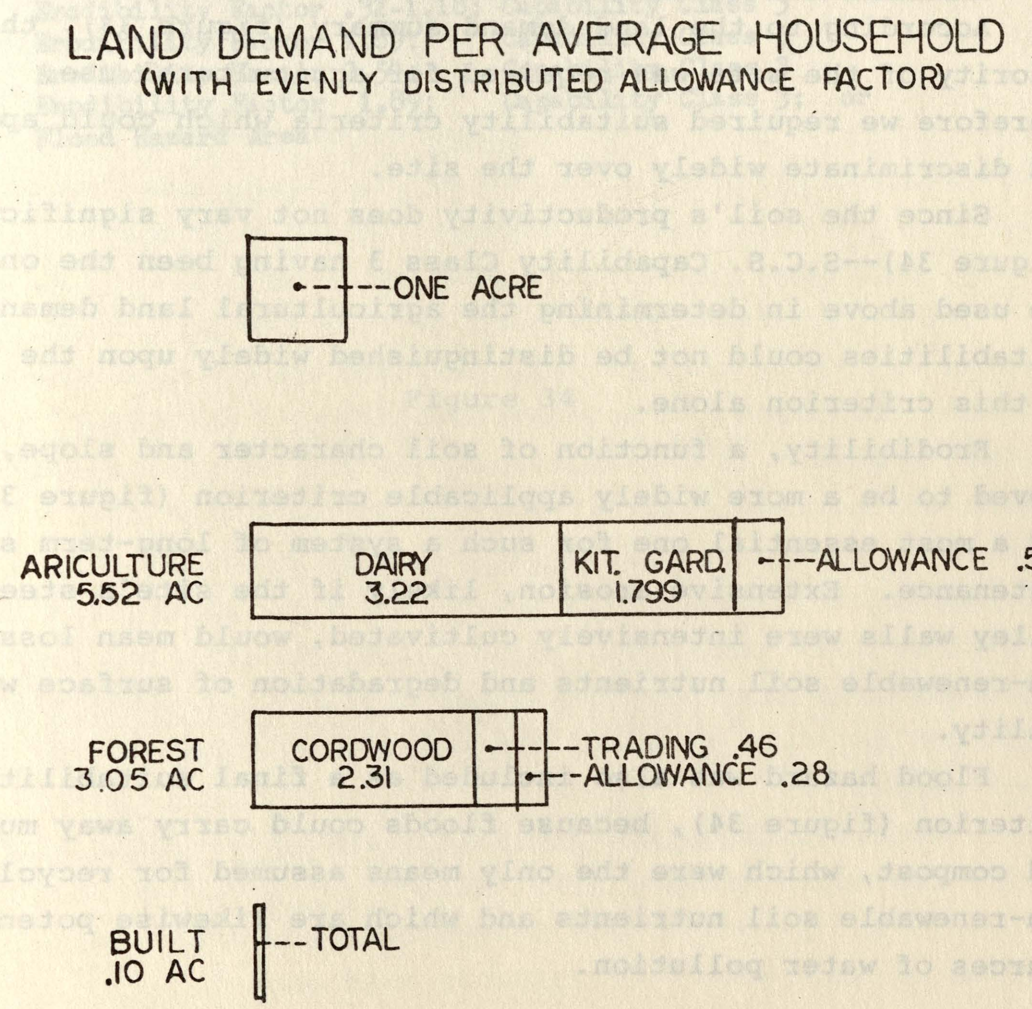


Figure 33

LAND USE SUITABILITIES

Having found the population which our site could support under the specified conditions of self-sustenance, we next prepared to designate agricultural, forest, and built areas of the site in proportion to the population's demand for each of these land uses (figure 33). The first essential input to this task was determination of site suitabilities for these uses.

We defined and individually mapped suitabilities for agricultural and built shelter, the more intense and demanding of the three land uses. Forest, the less intense use and the one whose productivity had not been found to vary significantly over the site, would occupy the residual land.

Agricultural Suitability

According to the land demand summary (figure 33), the majority of the site was required for agricultural use. Therefore we required suitability criteria which could apply and discriminate widely over the site.

Since the soil's productivity does not vary significantly (figure 34)--S.C.S. Capability Class 3 having been the only one used above in determining the agricultural land demand, suitabilities could not be distinguished widely upon the basis of this criterion alone.

Erodibility, a function of soil character and slope, proved to be a more widely applicable criterion (figure 34) and a most essential one for such a system of long-term self-sustenance. Extensive erosion, likely if the site's steep valley walls were intensively cultivated, would mean loss of non-renewable soil nutrients and degradation of surface water quality.

Flood hazard was also included as a final suitability criterion (figure 34), because floods could carry away mulch and compost, which were the only means assumed for recycling non-renewable soil nutrients and which are likewise potential sources of water pollution.

AGRICULTURAL SUITABILITY

Soil Erodibility and Productivity
Soil-Slope Erodibility Factor = K X (SL Factor at L=200 ft)

soil	K	slope: 0-10% 5=med SL=.75	10-15% 12.5=med SL=2.75	15-25% 20=med SL=5.9	25%+ 30=med SL=large	SCS capability class
Atkins	?	(flood	hazard)	(not	present...)	3
Ernest	.43	.32	1.18	(not	present...)	3
Wharton	.43	.32	1.18	(not	present...)	3
Hazleton	.24	.18	.66	(not	present...)	1
Berks-Weikert	.32	(not	present...)	1.89	large	3
Gilpin-Rayne	.32	(not	present...)	1.89	large	3

Suitability Classes

1: Erodibility Factor .18-.66; Capability Class 1
2: Erodibility Factor .32-1.18; Capability Class 3
3: Erodibility Factor 1.89; Capability Class 3
4: Erodibility Factor 2.54; Capability Class 3
5: Erodibility Factor 1.89; Capability Class 3; or Flood Hazard Area

Figure 34

Within the site areas thus found suitable for agriculture (map not included here), the steeper slopes and more poorly drained areas were intended for permanent pasture use, leaving the better areas for crop/pasture rotations.

Built Shelter

While constituting only a small land demand upon the site (figure 33), built shelter (as defined in the Appropriate Technology section and as diagrammed in figures 8-10) was fairly rigorous in its siting demands and therefore in its suitability criteria. Many criteria were considered, but only a few served to distinguish varying suitability over the site.

The first criterion established was that requiring adequate insolation, a function of slope aspect and gradient, for the shelter's solar space heating (figure 35). This implied either a flat site, a site sloping to the south, southeast, southwest, east, or west, or a site sloping to the north, northeast, or northwest so gently (at 15 percent or less) that design adaptations could still provide adequate building exposure to the south, southeast, southwest, east, and west.

Slope gradient, considered as a factor in itself, was the second criterion (figure 35). For slopes of optimum aspect (south, southeast, or southwest) or even good aspect (east or west), moderate (10-25%) gradients would be best due to the trade-off between maximizing gradient to reduce heat loss from the solar-heated shelter which can then be built into the slope and minimizing gradient to allow easy road access and to diminish potential soil loss. For slopes of more difficult aspect (north, northeast, or northwest), minimal gradients (0-10%) would be best for purposes of solar space heating, road access, and soil loss reduction.

Protection from the prevailing westerly winter wind was the third criterion (figure 35). Therefore slopes of southeast aspect would be preferable to those of southwest aspect, and slopes of east aspect to those of west aspect.

BUILT SHELTER SUITABILITY

CRITERIA: Insolation, Slope Gradient, Wind Direction, Flooding*, Bedrock Depth, Water Table Depth

SUITABILITY DESIGNATIONS
(Most Suitable = 1; Least Suitable = 4)

SLOPE: Aspect \ Degree	0-10%	10-15%	15-25%	25%+
N	2	2	3	4
NE	2	2	3	4
E	2	1	2	3
SE	2	1	1	2
S	2	1	1	2
SW	2	1	1	2
W	2	2	3	3
NW	2	3	4	4

*All Flood Hazardous Areas Designated 4

Figure 35

The necessity of excluding structures from the mapped Flood Hazard zone was the fourth criterion (figure 35).

The potential soil criteria of depth to bedrock and depth to seasonally high water table balanced out within the site's soil series (those series characterized by greater depth to bedrock also being those with less depth to seasonal high water table and vice versa). Therefore these factors did not serve to distinguish varying suitability over the site. In addition, it should be noted with respect to all such soil factors as depth to bedrock, depth to water table, and erodibility, that these shelters would be modified in design and built by hand with an emphasis upon minimizing disturbances to existing soil and vegetation, as opposed to the average contemporary "development" of a site by massive mechanized site modification with an emphasis upon packing in a large number of structures of rigidly pre-determined design.

The resulting map of built shelter suitability (not included here) showed the best areas to be moderate south, southeast, southwest, and east facing slopes and the worst to be steep north, northeast and northwest facing slopes or those areas subject to flooding.

Suitability Composite

Having defined suitabilities for these two pre-emptive land uses, we placed onto a "Suitability Composite" map (slide 13) the top three classes from the agricultural suitability map and the top two from the built shelter suitability map. The residual areas, designated suitable for neither agriculture nor built shelter, would go to forest use.

The resulting pattern of suitabilities can be understood through a schematic section of the site (figure 36). The level

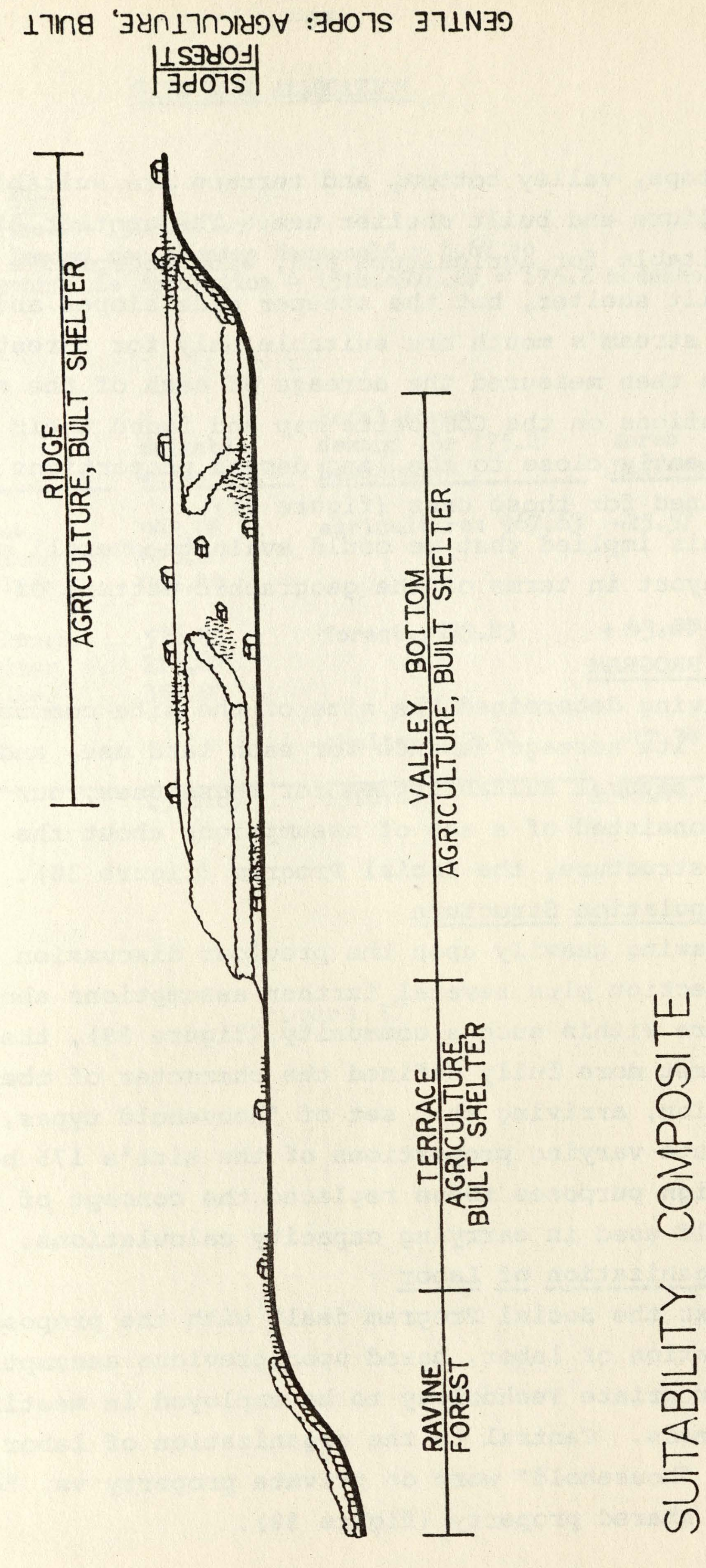


Figure 36

ridge tops, valley bottom, and terrace are suitable for both agriculture and built shelter use. The gentler side slopes are suitable for agriculture and, with acceptable orientation, for built shelter, but the steeper side slopes and the ravine at the stream's mouth are suitable only for forest use.

We then measured the acreage of each of the suitability combinations on the Composite map and found their proportions conveniently close to the land demand proportions previously determined for those uses (figure 37).

This implied that we could evaluate overall options for site layout in terms of the geographic pattern of the suitabilities.

SOCIAL PROGRAM

Having determined the size of the site community's population, its acreage demands for each land use, and the site's varying natural suitabilities for these uses, our final design input consisted of a set of assumptions about the community's social structure, the Social Program (figure 38).

Population Structure

Drawing heavily upon the previous discussion in the Human Needs section plus several further assumptions about household structure within such a community (figure 39), the Social Program first more fully defined the character of the proposed population, arriving at a set of "household types," which would constitute varying proportions of the site's 175 household total. For design purposes these replaced the concept of the "average" household used in carrying capacity calculations.

Organization of Labor

Next the Social Program dealt with the proposed community's organization of labor, based upon previous assumptions about the Appropriate Technology to be employed in meeting the defined Human Needs. Central to the organization of labor was definition of "household" work on private property vs. "community" work on shared property (figure 38).

SITE LAND ALLOCATION

Population Size
Total Site Area = 1518.89 ac
Total Land Demand per Average Household = 8.67 ac
Maximum Supportable Population = 1518.89/8.67 = 175.2 households

Land Uses

land use	suitable acres	total acres demand for 175.2 households	Acres Difference
agriculture:	942.06	agriculture: 967.63	-25.57
and shelter	676.66		
not shelter	265.40		
not agriculture:	576.83	forest: 533.83	+ 43.00
and shelter	216.87		
not shelter	359.96		
		shelter: 17.34	-17.34
total	1518.89	1518.89	± 43.00

Figure 37

SOCIAL PROGRAM

Population Structure

- "Stationary" population at site's self-sustaining carrying capacity
- "Age-Sex" Pyramid specified
- "Household Types" in proportions specified (see figure 39)

Organization of Labor

- Necessary labor and skills available
- "Household" work (private property):
  - Dwelling
  - Human and poultry plant crops (kitchen garden)
  - Child and pet play (yard)
  - Maintenance and minor repairs (work shed)
  - Poultry (chicken coop)
  - Domestic energy generation (windmill)
  - Food and wood and water storage (cellar, wood shed, cistern)

  (Household property varies with size of each "household type")
- "Community" work (shared property):
  - Dairy (cattle crop land, pasture, barns)
  - Timber (forest, timber sheds)
  - Crafts/Repair
  - Trade

  (Community work evenly distributed among "household types")

Spatial Structure

- "Household" elements contiguous
- "Neighborhoods"
  - Households grouped into "neighborhoods" offering ready access between households within a natural site division
  - Neighborhood facilities: common street(s), water well(s), dairy barn, timber shed

  (Neighborhoods include even distribution of "household types")
- "Community"
  - Neighborhoods linked into one site "community"
  - Community facilities:
    - "Barn" meetinghouse and school
    - "Pasture" sport and fair grounds
    - Inn-Pub-Cafe
    - Doctor-Vet-Constable Offices
    - Volunteer Fire Dept.-Heavy Equipment Shop-Blacksmith

    (Located within easy access of all neighborhoods)

Figure 38

ASSUMED HOUSEHOLD TYPES
(for use in community design)

Assume:

1. Age/Sex Pyramid Previously Determined for "Stationary" U.S. Population.
2. Age Class Breakdown of <25 years, 25-60 years, and >60 years.
3. All People Live in Households of At Least 2 People.
4. When Person <25 years, He Lives with People 25-60 years.
5. When Person >60 years, if Single or Widowed, He Lives with People 25-60 years or with Another Person >60 years.

Household Type	Nos. and Ages of Members within the Household	The Type's % of Total Households	
A. Childless Married Couple OR Married Couple Whose Children Are Grown OR Unmarried Roommates	Two Persons 25-60 years	19%	
B. Married Couples with Children	1. Two Persons 25-60 years One Person <25 years	13%	30%
	2. Two Persons 25-60 years Two Persons <25 years	17%	
C. Married Couples with Children and One Older Relative	1. Two Persons 25-60 years One Person <25 years One Person >60 years	6%	15%
	2. Two Persons 25-60 years Two Persons 25 years One Person 60 years	9%	
D. Two Single-Parent Families with One Older Relative	Two Persons 25-60 years Three Persons <25 years One Person >60 years	14%	
E. Childless Married Couple OR Couple Whose Children Are Grown with One Older Relative	Two Persons 25-60 years One Person >60 years	7%	
G. Older Married Couple OR Two Older Single/Widowed Roommates	1. Two Married Persons >60 years	13%	15%
	2. Two Roommates >60 years	2%	

Figure 39

Included in household work were small-scale tasks requiring close individual attention and a minimum of specialized knowledge and equipment. Examples would be cultivation of the small kitchen garden of human and poultry plant crops and care of the household's chicken flock, often fed leftover human foods as well as kitchen garden crops.

Community work encompassed those tasks more efficiently performed on large land areas (often of unevenly distributed site suitability), demanding cooperation among a large number of laborers, and specialized knowledge and/or equipment. Examples of on-going community work would be timbering or care of the dairy herds (appropriate since the average household requires only .55 dairy cow to satisfy its needs). Seasonal community work would include the fall's harvest of dairy crops and the spring's maple sugaring.

Spatial Structure

Finally the Social Program outlined the spatial implications of the community's assumed social structure (figure 38). There would be three major levels of spatial organization: the "household," the "neighborhood," and the "community." The nature of the household's work and associated property, all of which would be contiguous, were noted above. The neighborhood would consist of a number of closely interacting households, located within a natural physiographic site division, sharing specified facilities, and cooperating in carrying out their portion of the previously noted community work. The site community as a whole would consist of several neighborhoods, physically linked and sharing a set of unique community facilities located within easy reach of all neighborhoods.

DESIGN:

COMMUNITY

After completion of the three major inputs to the community's design: carrying capacity analysis (figure 32), land use suitabilities (slide 13 and figure 36), and social program (figure 38),

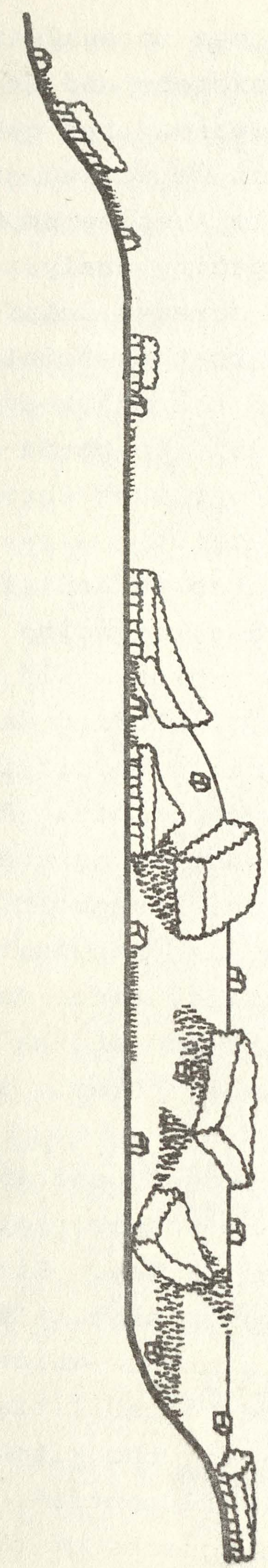
we first employed them in evaluating overall community layout options, both as concepts and as "yellow trace" site map overlays. The chosen option then guided us in detailed community design, during which we worked directly over the suitability composite map, while keeping in mind the spatial implications of the carrying capacity analysis (as to the total supportable population and the acreage demand for each land use type) and social program (as to the social structure).

Examination of the major options which we considered begins below with those found to be in greatest conflict with the design inputs and continues through to that option selected and developed in detail.

Option 1 (figures 40 and 41) would disperse the population as widely as possible, dividing the site into 175 self-sustaining households, each of which would contain its share of all the required land uses, including dairy and forest areas in addition to the social program's specified kitchen garden and built shelter household components. As well as thus violating the social program's assumptions about the nature of community work (shared property) vs. household work (private property), this option would often also necessitate disregard for the mapped land use suitabilities, since most parcels of the required size (a little over eight-and-one-half acres) would not include the full range of suitable forest, agriculture, and built shelter areas.

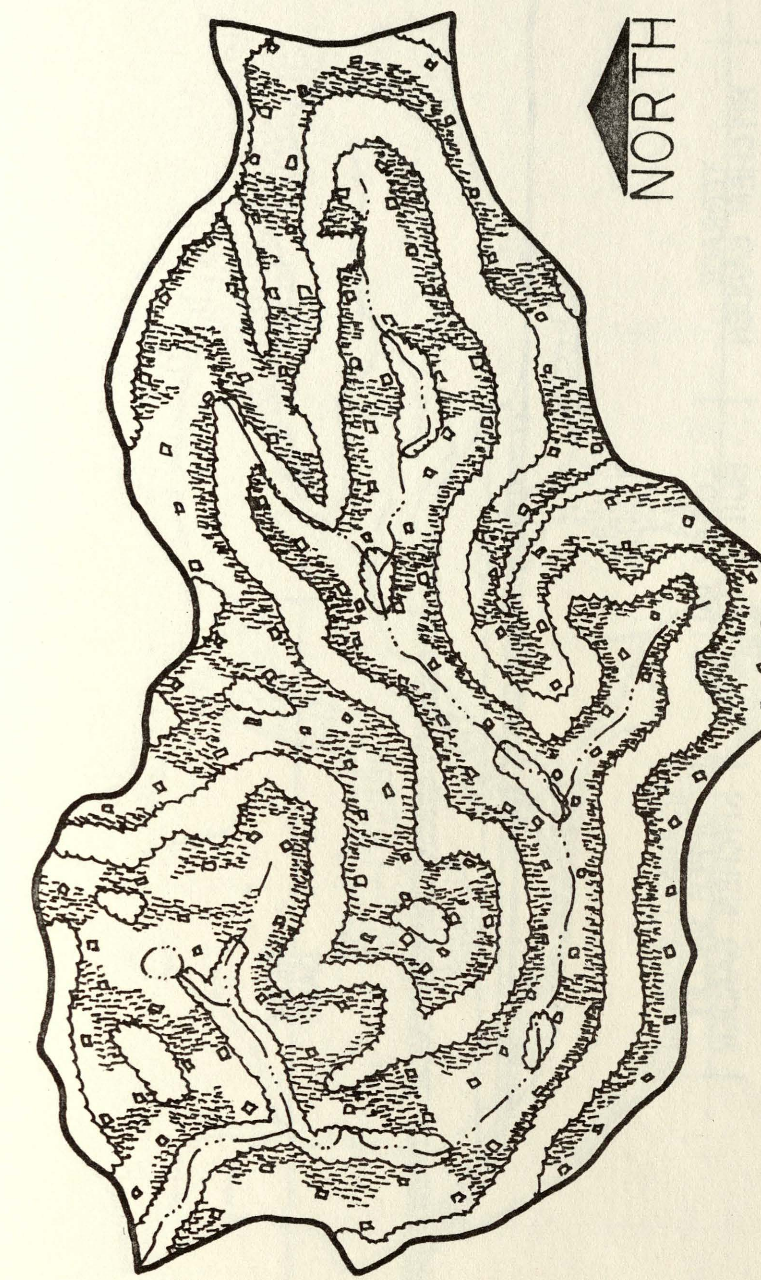
Option 2 (figures 42 and 43) would concentrate the population as closely as possible, packing all of the built shelter area into the lower valley. Kitchen garden, forest, and dairy lands all would lie outside. This option, unlike the first and like all of the others which follow, would satisfy the pattern of land use suitabilities. But, unlike all the other options, by separating the kitchen gardens from the built shelter areas it would contradict the social program's stipulation that all components of the household's work and property

UNIFORMLY DISTRIBUTED LAND USES



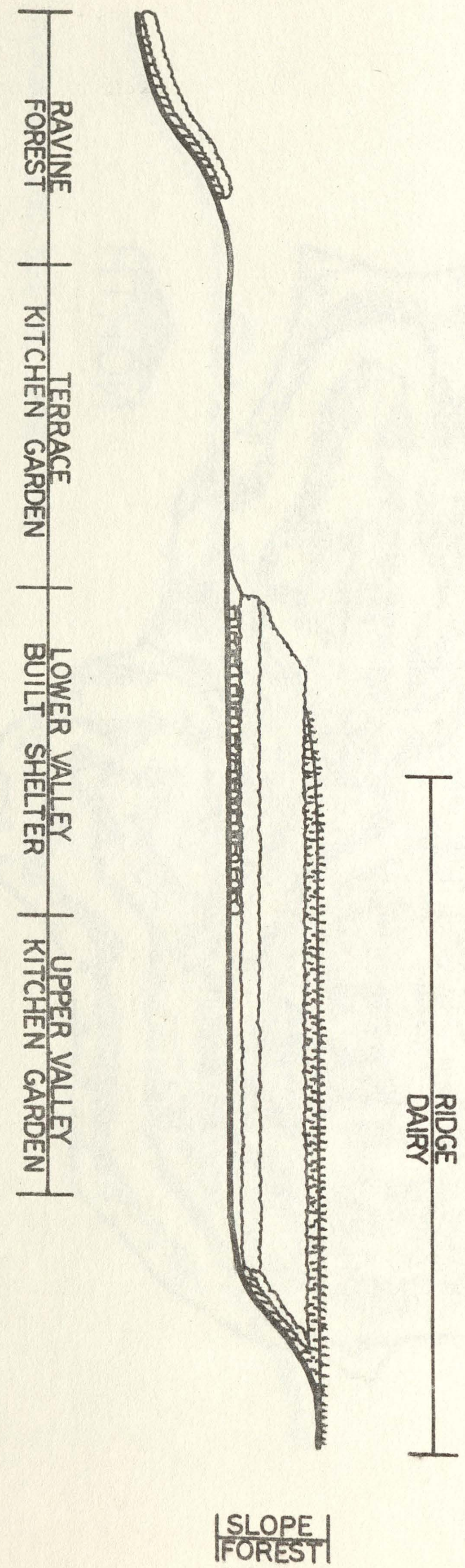
DESIGN OPTION I

Figure 40



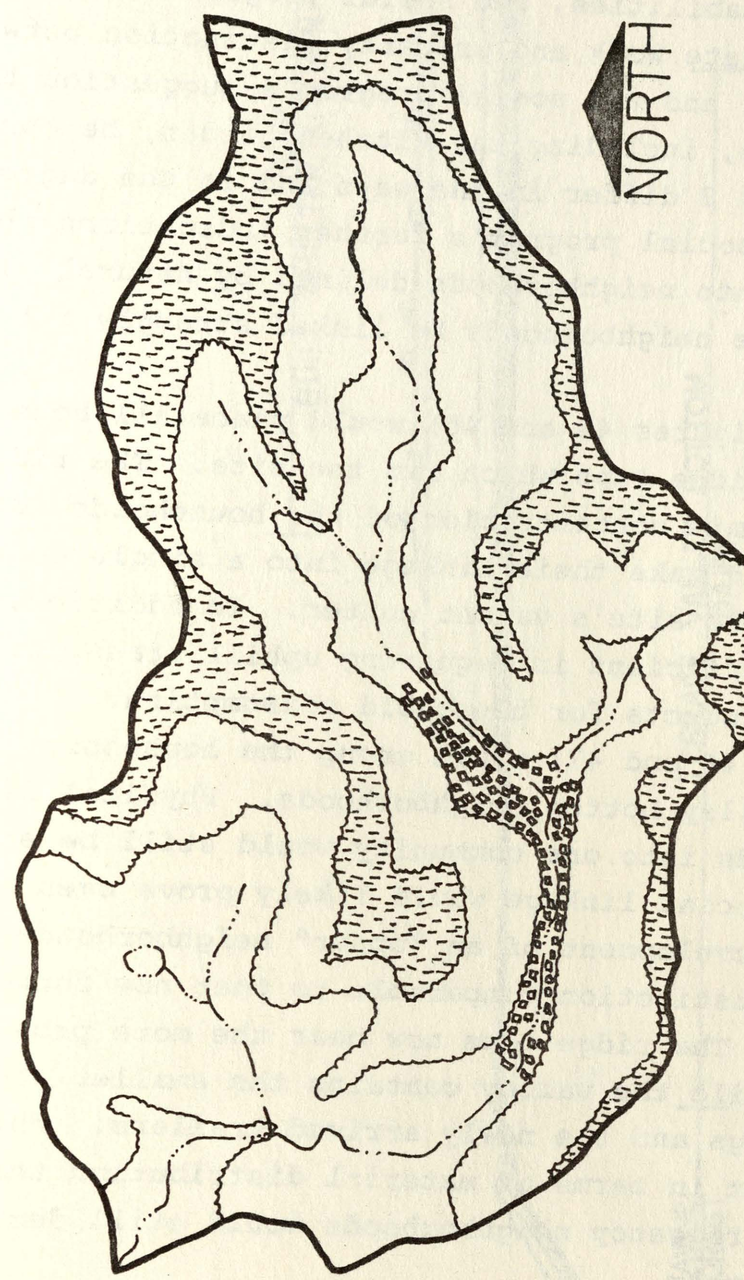
DESIGN OPTION I

Figure 41



DESIGN OPTION 2

Figure 42



DESIGN OPTION 2

Figure 43

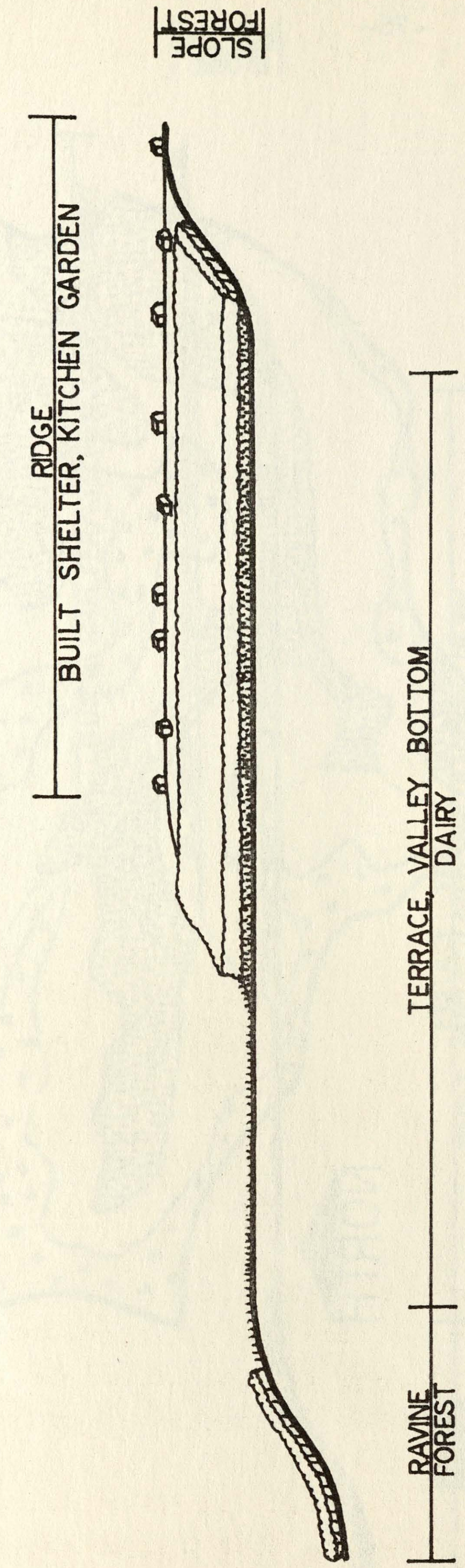
be contiguous. Further inefficiency would result from the long distances which people and materials must travel to and from timber and dairy work areas at the site's extremities.

Option 3 and all of the others below follow the established pattern of land use suitabilities, the social program's recommendations as to the appropriate work and property distinction between household and community, and the social program's suggestion that all household components, including the kitchen garden, be contiguous. Options 3 through 7 differ in the ways and in the degree to which they meet the social program's further indications that households be grouped into neighborhoods defined by natural site divisions and that these neighborhoods be linked strongly into a single site community.

Option 3 itself (figures 44 and 45) would place all households along the level ridge tops which rim the site. The ridge configuration would permit concentration of the households into neighborhoods, but would make their linkage into a single community awkward due to the site's vacant center. In addition, the option would be inefficient in requiring uphill transport of all dairy and forest products for household consumption.

Option 4 (figures 46 and 47) would group the households into several ridgetop or valley bottom neighborhoods. Physical linkage of the neighborhoods into one community would still be somewhat difficult. But social linkage would likely prove even more difficult due to the development of an "upper" neighborhood--"lower" neighborhood distinction comparable to that now found among site residents. The ridge tops now bear the more prosperous dairy farms, while the valley contains the smaller and less prosperous holdings and the newly arrived trailers. While somewhat more efficient in terms of material distribution than previous options, the ridgetop neighborhoods would still demand uphill transport of timber.

Option 5 (figures 48 and 49), unlike any previous option, would concentrate the households into neighborhoods each of



DESIGN OPTION 3

Figure 44

DESIGN OPTION 3

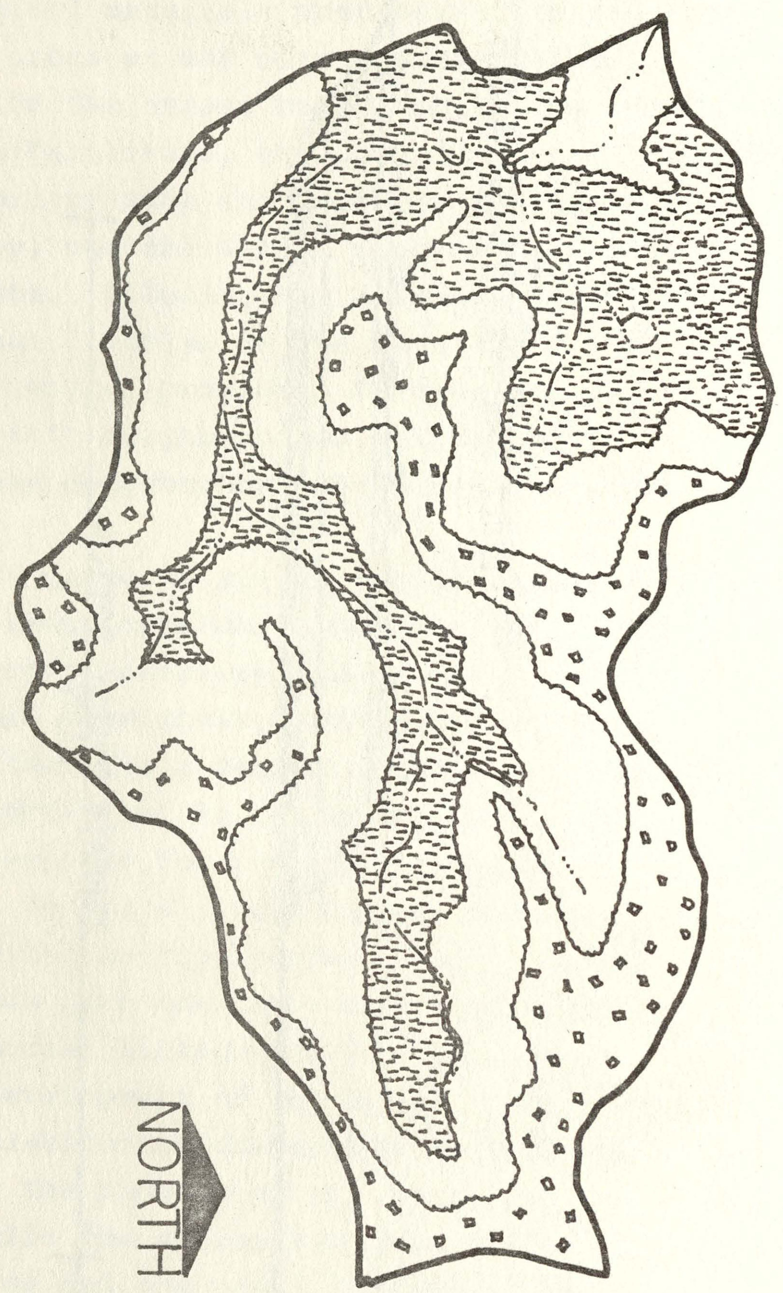
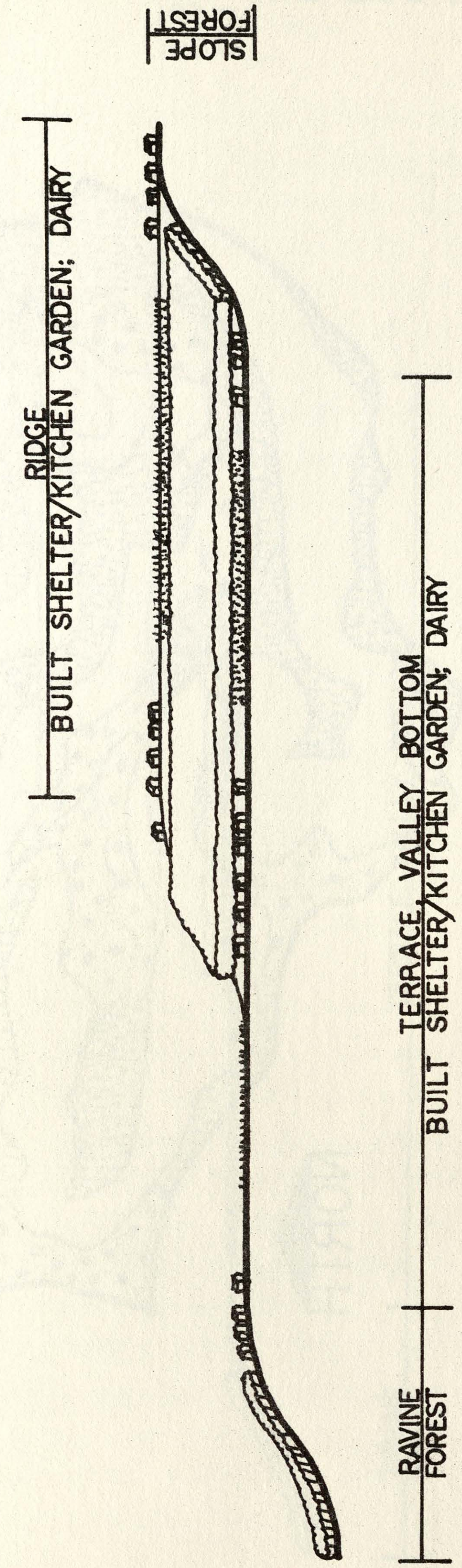


Figure 45



DESIGN OPTION 4

Figure 46

DESIGN OPTION 4

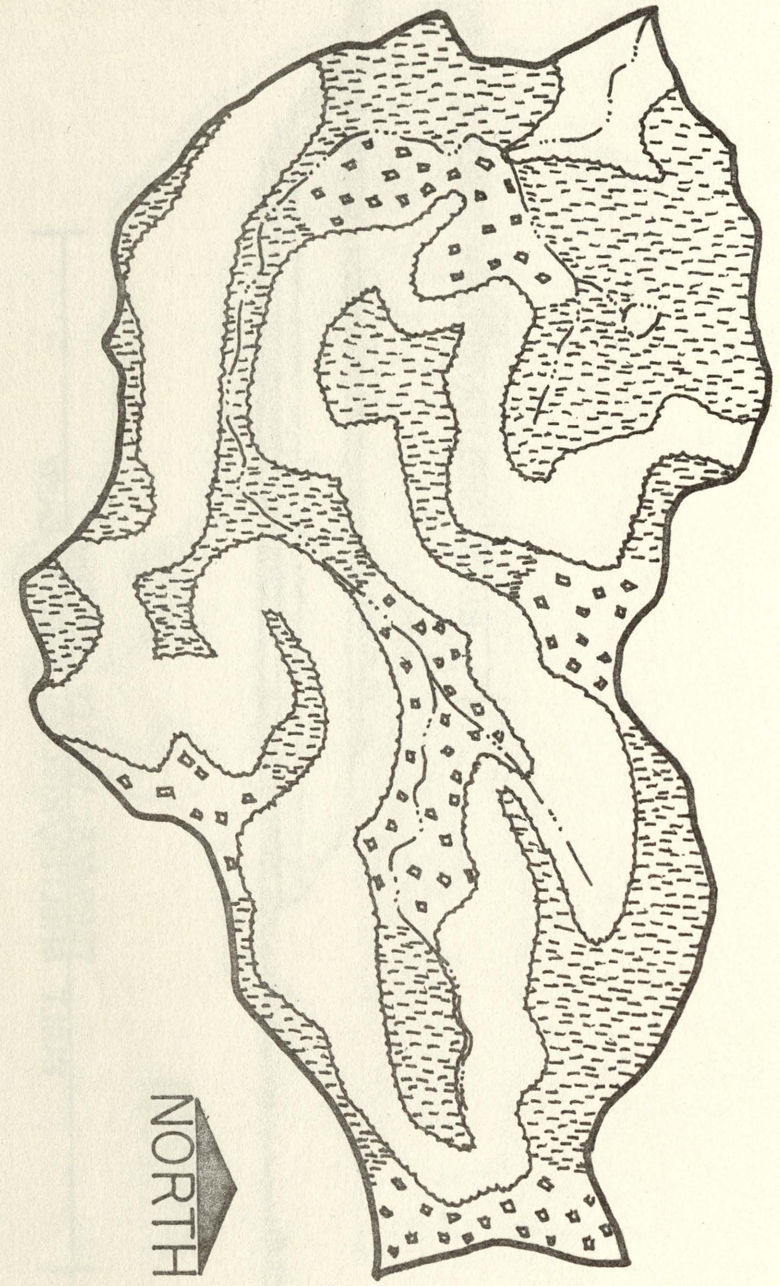
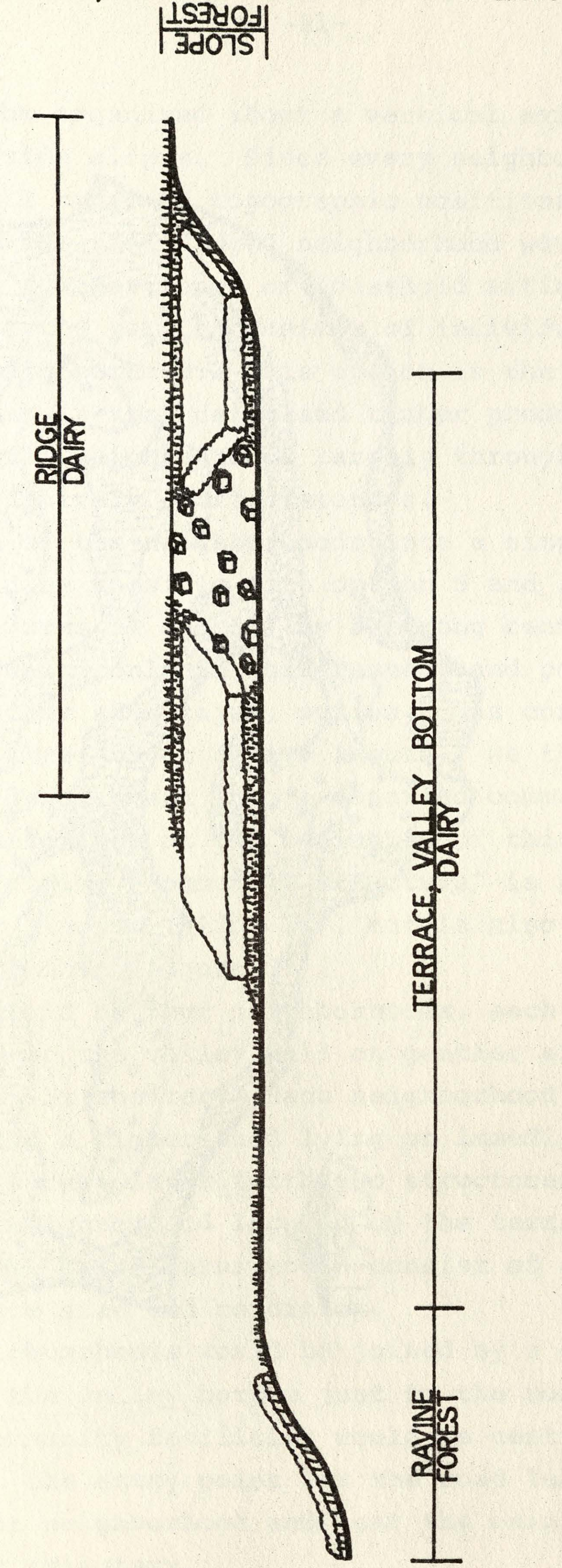


Figure 47

GENTLE SLOPE: BUILT SHELTER/KITCHEN GARDEN



DESIGN OPTION 5

Figure 48

DESIGN OPTION 5

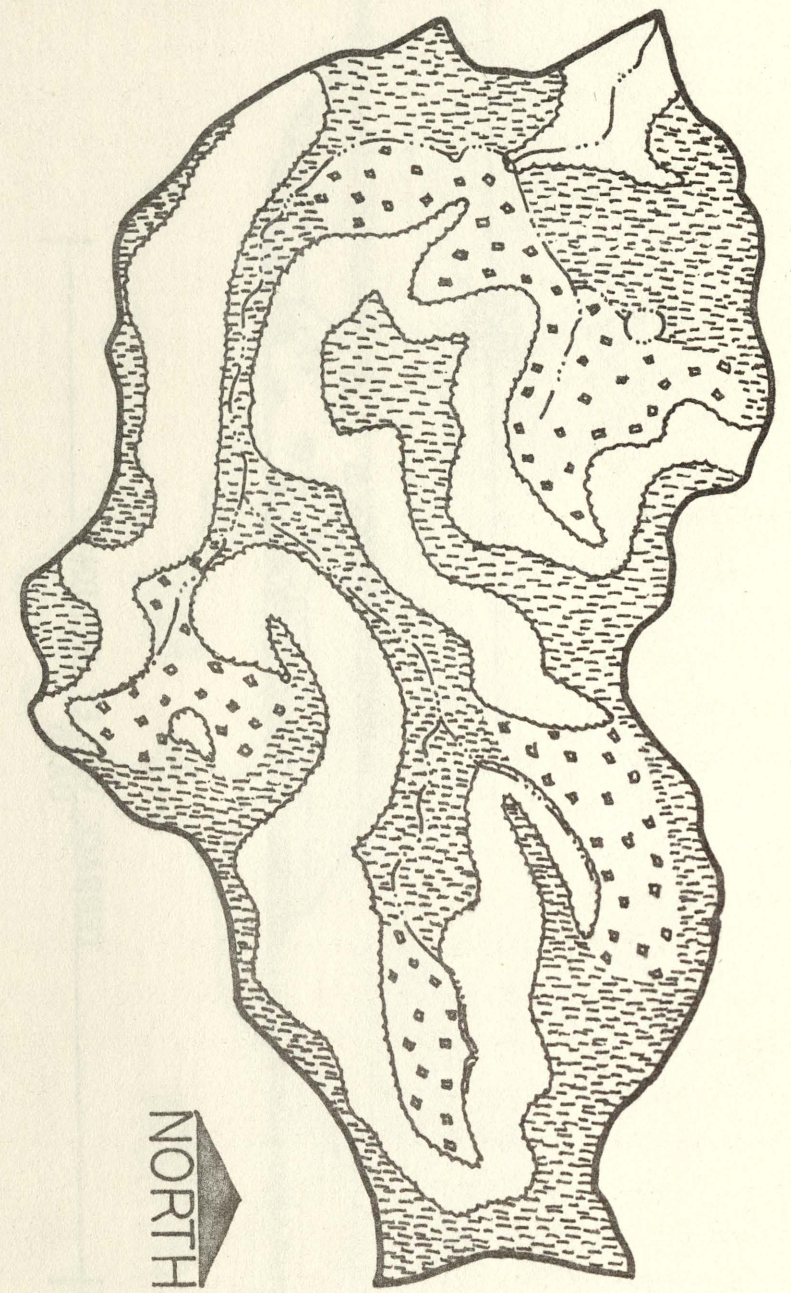


Figure 49

which would be organized about a vertical axis running up one of the gentler side slopes. Since every neighborhood would encompass a full range of topographic positions, the stigma of the "valley" vs. the "ridge" neighborhood would be more easily avoided, and a wider range of household siting options would exist to meet the varying desires of individual householders within the neighborhood. This option is the most efficient considered so far in that dairy and timber products could be distributed to all neighborhoods largely through horizontal movement over relatively short distances.

Linkage of the neighborhoods into a single site community clearly would be possible with option 5 and is accomplished in option 6 (figures 50 and 51) by a strong central valley bottom spine. Differing only in this respect and possessing all of option 5's other advantages, option 6 was considered to best satisfy the three major design inputs. We therefore chose it for further development into a detailed community design through the manner described at the beginning of this section.

The resulting "Community Structure" is shown most explicitly in the color diagram (slide 14), but is also implied in the plan sketch of option 6 (figure 51).

There would be four neighborhoods, each organized about a road running up the valley wall on gentler slopes of suitable aspect for built shelter. Each neighborhood would include a dairy barn and a timber shed lying on immediately adjacent pasture and forest lands (with two structures of each type for the largest neighborhood located on the terrace to the northwest). Several of the dairy barns would consist of existing structures of appropriate size and condition.

The neighborhoods would be joined by a community link road lying along the valley bottom just to the north of the stream. The major community facilities would be centrally located along this link at the entry point for the road leading to the southern most neighborhood and near the mainstream's junction with a major tributary.

DESIGN OPTION 6

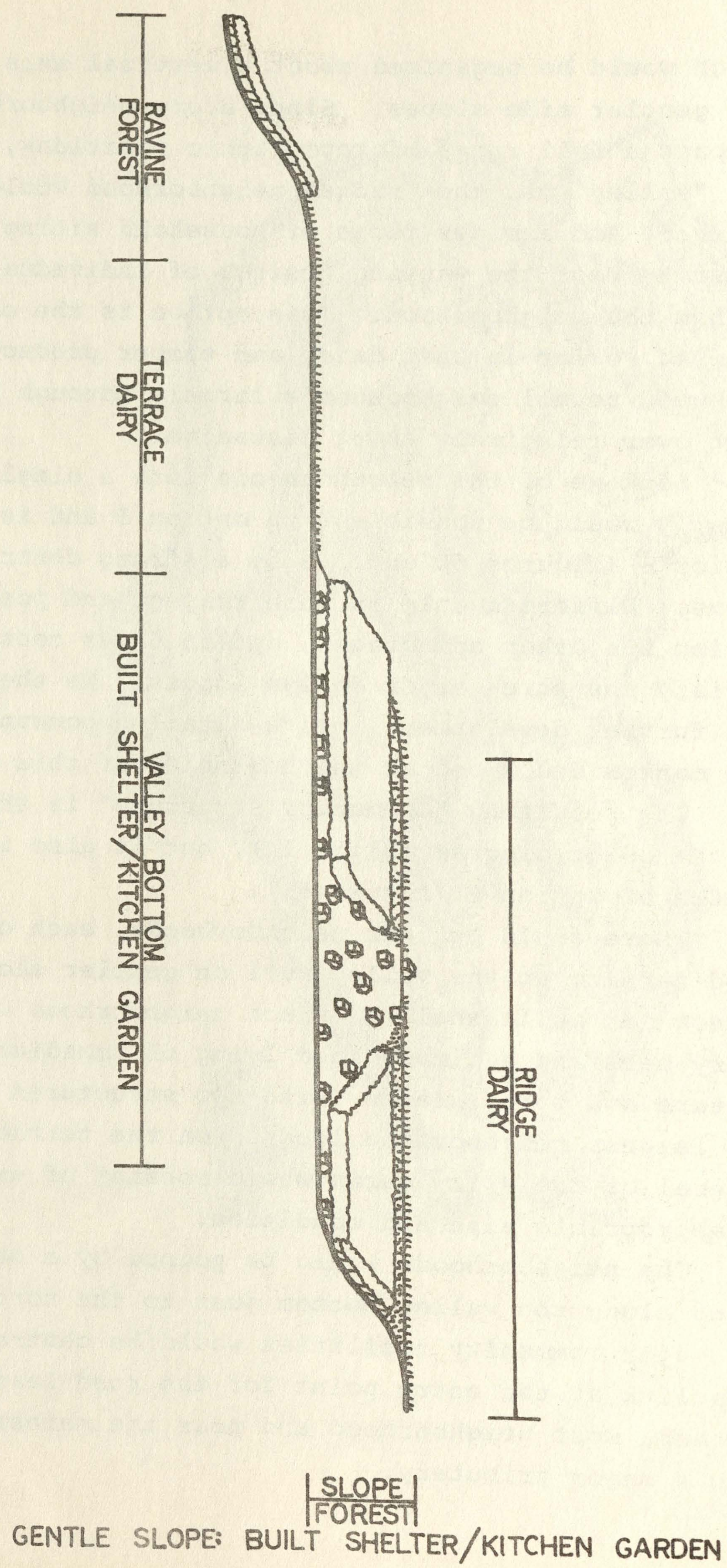
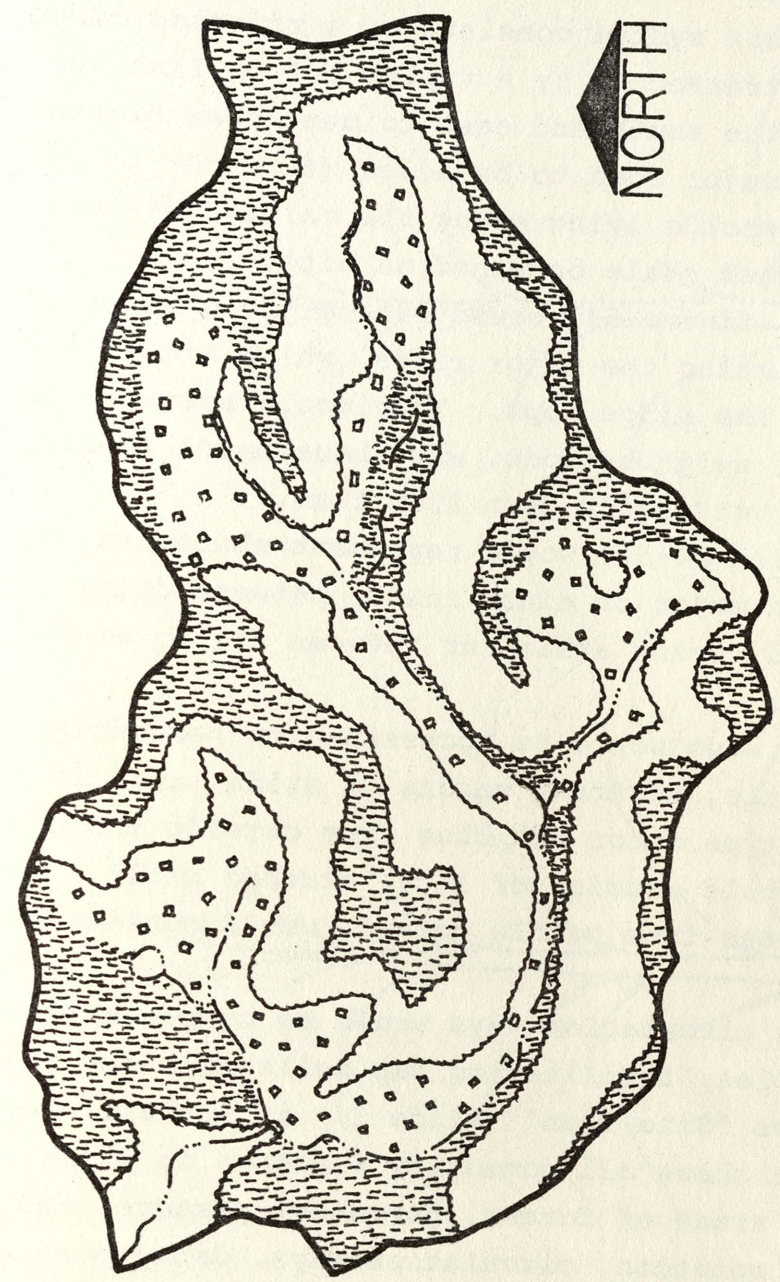


Figure 50



DESIGN OPTION 6

Figure 51

"Site Circulation" (slide 15) would depend upon a hierarchical system of "major" roads, "minor" roads, and "paths."

Most of the community's major roads (figure 52) would coincide with the existing system of two-lane asphalt roadways which usually follow the most logical routes through the site's difficult terrain. This system consists of a ridgetop circuit of the site which is transected by a valley bottom link and which is extended on the south and east to meet area highways. The small segment of major road to be added (in order to provide uphill access to households lying along the valley bottom link) would consist of crushed shale obtained on site.

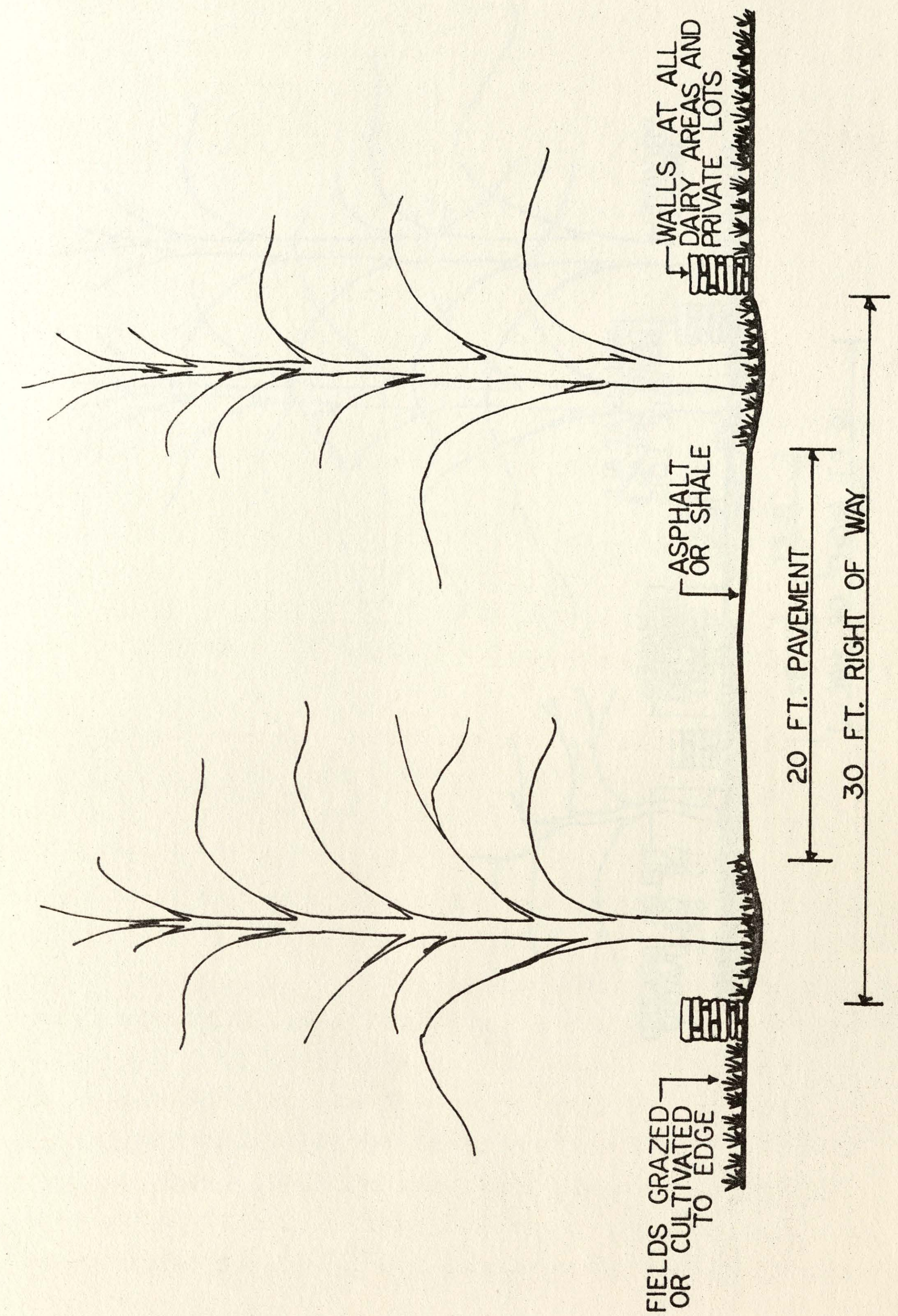
The minor roads (figure 53) would run up the gentler side slopes, thereby connecting the major roads, which lie in the valley bottom and on the ridge tops. They would serve as the common streets of the neighborhoods, with households feeding horizontally off and vertically down from them.

The paths (figures 54-56) would represent shortcuts, often somewhat steeper than major or minor roads, between dairy or timber work areas and living areas, or between living areas and community facilities.

All circulation ways would be accessible to pedestrians, bicycles, driven cattle, ox-drawn wagons or skids, and, in most cases, also to jeep-type motor vehicles from outside the community. Road beds would consist of local crushed shale. Walls, placed to protect trees from cattle damage, would consist of local sandstone.

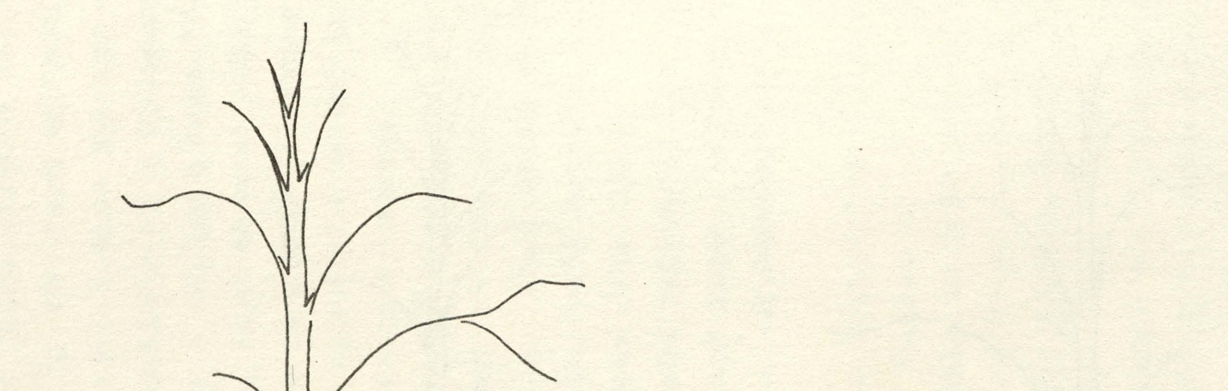
Hedgerows along circulation ways would be composed principally of sugar maples, facilitating sap collection and transport.

The illustrative "Site Plan" (slide 16) at the scale of one inch to 500 feet shows all community elements in place on the site, including areas of forest, permanent pasture, and cattle crop/pasture rotation, circulation ways, dairy barns, timber sheds, major community facilities, and all 175 households composed of dwelling complexes plus kitchen gardens.



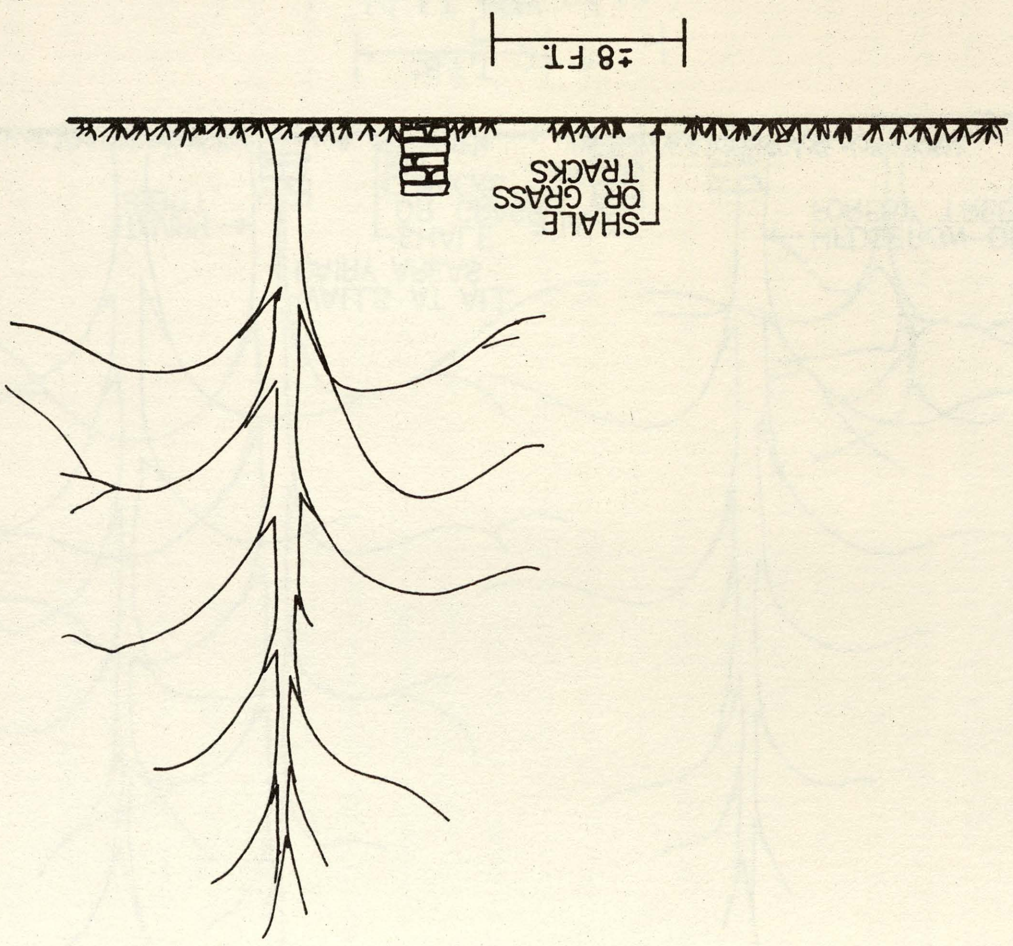
MAJOR ROAD

Figure 52



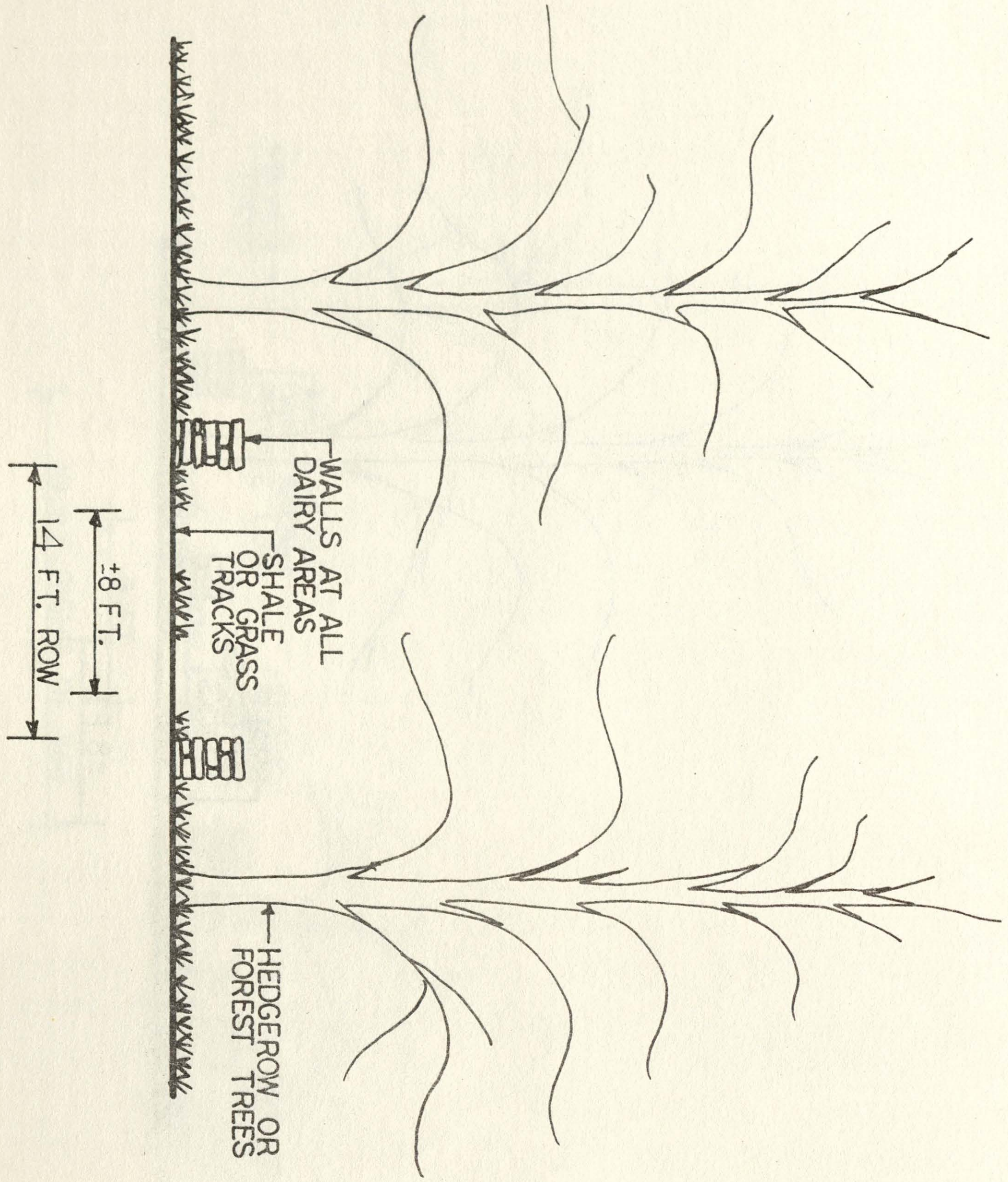
MINOR ROAD

Figure 53



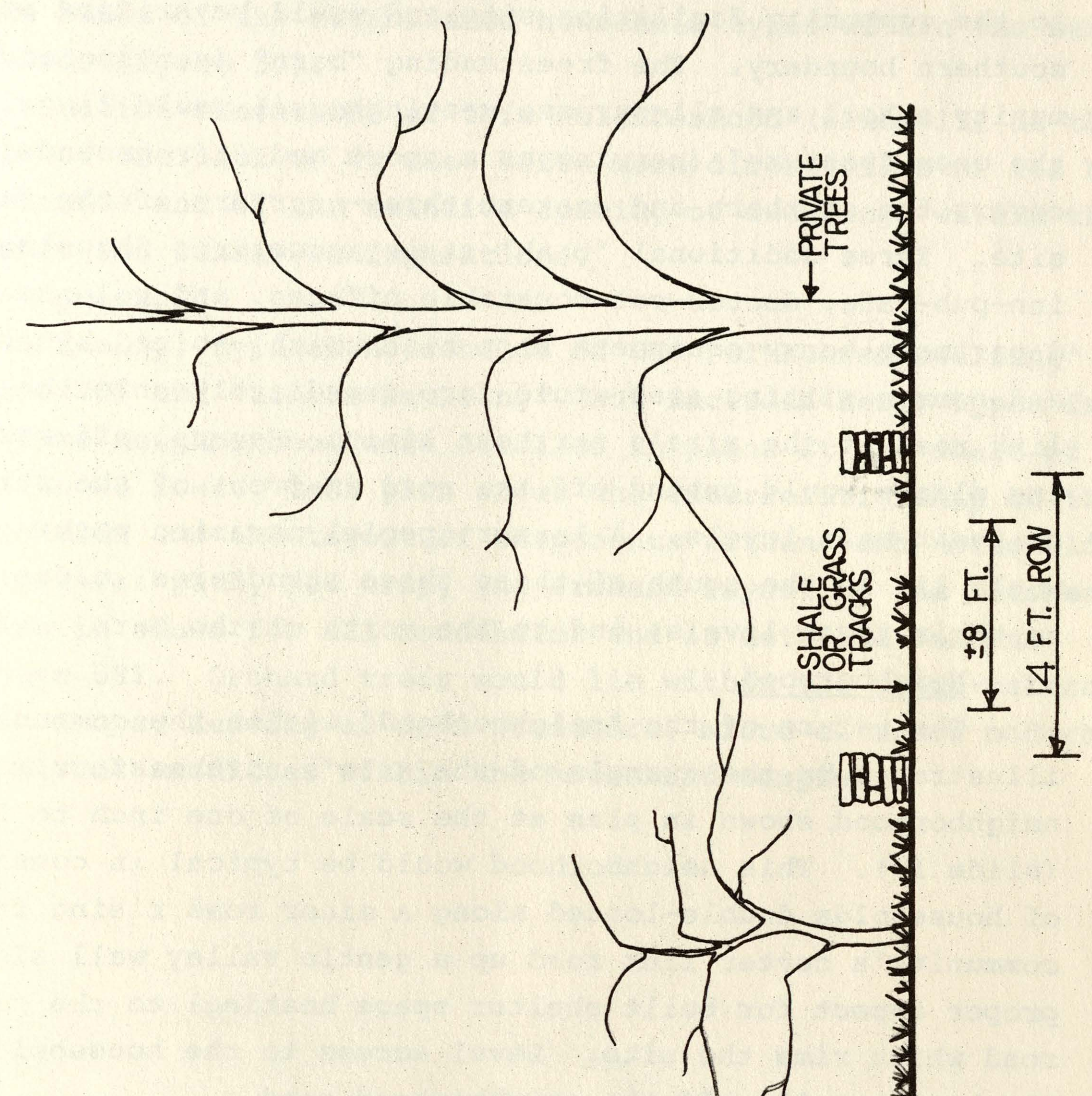
PATH
AT SINGLE HEDGEROW

Figure 54



PATH AT DOUBLE HEDGEROW

Figure 55



PATH BETWEEN PRIVATE LOTS

Figure 56

The major community facilities, also shown in a closer plan view (slide 17), would be centrally located along the valley bottom community link road at a major crossroads joining the community's neighborhoods and joining the community with the region beyond. A major tributary joins the mainstream adjacent to the community facilities site and would be bridged at its southern boundary. The freestanding "barn" (serving as a community school and all-purpose meetinghouse) would lie within the open "pasture" (serving as a sport and fair grounds), which covers the southern and eastern three-quarters of the facilities site. Three additional "bank"-style structures (housing the inn-pub-cafe, doctor-vet-constable offices, and volunteer fire department-heavy equipment shop-blacksmith) joined by an arcade and common sitting area would face immediately onto the community link road at the site's northern limit. Several off-street parking places would extend off the road in front of the structures at their main levels. A larger special-occasion parking area would lie to the south of these three structures, offering entry to their lower levels, and to the north of the barn.

Neighborhood

The nature of the "neighborhood" within the community is illustrated by the example of the site's northeastern most neighborhood, shown in plan at the scale of one inch to 200 feet (slide 18). This neighborhood would be typical in consisting of households double-loaded along a minor road rising from the community's center link road up a gentle valley wall slope (of proper aspect for built shelter space heating) to the ridge top road which rims the site. Level access to the households would lie horizontally off the neighborhood road.

The spacing and configuration of the households along this road could vary with the neighborhood's changing topography in order to offer a lifestyle option to prospective residents. Near the top of the road where the slope is gentler, the household lots would be shorter and wider, and the dwellings could

assume a clustered configuration, commonly in groups of three. Near the bottom of the road where the slope is steeper, household lots would be longer and narrower, and the households would assume a linear configuration along the roadway.

Household lot sizes would change according to the differing space needs of the established household types within the neighborhood (figure 57).

Section-elevations of this neighborhood (slide 19) at the scale of one inch to 40 feet offer more direct views of its built appearance and of the relative spacing of dwellings within the cluster and linear configurations.

Household

Finally, typical households of the "Clustered Dwelling" (slide 20) and "Linear Dwelling" (not included here) types from the same neighborhood were detailed in plans at the scale of one inch to 40 feet. Each plan shows the interrelationship of the households and the layout of components within each household lot. The general path, row crop, and orchard layout of the kitchen garden is shown for all households and is detailed for one (figure 58). Orchard trees would lie within the shade-tolerant grain crops, serving as food producers, micro-climatic moderators, and visual amenities within the household complex.

HOUSEHOLD LAND ALLOCATIONS WITHIN NEIGHBORHOOD ILLUSTRATED

Household Type*		Number in Neighborhood (assuming even distribution)	Acreage per Household
A		6	1.2
B	1	4	1.8
	2	5	2.4
C	1	2	2.4
	2	3	2.9
D		4	3.5
E		2	1.8
F		5	1.2
TOTAL OF		31	HOUSEHOLDS

*See Household Types definition (figure 39)

Figure 57

KITCHEN GARDEN
(for "average" household)

HUMAN FOOD	PERMANENT	Grains	Barley	.0120 ac.	(.2566 ac.)
			Oats	.0383 ac.	.2823 ac. w. allowance
			Rye	.0133 ac.	
			Wheat	.1930 ac.	
	ROTATION	Heavy Feeders	Cabbage	.0017 ac.	(.0437 ac.)
			Spinach	.0048 ac.	.0481 ac. w. allowance
			Lettuce	.0050 ac.	
			Squash	.0036 ac.	
			Corn	.0109 ac.	
			Tomatoes	.0144 ac.	
			Asparagus	.0033 ac.	
		Light Feeders	Green beans	.0060 ac.	(.1633 ac.)
			Soybeans	.1400 ac.	.1796 ac. w. allowance
			Carrots	.0018 ac.	
			Green peas	.0096 ac.	
			Lima beans	.0018 ac.	
			Potatoes	.0041 ac.	
POULTRY FOOD	SEPARATE ROTATION	Grains	Corn	.1651 ac.	(1.1609 ac.)
			Oats	.9958 ac.	1.2770 ac. w. allowance
				TOTAL	1.787 ac. w. allowance

Figure 58

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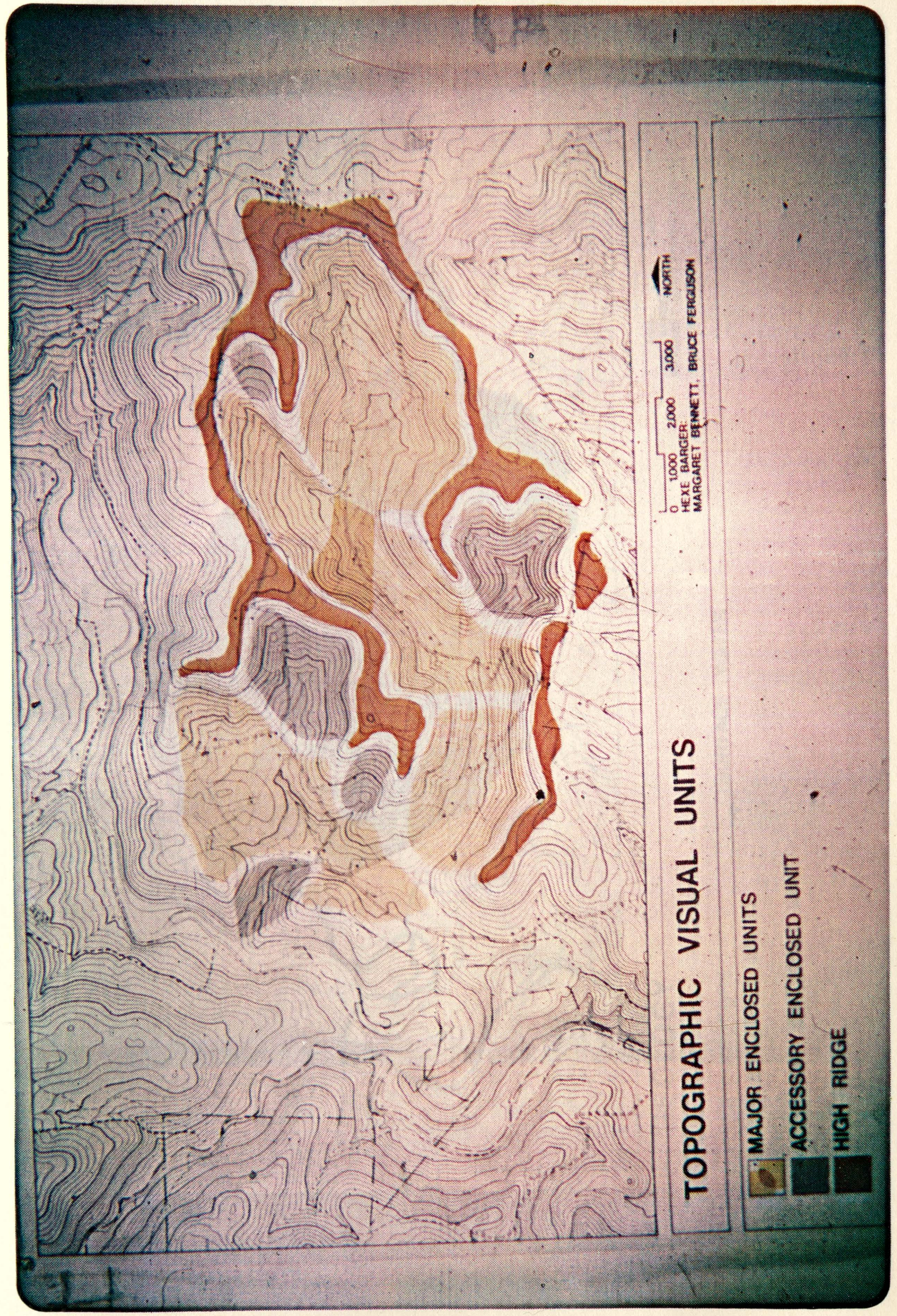
ACKNOWLEDGMENTS

We greatly appreciate the counsel of our three advisors in their respective fields of expertise: Dr. Jim Bockheim in soils, productivity, and suitability analyses; Dr. Nick Muhlenberg in project definition and carrying capacity calculations; and Laurie Olin in community design.

Three additional University of Pennsylvania faculty members also contributed generously to the project in time and advice: Jon Berger with project definition and natural resource inventories; Bob Hanna with community design; and Setha Low with human nutritional needs and the social program.

Watershed residents were friendly and helpful throughout our work there, especially Dr. and Mrs. Ferguson, who housed us during site visits to collect water, leaves, dirt, and pictures.

Evelyn Wydro's patience and typing skill were essential to preparation of this report.



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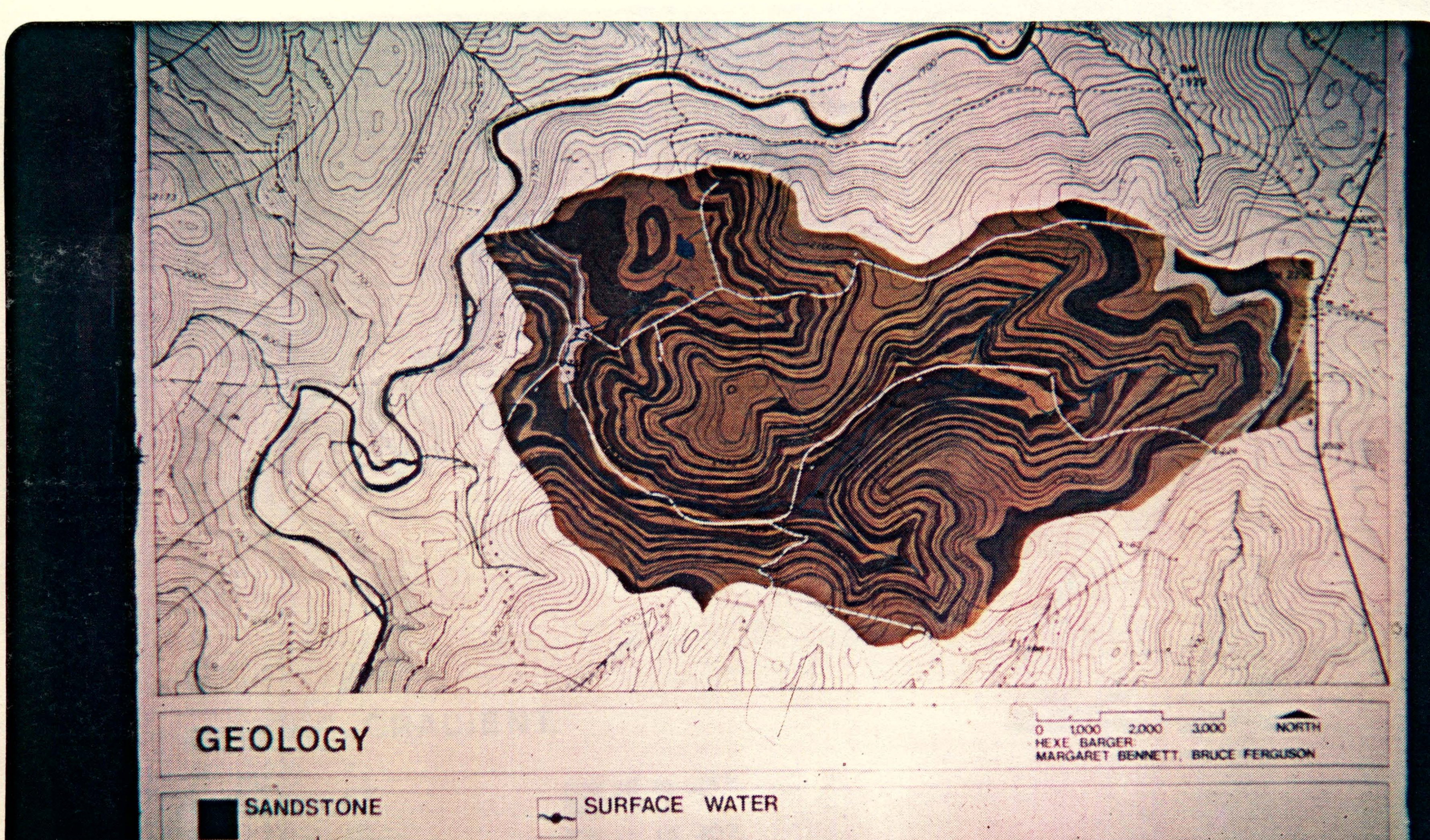
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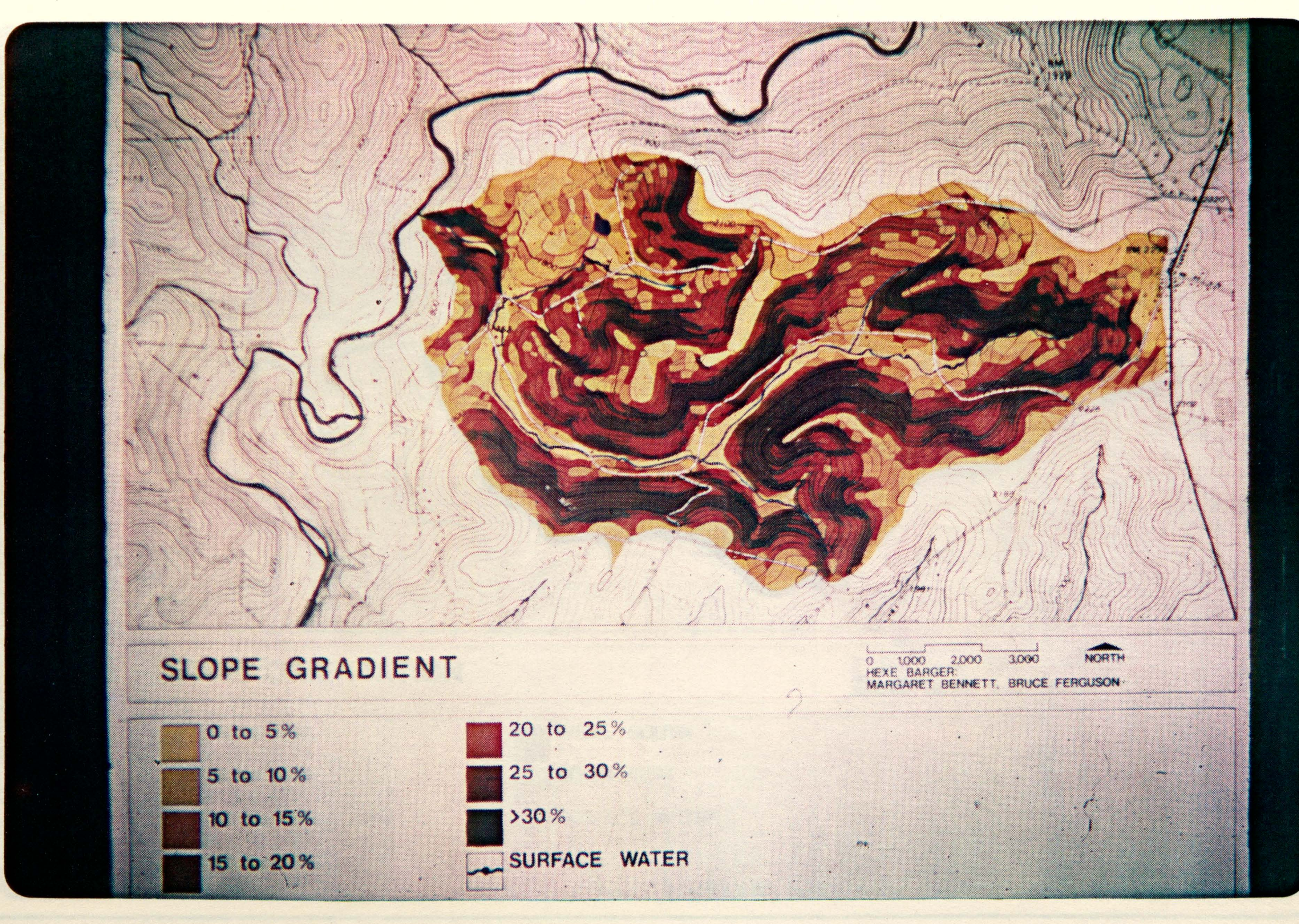
MARGARET BENNETT, BRUCE FERGUSON
SANDSTONE
SHALE
LIMESTONE
SURFACE WATER

Slide 4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MARGARET BENNETT, BRUCE FERGUSON
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15 to 20%
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25 to 30%
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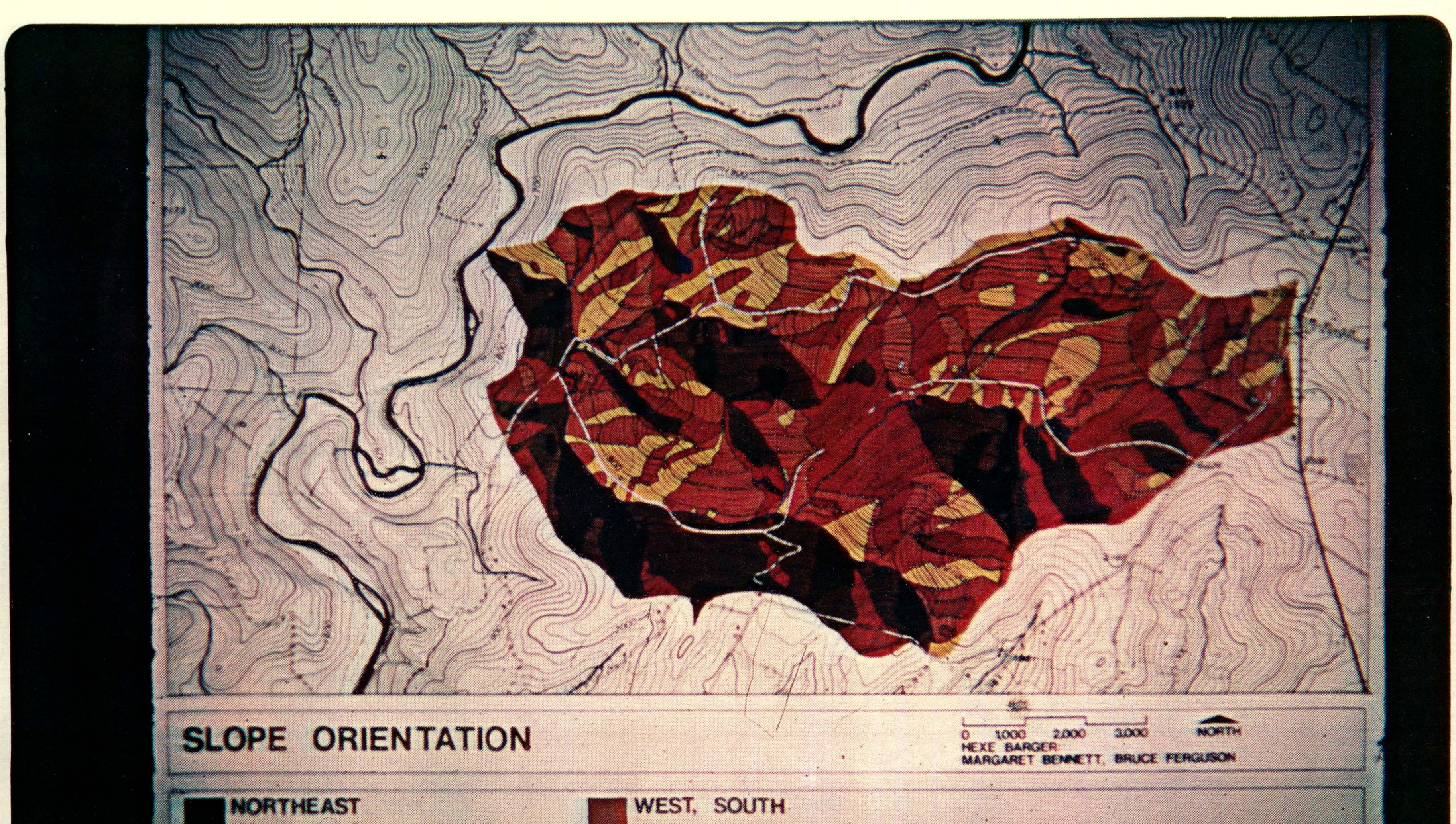
SURFACE WATER

Slide 5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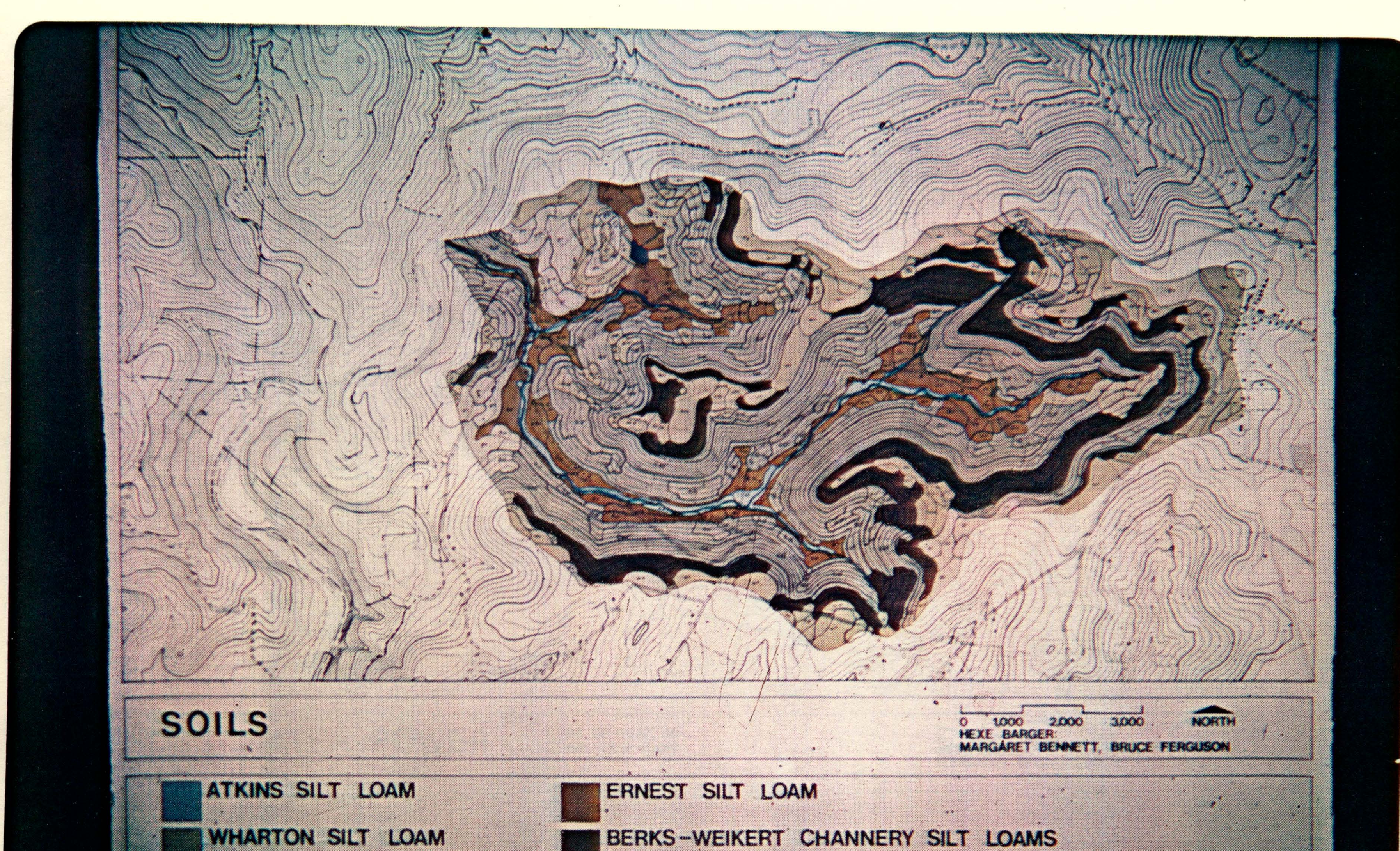
SURFACE WATER

Slide 6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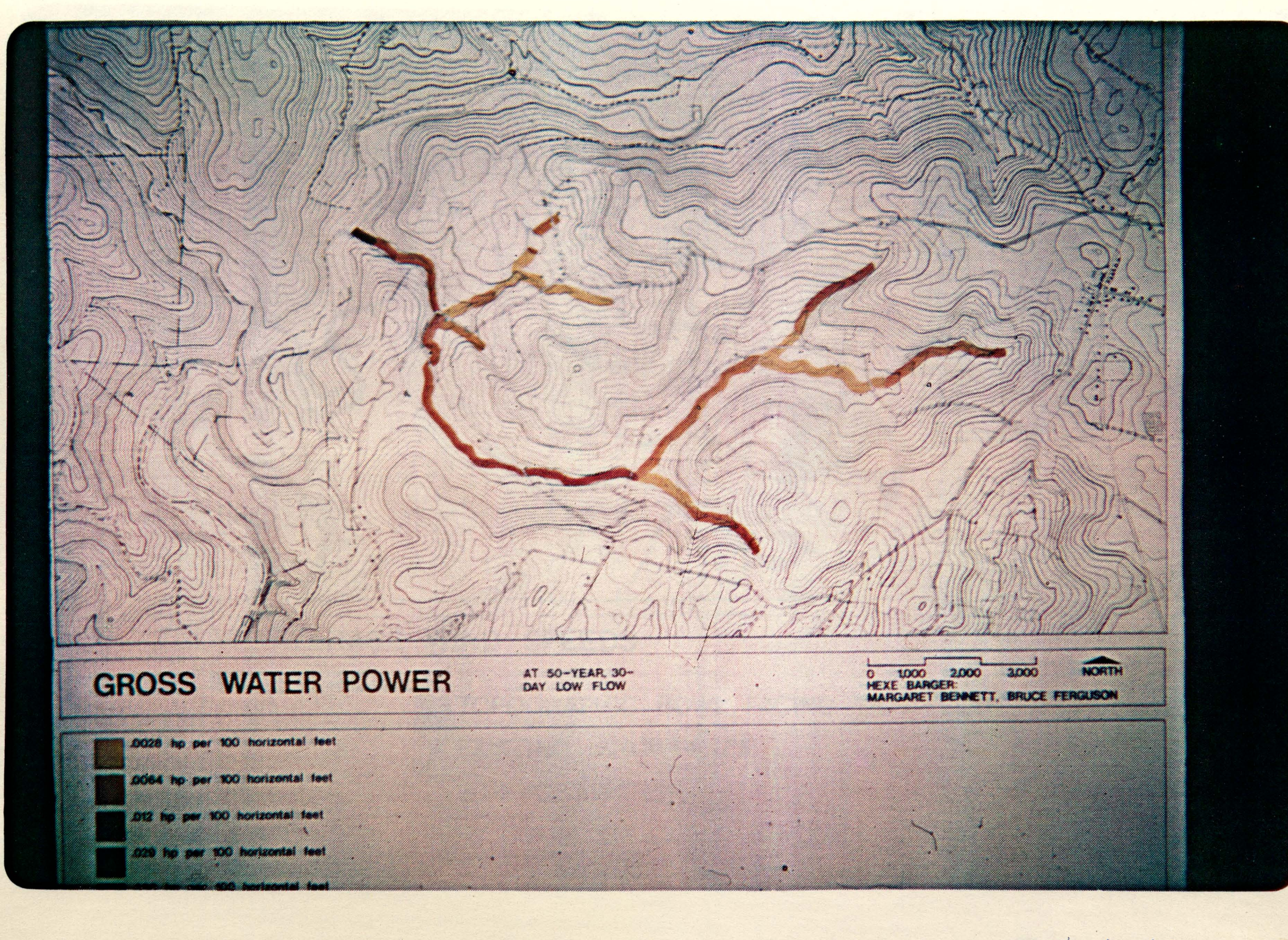
ERNEST SILT LOAM
BERKS-WEIKERT CHANNERY SILT LOAMS
GILPIN-RAYNE VERY STONY SILT LOAMS
SLOPE PHASES: 0(0-10%), 10(10-15%), 15(15-25%), 25(>25%)

Slide 7


GROSS WATER POWER
AT 50-YEAR, 30-DAY LOW FLOW
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MARGARET BENNETT, BRUCE FERGUSON
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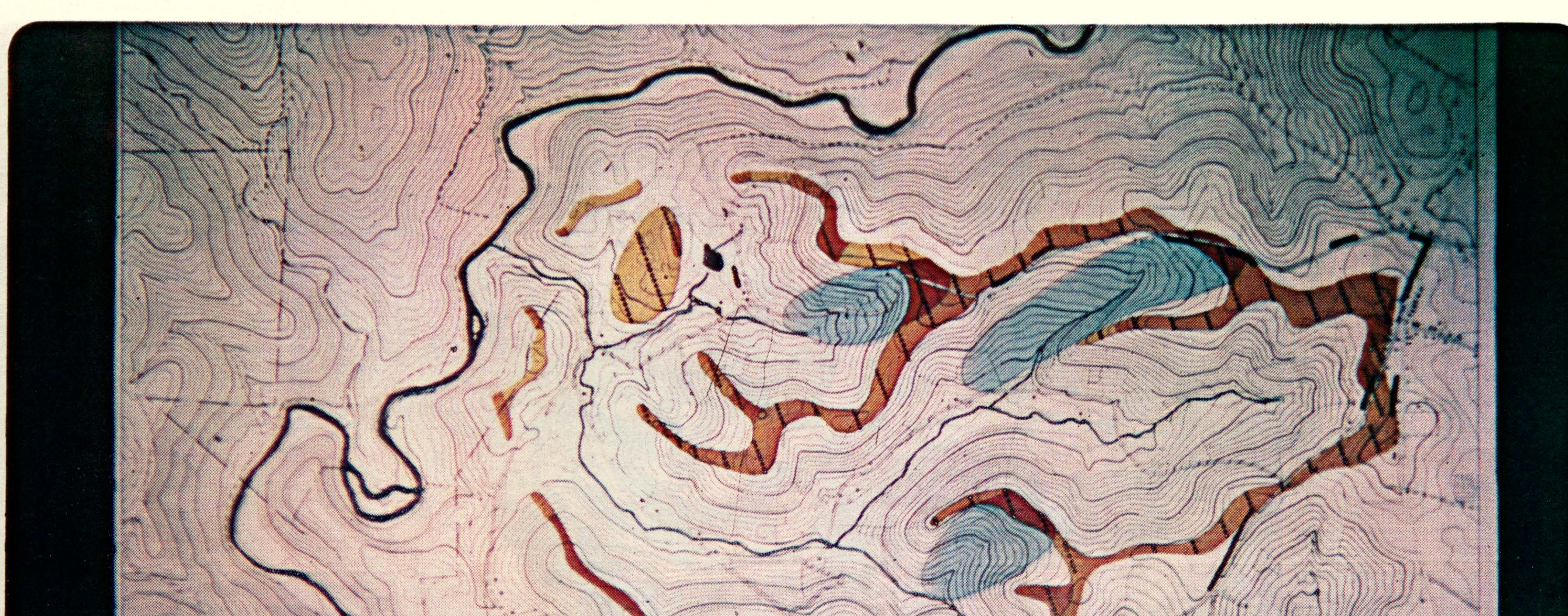
.012 hp per 100 horizontal feet
.028 hp per 100 horizontal feet

Slide 11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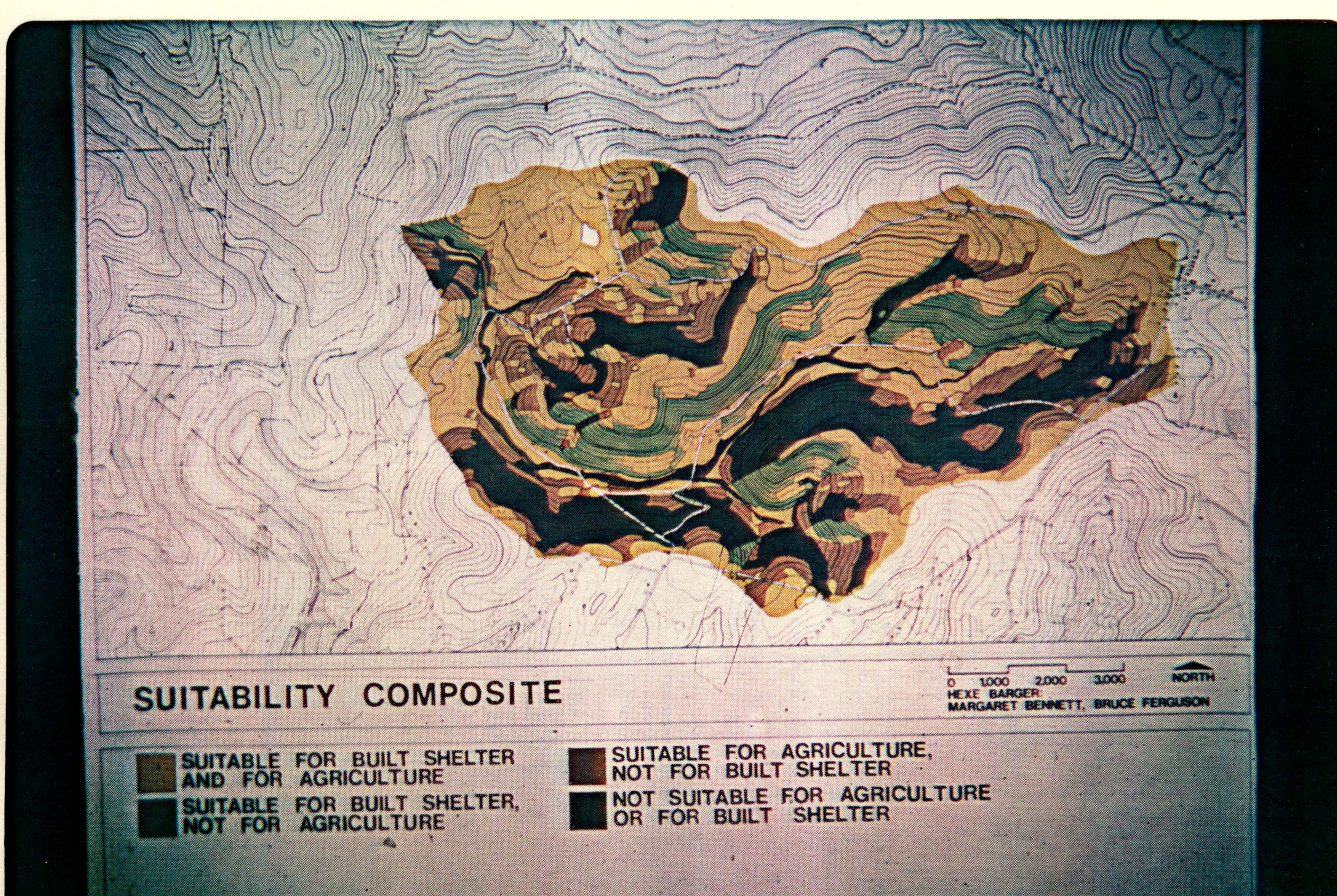
7 mph
8 mph
9 mph
10 mph
TOPOGRAPHIC BOWL FACING WEST-SOUTHWEST
EXISTING SNOWFENCE
SURFACE WATER
MAXIMUM EFFICIENT WINDMILL ARRAY

Slide 12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SUITABLE FOR BUILT SHELTER AND FOR AGRICULTURE
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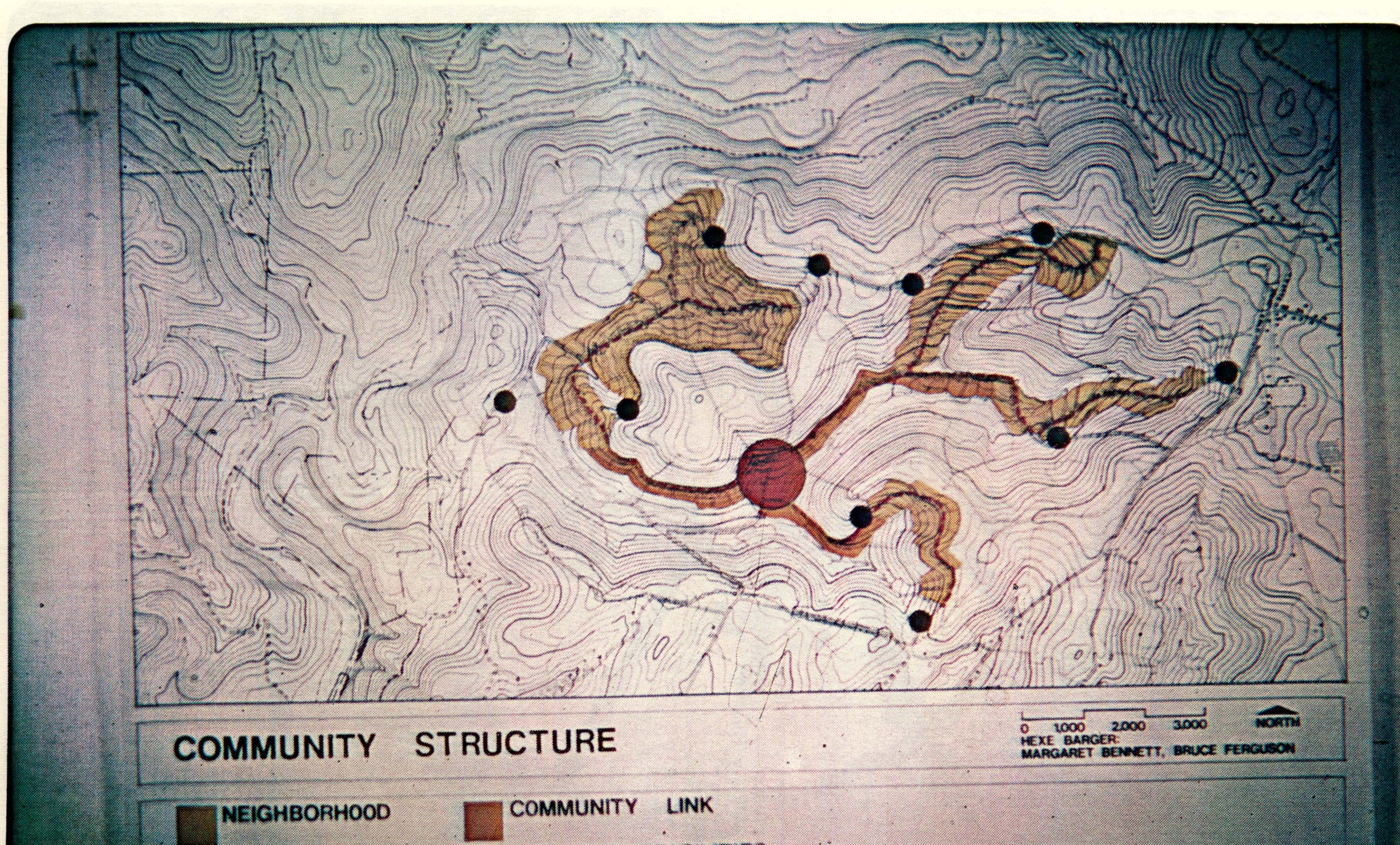
Slide 13



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HEXE BARGER:
MARGARET BENNETT, BRUCE FERGUSON
NEIGHBORHOOD
DAIRY BARN
TIMBER SHED
COMMUNITY LINK
COMMUNITY FACILITIES

Slide 14

Slide 18

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