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Options for Passive Energy Conservation in Site Design

MASTER

June 1978

Prepared For
U.S. Department of Energy
Assistant Secretary for
Conservation and Solar Applications
Division of Buildings and Community Systems

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June 1978

Prepared by
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For
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Assistant Secretary for
Conservation and Solar Applications
Division of Buildings and Community Systems
Washington, DC 20545

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Abstract

There is a traditionally recognized and scientifically calculated comfort zone for the human body. Throughout history man has either moved to a climate which is either closer to that comfort zone or has altered the environment to bring it close to that comfort zone. In the past man has built and designed to take advantage of the natural heating and cooling potential of the sun or wind. With the advent of modern technology man has been able to create, with the expenditure of vast amounts of energy, nearly ideal interior environments, regardless of the outdoor climatic conditions.

At a time of concern for energy supplies and costs it is essential to examine the energy conserving potential of once again using natural energy systems and patterns which exist on any site on which a building is to be or has been placed. This is a state-of-the-art study examining the existing research and existing applications of land planning and design for energy conservation purposes. It is organized around the basic principles of natural heating and cooling factors and the impact of site elements on human comfort, the regional adaptation of these principles, the steps in the site planning and design process and what energy conservation options are available in each of the steps. This is supplemented by an appendix and a bibliography of additional references.

The principles of site planning and design for energy conservation deal with the impact of the sun and wind on natural elements and conversely the ways in which landforms, water and vegetation affect the impact of the sun and wind on limited sections of the earth. For instance, the sun is able to naturally warm certain slopes more than others, certain surface materials naturally accentuate the warmth of the sun, while certain naturally occurring elements, such as vegetation, block and control the sun. The wind moving over the earth's surface has certain natural directions, patterns and characteristics. By recognizing these and by introducing or removing impediments it is possible to modify these patterns to provide natural ventilation and to conserve energy.

Four commonly accepted climatic regional divisions were utilized to illustrate the differing applications of these principles in the temperate, hot-humid, hot-arid and the cool regions of the continental United States. The typical site planning or design process was superimposed over each of these regions to illustrate the various energy conservation options which were possible depending upon the precise decision made in each step in each region.

Introduction

Almost all human cultures in modern society build with forms and in places with only a minimum of concern for the natural processes of the sun or wind which can heat or cool naturally and inexpensively. Modern technology enables human beings to make any area, whether in the desert or in the arctic, liveable and comfortable through the use of artificial and energy-intensive heating, air conditioning or humidity control. All of this is done, however, through the expenditure of great amounts of scarce and expensive energy.

In any discussion or study of energy conservation in any manner or form, it is essential to consider the potential of optimum site selection, building siting and orientation, and site planning and design, as a primary means of conserving energy. The underlying premise for this particular study is that a maximum response to or recognition of existing site conditions, processes and factors will result in optimum and less expensive energy conservation measures than can be achieved by any other means.

The conceptual approach in dealing with this premise entailed a state-of-the-art study of options available for passive energy conservation in site design in each of the climatic regions based on available data, research and case studies. This study is not concerned with new original data formulation or with field testing or evaluation of existing material or research techniques. The concept of the study was predicated on the fact that much had been gathered or written in the past in relation to the climatic impact of site elements, or orientation or siting of buildings. These studies were often done in many other fields and were not directly applied to energy conservation at the time they were done or since that time. These materials have not been readily available to those now making decisions on site design or planning for energy conservation. The concept here was further expanded to assume that there were a number of studies either under way or recently completed in offices, agencies or organizations, which were not generally known to a larger audience of potential users. In addition it was felt that there would probably be actual projects either under way or completed which could be used as illustrative case studies with lessons to be conveyed to other designers, builders, developers or administrators.

The process utilized to express this concept was as follows:

1. The gathering of already existing research through a literature search and contact with associations, trade and professional associations, and with agencies, institutions and offices;
2. The location of existing studies, projects or case studies, either under way or recently completed, dealing with land planning for energy conservation;
3. The development of basic general principles for land planning or site design based either on existing research or on exemplary projects or case studies;
4. The utilization of the typical site planning process to show where in the process the optimum energy conservation decisions may be made;
5. The theoretical application of these principles and this process to each of the four major climatic regions in the continental United States;
6. The illustration of the application of the basic principles in the regions through actual case studies which were discovered during the course of research on the project;
7. The graphic depiction, where possible, of ideas, concepts or applications in order to make these comprehensible to an interdisciplinary audience more accustomed to graphic than verbal communication;
8. The provision for additional research opportunities and options through a review of existing literature, as well as the provision of a bibliography on the subject.

Thus this summary report of the state-of-the-art study is organized in three sections. The first part deals with the general guidelines for site design and energy conservation. This section deals with the relationships between the sun and wind, landforms, water and vegetation, and the resultant climate control options. The second part of this summary document deals with regional site design guidelines. In the cool and temperate regions it is often more important to conserve energy by curtailing heat loss and by utilizing passive solar energy during the extended winter season. In the hot-arid and hot-humid areas it is possible to conserve energy by utilizing natural cooling through solar radiation control and by increasing and directing the natural cooling effects of wind flow. Therefore the site planning and design principles for each of these regions are distinctive and are treated in some detail in the text. The organization of the presentation for each of the regions is standardized, dealing with the:

- climatic characteristics
- design criteria
- gross site selection guidelines
- discrete site selection guidelines
- design guidelines
- use of natural and man-made elements

This allows for relatively easy cross reference and comparison between the individual regions. The material in the appendices is divided into six parts. These are:

- Appendix A—a comparison of the sources and topics in a review of literature on the subject
- Appendix B—data abstracts of much of the pertinent material on the subject
- Appendix C—a review of the measurements and quantification of the relative effectiveness of site design to assist in energy conservation
- Appendix D—policy suggestions either proposed or implemented in some location to assist in land planning for energy conservation
- Appendix E—suggestions for further research which could or should be implemented by a variety of organizations and entities in time to come in order to provide an adequate data base for informed and rational future design activities
- Bibliography—this is a listing of books, reports and periodicals dealing in some way with land planning and site design to conserve energy.

This publication is a first attempt by a major government agency to deal with gathering data of potential use to a wider audience of designers and decision makers. Due to time and resource limitations it has shortcomings and inadequacies. It is one more link in an information chain that stretches far into the past and hopefully will be continued far into the future by others with a need for such information.

State of the Art

Options for Passive Energy Conservation in Site Design

OPTIONS FOR ENERGY CONSERVATION IN SITE DESIGN

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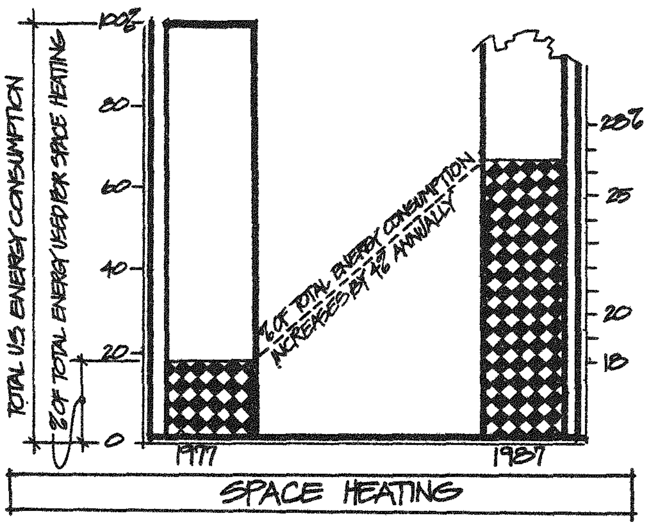
PART I
CLIMATE & ITS VARYING EFFECTS

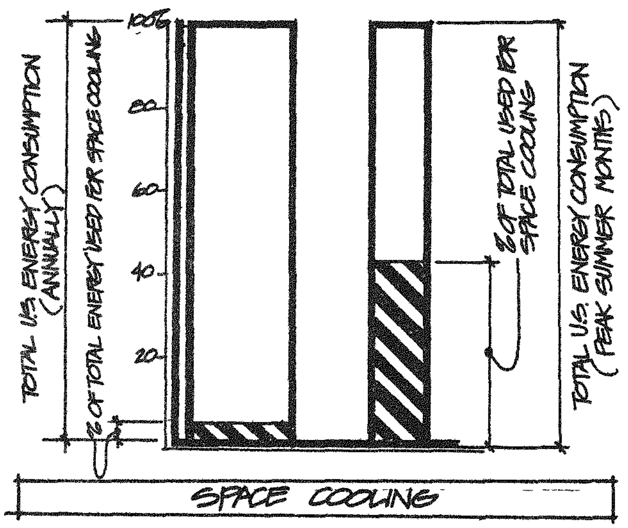
INTRODUCTION

The premise of this study is that maximum response to existing natural site conditions will result in energy conservation. This premise is based on the following factors identified during data collection.

ENERGY CONSUMPTION FOR SPACE HEATING & COOLING IS SIGNIFICANT



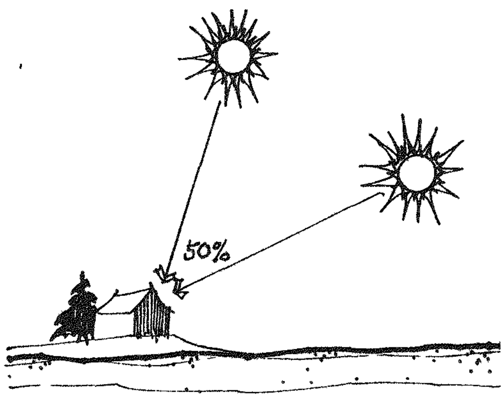
Almost 18 percent of the national consumption is used for heating residential (11 percent) and commercial (6.9 percent) buildings. The annual growth rate of fuel consumption for space heating is 4 percent (AIA 1974 p61).



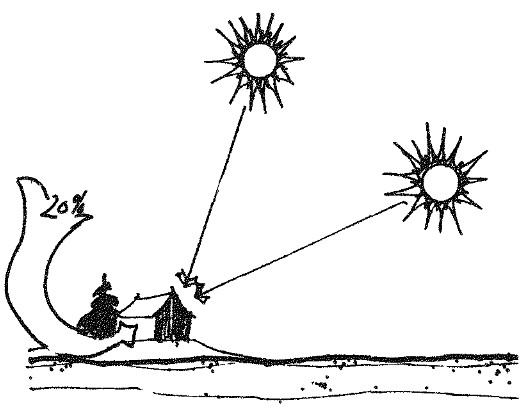
While only 3 percent of the total national energy consumption is used for cooling, energy consumption for interior space cooling during the hot months is 42 percent (AIA 1974 p.75).

NATURAL CLIMATE CHARACTERISTICS DETERMINE HEATING & COOLING REQUIREMENTS

Temperature, radiation and wind effects are the most significant natural conditions which have an effect on heating and cooling requirements of structures in the four major climatic regions of the United States. How warm or cold you feel in a room depends about half on the air temperature registered on your thermometer, and half on the temperature of walls, ceilings and floors not shown on your thermometer at any time of year.



The material forces that heat and cool your walls, ceilings and floors are the sun and wind. The sun's radiant heat effects are present in both summer and winter, both day and night. Sun radiation is responsible for half of the interior heat of a structure.



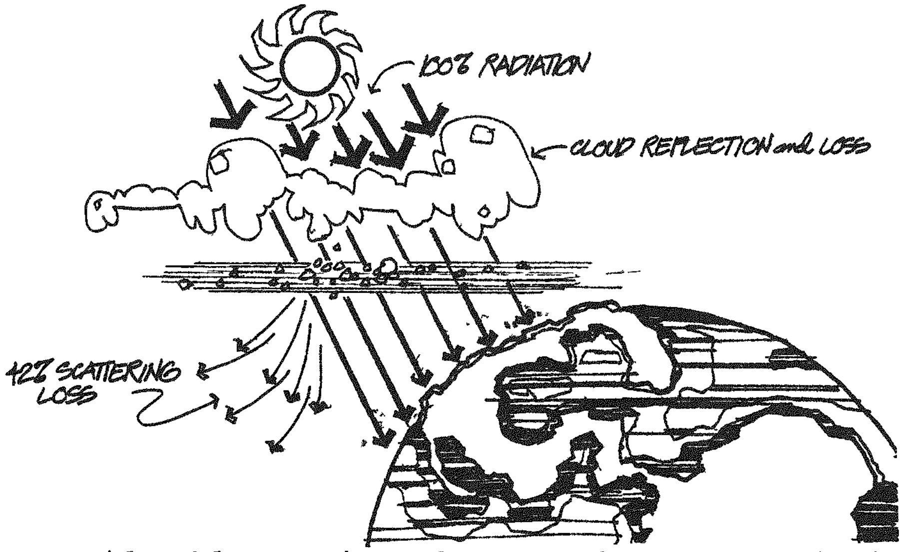
The wind velocity and pattern follow the same seasonal variation. The cooling effect of wind can contribute to as much as 20 percent to the interior cooling of a structure. The objective of site design for energy conservation is to respond to regional and site specific sun and wind patterns on a daily and annual basis. The goal of site design for energy conservation is to utilize or diminish these heating and cooling effects as desired.

As the above statements reflect, and as our common sense tells us, the main concern of people in the design and use of shelter is the requirement of human beings to maintain a desired level of comfort--neither too hot nor too cold.

In surveying data on climate, human comfort and design, the basic picture emerges that the primary considerations are sun and wind and the varying requirements for heating and cooling which they create. For this reason, the first part of this study will provide a cursory summary of relevant principles of climate and the manner in which existing surface conditions (landform, water, vegetation and ground surface) create variations in climate. It will also examine the various techniques by which desired effects of heating and cooling can be created.

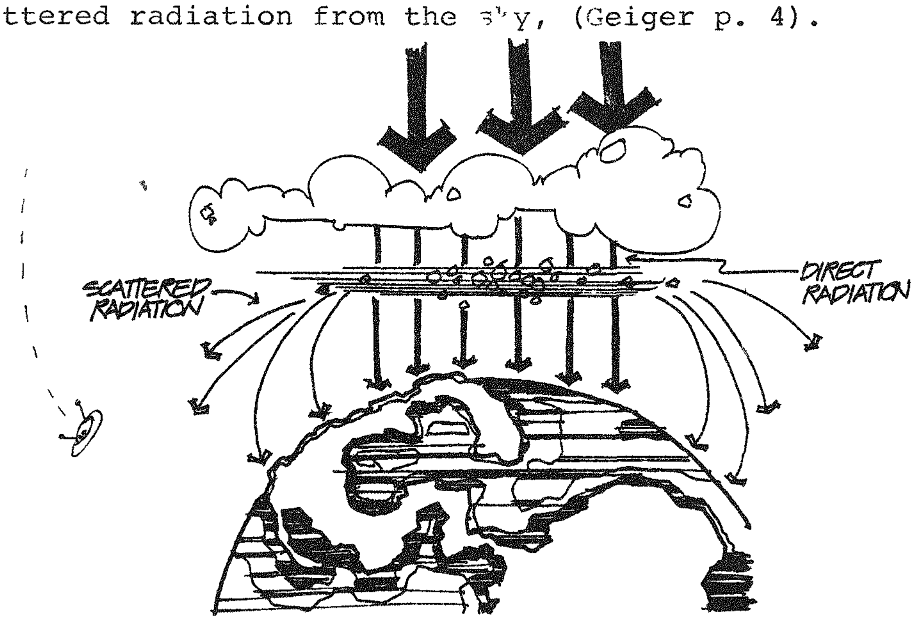
Sun and Radiation Principle

In considering sun and radiation, it is important to understand the type, amount and degree of radiation which has an effect of the earth's surface and on man. To begin with, sun and radiation are the main source of the earth's natural heat. However, not all of the suns radiation reaches the earth.

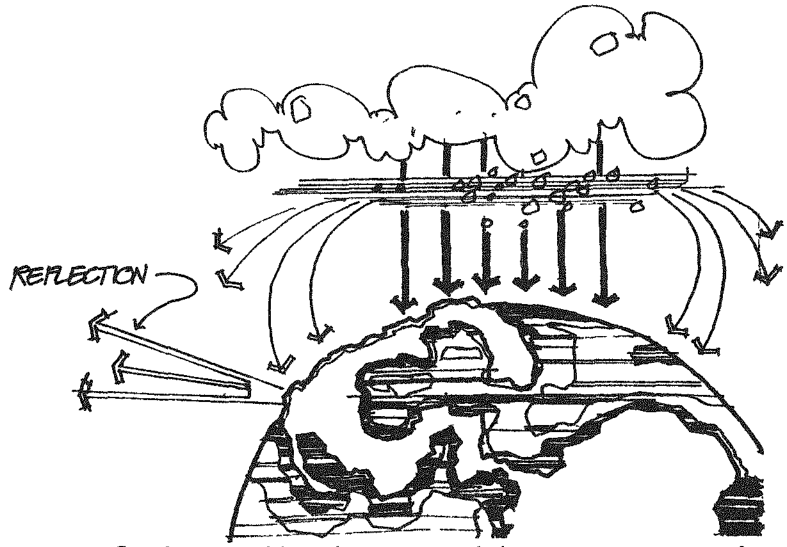


A considerable portion of the sun's total radiation (33 percent) is reflected by the surface of clouds and is ineffective for heating the air and the ground. In the atmosphere another 42 percent of the sun's radiation is scattered and diffused and deflected from heating the earth.

Finally, radiation is lost through absorption caused by ozone, water vapor and carbonic acid. Despite these losses, radiation does reach the earth's surface either as direct solar radiation or as scattered radiation from the sky, (Geiger p. 4).



Upon striking the earth's surface, a portion of the radiation is reflected from the surface and lost for heating purposes.

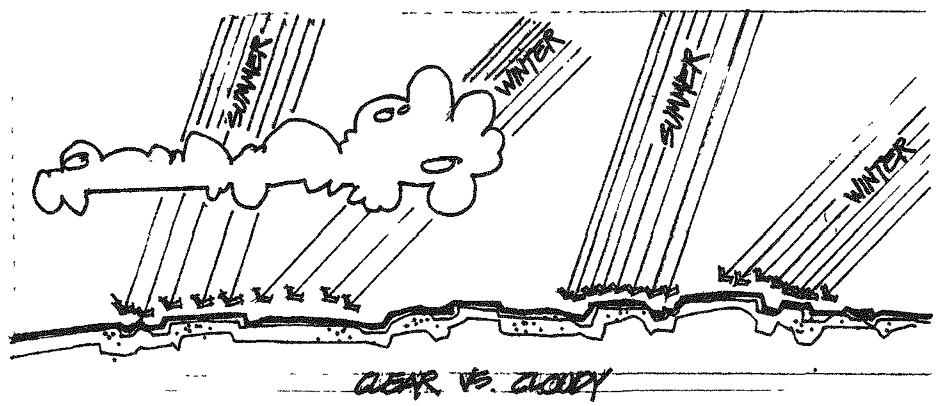


However, most of the radiation reaching the earth's surface is absorbed changed to heat and raises the temperature of the ground, the air and surrounding objects, (Geiger p. 4).

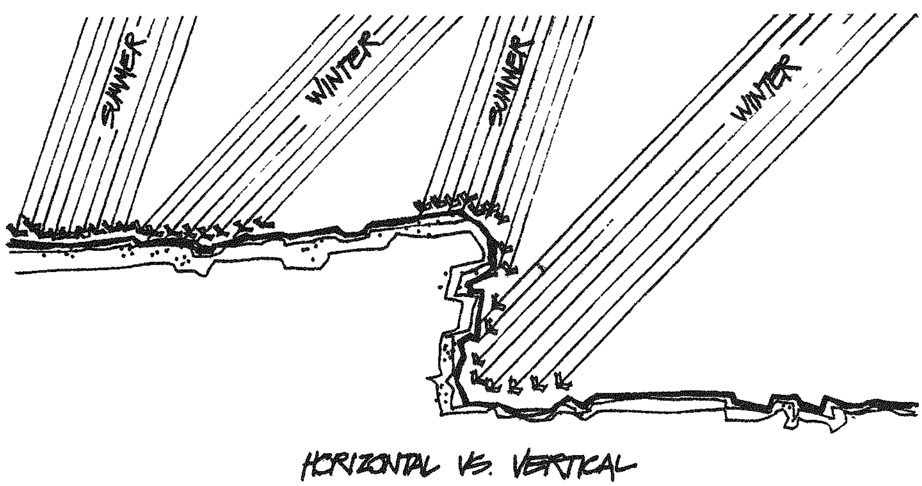
Ground temperature is therefore determined by the amount of heat which the ground surface absorbs while air temperature is indirectly determined by the amount of radiation which heats the air. Because this process occurs on a daily basis, the earth's surface and the air layer near the ground become significant areas where temperature control can be affected. In terms of its effect on human comfort and design, the earth's surface (partic--ularly during the noon day heat transfer) and its effects on the layer of air near the ground are the most significant factors. (Geiger p. 4).

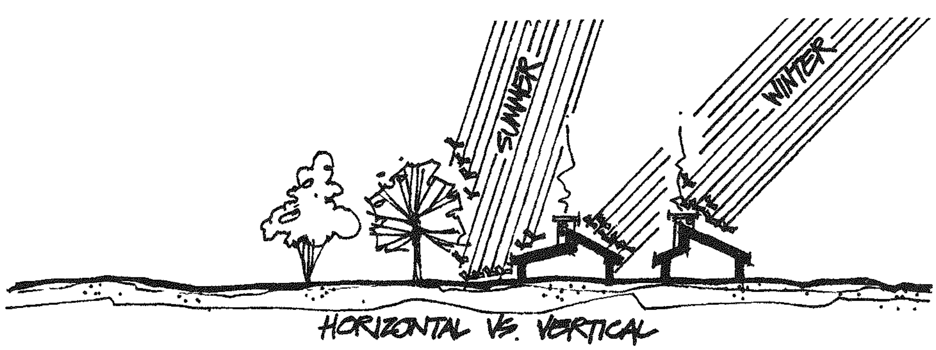
Classic climate studies have shown that variables affecting radiation effects on temperature are:

weather conditions: clear versus cloudy

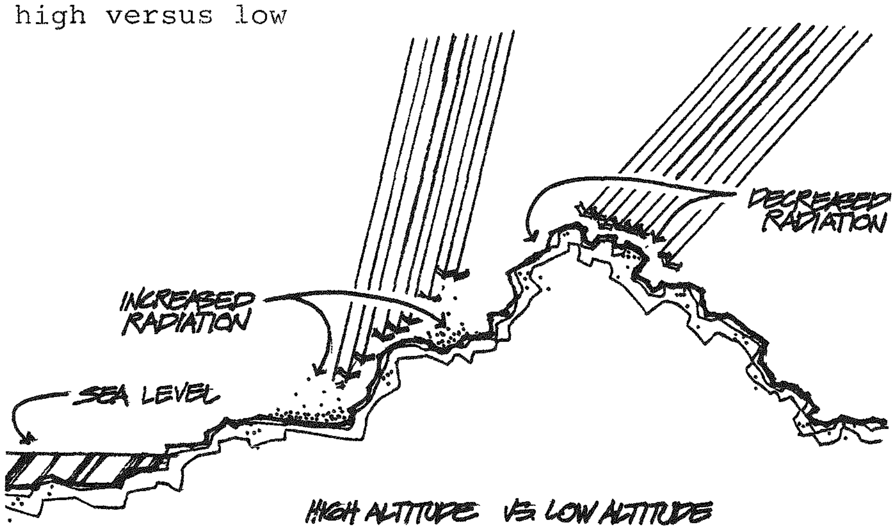


position of the surface: horizontal versus vertical





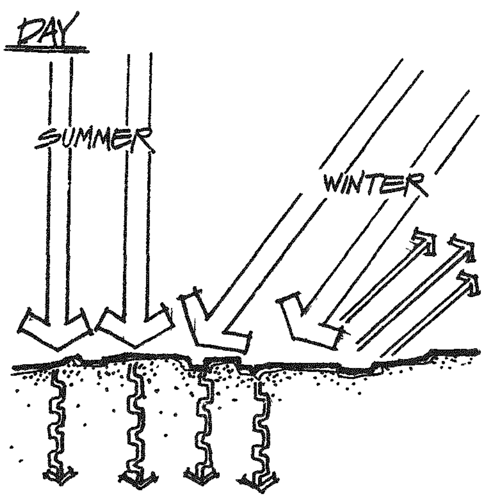
altitude: high versus low

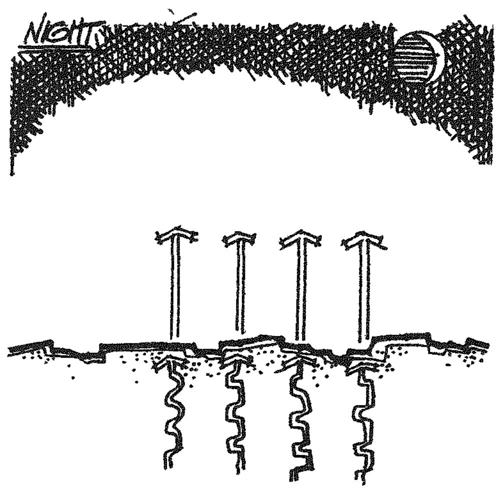


- solar radiation <u>increases</u> with altitude above sea level in the lowest air levels

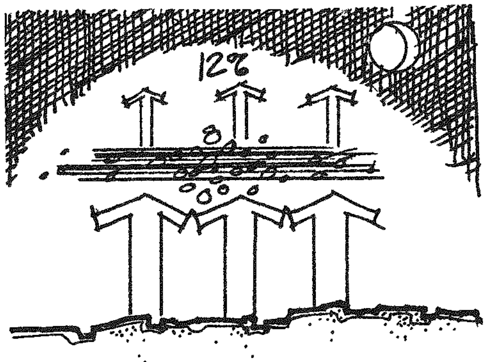
- however, solar radiation decreases with altitude above sea-level in the higher air level (Geiger p. 4)

So far we have looked at radiation patterns during the day, however, they should also be considered in terms of their night-time patterns. While solar radiation during the day is dependent upon incoming radiation from the sun and associated heat exchange with the ground surface and air. The process at night can be simply summarized as the reverse of the daily phenomenon. Most simply stated , heat exchange during the day is due to incoming solar radiation, while heat exchange at night is due to heat radiation from the surface of the earth (Geiger p. 14).

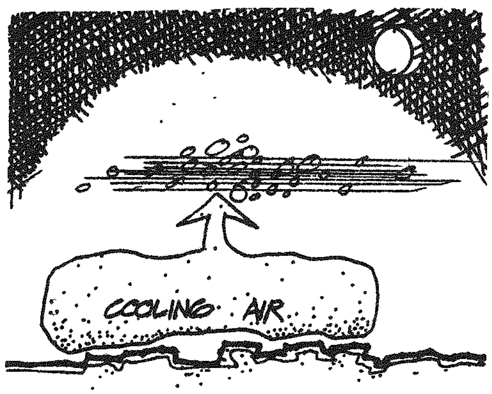




Just as with daytime radiation, certian variables affect nighttime radiation and can be summarized as follows:



radiation loss: The degree of nighttime radiation loss is affected by the atmosphere's water content. Only 12 percent of the evening radiation is lost to free space. The remaining radiation is absorbed by the various layers of air in a degree proportinate to their water vapor and carbon dioxide content (Geiger p. 14).

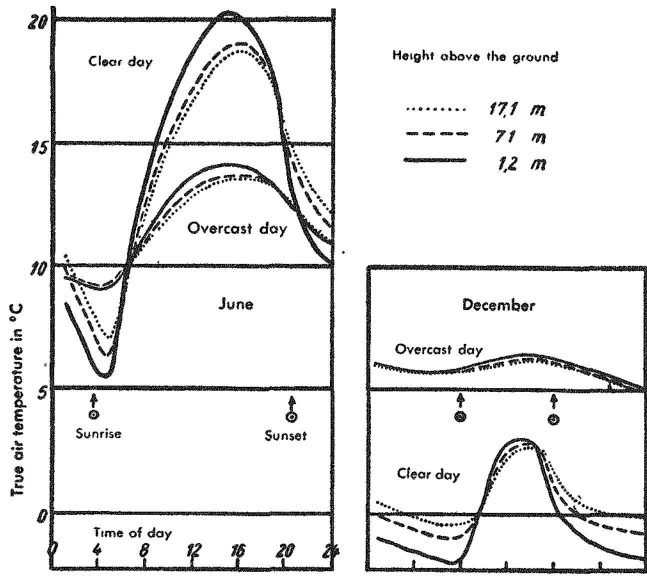


cooling: As hot air rises, the ground and air surface close to it begin to cool and cool the air mass above. This cooling extends vertically several hundred meters (Geiger p. 23).

The heat loss or cooling effect is greatest for the air near the ground and decreases with distance from the ground as the cold heavy lower air layers become trapped by warm lighter upper air layers. The significance of the dialy pattern of incoming (daytime) and outgoing (nighttime) radiation is due to its effect on daily and annual temperature patterns. Measurements on the effect of radiation patterns on temperature and shelter have been carried out by various classic climatic studies and can be summarized as follows (Geiger p. 63).

- increase of daily temperature range with approach to the ground is common to all macro-climates of the earth (Geiger p. 77).

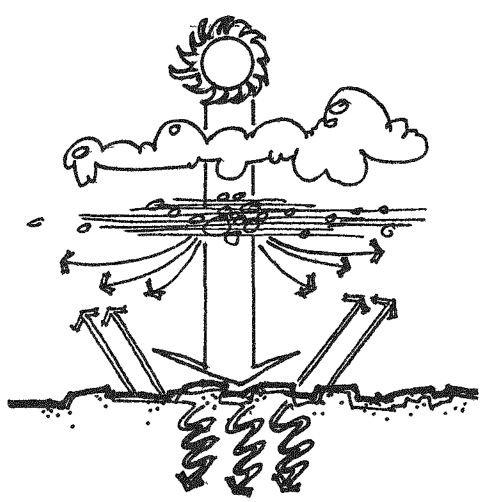
- cloudiness influences daily temperature according to the extremes of summer (June) and winter (December) as follows.



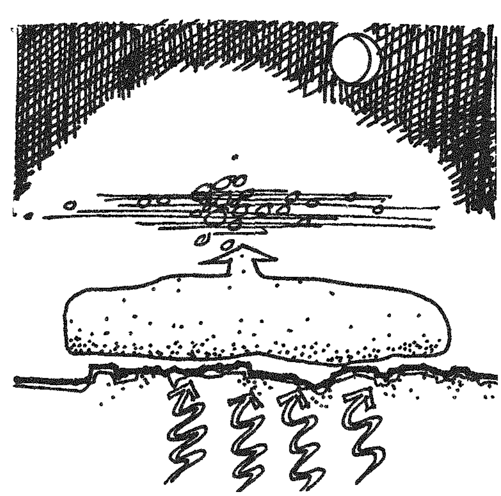
In summer: cloudy weather only slightly reduces temperature.

In winter: cloudy weather causes a rise of temperature while clear weather brings frost. (Geiger pp. 78-79.)

The varying changes of temperature and the effect of cloudiness on temperature are due to basic laws of physics. They explain heat transfer and radiation which affects climate in basically the same way in which climate affects the heating and cooling of structures.



radiation: every body emits radiant heat in accordance with its own temperature. Radiation during the day is a process of incoming radiation flow which causes heat gain. Radiation during the night is a process of outgoing radiation flow which causes heat loss.



The basic principles involved are based on molecular flow.

conduction: warm bodies give warmth to cold bodies and loose their own heat.

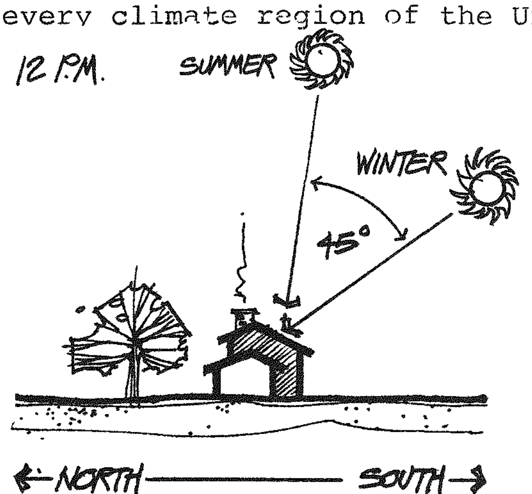
convection: masses of liquid and gas effect temperature change by displacement of the heat energy of their surroundings which they carry with them (Geiger p. 26).

Essentially, this is how exterior temperature causes structures to be heated and cooled. In the summer and winter, if radiation is permitted to enter a structure, it causes interior temperature to be raised.

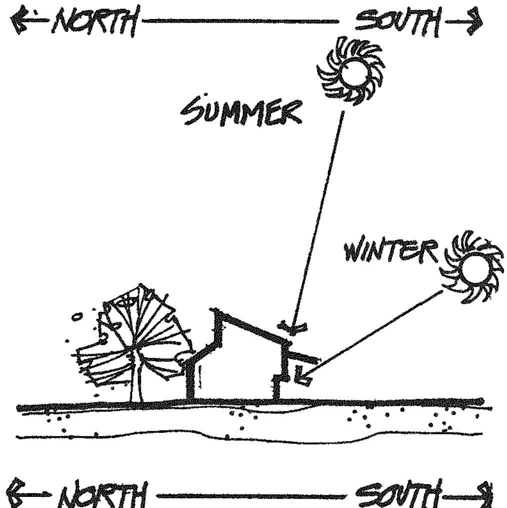
In order to understand the varying requirements of heating and cooling created by the sun and radiation, it is important to understand the manner in which radiation varies according to seasonal and daily requirements and existing natural conditions. These variations are summarized in the following section.

Radiation and Its Varying Effects

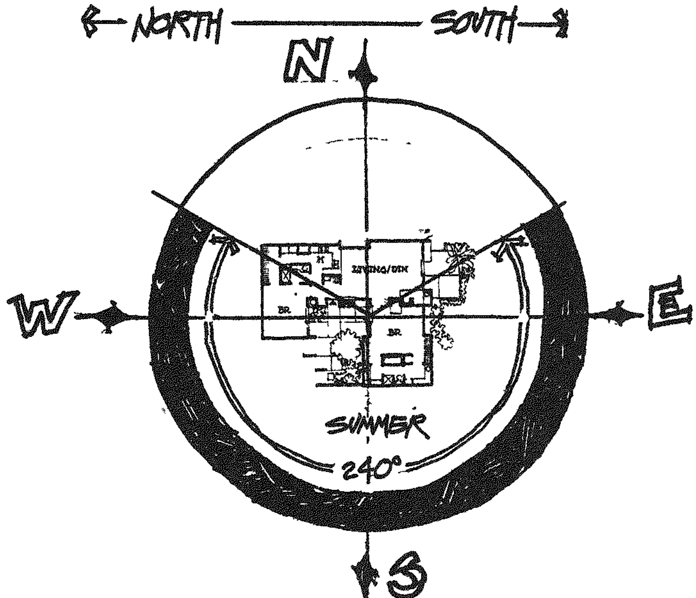
Though the specific characteristics and effects of radiation vary with different geographic regions and climatic zones of the United States, the following are variations which hold true for every climate region of the United States.



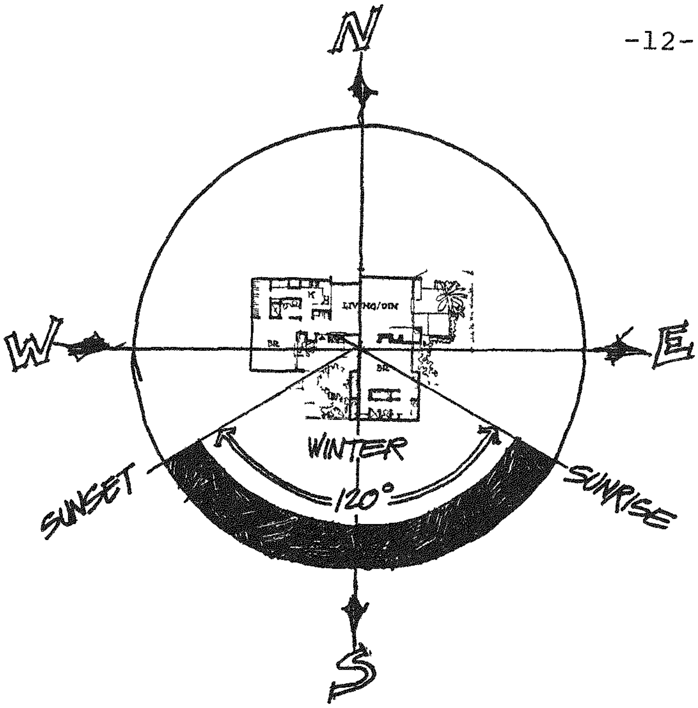
seasonal sun angle: the noon summer sun angle is 45 degrees higher in the sky than the noon winter sun.



The resultant effect on structures is that winter noon sun comes further into the interior of a structure, while the noon summer sun is easiest to stop. (Wright Oct.49, pp158-59).



seasonal path: in the temperate zone, the daily degree of the sun varies as follows: In summer, the sun path from sunrise to sunset is a full 240 degrees so that east to west facing surfaces receive more sun than the south or north. The horizontal roof surface receives a greater amount of radiation than all other sides of a structure. (Olgyay p.87)



In winter, the sun's path from sunrise to sunset is 120 degrees so that the greatest amount of sun is received on south surfaces (Wright p. 159).

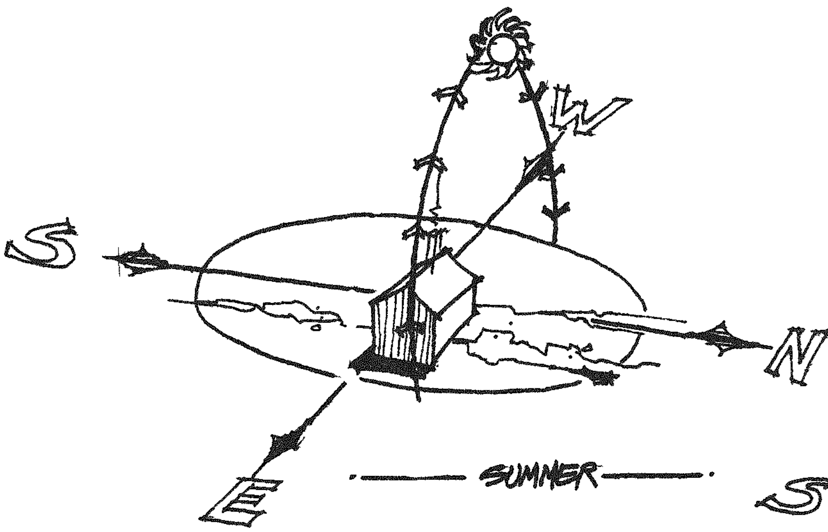
Site related implications of these variations are:

- slopes with southern orientations are always considered the optimum slopes for residential developments.

- site design for reduced winter heating requirements should optimize the winter south sun and minimize prevailing wind through siting, orientation and design of structures, activity areas, site circulation and site details.

- site design for optimum summer cooling effects should minimize the eastern and western sun and optimize cool breezes through siting, orientation and site details.

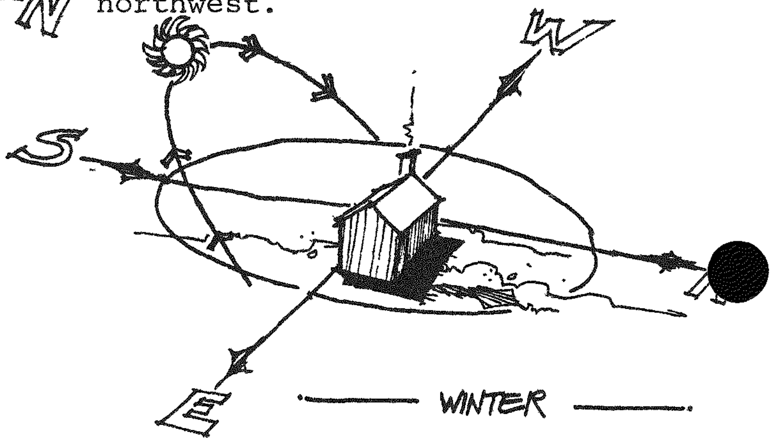
- for a year around balance, use southern sun and avoid western and southwestern sun (Wright p. 158).

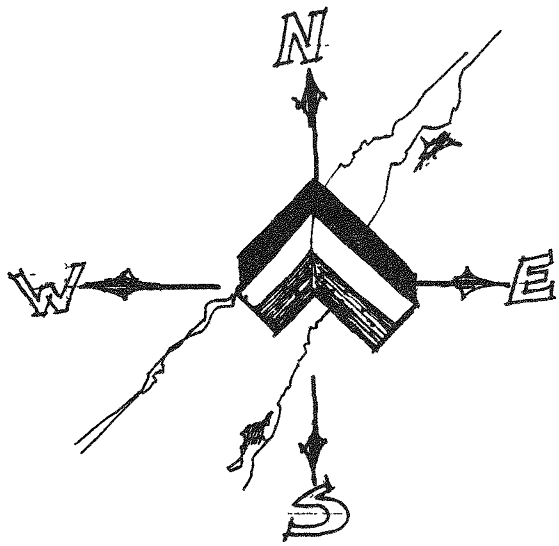


seasonal sunrise: the other variable is the daily pattern of sunrise and sunset which changes with the season.

In winter, sunrise is to the east, sunset is to the west.

In summer, sunrise is to the northeast and sunset to the northwest.





The significance of this data is applicable to the configuration and internal layout of structures, suggested form and orientation is an "L"-shaped plan with major windows facing southeast. (Wright Oct. 49 p.159)

Essentially these are the characteristics of the sun which combine with the natural factors of slope, water bodies, vegetation and ground surface to suggest desirable site characteristics with implications for design.

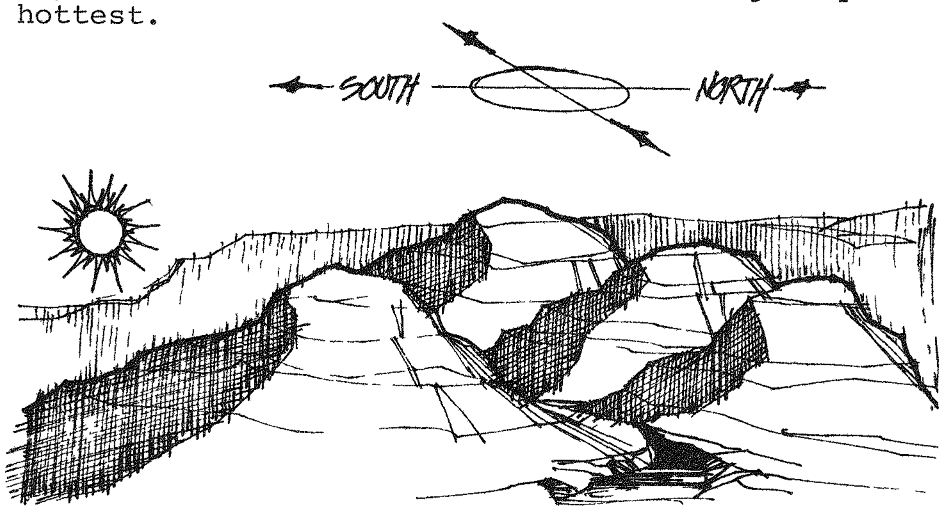
Radiation and Varying Surface Conditions

<u>TOPOGRAPHY AND LANDFORM</u>

During the day the topography has a great effect on climate in that the sun delivers different quantities of heat to sloping and flat ground. To what degree the ground is favored or on the contrary, depends on the directions and inclination of the slope, (Geiger p. 125).

While regional and site specific determinations frequently can only be made on the basis of sun angle calculations, radiation charts and climate data for annual diurnal variations, the following generalities about topography and radiation can be made.

Slope aspect or the direction of the slope in relationship to the sun is important for solar heat gain in every region of the country. On a year-round basis, south facing slopes are always the hottest.



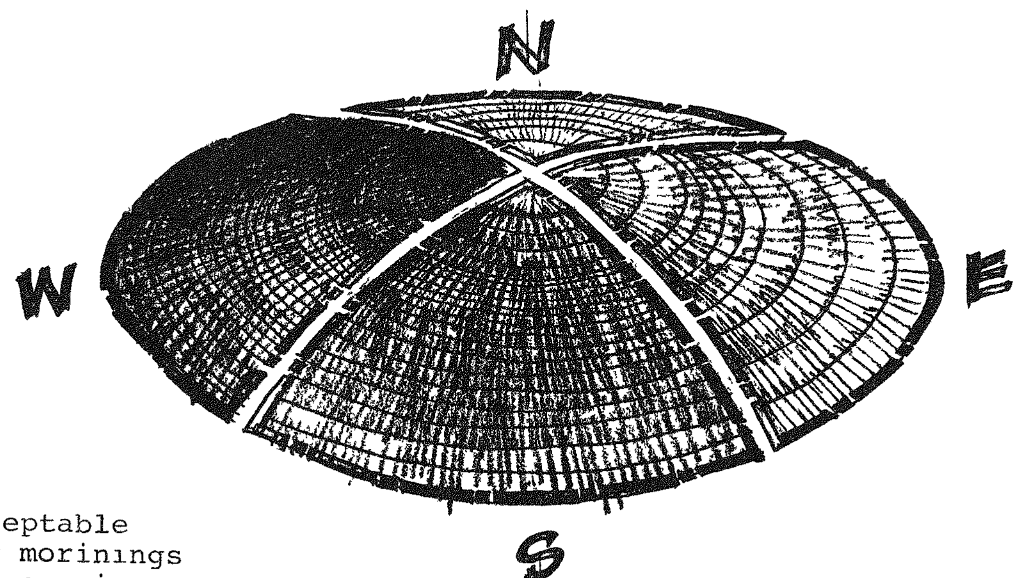
In summer

General slope characteristics for every region of the United States are as follows:

<u>southeast slope</u>: most desirable

<u>south slope</u>: preferred

- warm winter
- early spring
- late fall



east slope: acceptable
- warm winter morinings
- cool summer evenings

west slope: undesirable
- hottest summer slope

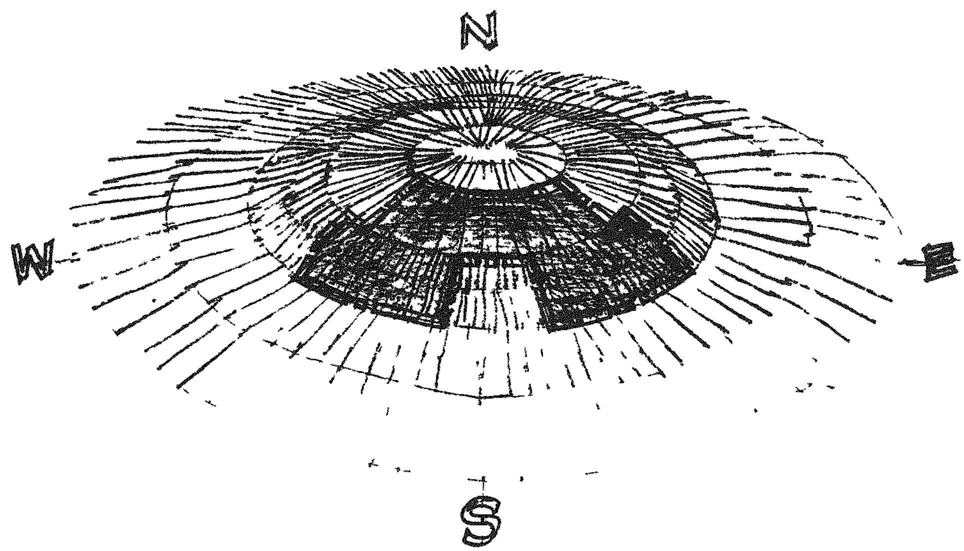
north slope: least desireable
- coldest in winter

* Measurement of Climate Modification

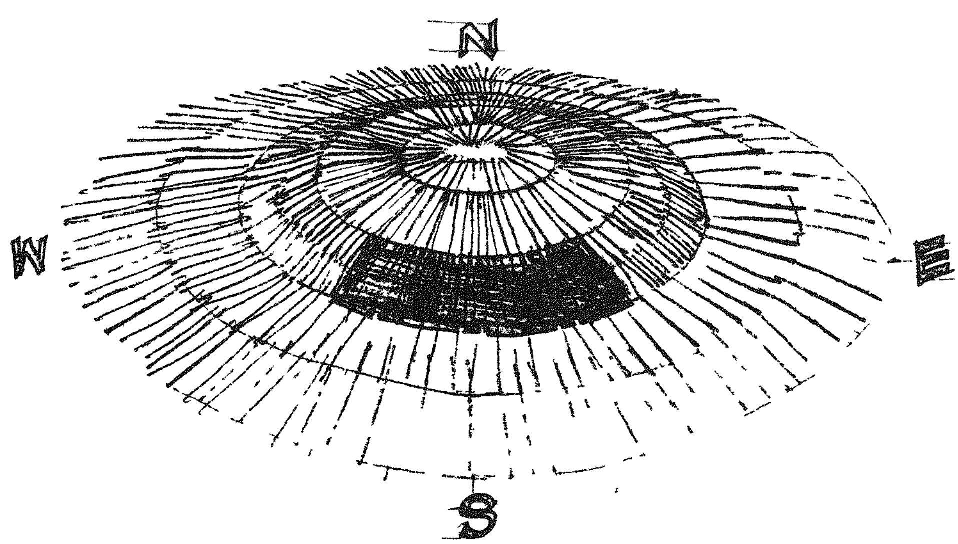
Studies in the New York-New Jersey region have measured the impact of radiation on slopes of varied orientation and degree of steepness in order to evaluate total radiation effect for site selection purposes.

Data surveyed indicates that preferred slope direction and gradient can produce the following extension of desired seasonal effect (Olgyay pp. 49-50).

Slopes of 10 percent gradient with south and southeast orientation receive 20 percent or more solar radiation and will be two weeks ahead of any other slope gradient or direction in the arrival of spring.



Slopes of 20 percent gradient with southern orientation receive 30 percent more solar radiation and will be three weeks ahead of any other slope gradient or direction in the arrival of spring.



SLOPE DIRECTION AND ANGLE

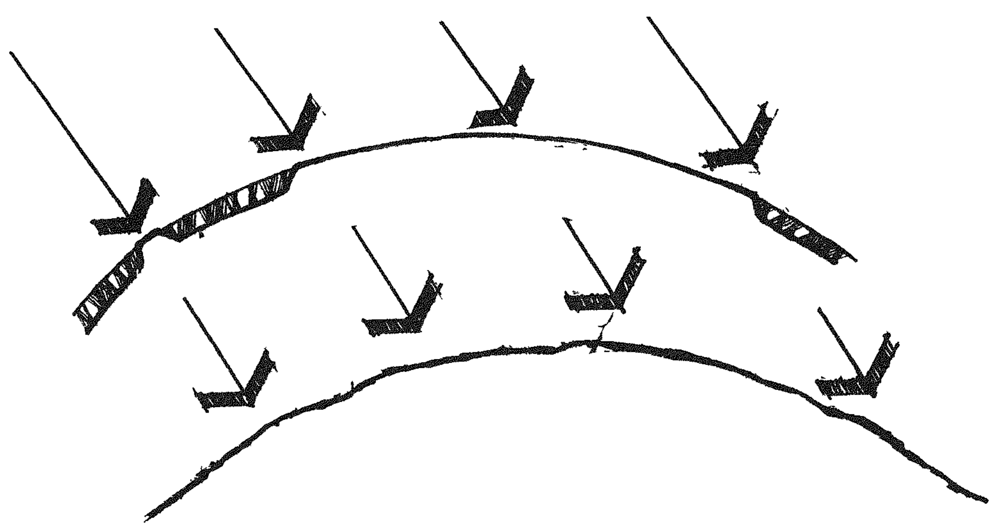
The amount of radiation received by topography depends on the slope of the land. Maximum direct radiation is received by a surface that is perpendicular to the direction of the sun. A site that faces the sun squarely receives more sun rays than one edgewise to the sun. For example, a 17½% slope at 40°N latitude on a cloudless day attains the following approximate percentage of radiation. (Lynch 68)

orientation	Midsummer	Equinox	Midwinter
North	95%	55%	15%
East or West	100	60	25
South	100	70	35

Difference in slope direction and angle can effect site micro-climate in the same way that differences in latitude effect the climate regions of the United States overall. Measures of effect on climate modification due to slope direction and angle are as follows:

Measure of Climate Modification (Langewiesche Oct. 49 p. 147)

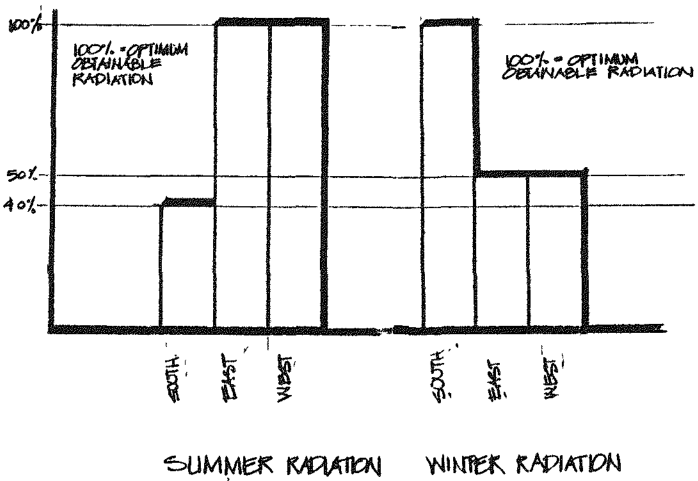
Ohio A south facing slope of 1:12 versus a north facing slope of 1:12 gradient can produce differences in site micro-climate as illustrated below.



The implications of this data are that slope direction and gradient do effect site micro-climate significantly.

REGIONAL VARIATIONS

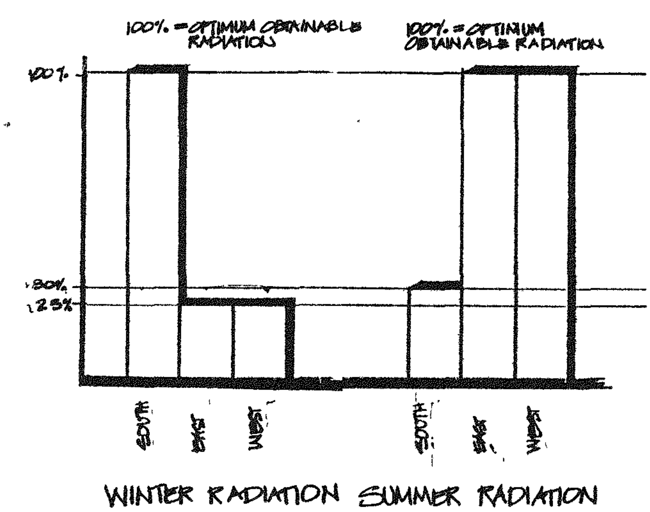
Dependent upon variation in regional climate and regional climate requirements, the following variations in radiation impact on vertical wall surfaces should be considered in siting, planning, and buffering structures.



Cool and Temperate Zone

In winter, south facing walls receive twice as much solar radiation as east or west walls.

In summer, east and west facing walls receive 2½ times the solar radiation of south facing walls. (Olgyay pp. 86-87)



Hot Arid and Humid Zone

In winter, south facing walls receive 4 times as mush solar radiation as east or west walls.

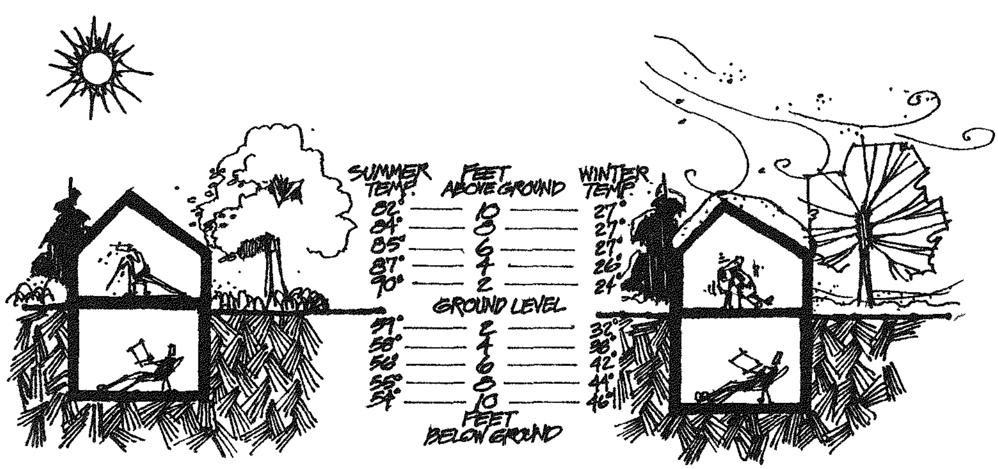
In summer, east and west facing walls receive 2 or 3 times as much radiation as south facing walls.

In the lower latitudes of this region, summer radiation impact is twice as great on north versus south walls. (Olgyay pp. 86-87)

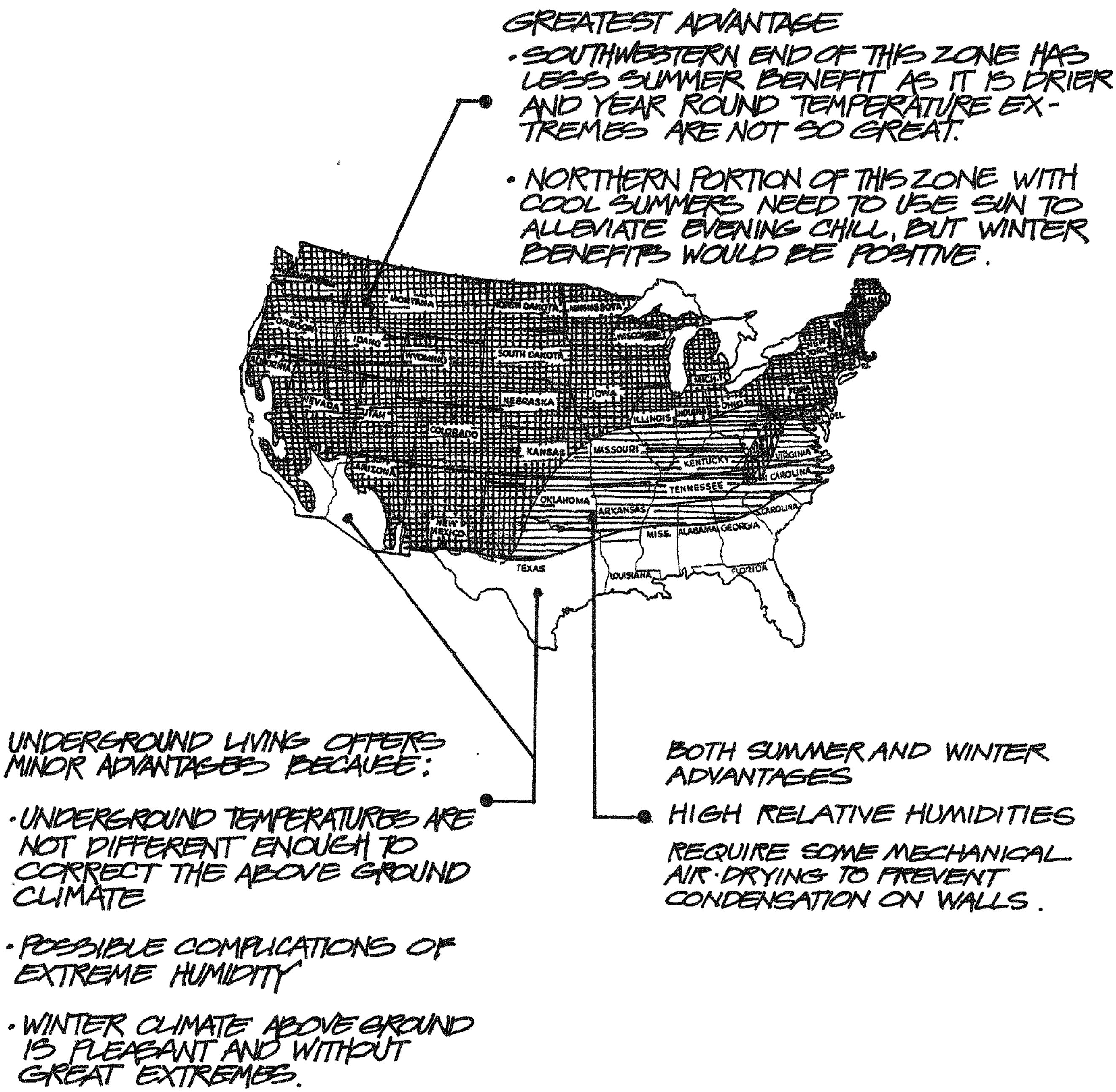
LOCATION ABOVE OR BELOW GROUND

As the discussion on radiation and ground surface indicates, radiation on the earth's surface is either absorbed into the ground or reflected into the lower air levels. An area of consideration is the correlation between temperature differences above and below the ground.

Classic studies on temperature and climate have shown that above ground temperatures are consistently hotter in summer and cooler in winter, while the reverse situation is true below ground, (Langewiesche, August 1950 p.92).



Weighing this data against other regional climate, a comparative analysis indicates the following regional suitability of completely or partially subterranean construction, (Langewiesche August 1950 p. 93)



SURFACE REFLECTIVITY

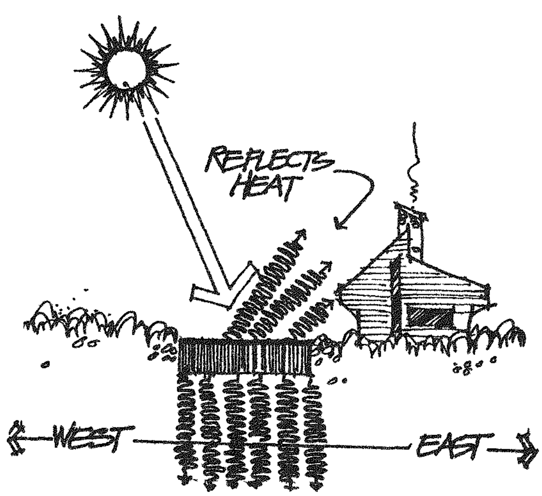
Another factor affecting radiation is the type of surface which the radiation strikes. Essentially, this characteristic involves two principles. One deals with the characteristics of sunshine, the other with the reflective characteristics of various materials. They can be summarized as follows.

sunshine: essentially the sunrays which affect the earth and its climate are of two types--ultra violet rays and infra red rays. Both of these types of rays are reflected by whatever surface they strike, however, infra red rays are heat rays, and have a greater impact on the surface they strike and should be considered more carefully (Wright Oct. 1949 p.153).

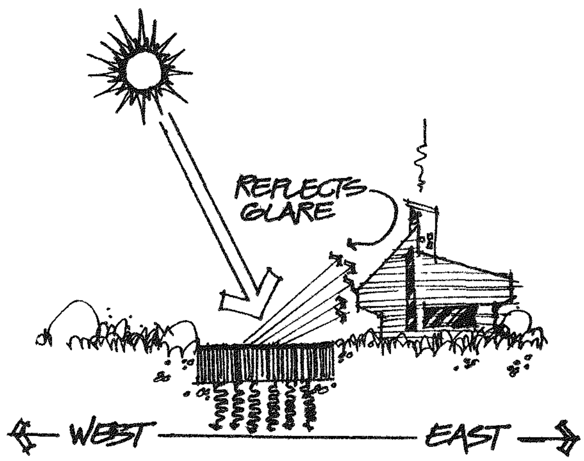
albedo: refers to the characteristic of any surface which reflects back, rather than absorbs radiation. Both natural surfaces, such as snow, water, earth, etc. and man-made surfaces such as asphalt,metal, etc. and surface colors possess varying albedo characteristics.

The interrelationship between radiation, albedo, and climate impact can be simply illustrated in the following example of the effect of varying surface paving exposed to western summer sun.

dark paved terrace: with a dark paved terrace on the west side radiation is absorbed by the paving while infra red (heat) rays are reflected against the house. This reflection heats the ground surface and the house's surface walls, windows and roof simultaneously. The result is undesired summer heat gain.



light paved terrace: with a light colored paved terrace, radiation is absorbed by the paving at a slower rate while glare is reflected against the house. While glare is undesirable for its effect on vision, heating impact is not so great.



Essentially neither situation is desirable. Instead, selection of a natural or man-made material which is exposed to intense sun should be based on the albedo of the surface. Extensive studies of albedo have identified the following characteristics of surface materials which should be considered.

Albedo for Visible Portion of Spectrum

Fresh snow cover	80-85%
Older snow cover (wet)	42-70%
Fields, meadows tilled soil	15-30%
Heath and sand	10-25%
Forests	5-18%
Surface of sea	8-10%

(Geiger p. 129.)

REACTION OF MATERIALS TO SOLAR AND THERMAL RADIATION

	percent of reflectivity		percent of emissivity
	Solar radiation	Thermal radation	Thermal radation
Silver, polished	93	98	2
Aluminum, polished	85	92	8
Whitewash	80	--	--
Copper, polished	75	85	15
Chromium plate	72	80	20
White lead paint	71	11	89
White marble	54	5	95
Light green paint	50	5	5
Aluminum paint	45	45	55
Indiana limestone	43	5	95
Wood, pine	40	5	95
Asbestos cement, aged 1 year	29	5	95
Red clay brick	29-30	6	94
Gray paint	25	5	95
Galvanized iron, aged (oxidized)	10	72	28
Black matte	3	5	95

(Olgyay p. 114.)

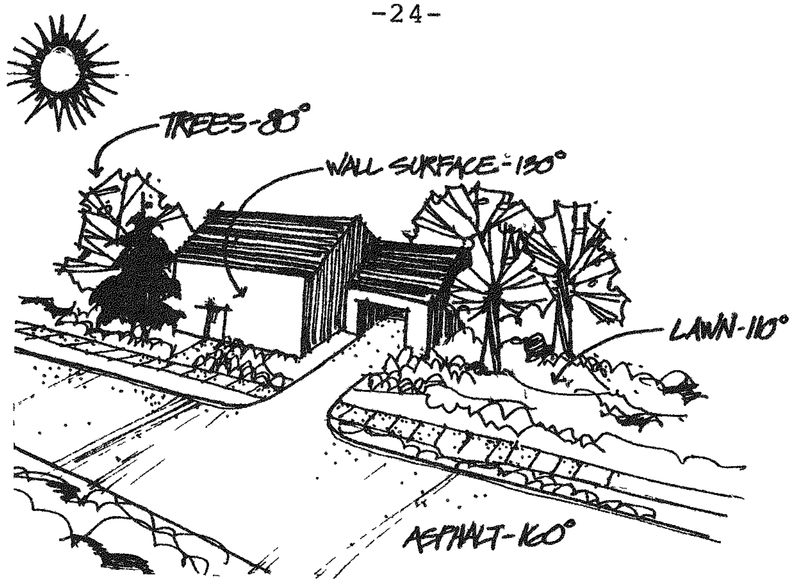
Other characteristics of surface materials related to reflection which should be considered are as follows:

moisture: the albedo of moist surfaces is less than that of dry surfaces (e.g. dune sand has an albedo of 37 percent when dry, but only 24 percent when wet). (Geiger p. 129.)

position: roughly twice as much radiation falls on a horizontal surface during overheated periods than on a vertical surface. Horizontal surfaces reflect a large portion of heat into surrounding buildings during over heated periods.

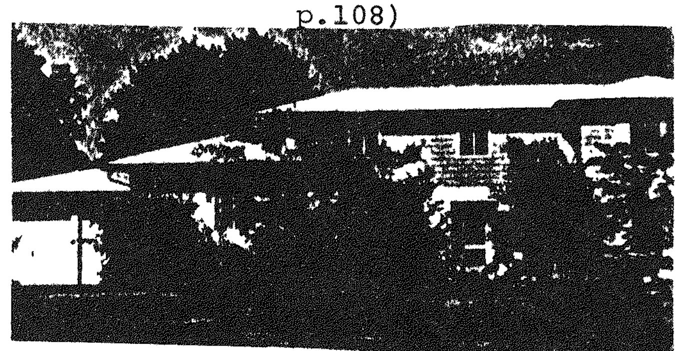
*Measurement of Temperature Effect

surface temperature variation: exposed to the same sun, varying surface temperatures have been shown in the following range. (Langewiesche Oct. 1949 p.192).

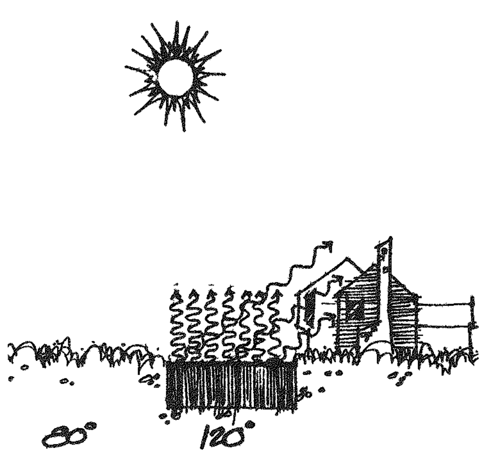


Material	Temperature	% Increase over minimum
Trees	80°	Minimum
Lawn	110°	38%
Wall Surface	130°	63%
Asphalt	160°	100%

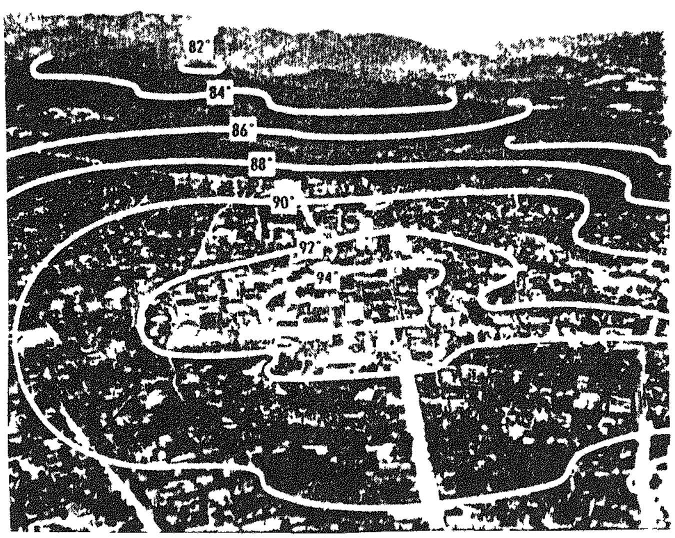
<u>grass surface</u>: 33 percent cooler than paving exposed to the same sun. Grass always keeps a constant temperature because the sun's heat disappears as fast as it hits green grass. You feel cool because you are radiating heat to the grass. (Langewiesche March 1950 p.108)



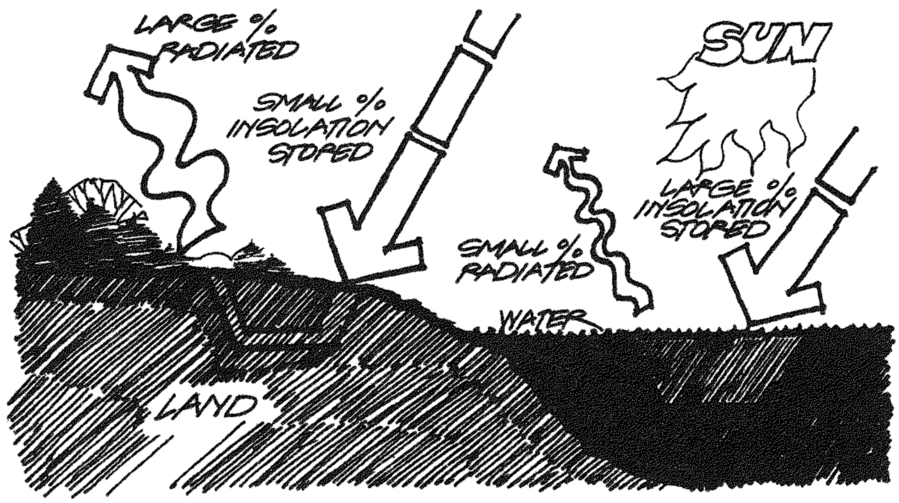
<u>White roof</u>: 10°-20° cooler than dark roof exposed to the same sun. (Langewiesche Oct.1949 p.152).



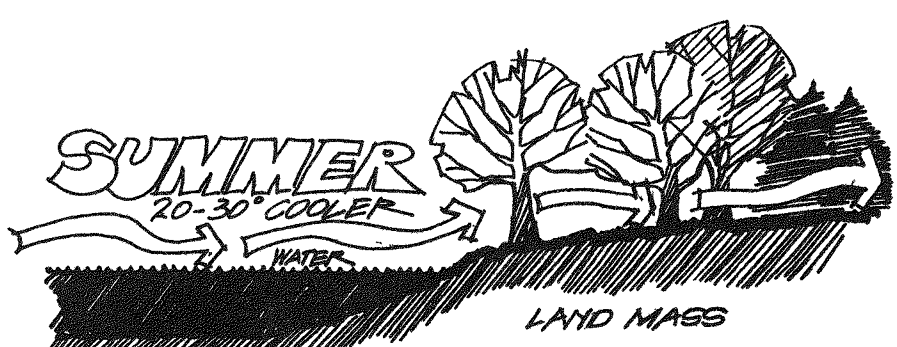
<u>regional climate variation</u>:
temperate difference between city and surrounding suburbs has been measured to be almost 13 percent less. (Langewiesche Oct. 1949 p.147).
Differences in temperature are due to the low albedo of suburban lawn and tree cover, as well as the greater absorption of solar radiation by urban pavement and buildings. Added consideration sould be given to the temperature differences created by the urban heat island phenomenon.

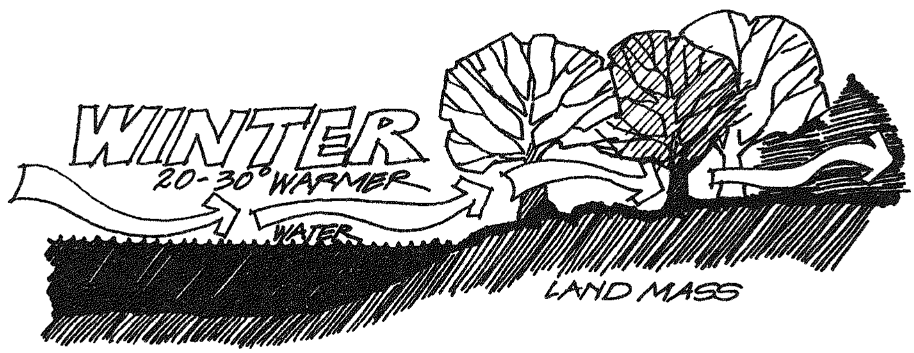


WATER BODIES: SURFACE ABSORPTION AND RADIATION



Water bodies store more insolated solar energy and radiate less energy than surrounding land masses. Proximity to water bodies has been found to moderate temperature extremes of adjacent land forms by raising winter temperature and lowering summer temperature. (Olgyay p. 51, ASLA p.61)





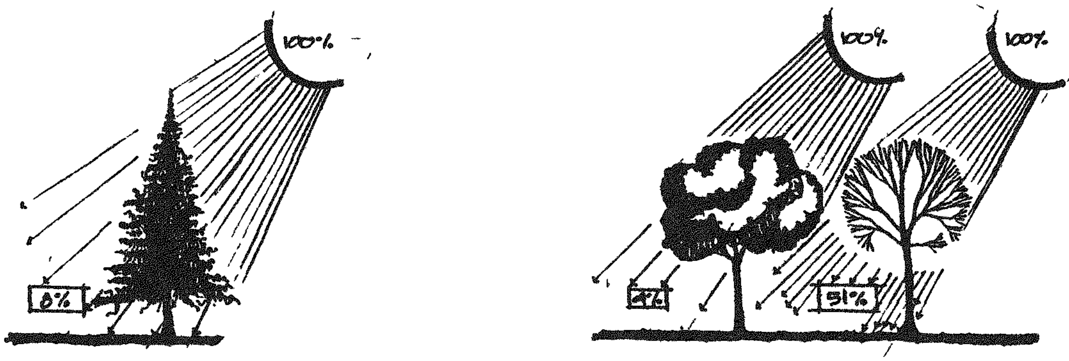
Water temperature variations have been identified in a range of 20°-30° difference for summer and winter. (ASLA p. 184.)

*Measurement of Climate Modification

Great Lakes Region (Olgyay p. 510)
Winter heat gain--5° F. average
Summer heat loss--3° F. average

Vegetation

Vegetation affects radiation by blocking direct solar radiation and reducing heat loads on exposed surfaces. Vegetation shades because plants absorb rather than reflect sunshine.



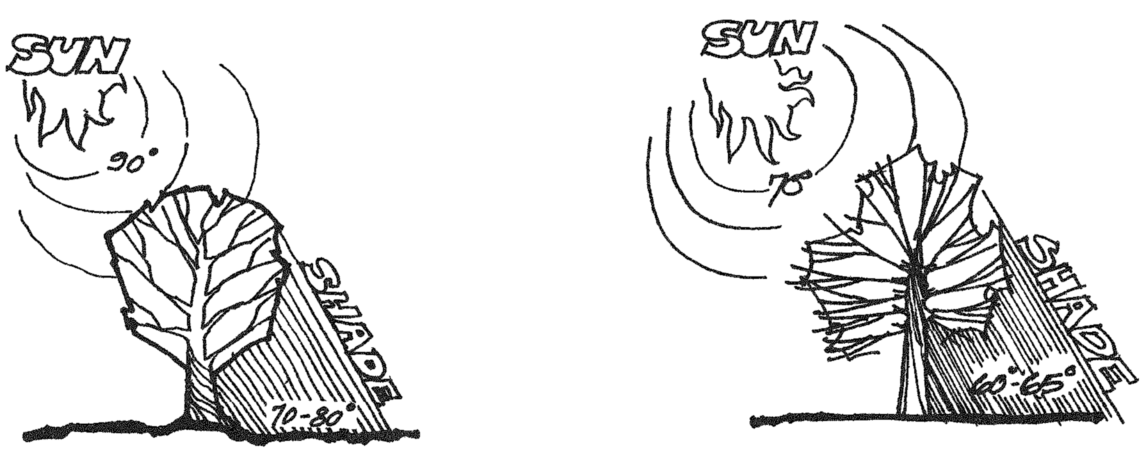
Vegetation can also improve summer micro-climate by filtering and cooling the air. (Davis and Schubert p. 43.)

*Measurement of Climate Modification

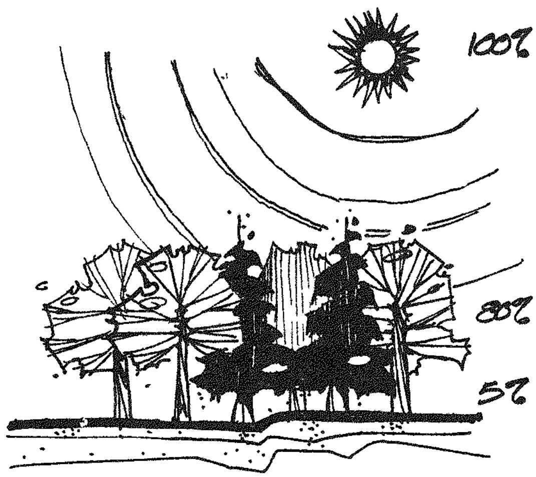
The measurement of vegetation as a tool for climate modification have been surveyed and is summarized as follows:

<u>degree of sun absorption</u>: Shading from trees can prevent as much as 70 percent of the sun's heat from being absorbed by the ground, and this combined with the trees' transpiration process will have a measurable effect on the air temperature around them. (Kerner p. 54.)

<u>effect on air temperature</u>: Air temperature can be cooled 10 to 20 degrees due to shading when the general temperature is 90 degrees.

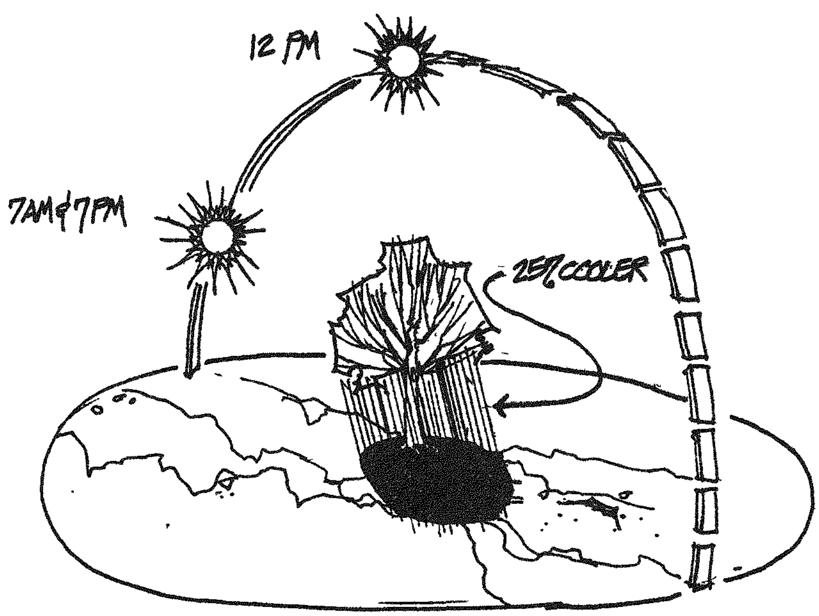


Air temperature can be cooled by 5 to 10 degrees when the general temperature is 70 degrees.



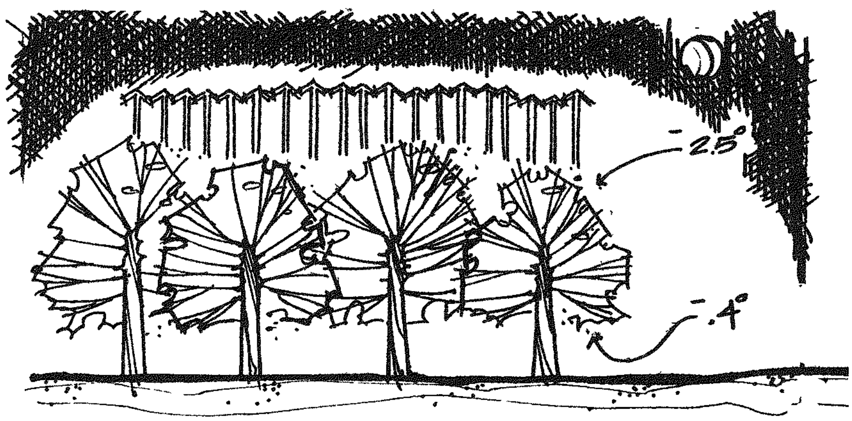
effect on ground temperature: In a forest situation 80 percent of the incident solar radiation is caught in leaves, needles, twigs and branches of vegetation, so that less than 5 percent reaches the forest floor during the day (Geiger p. 317).

cooling effect: During the day, the cooling effect of vegetation has been demonstrated as follows. At sunrise, it is coolest in the tree crown with a cool air layer maintained on the ground surface under it. For three hours, until the sun reaches noon level, the ground remains cooler and is not heated until radiation penetrates the entire canopy.

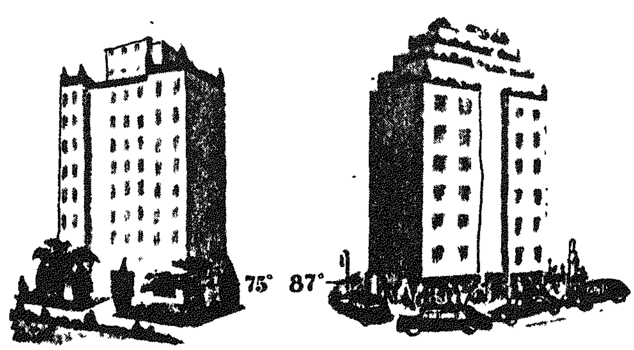


Observed temperature differences have shown the ground surface to be at least 25 percent cooler than the air above the crown (Geiger p. 333).

During the evening the outer surface of vegetation is the primary cooling agent and throws off the greatest amount of radiation. The outer surface is 2.5 degrees cooler than the surrounding air temperature and is almost 25 percent cooler than the lower part of the canopy (Geiger p. 325).



Other measured effects of vegetation on radiation and climate modification have been observed as follows.



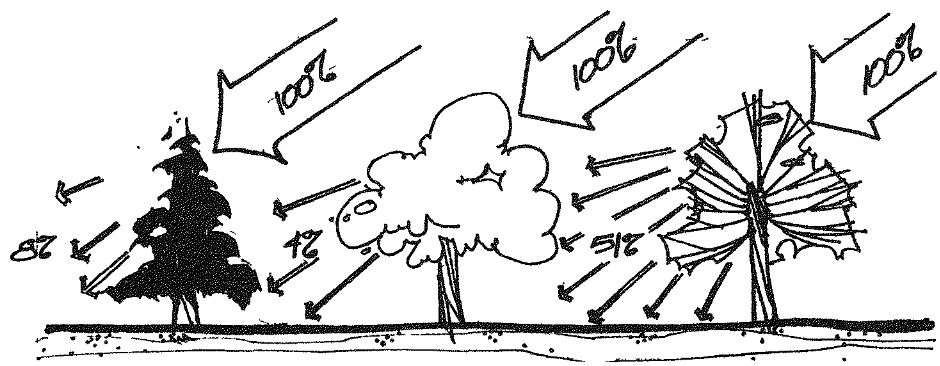
Cool Trees, Hot Pavements

Immediate surroundings of a house make a big comfort difference. Trees here kept ground from heating up. As sun sets, the house cools off soon, and lets you sleep. Bare pavements have heated up during the day. After sunset, hot pavements keep radiating heat at the house, keeping lower floors hot until after midnight (Langewiesche Oct 1949 p. 148).

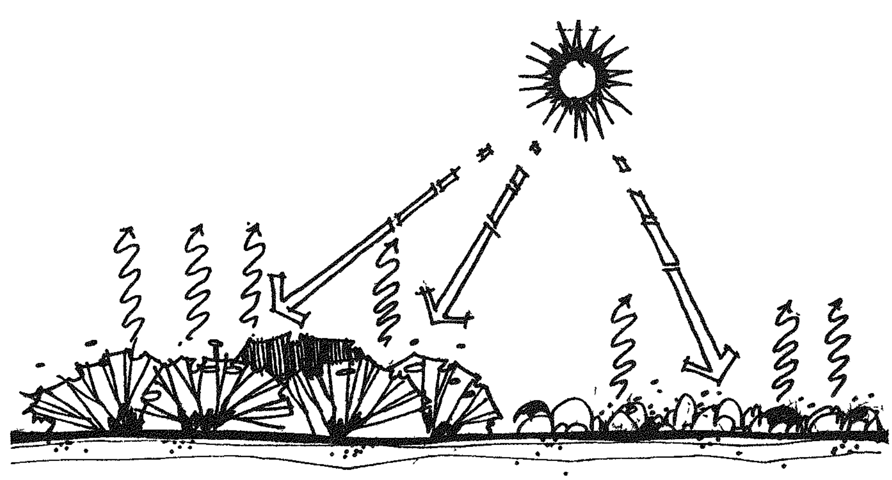
<u>Type of vegetation</u>: The type of vegetation used will affect the type and degree of radiation control.

Evergreen--reduces light penetration to 8 percent.

Deciduous--reduces light penetration in range from 51 percent to 4 percent. (Hastings and Crenshaw, p. 1-9.)

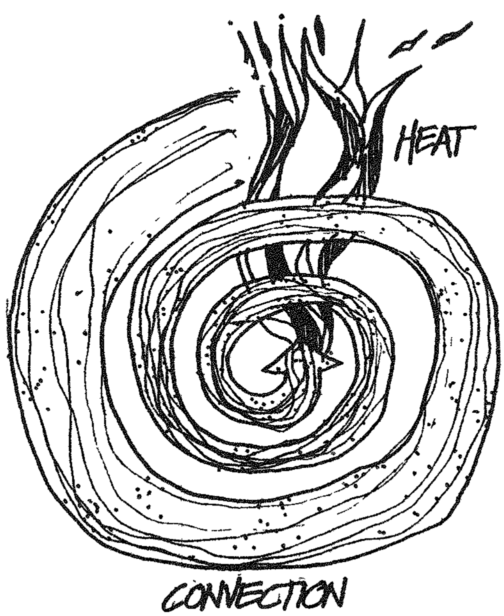


Shrubs and ground cover reduce temperature due to absorption and evaporation. Measured summer cooling effect has shown 10 to 14 degrees cooler temperatures for grass surfaces as opposed to exposed soil. (Olgyay p. 51.)



Wind Air Flow Principles

Wind moves large masses of air across the surface of the earth. This movement occurs in regular daily and seasonal cycles. The significant aspect of wind is that it increases evaporative and convective cooling. These principles are probably most easily explained in terms of their individual effects on climate and their joint effect on heating and cooling requirements.

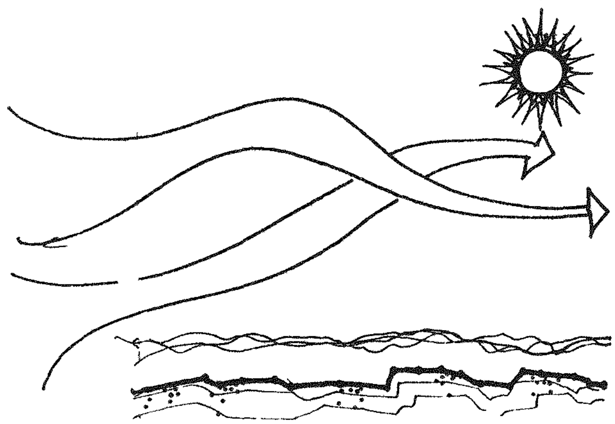


convection: affects temperature by the displacement of heat by means of liquid and gases which carry surrounding heat energy with them.

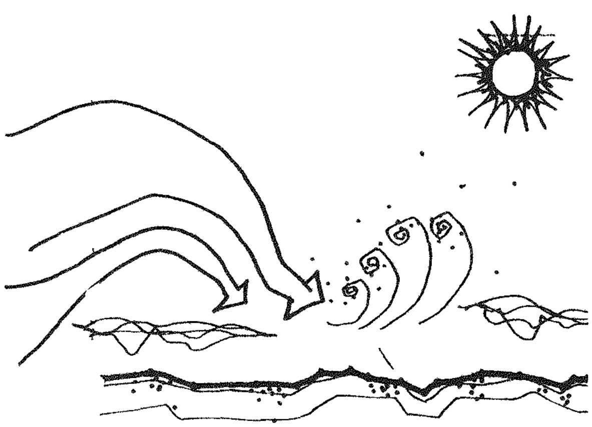
evaporation: affects temperature by changing the moisture content of air and ground and carrying surrounding heat energy with it. (Geiger p. 26.)

Convection and evaporation affect heating and cooling requirements by changing the temperature of air and the drying capacity of breezes.

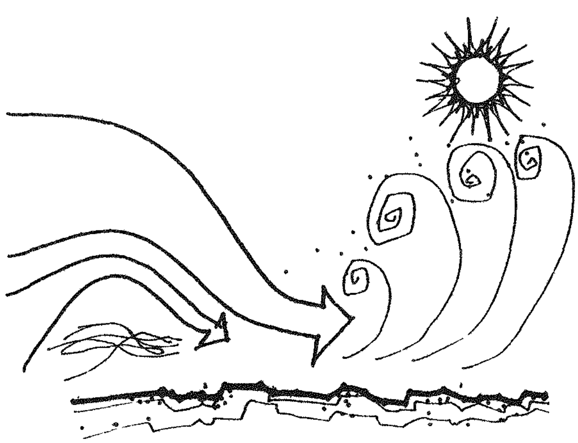
In every part of the country, air flow and wind velocity vary according to the following conditions.



daytime airflow: during the day, air directly at the ground surface is at rest.

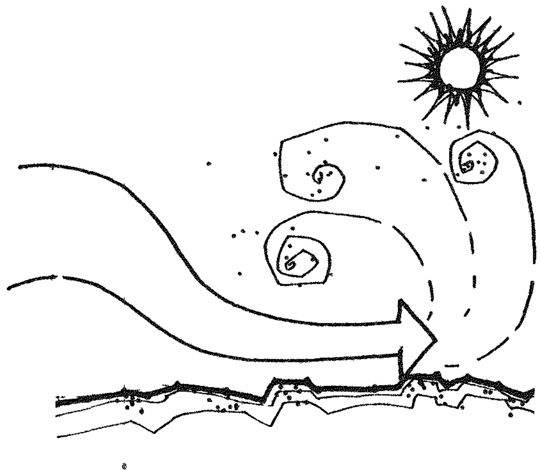


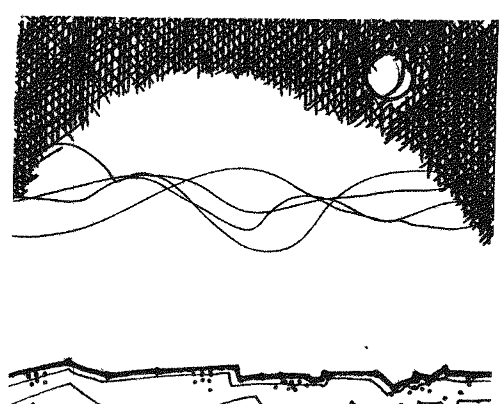
Through the breaking and eddying of wind on the ground, ground air moves up carrying with it a lesser horizontal motion.



When the slower air levels meet faster upper air levels, a breaking effect occurs

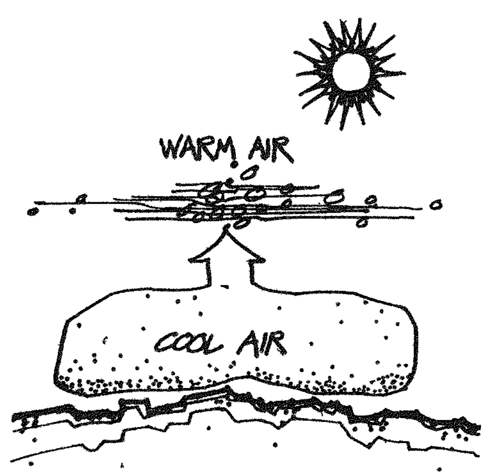
The higher more mobile air then flows into the lower level.



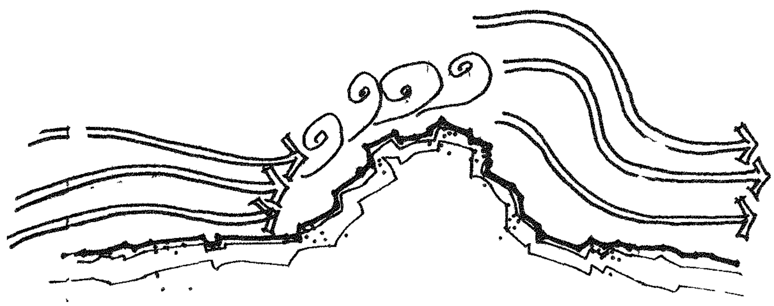


Nighttime airflow: at nighttime when upper air is at rest, the force of the air movement generally diminishes. Since there is less eddying diffusion, nighttime air is generally calmer than daytime air. (Geiger p. 102-115.)

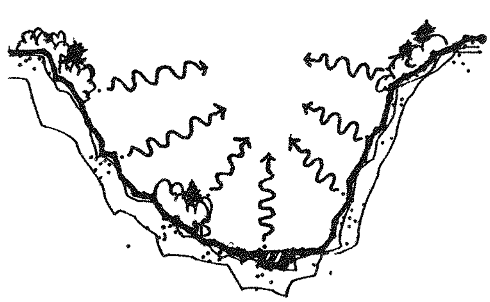
air temperature: air of low temperature is heavier than air of higher temperature. Cold air tends to push itself under warm air and creates air circulation until equilibrium is achieved. (Geiger p. 195.)



cold air floods: these are a result of air temperature differences. For example, at night in hilly country cold air from high places flows to low places and is replaced by warm air from low places.



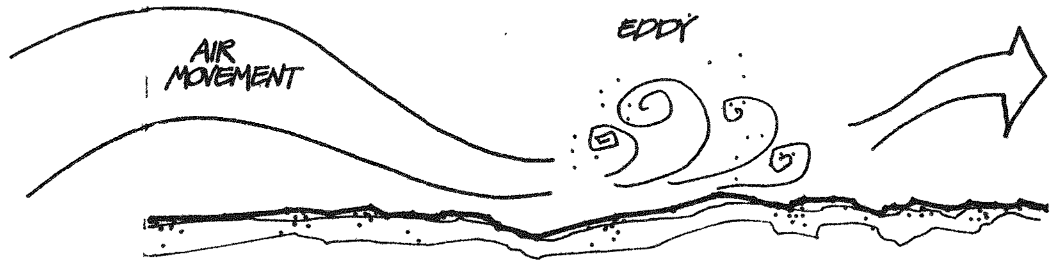
cold air flow in valleys: cold air movement gains significance when it occurs in great volume (Geiger p. 204). In large valleys, cold air flow at night is due to outgoing radiation from the valley floor and from the side slopes. (Geiger p. 211.)



Wind and Its Varying Effects

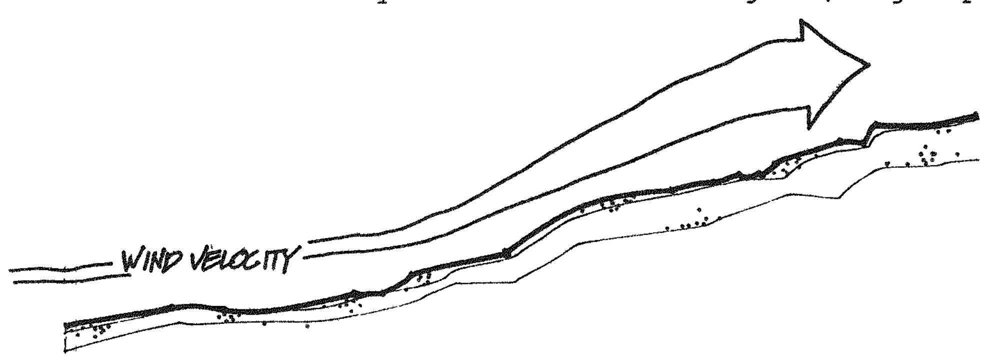
The most violent wind of the free atmosphere is to some extent slowed down by the ground. Directly at the surface, the air is entirely, or almost at rest. The movement of wind is effected in the following ways.

air flow: the breaking effect of the ground causes eddy diffusion and transmits air up.

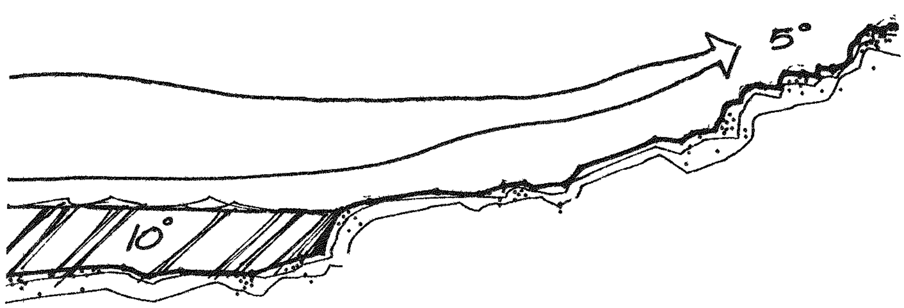


The nearer the air to the ground, the more all air movement is hindered.

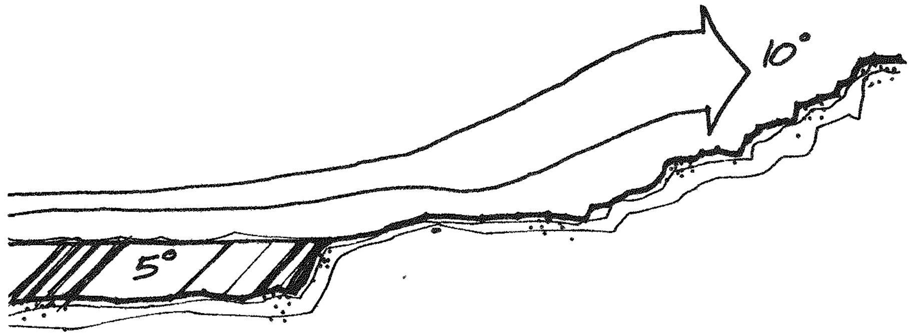
wind velocity: the air near the ground is the part of the atmosphere where wind velocity increases with height (Geiger p. 102).



The primary factor influencing the variation of wind velocity with height is temperature.



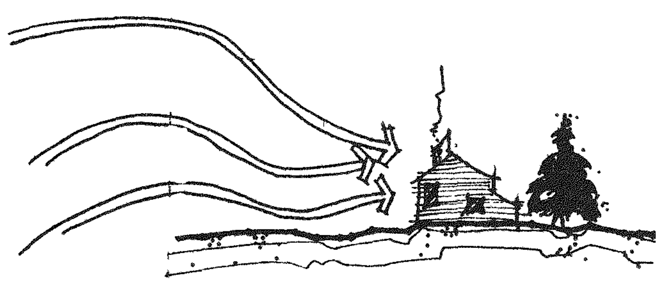
When temperature decreases with height, wind velocity increase is less than when temperature increases with height (Geiger p. 106).



The influence of wind velocity on temperature is due to the fact that high wind velocity increases convection. This results in a decreace of ground temperature by day and increase of ground temperature by night.

*Measurement of Impact on Heating Requirements

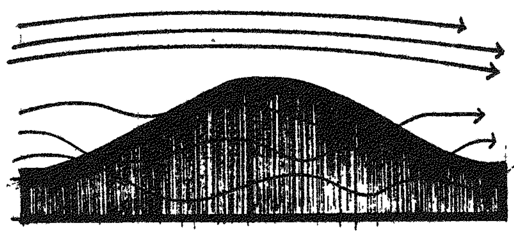
The main significance of wind velocity is that it can be correlated with temperature requirements for human comfort. Studies have showed the following correlation between exterior wind velocity and interior temperature required to offset cold air infiltration (Langewiesche p. 88).



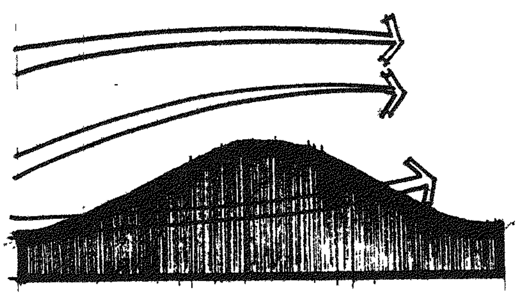
Wind Speed (mph)	Heating Requirements
1/10	68° F.
1/2	73° F.
1	75° F.
2	77.7° F.
3	78.3° F.
5	79.3° F.
10	80.6° F.

Wind and Varying Surface Conditions

Topography and Landform

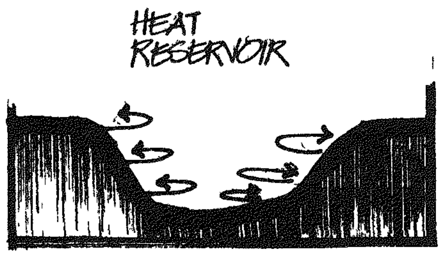


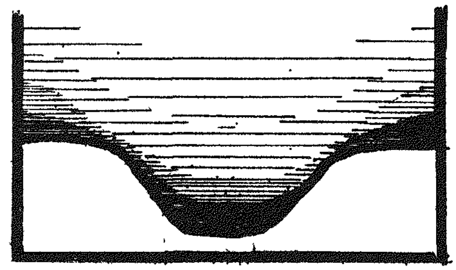
hills and wind velocity: hills affect horizontal and vertical windflow causing higher wind speeds at the top and windward sides of a hill and less turbulence on the lee side.



Greatest wind velocity is in the area at the sides and below the crest. Lowest velocity is at the bottom of the hill and in the wind shadow (Olgyay p. 50).

valleys and cold air pockets: cool air is heavier than warm air and forms a cold air layer near the ground at night. In valleys, surrounding slopes cause warm and cool air to mix and create a warm slope region.

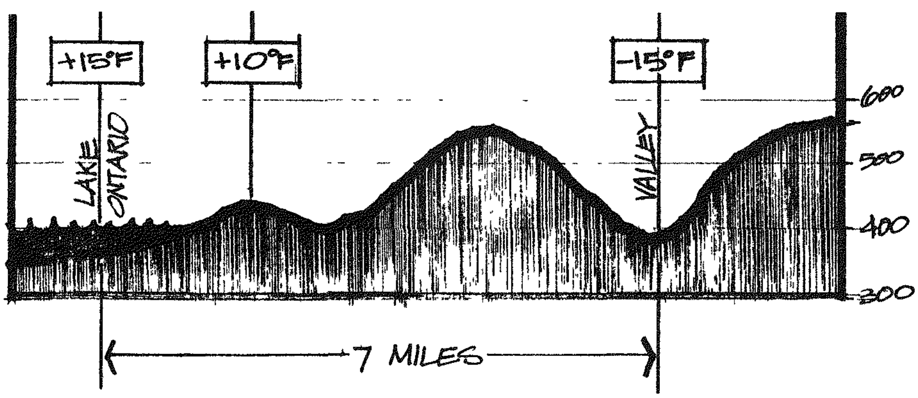




As a result, the floor of the valley and upper plateau are the coldest locations, while the warm slope region, unless exposed to the wind is the warmest location (Olgyay p. 45).

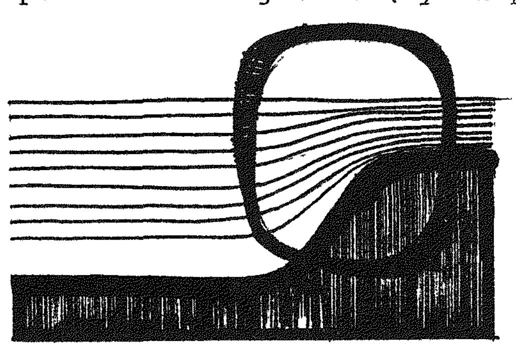
*Measurement to Climate Effect

1. Toronto, Canada
   Valley bottom--34° colder due to cold air lake effect



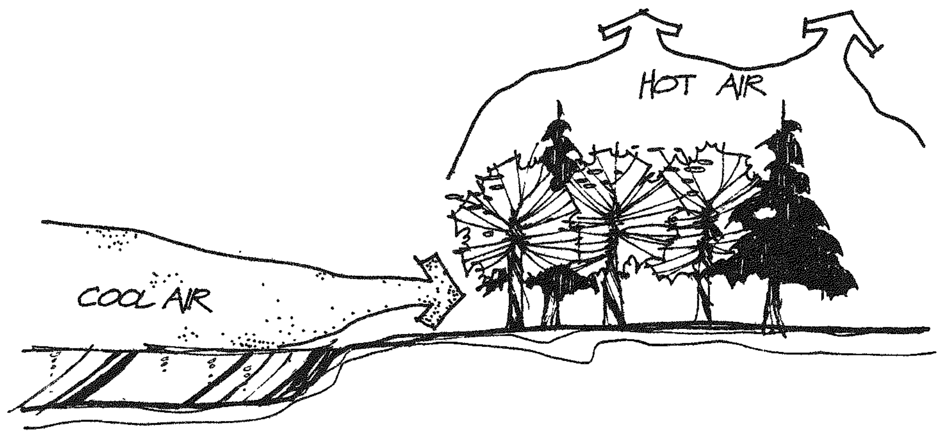
2. frost holes
   11° colder than surrounding terrain (Davis and Schubert, p. 29).

3. Wind speed on the crest of a ridge is up to 20% greater than wind speed on flat ground (Lynch p. 74).

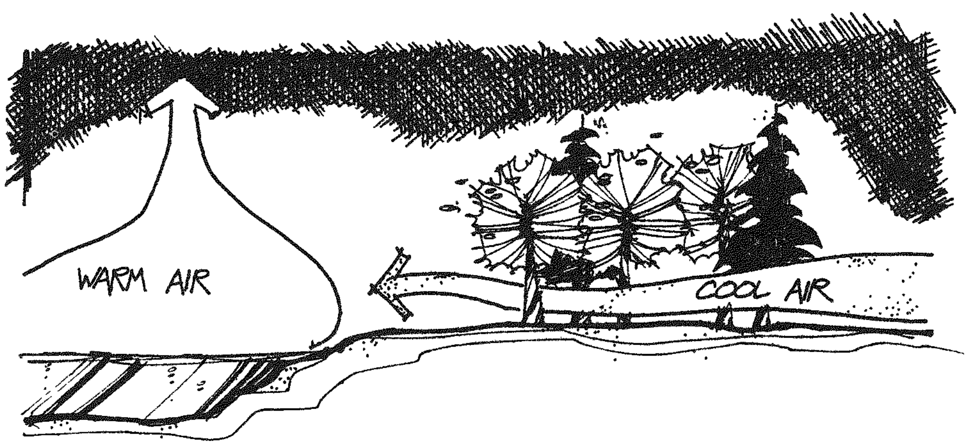


Water Bodies

Water bodies also affect the temperature of adjacent land masses on a daily basis due to the process of air flow.



During the afternoon, when land is warmer than water, low cool air flows over the land and cools it.



During the evening, the ground surface begins to radiate heat and cool off. At the same time, warm air above the water rises due to convection and is replaced by cool air flowing in a low pattern along the land's surface.

The degree to which this air flow is effective is dependent upon the size of the water body, and location on the lee side. In general, the effect of cooling is proportionate to the size of the water body (Olgyay p. 51).

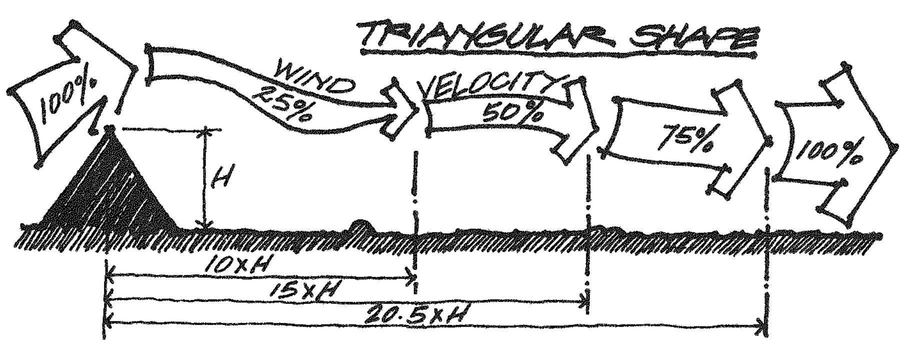
Measurement of Climate Modification

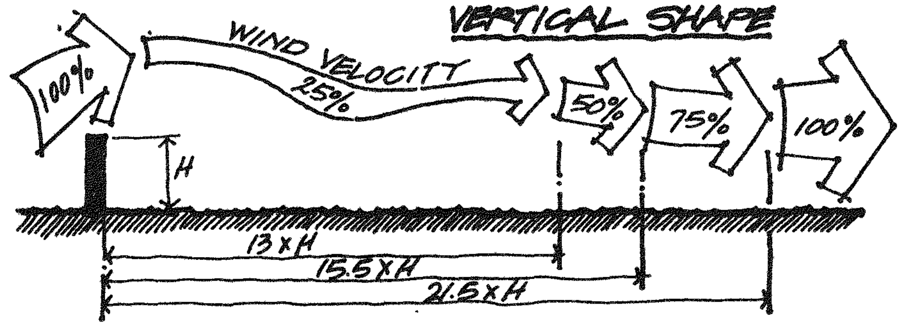
1. Great Lakes Region (Olgyay p. 51.)
   Daytime cooling effect of water 10° F. average

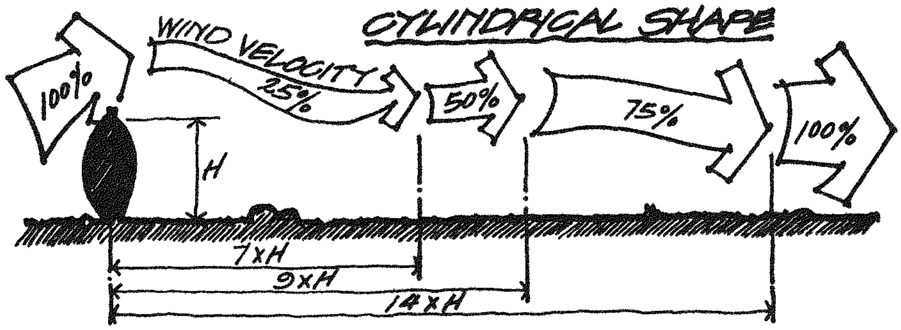
Vegetation

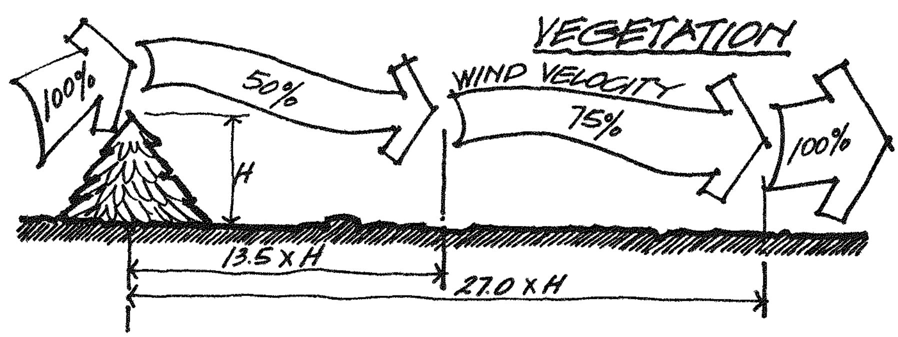
Though large air masses cannot be altered in motion, they can be reduced in velocity near the ground by the presence of vegetation. Essentially, vegetation reduces wind velocity due to frictional drag. Vegetation is an effective wind break because it permits jet air movement through it (Olgyay p. 78).

effect on velocity: vegetation provides a more extended area of protection than any other shape. According to classic climate studies (C. G. Bates) while various forms provided greater percentage of wind reduction over a limited distance, vegetation provided the greatest extended wind reduction when compared to other forms which were impenetrable (Olgyay p. 98).





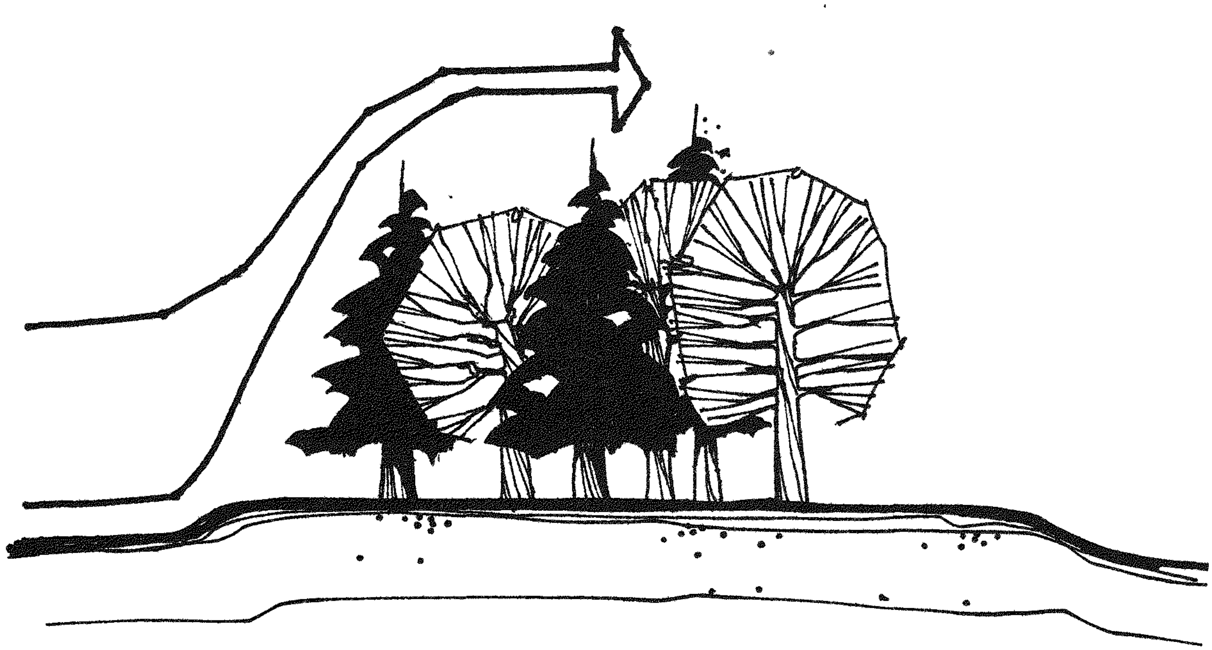




For the most extended area of wind protection, trees are the most effective windbreaks.

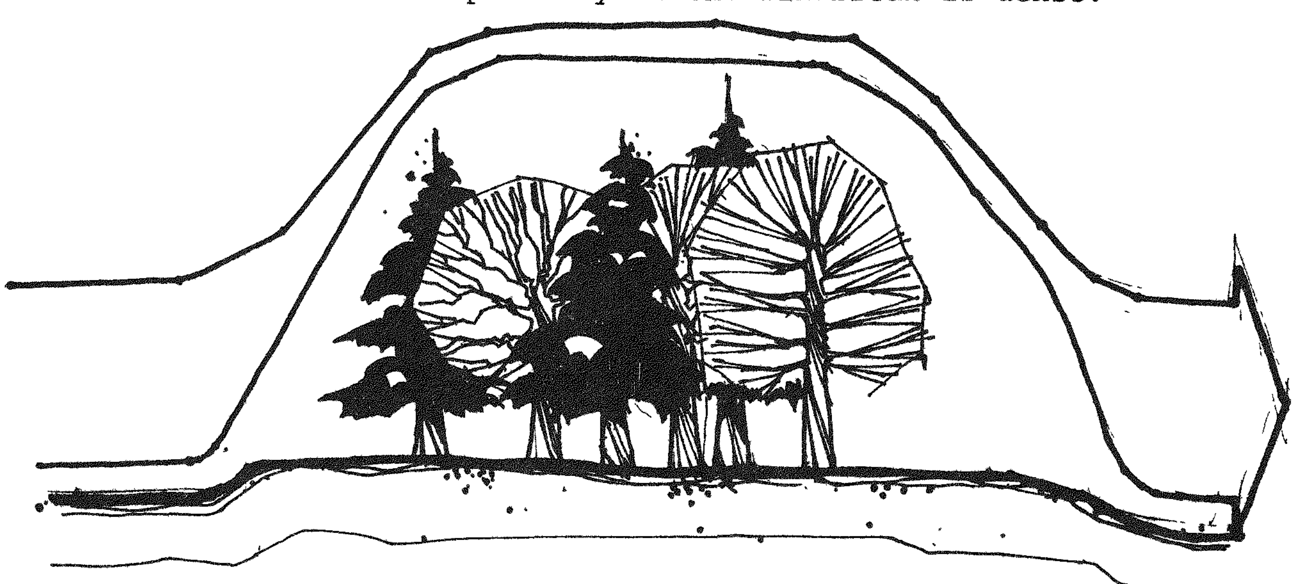
influence on air flow: Studies on vegetative windbreaks indicate that vegetation effects air flow in the following ways.

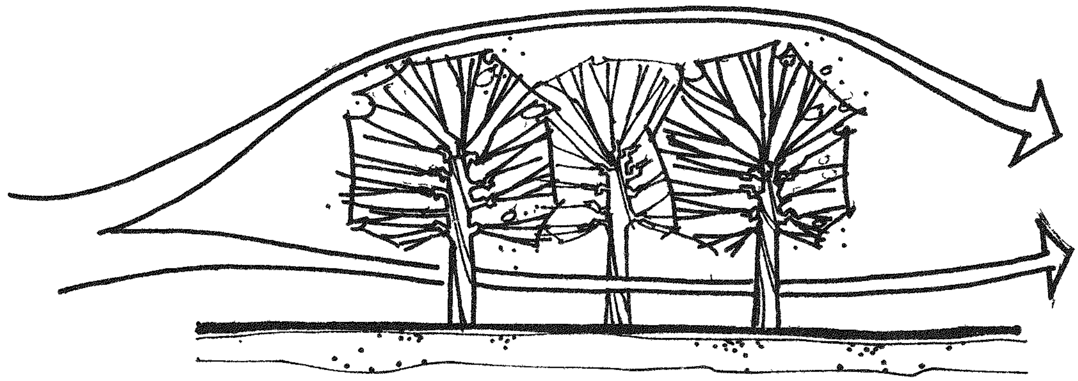
The first effect is that vegetation diverts air current upward on the windward side.



While the windflow does turn back and sweeps the ground, an area of calm is created near the ground on the lee side.

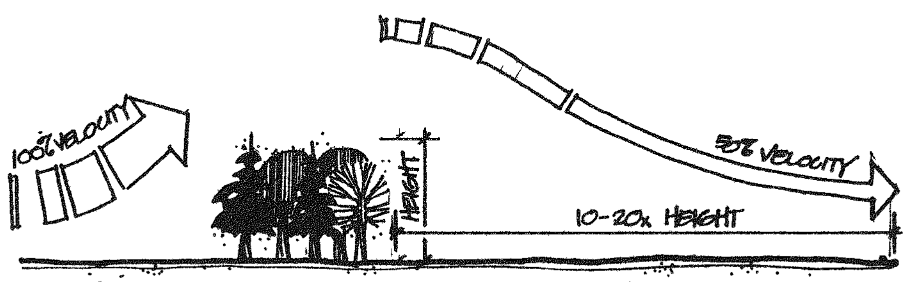
The most protected part of the "sheltered area" is close to the windbreak on the leeward side with a small protected zone on the windward side--especially if the windbreak is dense.





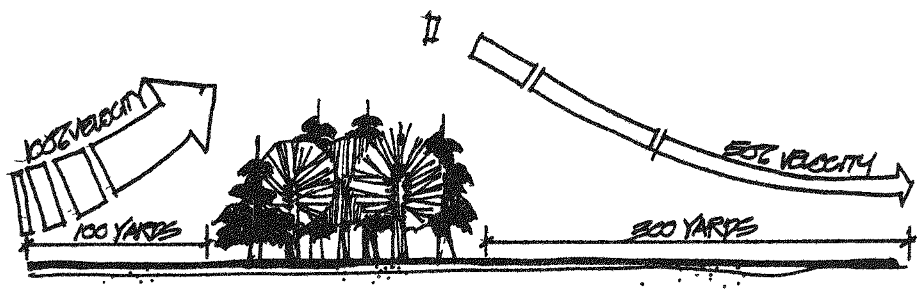
If it is so open that the wind can sweep under the trees, the windward side has little protection.

*Measurement of Climate Effect (reduced velocity)



Vegetation can reduce wind velocity by 50 percent over a distance from 10 to 20 times the height of the windbreak.

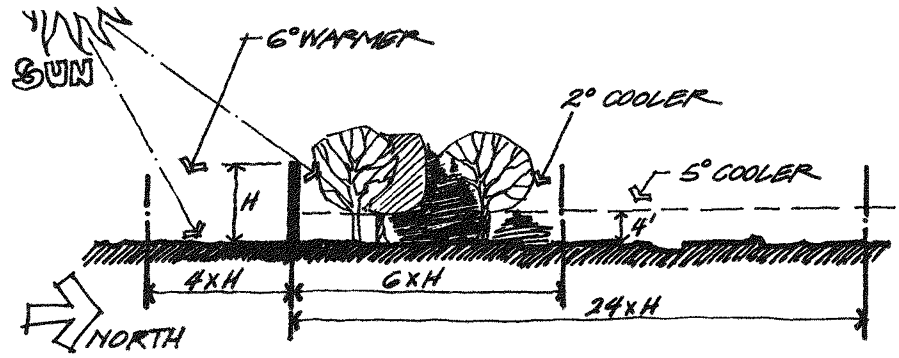
Vegetation can affect wind velocity on both sides of the wind break.



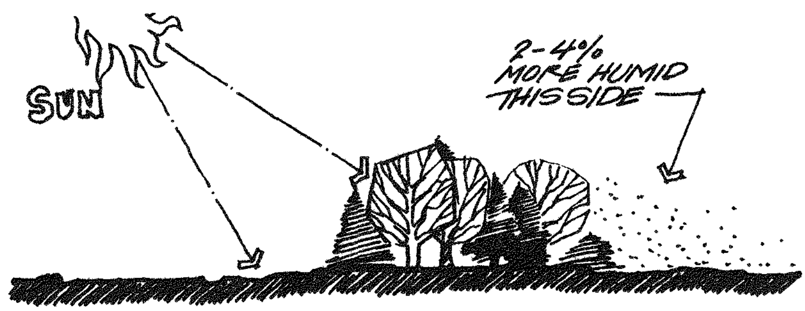
For example: A 30' high windbreak perpendicular to the prevailing wind will reduce wind velocity for 100 yards on the windward side and 300 yards on the lee side. (ASLA pp.72-78 .)

*MEASURE OF CLIMATE MODIFICATION FOR WINDBREAKS

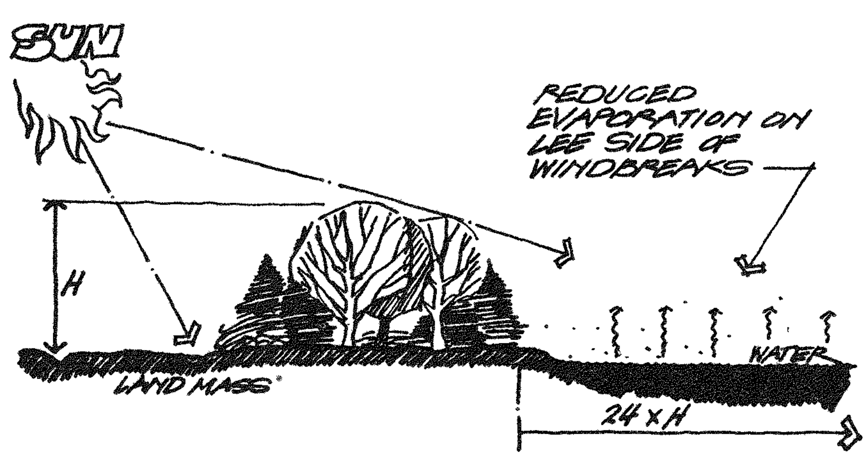
1. Kansas
   Air temperature reduction was recorded between 2 and 5 degrees cooler on the lee side of a windbreak and 6 degrees warmer on the exposed side for a distance of 6 to 24 times the height of the windbreak. (Read p. 4.)



2. Great Plains
   Increased humidity



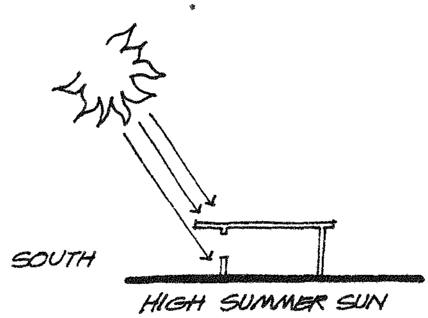
3. Reduced evaporation on lee side of windbreaks can extend to a distance 24 times the height of the windbreak on the lee side and reduce water loss from reservoirs and ponds. (Read pp. 4 & 5.)

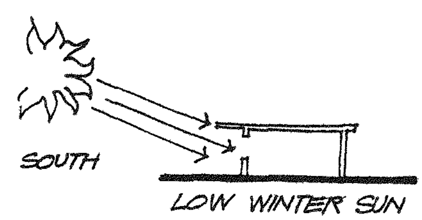


PART II
CLIMATE CONTROL OPTIONS

Radiation Control

The sun can contribute up to 50 percent of the interior heat of a structure. The sun's heating effect on a structure is due to the amount of radiation absorbed in a structure's roof, walls and ceilings which causes a rise in interior temperature. By proper planning and design, you can use this natural heat to heat you in the winter and still keep it from heating you excessively in the summer.





*Measurement of Energy Savings

Maximum response to sun and wind through orientation and seasonal sun shading and wind buffering has been modeled and demonstrates the following energy savings (Olgyay pp. 132-151).

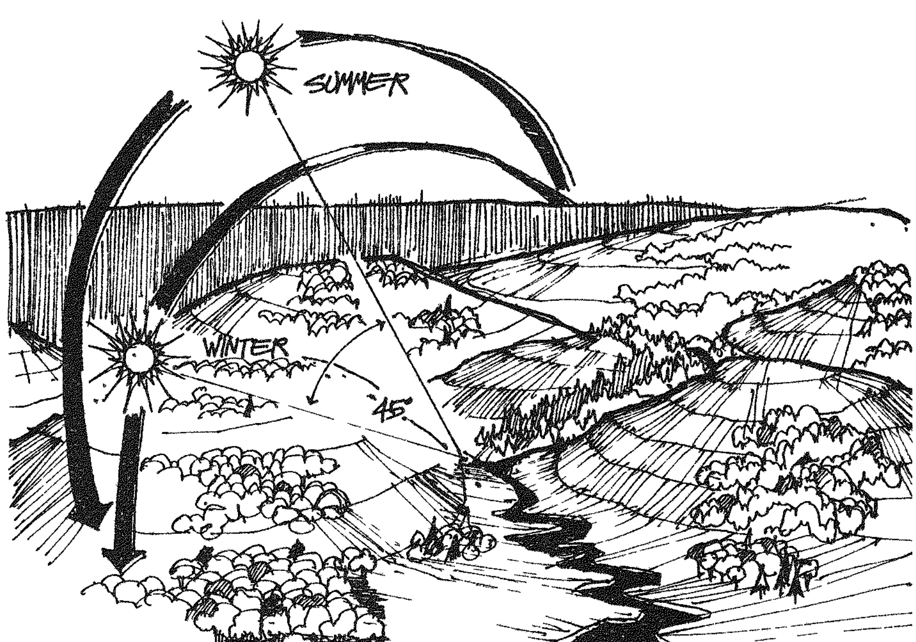
Winter	Cool	- 42% reduction of heat loss
	Temp.	- 49% reduction of heat loss
	Hot Arid	- 39% reduction of heat loss
	Hot Humid	-
Summer	Cool	- 75% of reduction of heat gain
	Temp.	- 71% of reduction of heat gain
	Hot Arid	- 42% of reduction of heat gain
	Hot Humid	- 55% of reduction of heat gain

PASSIVE SOLAR HOUSING

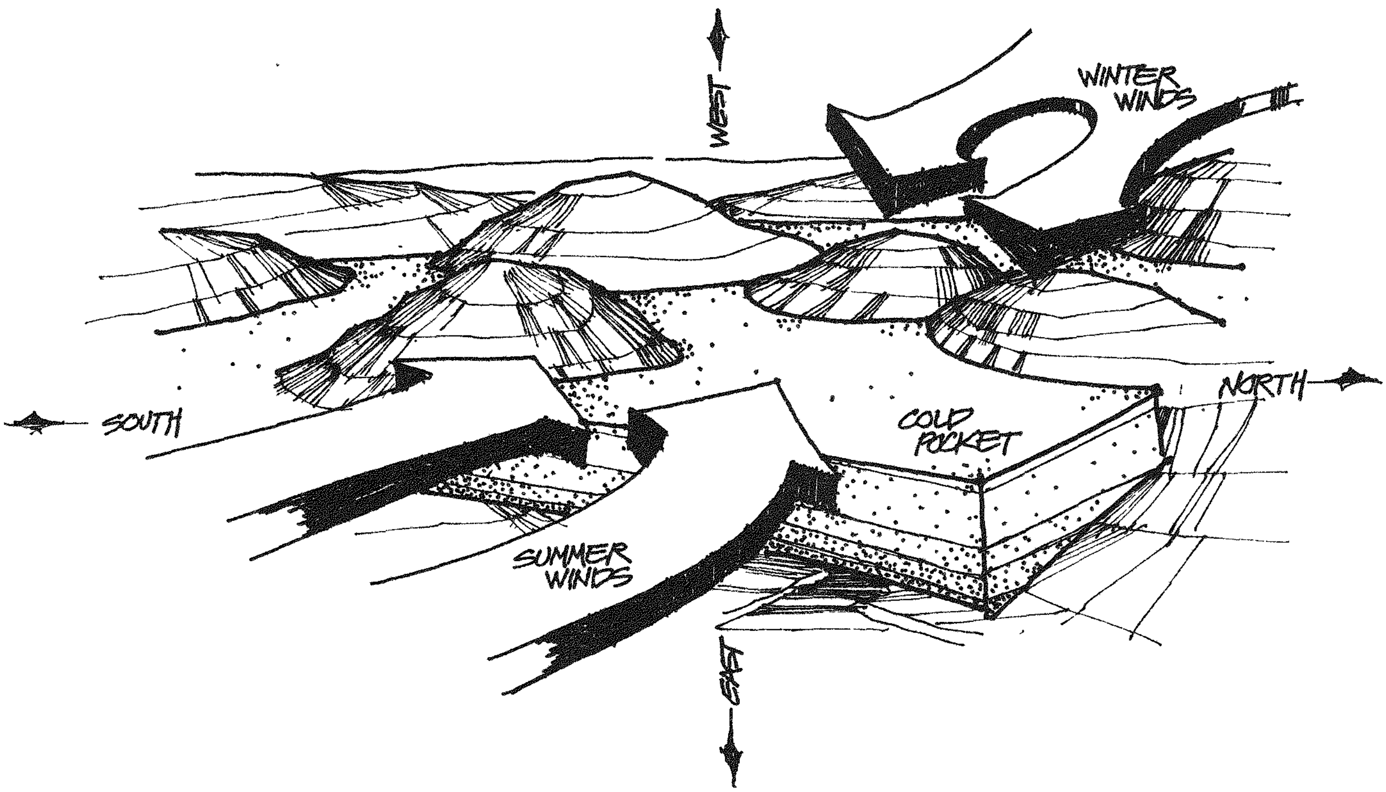
Direct (passive) solar heating can be achieved through a combination of optimum southern orientation and use of double glazed south facing walls to provide interior heat through diffuse radiation (JAE). This option is immediately effective and only requires proper siting. Design guidelines for passive solar heating can be summarized as follows. (AIA 1976 pp. 64-73.)

<u>gross site selection criteria</u>: in assessing and evaluating sites, look for:

- seasonal and daily path of the sun across the site.



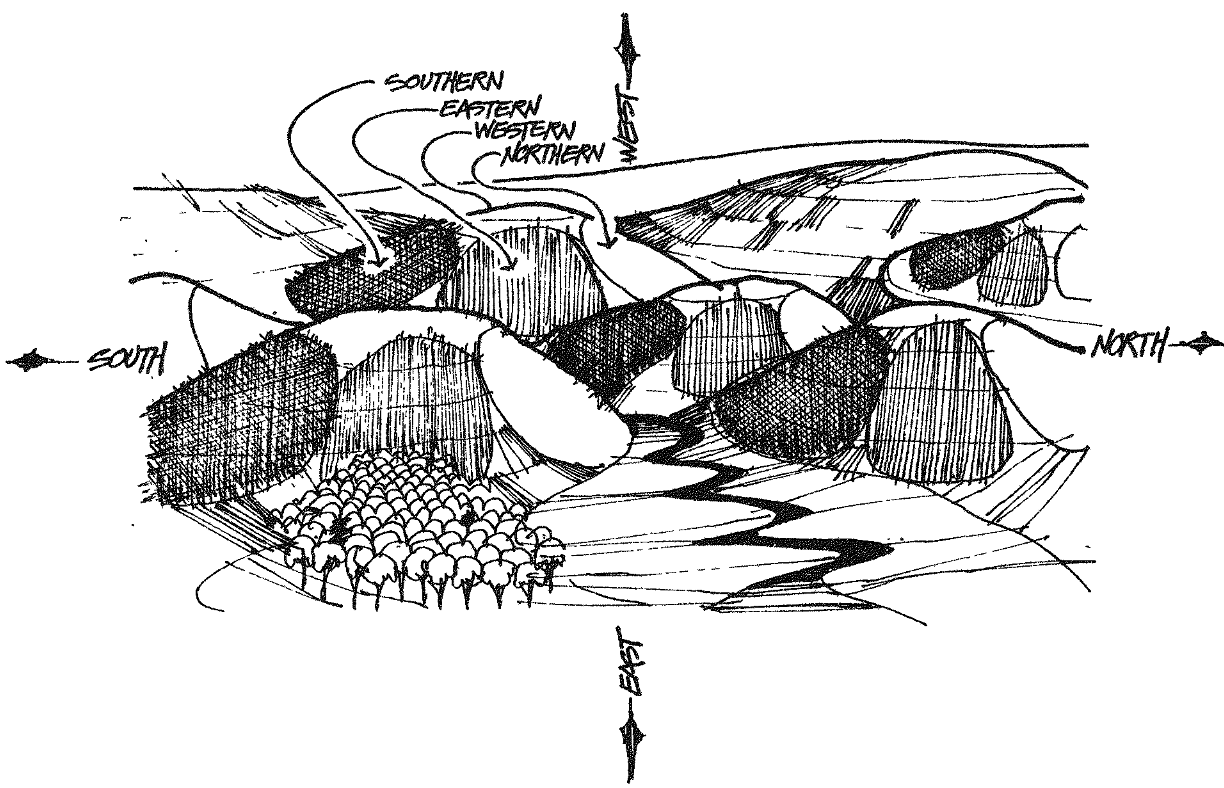
- seasonal and daily windflow patterns around and through the site.



- avoid earthforms that may block the sun or wind
- avoid presence of low areas where cold air can settle

discrete site selection criteria. Look for:

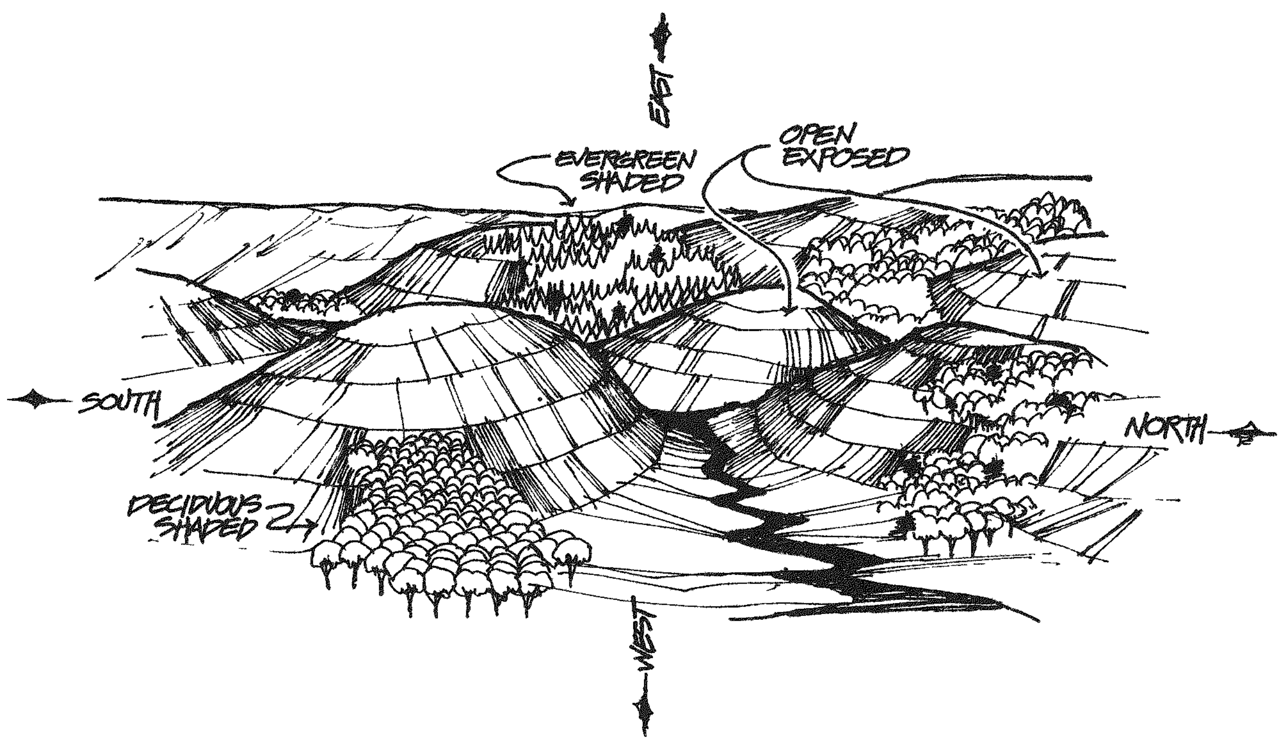
- south facing slopes for maximum solar exposure
- west facing slopes for maximum afternoon solar exposure
- east facing slopes for maximum morning solar exposure
- north facing slopes for minimum solar exposure



- depth and type of rock on site

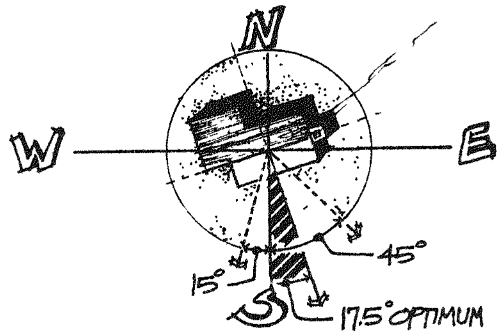
- unbuildable areas on site

- existing vegetation: type and location
- climatically exposed areas

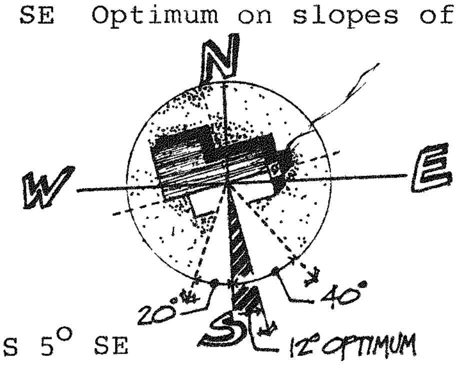


orientation: Depending on your climate region, orient your structure for optimum summer sun.

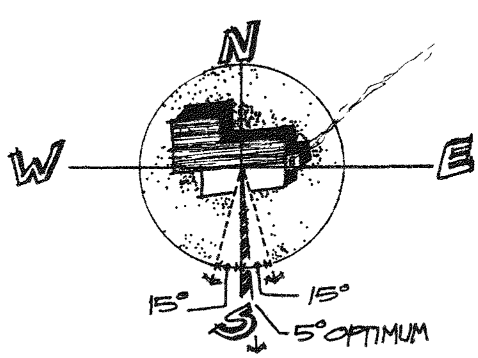
temperate zone: S 17° 5' SE



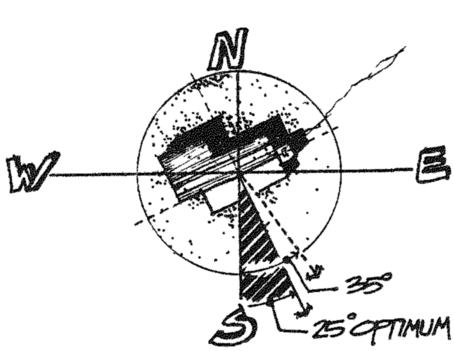
cool zone: S 12° SE Optimum on slopes of 0-20%



hot humid zone: S 5° SE



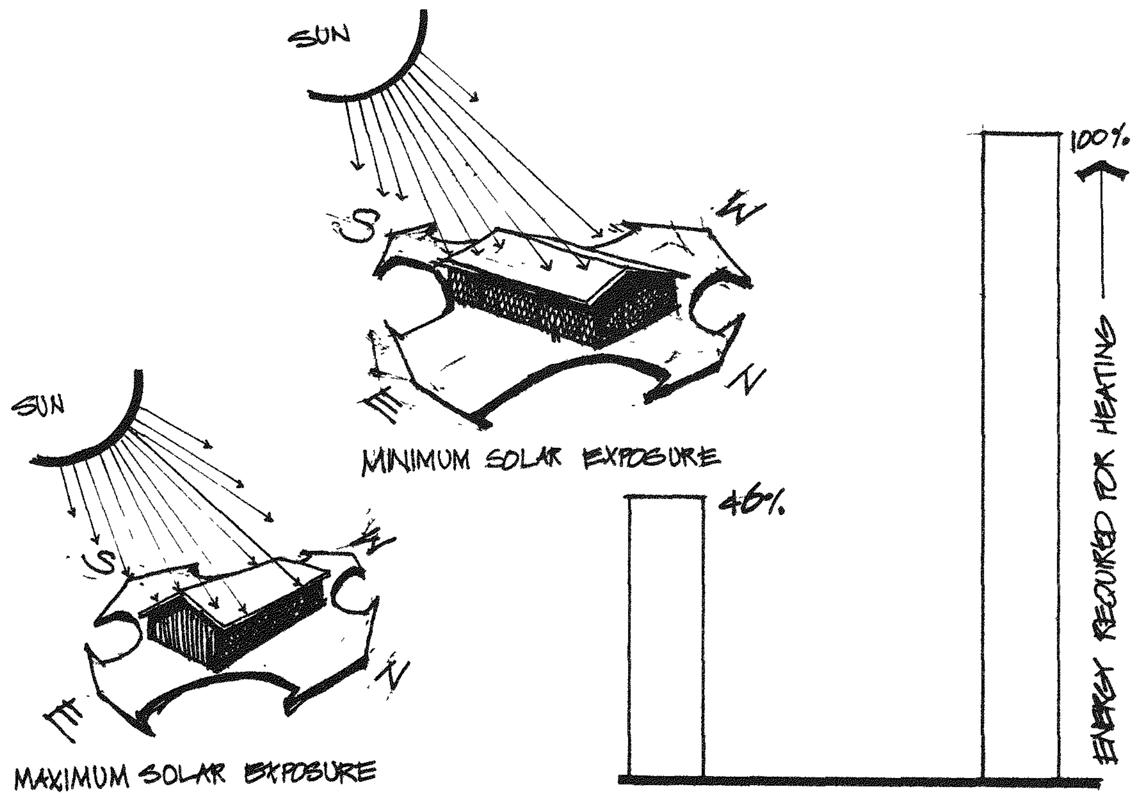
hot arid zone: 25° S SE



* Measure of Energy Savings for Optimum Orientation

Davis, California

- A 1500 square foot house with southern exposure, good insulation and ventilation, single pane windows, a white roof, and a bare concrete slab floor was monitored on typical clear December days with an average outdoor temperature of 45° F. During the middle six hours of the day, radiant heat gain through south windows was found to eliminate the need for other heating. Total heating requirements are reduced by one fourth and produce a 54% fuel savings over a house without southern exposure. This house is 61% solar heated, requiring 39% as much energy for heating for the entire winter as the average Davis house. (Hammond 1974 p. 41)



- A study of south facing unoccupied apartments during sunny, clear, cold days in December 1973 and January and February 1974, compared to similar apartments with north, east, or west orientations, identified the following energy efficiency for southern orientations:

1. Interior temperatures for south-facing apartments were 24° above the ambient temperature and 17° above the north, east, or west oriented apartments.

2. Average gas use for winter months in south facing apartments was approximately 12% lower than east and west facing apartments and approximately 25% less than north facing apartments. (Hammond & Hunt 1974 p. 14)

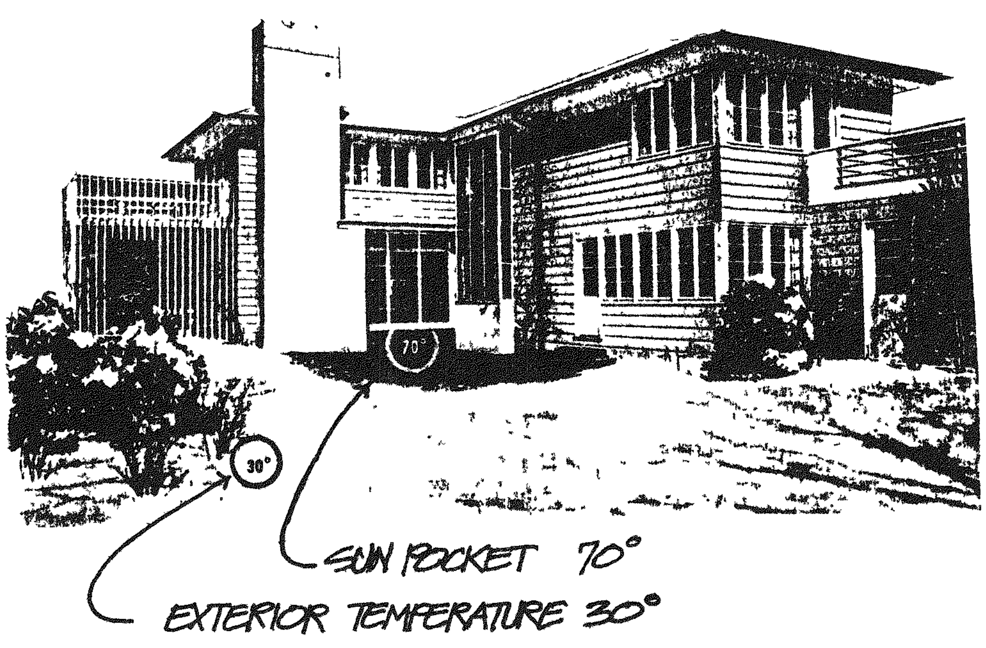
NAHB Test House

N-S orientation provided heat gain over assumed E-W orientation. (NAHB p. 15.)

configuration: If you want to increase the amount of sun you get and extend your outdoor living season, consider a configuration that will create a sun pocket. Use an "L" shaped floor plan with open part facing south to create the sun pocket.

*Measure of Climate Modification

In one New York Metropolitan area an "L" shaped floor plan was used on a NW hill to buffer wind and create a sun pocket. (Langewiesche p. 150.)



- on an April day, measured air temperature in the sun pocket was 50^o higher than ambient air temperature

  - the use of dark colored asphalt paving on the patio surface is the sun pocket and extensive glazing on the surrounding walls should be considered as contributing to the temperature gain in the sun pocket

SOLAR HEATING SYSTEMS

Another option you might wish to consider is a solar housing system. While this entails a large initial cost for equipment, operating costs are negligible. This option is suitable for new construction or as an adaptation on existing structures. General considerations for solar houses are as follows.

availability of solar energy: The basic climate variables which determine the availability of solar energy depends on:

- latitude
- season
- weather patterns

These factors are greatly influenced by the presence of fog, cloud cover, storms or smog, which can appreciably reduce incoming solar radiation.

Two basic methods to estimate actual availability of solar energy are:

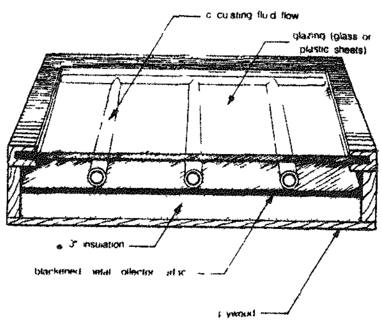
- national weather service has some stations which record these types of measurement, also local universities or pollution control districts may (Leckie p. 87.)
- by knowing the percentage of cloud-free days each month, you can adjust the cloud-less insolation data (ASHRAE values), accordingly.

design guidelines for site selection and design for solar housing are summarized as follows.

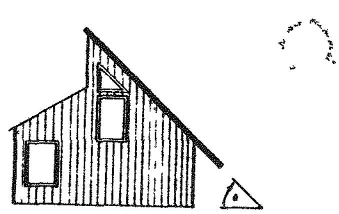
- minimize wind and shading during the heating season
- utilize natural windbreaks and decidous trees to reduce infiltration losses. Don't place large glass areas or poorly fitted doors on the windward side of the building.
- try to maximize insolation available by siting and orientation

systems requirements: Dependent upon the type of solar collecting system you use, the following siting considerations should be considered.

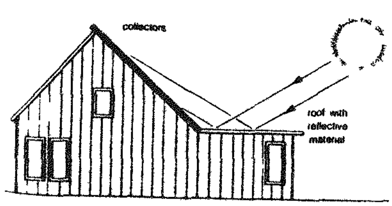
flat plate collector: siting and orientation (Leckie pp. 111-112)



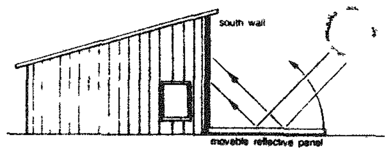
- should be exposed to direct sunshine
- operates well with diffused/ indirect radiation or under hazy conditions
- panel should always be perpendicular to incoming sunlight, this isn't totally possible if you have a stationary collector



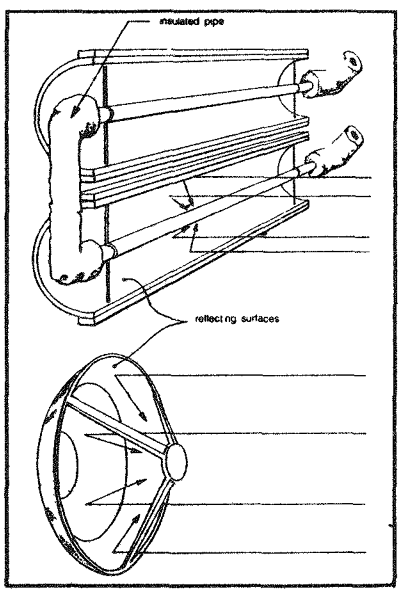
- orient for sun angle during winter months, low in the southern sky (S-SW), optimum winter tilt equals local latitude plus 15 degrees measured from the horizontal



this requires a relatively steep roof if roof mount is desired, but the angle need not be perfect, particularly with additional reflection from another roof surface (Leckie p. 118)



- reflective panels may also be used to supplement

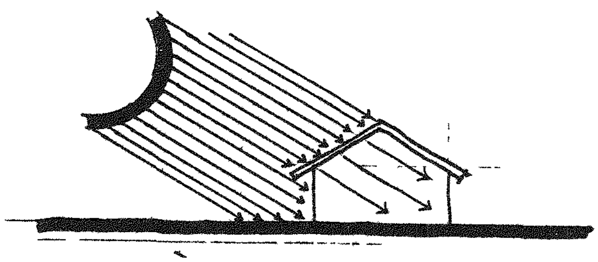


focusing collectors: siting requirements

Unclouded, direct sunlight is required. If it is not available, the focuser collects little useable energy. Consequently their use is limited to areas with very few days of cloud cover during the heating season. (Leckie pp. 122-123)

Radiation Control for Shading and Cooling

The undesirable effect of radiation is primarily the summer effect of excessive heat. Negative summer effects of radiation are due to the heating of building roofs, walls and ceilings, which raise the interior temperature of a structure.



It is not the exterior temperature which makes your house hot, but the hot air admitted into your house and trapped there. Even if you've selected the optimum site or orientation, or if your present one is less than optimum, you will probably be interested in one or several shading and cooling options.

The main considerations in selecting an option for shading and cooling are:

- cost versus effectiveness

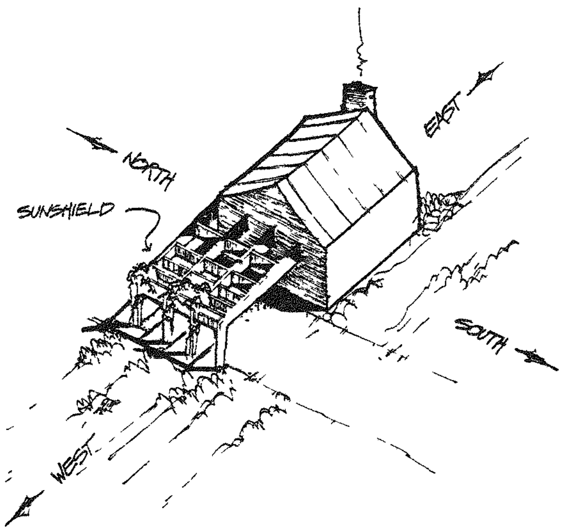
- time versus effectiveness

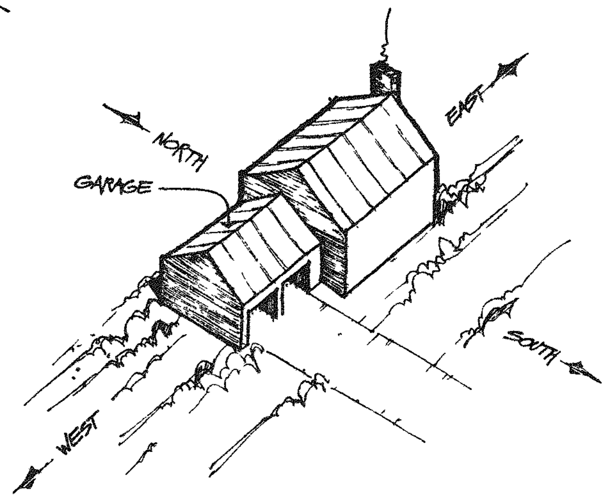
SHADING

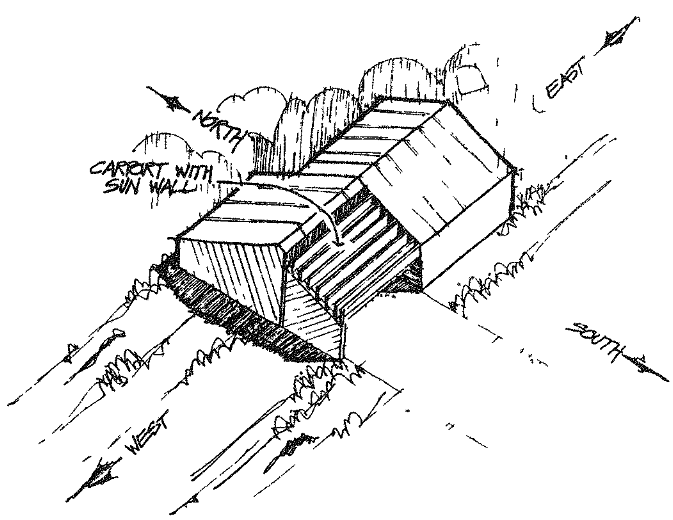
The primary determinant in selecting a shading device is the sun exposure to which you are responding and requirements of summer sun response versus winter sun response. Depending on your sun exposure, here are your options: (Wright Oct. 1949 pp. 220-222; Siple Nov. 1949 p. 199)

<u>Large scale control</u>: Primarily involve response to western sun to optimize winter sun and shade summer sun. These should be considered in siting, orientation and design of your

- house
- garage
- sun shields



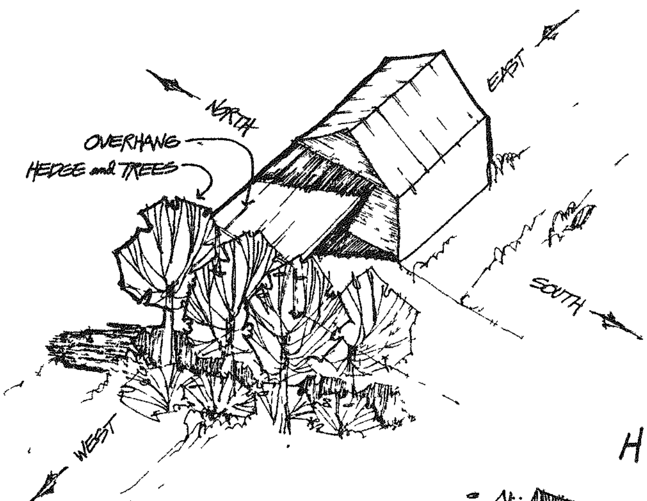


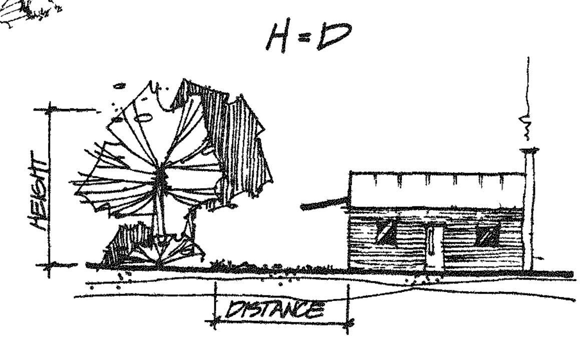


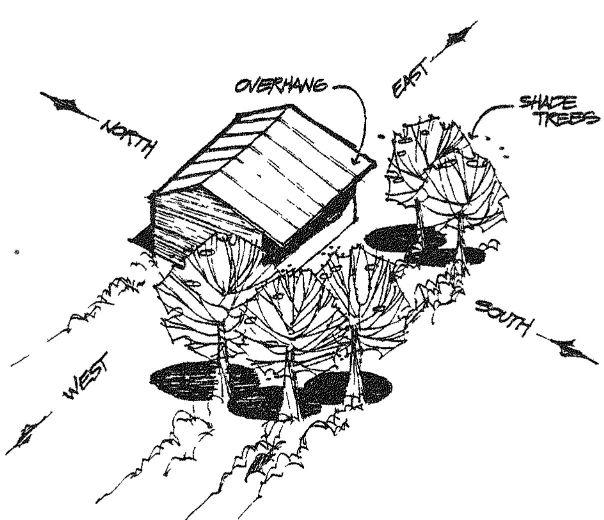
Small Scale Controls: Primarily involve response to added shading requirements for southern and western sun. Such options should be considered as the design and placement of

- trees

- overhangs





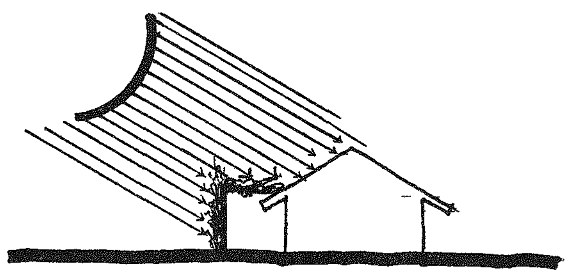


WESTERN SUN

Western sun is the hottest summer sun with the most prolonged intensity during that part of the day when heat gain to a vertical surface is undesireable. The most effective shade for western summer sun is a vertical sun shade (Wright Oct. 1949 p. 158).

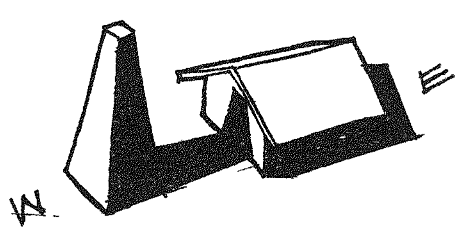
Overhangs are ineffective against western sun because the severe sun is afternoon sun, which comes in at a low angle. This sun requires a vertical wall to the west to screen it.

sun shield: Your best option is the use of a trellis sun shield with vine plantings. It is more effective than a sun shield wall of ordinary building materials since absorption and evaporation keep the vegetation and wall cool, as well as shading the structure (Wright Oct. 1949 p. 158).

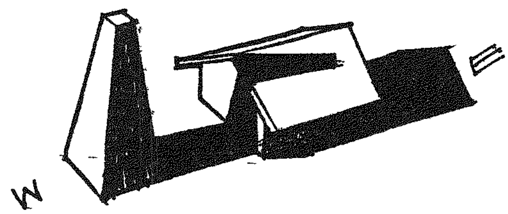


vegetative shading: Among other options for vegetative shading for western exposures are tree plantings. The way in which west side tree plantings can provide shade for summer and permit sun in winter is illustrated in the following series. (Langeweische 91)

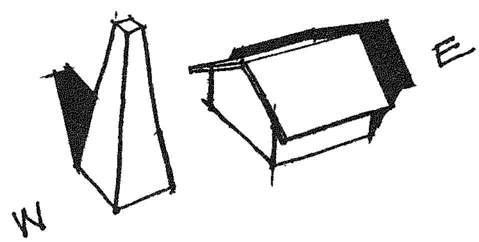
- summer 3 p.m., shade wall of trees on western side tappering from tall to short shades west wall.



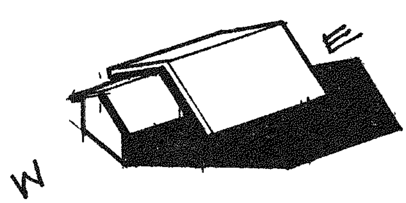
- summer 5 p.m., shade provided to front lawn, NW corner and most of the west side.



- winter 12 a.m., winter sun is not blocked, location of shade trees not selection of type (deciduous versus evergreen) makes the difference.



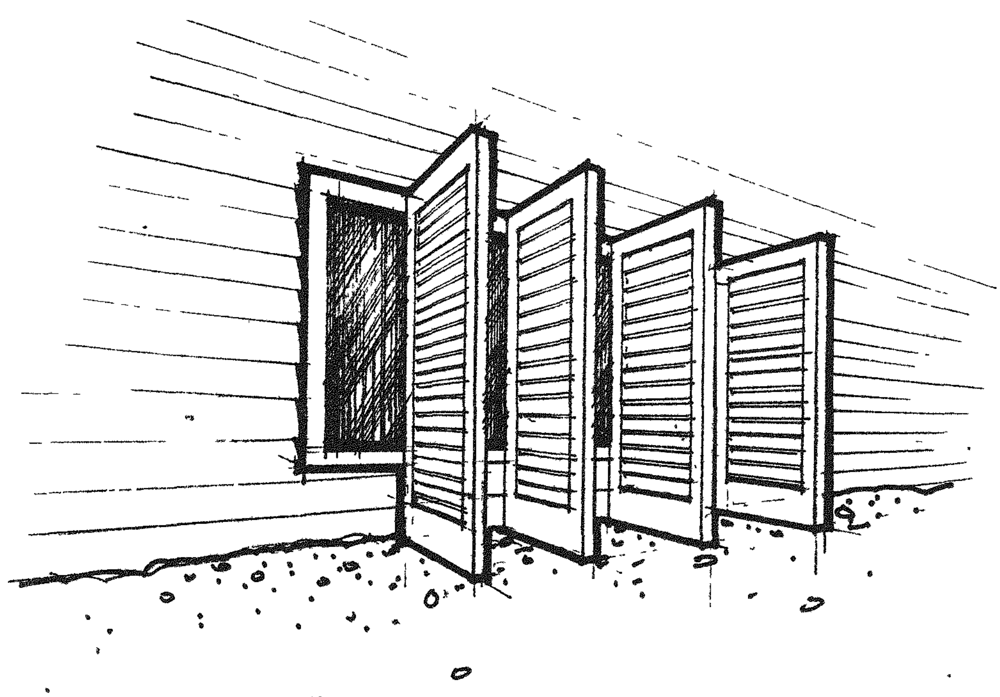
location of structures: If you can't afford the time and money it takes for vegetative shading, consider the location of your garage. It can serve the same function as a buffer wall and shade summer western sun.



Like the trees in the previous shading example, it won't block your winter afternoon sun either. Remember, a neighboring house can do the same. (Langewiesche July 1950 pp. 91-92)

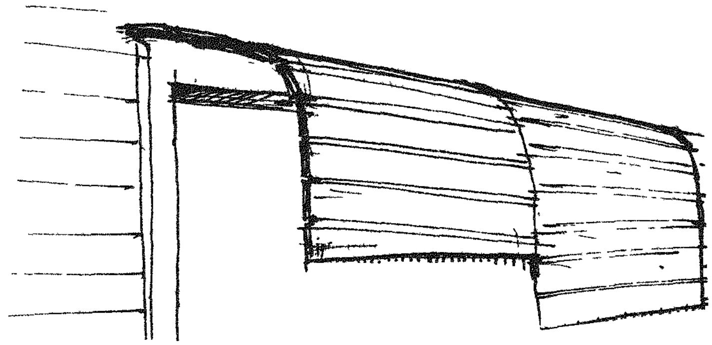
flexible sun shades: If these options aren't suitable, consider a flexible sun shade on your house, while they are an immediate investment in dollars, they are immediately completely effective. Among these options are:

- flexible shutters: provide view and block the sun

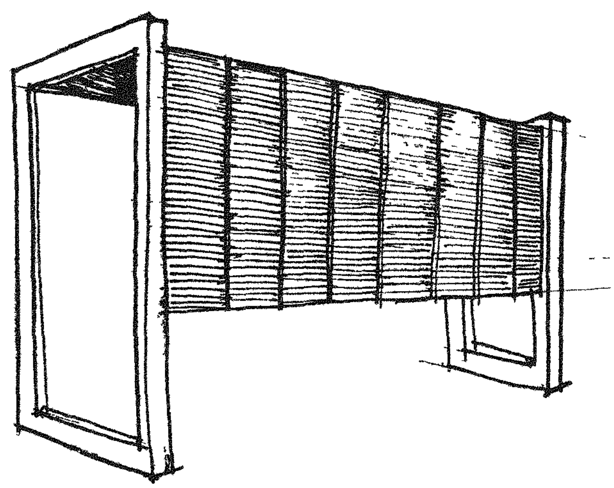


- awnings: awnings with long aprons block western sun

- sliding sun screens: provide shading to top and front of windows and wall as well.



- roll up porch shades on trellis frame blocks front of window but also permits ventilation.



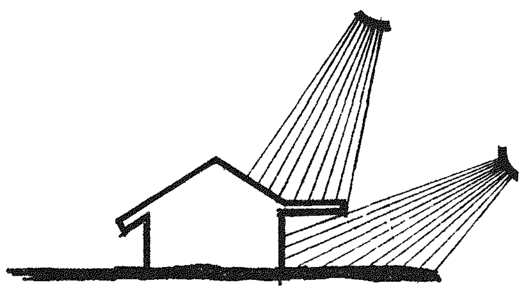
(Langewiesche March 1950 p. 131)

EASTERN SUN

Eastern summer sun is as intense as western summer sun; however, its effects are less extreme because its incidence does not coincide with the usual daily maximum air temperatures. Shading response for eastern exposures utilizes the same techniques as those identified for western exposures.

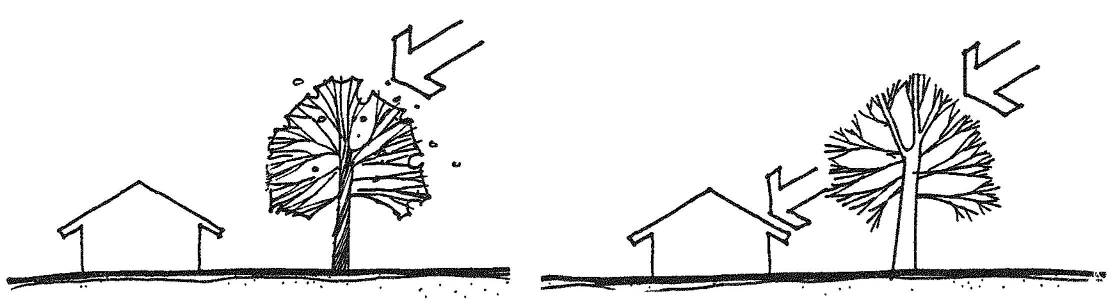
SOUTHERN SUN

Southern summer sun is less intense on south-oriented vertical surfaces than an eastern summer sun is on an east-oriented vertical surface. During the winter, southern sun penetrates structures easily due to its low angle. However, during the summer there is a 45 degree increase in the southern sun angle so that it can be stopped with an overhang. An overhang is 100 percent effective in blocking southern summer sun and will not interfere with winter sun penetration and heating gain.

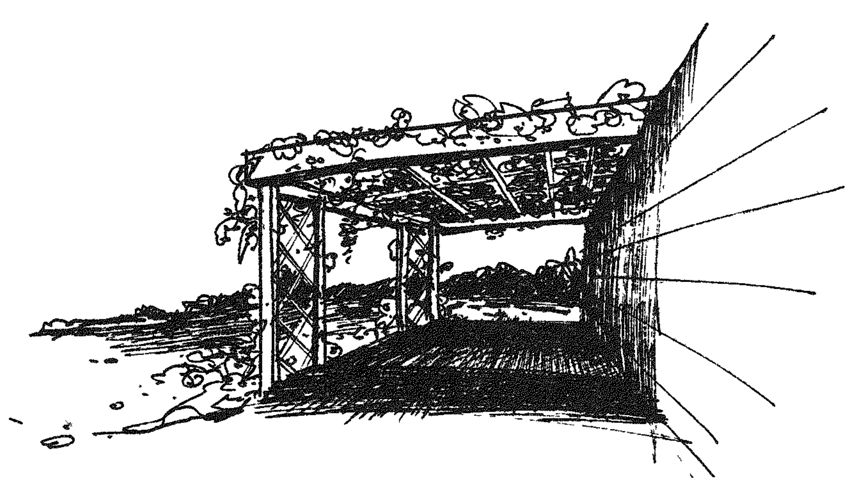


Your southern shading options might also include vegetative shade plantings in conjunction with an overhang. Some vegetation absorbs radiation and also cools due to evaporation. It is particularly suited for a south side where a paved terrace or patio is planned. The following planting options should be considered. (Siple Nov. 1949 p. 159)

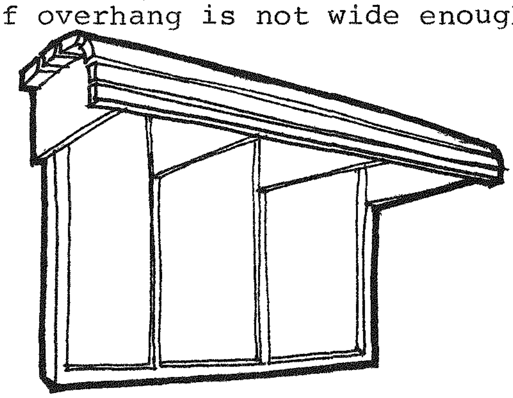
- deciduous shade trees spaced at a distance equal to their height will give summer shade and let in winter sun.



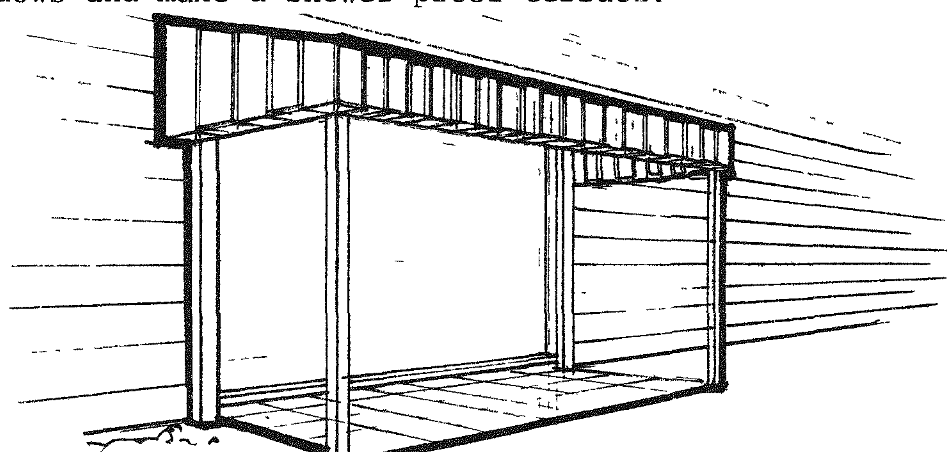
- trellis with deciduous vines gives shade in summer and lets in winter sun. It can also be extended to create a patio breezeway.



- wood lath, nailed to quarter rounds of wood, makes a permanent eyebrow if overhang is not wide enough. (Langewiesche, March 1950 p.135)



- ventilated metal awnings, that detach for winter, can shade windows and make a shower-proof terrace.



*Measurement of Energy Savings

- shade plantings on ES & W reduce solar heat gain (NAHB 1974 p. 54)

- shading on E & W can reduce sun loads by 1/5 (Olgyay p. 54) and reduce indoor temperature by 8 percent. (AAN.)

- exterior shading devices can reduce solar heat gain up to 80 percent, if they provide complete shading and permit air circulation (Hastings & Crenshaw pp. 2-16)

- exterior shading is 35 percent more effective than indoor shading because interior shading devices absorb, convert and reradiate some of the radiation, striking them back into the interior of the structure (Olgyay pp. 69-71).

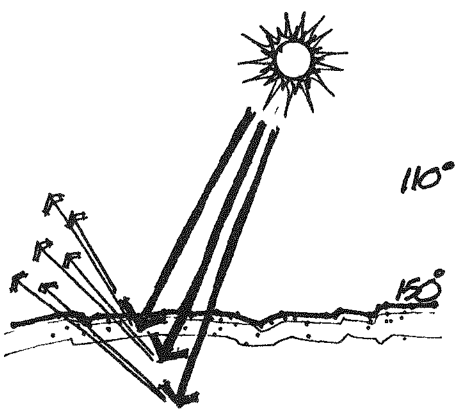
- shading glass windows can reduce heat impact by 1/3 (Olgyay p. 66).

- the shading on a roof or wall can reduce temperature of surface between 20 and 40 degrees.

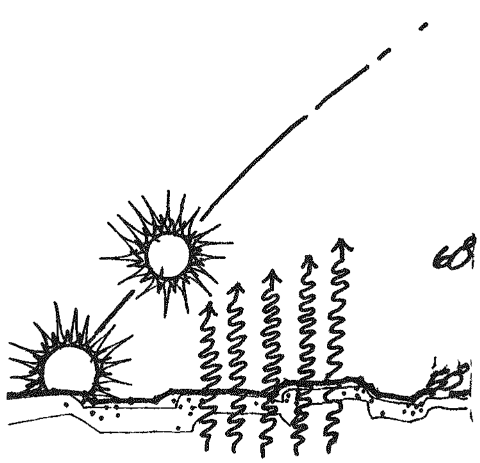
COOLING

While we normally think of radiation effects in terms of daytime heating, the total cycle of radiation--incoming to the ground during the day, outgoing from the ground at night, is a consideration for overall cooling effects. The primary response to using radiation patterns for cooling is an architectural one using court-style housing as a 24 hour temperature control device. It was developed in hot arid climates and is primarily suited for hot arid regions of this country.

The climate principle on which this response is based is that the heat of the day and the coolness of the night both rise from the ground. (Langewiesche April 1950 pp. 205-207)

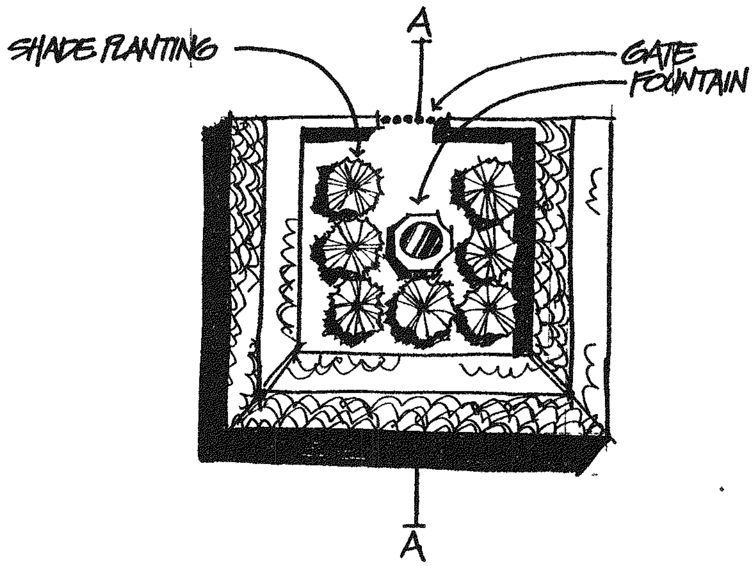


During the day, the sun heats the ground and the ground heats the air.

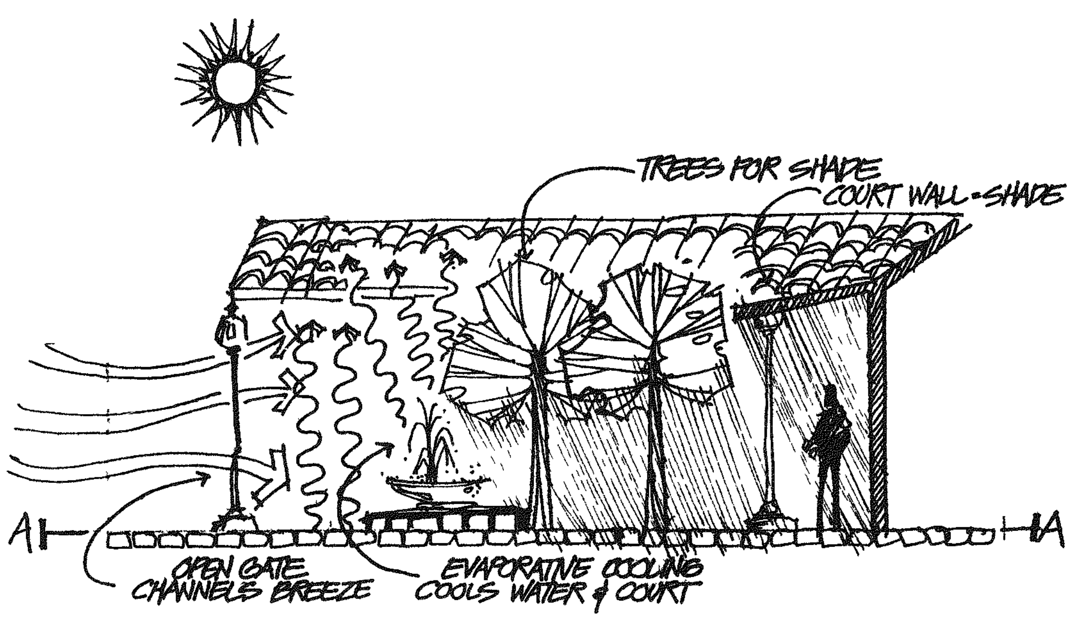


Just before sunset, the earth gets cool and begins to cool the air. (Langewiesche April 1950 pp. 205-207)

Use of court-style housing permits you to cut off radiation heat during the day and store cool nighttime air for coolness during the day.

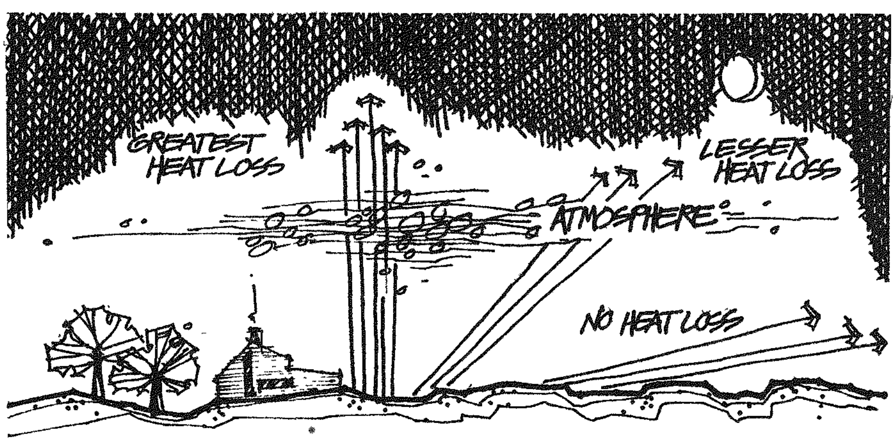


Basic components of the layout of court housing are court walls which enclose space, shade the dwelling unit and store evening coolness; open gate, which channels breezes; and water element, which provides evaporative cooling. Essentially, this is how the complex works during the day.



For evening cooling, it is primarily the following principle of nighttime radiation which makes this layout desirable.

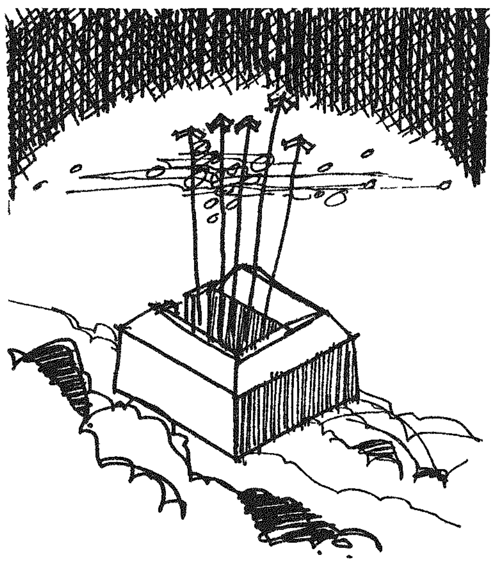
nighttime heat loss varies with direction: Heat loss from the ground at night occurs in three directions.



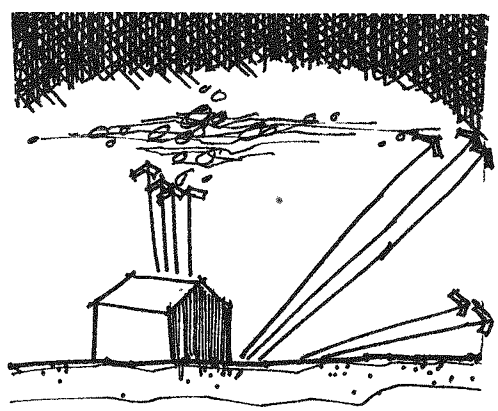
- perpendicular to the ground surface, which permits the greatest heat loss as raidation has to travel through the least amount of heavy atmosphere.

- oblique to the ground surface, which permits the least heat loss as radiation has to travel through the greatest amount of heavy atmosphere.

- almost level to the horizon, which traps hot air on the ground, permits no heat loss and often results in heat gain.



If we go back to our patio court layout, we can see that it permits maximum upward heat loss to the sky directly above--unlike an opened traditional structure which permits movement of evening heat in all directions. (Langewiesche April 1950 p. 205)



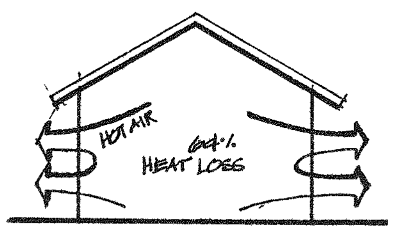
In considering this option, consider cost, time and effect. Also consider that on a larger scale the same principle holds true for planning and layout of structures. A multi-family cluster in the hot arid region could use the same principle.

Wind Control to Prevent Heat Loss

Wind and Its Relationship to Heat Loss

The primary reason that wind control is important in reducing heating requirements is due to the its effect on heat loss in a structure. The principle effects of heat loss can be summarized as follows.

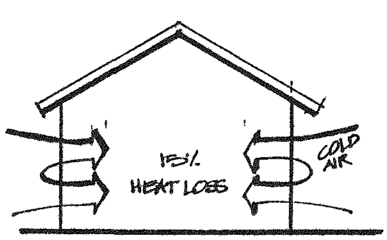
64% heat loss



HEAT TRANSMISSION OUTWARD.

heat transmission is the flow of hot air from the interior to the exterior of a structure which results in the loss of 64 percent of interior heat.

15% heat loss



COLD AIR INFILTRATION INWARD

cold air infiltration is the flow of cold exterior air to the inside of a structure which results in a loss of 15 percent of your interior heat. (NSF p. 98.)

This significance of wind in terms of heat loss is due to its velocity. The following effects of wind exposure on heat loss and energy consumption have been identified.

*Measurement of Heat Loading Effects

The following effects of wind on heating load of structures have been identified.

- a 20 mph wind can double the heating load of a building (Fitch, p. 104)

- heating of an unprotected house is 4x heating load of a protected house (Olgyay pp. 98-99)

* Measurement of Energy Consumption Effects

The following effects of wind exposure on energy consumption for heating have been identified.

1. Princeton: Townhouse Experiment

   - Townhouses exposed on the windward side use 5 percent more gas than houses on the leeward side sheltered by other buildings.

   - Townhouses at the end of the row with an exposed wall use 10 percent more gas than other units. (Harwood pp. 21-22)

2. South Dakota: House

   - An electrically heated house, fully exposed to the wind, uses more energy for the entire winter to maintain an interior temperature of 70 degrees F. than an identical house sheltered by a windbreak. (Hastings and Crenshaw pp. 1-5)

*Measurement of Energy Conservation Effects

The following effects of wind protection on energy conservation have been identified.

Nebraska Test House : Experiment conducted on two identical test houses with one exposed to the wind and one protected. A 70 degrees F. constant interior temperature was maintained. The following fuel savings were identified:

- The protected house had a 22.9 percent fuel savings.

- With good protection on 3 sides, 30 percent fuel savings were estimated.

(Olgyay p. 99)

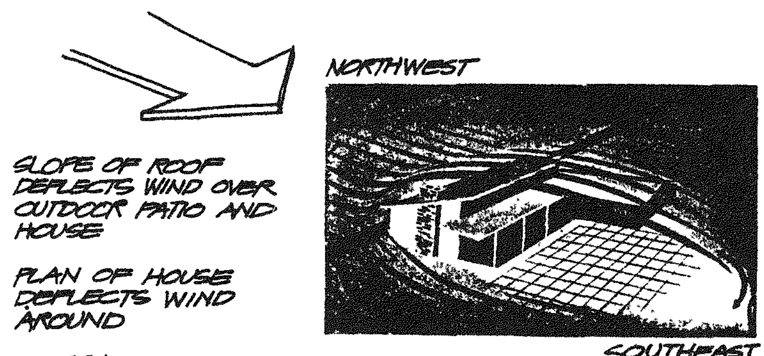
Principles of Wind Control

The primary characteristic of wind is velocity and flow pattern. In responding to wind by either attempting to buffer wind or channel breezes, the following principles must be considered.

velocity: wind cannot be stopped, it can only be slowed down and averted. An attempt to stop wind with a solid barrier does not work, instead it causes suction pressure and swirling on the windward side of the wall forcing the wind to break over the top and whirlpool. This effect is magnified with the height of the barrier, the most commonly seen example being the wind pattern around tall buildings in cities. (Langewiesche Oct. 1949 p. 194)

flow pattern: wind cannot be stopped it must have a place to go to deflect wind, but still permit a flow pattern to be maintained. A surface slant-wise to the wind is better than one set squarely against it. (Langewiesche June 1950 p. 91)

A good example of this is the slant of a pitched roof set against the wind which provides a better deflection and flow director than a wall.



(Langewiesche June 1950 p. 91)

OPTIONS FOR WIND CONTROL

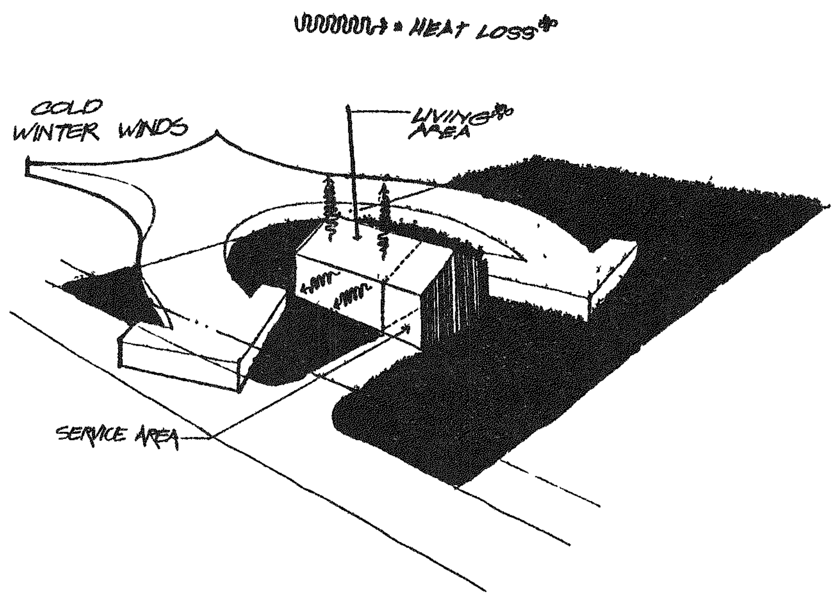
Because the velocity of wind is correlated with winter heating requirements, wind barriers are often required. Even if you have selected the optimum site or orientation, or if your present one is less than optimum, you might consider one of several wind barrier techniques. Keep in mind that different techniques are suited to different levels of planning and design.

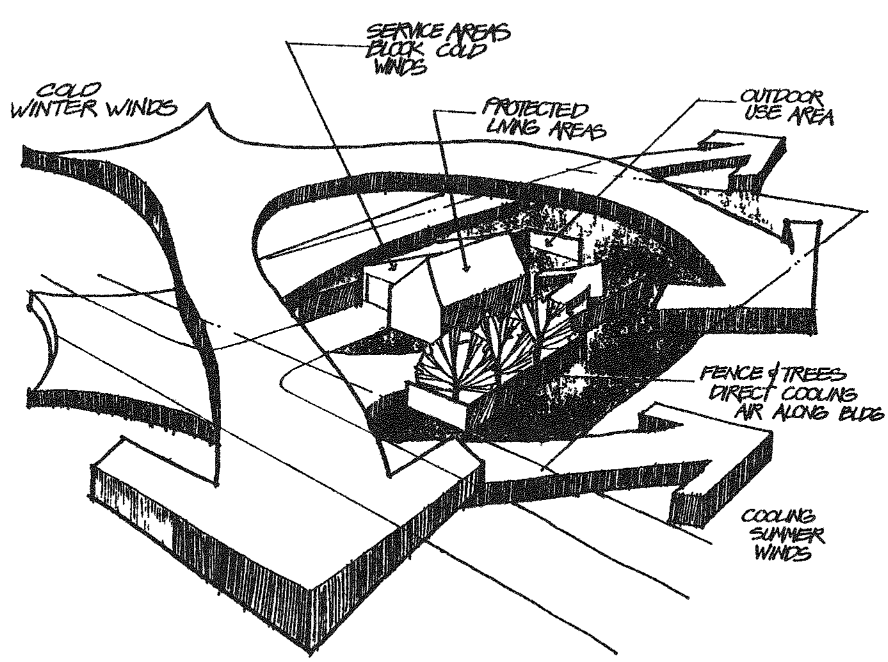
<u>large scale control</u>: To direct and deflect wind involves siting, orientation and design of your

house

trees

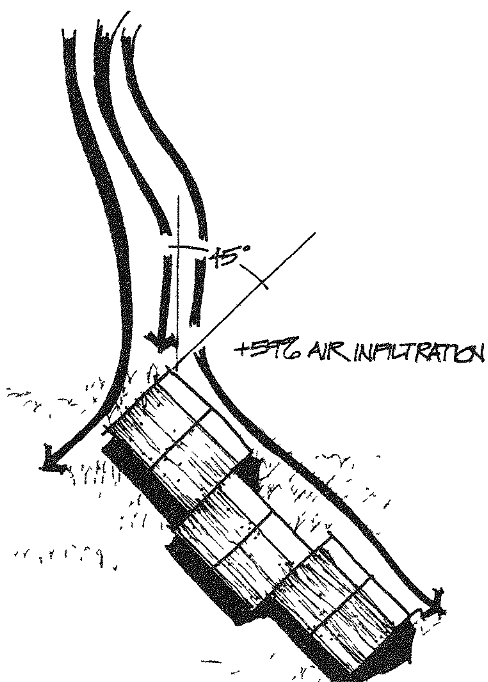
garage



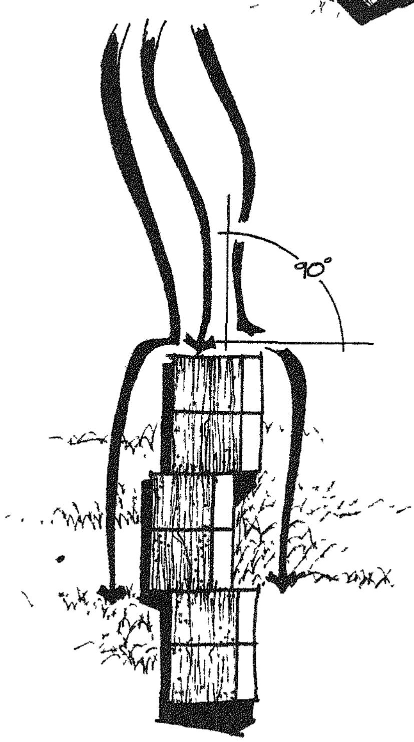


*MEASUREMENT OF ORIENTATIONS EFFECTS ON AIR INFILTRATION

According to simulation studies of comparative effects of orientation and air infiltration conducted at Twin Rivers, New Jersey, the following correlation between building orientation and air infiltration for exposed town house units have been identified.



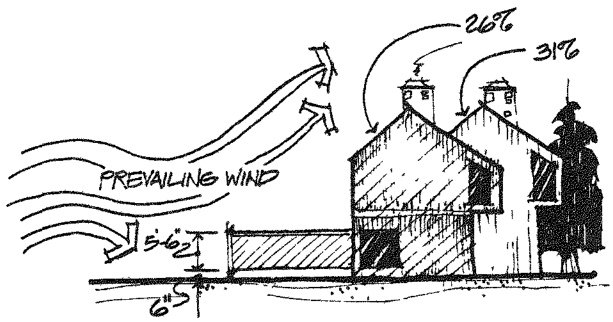
45° angle orientation to the wind is the worst possible orientation as it causes wind to flow towards the corner of structures, striking the front and side walls. Air infiltration measured for this unit orientation was 59% greater than an orientation with the front of units perpendicular to the wind. The 59 percent increase was measured for the end unit of the townhouse row. (Mattingly and Peters 1975 p. 33)



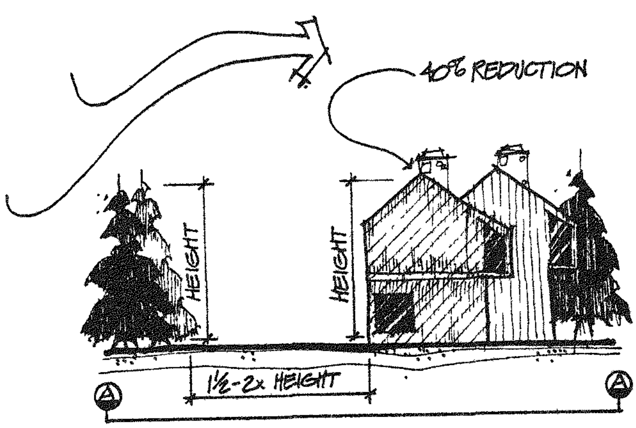
Parallel orientation of the sidewall to the wind produced the minimum amount of infiltration when the measured unit was either on the interior or lee side of a townhouse row. However, when measurements were taken at the end unit exposed directly to the wind, air infiltration was recorded as 52 percent greater than when the front wall of unit was hit directly. (Mattingly and Peters 1975 p. 37)

*MEASUREMENT OF BUFFERING EFFECTS ON AIR INFILTRATION

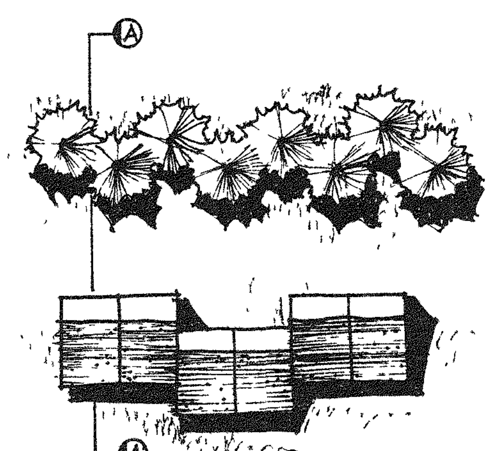
According to the Twin Rivers, New Jersey, study already cited (Mattingly & Peters), use of solid fencing and evergreen vegetation on the windward side of town houses resulted in the following reductions in air infiltration.



Solid fence: 5'6" at 6" off the ground on the windward side reduced air infiltration by 26% for end wall units and 31% for interior units. (Mattingly & Peters 1975 p. 37)



Single row of evergreens: At a height equal to the height of the unit located at a distance equal to 1½ - 2 times the height of a unit spaced to permit boughs at the base to touch resulted in a 40% air infiltration. (Mattingly & Peters 1975 pp. 37-38)

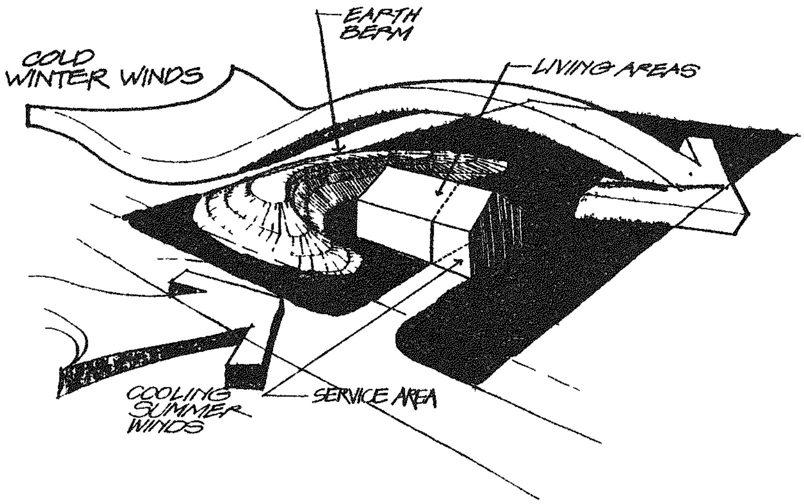


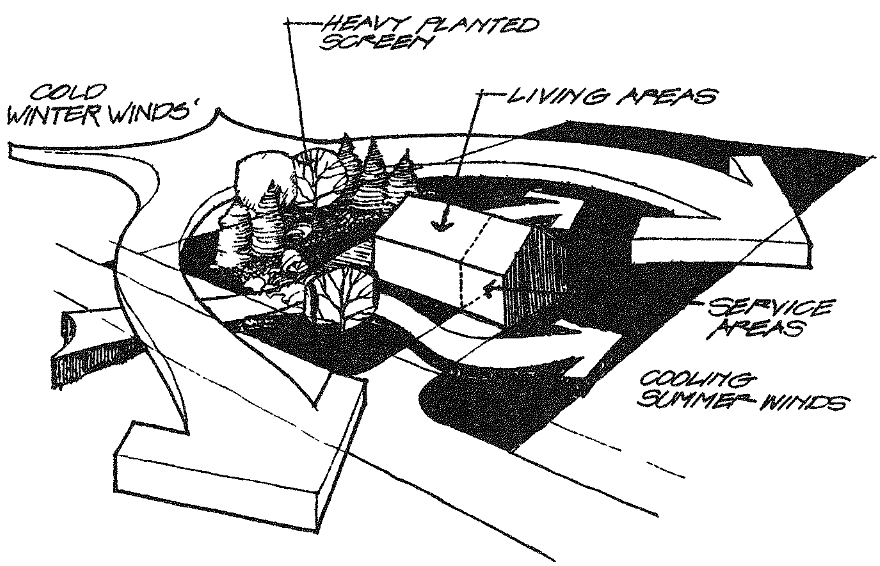
Combined fence and evergreens: On windward side of town houses resulted in a 60% reduction in air infiltration. (Mattingly & Peters 1975 p. 38) small scale control: To stop spillage, cross flow and whirlpool effects involves siting and design of

walls

fences

hedge

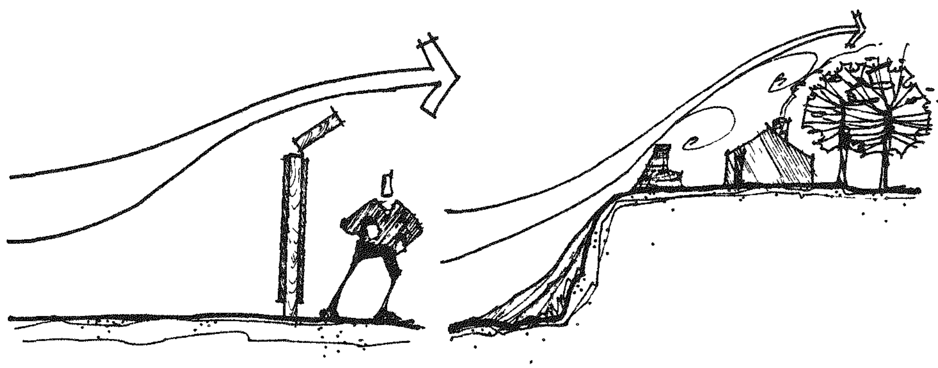




In buffering wind, remember that it should be deflected not stopped. Also, it should be deflected so that it has a place to go, through proper design of wind barriers you can determine where the wind will go. (Langewiesche June 1950 p. 91)

Essentially, there are two types of control--deflectors and barriers. Here is how they work.

wind deflectors: Divert air flow, they do not stop wind. They scoop up oncoming air, bend it and make it flow higher.



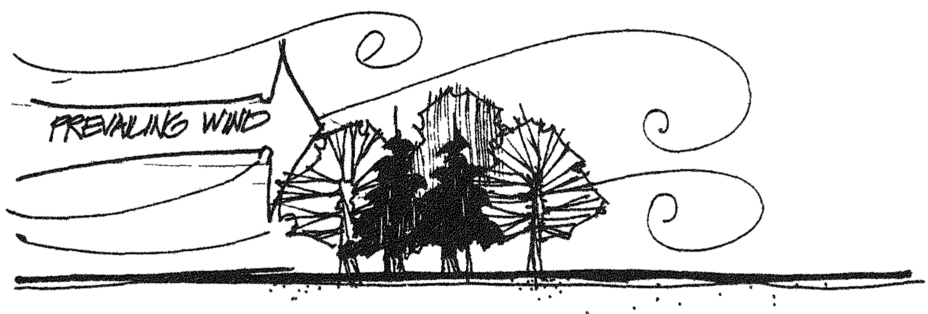
wind barriers: Effective wind barriers are wind penetrable barriers, they do not stop wind but slow it down due to frictional drag. The most effective wind barriers of this type are man-made barriers based on a half-slot snow fence design or natural tree barriers whose branching and twigs permit the same type of through flow. (Langewiesche June 1950 p. 97)

Though there are regional and site specific variations, the general cold wind pattern for the United States is NW wind. In buffering and directing wind with any device, first determine the site specific pattern of prevailing cold wind and respond to that specific condition. Options for controlling cold winter wind are illustrated below. In selecting any option, consider the needs versus cost, time and degree of effectiveness.

VEGETATIVE WINDBREAKS

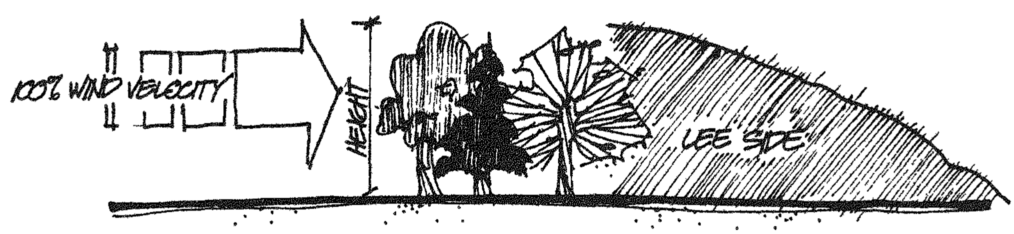
In using vegetation as a windbreak, the following design criteria should be considered.

placement: Shelterbelts and windbreaks are most effective when they are placed perpendicular to the prevailing wind.

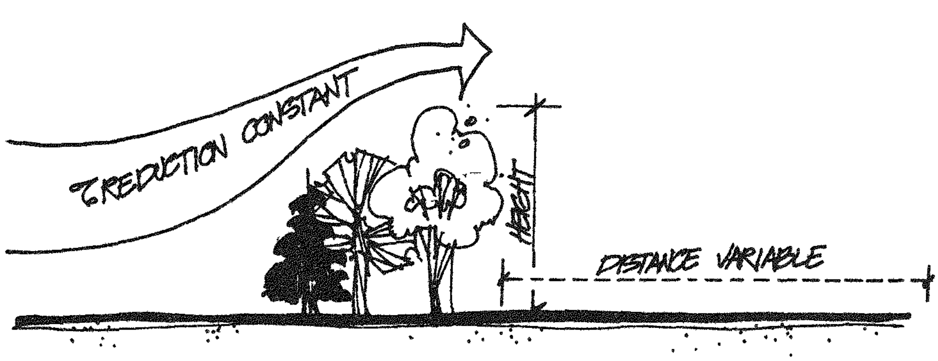


Height

- Height of trees is probably the most important characteristic, because the distance that protection extends to leeward is proportional to the height of the windbreak. The distance that protection extends is therefore commonly expressed in windbreak heights.

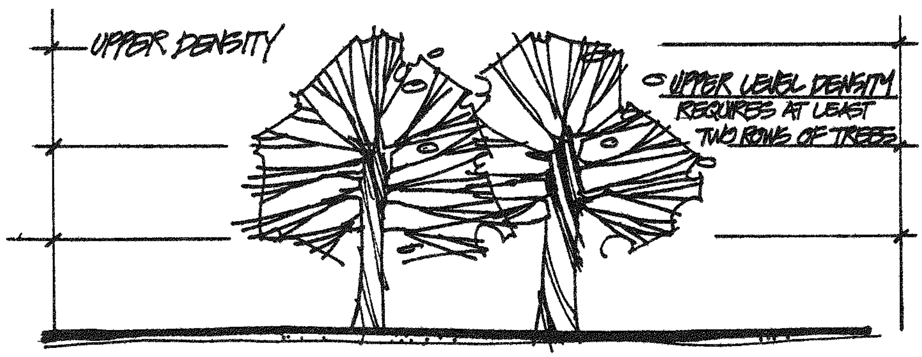


- For example, the amount that wind is reduced will differ at leeward distances of 4, 10 or 20 times the average height of barrier, but the percent reduction at 4 H, for example, is the same regardless of barrier height.

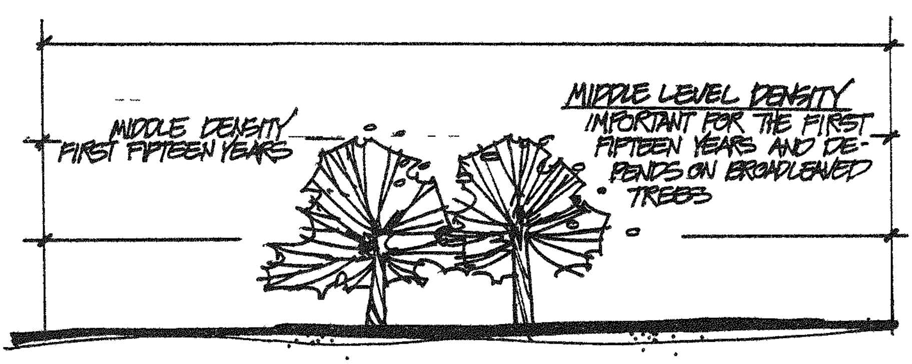


density: Density of different height levels in windbreaks is important for wind reduction. It is also a consideration in terms of the amount of time required for effective wind protection. The following series illustrates density levels and comparative effectiveness over time. (Read pp. 11 & 12.)

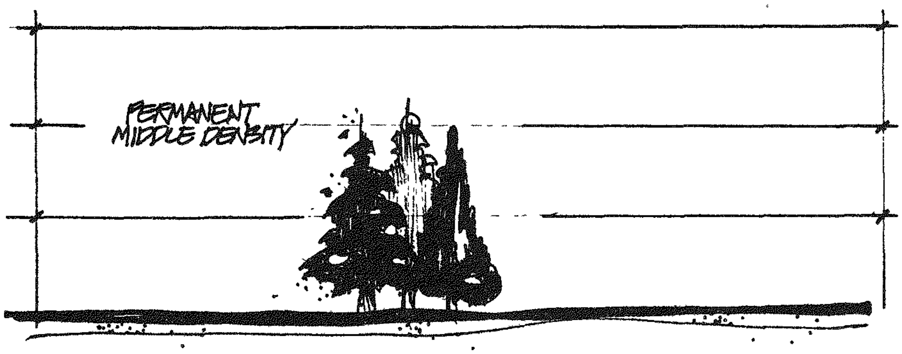
- upper level density requires at least two rows of tall trees which are effective for the first 15 years of growth.



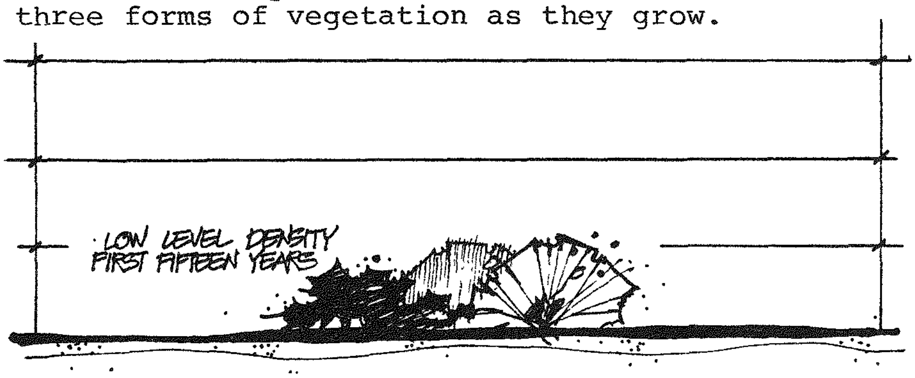
- middle level density is also important for the first 15 years of growth and requires low, broad-leaved trees.



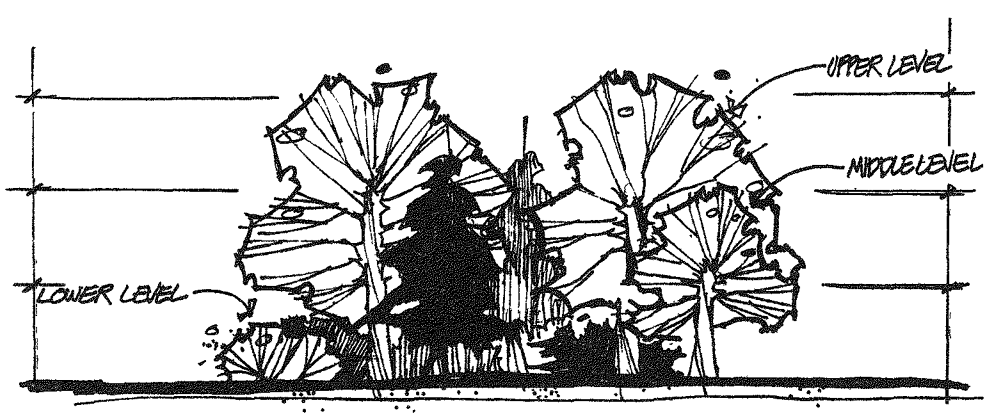
- permanent middle level density depends on pines and red cedars for lifetime effectiveness.



- lower level density for the first 15 years is provided by all three forms of vegetation as they grow.



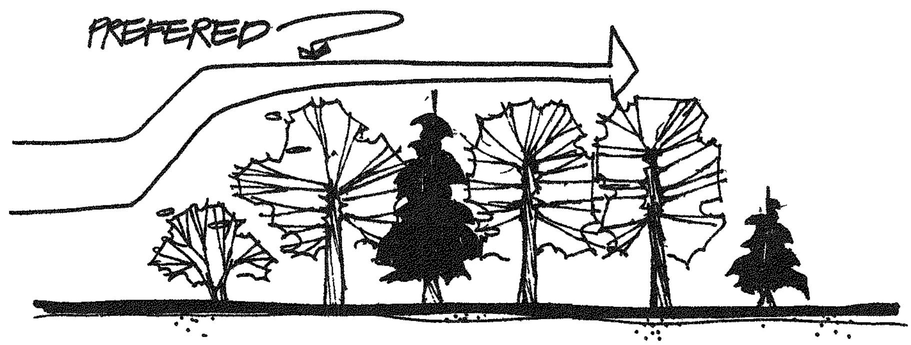
- after 20 or 30 years, most conifers and broad-leaf trees loose their leaves, and permanent density must be provided by low thick shrubs.



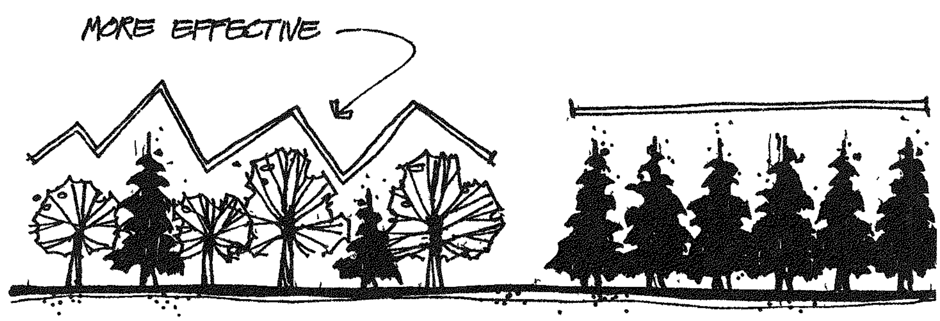
<u>length and width</u> of windbreaks is only important in so far as it effects density. Making windbreaks wider than necessary to achieve moderate density has no added effect on wind reduction. In general windbreaks patterned on multiple rows produce maximum desired foliage density at all levels. (Read p. 15.)

configuration of windbreak effects the degree of wind reduction and penetration. Shelterbelts with a pitched roof cross-section are the least effective at stopping wind and should be avoided.

Preferred configuration is one with a strong vertical outline.



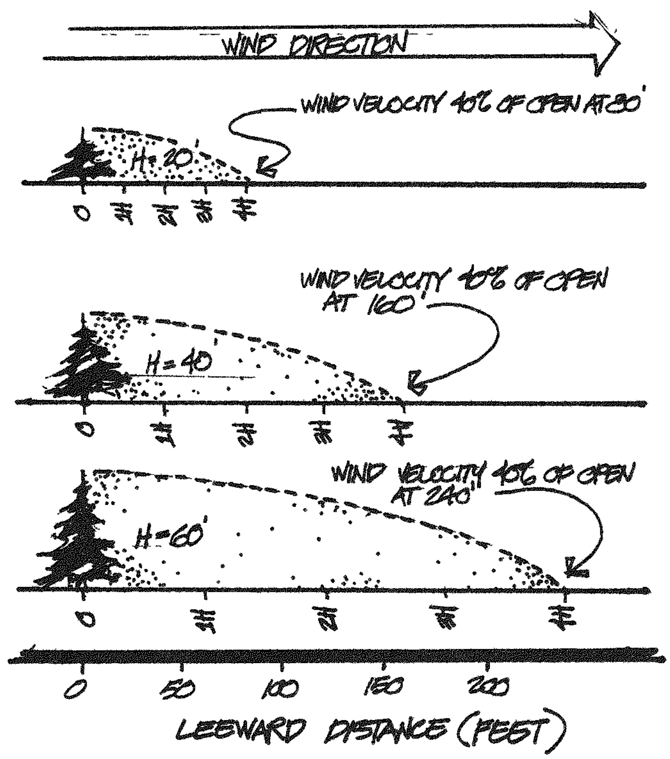
The most effective windbreak configuration is an irregular one which is most effective in reducing eddying than a uniform one.



Also, a mixture of species and sizes producing a rough upper surface is more effective in controlling wind (ASLA p. 35).

*Measurement of Climate Modification

(Effect on wind velocity) Windbreaks can produce velocity by 40% over horizontal distances up to 4 times their height. Wind at 20 mph can be slowed to 10 mph, and a 40 mph wind can be slowed to 20 mph. General effect is in proportion to height and distance as illustrated. (Read p. 3.)



*Measurement of Energy Savings

1. Wind barriers of trees, vines and plantings on the south and west side can reduce winter fuel consumption in range from 10 to 40 percent. (AAN)

2. Formula for Quantification (Olgyay p. 98.)

   heating load/wind velocity/temperature difference/shelter belt location

$$\frac{Q}{T} = 1.3\ (10^{0.018L0.7u})$$

Q = heating load in BTU per hour

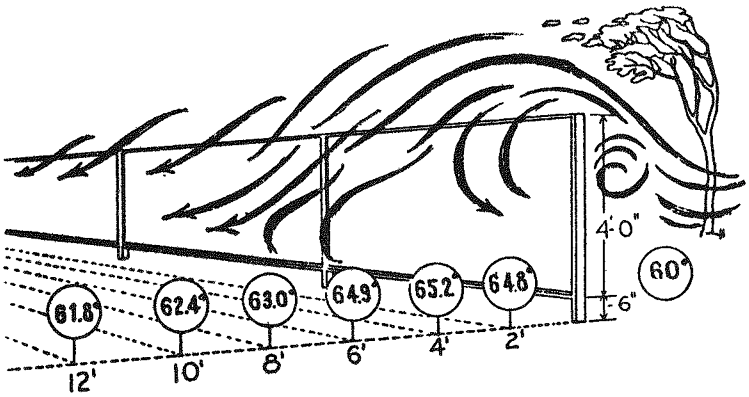
T = difference between inside and outside temperature in degrees Farenheit

L = distance from belt to house in barrier heights

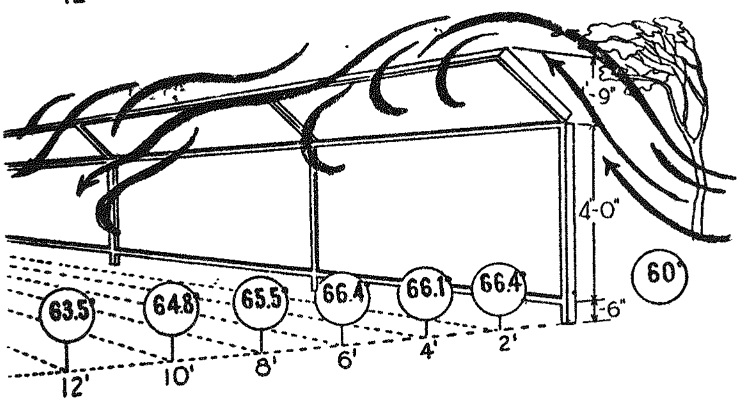
u = wind velocity in mph

WIND FENCES

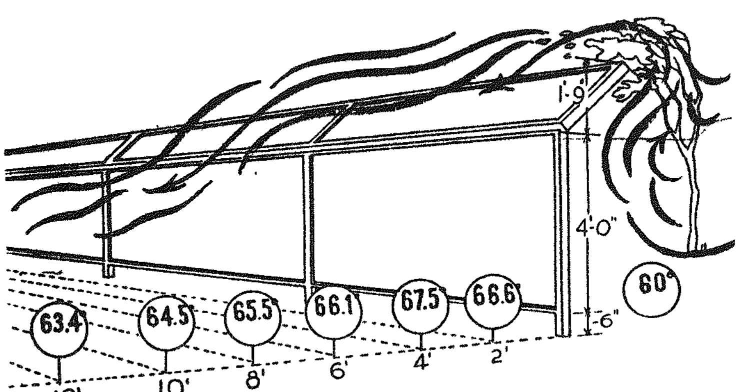
Since the chilling effect of wind is proportionate to its speed, wind fences which decrease velocity can be effective in creating warm zones on the lee side. (Howland June 1950 pp 101-102)



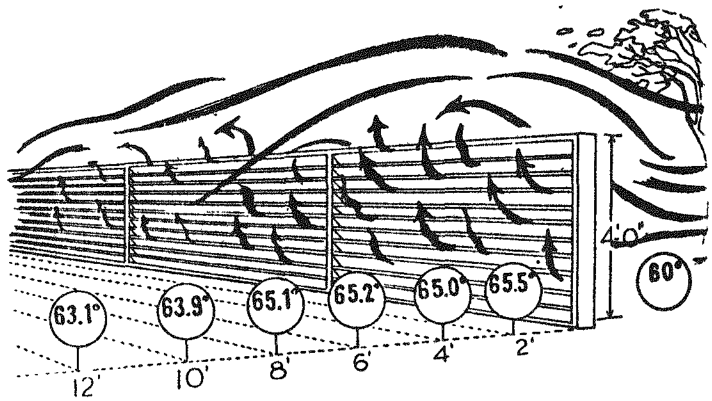
Solid barriers are ineffective windbreaks as they try to stop wind and create problems of eddying and swirling. Don't use them.



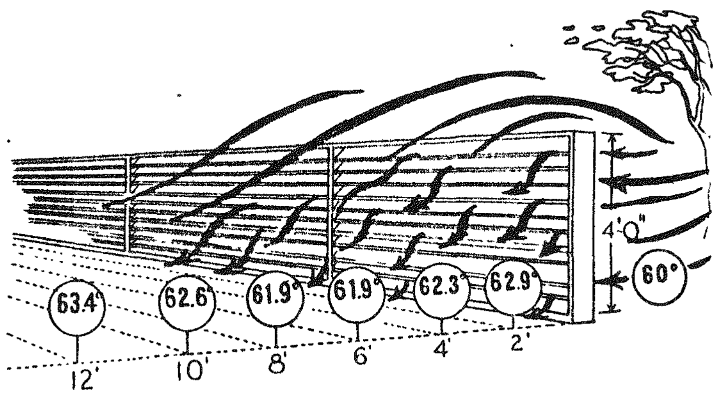
Solid barriers with sloping baffles are effective in creating a warm zone and decreasing velocity because the baffle directs wind up in a gentle arc and avoids downward; wave-like whirlpooling



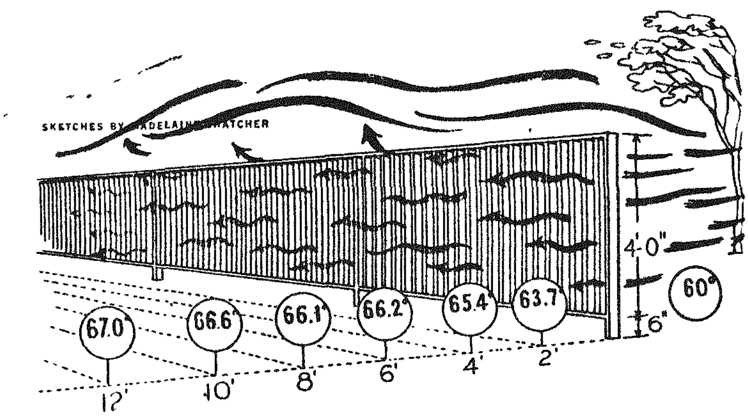
Solid barriers with slanted baffle toward the wind gets a somewhat smaller protected area, but note that close in lee of fence, you get highest temperature readings in any fence tested: 67.5 degrees F. Even at three times its height behind fence, protection was noticeable.



Horizontal louvers tilted up away from wind, proved better, all-around windbreak than solid fence. Temperatures were not quite as high but protected area was wider. This fence would be good where wind velocities had to be reduced but ventilation kept.



Tilting the louvers down makes the least effective windbreak of all fences tested because the louvers bounce the wind right down into the area to be protected. This is not a warm fence.



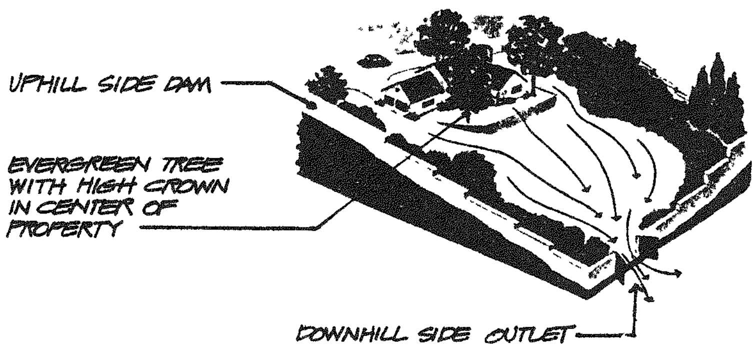
Vertical laths, spaced a half inch apart, made a good windbreak. Although temperatures were fairly low in immediate lee, they rose steadily as you moved away. At a distance of three times its heights, this fence gave best protection of all.

WALLS

Walls are another device which can be used to modify cold wind and air. They are most suited to climate regions or sites where frost and severe cold night air is a problem. As with any other of the wind devices, they work on the principle of channelling cold air flow and draining frost--they do not attempt to stop it, merely to direct it.

At night, cold air creeps along the ground and brings frost to low places where it collects. If you have a site with cold air pockets, you might consider a device such as the wall illustrated below. It works by daming, draining and collecting cold air.

The wall is designed to calm cold air on the uphill side with a wall opening on the downhill side to act as an outlet. The house plan and evergreen divert air from the center of the site and the house. The design is based on the pattern of cold air flows down hill at ground level and encourages the natural pattern to eliminate frost pockets. (Langewiesche June 1950 p. 204)



SUBTERRANEAN HOUSING

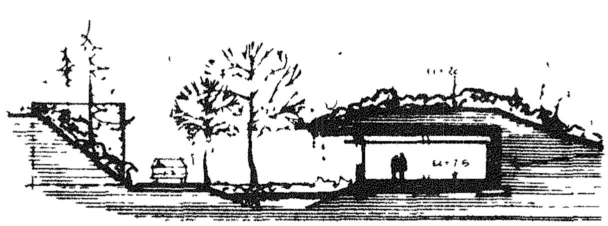
While this technique is primarily suited for areas that are not humid, it is an immediate and effective way to insure minimum heat loss in a structure. Subterranean housing is based on the following principles. (NSF, July 1975 pp. 89-92)

elimination of heat loss: Conventional structures lose heat in two ways. One is by heat transmission through walls, the other is air infiltration into the building. Since underground houses have a minimum surface exposure to the cooling effect of air and wind, infiltration loses are greatly reduced.

soil temperature: Soil temperatures are very slow in change. About the time that you start to need to heat your house the soil is reaching its maximum temperature from the summer heat. This thermal lag reduces heating and cooling needs.

Basic requirements for subterranean housing are as follows:

- insolation, waterproofing and dehumidification
- low water table
- subsurface drainage
- detailed soils analysis of your site



CONCRETE STRUCTURE
AIR SPACE ALL AROUND
INSULATED LIVING ENVELOPE

CROSS SECTION A-A

*Measurement of Energy Savings

In studies done at 25 degrees Farenheit, it was determined that heat loss through a wall with eight inches of insulation is 6.5 times greater than that through an uninsulated underground concrete wall.

- heating needs can be reduced by up to 75 percent

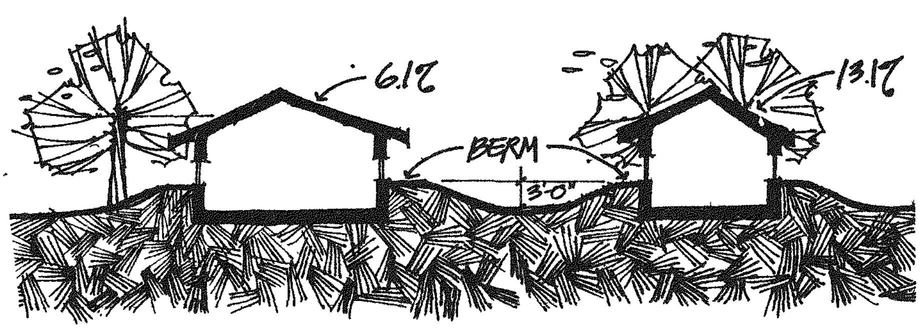
- even a thin layer of soil on the roof of a house and a berm around it can reduce energy usage by 30 percent.
  (Smay April 1977 pp. 85-91)

EARTH BERMING

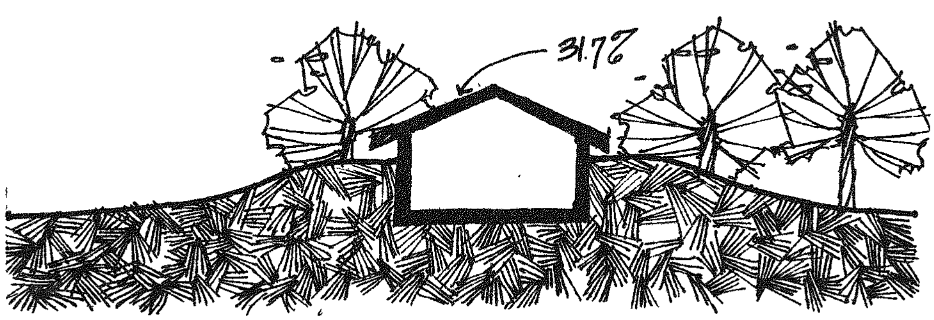
If site conditions are unsuitable, or the concept seems to radical, earthberming might be considered as another option for reducing heat loss. By using the earth berming on the windward side and orienting major windows for optimum sun, measurable heating savings can be achieved.

Measure of Energy Savings

Three feet earth berming to windows sill reduced heat loss 6.6 percent for rectangular house and 13.1 percent for a square house. (Kroner and Haviland pp. 30-31)



Earth berming two feet below roof eave, leaving full length door and window areas, provided a 31.7 percent reduction in heat loss.



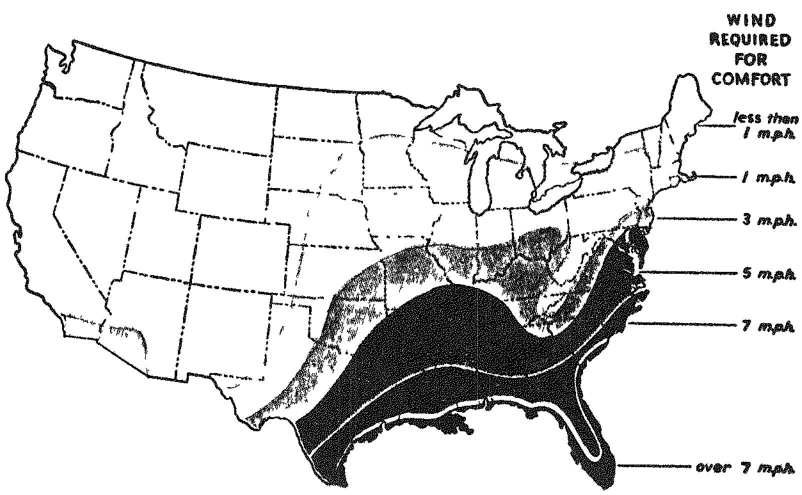
Wind Control for Cooling

We've looked at techniques to modify winter wind, now let's look at techniques to use summer breezes to your advantage.

The positive role of wind which you want to maximize is the cooling effect of summer breezes. Basically, the hot weather wind requirement is to pick up enough wind to dry perspiration. Too little wind makes you feel damp and hot. Too much wind makes you feel dry and hot.

The big factor effecting response to summer wind is the degree of humidity in a climate region. Humidity or mugginess is due to vapor pressure which prevails during July and August, and which keeps.perspiration from evaporating.

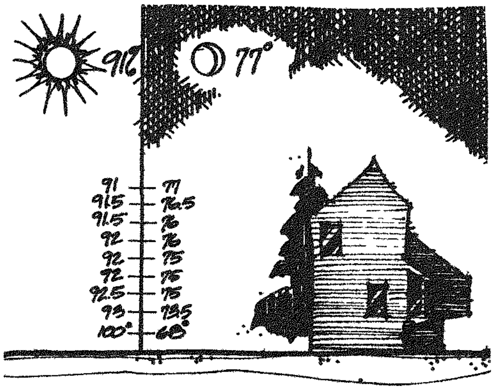
Regional requirements for summer wind correlated with humidity are illustrated on the map below:



Variable wind requirements are as high as 7 mph in the hot humid zone (Florida, Georgia coastal regions) and as low as 1 mph in the temperate zone (Kansas City, Chicago and New York City). (Langeweishe June 1950 p. 125)

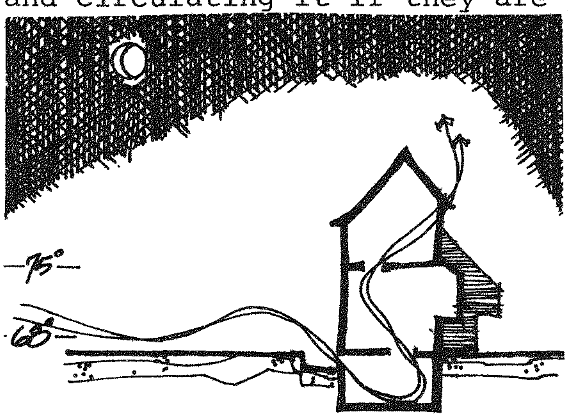
Basic principles of climate which relate to summer cooling are as follows:

day and night temperature distribution: As the discussion of radiation pointed out, daytime radiation is incoming radiation to the ground Temperature distribution measured along the vertical height of a two-story house illustrates how significant the differences are: During the day, temperature is hottest at the ground level and 9 degrees cooler (almost 10 percent) at the roof line. (Langeweishe June 1950 p. 165)

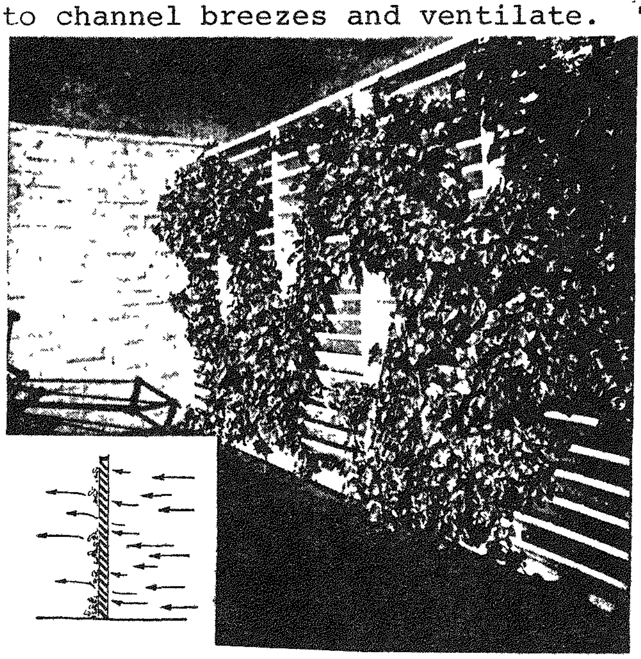


The air you want to capture is the coolest available--lower ground air at night, upper level air during the day. Remember, however, that air above 85 degrees cannot cool and if carried by a breeze it can even make you hotter, so only encourage summer air flow of cooler air. Your main response will be to capture evening breezes as close to the ground as possible. Most of these techniques relate to the layout and design of your structure.

<u>air intakes:</u> Can be 100 percent effective at capturing cool air and circulating it if they are placed at the right level. Remember the comparative day and night temperatures near the ground for air intakes should be taken at ground level, locate them here and don't block them with vegetation or earth. (Langeweishe June 1950 p. 124)



<u>shade fences:</u> If your daytime temperature is cool enough and winds aren't hot, remember your windbreak or sun shade can also be used to channel breezes and ventilate. The proper combination of an open slat system with vegetation to cause evaporative cooling can make your sun shade a breezeway as well. (Langeweishe June 1950 p. 124)



Regional Applications

Options for Passive Energy Conservation in Site Design

Regional Site Design Guidelines

Site planning or design for energy conservation takes different forms and serves different purposes in different climatic regions.

There have been a variety of climatic classifications to indicate appropriate design regions in the continental United States over the years. These vary from some categorizations of over one hundred, to others which list a dozen or more, to the four areas identified by Victor and Aladar Olgyay in the book, "Design with Climate," first published in the 1950's. These four regions— the cool, the temperate, the hot-arid and the hot-humid, though not exact or precise, are most easily understood and applied. Therefore these are the ones used in this book. The regional boundaries are not exact and the guidelines or principles for climate control, and thus energy conservation, may be applied to varying degrees depending upon where a site is located in a region.

The fundamental concept behind the regional application of land planning for energy conservation is to use natural patterns and forces to bring the local microclimate as close as possible to the optimum range of human comfort. In this way it will require less energy to heat or cool a building or an area. Obviously in the cooler regions this means optimizing solar radiation and minimizing the effect of cold winds. In hotter regions, it is clear that it is necessary to reduce to the extent possible the warming effects of solar radiation and to direct and enhance the effect of the cooling winds or breezes. Starting with those basic premises a large number of subtleties and nuances are covered in greater detail within the following sections. After a brief description of the climatic characteristics of the region in each section, the energy conservation options available in each stage of the typical site planning process are explored. These usually move from gross to discrete site selection, to site planning and design and from that to the alternatives in the selection of site materials or elements. All of this is with an eye to conserving to the maximum extent possible the use of energy.

These expositions are not definitive. They do provide a skeleton or a framework on which further research or study can be undertaken in order to "flesh out" the ultimate data available to a user, designer or decision maker.

SECTION II
REGIONAL SITE DESIGN GUIDELINES

INTRODUCTION

This section provides an overview of site design considerations for the four major climatic regions of the United States. These regions are the Cool, Temperate, Hot Humid and Hot Arid regions, respectively. Due to the great variation in climate and site characteristics in any of the designated regions, emphasis has been placed on design process and varied design options for prototypical situations. The only reference to specific geographic locations are those studies which are cited in the context of the climate region in which they would fall (e.g., Davis, California, studies are cited in the Hot Arid region; Princeton, New Jersey, studies are cited in the Temperate region). In terms of internal organization, each climate region is structured as follows:

Climate Characteristics

Design Criteria

Gross Site Selection Guidelines

Discrete Site Selection Guidelines

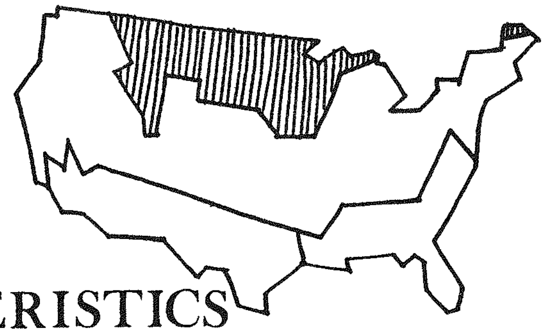
- Site Analysis
- Site Selection

Design Guidelines

- Plan Layout
- Building Relationships

The guidelines presented are general, but do cover the range of considerations which should be taken into account on a site specific basis. At this level, trade-offs between site, program regulatory and market constraints would have to be taken into account.

PART I
COOL REGION



COOL REGION

CLIMATE CHARACTERISTICS

Winter

- Sunlight probability 0.35 (BSIC p20)
- Maximum radiation on S vertical walls (2 x E & W)
- Prevailing wind NW & SE

Summer

- Sunlight probability 0.60
- Maximum radiation on E & W vertical walls (2½ x S)
- Prevailing wind NW & SE

DESIGN CRITERIA

Winter

- Heating requirements: 7,000 degree days (BSIC p23)
- Increase heat production, radiation absorption
- Decrease radiation loss
- Winter response is 3 times as important as summer response (Olgyay p.155).

Summer

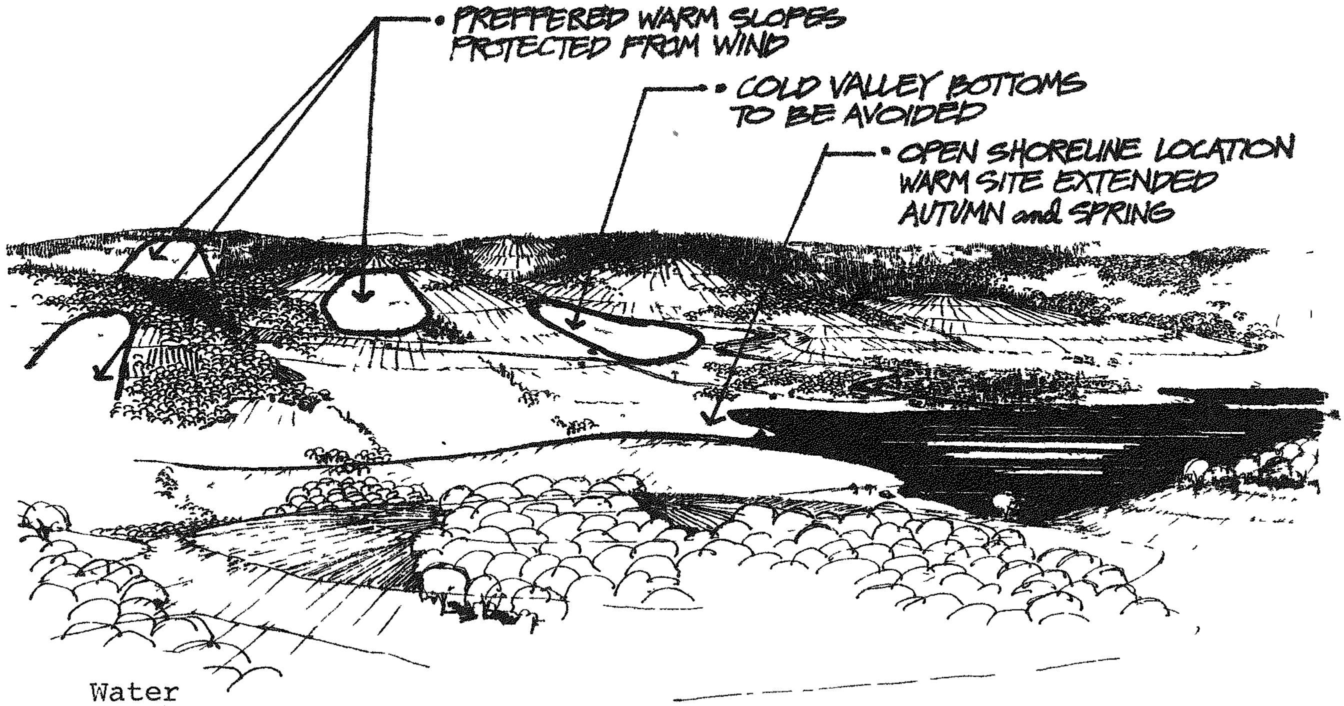
- Reduce conduction and evaporation loss (Olgyay p. 155).

GROSS SITE SELECTION GUIDELINES

Look for sites with slope and orientation to increase day time winter radiation and decrease winter winds. Look for:

Landform

- Lee side of hill
- Any location out of prevailing NW winter wind
- Avoid valley bottoms



Water

- In Great Lakes region, shoreline locations have the advantage of:

  heavier cloud cover

  extended autumn and spring season

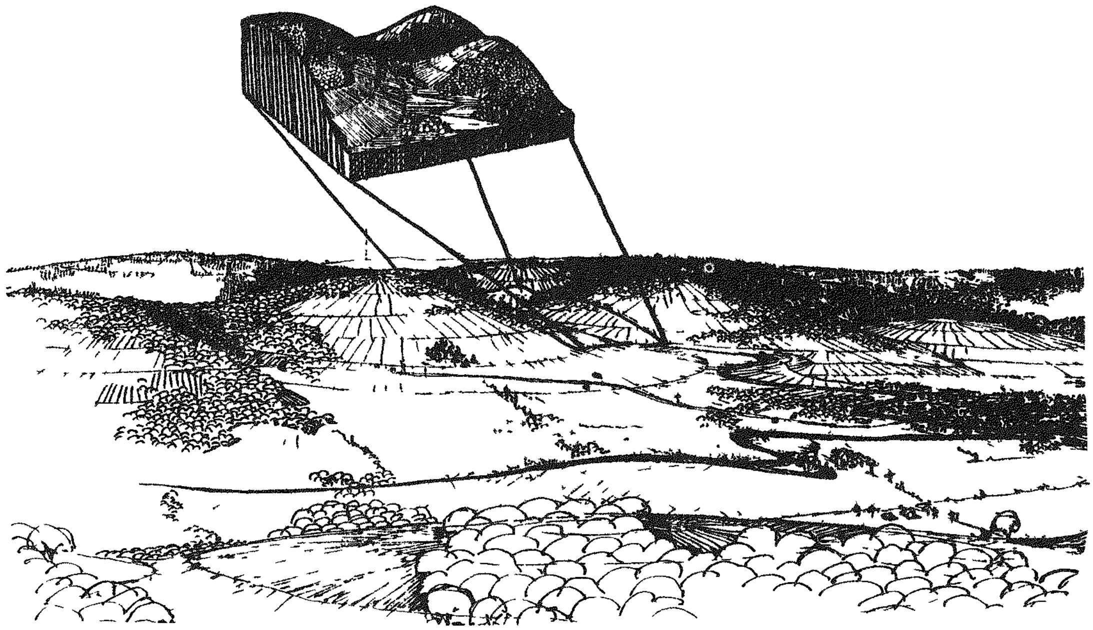
  shoreline breezes

- In Great Lakes region, inland locations have:

  greater temperature extremes

  lighter snow blanket

DISCRETE SITE SELECTION GUIDELINES



Site Analysis

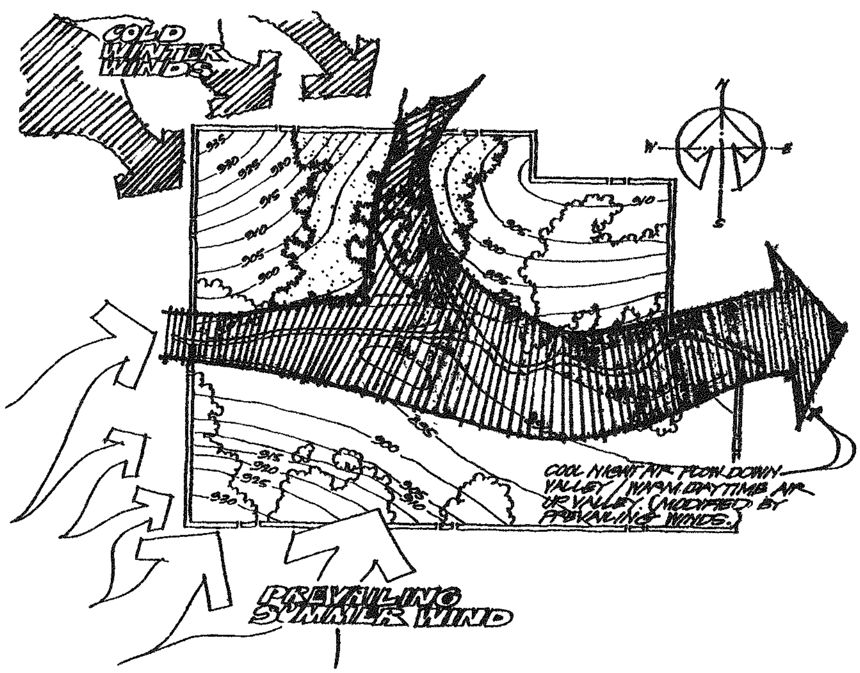
Analysis and selection of optimum residential sites should be based on the following general criteria:

- Identify and select sites with the greatest protection from prevailing winter winds as cool region has the highest winter heating requirement (7,000 Degree Days) of any part of the country.

- Identify and select sites with warm slope orientations South or Southeast preferred.

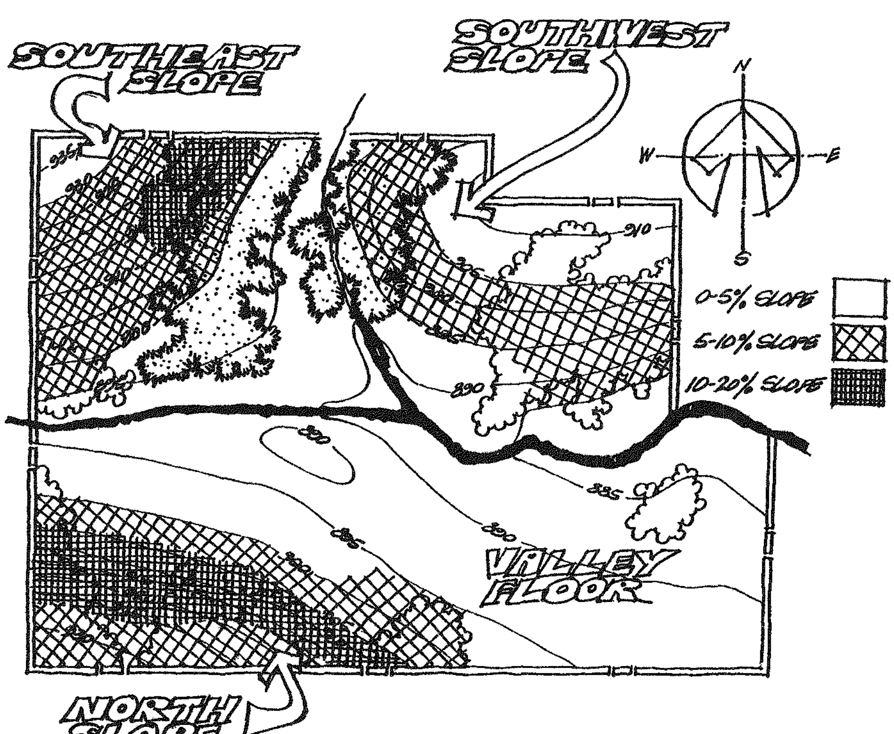
- The relationship of topography and vegetation to winter wind and sun are the primary determinants for site selection.

Seasonal Wind and Cold Air Flow



- Avoid ridge locations exposed to winter wind
- Avoid valleys locations which are cold, damp potential frost pockets
- Select SE slopes with exposure to summer breezes

Slope Direction and Gradient

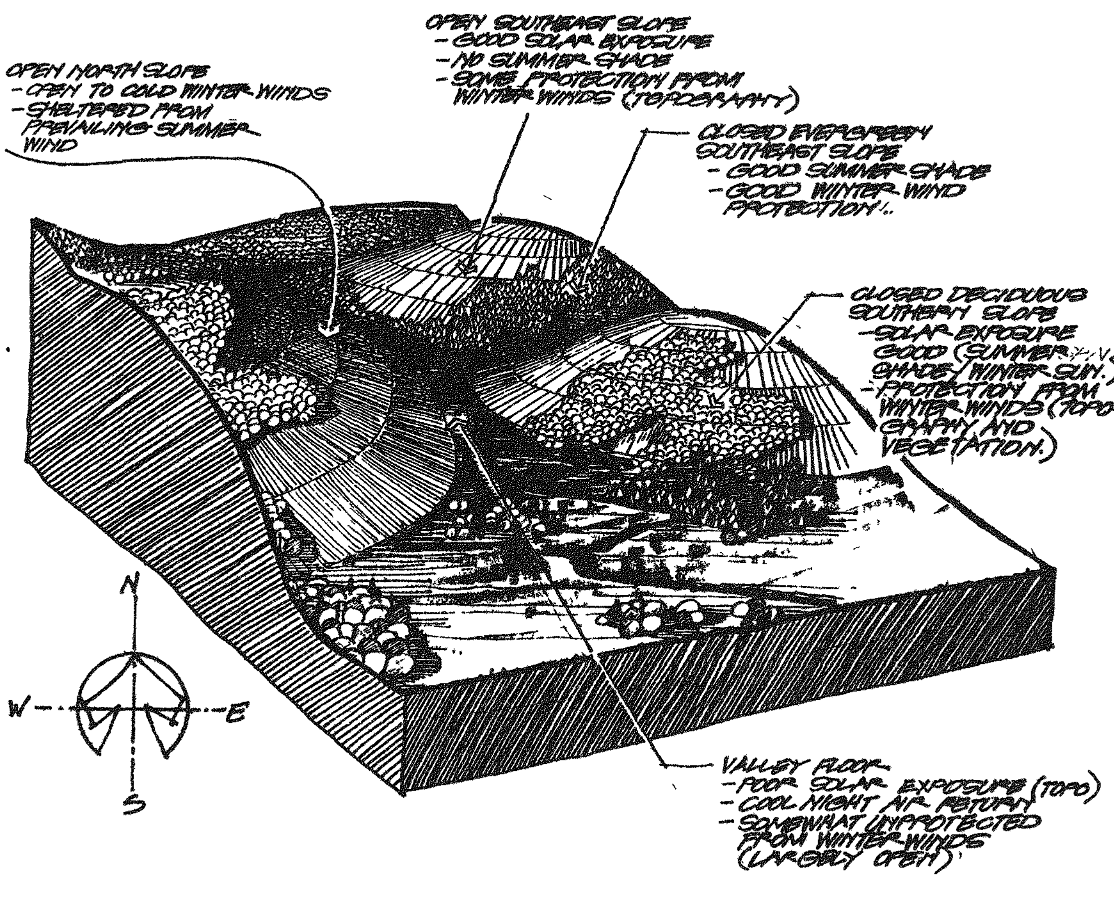


- Select South-Southeast slopes for residential development
- Avoid high water table due to humidity and frost
- Avoid gradients in 10%-20% due to susceptibility to erosion, cost of development and potential of disturbing surface air flow and snow drifting patterns

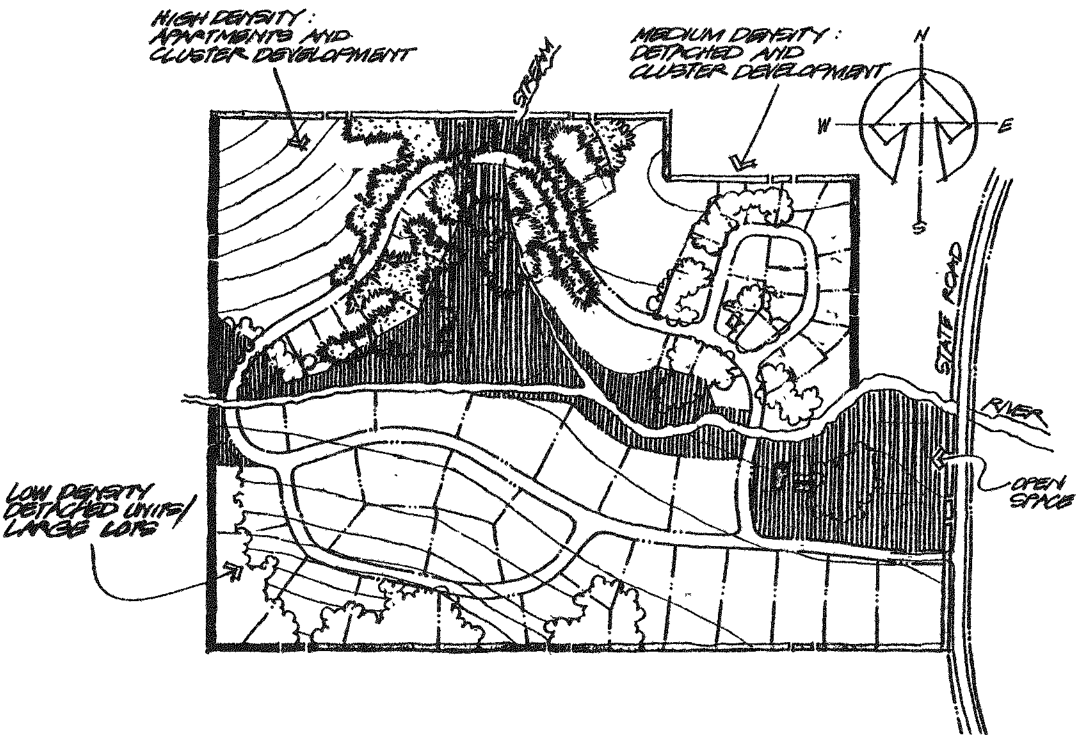
Site Selection

Site selection should be based on combined consideration of:

Winter and Summer Climate Influences related to existing landform, vegetation and natural features.



Development Suitability for various uses, structural types and use intensities.



Recommended guidelines for various uses and structural types are as follows:

- residential structures: select S-SE slopes for winter sun gain

- tall structures: select sites out of prevailing wind and downward from lowest elements (ASLA p. 183)

- exterior open space: select open sites with periodic shading sheltered from NW wind

- exterior living space: select sites on S side of dwelling for protection fron NW and N wind and exposure to summer and winter sun

Development Suitability for various use intensity should be based on combined consideration of landscape type slope orientation and gradient, presence of dense mature vegetation and site accessibility.

Guidelines for various use intensities correlated with landscape type have identified as follows (Kaminsky p.35*):

- high intensity use: warm slopes (S, SE, SW, E) and flat or rolling land (0%-8%) with high accessibility.
- moderate intensity use: warm slopes over 8% with high accessibility.
- low intensity use (low building coverage): cold slopes (N, NE, NW) with extensive tree cover.
- semi rural intensity use (low intensity and low building coverage): slopes in excess of 15%.

* Note: Classification system and landscape types developed for a specific study site in Baltimore County but are suited for requirements in this region. Conceptual framework of the system, which incorporates Floor Area Ratio (FAR) and trip distance, suggests adaptability to various regions of the country.

Existing Regional and Site Specific Energy Consumption Patterns as indicated by existing developments.

An independent study conducted jointly by the Reimann·Buechner·Crandall Partnership, Landscape Architects, and the Niagara Mohawk Power Corporation of Central New York has been ongoing for the past year (July '77 -).* The study attempts to correlate energy consuption for heating and the following site characteristics:

- topography: slope gradient and orientation

- vegetation: type and degree of coverage

The site factors identified above have been used as comparative variable factors. The following factors have been held constant:

- housing characteristics: construction, age, size

- development characteristics: density, housing type

The study methodology has been to select specific residential development sites in Syracuse, New York, with variation in either topography or vegetation characteristics. Energy consumption data for space heating of houses on these sites has been provided by the Niagara Mohawk Corporation and used as the basis for comparing energy efficiency.

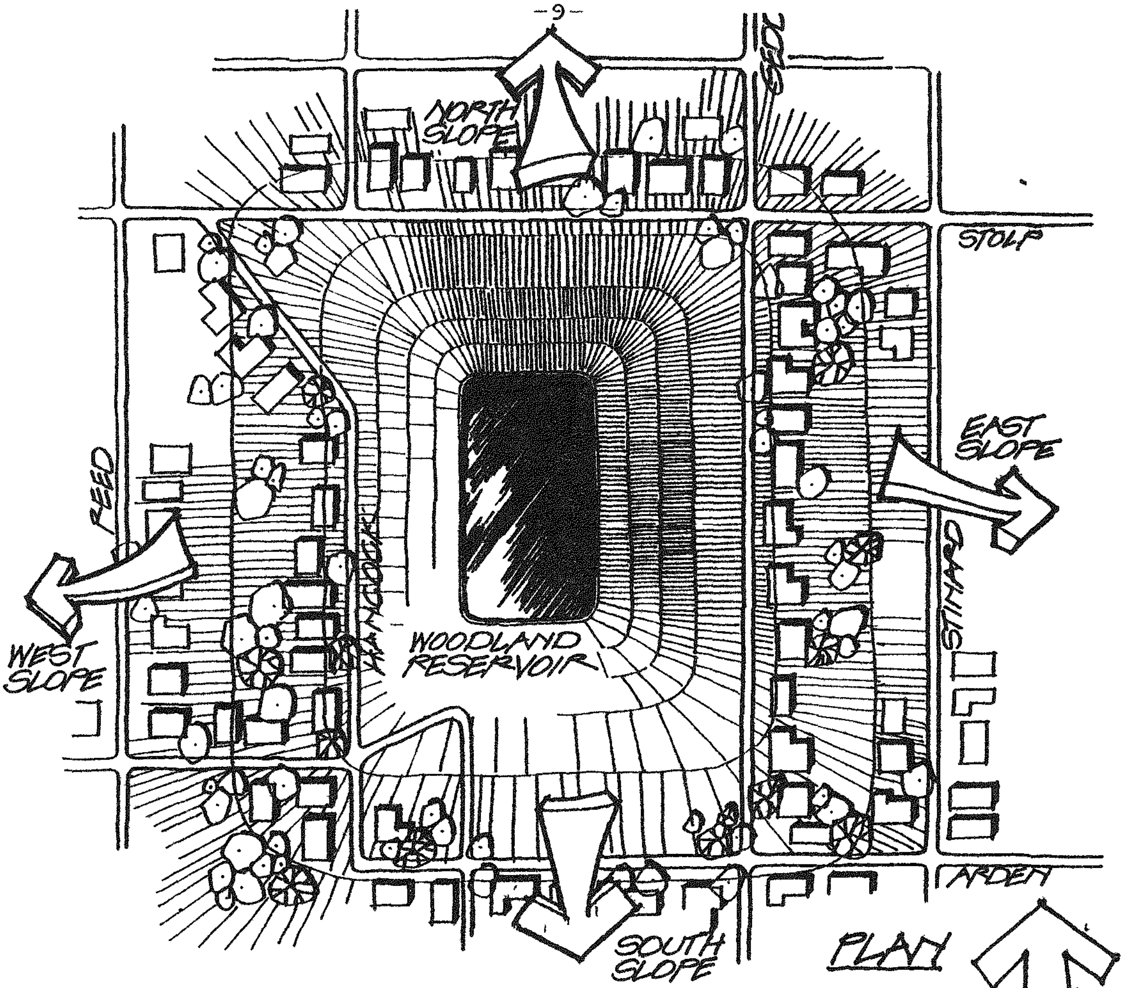
Preliminary study conclusions and sites illustrated on the following pages indicate the following:

- highest energy efficiency related to slope orientation: is found on south or southwest slope developments.

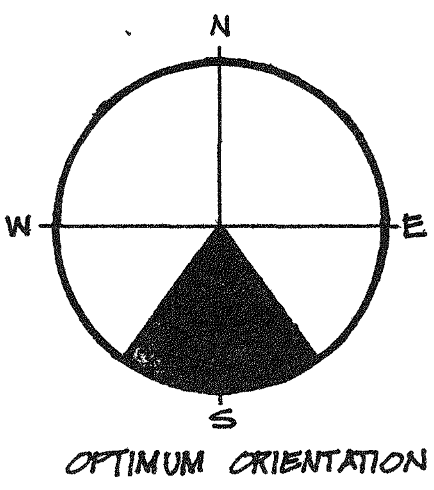
- highest energy efficiency related to vegetation: is found on heavily vegetated north slopes.

Preliminary findings for three site comparisons are illustrated on the following pages. Figures depict site conditions and graphs depict optimum recommended orientation (to the left) and orientation for which optimum range of energy efficiency was measured.

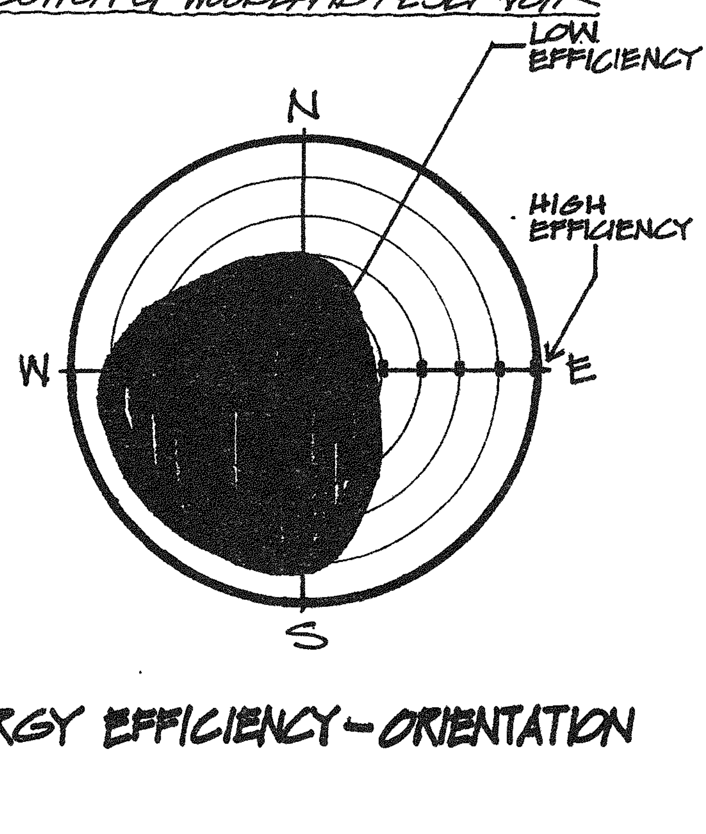
* Note: Study is still preliminary but indications are that study findings correlate with climate studies by Olgyay, Geiger, Langaweische, et.al. Study techniques due to similar operations of utility companies could be expanded for use in various parts of the country.



TYPICAL CROSS SECTION OF WOODLAND RESERVOIR

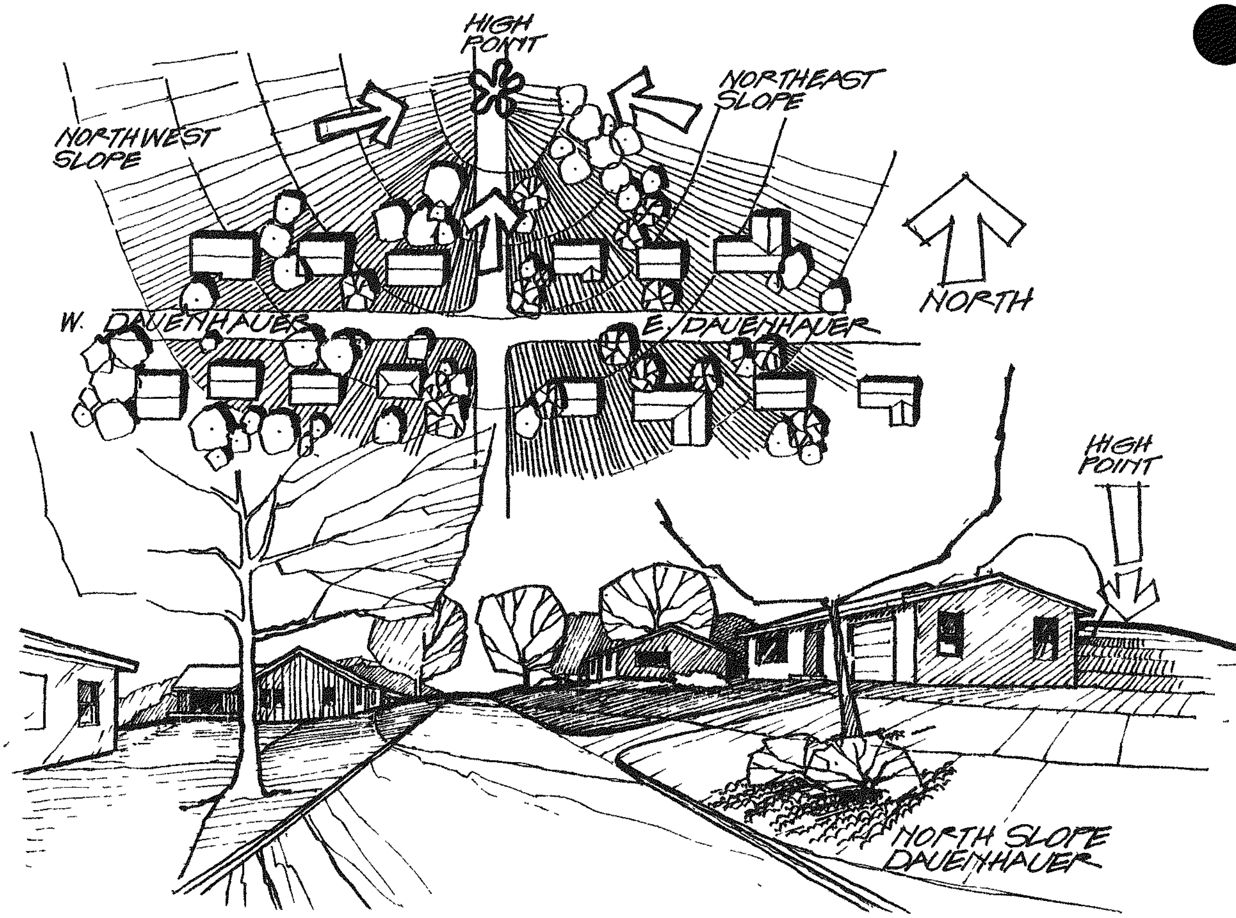


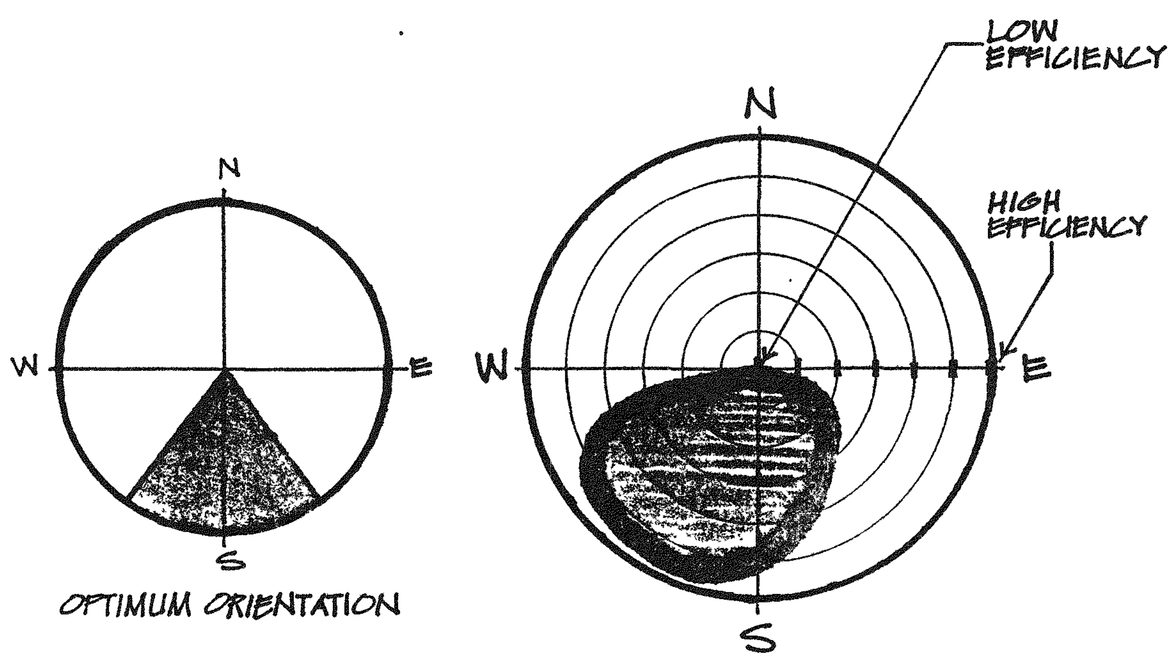
OPTIMUM ORIENTATION



MEASURE of ENERGY EFFICIENCY - ORIENTATION

Woodland Reservior

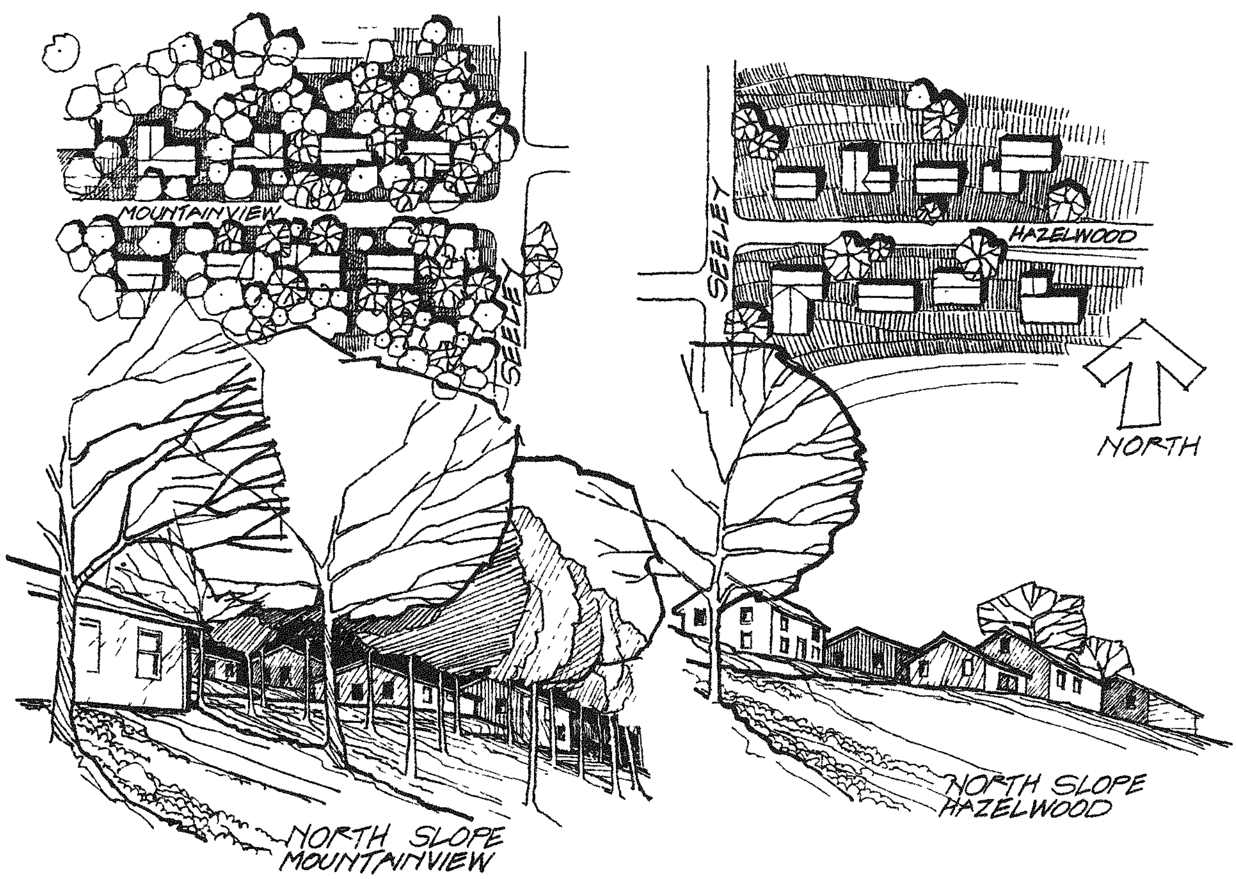


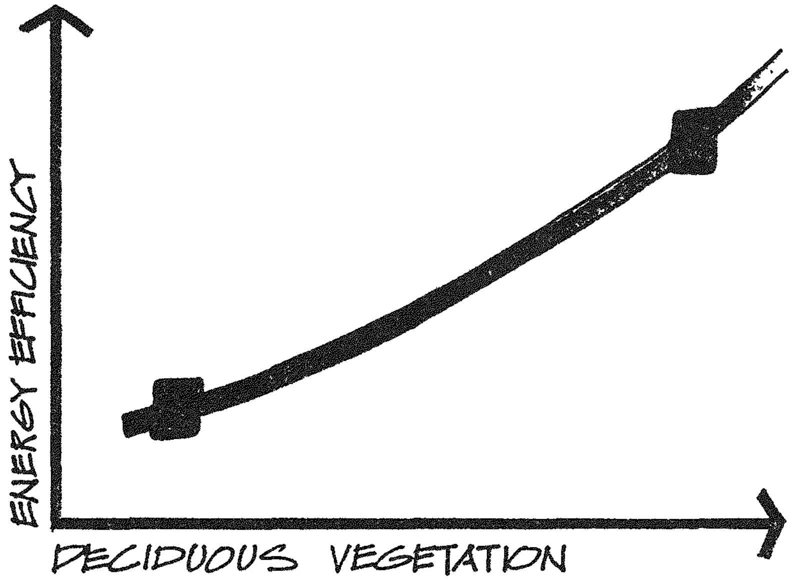


MEASURE of ENERGY EFFICIENCY-ORIENTATION

West and East Davenhauer Streets

Syracuse, New York



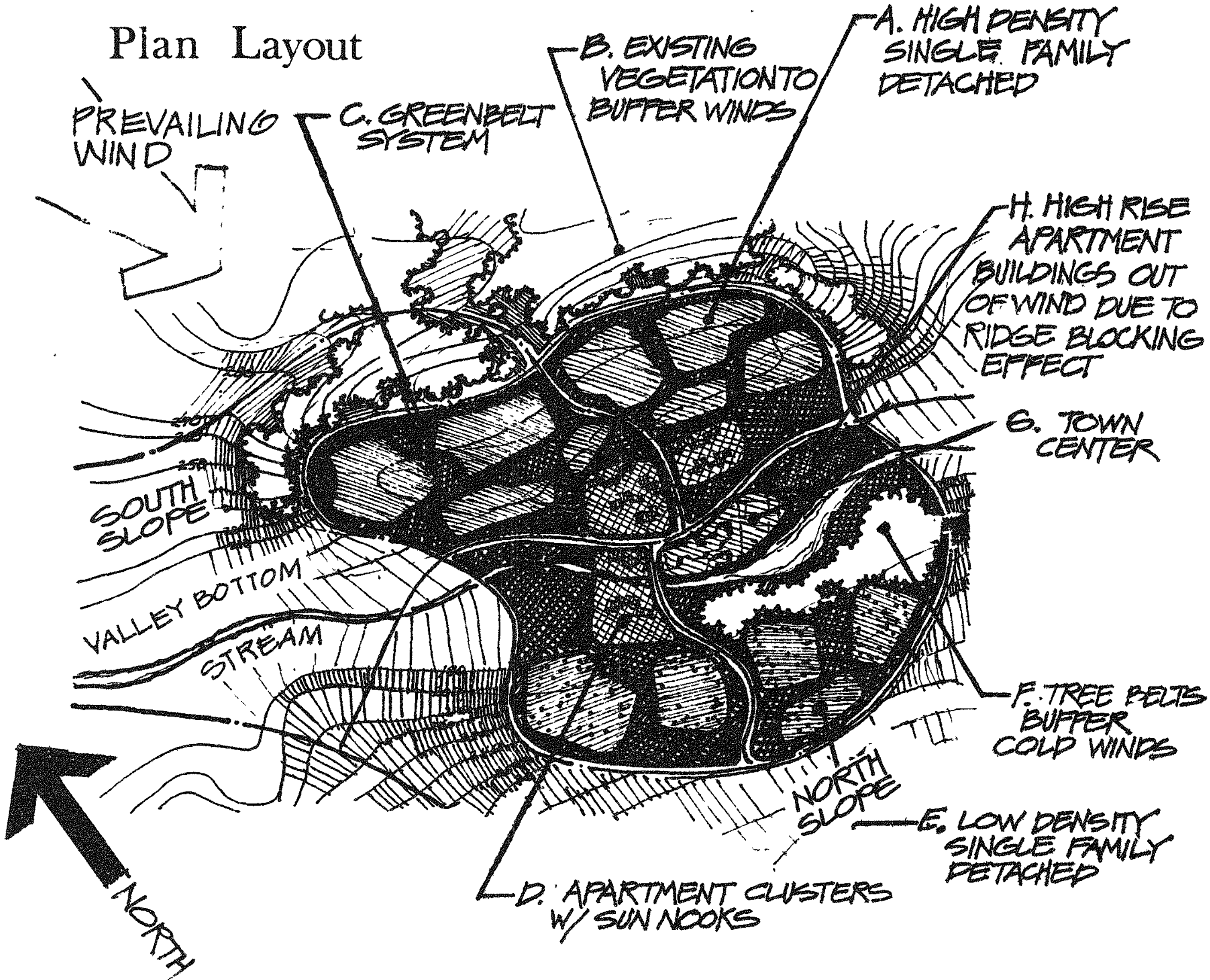


MEASURE of ENERGY EFFICIENCY - VEGETATION

Mountainview Avenue & Hazelwood Avenue. Syracuse, New York

DESIGN GUIDELINES

Plan Layout



Guidelines for Plan Layout are as follows:

- high density single family detached: highest density sited on preferred SE slope below ridgeline for wind protection using compact square housing form for minimum wall exposure

- low density single family detached: sited on cool north slopes will require buffering to reduce air infiltration and heat loss.

- high rise apartment buildings: are sited at low point to use ridgeline for wind buffer and prevent them from blocking sun to lower units on sloping sites. Best intensity and development type to use in a potential cold pocket.

- mid rise garden apartments: are clustered on south slopes to create sun pockets.

- town center: major public uses are concentrated on open site exposed to the sun with central open green space partially shaded for summer use.

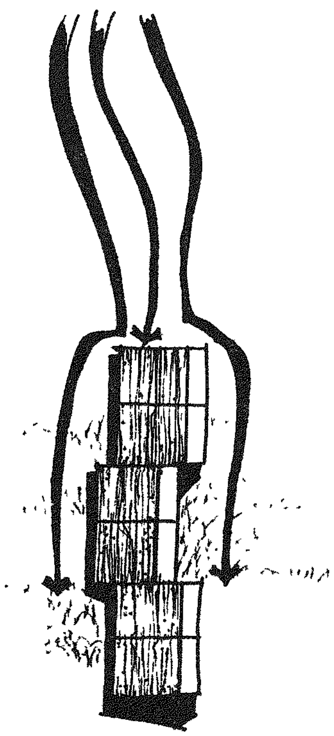
- green belt system: throughout the development site to be used as wind buffer and define pedestrian circulation system also used to channel summer breezes.

Building Relationships

Wind Response: orientation and buffering

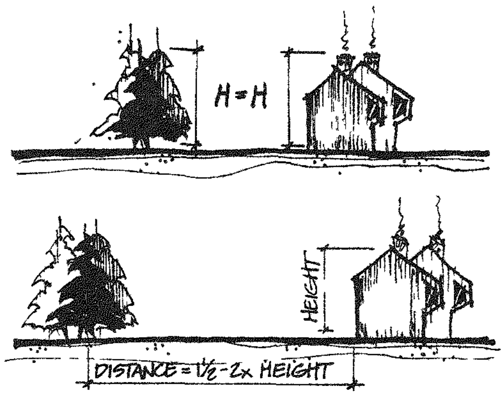
Major design consideration in the cool region is orientation, clustering and buffering structures to reduce impact of cold winter winds and associated air infiltration. Since cold air infiltration rates and resulting heating load increases correlate with the amount of wall surface exposed to the wind the primary design goal in siting buildings is to reduce the exterior wall surface exposed to the wind.

Guidelines for siting buildings are as follows (Mattingly & Peters):

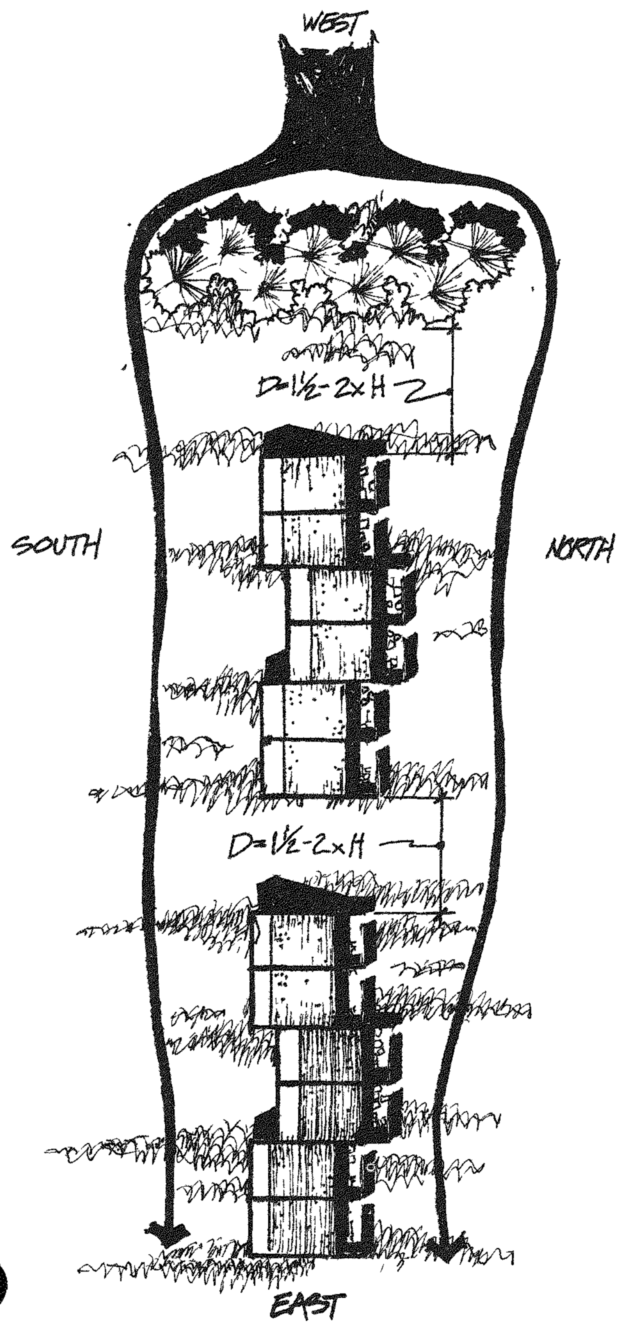


Preferred wind orientation of attached units sites long axis parallel to wind. This results in a parallel air flow around structures with the least cold air infiltration for exposed units. (Mattingly & Peters pp. 36,56)

Aside from preferred orientation, additional buffering of wind is desired and can reduce air infiltration up to 90%, as shown in the following examples.



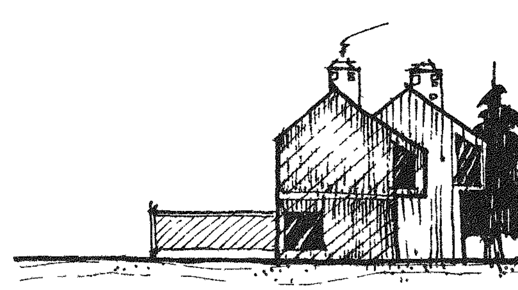
Buffering of the end unit by a single row of evergreen vegetation of equal height to the units and located at a distance 1½ - 2x the height of the unit on the windward side will almost negate the air infiltration impact on the end unit. (Mattingly & Peters pp. 37-38)

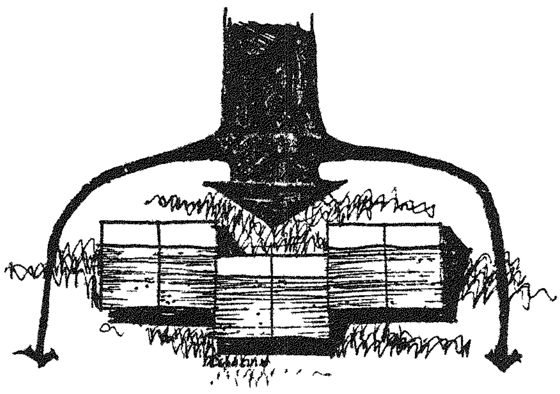


The same buffering affect can be provided by using unit clusters to buffer one another. Again siting units at a distance of 1½ - 2x the height of the unit.

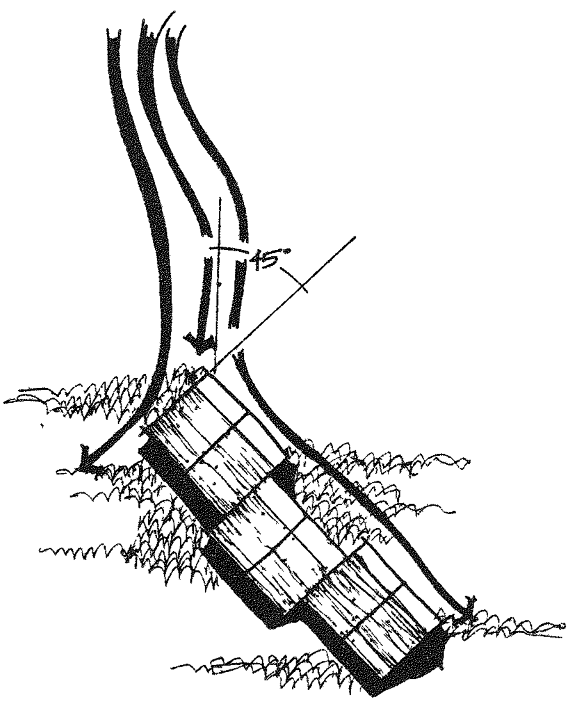
With the additional location of solid fences on the north side of attached units. reduced air infiltration rates for combined orientation and buffering in this manner has been measured up to 96% for town house units

Fences recommended by this study were 5.5 feet in height and 6 inches from the ground and attached to dwelling unit.

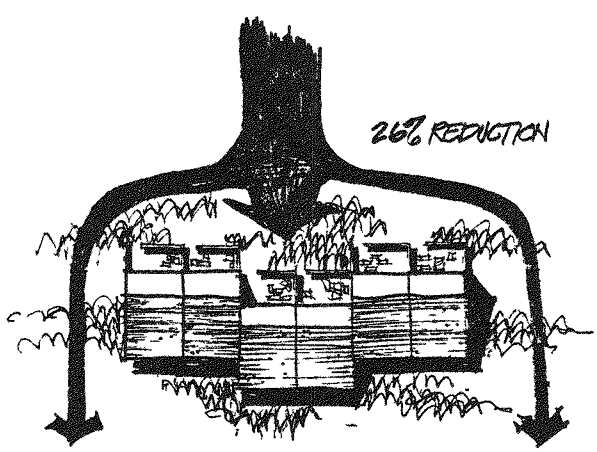




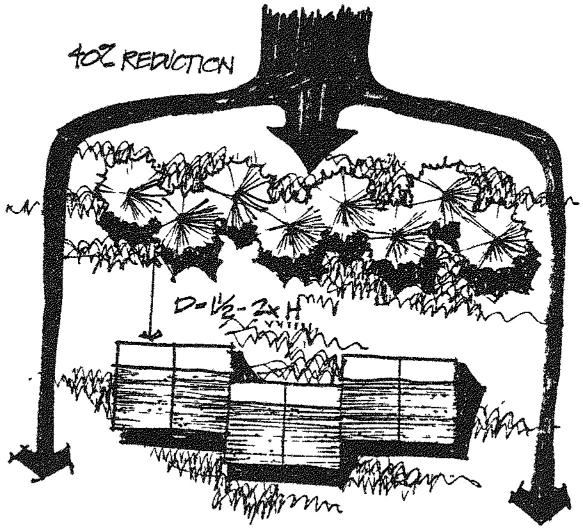
Further findings of the Mattingly and Peters study indicate that front wall exposures perpendicular to the wind increase wall exposure and wind infiltration.



Worse still is a 45° angle tilt to the wind which will increase air infiltration by 59% over the perpendicular orientation due to exposure of both side wall and front wall.

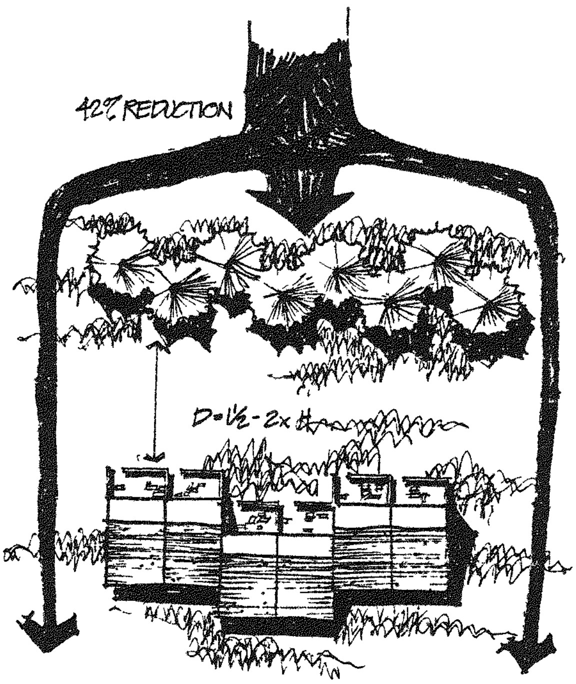


If forced to use a front wall exposure perpendicular to the wind consider use of fencing on the windward side for a 26% reduction in air infiltration.
(Mattingly & Peters p. 37)



OR

Consider a straight line of evergreen trees on the windward side located at a distance 1½ - 2x the height of the unit and spaced so that bottom boughs touch. This has been shown to result in a 40% reduction in air infiltration versus an unsheltered situation.
(Mattingly & Peters pp. 34,56)



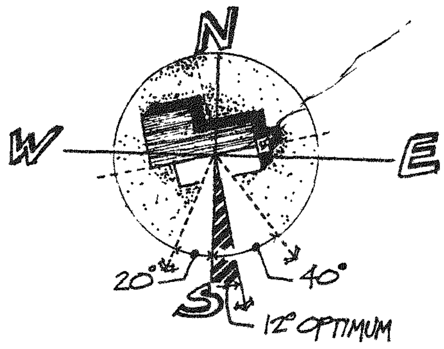
OR

Consider combining hedge wood fence combinations for a 42% reduction in air infiltration versus an unsheltered situation.
(Mattingly & Peters pp. 35,36)

Essentially, all of these responses are patterned on parallel air flow orientation which is the recommended optimum.

Sun Response: orientation and exposure

Sunlight probability for the cool region of the country is the lowest of all regions. While utilization of solar heating devices does not seem likely, building relationships should still be considered in terms of maximizing winter sun.

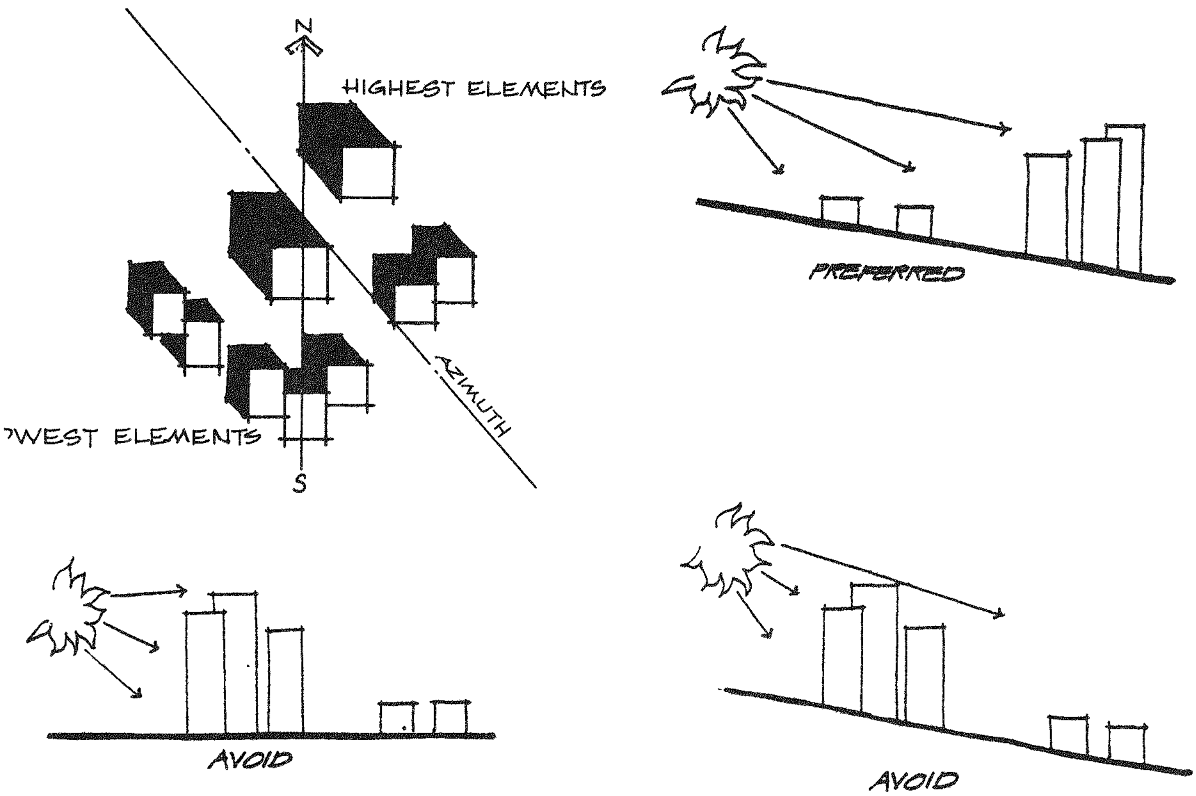


Orientation 12° south-southeast on slopes of 0-20% is the optimum. Even though winter sun is not predominant in this region, preliminary indications are that south-southwest orientations can be up to 10% more energy efficient for winter heating. (Reimann·Buechner·Crandall/Niagara Mohawk)

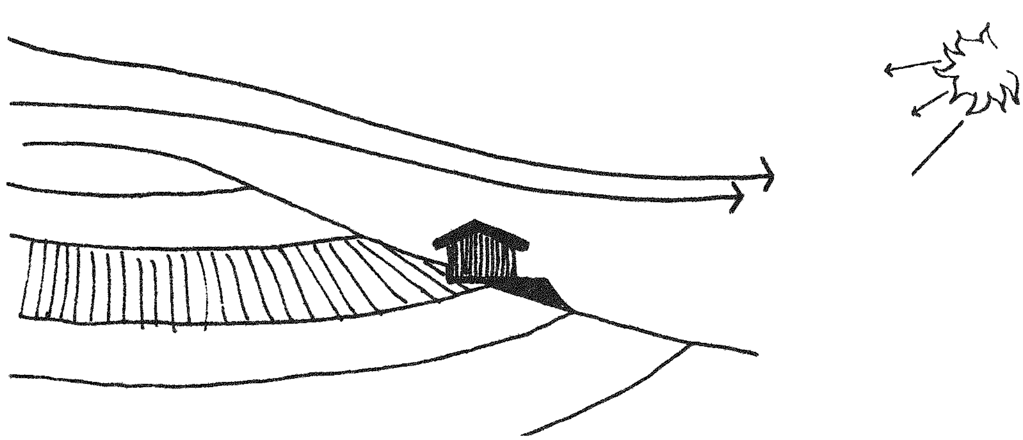
Also, in winter, south facing vertical walls receive twice as much solar radiation as east or west.

The following guidelines are recommended for optimizing winter sun:

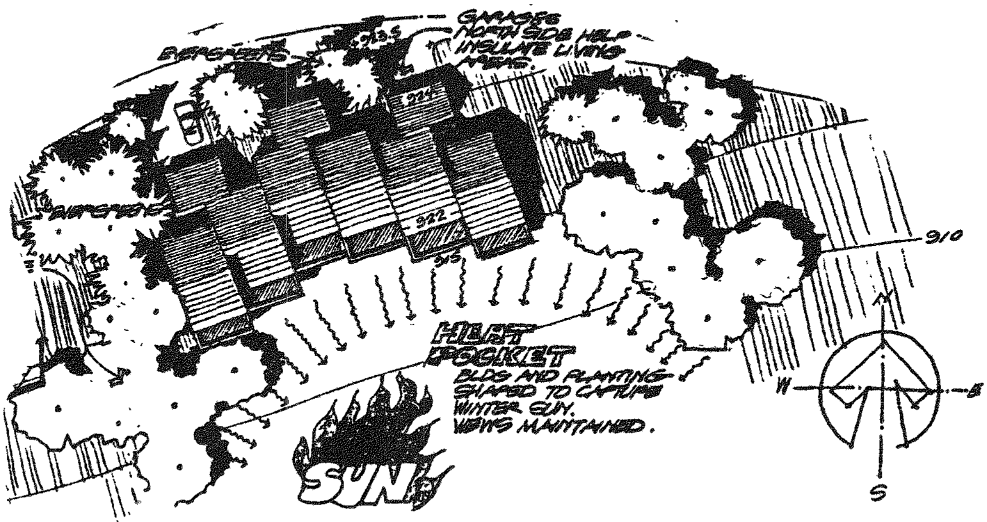
- Avoid placing taller buildings between sun and lower structures. Place highest elements down sun from lowest elements to minimize winter shading. (ASLA p. 183)



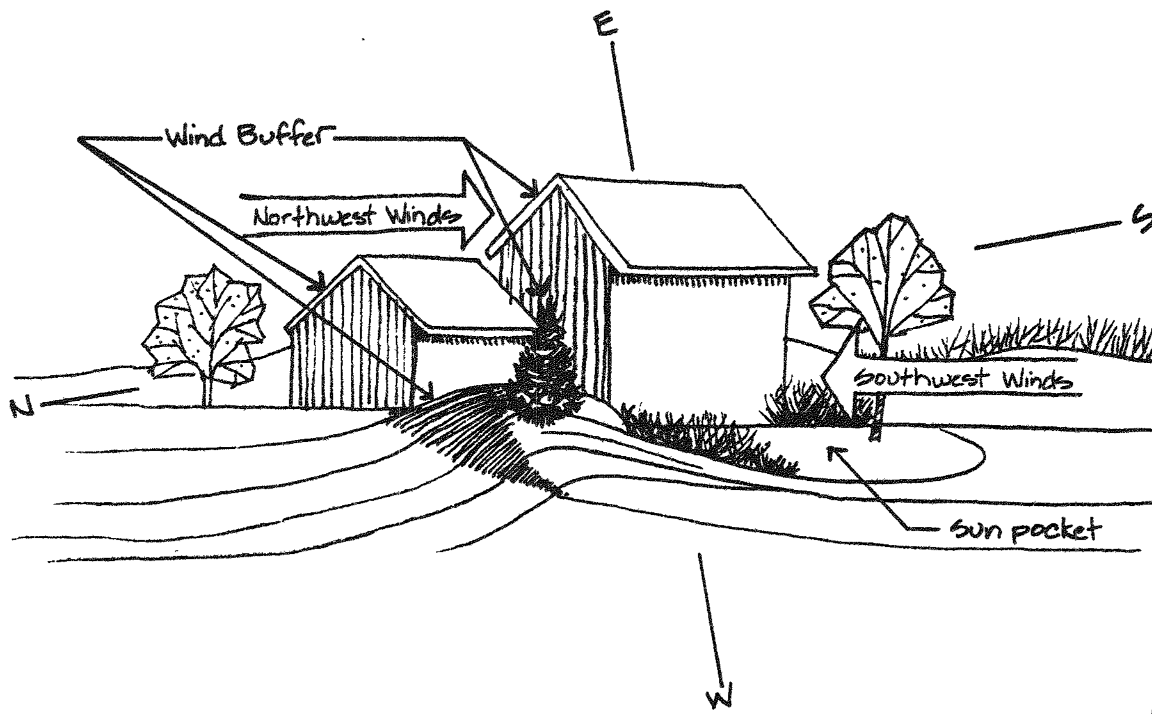
- Place structures halfway up S SE slopes using middle to lower middle of slope to prevent excess winds effects and cool air pockets. (Olgyay p. 155)



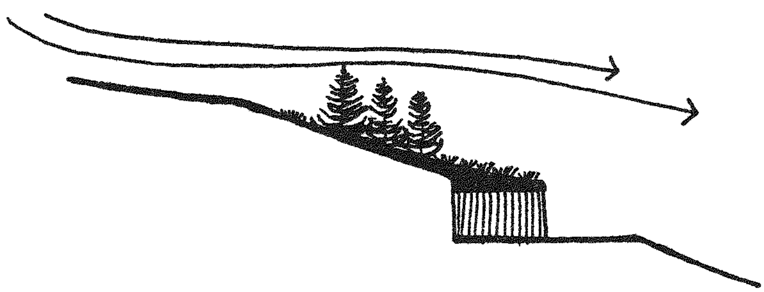
- Cluster multiple dwellings around sunny courts to create sun pockets.



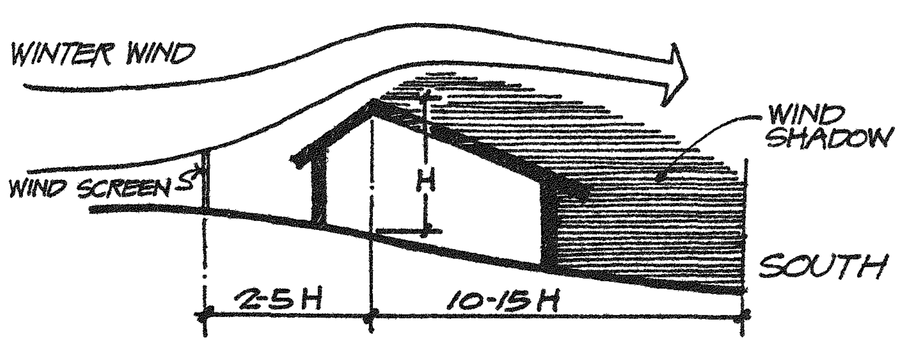
- On detached dwelling units, utilize exterior walls and fences to capture the winter sun and reflect warmth into activity areas.



- Structures can be built into hillside or partially covered with earth and planting for natural insulation.

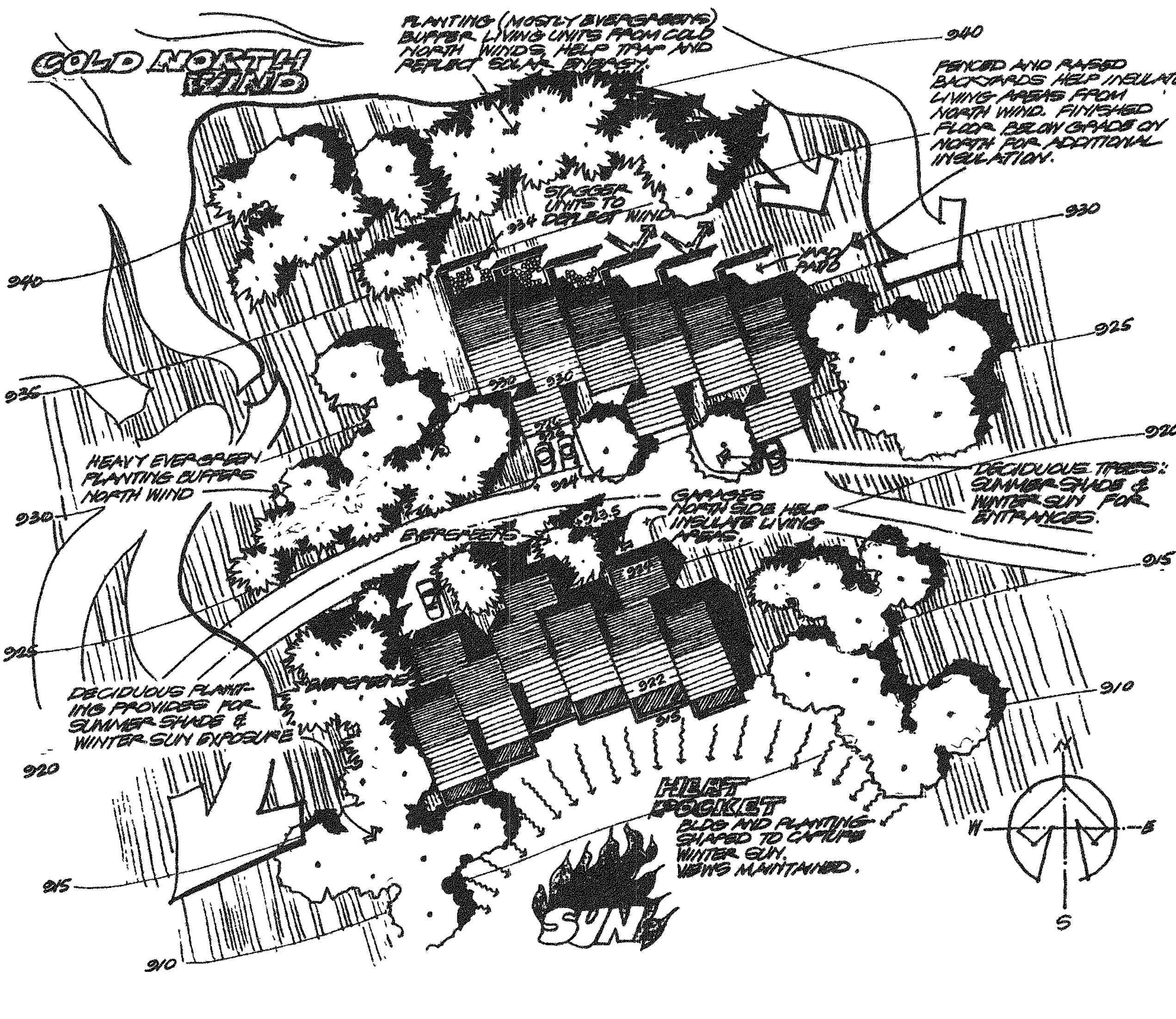


- Place blank walls, garages and storage areas on the north or northwest side of dwellings to buffer winter winds.



Clustered Attached Dwellings

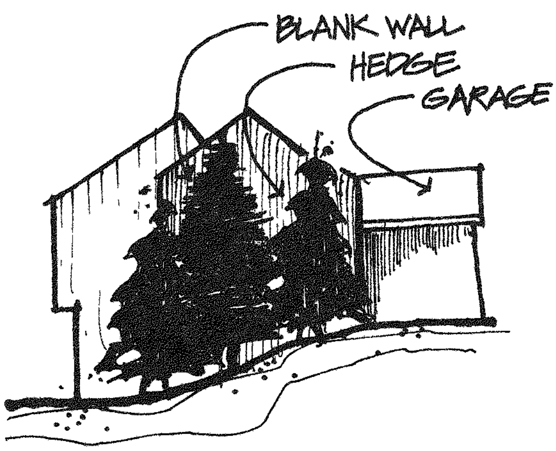
- For clustered multi-family dwellings, terraces and outdoor living areas should be integrated within the building clusters. This will reduce cold air movement in winter and will channel and direct breezes in summer.

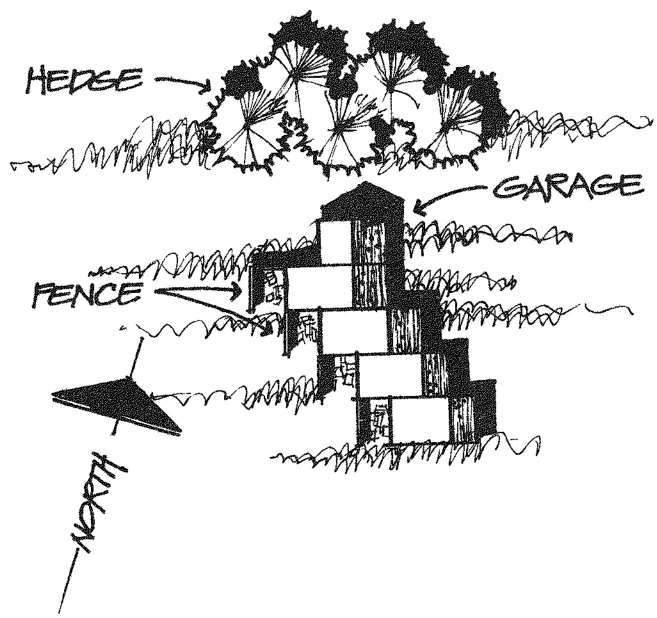


- Streets and parking areas shaded with deciduous vegetation will also channel summer breezes and reduce radiation reflection while allowing the sun to penetrate during the winter.

- Cluster buildings to create sun pockets and take full advantage of winter sun.

- Use solid walls and single row hedge planting on end units facing north westerly wind pattern.

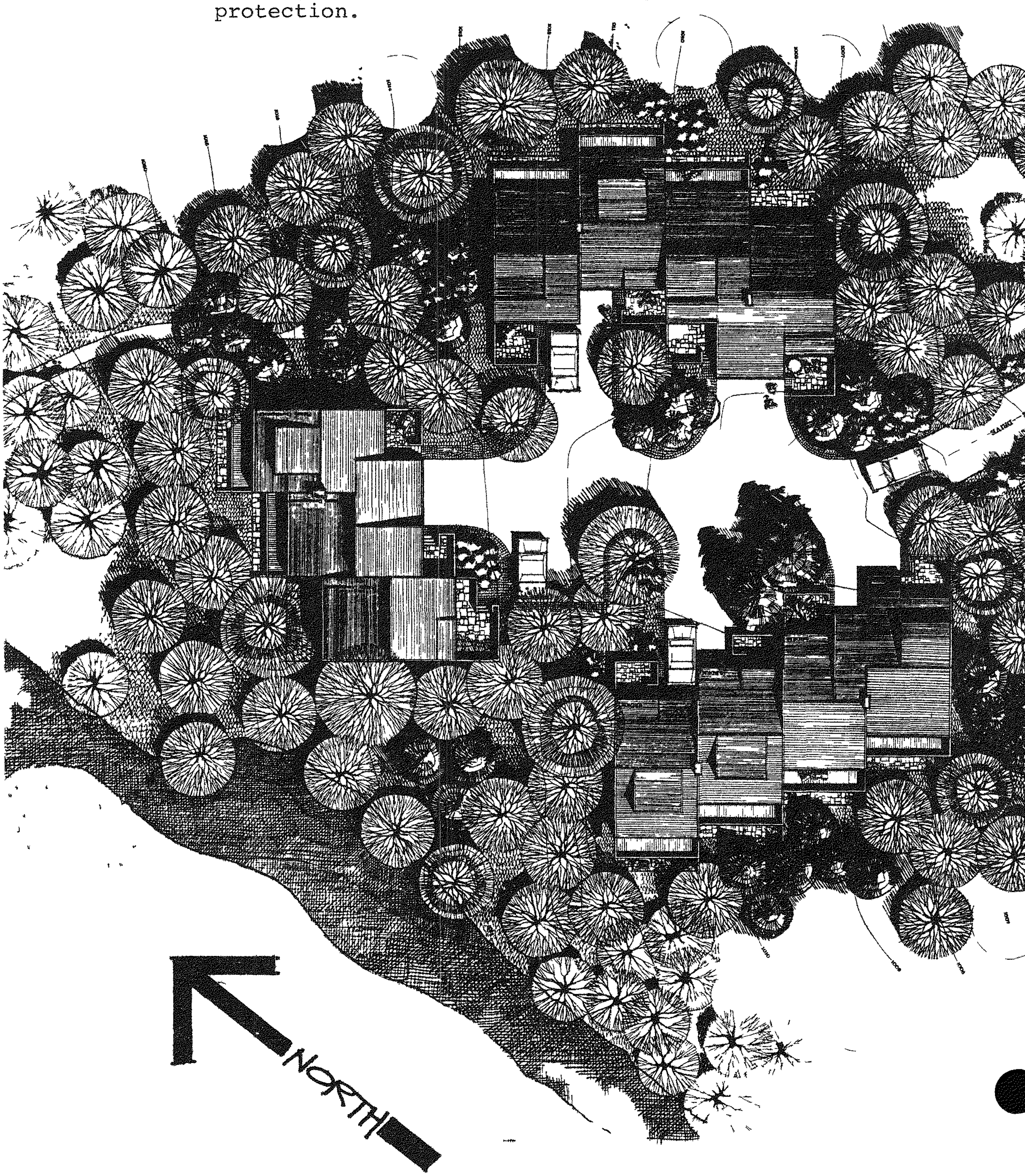




- Locate fences on northside and evergreen wind break at 1½ - 2 x the distance of the height of the unit. Use vegetation equal to the height of the unit and spaced so that bottom boughs touch.

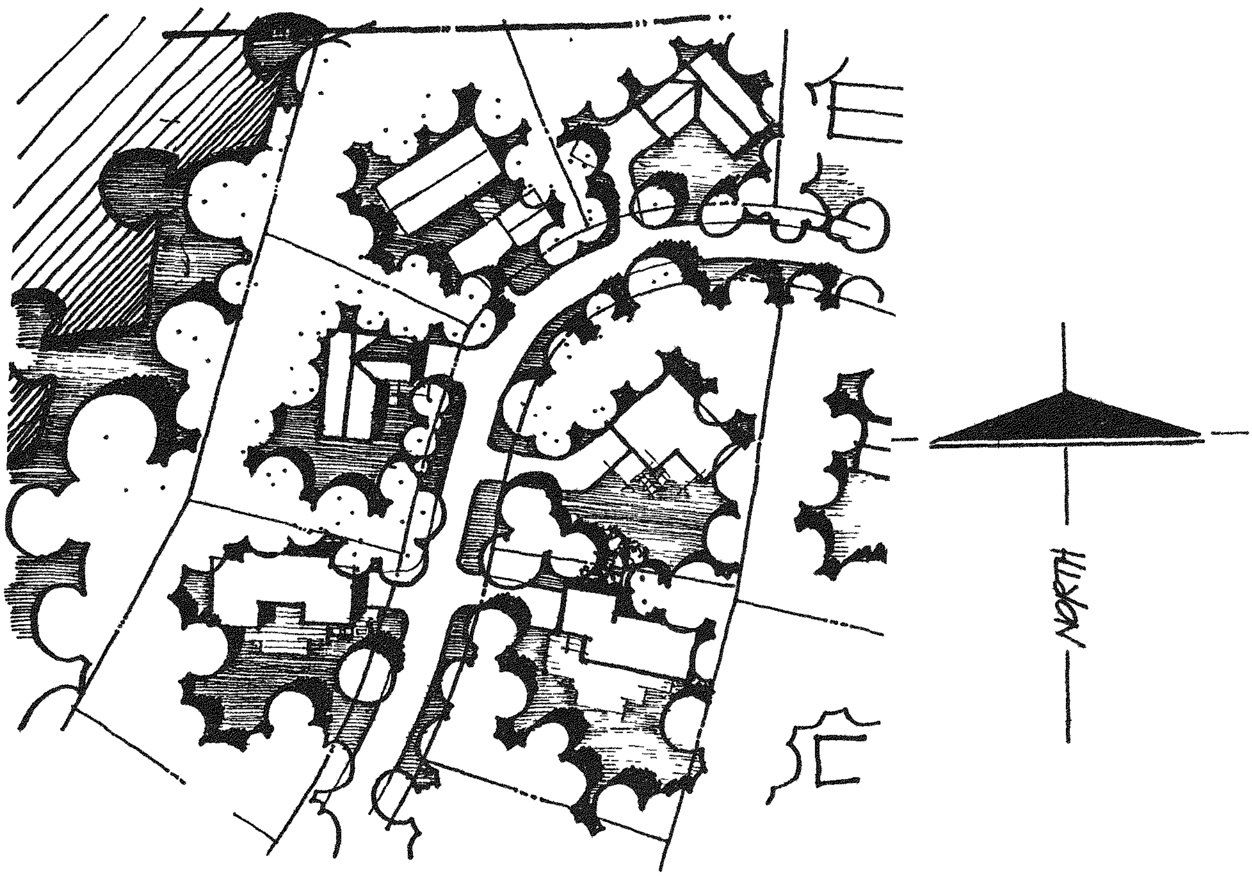
- Wind barrier and blank westerly wall will also isolate undesired summer westerly sun.

-Also consider compacted layouts around interior court combing end walls, fences and vegetation for wind protection.



Single Family Detached Dwellings

- Space structures and circultion systems to permit maximum radiation, buffer winds and channel breezes

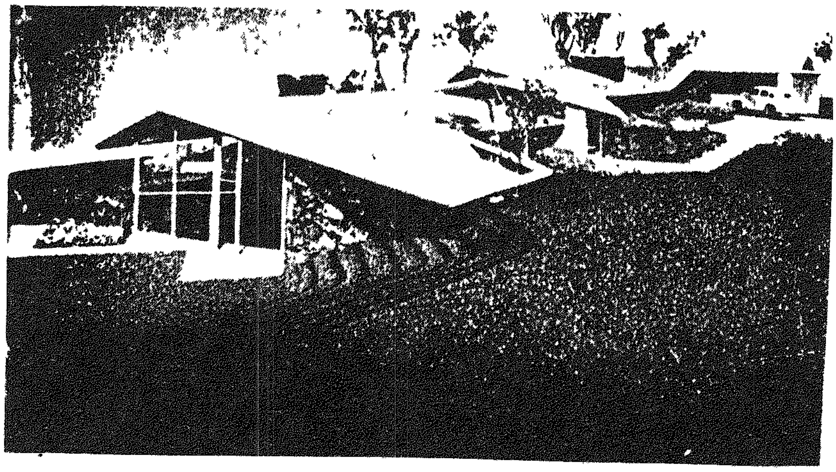


- Orient buildings on EW axis
- Minimize and insolate wall surfaces exposed to wind.
- Locate garage and service structures as wind buffers to channel wind flow and snow drifting

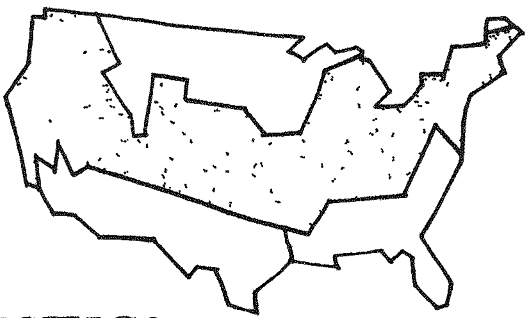
- Underground or semi-subterranean site integration is suitable if:

    soil is suitable

    region is not humid (see Wind Control, Section I, Part II)



PART II
TEMPERATE REGION



TEMPERATE REGION

CLIMATE CHARACTERISTICS

Winter

- Sunlight probablity 0.45 (BSIC p.21).
- Maximum solar radiation on S vertical walls (2 x E&W).
- Major wind pattern Northwest.

Summer

- Maximum solar radiation on E & W vertical walls (2½ x S).
- Major wind pattern SSW.

DESIGN CRITERIA

Winter

- Heating season 5,000 degree days (BSIC p.21).
- Maximize solar radiation and heat gain.
- Minimize northwest exposure and heat loss 60% of the year (Siple Nov. 1949 p. 203)

Summer

- Cooling requirements 479 hours (BSIC p.24)
- Maximize breezes and exterior living area, 31% of the year (Siple Nov. 1949 p. 203).

Year Round

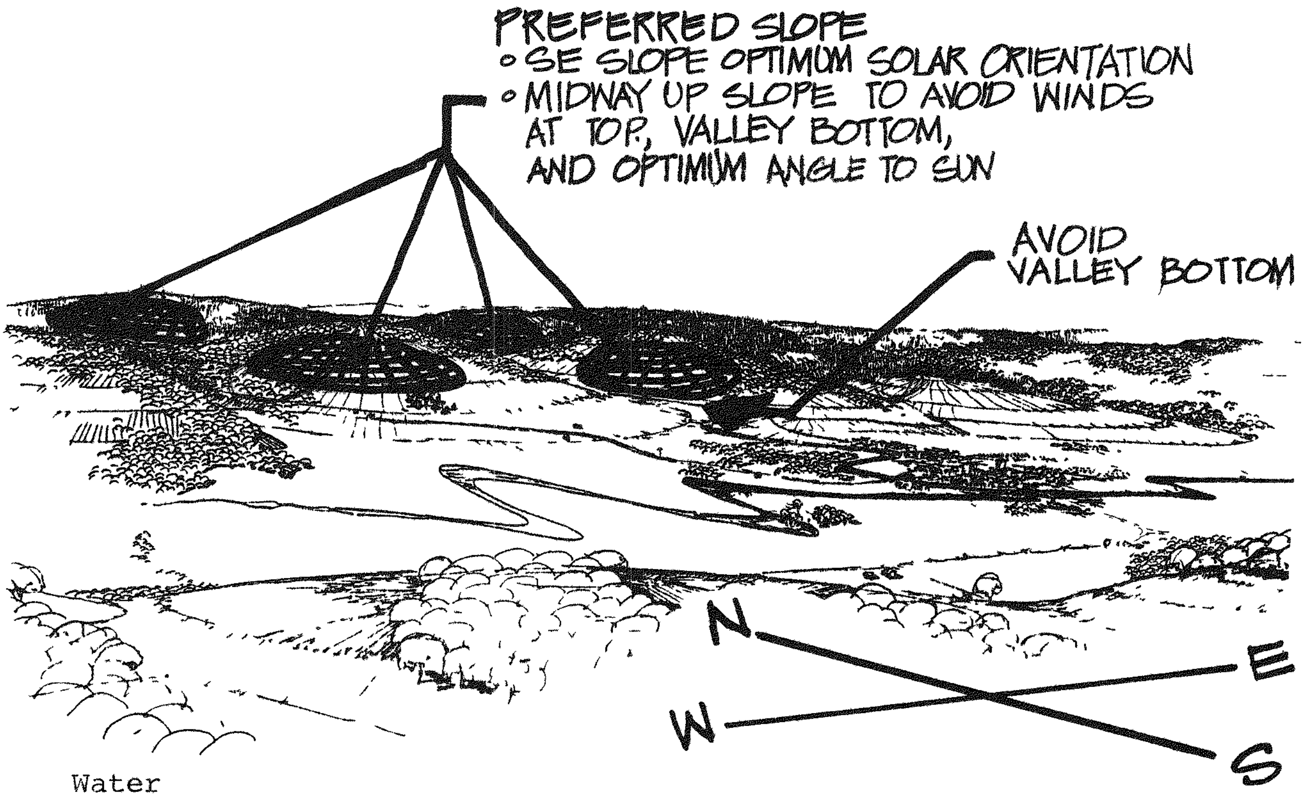
- Maintain seasonal balance of heat production, radiation and convection (Olgyay p. 161).

GROSS SITE SELECTION GUIDELINES

Look for sites with optimum combination of winter radiation and summer breezes. Look for:

Landform

- Sloping sites with south southeast direction preferred, will be warmest.
- Avoid valleys which are cold, damp and potential frost pockets.



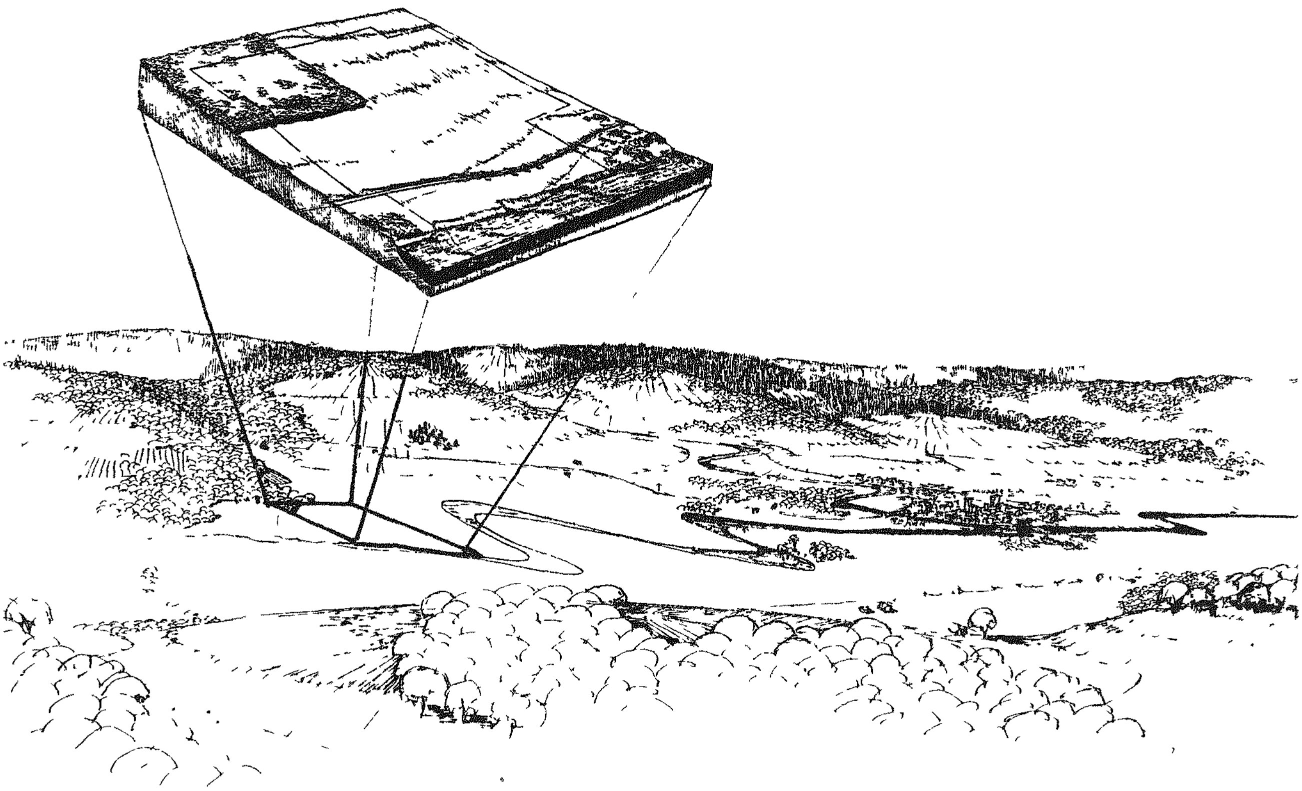
Water

- Proximity to large water bodies is preferred for summer cooling effect.
- Avoid areas of coastal fog.
- In areas of fog, look for higher elevations where fog retention is less

Prevailing Wind

- Avoid sites with N NE wind exposure especially where topography is steep and open, they will be extremely cold in winter.
- Look for sites with S SE winds, they are warmer in winter and cooler in summer.

DISCRETE SITE SELECTION GUIDELINES



Site Analysis

Analysis and selection of optimum residential sites should be based on the following general critera:

- Identify and select sites with the greatest balance between winter heating requirements due to wind exposure an and summer cooling requirements due to sun exposure. This region falls in the middle in terms of heating and cooling requirements.

- Identify and select slopes with warm orientations (S-SE) Avoid western slopes due to summer cooling requirements.

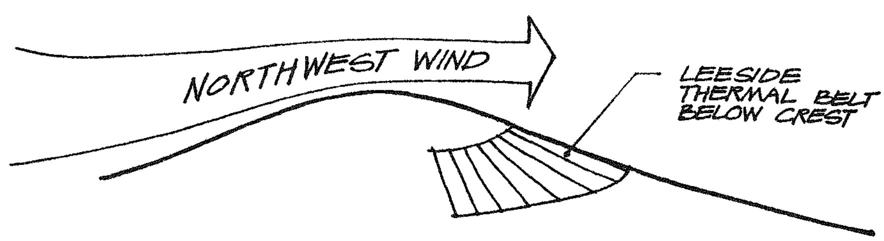
- The relationship of topography, vegetation and proximity to water to sun & wind in both winter and summer are the primary determinants for site selection.

Summer Breezes and Winter Wind Patterns

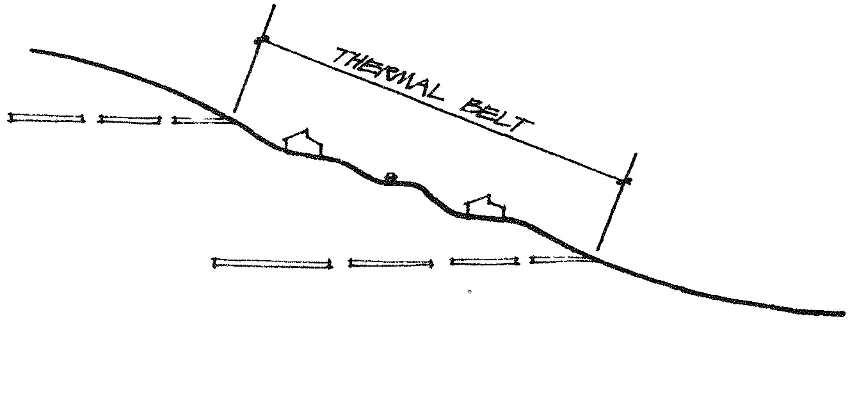
- Avoid sites which are opened to N-NW winter winds
- Select sites which are opened to S-SE summer breezes
- Avoid valley bottoms and low spots which are potential cold air dams and frost pockets

Slope Direction and Gradient

- Select S-SE slopes for residential development for greatest balance of summer and winter sun and wind
- Select sites on middle slope, within thermal belt, rather than at the foot or crest of a slope, for maximum radiation. In general sites on upper or middle slope receive maximum winter radiation and less summer radiation than horizontal sites at the foot or crest of a slope



- In valley situations the thermal belt is preferred unless the slope is exposed to winds, then aovid crests and locate halfway up the slope. (ASLA p. 172)



Site Selection

Site selection should be based on combined consideration of:

Winter and Summer Climate Influences: related to existing landform vegetation and natural features.

Planning and design studies conducted by the firm of Rahenkamp, Sacks, Wells and Associates in metropolitan New York and New Jersey indicate the following guidelines for site selection and use:

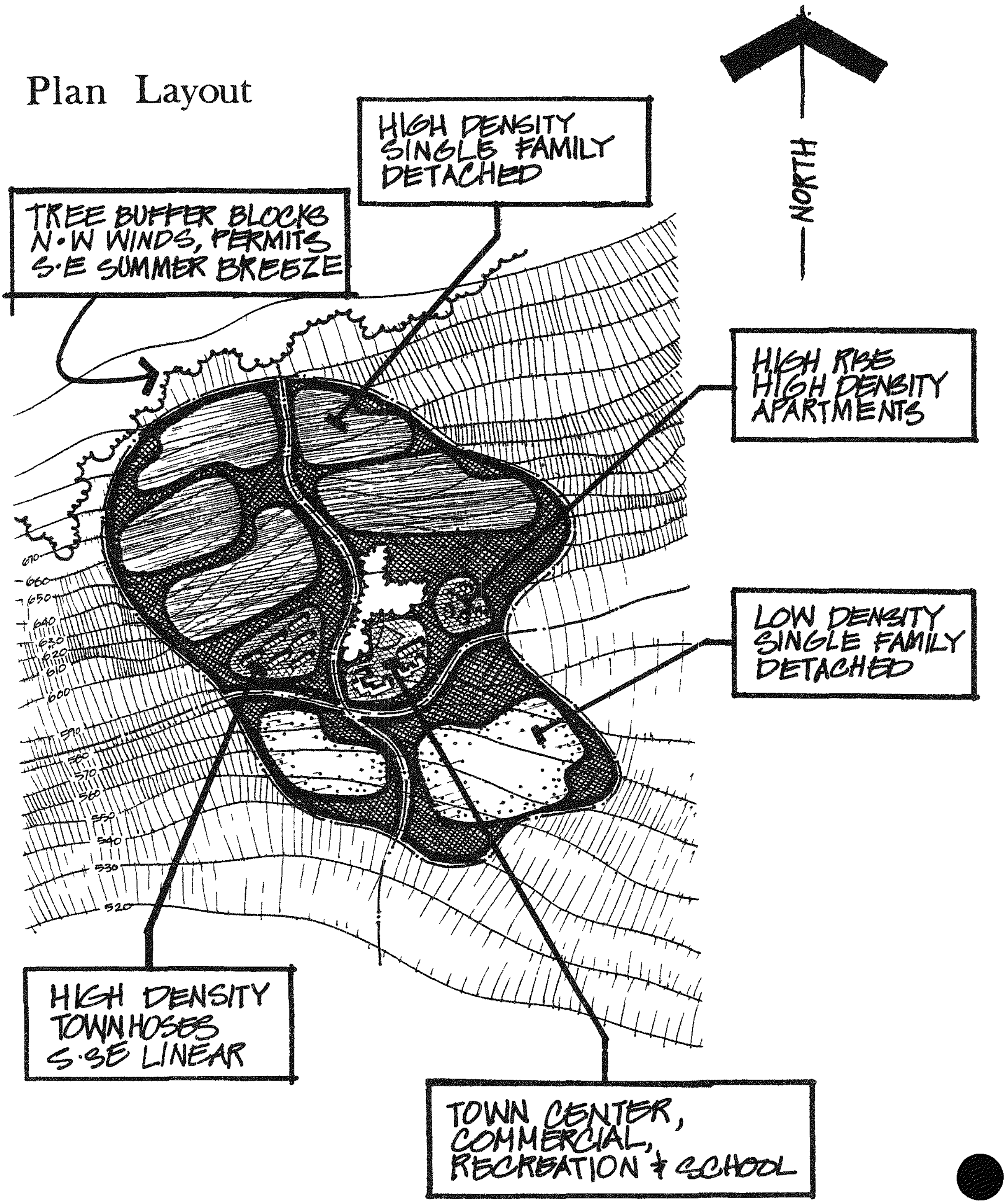
- In a valley situation (running Northeast to Southwest) with high water retnetion soils, the valley was eliminated for residential development and maintained as a natural drainage system.
- Vehicular circulation systems were sited diagonally across the valley and used as dams for natural holding ponds.
- Valley sites were permitted to maintain natural vegetated character and serve as shelter belt in the winter and cross ventilating natural air conditioner parallel to summer breezes for cooling (Goldberg, unpublished).

Development Suitability for various uses and structural types. Climate and design studies by Olgyay recommend the following guidelines for various uses and structural types:

- Residential Structures: Select S-SE warm slopes
- Large Structures: Locate high buildings out of prevailing winds and venture effects.
- Exterior Open Space: Locate in open shaded areas
- Exterior Living Space: Utilize S-SE orientation for patios and sun pockets

DESIGN GUIDELINES

Plan Layout



Guidelines for plan layout are as follows (Olgyay p.160-65):

High density single family clusters: are sited on preferred south east slopes in loose arrangements to premit free air movement and solar penetration.

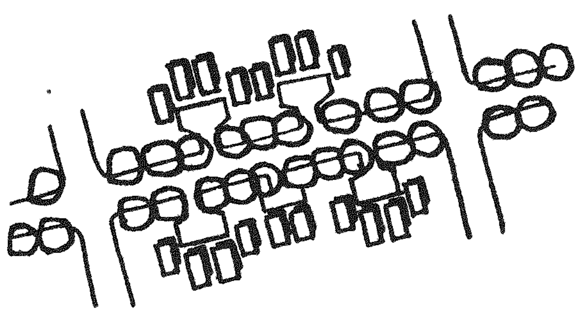
Low density single family detached: are sited on northeast slopes with short axis oriented toward wind.

High density apartments: are sited on flat area near water for ventilation with vegetative wind break.

Townhouse units: are sited on flat area with blank short end oriented to wind and balcony arrangements for exterior southern clearing space.

Town center and commercial facilities: are sited in flat area central to all development and connected to rest of site through open space system.

Road Layout: uses preferred E to orientation parallel to slopes to reduce grading requirements and channel breezes and cold winds



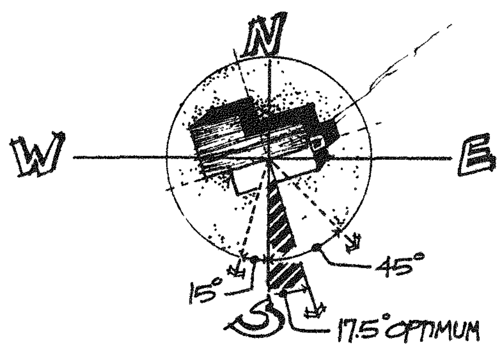
Building Relationships

Wind Response: orientation and buffering.

Response to wind buffering in the temperate regions follows the same orientation guidelines based on the Mattingly and Peters study and identified for the cool region.

Sun Response: orientation and exposure

Sunlight probability for the temperate region of the country is in the mid range. (.45 winter, 170 summer). While utilization of solar heating is feasible building relationships for all developments should be considered in terms of maximizing winter sun.



Orientation S17.5°SE is optimum.

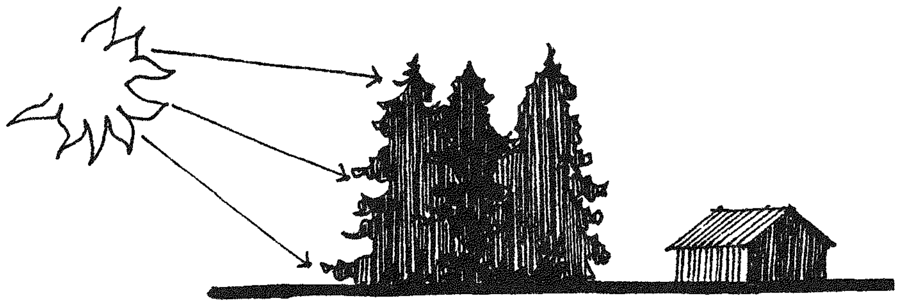
Also in winter, south facing vertical walls receive twice as much sun as other orientations.

A building lot doesn't have this orientation siting adjustments through set back flexibility can begin to approach it.

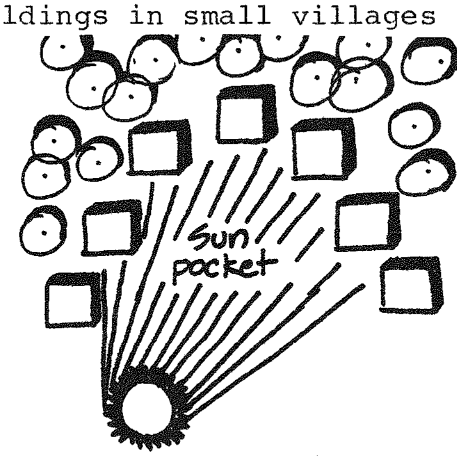
The following guidelines are recommended for optimizing winter sun:

- Avoid locating buildings immediately to the North of large evergreen vegetation which would reduct solar radiation by blocking winter sun. (ASLA p. 173)

- Preferable building sites are those shaded by existing deciduous vegetation which does not block winter sun and provides summer shade.



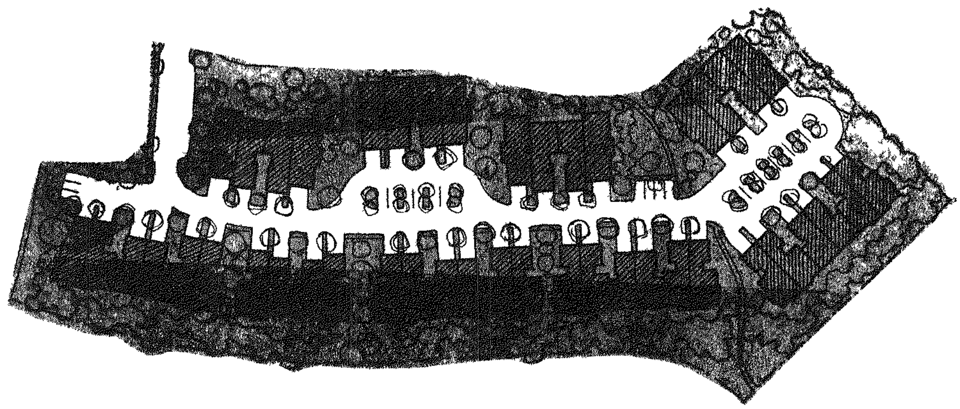
- Cluster buildings in small villages to provide protected enclaves.

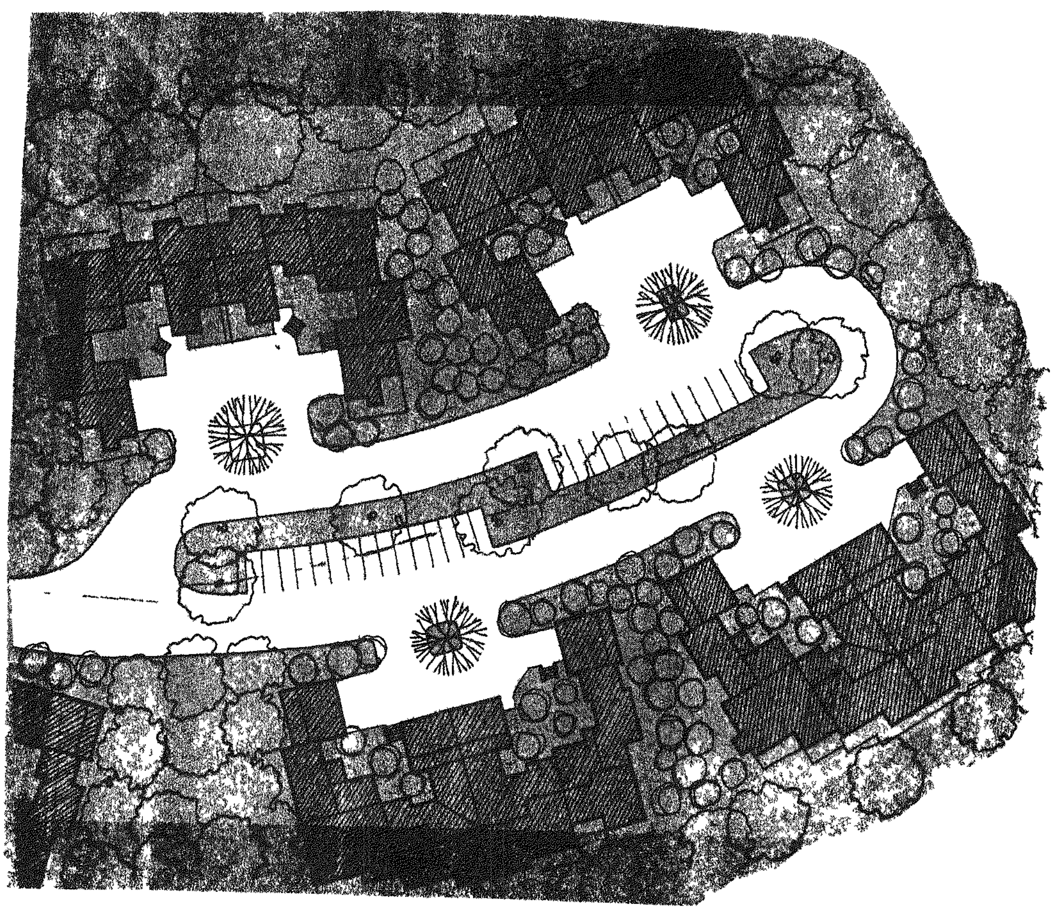


Cluster buildings for heat absorption S-SE.

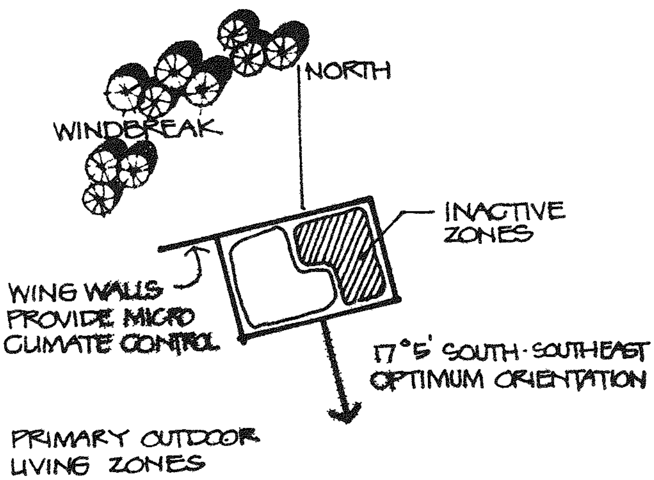
- Protect West and East exposures of buildings by "row house" pattern

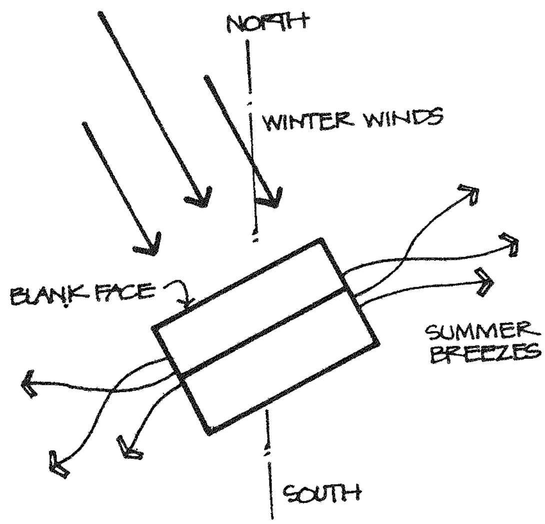
- Generally linear plans are recommended in mild or balanced climate regions to permit the maximum use of natural radient heat and through ventilation (BSIC p. 8).





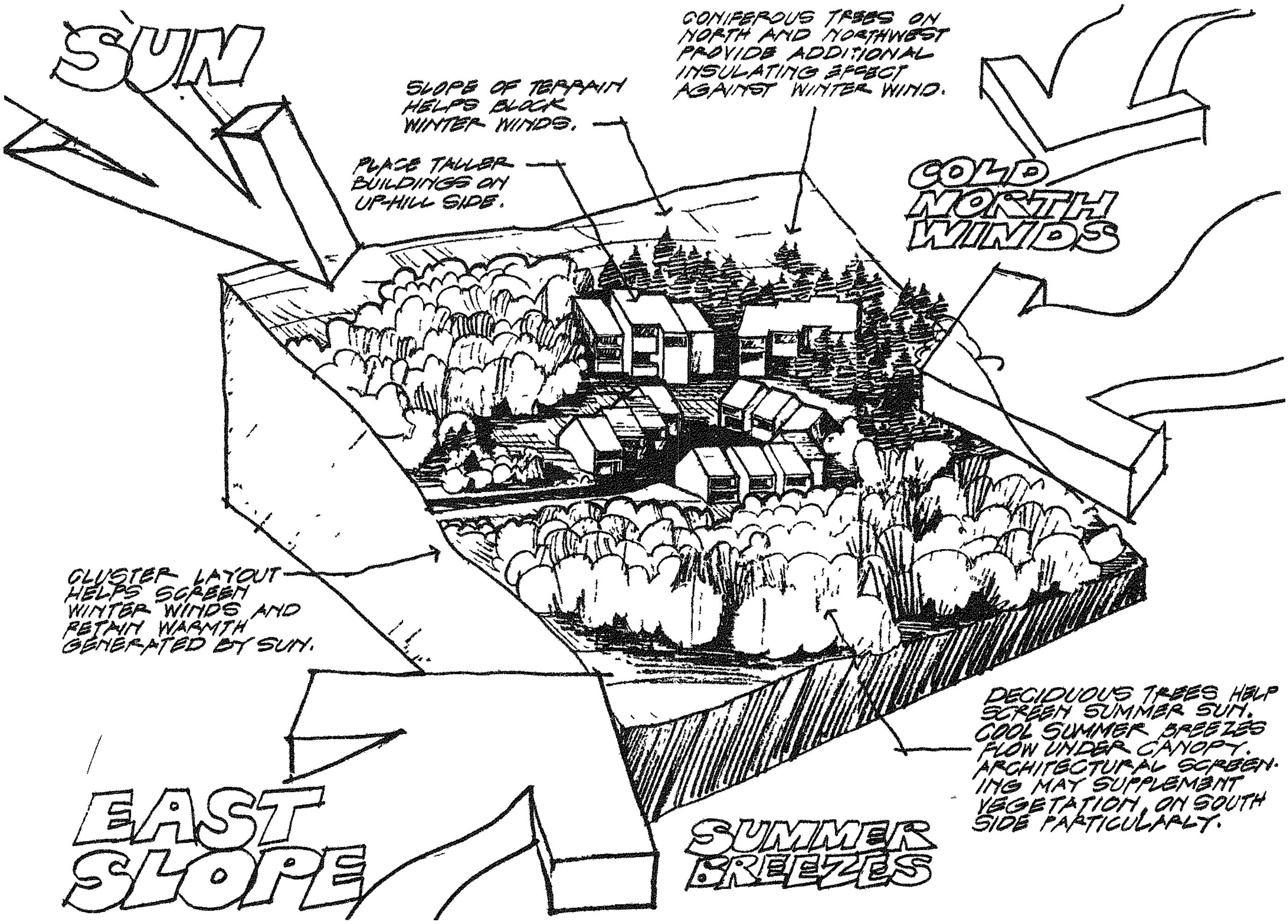
- Locate lightly used activity area on northern exposure.
- Locate exterior living space and active zones on S-SE.





- Locate Lawns: near structures
- Locate Overhands: S side on low structures.
- Locate egg crate sun shades on East and West exposure.
- Locate vertical fins: N side

Combined Responses to Sun and Wind:



- Windbreaks against NW wind evergreen preferred
- All vegetation: permit open S-SW breezes in summer
- Deciduous: shade and open for S SW breezes, best on E and W sides
- Use roadways to channel and direct desirable breezes or direct unwanted cold winds
- East West street orientation is preferred.

Additional guidelines identified during data collection are based on planning and design studies conducted by the firm of Rahenkamp, Sachs, Wells and Associates (ASLA pp 203-213) as follows:

Mixed Residential Uses: Pine Run, PUD in Camden, New Jersey mixed residential development of single family, townhouses and garden apartments was sited in response to a valley situation with typical cold air flow patterns at the valley bottom.

Development pattern essentially sited high density residential usus on steeper woodland areas and low density single family residential uses in flat open farm land.

Multi-family units were designed as a modular unit with a standard angle to bend the building to the existing gradient and employ contour clustering. The density pattern and contour clustering system for multi-family housing produced greater protection from winter wind by capitalizing on the existing air flow pattern and vegetation. Clearing costs were reduced between $250-270 per acre. Siting buildings within fifteen feet of existing vegetation reduced landscape costs between $300-500 per unit (ASLA p.204).

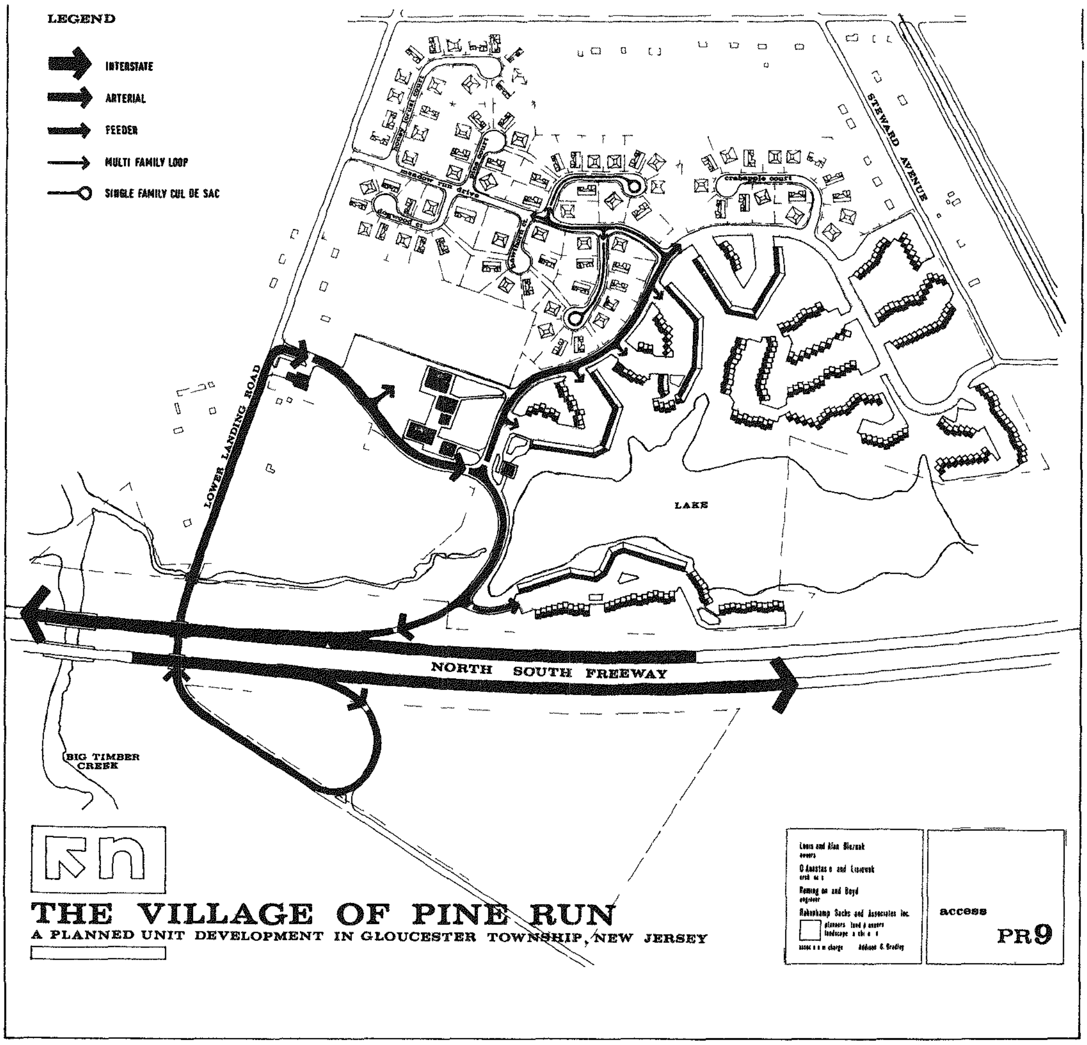
In terms of building unit relationships, experimentation in energy conservation in the design of single family units was employed as follows:

Single Family Units

- Townhouse type unit with an attached garage was placed for standing on a small lot.

- Fencing was used around the unit creating an internal housing space

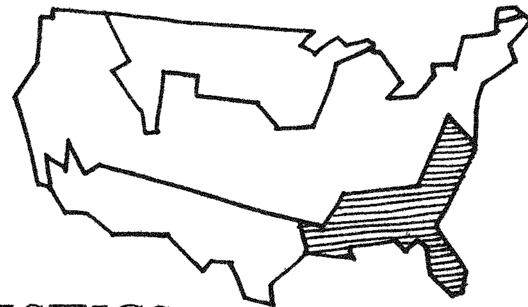
- Buffering of exterior and end walls with the system resulted in reduced winter heating requirements.



Also minimum disturbance of existing topography resulted in savings between $.10 to $.15 per sq. ft. for bank stabilization plantings with an annual maintenance savings of $1,900 per year.

Multi-family units: concentrated on steeper wooded sites with contour clustering and a modular unit. A loop parking lot was created on one side of the building with open space and pedestrian connectors on the other side. This unit design and layout provides access to summer breezes while existing vegetation buffers the structures from the winter wind.

PART III
HOT HUMID REGION



HOT HUMID REGION

CLIMATE CHARACTERISTICS

Winter:

- Sunlight probability .55 (BSIC p.22)
- Maximum solar radiation on south vertical walls
  4x intensity of E & W

Summer:

- Sunlight probability .75 (BSIC p. 25)
- Maximum solar radiation East & West facing vertical walls
  (2-3 x intensity of S)

Year Round

- Typical warm climate with small yearly variation
- 3/4 of the year's temperature -- 65° - 85° range
- High humidity due to high precipitation, effects of ocean and underdrained low land evaporation (ASLA p.147)
- Shading required 75% of year (Olgyay p. 173)

DESIGN CRITERIA

Summer

- Cooling requirements -- 633 hours (BSIC P.25)
- Reduce heat production and radiation gain
- Promote evaporation loss
- Minimize sun, maximize wind

Winter

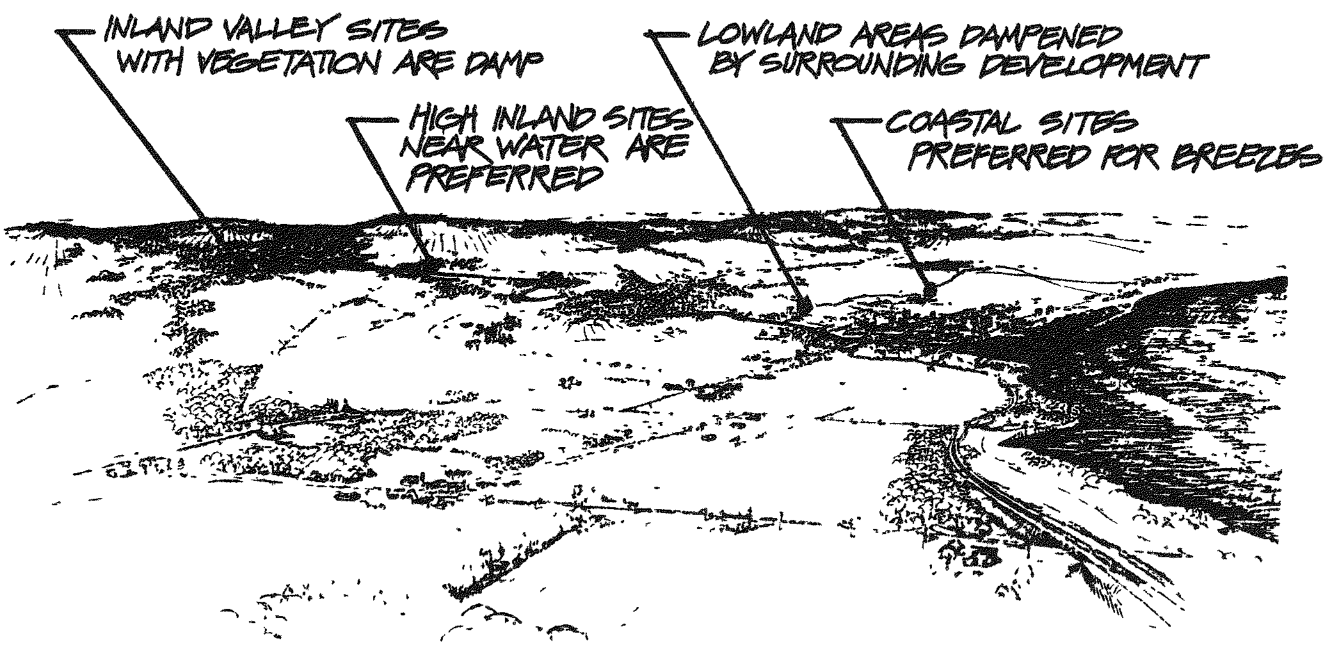
- Heating requirements -- 2,000 degree days (BSIC p.22)

GROSS SITE SELECTION GUIDELINES

Look for sites with slope elevation, orientation, vegetation and wind pattern to increase summer and winter cooling and decrease radiation effects. Look for wind patterns in relationship to:

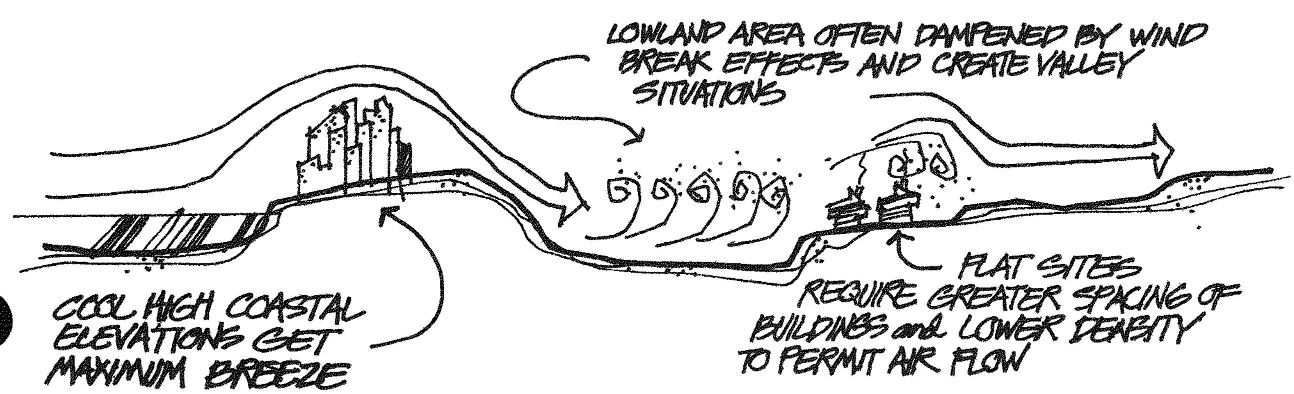
Landform

- Mountainous or hilly coastal site which are more open to breezes
- Avoid coastal lowland areas if dampened by the effect of dense planting or buildings which act as wind breaks

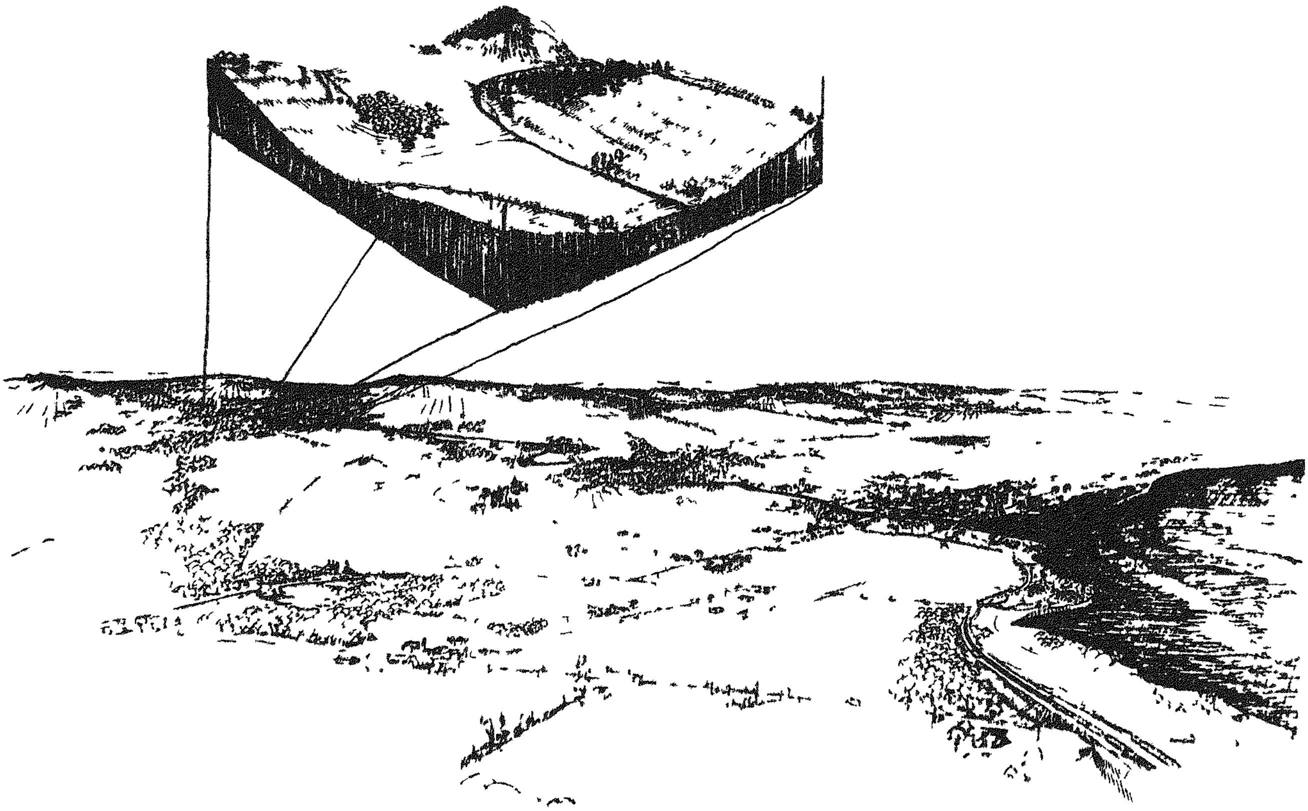


Water

- Look for sites with water or near water. Inland water bodies produce cooling effect when breezes are present. (ASLA p. 148)



DISCRETE SITE SELECTION GUIDELINES



Site Analysis

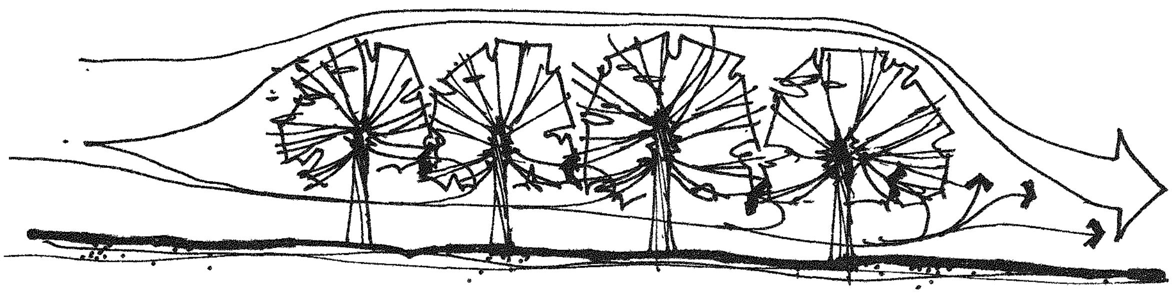
Analysis and selection of residential sites should be based on the following general criteria:

- Identify and select sites with the greatest exposure to summer breezes for ventilation and cooling. Most important features are wind exposure, topography, and vegetation.

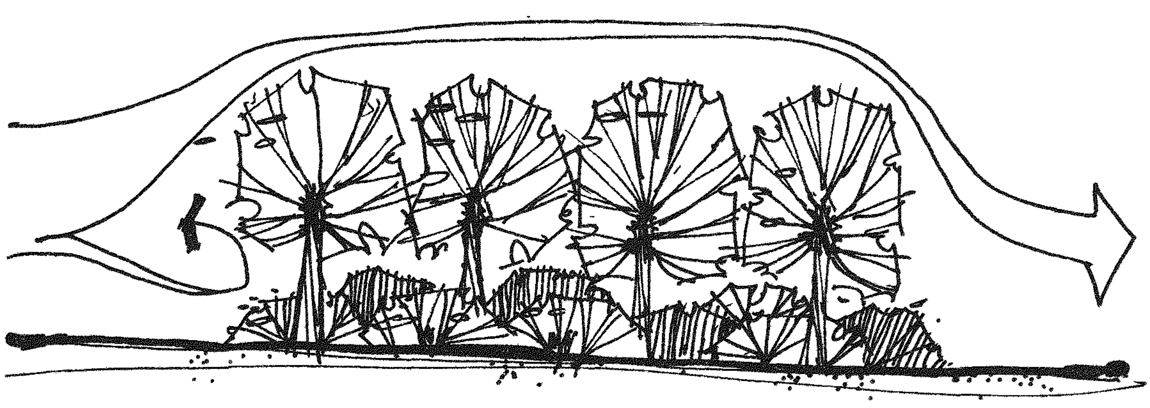
- On inland sites look for high elevations and slopes to capture breezes.

- Avoid low inland sites which are poorly drained or sites with dense adjacent development. These are potential air pockets.

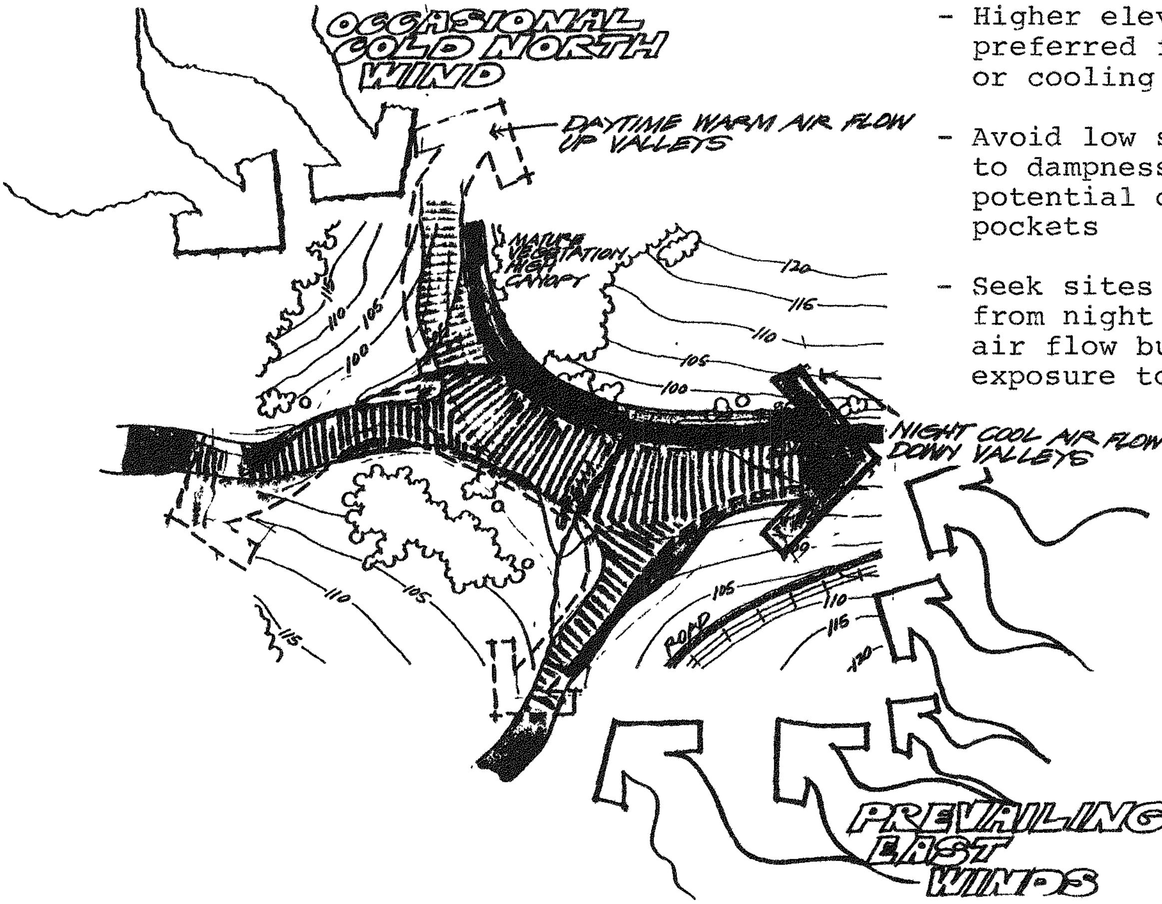
- Look for wooded sites with high canopy trees which permit air movement and provide shade



- Avoid sites with dense low canopy trees which block breezes and trap humidity in dead air pockets. (ASLA p. 148)

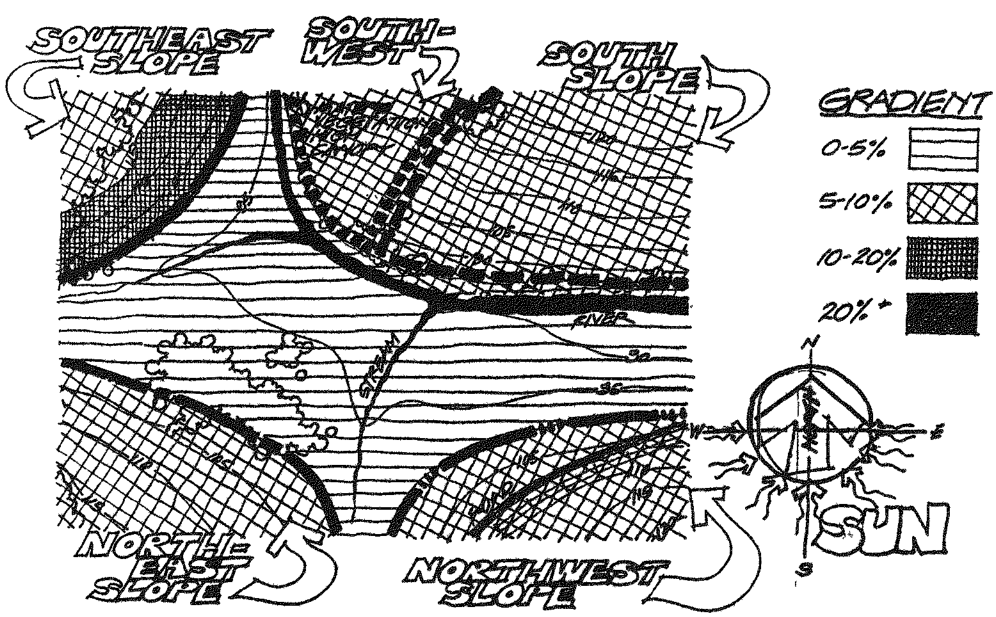


Seasonal Wind and Cold Air Flow



- Higher elevations preferred for ventilation or cooling
- Avoid low spots subject to dampness, frost and potential dead air pockets
- Seek sites protected from night time cold air flow but with exposure to breezes

Slope Direction and Gradient

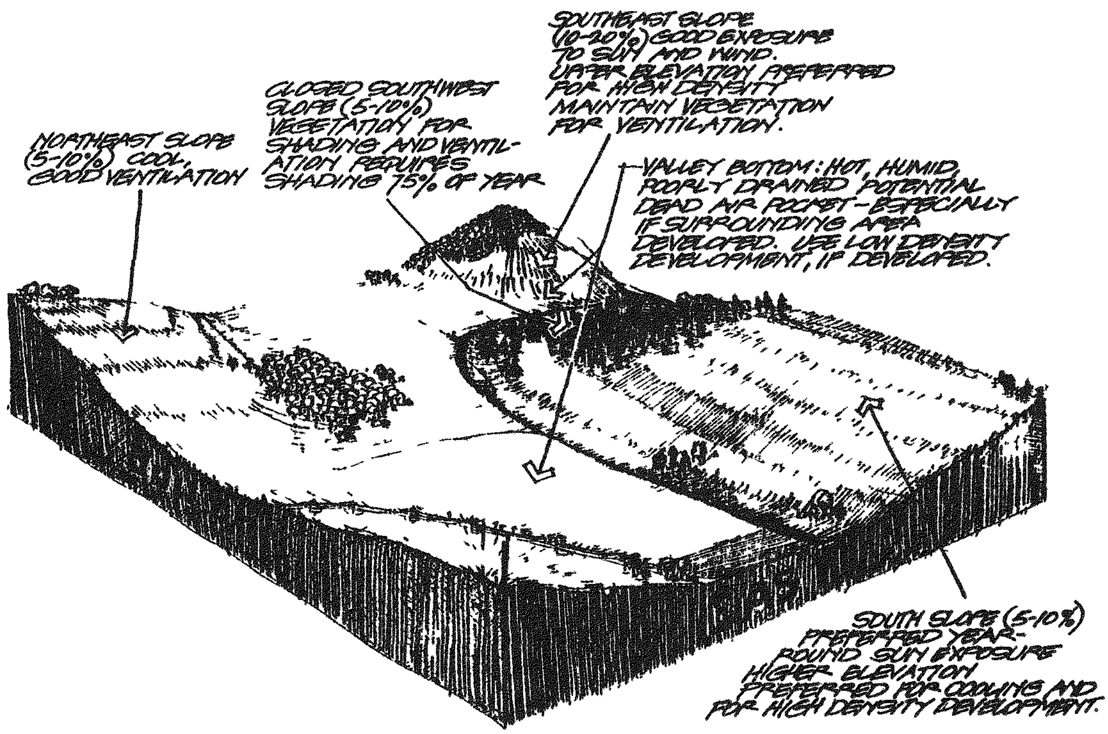


- Avoid slopes in excess of 20% due to erosion problems
- Avoid high water table due to associated dampness and humidity

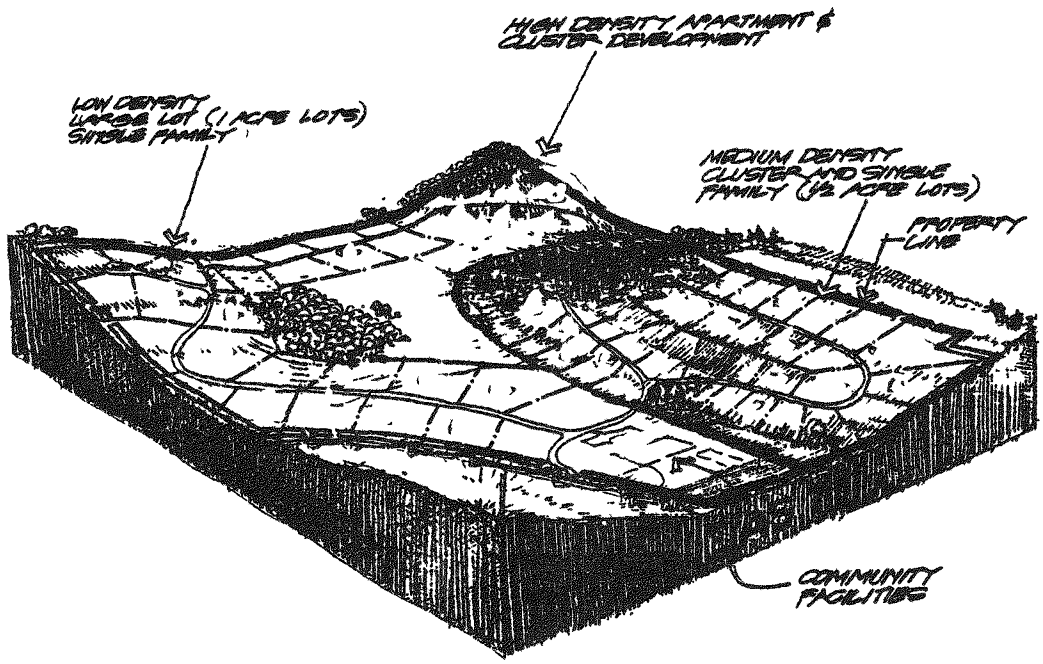
Site Selection

Site selection should be based on combined consideration of:

Winter and Summer Climate Influences related to existing land form, vegetation and natural features.



Development Suitability for various uses, structural types and use intensity



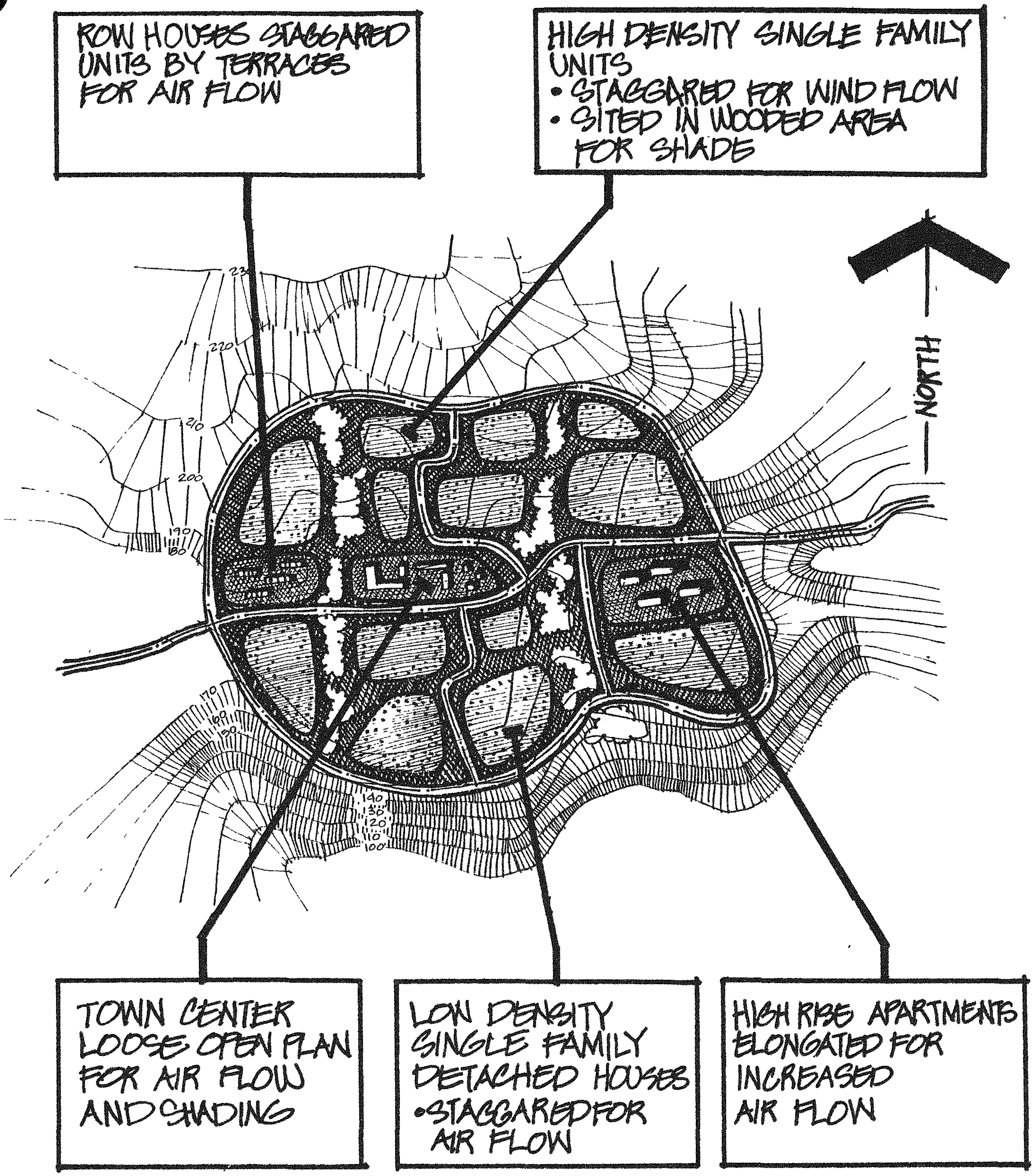
Recommended guidelines for various uses and structural types are as follows (Olgyay p.173-77).

Residential structures: select southern and norther slopes which are cooler year round. Avoid east and west slopes which are too hot.

Tall structures: select sites down wind of lower structures so as not to prevent through ventilation

Exterior Open Space: select shaded areas

Plan Layout


ROW HOUSES STAGGARED UNITS BY TERRACES FOR AIR FLOW
HIGH DENSITY SINGLE FAMILY UNITS
• STAGGARED FOR WIND FLOW
• SITED IN WOODED AREA FOR SHADE
NORTH
TOWN CENTER LOOSE OPEN PLAN FOR AIR FLOW AND SHADING
LOW DENSITY SINGLE FAMILY DETACHED HOUSES
•STAGGARED FOR AIR FLOW
HIGH RISE APARTMENTS ELONGATED FOR INCREASED AIR FLOW

Guidelines for plan layout are as follows (Olgyay p. 174-77):

- loose scattered plans for air flow

- low building coverage with high density (apartments) on terraced sites

- higher building coverage with low density single family detached units on sloping sites. Separate structures encouraged to permit air flow.

- town center open loose connected structures for air movement and overall shading

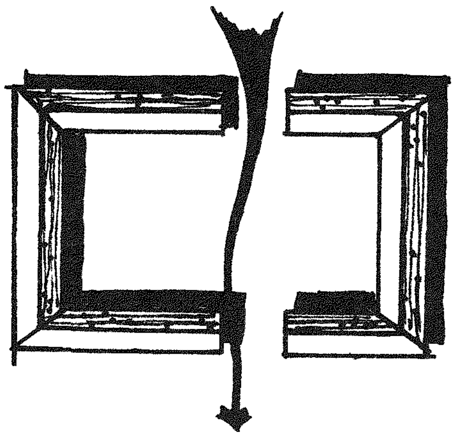
street layout uses E-W pattern to channel air flow

The generally desired character of development is low density layout with consistent sun wind orientation.

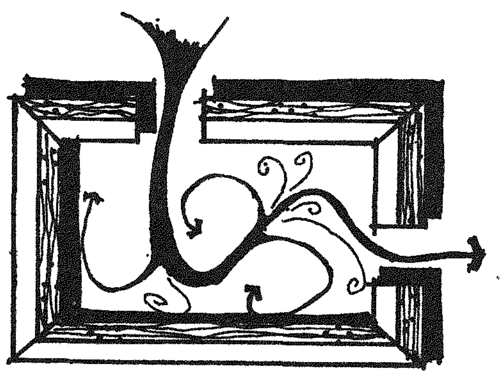
Building Relationships

Wind Response: orientation and layout

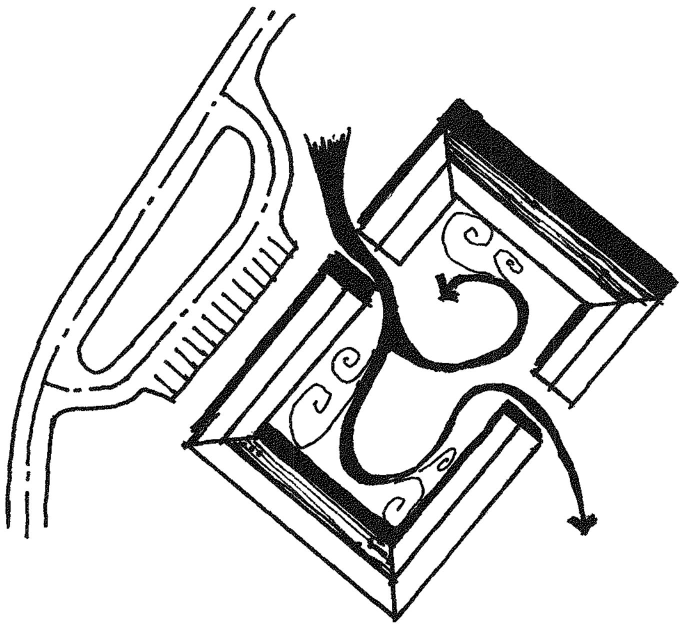
The goal in the hot humid region is to use the wind by slowing it down. In grouping buildings, remember that if wind encounters an inlet and an outlet is direct alignment with its direction, it will pass through the interviewing space in a narrowly defined path with minimal ventilation resulting.



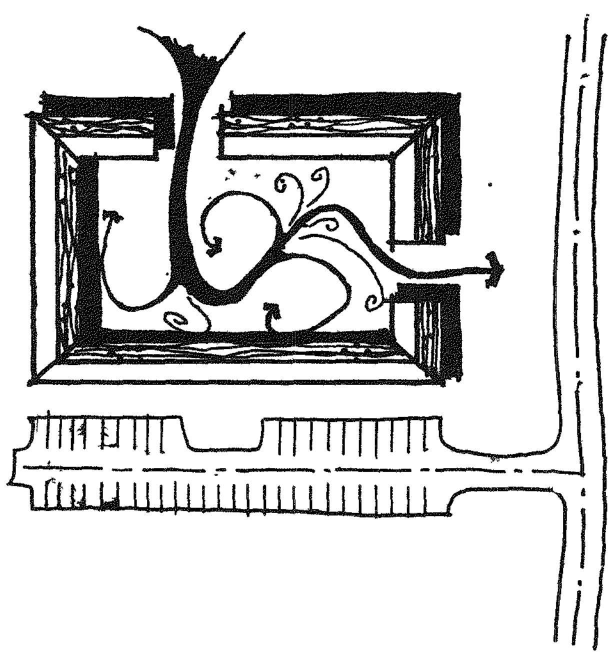
To increase ventilation within a building cluster you want to cause a change in direction between inlet and outlet and create an interior circulation air current to improve overall ventilation. (Hastings and Crenshaw 1-32)



In siting detatched structures or clustering attached structures encourage maximum ventilation by orienting structures and groupings as follows:



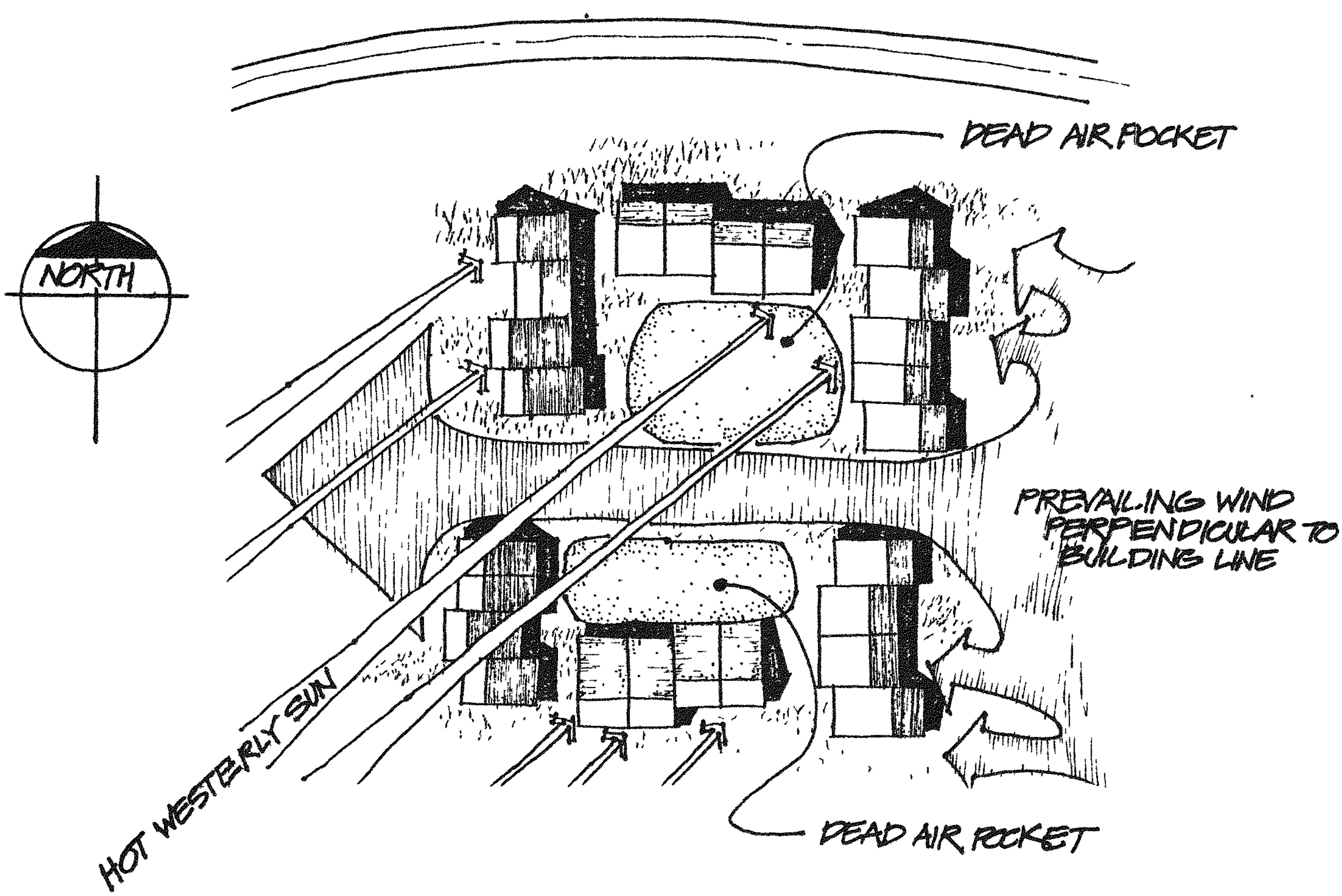
When overall orientations is askew to the direction of the prevailing wind use building groupings with openings on opposite sides for maximum local air circulation and cooling (Hastings and Crenshaw 1-31)



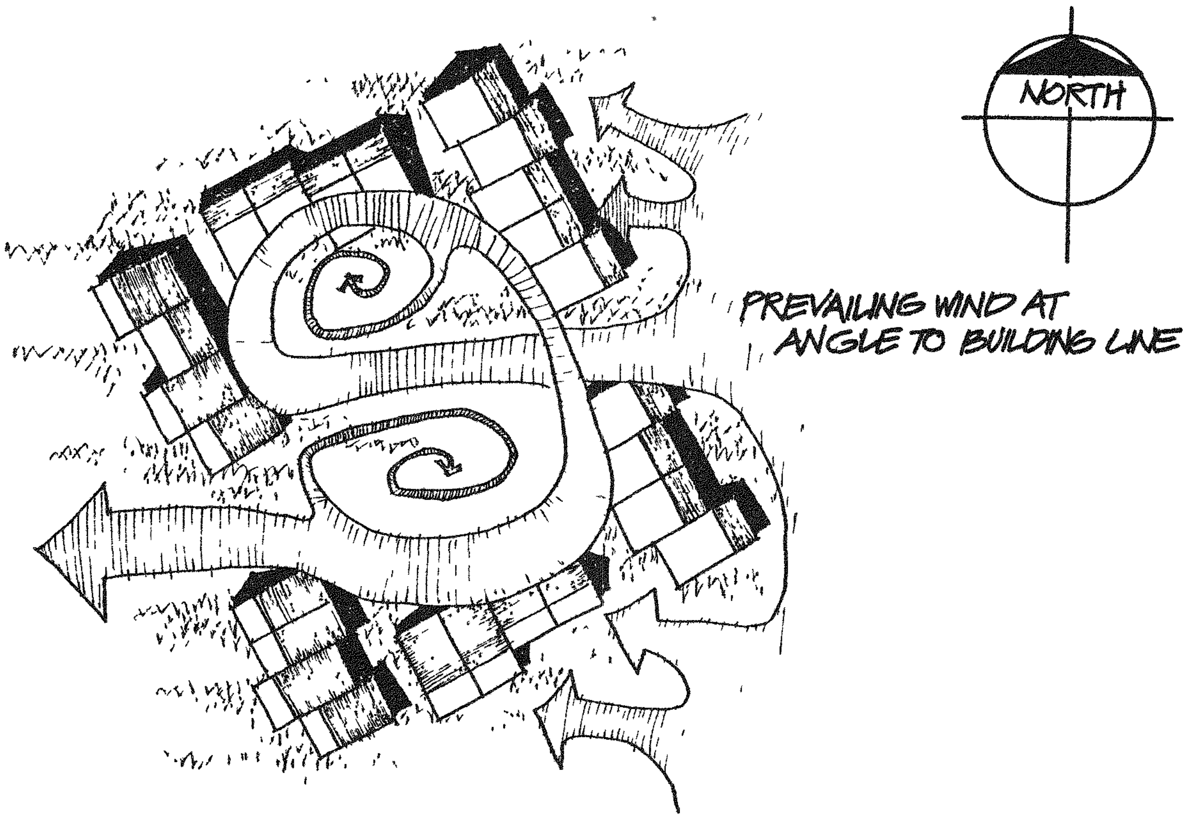
When overall orientation is perpendicular to the prevailing wind, group buildings with oepnings on adjacent sides for maximum local air circulation and cooling.

The following series illustrates building clustering responses to prevailing wind pattern.

The most undesiriable building layout is one with major openings perpendicular to the prevailing wind. In this situation wind funnels through at maximum velocity with minimum cooling effect. Dead air pockets are created near units and minimum cooling results.

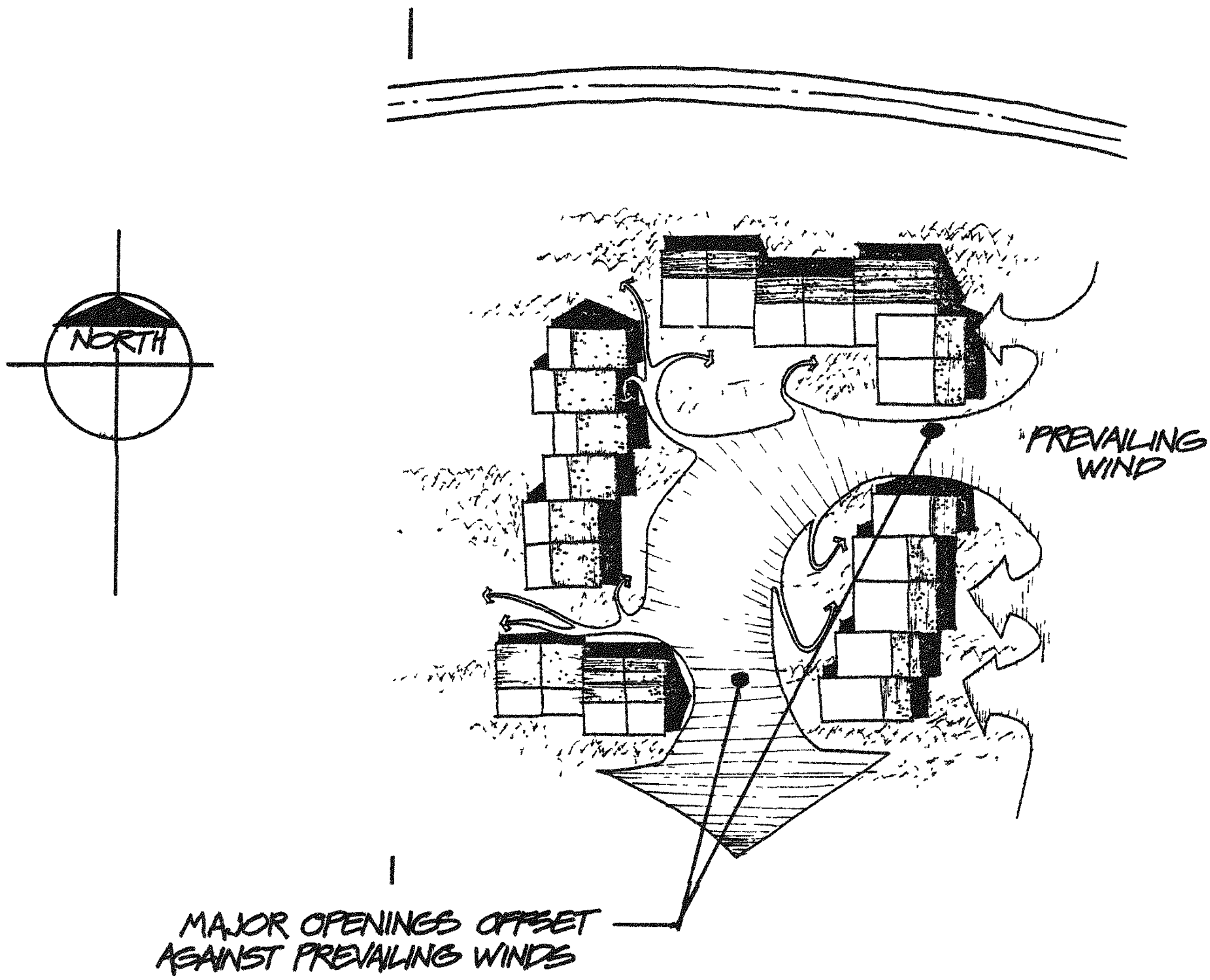


For this wind pattern maximum response in terms of building grouping is to site cluster with major openings diagonal to the prevailing wind flow.



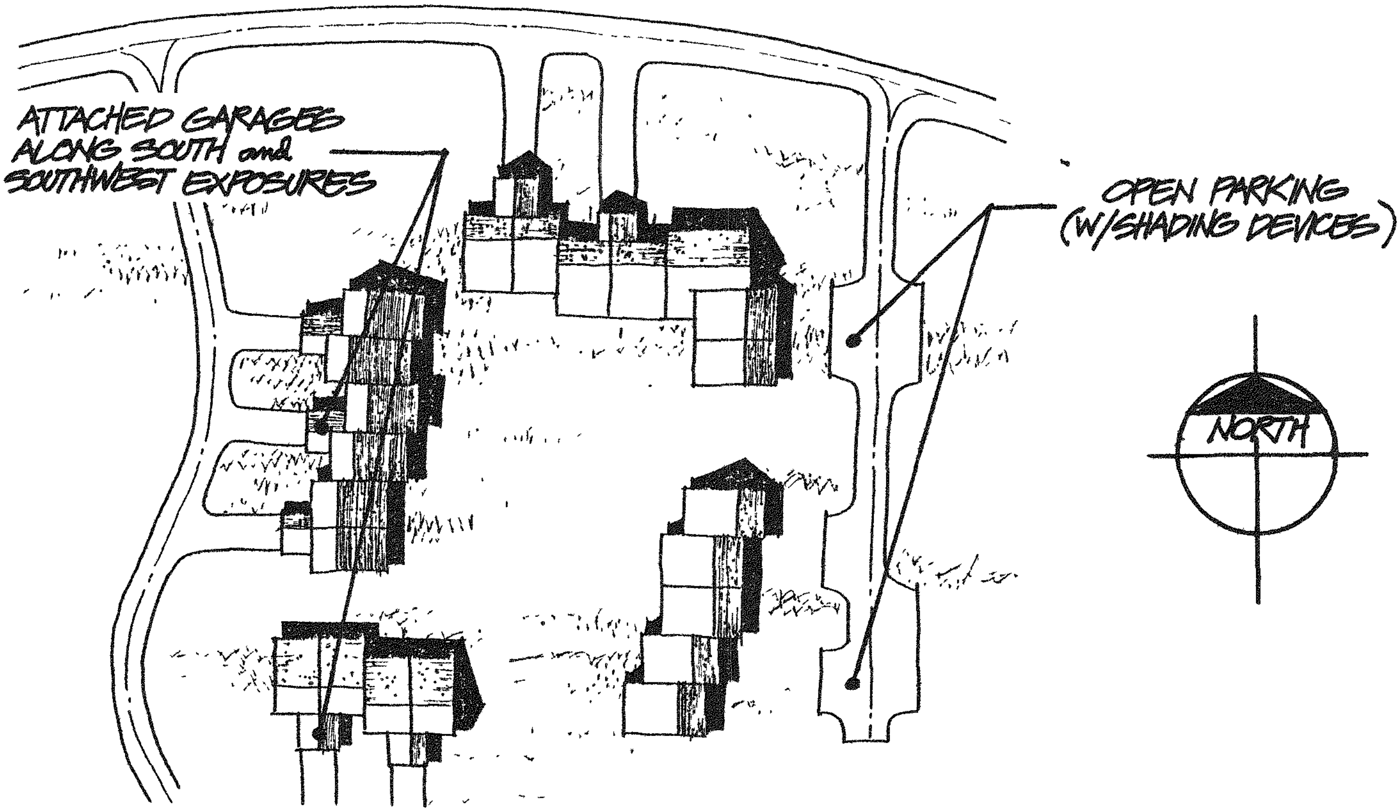
This clusterings pattern results in maximum local ventilation air pockets and cools surrounding units

When building clusters are perpendicular to the prevailing wind major openings in cluster groupings are desired as illustrated.



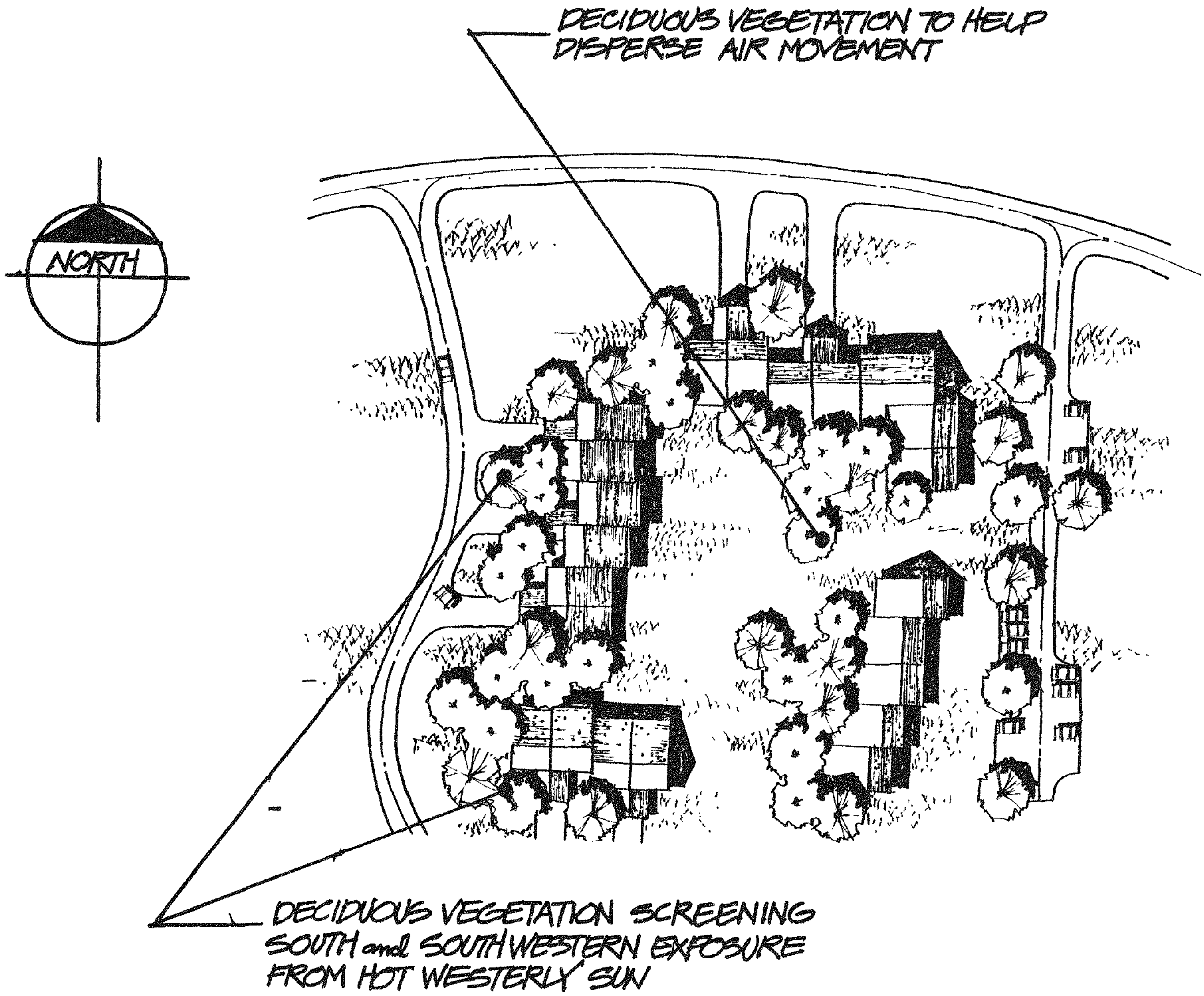
This arrangement encourages a natural air flow for cooling and eliminates dead air pockets.

In addition to clustering the units as previously illustrated further cooling can be induced by locating attached garages on westerly (hot afternoon sun) E xposures.



This arrangement of garage units results in reduced radiation absorption into living areas and further provides a buffer from cold winter winds.

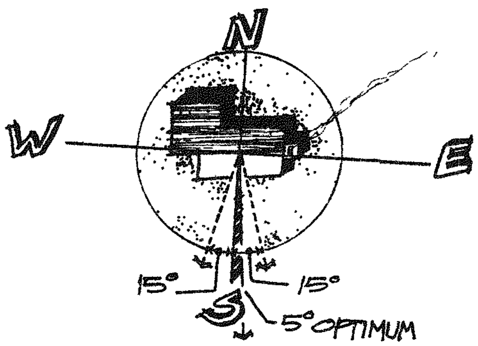
Finally consideration should be given to placement and selection of plant materials such as mature high canopy decidious vegetation planted on westerly and south westerly exposures.



This planting arrangement results in summer shading and evaporative cooling in association with the wind. It also increases local air circulation further by dispensing air flow patterns. Again consideration is given to buffering of cold winter winds and minimizing radiation on western exposure.

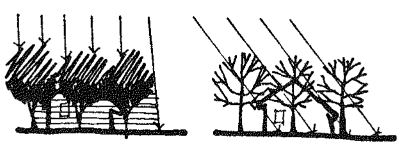
DESIGN GUIDELINES

Sunlight probability for the hot, humid region of the country is highest than other regions except the hot arid (.55) winter, .75 summer) and should be considered in terms of minimizing overheating effects.

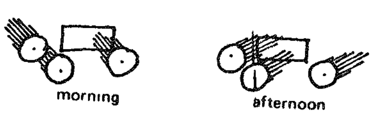


Orientation S 5° SE is optimum for residential developments. East and West slopes should be avoided and balance of sun and breezes is preferred.

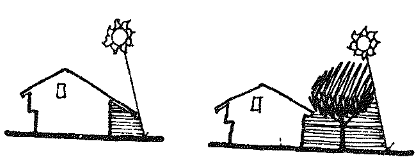
The following guidelines are recommended for maximum summer shade and winter sun (ASLA p.76).



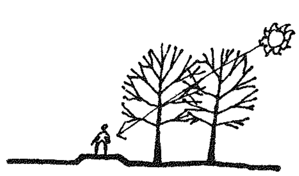
- Locate structure in deciduous woods or plant deciduous trees for summer shade and winter sun.



- In summer the structure should be shaded in the late morning and afternoon.



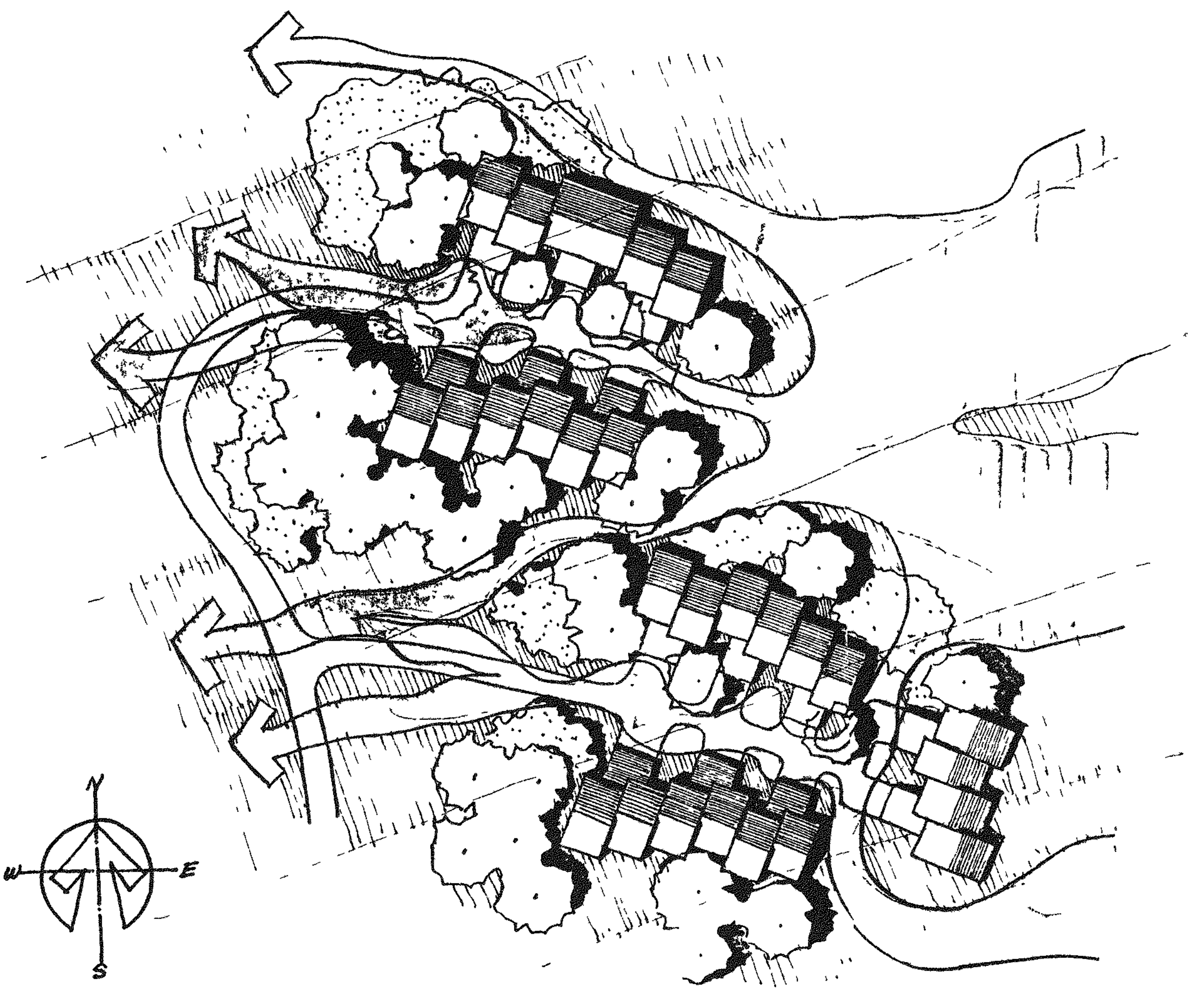
- Frequently used outdoor spaces should be shaded from late morning and afternoon sun in summer.
- Pedestrian circulation routes should be shaded by vegetation, canopies, pergolas, or arcades.



- Deciduous trees should be located on the south side of pedestrian paths to allow winter sun.

Multi-Family Houses (Townhouses & apartments)

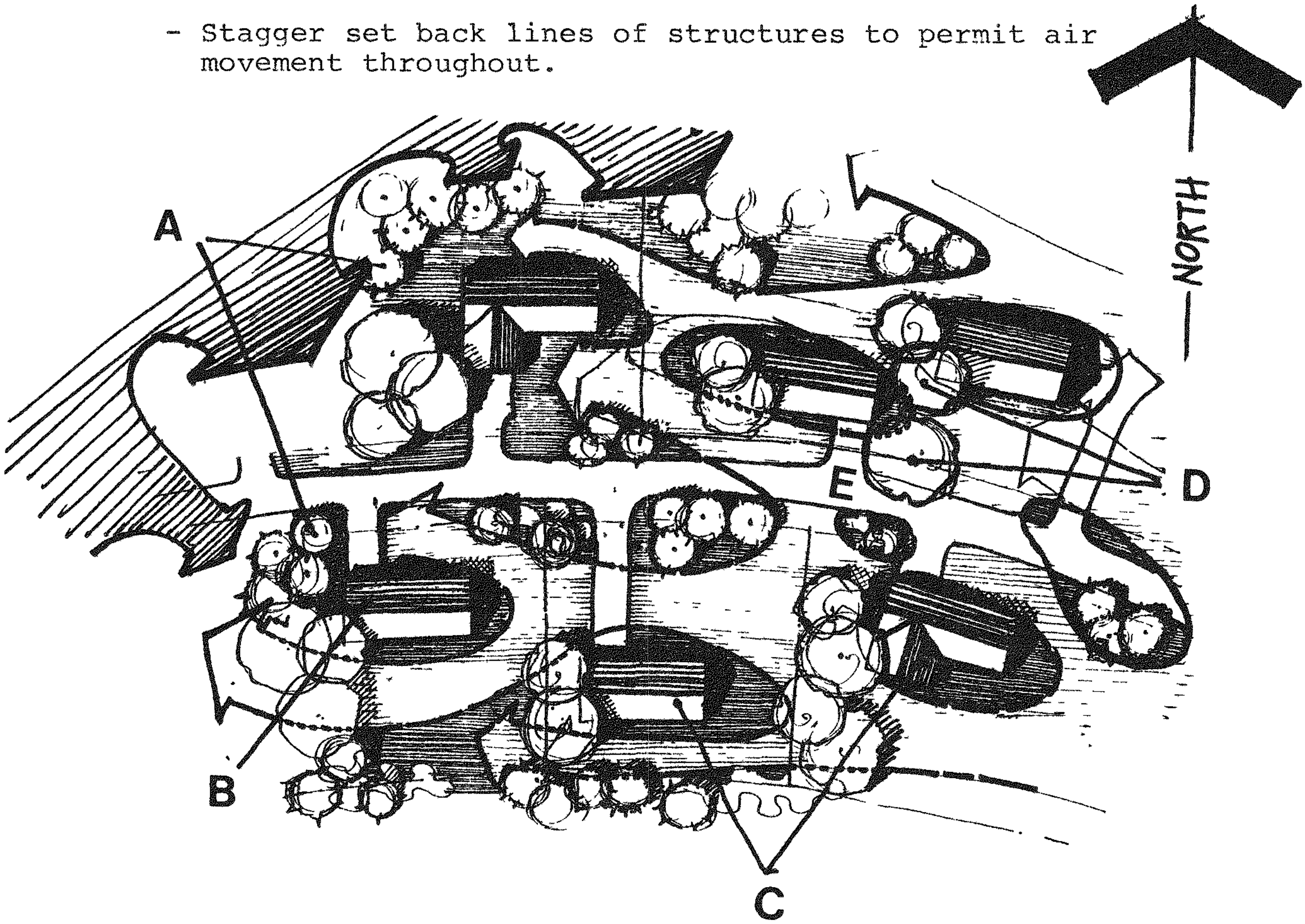
- Make linear axis of structures E-W to reduce wall surface exposed to radiation
- Cluster townhouses or apartments to catch breeze and use open space to channel wind



- E-W linear axis of units for minimum sun exposure in the afternoon
- Open spaces to channel breezes

Single Family Housing

- Stagger set back lines of structures to permit air movement throughout.



A. Dense evergreen plantings to buffer cold winter winds

B. Garage West end to block hot West sun

C. Setbacks varied to allow cooling, shading, ventilation

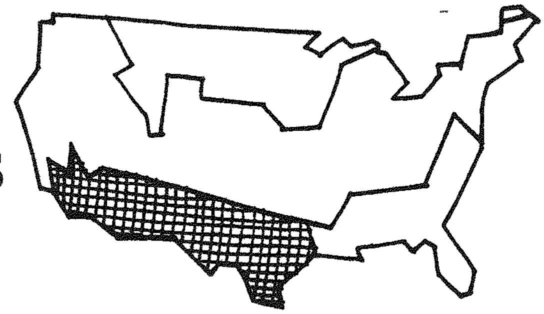
D. High canopy ventilation planted on Southwest: shades and cools in summer, maximizes winter sun, minimizes dead air pockets

E. Major street on E-W axis maximizes air flow and provides optimum orientation

- Utilize property lines in common as windbreaks to channel easterly breezes and shading for both properties (ASLA p. 166-167)

PART IV
HOT ARID REGION

HOT ARID REGION



CLIMATE CHARACTERISTICS

Winter

- Sunlight probability .55 (BSIC p.22)
- Maximum radiation on S facing vertical walls (4 x E&W)

Summer

- Sunlight probability 0.75
- Maximum radiation E & W facing walls (2-3 x S)
- Peak afternoon sun 3 p.m.

Year-Round

- Clear skies, dry atmosphere, low precipitation
- Extended periods of overheating, large diurnal temperature range
- Wind generally along E-W axis with diurnal variations

DESIGN CRITERIA

Summer

- Cooling requirements 633 hrs (BSIC p. 23-24)
- Maximize shade
- Maximize air movement

Year-Round

- Maximize Humidity
- Reduce effects of daytime radiation
- Maximize morning and afternoon shade

GROSS SITE SELECTION GUIDELINES

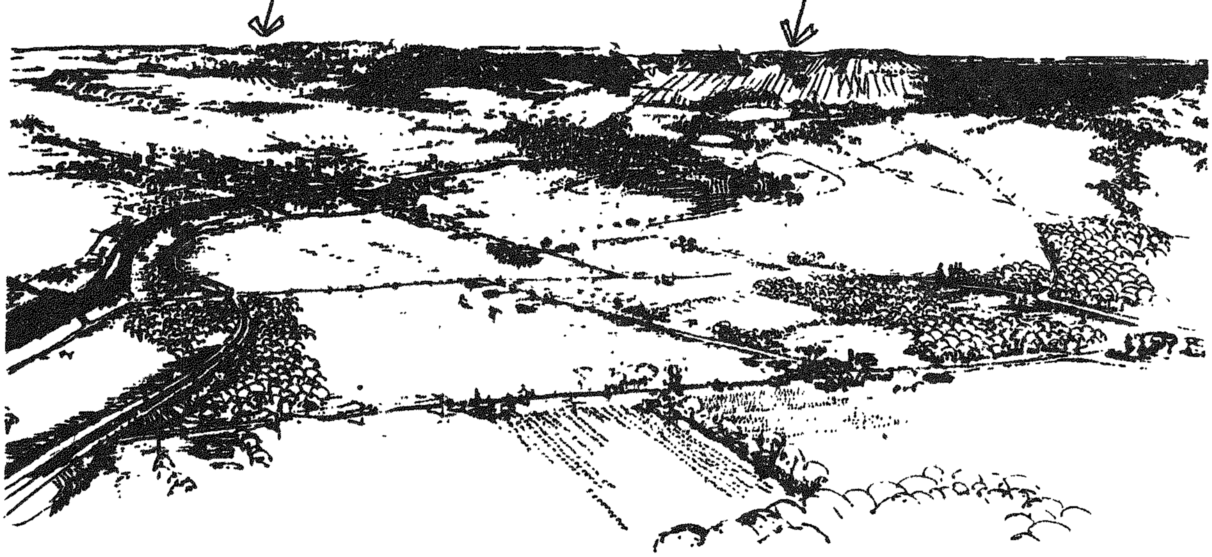
Look for sites with slope and orientation to <u>reduce</u> daytime radiation. Look for:

Landform

- Low hillside locations where cool air can be controlled.
- Avoid valleys & concave landforms which are too cold at night.
- Select high altitudes and positive landforms to minimize radiation on trap during the day and minimize cold air drainage at night.
- Optimum location is well upon a Southeast slope with a mountain to the west

East slopes are cooler on hot evenings and warmer on cold mornings

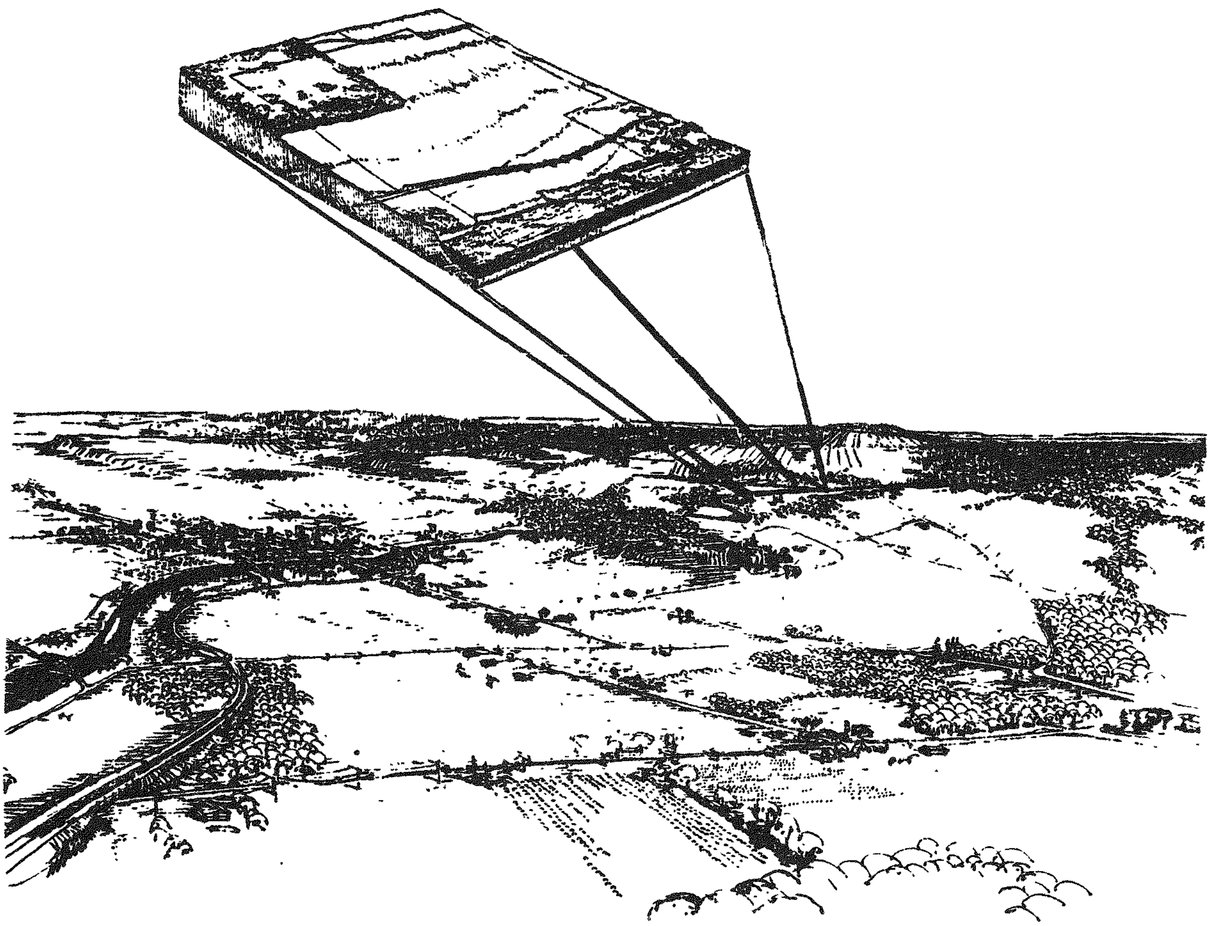
A mountain to the west can cut off an hour or two of hot summer sun



Prevailing Winds

- East-West breezes are important for daily cooling
- Avoid desert hot breezes
- Maximize the humidity and cooling effects of breezes blown from across water

DISCRETE SITE SELECTION GUIDELINES



Site Analysis

Analysis and selection of an optimum site should be based on the following general criteria:

- Identify and select sites with slope and orientation which reduce the effects of extreme daytime radiation and cooling requirements.

- Warm sites with S-SE orientations are preferred, avoid western orientation.

Summer Breezes and Winter Wind Pattern

- Select sites with preferred E-W breezes
- Avoid sites subject to hot desert breezes
- Cool air flow and evaporation associated with water locations is preferred

Slope Direction and Gradient

- Avoid valley bottoms, especially narrow valleys
- Select sites on higher locations which are cooler during the day and warmer at night
- Select slopes with S-SE exposures

Site Selection

Site selection should be based on combined consideration of:

Winter and Summer Climate Influences:

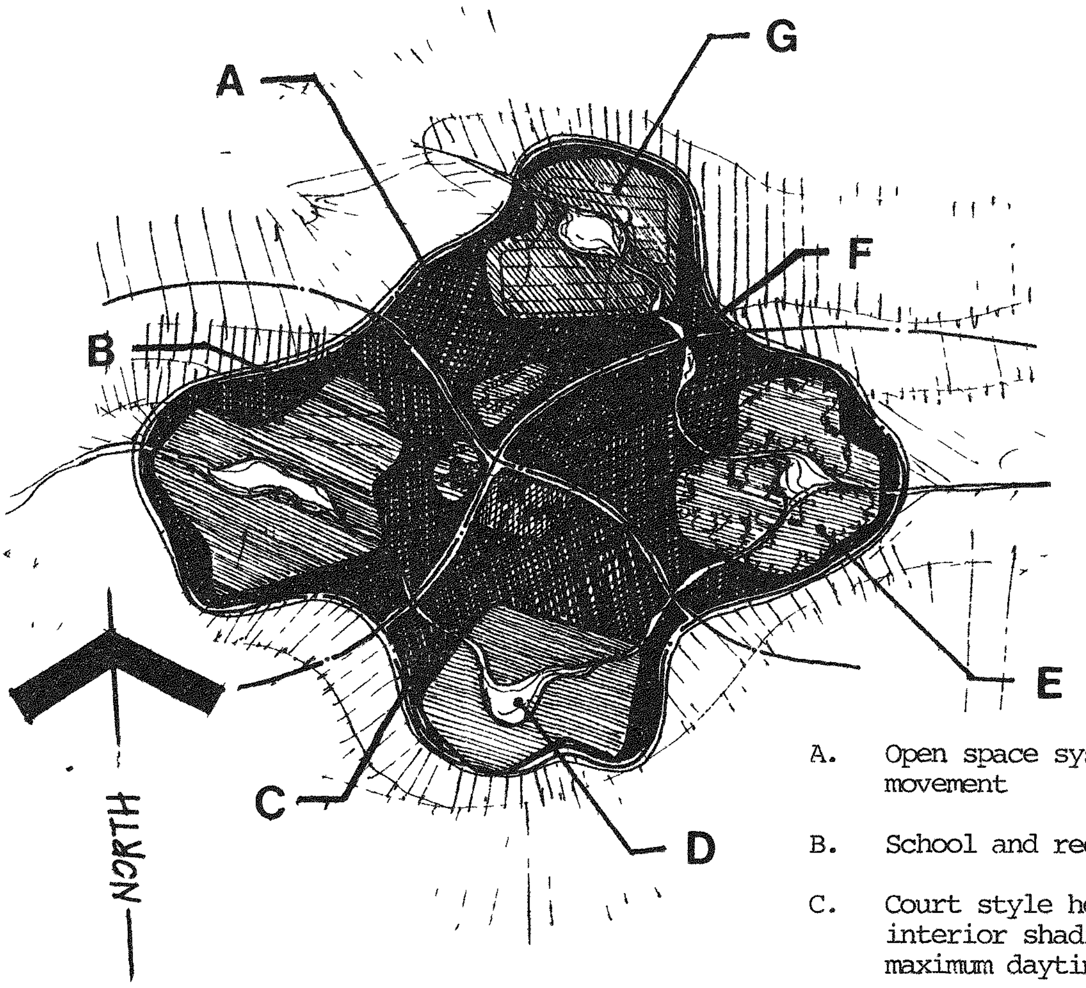
- select sites below middle of S-SE slope but above toe to benefit from cool air movements in early evening and warm air movements in early morning
- avoid valleys (ASLA p. 176)
- in vally situations, avoid valley floor and use cooler sites above for preferred evaporation
- ridge locations avoid heat traps and catch breezes
- select sites for subterranean or quasi-subterranean structures when possible, they are cooler and reduce energy requirements (ASLA p. 178).
- select sites where existing vegetation or topography can be used to shade E and W walls.

Development Suitability for varous uses and structural types. Studies by Olgyay recommend the following guidelines for various uses and structural types.

- Residential structures: select S-SE slopes
- Exterior Open Spaces: select half and full-shaded areas for public open space.
- Exterior Living Spaces: interior courtyards preferred porches and patios generall too sunny, best location if used is on SE corner of house

DESIGN GUIDELINES

Plan Layout



A. Open space system and pedestrian movement

B. School and recreation facilities

C. Court style housing permits interior shading and ventilation, maximum daytime cooling

D. Cluster housing near water body for maximum cooling

E. Locate clusters of high density single family housing to best utilize existing vegetation for shading

F. Town center commercial

G. High density single family detached, maximizes East, West streets for air movements.

Guidelines for the Plan Layout are as Follows (Olgyay p.169-171):

High Density Single Family: Sited on south-southeast slopes utilizing compact patio arrangements with shared common walls and closed configurations where possible to maximize shading and evening radiation loss and cooling effect.

High Density Row House Units: Sited on south-southeast slopes with high building coverage and massing in cube conficturation preferred to elongated linear attachments.

Exterior Living Space: Concentrated in interior courts formed by unit configuration utilizing building walls for shading.

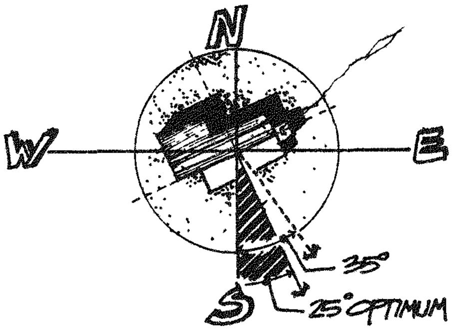
Town Center: Centrally located, shaded and in walking distance of all units.

Street Layout: Narrow streets on east-west axis preferred to channel breezes. Streets should be shaded to reduce radiant heat.

Building Relationships

Sun Response: orientation and exposure

Sunlight probability for the hot, arid region is the highest in the country. Utilization of solar heating systems is extensively used. Whether using solar systems or conventional development, building relationships for all development should utilize maximum winter radiation.

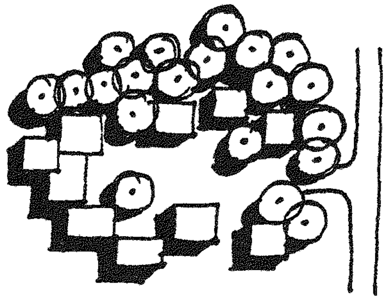


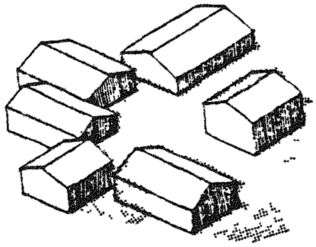
Optimum Orientation is 25° S SE

The following guidelines are recommended for optimizing winter sun:

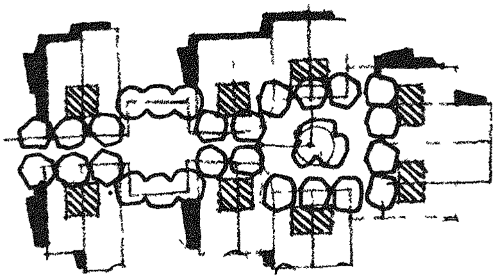
- Closed building arrangements around grass courts are preferred to promote heat loss through evaporation and cooling
- Use compact building forms to expose minimum surface to radiation

- Cluster houses to minimize building surface and utilize structures created by shade





- Arrange dwellings around courtyard-like cooling wells for shading (ASLA p. 177)

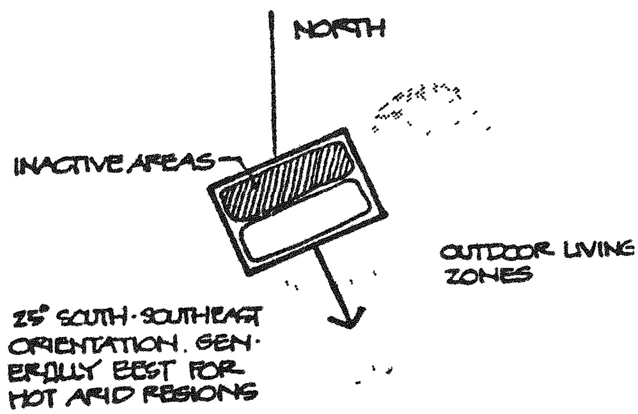


- Provide close connections between residential and other uses
- Small parking bays reduce sun pockets
- Shaded and dense layout desirable
- Interior courtyards provide shading opportunities
- Locate activity areas to the south east to collect early morning sun and permit afternoon shade
- Orient outdoor living and working areas according to the times during which they are most frequently used, seeking cooler locations for afternoon activities and warmer locations for evening activities

- Locate outdoor utility, storage and similar areas in those locations on the site not otherwise better used for living and working activities

- Avoid west windows and bedrooms

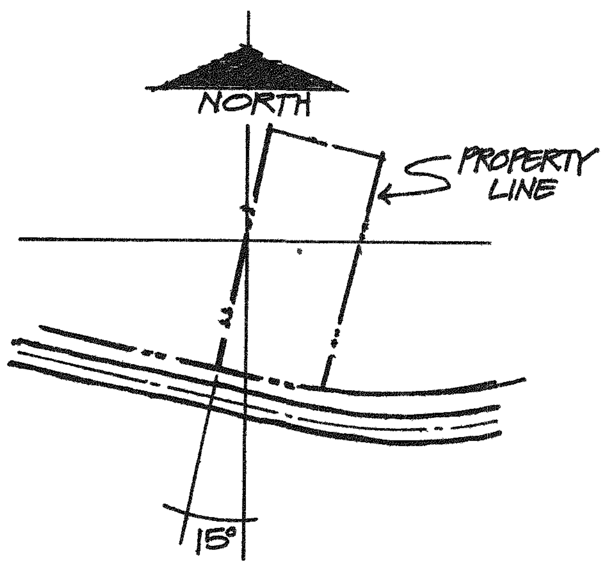
- Locate carport, garage, tool shed and blank walls on west to minimize sun impace



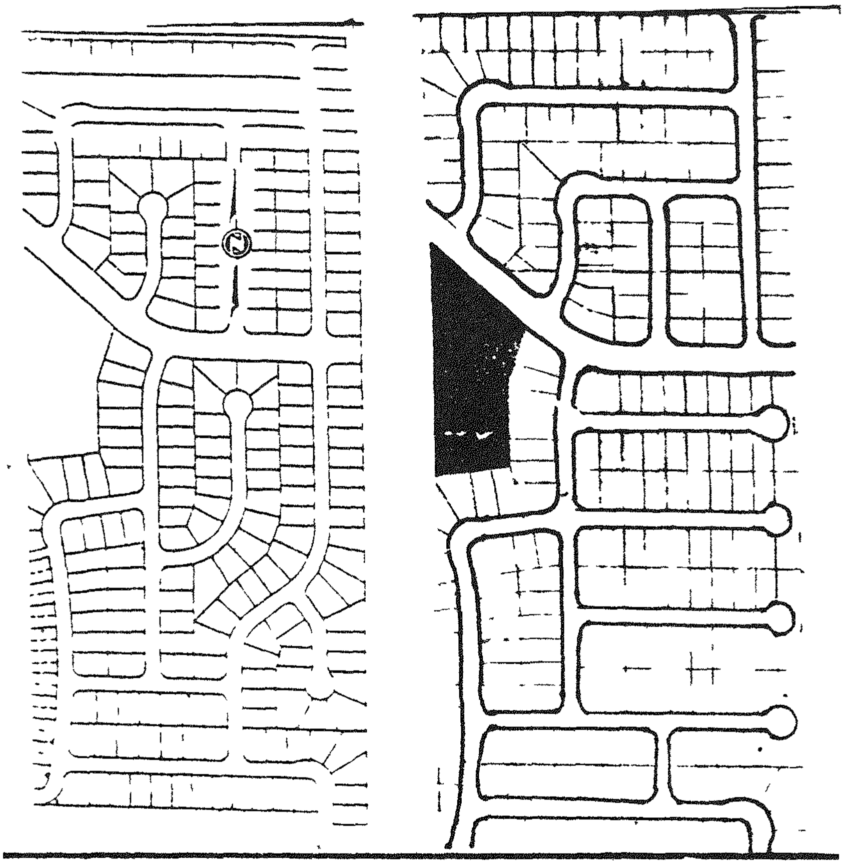
Solar planned communities in California which have been reviewed (Village Homes, Inc., City of Davis, Tandem, Indio) have identified the following guidelines for maximum solar utilization and energy conserving design.

<u>Lot and Street Orientation</u>

Recommended lot orientation is within 15° of South on the long axis of the lot to minimize southern sun for heating.



Recommended street orientation is E.W. to channel breezes and permit maximum number of S. oriented lots.

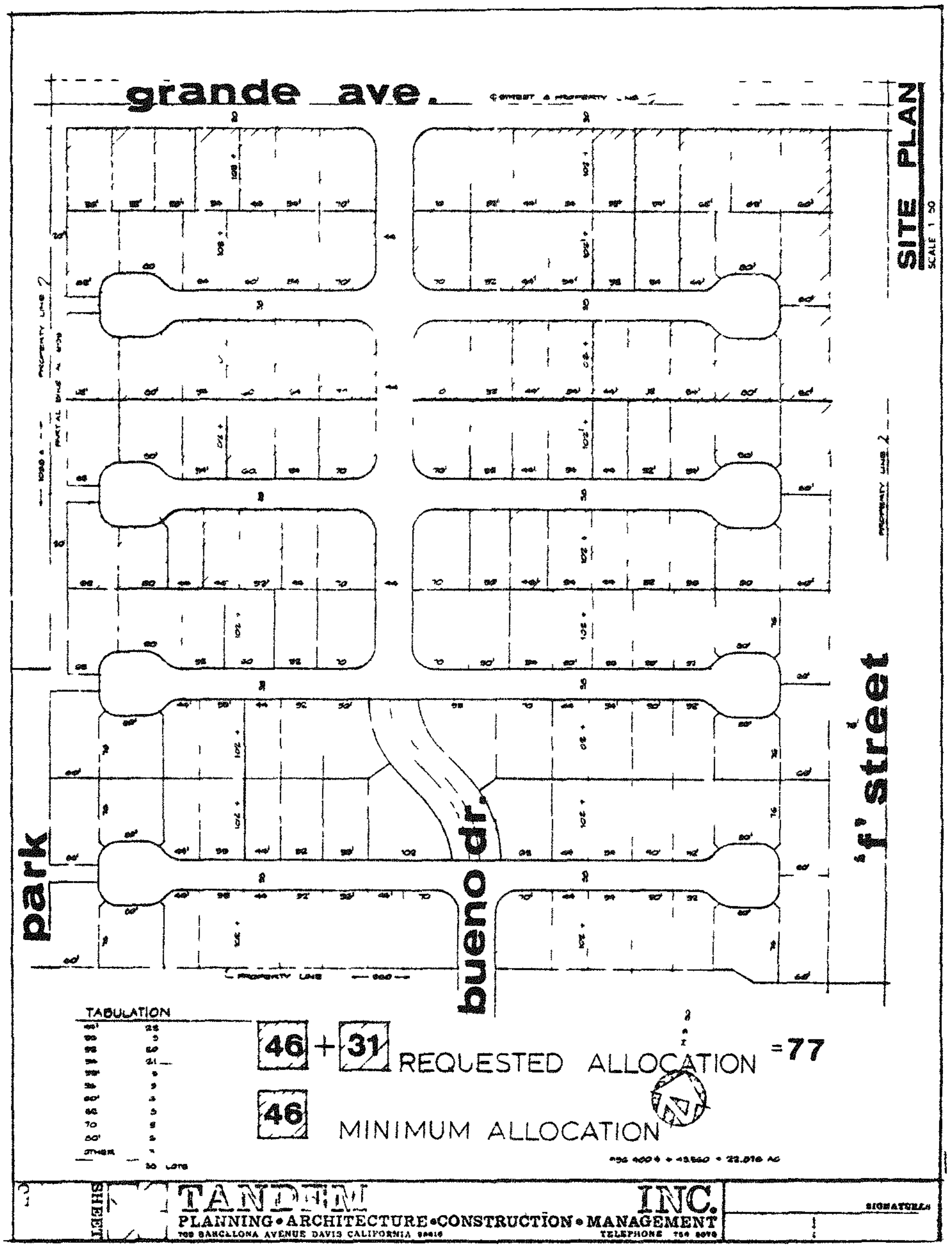


The above Stanley Davis subdivision was redesigned from east-west to north-south orientation

The lot and street layout illustrated demonstrates the feasibility of optimum southern lot orientation in a typical subdivision.

By redesign of street layout to a major E.W. pattern, example at right, most residential lots in a traditional subdivision are given an orientation within 15° of South. (Hammond April 1977)

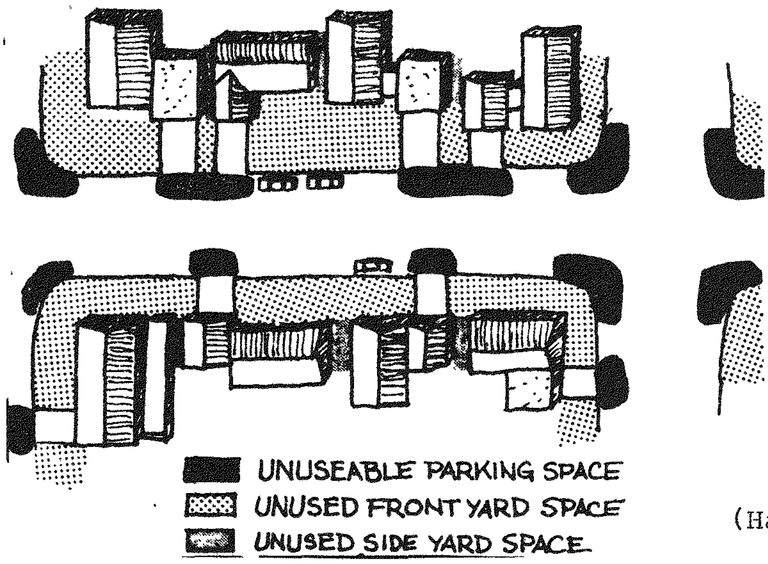
A similar example of this type is the Tandem development in California where again E.W. orientation of residential feeder streets permits maximum number of S. oriented lots. (Tandem, unpublished)



Alternative Plan Layout

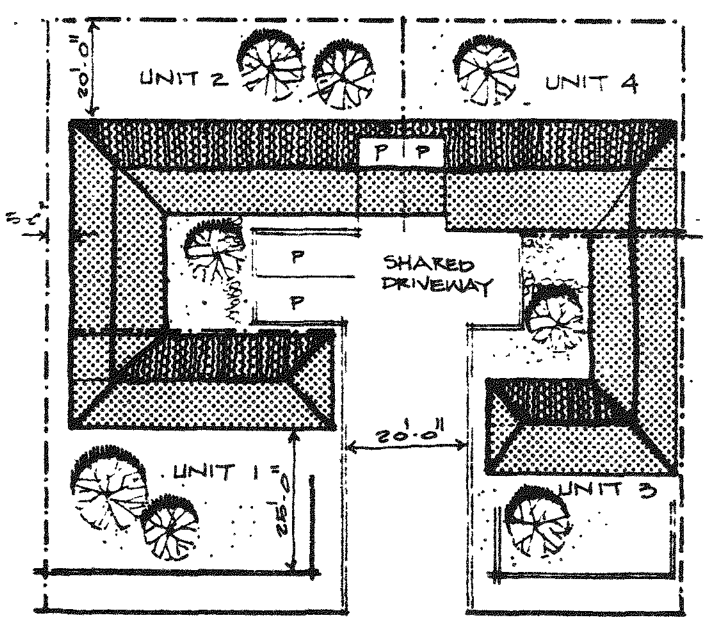
In examining traditional subdivision layouts, communities surveyed have identified wasted space and unused development costs for traditional linear subdivision blocks as illustrated in the plan below.

Fig. 46 Typical Subdivision Block Showing Wasted Space



(Hammond 1977 p. 38)

Recommended alternative development patterns include

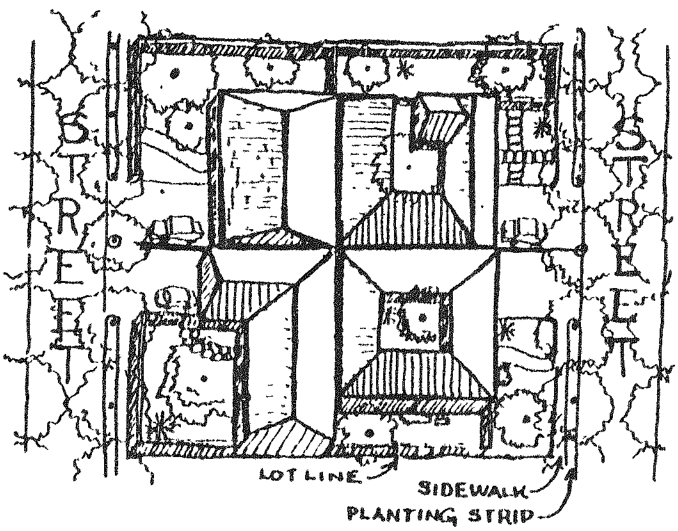


- compact arrangement around common court permits maximum daytime shading and evening cooling
- land developed on zero foot lot line requires conditional use permit and set back flexibility but permits common wall construction which reduces undesired heat loss and gain and construction costs (Hammond 1977 p.39)

- reduced paving for driveway and court system minimizes reflective heat surfaces, impervious drainage and facilitates shading

- system suited for adaptation to passive or active solar heating systems.

Back-to-Back 4-Unit Cluster



BACK TO BACK 4-UNIT CLUSTER FIG.V-10

- Alternative to compact courtyard where greater privacy is provided

- Adapts to E.W. street system

- Permits common wall construction which reduces undesired heat loss and heat gain and construction costs (Hammond 1977 pp. 38-39)

Increased Setback Flexibility

When single family lots and detached housing are mandated by program, client or zoning restrictions, or when lot orientation deviates from optimum. Preferred unit orientation can be accomplished through flexible setback arrangements as illustrated:

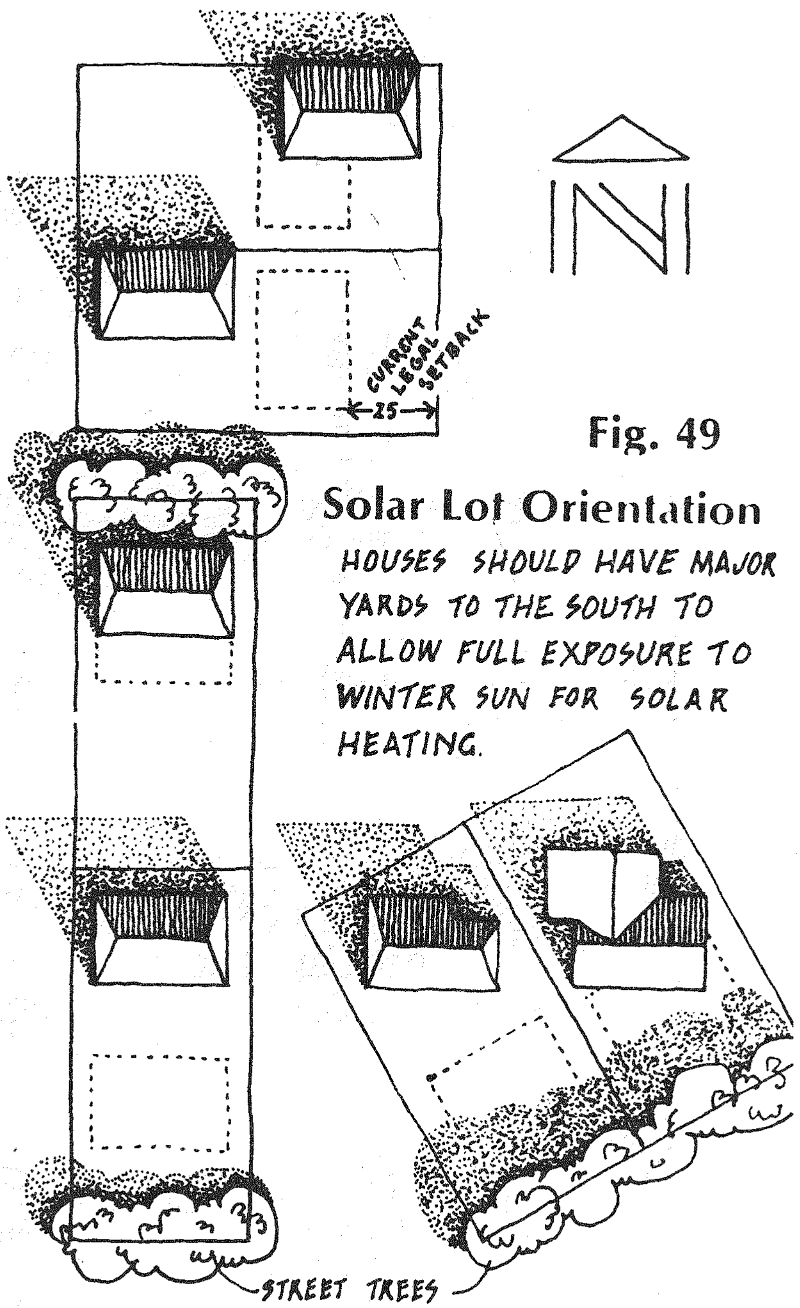
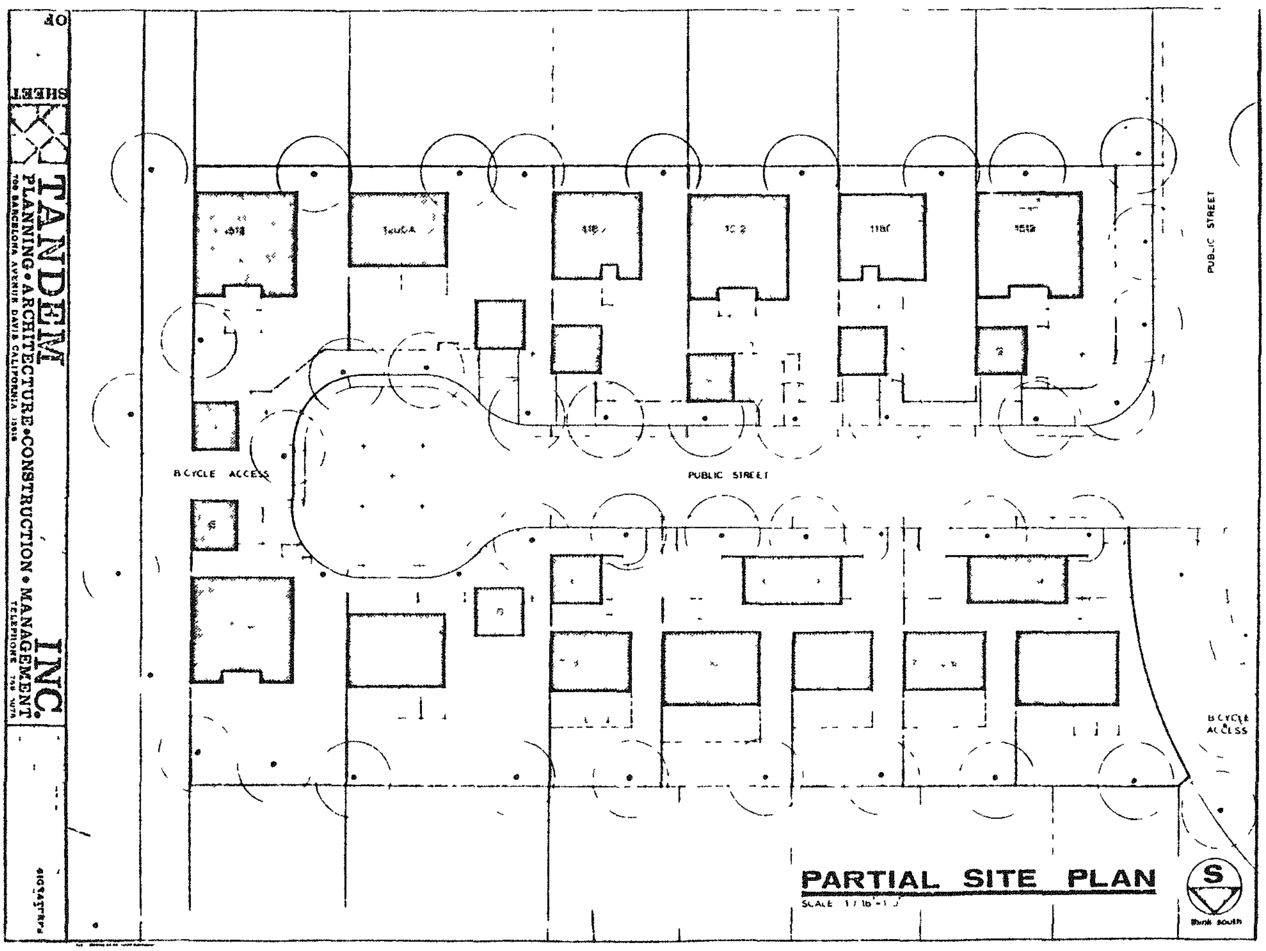


Fig. 49

Solar Lot Orientation

- permits full exposure to southern winter sun for heating
- prevents shading where undesirable
- permits southern orientation of structure where lot orientation is not N.-S. (Hammond 1977 p.39)

Flexible setbacks on detatched dwelling units also permits optimum solar access on both sides of the street as illustrated below.



10' rear yard setbacks on north side of the street provide large front yard living space on south; permits developer flexibility and varied visual pattern by reversing building, plan. Dependent on location from front to back. (Tandem, unpublished)

*Measurement of Energy Surveys

Communities examined identified the following energy savings for combined solar planning of new communities and retrofit of existing development.

DAVIS (Hammond 1977 p.1)

- Total energy savings - 50% (Hammond 1977 p.1)
- Energy savings for peak summer cooling - 10%
- Total growth in electricity use - 0

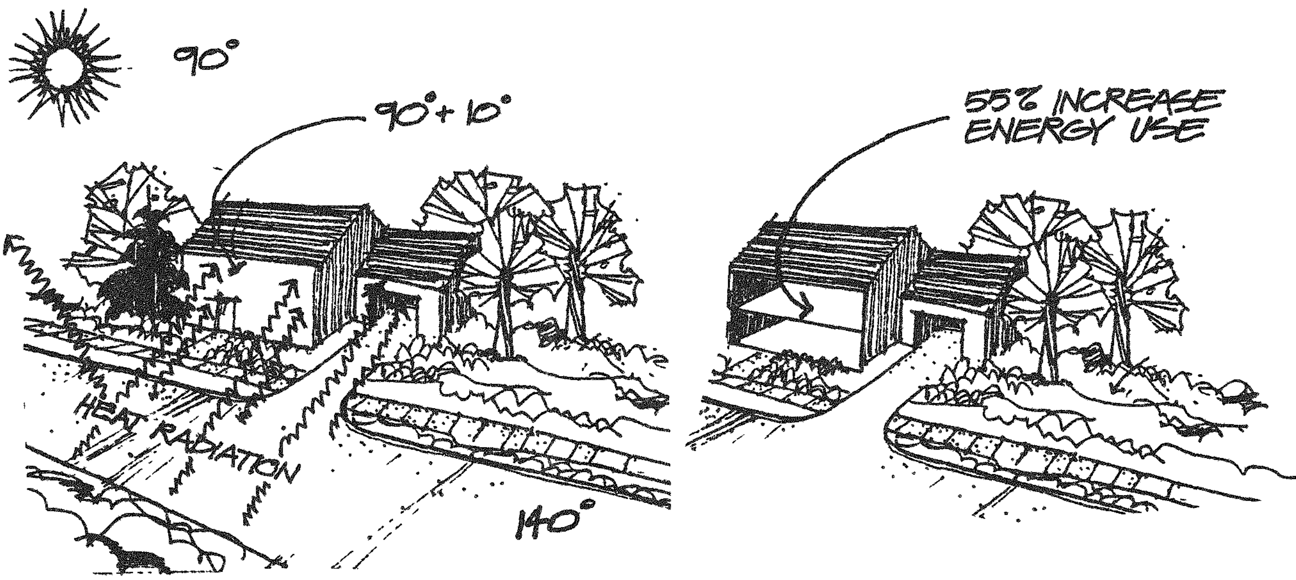
TANDEM PROPERTIES (Tandem, unpublished)

- Total solar heating efficiency - 90%
- Total cooling efficiency - 100%

Reduced Street Width

Several California energy conscious developments (Davis, Mission Viejo, Tandem, Village Homes) have advocated reduced street widths for the following reasons:

- Surface temperature of asphalt on a 90° day can reach 140°



- Increased asphalt surface temperature can increase air temperature by 10° and increases energy use for cooling by 55% with a wider paving (Hammond 1976, p.23)

- Construction costs and use of energy for construction operations are reduced with narrower street width. For example:

	34' Street	16' Street
Construction costs	$9,800	$4,800
Air conditioning efficiency	x +10%	x

(Hammond 1976 p.26)

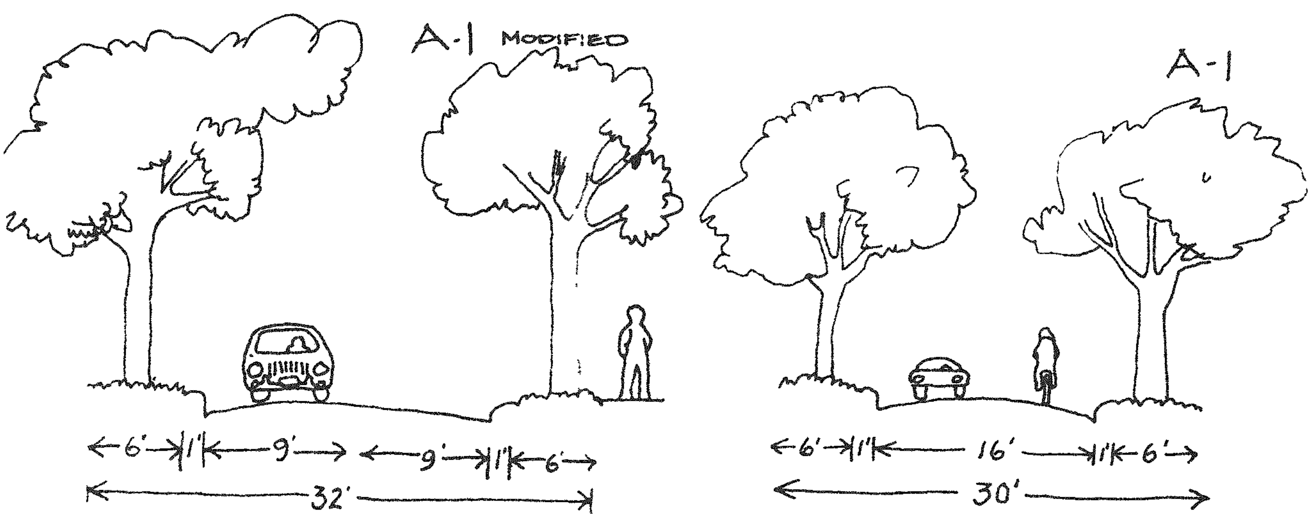
- recommended street widths for local residential streets should be based on the number of units served.

Reduced Street Width Standards

LOCAL STREETS: Based on Units Served

	Width	Units served	One/two way	Street parking	Side-walk	Sep. paths	Max/ length
Access A-1	16'	<20	1-2	no	no	no	300'
Modified	+ 7'			yes one side			
Access B-1	24'	20-40	2	yes one side	no	no	600'
Access B-2	21'	20-40	1	yes one side	no	no	300'
Modified	+ 7'			yes both sides			
Access C-1	24'	>40	2	no	no	yes	600'
Access C-2	20'	>40	1	no	no	yes	300'
Modified	+ 7'			yes one side		no	

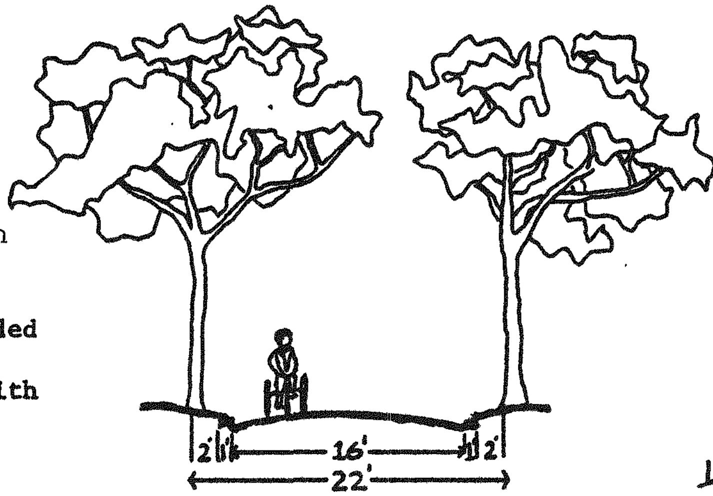
(Hammond 1977 p. 43)



Revised Standards

STANDARDS
- No Parking
- No Sidewalk
- No Paths
- 1-2 Way
- 300' Max. Length

No sidewalks are needed because very little traffic will occur with twenty units.

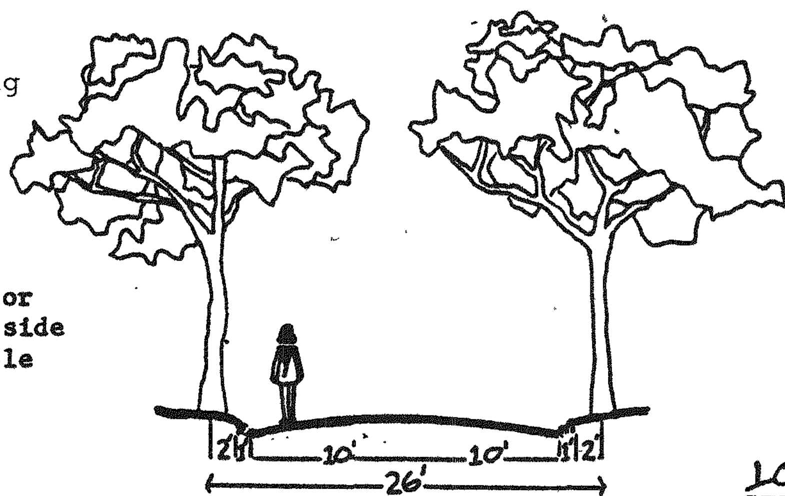


LOCAL: TYPE A

SERVES < 20 UNITS

STANDARDS
- 1 Side Parking
- No Sidewalk
- No Paths
- 1 Way
- 300' Max.

Stepping stones or sidewalk on one side might be desirable here.

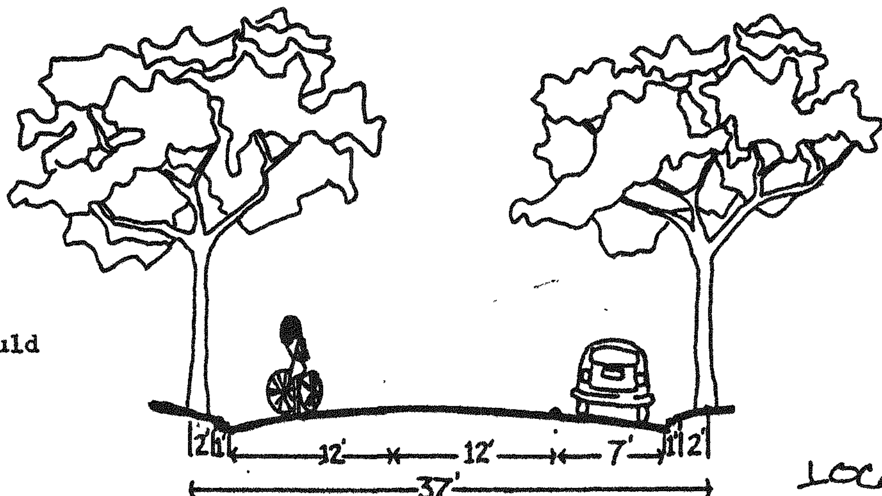


LOCAL-TYPE B2

SERVES 20-40 UNITS

STANDARDS
- No Sidewalks
- Sep. Paths
- 2 Way
- 300' Max.

Here a narrow ped/bike path off street would work well.



LOCAL-TYPE C-1M

SERVES > 40 UNITS

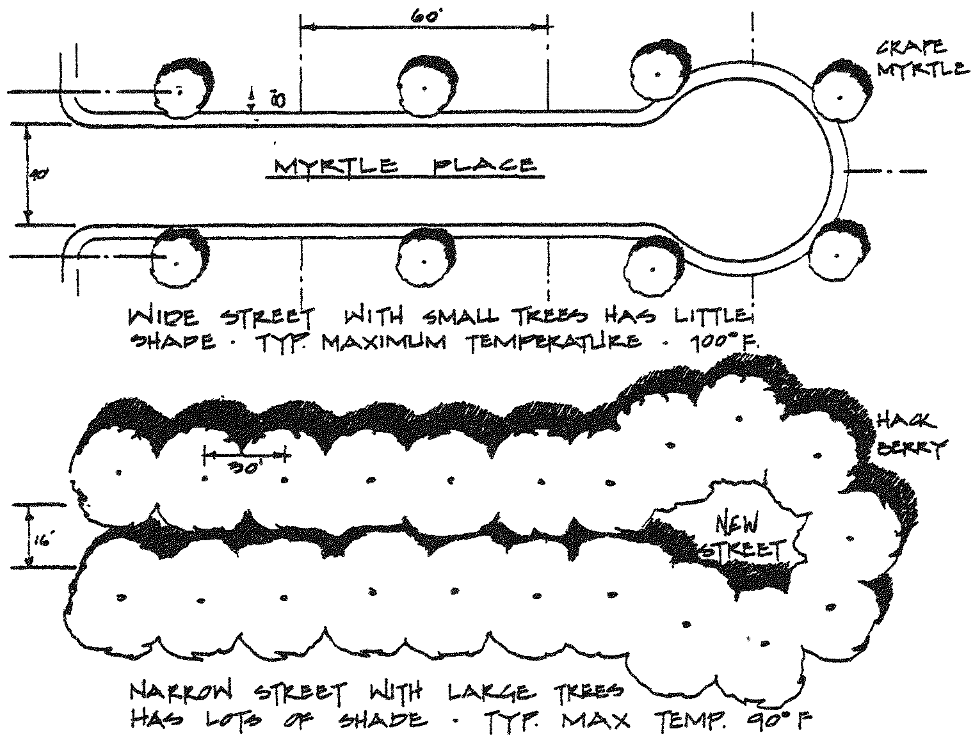
Concerns raised in response to modified street widths at Davis can be summerized as follows:

Fire Access: According to the City of Davis reduced street widths, if designed so as to eliminate parking,actually facilitate the movement of fire and emergency vehicles (Bainbridge and Hammond p.34)

Pedestrian Safety: According to the City of Davis, reduced street widths result in lower traffic speeds and increased pedestrian safety. (Bainbridge and Hammond p. 34)

SHADING

Shading of streets with reduced pavement has been found to result in a 40% - 50% reduction in air conditioning requirements. Effectiveness of shading is illustrated below. (Bainbridge and Hammond p. 52)



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Tandem Properties, Inc. Tamdem. Barcelona Avenue, Davis, California. (Unpublished)

Wright, Henry. "How to Put a Harness on the Sun." House Beautiful. October 1949. pp. 153,158,185.

Appendix

Options for Passive Energy Conservation in Site Design

INTRODUCTION

The appendices contained in this document summarize pertinent data collected during this project.

They are intended to give as a supplement to literature cited in the first two sections of this report and as such describe data in greater detail. Appendix A: Data abstract is intended to give an evaluative description of selected literature. Appendices B, C & D are intended to summarize data in areas of future interest to ERDA.

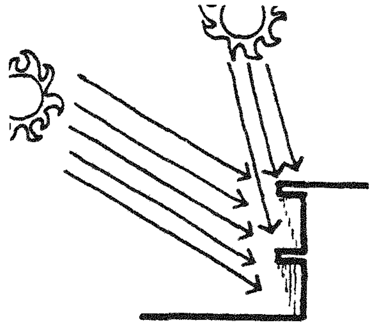
The methodology used for collecting data entailed literature search and survey techniques. Literature search was conducted using both manual search and information retrieval systems. Survey technique employed and standard request form. Upon completion of data categories identified below. These categories have been used to organize appendices B, C & D.

DATA CATEGORIES

Data review under this study had been broad and diverse, extending to varied types of projects and land uses and attempting to identify energy conservation impacts and measurements associated with each. However, in reviewing and analyzing data, it has been apparant that four basic categories of data can be established to classify material reviewed. These categories can be summarized as follows:

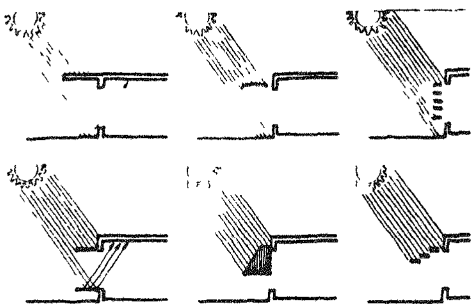
CLIMATE ANALYSIS AND CONTROL (1)

CATEGORY 1: ANALYSIS AND DESIGN TECHNIQUES FOR CLIMATE CONTROL: generally the data in this category is derived from classic climate studies done by the A.I.A., Victor Olgay, Langewiesche & Geiger during the late 1940's. These studies generally examined basic climate characteristics such as sun angle and radiation impacts, wind velocity and directional pattern. They also developed techniques for analyzing climate characteristics and developed



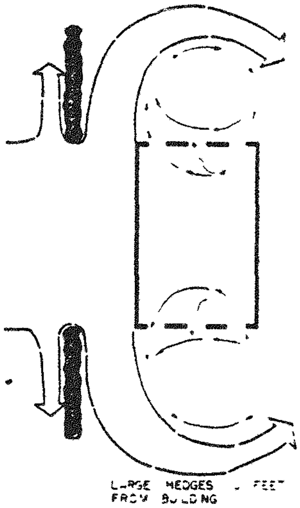
methods of climate control for human comfort in e four major climatic regions of the United States hot humid, hot arid, temperate and cool. These studies have formed the basis for the majority of subsequent climate design studies which are concentrated in one or several of the following areas.

Structural Modification



<u>Structural Modification for Climate Control:</u> These studies generally deal with retrofitting; structural form use of architectural features (screen, shades, overhangs, etc.) Prominent studies in this area include design of specific features, such as window design strategies (eg. Hastings and Crenshaw, Olgay) and modification through use of materials, form or architectural extensions (eg. A.I.A., <u>Energy Conservation in Building Design</u>; <u>Davis Retrofit Manual</u>; House Beautiful <u>Climate Control Studies</u>.)

Site Modification

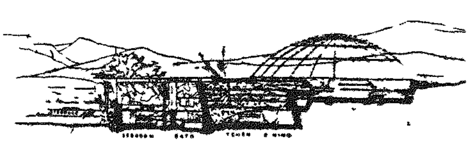


<u>Site Modification for Climate Control</u>: These studies generally deal with the use of wind breaks, land forms and vegetation for control of sun and wind. Prominent studies in this area include Heisler's <u>Trees and Human Comfort in Urban Areas</u>; Robinette's <u>Plants People and Environmental Quality</u>; White's <u>Effects of Landscape Development on the Natural Ventilation of Buildings and Their Adjacent Areas</u>; and The National Forest Services' <u>Tree Windbreaks for the Central Great Plains</u>.

In general, all of these studies have concentrated on residential site design for climate control, which has been measured in terms of the degree of climate control (eg. wind velocity reduction or breeze flow, sun radiation and absorption, reflection) or human thermal comfort (eg. control of interior and exterior temperature) affected, not in terms of energy conservation.

ADAPTIVE ARCHITECTURE (2)

CATEGORY 2:
<u>ARCHITECTURAL ADAPTATIONS FOR ENERGY CONSERVATION:</u>
These studies deal with adaptive or non-traditional architecture. Prominent studies in this area include use of earth covered structures (Malcolm Wells et al); Solar Dwelling Design Concepts using collectors, heat sinks, reflectors, etc. (HUD; Mass. Design; Olgay; Robinette; Davis, California, Winona, etc.)



:E PLANNING AND DESIGN (3)

CATEGORY 3:
<u>PLANNING AND DESIGN FOR ENERGY CONSERVATION</u>: These studies are generally demonstration projects such as Davis, Winona, City of Indio; or private project work such as RahenKamp, Sachs and Wells Design f

Pine Hills; Wallace, McHarg, Roberts and Todd's study for the Woodland New Community.

POLICY CONTROL (4)

CATEGORY 4:
POLICY CONTROL FOR ENERGY CONSERVATION: These studies generally deal with policies that have, or can be implimented in order to promote energy savings. Prominent studies of this type are analytical such as Corbin Harwood's Using Land to Save Energy; model codes and guidelines such as the NAHB's The Builders Guide to Energy Conservation; the NBS Research and Innovation in the Building Regulatory Process; Davis, California's Energy Conservation Building Code Workbook; and the FEA State Energy Conservation Program.

Data Sources

Sources for Data Collection

1. Literature: books, periodicals, abstracts
2. Government Agencies
3. Academic Institutions
4. Professional Offices
5. Research Laboratories
6. Model Projects

Data Appendices

Because the research investigators under this study are specifically interested in Environmental Planning and Design for Energy Conservation, detailed inventory and evaluation of this information has been consolidated in appendices to this study. These appendices are contained at the back of the report, and have been classified according to the four data categories outlined above. These appendices are referred in the body of the report under the following key phrases:

State of the Art Sources of Data which identifies the pertinent studies for a specific area, which can be found in the appendies.

State of the Art Significance of Data which discusses the significance and value of particular studies is examined.

APPENDIX A

TOPICS / SOURCES — STATE OF THE ART

SOURCES	Topography (slopes)	Geology & soils	Hydrology	Macroclimate	Microclimate	Vegetation	Man-made features	Visual quality	Legal controls	Proximity	Program requirements	Phasing	Site preparation	Stripping, Stock piling	Grading	Replacing topsoil	Utilities layout	Roads, walks, paving	Site details	Integration	Orientation	Vegetation (shading)	Windbreaks	Materials, Use of	Shading devices, ext.	Building configuration	Town layout	Street design	Measurements	Regulatory polici
	Site Selection and Analysis											Site Development								Climate Modification									*	
The AIA Research Corporation. Energy Conservation in Building Design.	X				X					X											X			X						
The AIA Research Corporation Solar Dwelling Concepts			X		X																X		X	X						
ASLA. Landscape Planning for Energy Conservation	x	x	x	x	x	x	x	x		x											x	x	x	x	x	x	x		x	
Doddez Douglas Energy Conservation																						x							x	x
Harwood, Corbin Crews Using Land to Save Energy																						x	x						x	x
Hastings & Crenshaw. Window Design Stratergies To Save Energy																					x	x	x	x	x				x	
House Beautiful. Climate Control Project	x			x	x	x														x	x	x	x	x	x	x			x	
Leckie, Jim etal. Other Homes & Garbage	x	x	x		x		x													x		x	x		x					
Living Systems. Energy Conservation Advisory Program																						x			x				x	
Living Systems. Davis Retrofit Manual																									x					
Living Systems. Indio, California: Energy Conservation Project																					x	x			x				x	x
Lynch, Kevin Site Planning	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x		x								x	x
McCullough, etal. A Handbook of Considerations for the Envir.Review Process	x	x	x		x	x	x														x	x	x	x	x	x	x		x	
NAHB. The Builders' Guide to Energy Conservation	x									x						x					x									x
NAHB Land Development Manual	x	x	x		x	x	x		x	x			x	x	x	x		x											x	x

* See Appendices C & D

STATE OF THE ART

SOURCES ↓ / TOPICS →	Topography (slopes)	Geology & soils	Hydrology	Macroclimate	Microclimate	Vegetation	Man-made features	Visual quality	Legal controls	Proximity	Program requirements	Phasing	Site preparation	Stripping, Stock piling	Grading	Replacing topsoil	Utilities layout	Roads, walks, paving	Site details	Integration	Orientation	Vegetation (shading)	Windbreaks	Materials, Use of	Shading devices, ext.	Building configuration	Town layout	Street design	Measurements	Regulatory policies
	Site Selection and Analysis											Site Development								Climate Modification									*	
Robinette, Gary O. Plants, People & Environmental Quality																						x	x						x	
Wells, Malcolm. Underground Designs																				x										
White, Robert F. Effects of Landscape Dev. on the Natural Ventilation of Bldgs.																						x							x	
Whittmus, Waldemar Albert The Effects of Trees on Wind as Related to Drifting snow.																							x						x	

* See Appendices C & D

STATE OF THE ART

SOURCES / TOPICS	Topography (slopes)	Geology & soils	Hydrology	Macroclimate	Microclimate	Vegetation	Man-made features	Visual quality	Legal controls	Proximity	Program requirements	Phasing	Site preparation	Stripping, Stock piling	Grading	Replacing topsoil	Utilities layout	Roads, walks, paving	Site details	Integration	Orientation	Vegetation (shading)	Windbreaks	Materials, Use of	Shading devices, ext.	Building configuration	Town layout	Street design	Measurements	Regulatory polic
	Site Selection and Analysis											Site Development								Climate Modification									*	
Hammond, Jonathan, et al A Strategy for Energy Conservation				X													X	X			X	X						X	X	X
Hammond, Jonathan, Proj. Coor. Davis Engy Cnsvn Report: Prac use of sun				X																	X	X								X
Shepard, Gloria. "Davis CA. Imp. Engy. Bldg Code Practicing Planner				X																		X		X				X		X
Way, Douglas Terrain Analysis	X	X	X	X																									X	
McGregor, Gloria Shepard, "Davis, CA. A Pace Setting Engy Con. City										X												X	X			X		X	X	X
Living Systems & City of Davis. Engy Con. Bldg Code Workbook																					X	X			X				X	X
NAHB. Land Development Manual.		X	X			X			X					X	X		X	X											X	X
Goldberg, Philip. Planning with Energy													X	X	X			X	X											
Sunset editors Low Maintenance Gardening.																			X			X								
Holloway, Dennis. Winona Towards an Energy Conserving Community																							X	X						
AIA. Solar Heating and Cooling, Demo, Program Cycle 1 & Cycle 2	X			X																X	X	X	X		X	X				
Energy Con. Guidelines for Existing Office Bldg AIA Research Corp et al																			X			X	X	X	X					
Energy Con. Guidelines for New Office Bldgs AIA Research Corp, et al				X	X															X	X	X	X	X	X	X	X			
Minn Campus Long Range Dev Plan: Planning Framework																												X		

* See Appendices C & D

APPENDIX B - DATA ABSTRACTS

The AIA Research Corporation. Energy Conservation in Building Design. Washington, D.C.: The American Institute of Architects, 1974.

Climate
Orientation

Building
Configuration

Topography

Vegetation

This book is comprised of three main sections: physical design alternatives; alternative power sources and an appendix which includes a breakdown of energy consumption in the United States. The physical design alternatives section outlines areas of the building process where energy savings may be achieved and attempts to describe some of the trade-offs that must be considered in selecting one measure over another. A matrix of a buildings subsystems energy conservation potential (represented by a scale of one to ten, and shown to have a direct, indirect effect or no relationship) is plotted against physical design components, (eg. climate, building site, orientation, codes and standards, etc.). The magnitude of energy (high, medium and low) is also indicated. Each of the subsystems of a building site analysis, building orientation, configuration, heating, cooling, lighting, etc.) are further described. It is recommended that energy conservation techniques be used in addition to the traditional architectural design criteria (physical, aesthetic and social), not instead of these. Some statements made in the section discussing site analysis under the headings of design response, weather, sun, wind, topography, trees and site development are as follows:

- In the Northern Hemisphere, the north and west sides are most exposed to wind. Therefore, orient entrances and other openings away from the prevailing winds.
- Northern Hemisphere sunlight is most important on the southern side of a building, then on the eastern, western and northern, in that order.
- The overall shape of a building affects the amount of energy it will consume. A spherical, or round building has less surface, hence less heat gain or loss, than any other shape with an equal amount of volume. A square building has less surface than a rectangle of equal floor area and so uses less energy. Note: these latter two statements contradict Olgyay in Design with Climate.

The dimensions and shape of a site can impose a similar shape on a building design, which can be an advantage or a disadvantage. A rectangular building with a 2:5 length/width ratio absorbs considerably less solar heat if its long axis is aligned in an east-west instead of a north-south direction.

- Cool air tends to collect in low areas.
- Wind direction, velocities and pressures can be altered by hills, valleys, trees and adjacent buildings.
- Leaving the site exposed to absorb runoff. Also leads to energy savings. For example, not covering a site with a parking lot or building means less storm drainage and consequently less horsepower devoted to pumping water.

Soil quality
- The quality of soil, for vegetation growth, and subsoil is important for landscaping.

Vegetation
- Trees provide shade and deter wind.

Proximity
- The proximity to desired services and utilities for a building is important. eg., centralized electricity plants lose efficiency when energy must be delivered over long distance.

Materials coloration
- Light colored walls reflect, and dark colored walls absorb light.

Many other statements regarding energy consumption relating to the building's structure, in addition to the site planning factors, are also given.

esidential

The AIA Research Corportaion. Solar Dwelling Design Concepts. For the U.S. Department of Housing and Urban Development, Office of Policy Development and Research, Washington, D.C.: The AIA Research Corporation, May 1976.

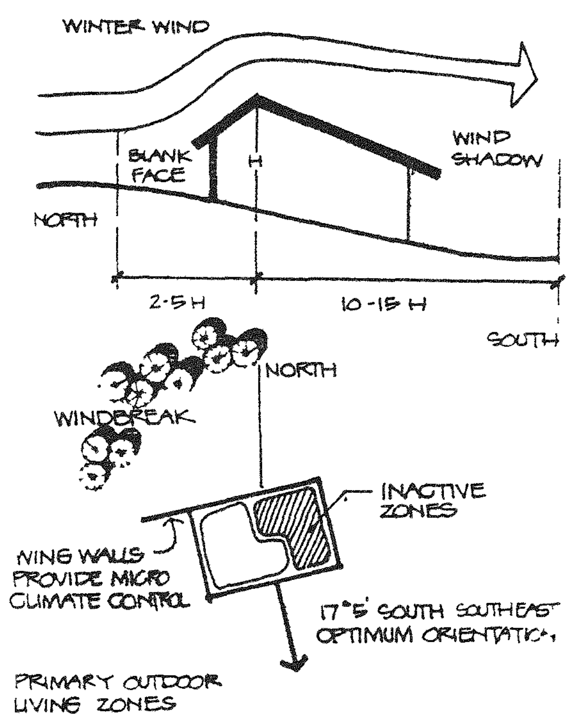
Orientation
Passive
Collector

Climatic zones

The objective of this book was to demonstrate the economic and technical feasibility of solar heating and cooling. In doing so, it reviews the basic principles of site planning such as orientation, position on slope and use of trees. The objectives of designing for each of the four major climate regions are discussed, illustrated and summarized in a chart. A site plan with accompanying notes is given, indicating the placement of buildings, streets and plantings in the hot, humid zone.

Adaptations

Also included in this chart are adaptations that can be made for each of the climatic zones. These are position on slope, orientation on slope, relation to water, preferred winds, clustering, building orientation, tree forms (deciduous and evergreens; and where best located) road orientation and materials coloration.



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Cool region

American Society of Landscape Architects Foundation. Landscape Planning for Energy Conservation. Reston, Virginia: Environmental Design Press, c. 1977.

A good review of the natural elements of site planning and design and their implications for energy conservation. First, the overall macroregional climatic conditions are presented, then the climatic impact of landforms and vegetation, their combined effects and water are discussed. These principles are then used to support the remaining body of material which details measures for maximum solar utilization at the site planning and design phases. These are also summarized. Finally, case studies are given applying these principles to the four major climatic regions of the U.S. (cool, temperate, hot humid, hot arid). The specific information presented on the natural elements includes windflows, air flow patterns, shelterbelts, seasonal variation of trees, types of ground cover, slope orientation, solar angles, earthforms, walls etc. Site analysis, site selection siting and orientation, building site integration and selection and use of natural and man-made materials are also discussed. All of the above information is described and supported with extensive graphics in the form of charts, graphics, plans, elevations, sections, details and perspectives. This book represents an exhaustive search of the literature (from studies done in the early 1950's on human comfort to, and including the 1970's), on natural factors affecting site planning and design.

Climatic Zones

Site selection

Site Analysis

Dodds, Douglas. Energy Conservation: An Introductory Guide for Local Government. Berkeley, California: Department of City and Regional Planning, June, 1977.

The material discussed in this report is divided into two parts. The first part covers energy conservation in municipal operations, ie., the role of administrative policies, employee programs, carpool and transportation programs, vehicle fleet management and building design and retrofiting. The second part discusses building codes, community retrofit programs, land use regulation and neighborhood design and community education programs as a means for the potential refuction of energy consumption. Building codes are discussed in relation to those ordinances adopted in Davis, California. The ordinance sets forth minimum performance standards

Neighborhood design

Life Cycle Cost

Davis Energy Conservation Ordinance

Residential
Retrofit
Prescriptive
Performance
Standards

Building
Codes

Land Use
Regulation

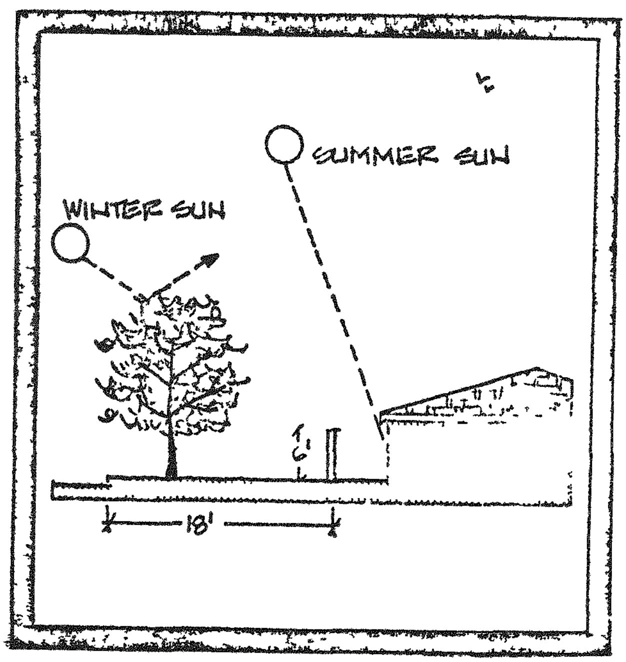
Street design

Vegetation shading

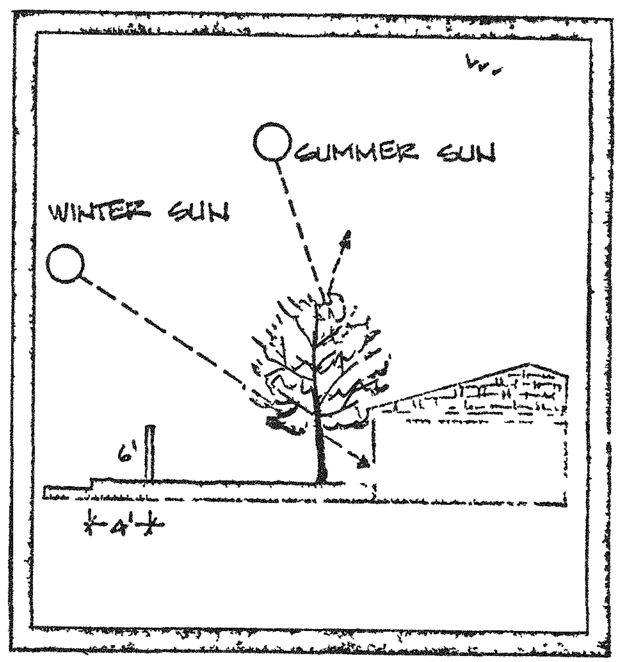
Street Costs

for heat loss in the winter and heat gain in the summer, but allows two methods of compliance, a prescriptive method and a performance method. The prescriptive method requires specific actions to be taken to meet the minimum standards for heat gain and heat loss (eg. window shading and reduced window area) whereas the performance method allows flexibility in achieving these standards. Similar ordinances have been passed by the city of Indio and Sacramento County. The actions of the local government in energy conservation through land use regulation were identified as follows: clustering, lot size reduction, provision of centers of mixed activity to allow proximity to employment, higher densities, solar access (height restriction, controls on vegetation including removal of those interfering with solar collector, mandatory solar-air space easements, optimum orientation), street widths, planting more mature trees in new subdivisions, tree planting in existing developments, shade trees in private and public parking lots and flexibility in use of surfacing in parked lots (eg., gravel, turf blocks, cement). A break-down of the costs of existing wide streets (26' - 0") versus proposed narrow streets (16' - 0") is given.

FENCES



EXISTING



PROPOSED

Harwood, Corbin Crew. *Using Land to Save Energy.* Cambridge, Massachusetts: Ballinger Publishing Company, 1977.

Policies

Land Use

Regulation

Land Use Planning

Space Heating and Cooling

Transportation

Construction Cost

Zoning

Clustering

Standards

PUD's

Developer Incentives

Legislation

An identification of energy-efficient land development patternsthat land use policies should promote. Discussions of modifications in state and local regulations, spending and taxing policies to promote energy efficient land use. Emphasis is on measures to save energy in new developments versus energy savings associated with land use planning, and design in the areas of transportation, space heating and cooling and construction costs. The strategies for transportation energy savings are identified as to the amount (large, lessor, small) and implementation ease (difficult or easy). The land use policies best able to reduce transportation energy demand..would promote moderately high density, contiguous development with mixed residential and employment opportunities, which would be served by public transportation. Promoting the construction of low-rise and small high-rise multifamily buildings and taking advantage of the natural environment are strategies for reducing heating and cooling cost. Goals for reducing construction cost include the elimination of wasteful construction practices associated with haphazard growth, eg., unnecessarily wide streets, excessive grading, leapfrog, or non-contiguous development. These are indirect costs which involve the fuel for operating and maintaining construction equipment as well as the cost of materials used. Some examples of energy savings in terms of studies are given for each major energy consumer mentioned above. The greatest value of this book is that it identifies what policies can be implemented at the local and state levels to achieve these strategies. Comprehensive land use planning, zoning, clustering, energy efficient standards, PUD s and incentives to developers are discussed. The first part of the appendix covers legal issues raised as a result of implementation of energy conserving techniques, and the second part provides selections of legislation, both adopted and proposed, in regard to energy conservation.

Residential

Hastings, S. Robert and Richard W. Crenshaw, <u>Window Design Strategies to Conserve Energy</u>. NBS Building Science Series 104, Washington, D.C.: Architectural Research Section Center for Building Technology, Institute for Applied Technology, National Bureau of Standards, June 1977.

Windbreaks

Deciduous Trees
Ground Surfaces (material type)
Orientation

Shading Devices

A report on strategies to make windows energy conserving, including site strategies. An explanation of the principles of each strategy is followed by a list summarizing the energy and non-energy advantages and disadvantages. An extensive list indicates measurements and cost savings as evidenced from various studies for each of the modifications that can be made for energy savings. Under the site strategies, windbreaks, shade trees, ground surfaces, orientation to sun and wind are discussed and in some cases described graphically. Energy savings in percents of fuel consumption, energy requirements, air infiltration, etc., and sometimes cost savings are given for varying conditions of wind, deciduous trees, ground surfaces, orientation, and external shading devices.

Human Comfort

<u>House Beautiful</u>. "Climate Control Project" A series of monthly articles on climate controlled houses, October 1949 to January 1951.

Climatic Zones

An extensive study carried out in the late forties and early fifties by a group of scientists and the editors of <u>House Beautiful</u> on how climate can be controlled for comfort performance in the various climatic regions of continental U.S. Many of the various principles and concepts of landscape planning were discussed. These included: site selection at the gross level (the selection of one site

Building integration

SUMMER TEMP	FEET ABOVE GROUND	WINTER TEMP
82 F	10	[illegible]
84	8'	[illegible]
85°	6'	[illegible]
87°	4'	26°
90°	2'	24°
GROUND LEVEL		
59	2'	[illegible]
58	4	38°
56	[illegible]	42°
55°	8	41°
54	10	[illegible]
	FEET BELOW GROUND	

Aug 50, p 92

over another), site selection at the discrete level (the location of the building on the site), site selection at the activity level (the location of vegetation, terraces, driveways, etc.) and site building integration.

Vegetation

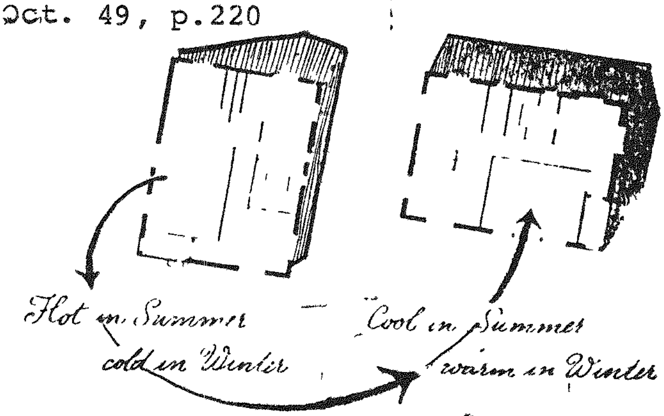
Shades
Overhangs
Climatic Regions
hot
cool
humid
dry

The uses of the various natural elements (trees, shrubs, hedges, turf) and man-made elements (exterior shades and overhangs) and their climate controlling effects were discussed with accompanying diagrams. Each of the climatic regions were described (eg., hot cool, humid, dry), and guidelines and recommendations were given as to how these conditions could be ameliorated. The list of landscape planning and design principles included the following:

South Slopes
Position on Slope
Material
Overhangs

south slopes are warmer than north slopes, overhangs on the south side of the house shades the window from the hot summer sun, but allows the winter sun in, the bottom of a valley is cooler than a slope, the more humid an area the more breeze that is needed, white material reflects--black absorbs, the west is hotter than the south side of a house.

Oct. 49, p.220



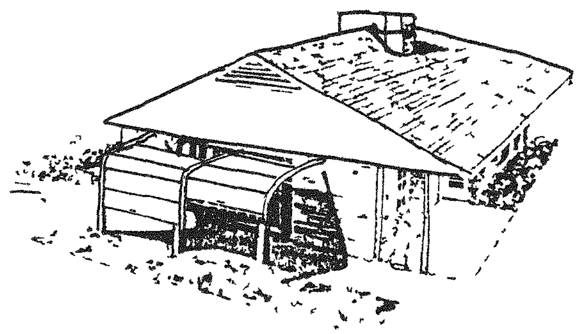
Orientation

Here, Architect Henry Wright shows how you can improve a house by merely turning an existing floor plan around, and putting bigger windows on south side. He uses one simple idea: Hottest sun in summer is afternoon sun; it shines from the west. Warmest sun in winter is noon sun; it shines from the south. Living room switched from west to south becomes cooler in summer, warmer in winter.

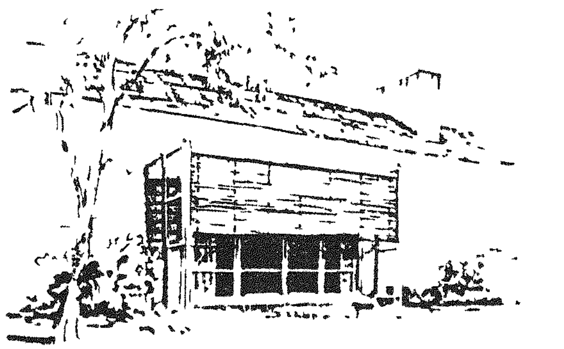
Basic conclusions were recommendations for manipulating the given climatic conditions in each region for optimal human comfort. Many of the basic principles and conclusions reached in this study were used repetitively in successive studies dealing with climate modification and energy conservation.

WAYS TO SHADE--WEST WINDOWS

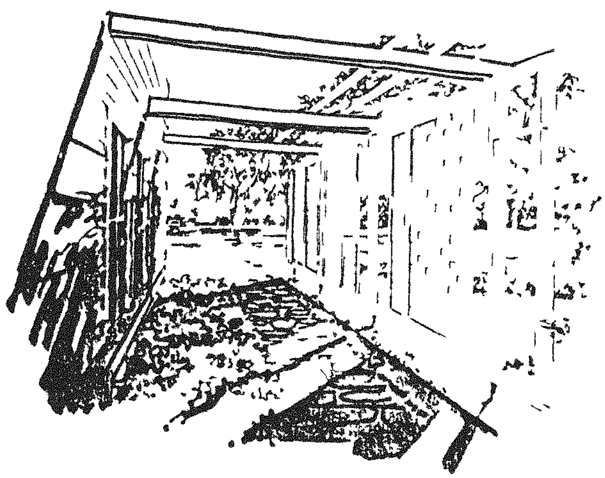
Western sun is horizontal sun. You need obstruction in front of, not over, your windows. This gives both.



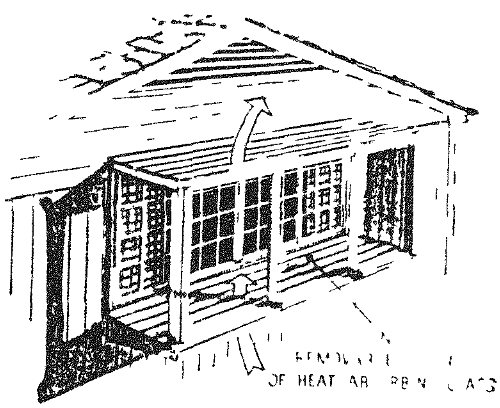
Roll up porch shade on a trelli-like frame out in front of window, doesn't block ventilation.



Sliding garden screens push out of way into small "bundle" all day, slide to work in late afternoon.



Use heat-absorbing glass as a shade for regular window to keep it cool, with air wash behind it.



(House Beautiful)

Leckie, Jim, et al. Other Homes and Garbage: Designs for Self-Sufficient Living. San Francisco: Sierra Club Books, 1975.

The first section of this book discussed site determinants and climatic factors in house design. Site determinants (subsurface characteristics, topography, surface water, vegetation and man-made characteristics), are discussed in terms of their effects in minimizing energy requirements for homes and maximizing human comfort. Some statements made are as follows:

Soils	- Adverse soil composition or water tables near the ground surface may prohibit building or limit buildable area.
Topography	- Excavation may be limited or eliminated entirely because of the presence of subsurface rock.
Slopes	- Building on steep slopes, above 10 percent is more difficult and consumes more material, time and money than building on flatter slopes.
	- Southern slopes are warmer in winter.
Hill crest	- Hill crest, where wind velocities are increased should be avoided, except in hot,humid climates.
Water Bodies	- Bodies of water have the ability to absorb heat during warm periods and release it during cold periods.
Clustering	- Clustering of housing units, both horizontally and vertically, also reduces exposed surface areas of walls and roofs.
Building Site Integration	- Any shelter sunk into the earth is cheaply insulated. About 30 inches or packed, dry earth is equivalent to one inch of urethane, but a lot cheaper.
Vegetation	- Vegetation can provide shade, reduce glare and serve as windbreaks.
Overhangs	- Shading can be provided by deciduous trees, overhangs, deciduous vine arbor and horizontal shading devices. Houses can also be clustered to provide shading.

Also discussed are other topics relating to energy such as generation of electricity from renewable energy sources, solar heating, waste-handling systems, water supply, agriculture and aquaculture.

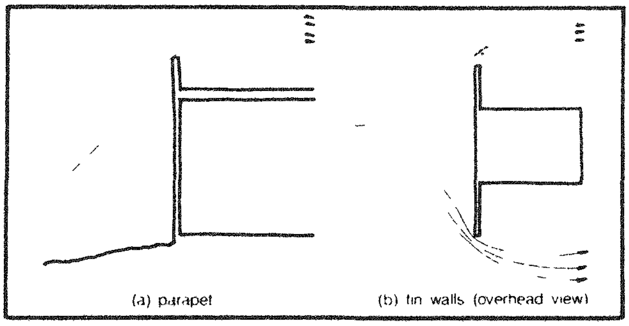


Figure 2.31 Windbreaks integrated into house construction.

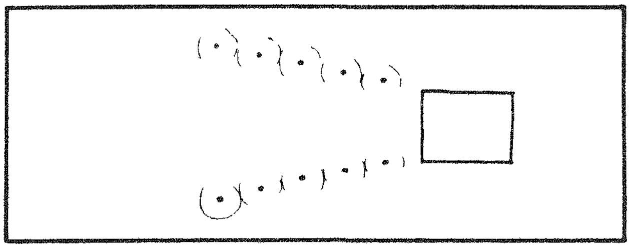


Figure 2.32 Channeling wind by trees

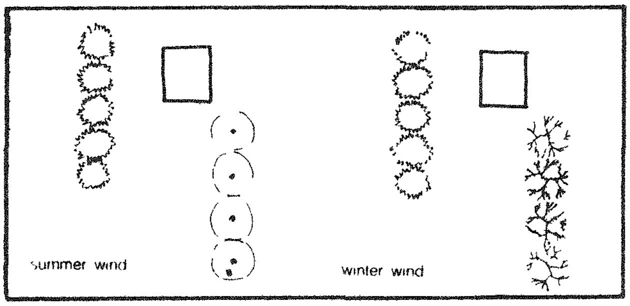


Figure 2.33 Channeling summer and winter winds from the same direction.

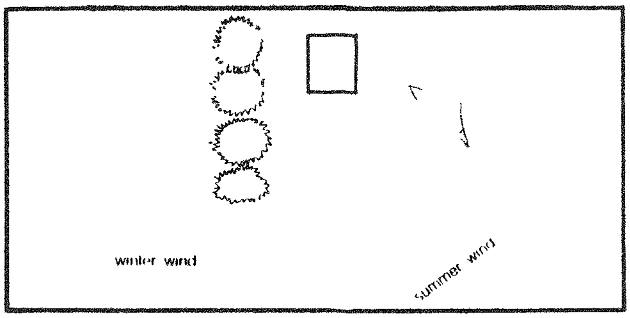


Figure 2.34 Channeling summer and winter winds from different directions

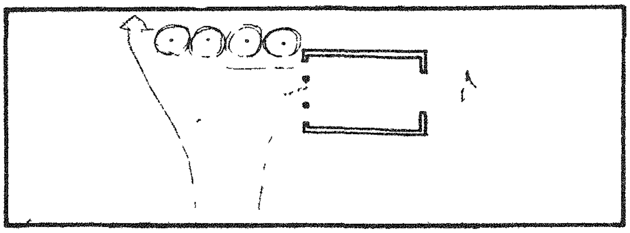


Figure 2.35 The deflection of summer winds into a house

(Leckie, et al)

Living Systems. Energy Conservation Advisory Program. A report prepared for City Council, City of Davis, California. Sponsored by HUD, Washington, D.C., June 1976.

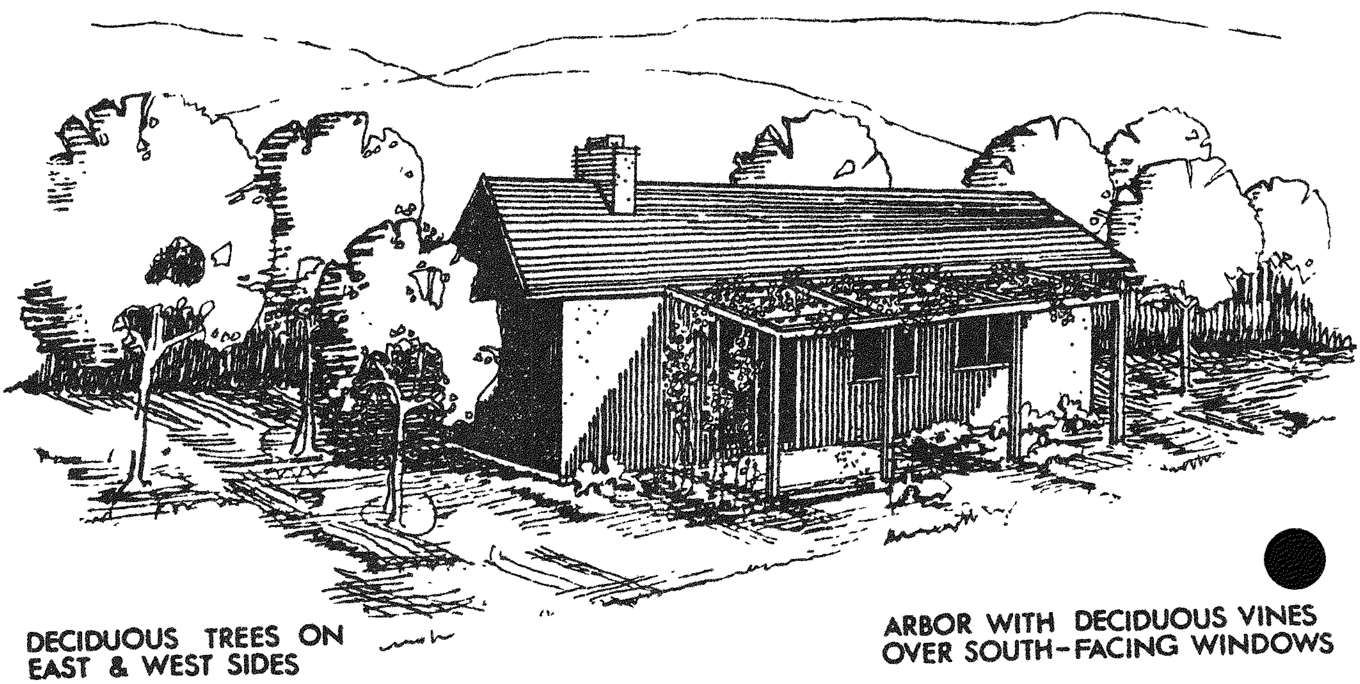
This report was initiated to test the performance and reliability of the Davis Code. Four different household types in Davis were monitored to determine the energy needs for each--for heating and cooling, and household appliances. The winters heat loss and the summers heat gain in walls, roof, doors, floors and windows were calculated. Then specific recommendations for retrofitting were given for each household. These included weather stripping, floor and attic insulation, landscaping, (use of deciduous arbor) and shading devices. For one household, initial cost was given and for the first three retrofitting measures, cost/benefit analysis for 1976 and estimated savings in 1981 was also given. These case studies were discussed to give examples of what residents can do to improve the energy efficiency of their dwellings.

Deciduous Arbor/ Exterior Shading

Living Systems and the City of Davis. Davis Retrofit Manual. Davis, California: no publisher given, June 1, 1976.

This manual briefly describes ways of reducing energy consumption in existing houses through the use of insulating, weatherstripping and exterior shading devices. Cost savings are given for a typical Davis home by shading the windows. An arbor with deciduous vines is recommended for the south-facing windows. The material is presented in a manner to be easily understood by the layman.

Shading Devices Cost Savings



Living Systems and the Department of Planning and Development. <u>Indio, California: Energy Conservation Project</u>. Indio, California: City of Indio, March 16, 1977.

Transportation
Street Design
Building De-
Land Use Land-
scaping
Resolutions/
Ordinances
Cost Savings

Administrative
Tools:
- general plan
- zoning
- environmental
impact review

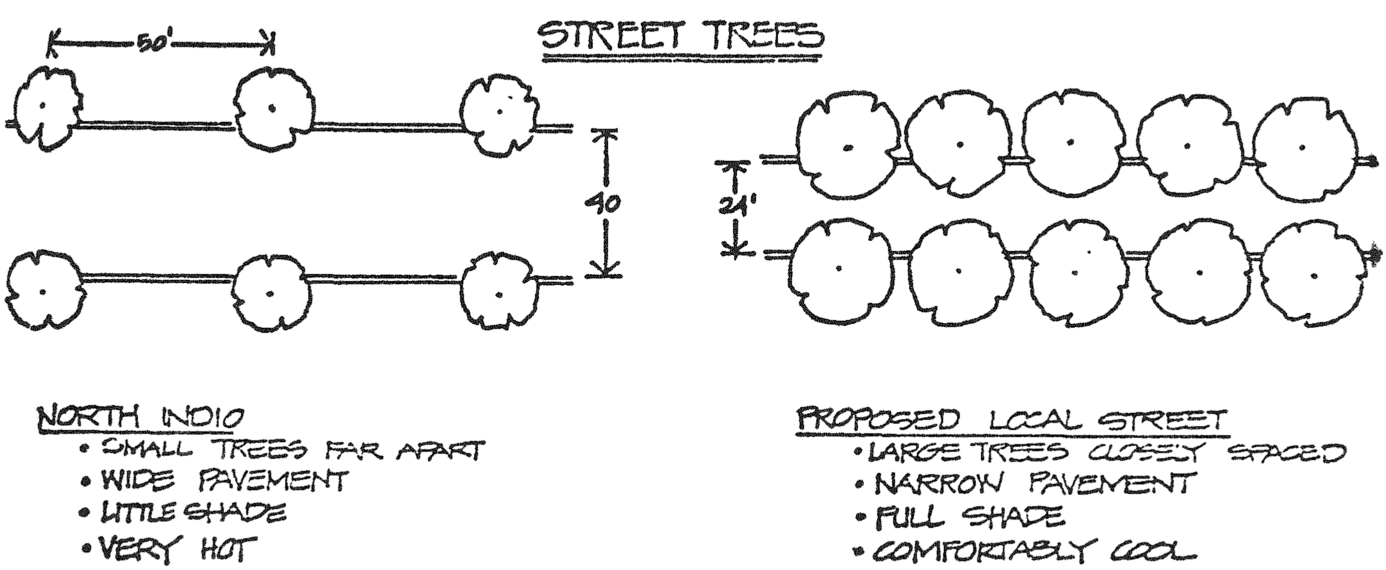
Building Codes
Subdivision Impact
Physical Tech-
niques

treet Design

Climate Control
Orientation
Thermal Mass
Water Ponding

Cost Comparison

The contents of this Final Draft Report includes energy conservation measures in the areas of transportation, street design, building design, land use and landscaping (of streets, parking lots and buildings). For each of the above, ordinances/resolutions are also listed. Measures (cost savings) are dispersed throughout the study project. Administrative tools proposed to encourage energy conservation include a general plan (outlining goals, objectives and policies of the city as they relate to the use of energy and the physical development of the city), zoning, environmental impact review, building codes (requiring energy conservation, building standards and performance standards for all new residential construction) and subdivision map act (requiring developers to bring uniformity to subdivision development, and conformance and consistency to general and specific plans.) Physical techniques to encourage energy conservation were discussed as: energy conservation , site planning, (eg., reduced lot width and size), street design (reduced street widths), environmental review, energy building code (eg., building height, shading). Climate control through orientation, thermal mass and water ponding are discussed. A checklist has been developed by the City of Indio under the environmental impact report, which includes the areas mentioned above i.e., transportation, building design, land use and landscaping. Each of these are summarized in more detial. For example, a cost-comparison for wide versus narrow streets is given along with all cost associated with the construction and maintenance of streets. Energy conservation in the area of lighting is also discussed.



Lynch, Kevin. Site Planning, second edition. Cambridge, Massachusetts: The M.I.T. Press, c. 1971

Site Planning
Site Selection

Site Analysis

- topography
- soils
- water
- climate
- microclimate
- vegetation
- man-made structures

Costs
- site improvement
- construction
- maintenance

Because the intention of this book was to introduce the art of site planning by way of identifying its principles and relevant technical information, it naturally included information relevent to energy conservation in site planning and design. Natural factors such as topography (slopes, cold air pockets, etc.) soils (plant medium, stability, bedrock depth, water (availability, drainage, quality), climate (wind direction, precipitaiton, humidity, etc.), microclimate (local breeze, shade, etc.), and vegetation were discussed in terms of site improvement cost (usually associated with construction costs) and maintenance costs. Man-made structures (existing buildings, circulation facilities and utilities) were also discussed. These factors formed the basis for the site planning phases of site selection and analysis. A checklist of site data as well as a typical cost breakdown of site preparation and earthwork, roads, walks paving and utilities are included.

NAHB. The Builders Guide to Energy Conservation. Washington, D.C.: National Association of Home Builders of the United States, c. 1974.

Site Selection
- proximity

Land Use Planning
- high densities
- contiguous development
- proximity to recreation, shopping, etc.
- public transportation

This manual was written to inform the builder of the relative effectiveness of alternative methods of energy conservation in the home. Much of the material presented deals with the structure of the building itself (e.g., insulation, shape of house, building mass, light, type of glazing, weatherstripping, mechanical heating and cooling devices, etc.) There is mention of factors to consider in site selection (accessibility to roads and utilities, proximity to church, schools and shopping centers, topographic factors and drainage patterns) and orientation for solar radiation, but these are not discussed in any length. The significance of land use planning as a long range approach to energy conservation is identified as: new developments planned with: higher densities than the traditional suburbs, located in bypassed sites (open spaces passed over), and convenient access to recreation and shopping centers and to public transportation. Utilities can then be grouped. Higher densities would imply that zoning policies must become more flexible and less restrictive in order to allow the cluser and planned unit developments. These layouts are energy conscious in that they allow for shorter streets and utility systems, serving more residences with a corresponding reduction in installation and maintenance cost. On site shopping, with convenient paths, reduce the use of the auto for short trips.

McCullough, Sandra G., Mary S. Harnan and Kim J. Gillan. A Handbook of Considerations for the Environmental Review Process. Prepared for the Southern Tier East Regional Development Board and Broom County Environmental Management Council, New York, June 1977.

Soil
Slopes
Vegetation

Planned
Development
Regulations

The purpose of this book was to provide participants in the land development process, a framework by which environmental criteria can be incorporated into the decision-making process for industrial and commercial and residential development. Of the major environmental components (land, air, water, and noise) treated, the land considerations have implications for energy conservation for site planning and design. This section includes discussions on natural factors (soil, slope and vegetation) and man-made factors (site design and transportation.) Each factor is organized into principles, their implications for development cost and further source of information. Some of the limitations posed by these factors are: type of soil effects; drainage, stability, suitability for vegetation bearing capacity; slopes effect erosion potential, lateral stability of soil, drainage conditions and runoff conditions as well as amount of construction cost; vegetation effects, soil stabilization runoffs control, erosion control, water quality, local weather patterns, etc. The advantages of planned development over sprawl are discussed in the site design section. Land use regulations such as master plan, zoning, subdivision and housing and building codes are mentioned.

Olgyay, Victor. Design with Climate: Bioclimatic Approach to Architectural Regionalism. Princeton, New Jersey: Princeton University Press, c. 1963.

Climatic
Region
- cool
- temperate
- hot humid
- hot arid

This book presents a thorough investigation of the effects of climatic influences (temperature, humidity, radiation and wind) on buildings in the four major climatic regions (cool, temperate, hot humid, hot dry.) Each of the four regions in analyzed in terms of the general weather conditions, their

Microclimatic Effects Adaptation Shading Devices

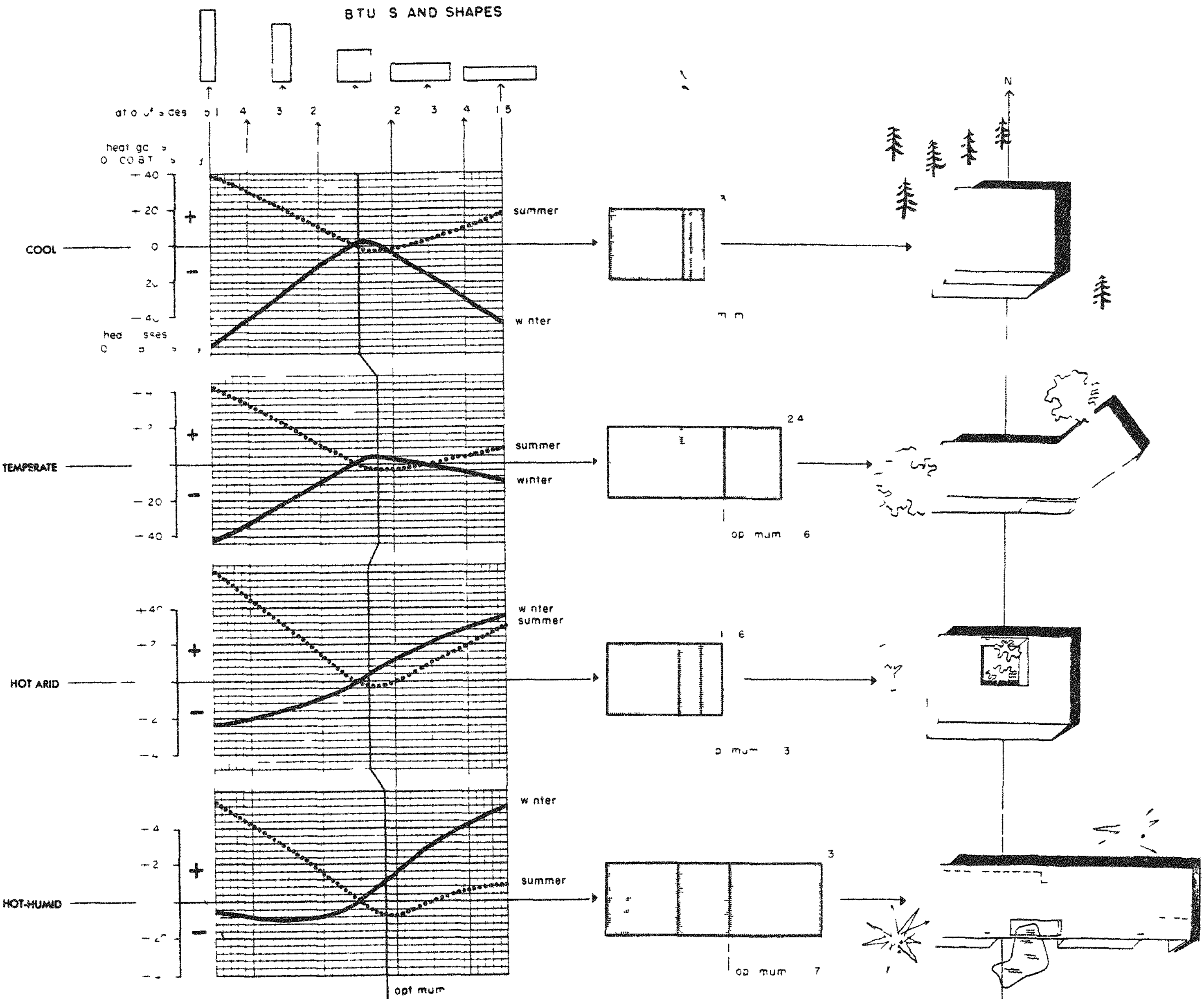
Site Selection Orientation

Air Movement

Town Layout

significance and requirements. Then specific data of direct applicability and recommendations is given for each region in terms of housing layout, building design and building elements. Also included are such factors as site selection, orientation, location on slope, use of vegetation, and use of overhangs and shading devices. The conclusions reached regarding site planning and design in the four regions are summarized as follows: the cool zone requires protected sites, so location about half-way up a slope and 12° east of south (Minneapolis, Minnesota) is ideal; the temperate zone must meet needs for both underheated and overheated periods, so lower hillside locations with an orientation of $17^\circ5'$ east of south (New York/New Jersey area) is preferred, the hot arid zone (Phoenix, Arizona) requires lower hillside locations for cool air flow with an orientation 25° east of south, the hot humid zone is best located near the crest of a hill on the windward side for wind flow effects and an orientation of 5° east of south (Miami, Florida.) All of this information and the material on vegetation and shading devices and overhangs is substantiated by extensive studies, diagrams, charts, and illustrations, many of which were carried out by the author. These include the basic principles of solar, humidity, wind and precipitation, topography, water bodies, vegetation, etc. Objectives are also presented for town layout for each of the climatic zones. Although the material was presented in this book for adaptation of buildings to the environment to create human comfort, it is also relevant to energy conservation in environmental planning and design. Its value is evidenced by the fact that many of the basic principles described and the conclusions reached have been used repeatedly by other authors dealing with similar subject contents.

Building Form

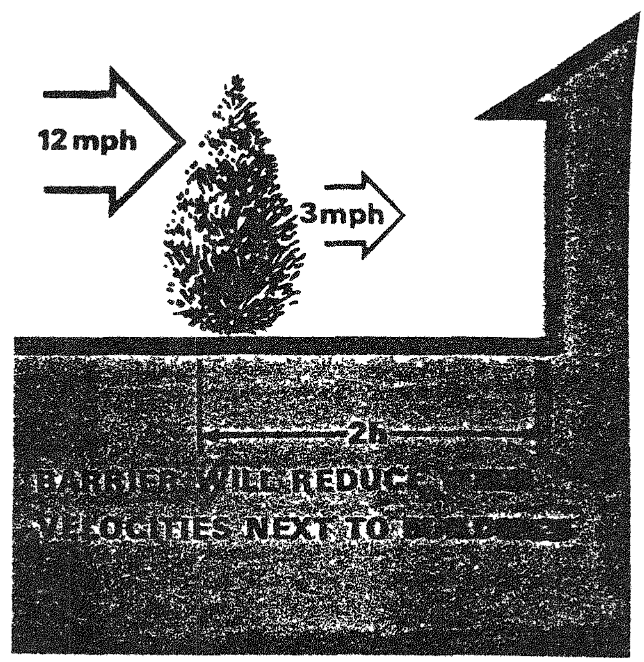


174. Basic forms and building shapes in different regions

Robinette, Gary O., Plants, People and Environmental Quality. Washington, D.C.: U.S. Department of the Interior, 1972.

Vegetation
Radiation Control
Erosion Control
Wind Control

A review of the uses of plant materials which includes climate control. Information is organized into the following uses: architectural (for screening, privacy control, etc.); engineering (erosion control, atmospheric purification, glare and reflection control, etc.) climatological (solar radiation, wind, precipitation and temperature controls) and aesthetic. The areas which have implications for energy conservation include the engineering and coimatological uses of plants. Plants control temperature, air flow and moisture content as well as controlling wind and water erosion. These uses are fully described and illustrated. The amounts in measurements of degrees of cooling and miles per hour and percents in wind reductions are given. Use of plants to block the wind, various species and their shadow patterns for desired radiation control are also discussed.



Wells, Malcolm, Underground Designs. Cherry Hill, New Jersey: no publisher indicated, 1977.

Site/building Integration

This book deals exclusively with the design of underground structure for varying uses (residences, offices, institutions, etc.) for minimizing full cost and development impacts on the land. Here are alternatives to traditional structures. It is a graphic compilation of plans, perspectives and sections of designs for underground structures. Many of these structures have been built, some are proposed. All were designed by Malcolm Wells. These structures reflect one type of response to adverse environmental conditions.

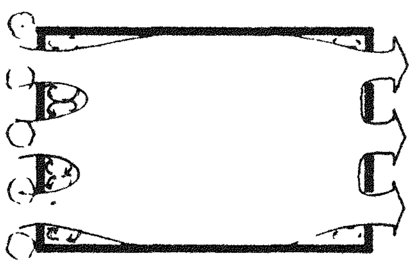
Air Movement

White, Robert F., Effects of Landscape Developm on the Natural Ventilation of Buildings and Their Adjacent Areas. Research report 45. College Station, Texas. Texas Engineering Experiment Station, The Texas A & M University System, 1954. Reprint, October 1975.

Human Comfort

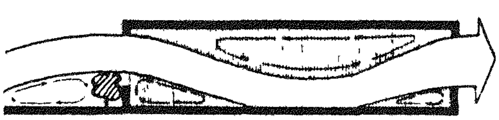
Natural Elements

This study was concerned with the effects of the natural landscape design elements such as trees, shrubs and hedges, upon the air movement within a building. More specifically, it dealt with the methods of making desirable breeze work toward increasing human comfort (rather than dealing with use of a shelter belt or wind barrier to reduce the cool winter winds.) It discusses each of these elements and various combinations and their arrangements (positions in distance) to building and the air movements the various positions create.



PLAN
SHRUBS 5 FEET ON CENTER

Variables, in addition to the distance of these elements, and various combinations, to a building (0', 5', 10', 20') are included; their heights, their relation to the buildings air inlet openings and two types of deciduous trees. Measurements of air movement effects were given in wind speeds at varying heights above the ground. Air movement patterns were also diagramed.



AT BUILDING

Figure 14.
MEDIUM SHRUB

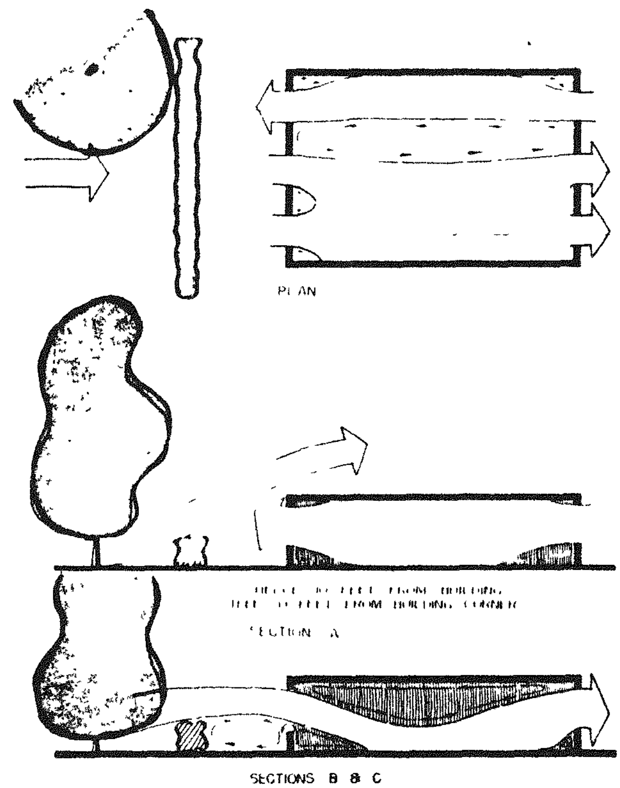
Most of the tests made were done so with the use of models. Then field tests were made to support the conclusions of the model tests. Models were used for testing the air movements, the validity of which was proved in earlier Research Reports. The evidence of the various tests carried out concluded the following:

AT BUILDING

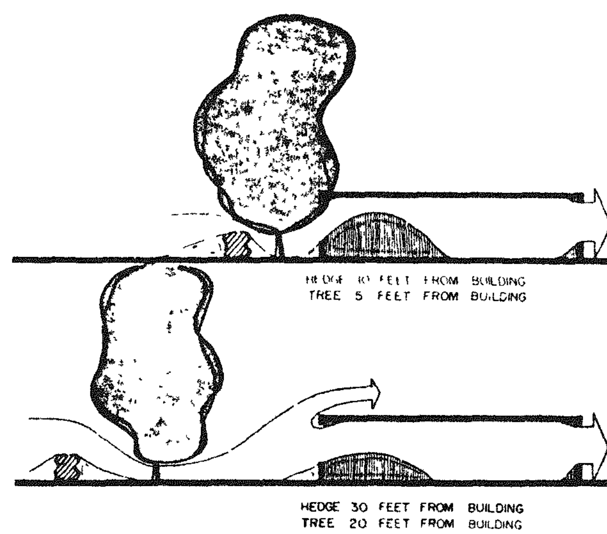
HIGH SHRUB

P. :

"1. Planting can materially affect the movement of air through and about buildings.
2. Depending on the way it is used, planting may either augment or reduce the natural air flow through the building.
3. Planting may cause actual change of direction of air flow within the building.
4. Planting on the lee side of buildings has little or no affect on the movement of air through the building unless it is in such a position that it obstructs the outlet openings."



Figures 28, 29, and 30.



Figures 31 and 32. (WHITE)

Hedge-Building Combination

Whittmus, Waldemar Albert. The Effect of Trees & Wind as Related to Drifting Snow. A thesis. Wisconsin: University of Wisconsin, 1940.

Vegetation for Controlling Snow

This thesis in one of the earlier studies carried out which deals with ameliorating existing conditions caused by snow. It first describes and reviews the results of similar research studies concerned with controlling snow. These included use use of various fences (horizontal slot, vertical slot and solid); planting methods in use by transportation departments and use of various types of vegetation. Their results were recorded in terms of their effectiveness in controlling snow and the snow patterns created. Some of the general conclusions reached: the greater the height of a barrier, the greater the area affected by it; in multiple row hedges, trees perform the function of a trap, as well as a barrier; and a single row barrier is not very effective.

Although the only mention of this study to energy conservation was indirectly stated as lessening the hazardous impact of snow on highway travel, related costs can be inferred, such as decreasing cost of maintenance in snow removal, salting and sanding, ect.

Energy Conservation Design Guidelines For New Office Buildings. 2nd edition, AIA Research Corporation, Dublin-Mindell-Bloome Associates, P.C., Heery and Heery, Architects. General Services Administration/Public Buildings Service, 1974.

Site Selection
- topography
- water bodies
- man-made features

Climate Modification
- orientation
- building/site integration
- berming
- vegetation shading
- windbreaks
- use of materials
- exterior shading devices
- town layout
- building configuration

Computers

Macroclimate

The guidelines presented in this book for optimum energy conservation in new office buildings, cover design principles and criteria for site selection and climate modification. Many of the methods presented have been applied to an office building in Manchester, N.H. This is perhaps the most comprehensive book which exists dealing with energy conservation in new office buildings, however, the information on site selection is rather vague--mentioning only factors of topography, water bodies and man-made features, (proximity to public transportation systems.) The material dealing with modifying adverse climate conditions is much more extensive and includes: orientation, building/site integration; berming; vegetation shading; windbreaks; use of materials (light versus dark); exterior shading devices; town layout, (staggering buildings and building configuration. Also, information on energy conserving techniques, involving the building itself, is also included. A list of individuals/organizations associated with the use of computers as an energy conservation design tool is given. Prior to radiation charts for various cities in the United States, (representing various latitudes) ie. temperature and the average monthly total radiation (in BTU's) on a horizontal surface. The above guidelines (techniques for improving energy efficiency) for new office buildings are summarized in a chart towards the back of the book and are identified for various cities in the United States.

<u>Energy Conservation Design Guidelines For Existing Office Buildings</u>. AIA Research Corporation, Dublin-Mindell-Bloome Associates, P.C., Heery and Heery, Architects. General Services Administration/Public Buildings Service, 1974.

Climate Modification

Vegetation Shading
Exterior Shading Devices
Overhangs
Materials

Climatic Zones

This book evaluates existing office buildings for reducing energy usage. The material covers both energy conserving techniques related to the structure of the building and to the site. Since existing office buildings have already established the major determinants (eg., site location and orientation) in the buildings design, the information in this book concentrates on ameliorating the unfavorable conditions such as excessive thermal transmittance through glazing and heat radiation from adjacent pavements. The methodology involves first the identification of these unfavorable conditions, then a discussion of the means to lessen these problems. Information relevant to climate modification is arranged under the headings of site and building. Information relevant to the building itself can also be found under these headings as well as headings of lighting, power, HVAC, plumbing, veritcal transportation, solid waste and operation and maintenance. Issues covered under buildings and site include: shading walls and paved areas, using deciduous trees and exterior shading devices (grills, fins, screens, louvered solar screens); vines and overhangs; planting shrubs or lawns between buildings and sidewalks; using ponds and water features to reduce ambient outdoor temperature around buildings; using light colors to minimize, etc. All of these efforts to improve energy efficiency of buildings are presented towards the back of the book, and are identified for particular cities (representing various climatic zones) in the United States.

AIA Research Corporation. Solar Heating and Cooling Demonstration Program. Cycle 1 and Cycle 2 funded by the Department of Housing and Urban Development. Washington, D.C.: U.S. Government Printing Office, July, 1976 and Fall 1976.

Climate Analysis
- cool
- temperate
- hot arid
- hot humid

Housing Types

Climate Modification
- overhangs
- orientation
- shading devices
- vegetation (shading)
- windbreaks
- earth berming
- clustering
- activity location

Site Selection
- south slope

Although the purpose of this publication was to demonstrate solar heating and cooling systems in selected residential structures throughout the U.S., it also contains information relevant to climate modification of the site. For each project, (residential structure) the builder, designers, location, housing type (eg. single family detached, row units, low-rise multi-family, single family attached): climatic data (degree days for heating and cooling expressed in hours; average temperature in winter and summer and horizontal solar insolation; building description and solar energy system is described. The climatic data provides the necessary analysis for the solution provided in building description. Climate modification measures include: extended overhangs; south orientation (for the majority of windows); shading devices (awnings, sunscreens, shutters); deciduous trees for shading; earth berms; clustering of buildings; windbreaks; location of garage on the northwest to act as a thermal buffer; and north-south sloping site (to maximize area of above grade southern exposures and minimize square footage of northern face exposure.) A list of terms and definitions and climatic maps of the United States are contained at the end of Cycle 2, (a continuation of volume 1, Cycle 1.)

Holloway, Dennis, Project Director. Winona: Towards an Energy Conserving Community. Minneapolis, Minnesota: University of Minnesota, School of Architecture and Landscape Architecture, c.1975.

Transportation Reduction

Shelterbelts

This book consists of a series of essays discussing the application of energy conserving techniques to the existing community of Winona, Minnesota. Each of the ideas proposed are aimed at the neighborhood level by focusing on a particular section of the city. Most of these advocate a complete self-sufficient community for Winona, and address such topics as: reduction of auto and recreation vehicles; retrofitting; food production; active solar collectors and wind power; trees planted in shelterbelts to give protection from winter winds and summer heat and a revitalization of the Central Business District. The limitations of this book lie in the fact that these are only proposals which are only briefly discussed (a more thorough and comprehensive investigation would be necessary before any implementation of these ideas), yet the concern for energy conservation by the community is a start in the right direction.

Sunset editors. <u>Low Maintenance Gardening</u>, Menlo Park, California: Lane Books, c.1974.

Vegetation

The main emphasis of this book is on identifying the type and use of vegetation for low maintenance gardening. Numerous residential lots are diagrammed, the problems cited and the solution given. The residential lots vary in shape from the typical rectangular, to the corner lot, to pie-shaped, and lots on hillsides. For each lot shape, examples and solutions are given for various parts of the country. Within these examples are other energy conserving techniques such as using a trellis to control the sun, and using paved surfaces to minimize lawn upkeep--although these are not discussed in any detail. A list of plants requiring low maintenance (eg. drought resistant, minimum litter, disease resistant) and their planting requirements are given for the hardiness zones in the United States.

Shading Device
Paving

Goldberg, Philip. Planning with Energy. Philadelphia, Pennsylvania: Rahenkamp, Sachs, Wells & Associates, Inc., January, 1975.

Site Development

Existing Vegetation for Windbreaks
Site Preparation
Clustering
Street Design
Mixed Land Use
Natural Drainage Swalls
Contour Clustering
Stock Piling

This report reviews the application of energy conserving techniques in the site development phase for four residential projects. The implications for cost savings are quite extensive. Some of these include: keeping existing natural vegetation to buffer buildings from temperature extremes and reduce clearing and landscaping cost; clustering of buildings to reduce the number of exterior heat-losing surfaces, minimizing road network for a savings in materials and construction; substituting natural drainage swabs for curbs and gutters; mixing various housing types, commercial, recreational and industrial to reduce transportation demands, minimizing impervious ground cover to allow a maximum amount of open space available to absorb storm water runoff; clustering buildings in a linear fashion parallel to topographic contours to reduce cut and fill and end wall construction; stockpiling excess dirt excavated during construction to create a less monotonous land form at minimal cost; and aligning roads along contours to reduce grading. These specific energy conserving measures were mentioned for the particular project they were utilized in. Some cost savings were indicated and many implications were stated.

NAHB. Land Development Manual

Site Factors
- topography
- hydrology
- soils
- vegetation
- man-made features
- legal controls

Site Selection
Site Analysis

Site Development
- grading
- clearing
- landscaping

Cost Savings

A thorough review of the basic principles and criteria for land development--the factors of a site and their cost implications are discussed for both site selection and analysis phases, and for site development. The list of site factors (environmental design considerations) is comprehensive and includes topography (flat and steep slopes) utilities, transportation networks, legal controls, vegetation, water courses, (the water table, drainage patterns and flood plains) soil conditions, and off site conditions such as adjacent land-use; airports and industries. Some of the cost implications of these site factors discussed are grading, clearing and landscaping for site development. One example which can be cited is flat land versus steep slopes. Flat land might require larger storm and sanitary pipes (which cost more) whereas grades in excess of 15-20 percent might require expensive mass earth moving, compacted fills, subfoundations beneath homes, retaining walls, or a combination of these. (Other cost implications for flat versus steep slopes are also discussed.) The cost associated with the selection and development of a site are stated for the developer, since these are ultimately passed on to the home owner. Lower costs of site development will mean greater marketability. The value of this book lies in its thorough examination of a sites factors and their implications for site selection and design. The short comings of this manual for energy conservation is the lack of material or insufficient discussions on those elements usually associated with climate modification for energy conservation (building site integration, orientation, vegetation shading, windbreaks, various man-made materials, exterior shading devices, etc.)

Living Systems and City of Davis Development Department. Building Inspection Division. Energy Conservation Building Code Workbook. Winters, California: Living Systems and City of Davis, California, July, 1976.

Ordinances
Shading
Perscriptive Method
Performance Method

This workbook contains examples of completing the necessary forms and meeting the performance standards for heat gain and loss (in BTU's per square foot of floor area.) For both the design and permit issuance stages of newly constructed residential structures, a prescriptive method and a performance method are the approaches a builder can use. The prescriptive method specifies the actual amount of unshaded glazing that is allowed in a structure, whereas the performance method allows the builder to employ special construction techniques, which would result in meeting the required thermal heat gain and heat loss. Depending on the structure (whether it uses standard materials or uses materials with insulation values below standard values) one of two procedural paths (steps) will be used for the prescriptive method. This workbook completes examples for both the two paths of the prescriptive method as well as the path for the performance method. Some examples included in these paths are an explanation of how to calculate overhang dimensions to determine the amount of unshaded glazing and an explanation of how to determine the amount of winter solar glazing, taking into account all obstructions such as overhangs and fences, (height and distance from building.) Shading coefficients (effectiveness of various materials) as adapted from Victor Olgyay's Design with Climate, and ordinances adopted by the City of Davis are the concluding portions of this workgook.

verhangs
ence Setbacks

Shading
Coefficients

Hammond, Jonathan, et al. <u>A Strategy for Energy Conservation</u>, Proposed Energy Conservation and Solar Utilization Ordinance for the City of Davis, California. Winters, California: Living Systems, c.1974.

Neighborhood Planning

Shading Devices
Roof Overhangs

Performance Standards

Street Design

Setbacks
Vegetation
Shading
Measurements

The material in this report is organized into sections dealing with: household energy consumption; the improvement of existing buildings; proposed building standards; neighborhood planning for energy conservation and the use of solar heating and cooling. Much of the information for these sections is centered around studies carried out in the Davis community. For example, studies on apartment complexes revealed different internal temperatures for various floors, and orientations. Exterior shading devices and roof overhangs were shown to be effective in temperature reduction in another group of apartments studied. These studies were used to substantiate the proposed performance building standards discussed in detail in the section on building standards. Two approaches are outlined in order for designers to meet the proposed thermal performance standards for buildings in Davis. The section on neighborhood planning discusses the allocation of land in a subdivision and the economic impact of street design (narrower streets.) Cost savings per lot are given. Also discussed are: the importance and design of efficient circulation systems; the value of efficient use of land (requirements); envelope zoning to insure maximum benefit of the sun and landscaping for improving the climate. Proposed policies and measurements are included in these sections.

McGregor, Gloria Shepard, "Davis, California: A Pace-setting Energy Conservation City," <u>Environmental Comment</u>, July, 1977.

Ordinance
Land Use Planning
Orientation
Setbacks
Shading Streets
Street Design
Solar Rights
Cost Savings

This brief article summarizes features of the General Plan, apopted by the City of Davis, California, in 1973, for reducing energy consumptions. These features include: an energy conservation ordinance mandating a high degree of thermal resistance in new residences; efficient land use eliminating development in a checkerboard fashion; distributing city services in an efficient manner; neighborhood design siting houses on a north-south axis, deregulating fence setbacks and shading streets and reducing street widths; efficient transportation system (providing a bicycle circulation network); retrofitting and resale requirements; and a proposed ordinance to protect solar rights through requirements for building design and locations. The cost benefit ratio of such an energy efficient plan as Davis, was mentioned to be quite substantial. The article sums up by suggesting that the Davis Community be used as a model for implementing energy efficient plans in other communities around the country.

Hammond, Jonathan., Project Coordinator for Living Systems. Davis Energy Conservation Report: Practicle Use of the Sun. Winters, California: Living Systems, May, 1977.

Building Code

Hot Arid Climate

Orientation

Setbacks

Street Design

Shading
Paving Surfaces

This report explains the measures which have been taken to reduce the comsumption of electricity in the City of Davis. A comprehensive plan included: an energy conservation building code responsive to the Davis climate; planning policies advocating energy conservation; a retrofit program to improve the thermal performance of existing buildings; an energy-efficient transportation plan, and an educational program for the community on energy conservation. The material in the report is basically organized into these components of the comprehensive plan--the exception to this is a section on solar homes. The section discussing the Davis climate includes study on the internal temperatures of apartments for various floor levels, and orientations. It also includes typical houses tested for energy use. Land use policies which have been suggested include reduction in minimum lot size; increase in setback flexibility; deregulation in fence setbacks; establishment of solar rights in new residential developments, reduction in street widths; requirements of shading for commercial developments and parking lots; flexibility in paving surfaces, etc.

Way, Douglas S. Terrain Analysis: A Guide to Site Selection Using Aerial Photorgaphic interpretation. Community Development Series. Stroudsberg; Pennsylvania: Dowden, Hutchinson and Ross, Inc., c.1973.

Site Selection Analysis

Geology and Soils

Site Development Cost

This book is systematically organized into sections on landforms (drumlins, eskers, kames, lake beds, sand dunes, flood plains, etc.) with accompanying information of their characteristic range of soil and rock composition, and their implications for site development. These implications of landforms on site development are discussed in terms of higher cost or greater difficulty for highway construction, ground water supply, foundations, pond or lake construction (reservoirs), solid waste disposal, excavation and grading. The cost of these various soil types are summarized in a table included in the measurements section of this report (under site development.) The text is supplemented by numerous graphics (aerial photographs, tables, cross sections and three-dimensional sections), and also detailed definitions and discussions on the various soil types (eg. their drainage, stability.)

McGregor, Gloria Shepard. "Davis, California Implements Energy Building Code," Practicing Planner, February, 1976, pp. 24-6,31.

This article summarizes energy conservation techniques practiced in Davis, California. It mentions the adoption of an energy conservation building code, effective as of January, 1976, mandatory for all new buildings. It was expected that these performance standards and neighborhood planning would reduce heating and cooling requirements in new homes by 50 percent. Some of the measures included using a light colored roof, exterior glazing limited to 12.5 percent of the floor area, and unshaded glazing limited to 1.5 percent of the floor area. Instead of employing these measures, a builder may choose to take into account compensating construction methods. A bikeway network was developed in which bicycles have as much right of way and protection as autos. This network involved cross ties between cul-de-sacs, and interblock cuts which has reduced distances and encouraged more than 50 percent of the residents to use bicycles as the preferred form of transportation. Some of the design standards which were proposed for adoption include: street standards, (eg. width of streets reduced from 34 feet to 28 feet); setbacks (closer to the streets for fences when houses face the south and zero lot lines); street tree planting; and solar heating. The climate conditions (criteria for design) were mentioned to support the ordinances, standards and measures taken, (eg. since Davis is hot and arid, the performance standards were adopted to result in house construction with minimal amount of artificial cooling for the greatest savings in energy consumption. About 31 percent or 2,600 Kw of electricity could be saved if air conditioning could be reduced to water coolers and fans.

Ordinance

Performance Standards

Bikeway Network

Street Design
Setbacks
Street Tree Planting

Hot Arid

Minnesota Campus Long Range Development Planning Framework. University of Minnesota, Office of Physical Planning; Roger DuToit, Architects and Planners; Bather, Ringrose, Wolsfeld, Inc. January 1976.

Land Use Planning

Efficient Transportation Modes

Mixed Land Use

This report was developed as one in a series of planning reports to form the Long Range Development Plan for the Minnesota Campus of the University of Minnesota. This particular report covers two aspects of the long range development plan ie., land use and circulation. First, an analysis is given of the problems and issues that exist such as those associated with transportation and housing. Then the various open space types associated with the college community and their criteria (e.g., convenient pedestrian and vehicular , climatically sheltered, south facing site, etc.). The report concentrates on the framework plan (the organization of the various land use types and circulation systems) but it does briefly mention the energy conservation measures associated with the framework plan. These are as follows: modes of transportation emphasizing fuel-efficient vehicles (priority given to bicycles and walking.); the mix and distribution of land uses to enable people to meet their needs in the local area thus reducing the need for mechanical transportation; provision of housing and entertainment within easy walking distance of the campus; the desing of buildings to conserve energy by utilizing sunlight and the natural insulation provided by the earth; and through the maintenance and operation of facilities in energy-efficient ways. The overall advantage of the land use framework is that it allows objectives and strategies to be identified in a manner which allows for a systematic application of the plan.

Read, Ralph A. <u>Tree Windbreaks for the Central Great Plains</u>. U.S. Forest Service Agriculture Handbook, p. 250, February, 1964.

Windbreaks

Measurments

Energy Savings Implications

This handbook is a state-of-the art on the influences and values of windbreaks in the Central Plains. This area includes Nebraska, Kansas, eastern Colorado and southern South Dakota. The first part of the handbook discusses the affects (functions) of windbreaks on the environment (wind velocity, air temperature, humidity) whereas the second part of the book discusses practical recommendations for planting and care of the windbreaks. Numerous diagrams are given indicating the coverage of variious types (species of evergreens) and sizes (height, depth--single row or multi-row). This coverage or affect is defined both in terms of reduced velocity and reduced air temperature. Many purposes for planting windbreaks, in addition to the protection of crops and farm animals are mentioned which have implications for energy savings. These are public facility windbreaks and farmstead protection (to prevent snow drifting on driveways and work areas; to reduce fuel requirements for house heating; to reduce weathering of paint and other maintenance expences, to protect sensitive garden and orchard crops, etc.). No measurements are given for energy savings in cost figures for using windbreaks. The material was written for the rural area of the Central Great Plains. However, many of the basic principles discussed are applicable to other regions.

U.S. DEPARTMENT OF AGRICULTURE HANDBOOK NO. 250

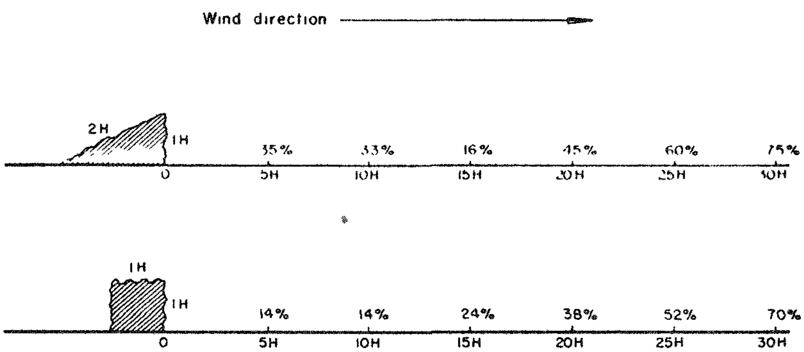


Figure 6.—Zones of reduced wind velocity as percentage of open field wind (at 0.2 H above surface) to leeward of different cross-sectional shaped artificial barriers in wind tunnel. Scale of models exaggerated. (After Caborn, 1957.) (Read, 6)

<u>A Competition For an Energy Efficient Office Building</u>. Sponsored by The California Energy Resources Conservation and Development Commission and The Office of the State Architect. State of California: Division of the Department of General Services. (No date given.)

Urban office building

Climate Analysis
- macroclimate
- microclimate

pedestrian circulation

imate modification
- orientation
- vegetation shading

The material in this booklet was organized to provide an opportunity for designers to engage in a competition for an energy efficient office building in downtown Sacramento. The majority of the booklet concentrates on stating the program requirements. This includes existing site conditions (both physical factors and socio-cultural factors) with an emphasis on the climate (sun, precipitation, wind, air quality, an application of Olgyay's bioclimatic evaluation method and summer and winter weather cycles). Energy conservation measures inherent in the Capitol Area Plan include design parameters which encourage employees to use either public transportation or car pools; encourage revitalization of residential areas within the Capitol Area; and provision of a network of attractive and convenient open spaces and pedestrian paths within the downtown area. One requirement of the office building program was the southern exposure for partially enclosed outdoor spaces such as decks, balconies and courtyards with adequate shade in the summer.

<u>New State Office Building. Eighth & 'P' Streets Sacramento, California.</u> Sim Van der Ryn, State Architect and Leonard H. Grimes, Jr., Director of General Services, State of California. Preliminary Design and Performance Analysis. Office of the State Architect. Department of General Services. March 1, 1977.

Urban
office buildings

Climate modification
- exterior shading devices
- overhangs
- vegetation shading

trade-offs
plant selection

policy

This booklet is a response to the booklet titled, <u>A Competition For an Energy Efficient Office Building</u>. It proposes an office building for Sacramento which integrates tested principles of energy conservation and responsive design. Some of these energy conservation measures include moveable exterior shades (which is controlled by a timer), overhangs and double glazing to reduce direct solar heat gain. Shade trees will be planted to reduce surrounding surfaces such as pavements or decks as well as lower windows of the office building. Drip irrigation and drought tolerant plants, to be utilized in the landscaping, are intended to reduce water use and cut maintenance cost. The proposed building was <u>not</u> oriented to face true south. It was calculated that by facing the street instead (a difference of 19°), the increased heating and cooling loads (for a building shaded by simple overhangs) was only 4-5%, which did not justify the additional cost of design and construction of the building facing true south. Other topics discussed include an abstract of the Capitol Area Plan which was prepared to ensure orderly growth of future state buildings in Sacramento's Capitol Area, existing conditions of the State office buildings and policies and actions needed to improve existing conditions of State office buildings in Sacramento.

APPENDIX C - MEASUREMENTS

SITE SELECTION AND ANALYSIS

Topography:

Implications of Cost for Various Slopes	Development on slopes above 10 degrees incur increasingly prohibitive construction costs. The only major category of development suitable for these slopes is individual residential uses, with a maximum limit of 12 degree slope for septic field systems, as drainage problems become increasingly severe. In general, slopes above 15 degrees not only incur prohibitive construction site costs, but also become dangerous with regard to extensive susceptibility to erosion during and after construction, necessitating protective practices and management. Possibility of mass wastage processes also increases greatly. (McCullough, et al., p. 13.)
Implication of Cost for Flat Land	If land is flat, drainage becomes more difficult. Storm and sanitary drainage may require costly methods of solving, such as: constructing special drainage ways or canals or special underground conduits, and creating high and low points by cut and fill operations (which would require pumping stations or underground conduits.) The flatter the grade, the larger the pipes required for drainage. The larger pipe is much more expensive than the smaller pipe. (NAHB, Land Development Manual, p. 41.)
Implications of Cost for Various Slopes	In general, slopes under 10 degrees are suitable for most types of development. Slopes of 0-5 percent usually incur the least development costs and are the most suitable for large scale development, such as industrial or commercial complexes. Drainage typically poses little problem within these slope limits. Slopes 5-10 degrees at times necessitate some added degree of cost to meet construction requirements. Drainage difficulties may become increasingly problematic. (McCullough, et al., p. 13)
Implications of Cost	Steep slopes, in excess of 15-20 percent, generally require either expensive mass earth moving, compacted fills, subfoundations beneath houses and/or retaining walls for single-family houses. In addition, grades around 15 percent can cause a problem since many road codes forbid construction of streets steeper than 8 to 10 percent--unless the property has a high value. However, the high density of townhouses, apartments or commercial developments generally means higher land values, which in turn mean cost is not as serious. (NAHB, Land Development Manual, p. 41.)

Implications of Cost for Slope versus Flat Land	The presence of higher, steeper slopes requires removal of more total materials to obtain the desired grade when excavating. (Way, p. 69.)

SITE SELECTION AND ANALYSIS

Geology and Soils:

Cost Difference of Various Soil Types for Site Development

The table below* was constructed to summarize the type of data contained in Chapters 5-11, inclusive, of Douglas Way's Terrain Analysis. Only a sample of the landforms and their associated engineering and construction problems is shown in this table. Excavating cost figures are given, relative values in relation to a base cost (1.0) of removing the same amount of deep, dry, moderately cohesive material. Thus, rock requiring blasting increases cost by a factor of 4 to 5, a high water table within 1 foot of the surface increases costs by 35 to 40 percent, and organic materials with a high water table increase cost by a factor of 3 to 4. (Way, p. 69.) These cost figures do not include increases in estimates due to changes in slope.

Trenching

All costs are compared to those for shallow trenching operations in which deep, dry, moderately cohesive materials are being removed. These conditions represent a cost unit of one. (Way, p. 69.)

The reader should note that some of the symbols assigned were interpreted from the authors discussion and do not always reflect exact statements. These symbols are shown below:

LEGEND:

D - Difficulty
SD - Some Difficulty
LD - Little Difficulty
ND - No difference to the cohesive material
HC - High Cost

* See next page

LANDFORM / SITE DEVELOPMENT	EXCAVATION	ON-SITE SEWAGE DISPOSAL	SOLID WASTE	TRENCHING FOR UTILITIES	WATER	RESERVOIR	HIGHWAY CONSTRUC-TION	FOUNDA-TIONS
SHALE	1.5 - 1.2X	D	D	1.8 - 1.2X	D	LD	D	SD
INTERBEDDED SEDIMENTARY DEPOSITS	4 - 5X, if thick, 2 - 3 if thin	SD	SD	4 - 5X	ND	LD	HC	SD
GRANITE MASSES	4 - 5X	D	D	4 - 5X in humid area 3 - 4X	D in lg. areas	D	HC, if much exca-vating	ND
BASALTIC SOILS	3 - 4X; 4 - 5 if welded tuff	D	SD	2.5 - 4	LD	D	LD in plain D/vol. tuff	SD
TILL (GROUND MORAINE)	same*	D	D	1.2 - 2.2X* 4 - 5X, if lg. boulders	SD	LD	SD	SD
END MORAINE	1.2 - 2.5*	SD	LD	1.2 - 2.2X* 4 - 5X, if lg. boulders	LD	SD	D	SD
GLACIAL DRIFT SOILS	1.5 - 2.8X 4 - 5, if lg. boulders	SD	SD	1.8 - 3X; 4 - 5X, if lg. boulders	SD	D	D	SD
FLOOD PLAINS	1.3 - 2.5X	D	D	1.3 - 2.5X	SD	SD	LD	D
ARC DELTA	1.3 - 1.6X 3 - 4X, if highly organic	D	D	1.3 - 6X or more	LD	--	D	SD
COASTAL PLAINS	Up to 4X, if deep peat and muck	LD	D	1.5 - 4X	LD	LD	D	SD

* 35-40% increase if encounter water table for excavation, grading and trenching.

Percentage of Site Improvement Cost	Total site improvement cost may increase 25 percent in rocky land and 85 percent in peat or muck. The latter may also substantially increase foundation costs. (Lynch, p. 60.)
Implication of Cost for Soils	Shallow or loose soils over bedrock may require excessive landscaping and/or sodding to make the property attractive for large lot development. (NAHB, Land Development Manual, p. 55.)
Percentage of Cost Increase for Site Conditions	Relative values are given in relation to the base cost (1.0) of removing the same amount of deep, dry, moderately cohesive material. Thus, rock requiring blasting increases costs by a factor of 4 to 5; a high water table within 1 foot of the surface increases cost by 35 to 40 percent, and organic materials with a high water table increases cost by a factor of 3 to 4. (Way, p. 69.)

SITE SELECTION AND ANALYSIS

Vegetation:

Implications of Cost for Preserving Existing Trees	Preserving existing tree cover may provide a long-run saving for the builder. Landscaping cost may be reduced at the end of the building period if individual sites are designed around the existing vegetation. (NAHB, Land Development Manual, p. 55)

SITE DEVELOPMENT

Site Preparation:

Cost Savings of Site Preparation and Grading

Pine Run, a Planned Unit Development in Camden County, New Jersey, by using contour clustering, restricted the amount of clearing, which resulted in a savings of $250-750 per acre. About 90 percent of the trees beyond 15 feet from the buildings were saved (through the construction of cribbing and retention walls, and a grading plan that was controlled and directed in a linear pattern along the length of the garden apartments), reducing landscaping cost by $300-500 per unit. The highest density residential uses (townhouses and garden apartments) were located in the steeper and more wooded areas and were clustered along the contour. Thus, the amount of broad grading typical for single family houses was reduced. This in turn, reduced the amount of ground cover needed for the steep slopes, which usually costs between $.10 and $.25 per square foot. A maintenance savings of roughly $1,900 per year was estimated for the sloped areas.

Cost of Grading

An example of varying the grading technique to reduce cost on a hill was demonstrated by the San Francisco firm of Hayes and Smith. Employing a sculpture method instead of the traditional mass grading method, the number of residential lots increased from 37 to 62 (68%) and the amount of grading was reduced from 127,000 cubic yards to 38,000 (130%). Instead of tailoring each house to fit the site as is required by the natural method, the sculpture method involved grading the site into five and six levels, thus only requiring five or six foundation designs for the subdivision. Instead of lopping off the top of the hill to acquire flat pads in the mass graded method, the hilltop was left as open space and a street was designed around it. The net savings for each house was $4,270. (NAHB, 130-32.)

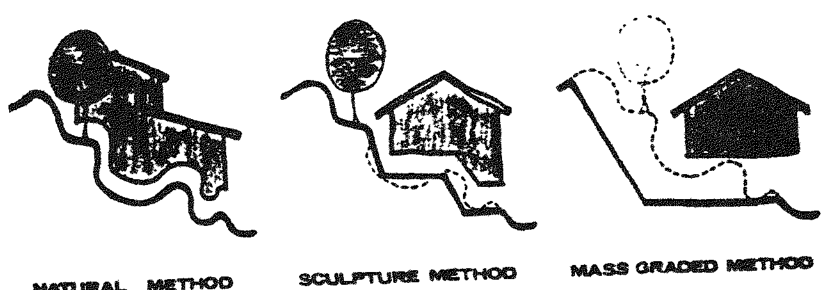


Figure 8-2. Hillside design methods.

Natural Drainage Cost Savings

A developer in Berks County, Pennsylvania, (Flying Hills Project) eliminated the use of curbs or gutters. Instead, water was allowed to run into grassed swales, which created a natural watering system and replenished the water supply. At a cost of approximately $5.50 per linear foot for 6" X 18" of concrete curb, the saving to the developer was nearly $174,000, about 50 percent of which is materials. (Harwood, p. 24.)

SITE DEVELOPMENT

Stockpiling: Fee Saving in Transporting Materials

In several subdivisions in Fremont, California, builders who are developing on the flat coastal plain are saving trucking charges by depositing soil and rock from basement excavation and locating it in common open-space strip parks. (NAHB, Land Development Manual, p. 101).

SITE DEVELOPMENT

Utilities Layout:

Amount of Cost Difference for Drainage Pipes

In regard to drainage systems, the cost, expressed as dollars per cubic foot of capacity, is almost seven times as great for a 15-inch pipe as for an 84" pipe. This means it is generally more economical to combine small pipes into a large one. (NAHB, 231.)

Costs for Utilities Design

In akland, California, one developer devised a plan for distributing water, storm and sanitary sewer lines in a joint trench on one side of the street, and gas, power, telephone, street lighting and fire alarm on the other. The services from these mains would criss-cross the streets in joint trenches to serve individual houses at regular intervals based on lot sizes. This type of installation allows for a savings in trenching; for one 24 X 40 inch trench instead of (4) 18 X 36 inch trenches, a difference of 136 cubic feet of soil for each foot of trench. This has been estimated to result in a savings of 60 percent (about $1.40 per foot   Other advantages include reduction in installation time, less disruption to curbs, roadway base, etc., resulting back fill is more closely supervised since less time is required, and less space is used. (NAHB, 241-2.)

SITE DEVELOPMENT

Utilities Layout: Added Cost of Storm Drain Requirements

The need for reform is indicated by an example of one subdivision in a northern community, where the total drainage area was about 12 acres and some lots were involved, an application of a 350 foot rule required a $20,000 extension of storm drainage even though the runoff was dispersed over three streets and there was no hydraulic justification for the extension. As a result, nearly $900. was added to the total cost of each individual lot, with no appreciable benefit to either property owner or the community. (NAHB, Land Development Manual, pp. 224-25).

SITE DEVELOPMENT

Roads, Walks and Paving:

Cost Saving of Natural Drainage

A land use plan for an open space community on a 350 acre site at Flying Hiss in Berks County, Pennsylvania, utilized grasses swales (creating a natural watering system and a natural replenishment of the water supply instead of utilizing curbs or gutters. At a cost of approximately $5.50 per linear foot for 6" X 18" of concrete curbing, the savings to the developer was nearly $174,800, about 50 percent of which is materials. (Goldberg.)

Cost Savings of Contour Clustering

At Flying Hill in Berks County, Pennsylvania, a cluster of housing units paralleled the contours of the land, resulted in an energy savings in both grading activity and material requirements. Contour clustering also allowed for a major reduction in road lengths. A comparison between the open space community (utilizing contour clustering) and the same site developed as a single family layout resulted in a 30 percent reduction in roads required at a cost savings of $720,720. (Goldberg)

CATEGORY	COST/ LINEAR FOOT *	OPEN SPACE COMMUNITY 3 MI OF RD.	SINGLE FAMILY PLANS 9 MI OF RD.
Clearing	$ 3.00	47,520	142,560
Grading @ 12"	$ 2.00	31,680	95,040
Gravel Base @ 6"	$ 4.50	71,280	213,840
Bituminous surface @ 2"	$10.50	166,320	498,960
Shoulder	$ 2,75	43,560	130,680
Total	$22.75	360,360	1,081,080

* Under each scheme 24 foot wide bituminous cartways were assumed.

Cost Savings for Road Material

To correct problems in existing subdivision streets in Hoffman Estates, Illinois, (despite a requirement for 6-7 inches of gravel with a two-inch asphalt surface), excavating to a depth of 16½ inches and replacing the clay with 14 inches of gravel and 2½ inches of asphalt surface was carried out. The total cost was $6.65 per square yard. A new pavement was designed using a combination of lime stabilization, soil cement and asphalt. This satisfactory pavement only cost $3.88 per square yard for a savings of 41.7 percent. (NAHB, p. 164.)

Cost of Road Paving

Road paving cost $.60 per square foot and the homeowner must pay for the land under the streets when he purchases a lot in a new subdivision. Then it becomes no longer taxable and the city maintains it. (Hammond, et al. p. 29.)

SITE DEVELOPMENT

Roads, Walks and Paving: Implications of Cost of Road Materials	Use of on-site aggregates, in a new subdivision, for paving may reduce or eliminate the need to haul excess material away or to grade excessively. (NAHB, Land Development Manual, 162).
Implication of Cost Associated With Wide Street	Additional costs associated with excessive widths for local streets and roadways are: 1. Initial construction cost to the city or to the developer which ultimately gets passed on to the homeowner; 2. The continuing cost of maintaining, resurfacing and repairing from 38 to 54 percent more roadway than is needed, plus the additional land removed from the tax rolls; 3. Higher taxes, which must be added to the first two. (NAHB, Land Development Manual, 158.).

SITE DEVELOPMENT

General:

Cost Breakdown For Site Development

A chart displaying itemized costs for development requirements (site preparation and earthwork, roads, walks and paving; utilities, landscaping and site structures) is given. They were modified from 1968 figures for budget estimates for State University Construction Fund, State of New York, by Clarke and Rapuano. (Lynch, pp. 292-5.)

Site preparation and earthwork	
Clearing and grubbing, per acre	$400.00
Demolition of structures, per cubic foot	$0.05
Removing pavement, per square foot	$0.25
Removing tree and stump, per inch of diameter	$7.00
Excavating and replacing earth, 500- to 1500-foot haul, per cubic yard	$0.80
Excavating unsuitable earth and removing it from site, per cubic yard	$1.90
Excavating rock, drilling and blasting, per cubic yard	$5.75
Borrow fill in place, per cubic yard	$1.80
Stripping, piling, and replacing topsoil, per cubic yard	$2.70
Topsoil furnished and placed, per cubic yard	$5.75
Roads, walks, and paving	
Asphalt parking pavement, light duty, per square foot	$0.35
Asphalt road, light duty, per square foot	$0.40
Asphalt road, heavy duty, per square foot	$0.60
Concrete road, light duty, per square foot	$0.75
Concrete road, heavy duty, per square foot	$1.10
Concrete curb and gutter, per linear foot	$4.00
Gravel walk, per square foot	$0.20
Asphalt walk, per square foot	$0.30
Concrete walk, per square foot	$1.00
Loose gravel or crushed stone surface, 4 inches deep, per square foot	$0.10
Brick or asphalt block pavement, per square foot	$2.00
Granite block pavement, per square foot	$3.00
Snow-melting system, electric mats, per square foot	$3.00
Concrete steps, 5 feet wide, with hand-rails, per square foot	$20.00
Utilities	
Concrete storm drains, in place, all fittings, 6-foot average depth, per linear foot of main:	
12-inch diameter	$16.00
18-inch diameter	$19.50
30-inch diameter	$29.00
Clay sanitary drains, in place, all fittings, 7-foot average depth, per linear foot of main:	
8-inch diameter	$15.00
12-inch diameter	$18.00

Underdrain lines, in place, 6-inch diameter, 3-foot average depth, per linear foot	$6.00
Six-inch water pipe, in place, all fittings, 5-foot average depth, per linear foot of main	$12.00
Four-inch gas mains, in place, all fittings, 4½-foot average depth, per linear foot of main	$12.50
For each foot of extra depth of a utility, add per linear foot	$2.00
For trenching in rock, 5-foot average depth, add per linear foot	$22.00
Overhead electric power, including poles and transformers, per linear foot of cable	$5.00
Underground electric power in fiber duct, including above-ground transformers, per linear foot of cable	$15.00
Lighting roads, per linear foot of road	$12.00
Lighting walks, per linear foot of walk	$14.50
Lighting park areas, per acre	$6000.00
Landscaping and site structures	
Hydroseeding of secondary areas, per acre	$500.00
Playfield, seeding and fine grading, using on-site topsoil, per square foot	$0.10
New trees, in place, standard varieties, including two-year maintenance, per inch of caliper squared	$10.00
Sodded swale, 3 feet wide, under 3 percent slope, per linear foot	$1.30
Asphalt gutter, 4 feet wide, per linear foot	$3.50
Concrete gutter, 3 feet wide, per linear foot	$5.00
Concrete culvert, per linear foot times clear span in feet	$18.00
Concrete retaining wall, per square foot of wall face	$14.00
Freestanding brick screen wall, per square foot of wall face	$7.50
Chain-link fence, 6 feet high, per linear foot	$6.00
All-weather tennis court, each	$9500.00
All-weather basketball court, each	$11,500.00
Outdoor swimming pool, including perimeter walks and equipment but no building, per square foot of pool	$17.50
Eight-foot wooden bench, concrete supports, each	$100.00

CLIMATE MODIFICATION

Integration: Percentage of Energy Savings

In a report concerned with the Minnesota long-range campus planning, it has been estimated that an energy savings of 75% is possible by utilizing underground space for buildings. Minnesota experiences climate extremes, but by building below grade, the temperature difference in winter would only be 20 degrees compared to 90 degrees above grade. In summer, the building above grade must be cooled 30 degrees.

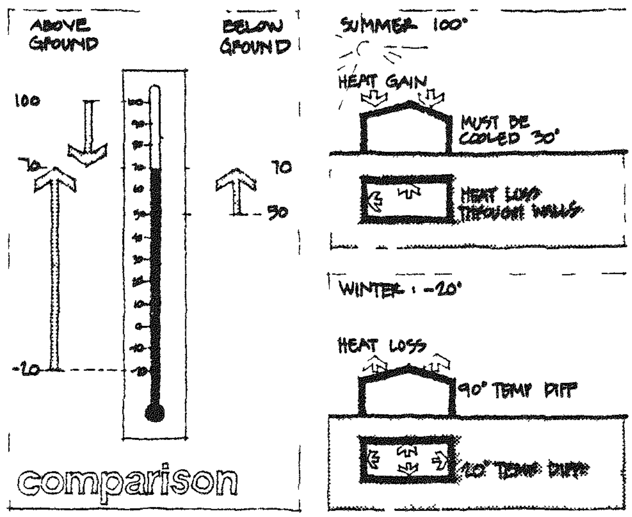


fig. 75

CLIMATE MODIFICATION

ORIENTATION:

BTU Savings from Proper Orientation	The effects of window orientation on heating requirements for two houses in Boston, revealed that the conventional house (with 100 sq. ft. of window area for the south, 100 sq. ft. for the north, 50 sq. ft. on the east and 50 sq. ft. for the west.), required 92 million BTU for heating and the revised house (changing the window area on the south to 180 sq. ft. and on the north to 20 sq. ft., and maintained the same on the east and west as the conventional house) required 83 million BTU. (Hastings and Crenshaw, pp. 1-26, 1-27.)
Degree Comparison of Different Orientation	Scale models were used at the Building Research Station at Haifa, Israel, to study the effects of window orientations on cooling loads. Four identical models, one side having a closed window, were constructed. These were positioned so that the window of the four models faced north, south, east and west. All four models had approximately the same inside air temperatures before sunrise. However, four hours after sunrise, the east-facing model had an inside temperature of 8° C. (14.4 F.) above the outside air temperature. The west-facing model reached an air temperature difference of 11° C. (19.8 F.) in the afternoon, whereas the south and north facing models only reached air temperature differences (inside to outside) of 3° to 5° C. (5.4 to 9° F.) (Hastings and Crenshaw, pp. 1-27.)
Percentage of Heat Gain from Orientation	A conventional two-story house located in a moderate climate would experience a 21 percent additional heat gain with a western orientation. With large glass areas, this percentage would be even higher. (NAHB)
Percentage of Wind Velocity Reduction	In a development in New York - New Jersey area, buildings positioned perpendicular to the wind direction receive on their exposed side the full sweep of the velocities. Positioned at a 45 degree angle, wind velocity is reduced to 50 percent; some calculations use 66 percent as the correction factor. (Olgyay, p. 100.)
BTU's of Heat Transmission	The daily total heat transmission of a wall consistin of a lightly painted insulatted wood frame construction, amounts to 40 BTU/ft2, and to 27 BTU/ft2 in shade. The daily total transmission of the glass pane is 1,227 BTU/ft^2 in sun, 346 BTU/ft^2 in shade. But, by shading the glass, this heat impact can be reduced to one-third. (Olgyay, p. 66.)

ount of Total Sun Energy

The orientation of a building is affected by the quantities of solar radiation falling on different sides at different times. In winter at 40 degrees latitude, a southern exposure receives nearly three times as much total sun energy as the east or west sides; while in summer the radiation falling on the south plus north sides is only half of that absorbed by the east plus west sides. At lower latitudes these ratios are even more pronounced and can easily mean the difference between comfort and distress. (Olgyay, p. 53.)

Degrees of Temperation for Various Directions

Studies, conducted at the Stonegate and Cranbrook apartments in Davis, California, showed south facing apartments, with good sun exposture, to be significantly warmer during the winter. A summary of temperature measurements for these apartments, during sunny, clear, cold days from December 1973 to February 1974, is given below:

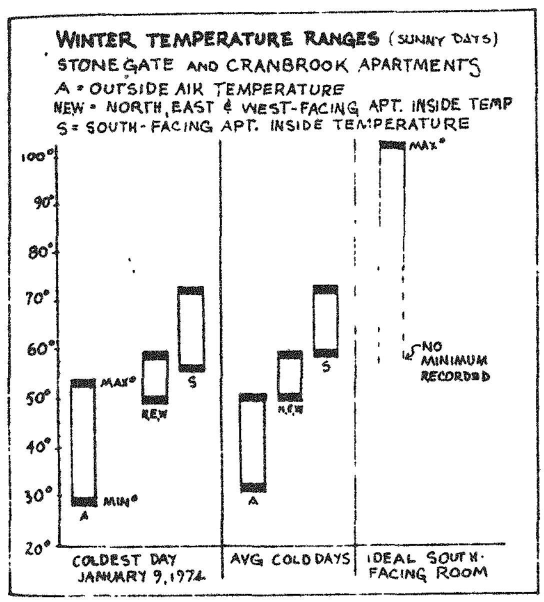


Figure II-12

Term Difference

The results of this study were then compared with natural gas usage of the apartments. It was revealed that south facing windows used less gas than other apartments facing other directions. (Hammond, et al., p. 14.)

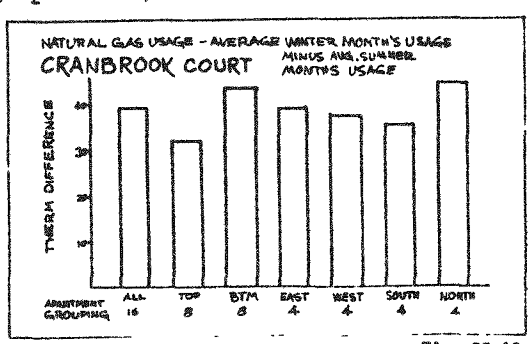


Fig. II-13

CLIMATE MODIFICATION

Degrees of Temperature

A study in Davis,.California, on the internal temperatures of apartment buildings for the first and second floors and for the various orientations was summarized in the following graph:

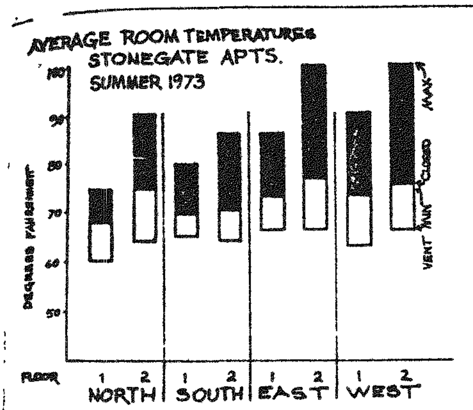


Fig II-2

WH of Winter lectrical Usage

In summer, the second floor rooms averaged 11 degrees F. warmer than those on the ground floor and north-south exposures were found to be much cooler than east-west exposures. The result of these temperature tests paralleled actual electrical use apartments in another section of the Stonegate apartment complex. (Hammond, et al. p. 10.)

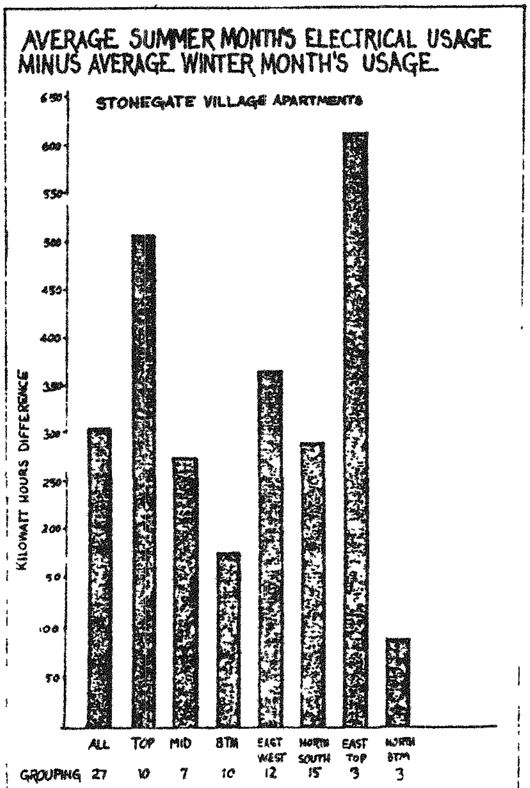


Fig II-3

Percentage of Fuel Savings Due to Orientation

A 1,500 square foot house with southern exposure (insulated, ventilated, standard single pane windows, white roof and bare concrete slab floor), in Davis, California, showed a savings of 54 percent over a house without southern exposure. For the winter season, this would mean a requirement of 39 percent--as much energy as the average Davis house, yet, would be the same construction cost. (Hammond, et al., p. 41.)

CLIMATE MODIFICATION

Orientation: $BTU/ft^2/day$ in the Major Climatic Zones for Various Building Sides

Four locations in the United States were chosen to represent the cool, temperate, hot-arid and hot-humid climate zones. These were Minneapolis, New York, Phoenix and Miami. The object of this study was to investigate the impact of external forces on buildings. The coldest day (January 21) and the warmest day (July 21) were used to represent winter and summer conditions. The $BTU/ft^2/day$ in the various locations for each side of a building was illustrated in the table below:

		Btu/ft²/day Winter	Summer
Minneapolis	E	416	1314
	S	1374	979
	W	416	1314
	N	83	432
	Roof	654	2536
New York	E	517	1277
	S	1489	839
	W	517	1277
	N	119	430
	Roof	787	2619
Phoenix	E	620	1207
	S	1606	563
	W	620	1207
	N	140	452
	Roof	954	2596
Miami	E	734	1193
	S	1620	344
	W	734	1193
	N	152	616
	Roof	1414	2568

The study indicated that, in the upper latitudes, the south side of a building receives almost twice as much radiation in the winter as in the summer. In the lower latitudes, this ratio was about four to one East and west sides in the upper latitudes receive about 2½ times more radiation in summer than in winter. In the lower latitudes, the east and west sides in summer receive two to three times as much radiation as the south side. In all latitudes, the north side receives only a small amount of radiation which comes mainly in the summer. But, in the low latitudes, the north side receives in summer nearly twice the impact of the south side. The amount of radiation received on a horizontal roof surface in summertime exceeds all other sides. (Olgyay, pp. 86-7).

CLIMATE MODIFICATION

VEGETATION:

Percentage of Light Penetration	A tree-shaded south-facing window receives less solar heat than an unshaded, north-facing window. This solar protection increases throughout the summer. For evergreen forest, the percent of light penetration is as follows: April, 8 percent; May, 7 percent; and September; 4 percent. The light penetration for deciduous forest is as follows: April, 51 percent; May, 23 Percent; and September, 5 percent.
Degree of Temperature Difference	At Indiana University, tests showed that when the air temperature was 84° F., concrete exposed to the sun was 108° F., while concrete shaded by a maple tree was only 88° F.
Degrees of Temperature Reduction	The following diagram illustrates the calculated effectiveness of a shade tree on the east or west side of a house in reducing the air temperature in the shaded area. (74, Weatherwise Gardening, p. 32.)

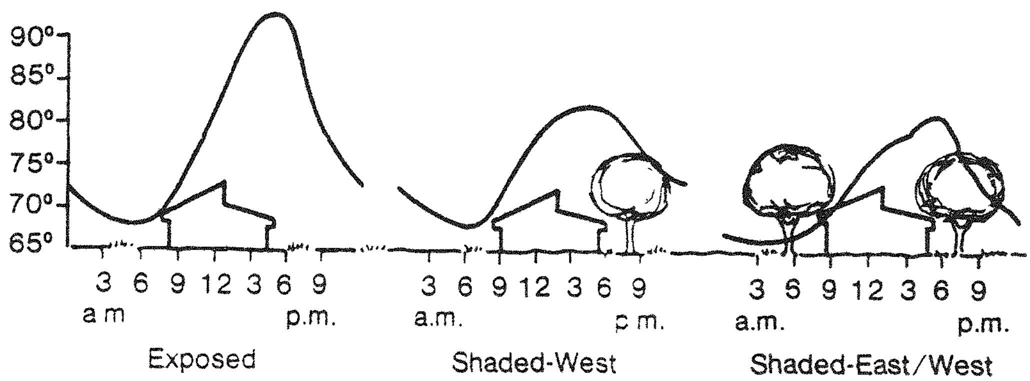


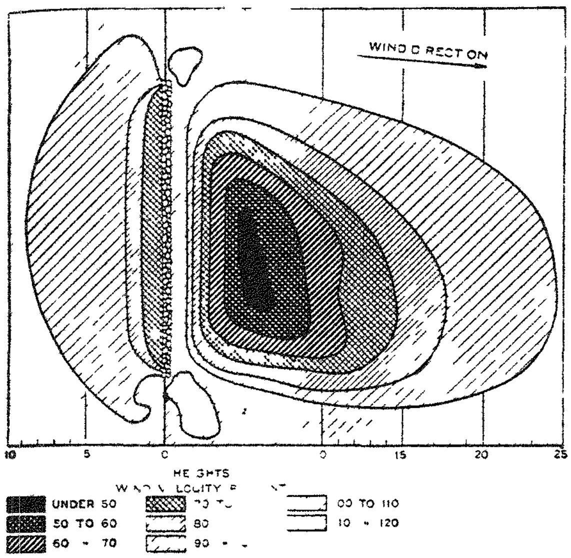
Figure 5. Shade Tree Effectiveness vs. Orientation

Degrees of Temperature Reduction	A tree located to shade the wall and roof in the afternoon will keep the house temperature more comfortable and may reduce the wall and roof temperature by as much as 20 - 40° F. (AAN 1950 p.2)
Degrees of Temperature Reduction	Shading from trees can prevent as much as 70 percent of the sun's heat from being absorbed by the ground and this combined with the trees' transpiration process will have a measurable effect on the air temperature around them.

CLIMATE MODIFICATION

Windbreaks: Percentage of Wind Velocity as a Result of Windbreaks

The Lake States Forest Experimental Station studied the wind shadow effect of windbreaks. The study used a slot windbreak constructed of 6" boards with 12" spaces in the lower half, but only 3" spaces in the upper half, to simulate a resistance similar to old trees with very few limbs near the ground. The wind was measured 16" above the ground, with 13 mph open wind velocities. The lowest velocity recorded was 47%, and occurred at five heights from the barrier. With greater density near the ground, the low velocity moves closer. (Olgyay, p. 99).



191. Actual field of protection of a windbreak.

CLIMATE MODIFICATION

Windbreaks: Reduction of Air Temperature

The effect of windbreaks on air temperatures has been studied in central Kansas. In the lee of a moderately dense windbreak during July, mid-day temperatures 1 to 4 feet above plowed soil in a zone 0 to 4 H from the windbreak, were up to 6 degrees warmer in the lee than in the open. But in the 6-24H zone, they averaged 2-5 degrees cooler than over open unsheltered fields. During the evening, air temperatures near the ground from 0 to 30 H were 1 to 2 degrees warmer than in the open. Averages of 2 to 4 percent higher humidity often prevails on the protected side of a windbreak. (Read, pp. 4, 6).

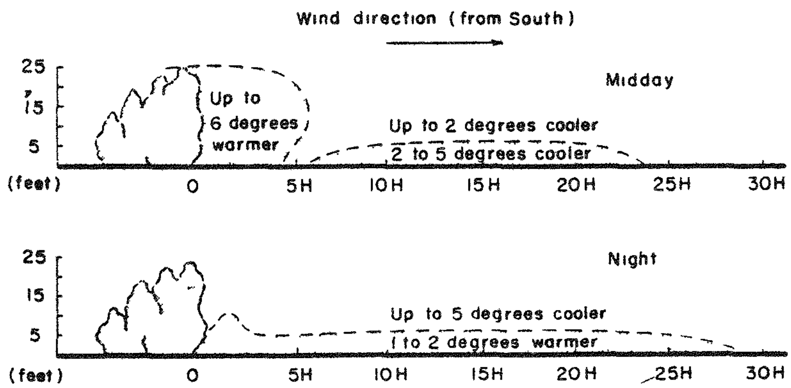
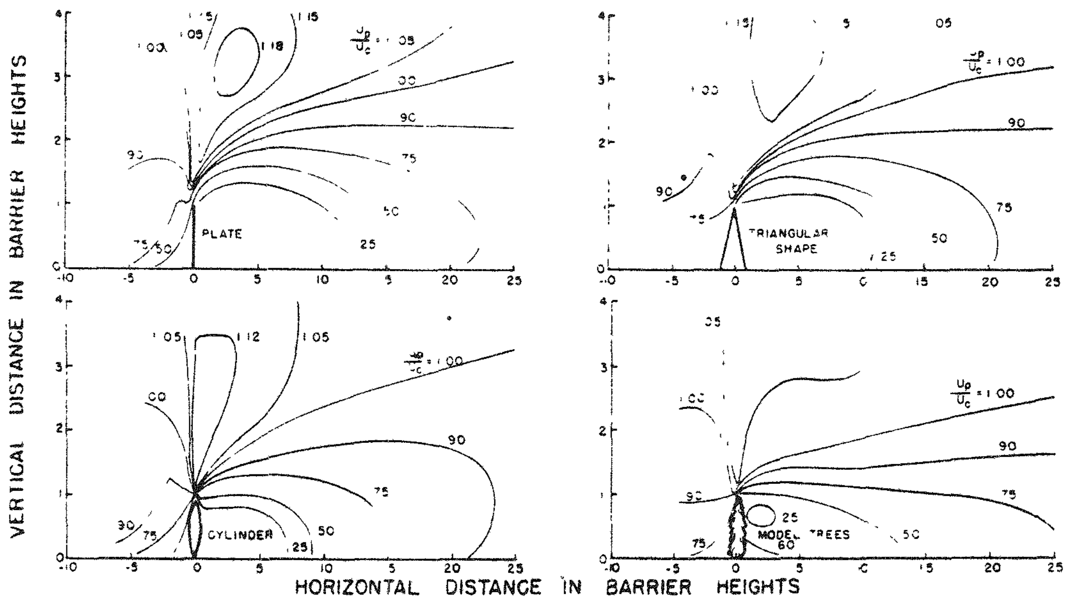


Figure 7 —Air temperature zones leeward of a 25-foot-tall moderately dense windbreak, compared with open field temperatures. Wind at 14 to 20 m.p.h. with open field temperatures ranging from 86° to 110° F in Kansas during July. Vertical scale exaggerated (After Woodruff et al., 1959)

CLIMATE MODIFICATION

Windbreaks: Percentage of Wind Reduction

Models were used at the Kansas Experiment Station to conduct wind tunnel experiments in order to study the effect of barrier shape on flow patterns for solids and trees. The tests were conducted at 25 mph constant velocities. Vertical profile maps drawn from the experiment are shown below:



190. Air flow around four barriers of varying shape.

The table below summarizes the more significant results of the figures above. Briefly, these are: there is no 75% reduction for trees because of the jet-air movement through them, however, they create a greater length of protection than the other shapes. For example, at 27 Horizontal Distance, there is still a 25% wind reduction. The vertical plate is second to the trees in wind reduction, reducing wind velocities approximately 44% more than the cylinder when near the object and 25% at positions farther from it. The plate also reduces the velocity approximately 10% more than the triangular shape at both near and far distances.

	Distance at 0.1 H to		
Object	75% reduction	50% reduction	25% reduction
Vertical plate	13.0 H	15.5 H	21.5 H
Triangular shape	10.5 H	15.0 H	20.5 H
Cylindrical shape	7.0 H	9.0 H	14.0 H
Model trees	–	13.5 H	27.0 H

Refer to "Comparison of Heating Requirements" for the effects of wind protection on house heating fuel usage. (Olgyay, p. 98.)

Percentage of Fuel Consumption	Careful tests have proved that a wind barrier of trees, vines, and other plantings on the north and west sides of a dwelling can reduce winter fuel consumption from 10 percent up to as much as 40 percent. On the south and west, they can save air conditioning energy by reducing inside temperature as much as 8 percent on a hot summer day. (AAN)
Percentage of Fuel Savings	Under 70° F. constant house temperature, the amount of fuel saved by protected house versus a house exposed to the wind, was 22.9 percent. (Olgyay, pp. 98-9.)
Percentage of Wind Velocity Reduction	Thick belts of trees or shrubs are effective windbreaks. They reduce wind velocities by more than 50 percent for a distance downwind of 10 times their height, and by 35 percent even for twice that distance. (Lynch, p. 74.)
Percentage of Heating Requirement	A 20-mile wind will draw 20 percent more heat out of your house than still air of the same temperature. (Fitch, March 1951, p. 104.)

CLIMATE MODIFICATION

WINDBREAKS:

Percentage of Air Infiltration

A study at Princeton University in 1975, by George Mattingly and Eugene Peters, using scale models suggested that: a 5.5' high wooden fence would reduce air infiltration 26 to 30 percent; a single row of evergreen trees the same height as the house would reduce air infiltration 40 percent, and a combination of the two would reduce air infiltration 60 percent. The best location for the windbreak being at a distance 1½ - 2½ windbreak heights upwind from the house. These results were being applied to townhouses at Twin Rivers, N.J. (Hastings and Crenshaw, pp. 1-5.)

Percentage of Fuel Savings

Two identical houses, one exposed to the wind and the other protected by dense shrubbery, were studied by the Lake State Forest Experimental Station in Nebraska, for the amount of fuel consumption for maintaining an indoor temperature of 70°. A savings of 23 percent was recorded for the protected house. (Hastings and Crenshaw, pp. 1-5.)

Percentage of Fuel Savings

Of two identical houses studied in South Dakota, the fully exposed house required 443 KWH and the one sheltered by a windbreak required 270 KWH to maintain an inside temperature of 70°, from January 17 to February 17. The difference in average energy requirements for the whole winter was 33.92 percent. (Hastings and Crenshaw, pp. 1-5.)

Percentage of Fuel Consumption

Researchers at Princeton, New Jersey, found that townhouses on Princeton's windward side needed 5 percent more natural gas than did houses on the leeward side, which were sheltered by the windward buildings. The townhouses at the end of a row, with an exposed wall, used an additional 10 percent more gas. (Harwood, pp. 21-2.)

Comparison of Heating Requirements

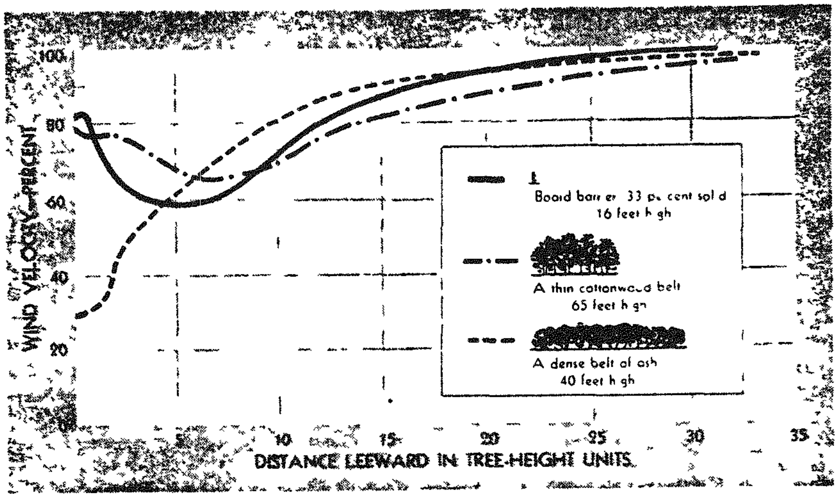
Architectural interest in wind protection lies not only in outdoor comfort conditions, but also in its effects on house heating. Calculations indicate that the heating load of an unprotected house with a 20 mph wind is approximately 2.4 times as great as that for a 5 mph wind under the same temperature conditions. The heating load for a protected house at 20 mph wind velocities, was approximately twice as great as for a similar house exposed to 5 mph wind effects. This indicates that a shelter-belt's effectiveness increases at higher wind velocities. (Olgyay, pp. 98-9.)

	10 - 15° cooler when the general temperature is 90° F. and 5 - 10° cooler when it is 70° F. - different trees offer varying shade patterns. (Kerner, p. 54.)
Degrees of Temperature Reduction	In Indio, California, it is thought that proper shading of streets, parking lots and lot areas could reduce temperatures by as much as 10 degrees on the microclimate of the buildings and surrounding area. (Living Systems, Final Draft Report, p. 14.)
Degrees of Temperature Reduction	Mature deciduous trees may cool the microclimate of a house by as much as 20° (ideal trees are carob, locust, elms, sycamore and alders.) <u>(Davis Retrofit Manual</u> p.22)

CLIMATE MODIFICATION

Windbreaks: Percentage of Velocity Reduction by Various Wind-break Types

Observations were made for three types of windbreaks to determine wind velocity idfferences. Measurements were recorded at 16" above the ground in a 15 mph wind at right angles to the barriers.



192. Wind velocity at three types of windbreaks

The above table indicates that near a dense belt of green ash, velocities are reduced 30%; for a thin cottonwood belt, the velocity is about 66% of that in the open; and for a board barrier, the maximum velocity reduction is about 58%. All three wind-breaks show the effect to be aobut 30 times their height, however, their effect beyond 20H is minor. (Olgyay, p. 99).

CLIMATE MODIFICATION

MATERIALS:

Percentage of Light Reflection

Light reflected from the ground represents 10 to 15 percent of the total daylight transmitted by a first floor window on the sunlit side of a building, and may account for more than half of the total daylight on the non-sunlit side. The amount of light reflected through the window is even greater when adjacent ground surfaces are light in color. The following a list of common ground surfaces and the percentage of incident light they reflect. Ground reflected light is beneficial for daylight and increases the ability of a window to provide supplemental heat. (72, IES, p. 75.)

MATERIAL	PERCENT REFLECTED
White paint (new)	75 percent
(old)	55
Snow (new)	74
(old)	64
Concrete	55
Marble (white)	45
Granite	40
Brick (buff)	48
(dark glazed)	30
Vegetation (average)	25
Macadam	18

Degrees of Surfaces Temperature

Dark-colored surfaces absorb more light than light-colored surfaces and, therefore, become warmer in sunlight. A window will radiate less heat in the winter when adjacent ground surfaces are warm. Also, on a calm winter day, the air temperature over dark-colored ground surfaces will be warm, further reducing window heat losses. Conversely, during the summer, light-colored surfaces are beneficial because they absorb less light than dark-colored surfaces and are consequently cooler. The following is a list of common ground surfaces and their sunlit surface temperatures when the air temperature is 84o F. (75, FEA, p. 4.)

MATERIAL	SURFACE TEMP.	DEV. FROM AIR
Dark Asphalt	124	+40
Light Asphalt (dirty)	112	+28
Concrete	108	+24
Short grass (1-2")	104	+20
Bare ground	100	+16
Tall grass (36")	96	+12

Percentage of Reflection	White materials may reflect 90 percent or more, black materials 15 percent or less, of radiation received. (Olgyay, p. 113.)
Degrees of Temperature Difference	A white roof is effective in modifying interior temperatures during the summer. Whiteness reflects away the heat rays of the sun, keeps the structure itself from absorbing heat. A white roof is 10 to 20 degrees cooler than a dark roof.
Degree of Temperature Difference	Because living leaves reflect most of the heat from the sunlight that reaches them, they get only 5 or 10 degrees warmer than the air on a sunny day. A leaf that the summer sun shines on is perhaps 80 degrees F. If the leaf were made of paper, and the same shape, same color, but not living, it would be perhaps 130 degrees F. A lawn exposed to the same sun would be perhaps 110 degrees F., still fairly cool. A wall of a house, exposed to the same sun, might heat up to 130 degrees F., an asphalt pavement to 160 degrees F. (Langewiesche, Oct. 1949, p. 192.)
Degrees of Temperature Difference	Tests show that the air temperature over a moist lawn may be 10-15 degrees cooler than it is over bare ground, and as much as 30 degrees cooler than it is over a black asphalt walkway. Plant and grassy covers reduce temperatures by absorbtion of insolation and cool by evaporation. This reduction can amount to 1,500 BTU/sq. ft./season. It is generally found that temperature over glass surfaces on sunny summer days are about 10-14 degrees cooler than those of exposed soil. (Olgyay, p. 51.)
Amount of Solar Heat Absorbtion	On a sunny day, a glass wall will admit eight times as much solar heat as a solid one. (Fitch, March, 1951, p. 104.)
Percentage of Light Penetration	Solar transmittances varies with awning materials. For direct transmittance, canvas and aluminum with separated slats both allow 0.0 percent transmittance whereas plastic allows 0.25 percent. For diffuse transmittance, canvas still maintains 0.0 percent, whereas the plastic allows 0.15 and the aluminum allows 0.20 percent. Transmittance refers to the amount of light penetrating over the total incident light.
Percentage of Reflection	A white canvas awning or a slatted, white aluminum awning reflects 70 to 91 percent of the sunlight (depending on how clean it is.) A dark green canvas awning reflects 21 percent, and a dark green, plastic awning reflects 27 percent.

CLIMATE MODIFICATION

EXTERIOR SHADING DEVICES:

Cost Savings from Sun Screens

It cost the Department of Public Works for Buck's County, Pennsylvania, $36,000 to install louvered sun screens on its administration building. It was estimated that annual savings in operating cost to be 35 percent or $16,283. Thus, the sun screens would pay for themselves in just two years. (Hastings and Crenshaw, pp. 2-4.)

Percentage of Solar Heat Reduction

An exterior shading device effective in blocking out all direct sunlight can reduce solar heat gain through a window, up to 80 percent. (Hastings and Crenshaw, pp. 2-21.)

Initial Cost Savings from Awnings

Initial cost savings have been calculated for a 400 sq. ft. room by installing awnings over two normal sized, unshaded windows. The awnings, in reducing the heat load, allowed for the purchase of an air conditioner with less horsepower (3/4 HP, instead of 1 HP.) This, in turn, permitted the use of the standard 110 volt electrical wiring, instead of the separate wiring required for 220 or 230 volts. The smaller air conditioner purchase price saves $60 to $100, and eliminating installation cost for separate wiring saves $50 to $100. (Hastings and Crenshaw, pp. 2-31.)

Operating Cost Savings from White Canvas Awnings

The operating cost savings have been calculated for the installation of white canvas awnings on six west-facing windows (totalling 100 square feet) for a house in New York City. The awnings would reduce the cooling load by 64,700 BTU's per day. Assuming an air conditioning system consumes one KWH to remove 6,826 BTU's, 9.5KWH would be saved. The savings would be $0.38 a day at $0.04/KWH. This was a figure given for August 1, a day which is less than the average for May through September. Thus, the $0.38 a day cost savings is a conservative cost figure. (Hastings and Crenshaw, pp. 2-32.)

Percentage of Heat Gain, Reduction and BTU Savings

At the 35° latitude, (North Carolina, Oklahoma, Las Vegas), a 32" overhang will completely shade in the summer, floor to ceiling glass, having a southern exposure will reduce heat gain 50 percent on that glass. This would save 1,200 BTU's. (Johnson, p. 5.)

Fraction of Sun (heat) Load Reduction	On the average, shading devices in an east and west glass surface reduce the sun loads to one-fifth, resulting in appreciable economies. (Olgyay, p. 64.)
Percentage of Shading Device Effectiveness	The effectiveness of shading devices increases 35 percent, by using outside shade protection, instead of an inside one. (Olgyay, p. 70.)
Cost Savings from Shading Devices	It was found in east Davis, a typical East-West oriented, 1,400 sq. ft. house could cut the operating cost of an air conditioning unit, averaging between \$150.00 and \$170.00, in half by shading the windows. The breakdown cost savings for each 10 sq. ft. of shade screen, each season was \$4.08 for east-west windows and \$3.83 for south windows. (<u>Davis Retrofit Manual</u> p.21)
Cost Savings of Shading	The investment cost per square feet of shading windows is from \$1.50 to \$5.00. The tax free return on investment is from 13.73 percent to 109.8 percent, a savings of \$0.55 per sq. ft. (These figures were given for a 1,400 square foot Indio tract home with R-7 attic insulation.
Cost of Fuel Savings	Cost benefits for a 1,400 square-foot house with R-7 insulation with attic in the Davis climate, with 2,189 heating degree days has shown that for an investment cost of \$150 for exterior shading, \$38.25 would be saved each season. (McGregor, July, 1977.)

CLIMATE MODIFICATION

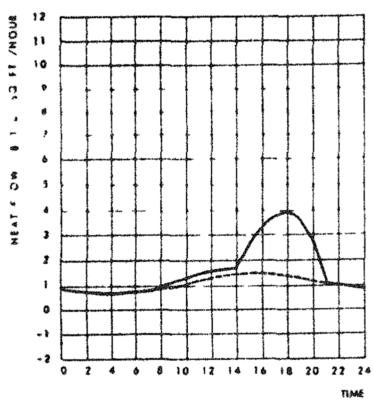
Shading Devices, Exterior:

Cost Savings for Shading

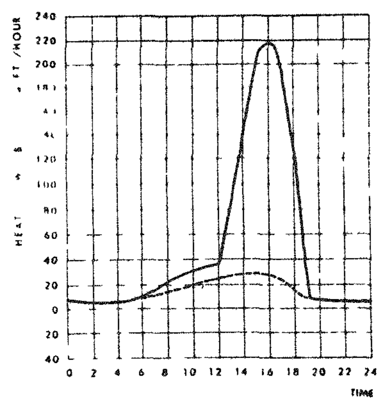
It has been estimated that by shading the windows, savings in air conditioning cost per square foot of window area on the east side would be \$8.60 - \$10.40 on the east side; \$3.00 - \$3.80 on the south and \$8.60 - \$10.40 on the west. These savings were given for a standard conventional wood-frame construction on an average summer day in July in the New York-New Jersey area. (Olgyay, pp. 72-3).

Reduction of Heat Impact by Shading

A comparison in Miami, Florida, was made between a solid wall and a glass window to determine their roles as heat barriers with their full thermal performance. Both surfaces had a west exposure. The total heat transmission of the wall (solid line) amounted to 40 BTU/ft^2/ in the shade (dotted line). The daily total transmission of the glass pane was 1,227 BTU/ft^2 in the sun, and 346 BTU when shaded. In this particular case, the glass was 30 times as vulnerable as the opaque wall to sunlit conditions. But, by shading the glass, the heat impace could be reduced to one-third. (Note, these ratios will differ according to latitude, orientation, time of year, etc.). (Olgyay, p. 66).



147. Heattransmission of a wooden wall.



148. Heattransmission of a glass pane.

CLIMATE MODIFICATION

Building Configuration:

Percentage of Reduction of Utility Usage	Detached houses were compared to apartments in the Davis community for gas and electric usage. The results indicated that the average Davis apartment uses 25 percent less electricity and 39 percent less gas per square foot than the average detached house. (Hammond, et al.)

CLIMATE MODIFICATION

Building Configuration: BTU Impact/Day in the Major Climate Zones

To investigate the shaping effect of the thermal environment, various house types were used and placed hypothetically in the four major climatic zones (cool, temperate, hot-arid and hot-humid). The house was an insulated frame construction (U = 0.13) with 40% single pane glass on the south side and 20% glass surfaces on the south side. The heat impact was calculated on an hourly basis for a 1,000 square foot house and revealed to be:

	Total Btu impact/day	
	Winter	Summer
Minneapolis	−352 400	196 600
New York	−194 300	190 300
Phoenix	42 500	338 500
Miami	171 800	231 000

Then this house was compared with houses of the same characteristics, but with different forms. In the following table, the first figure of the ratio column refers to the east-west sides and the north-south sides of the building.

MINNEAPOLIS

	Total Btu impact/day	
Ratio	Winter	Summer
5 1	−491 300	295 500
4 1	−455 600	272 500
3 1	−418 000	247 400
2 1	−380 200	220 800
1 5 1	−363 600	207 700
1 1	−352 400	196 600
1 1 5	−355 500	193 300
1 2	−366 800	196 600
1 3	−395 200	206 400
1 4	−425 500	220 600
1 5	−455 400	235 000

PHOENIX

	Total Btu impact/day	
Ratio	Winter	Summer
5 1	−15 400	489 600
4 1	−7 600	452 400
3 1	2 600	413 100
2 1	16 700	372 200
1 7 1	26 800	353 100
1 1	42 500	338 100
1 1 5	59 900	337 200
1 2	[illegible] 300	344 800
1 3	95 700	367 900
1 4	113 900	394 000
1 5	129 800	419 700

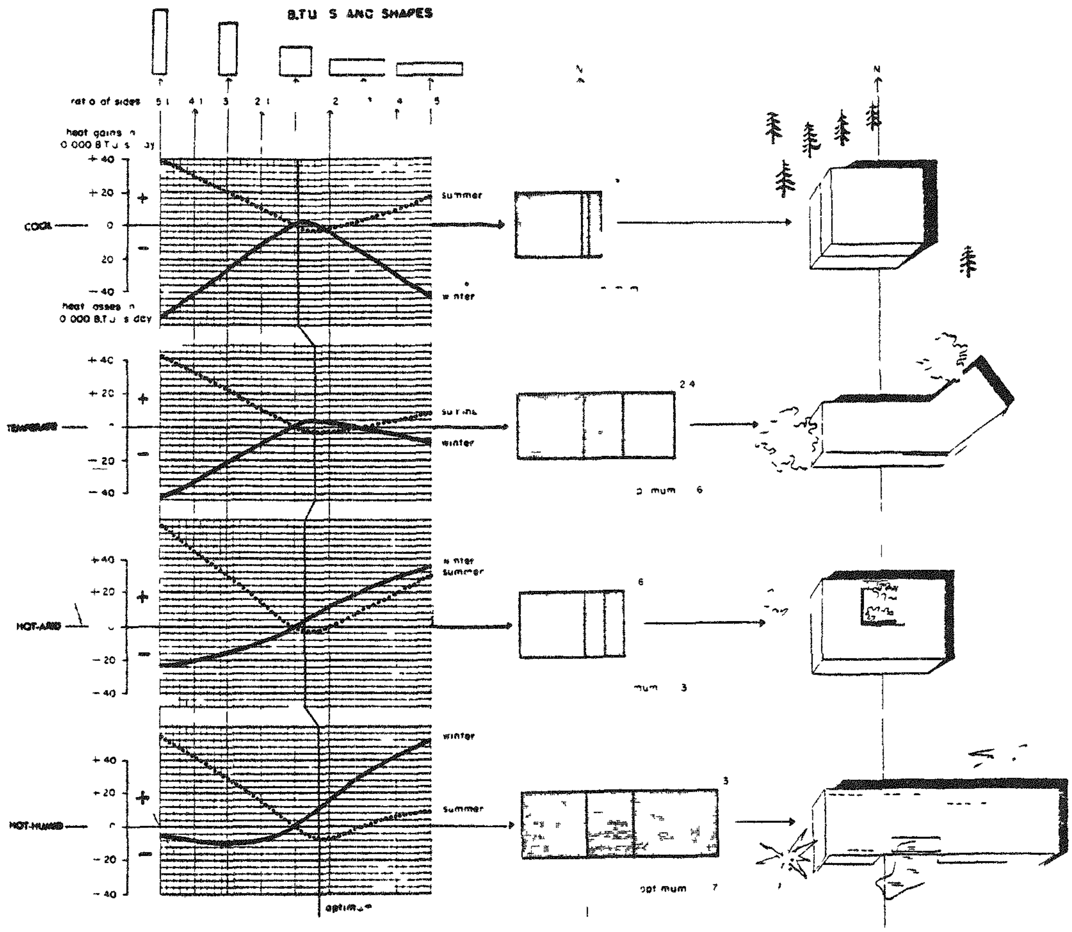
NEW YORK

	Total Btu impact/day	
Ratio	Winter	Summer
5 1	−300 900	296 300
4 1	−275 300	272 000
3 1	−247 900	245 600
2 1	−221 100	217 300
1 5 1	−207 000	203 400
1 1	−194 300	190 300
1 1 5	−189 000	184 700
1 2	−190 700	185 500
1 3	−199 600	193 300
1 4	−211 000	203 600
1 5	−222 900	214 500

MIAMI

	Total Btu impact/day	
Ratio	Winter	Summer
[illegible]	16[illegible]	364 400
4 1	155 800	334 200
3 1	152 900	301 100
2 1	154 100	265 900
[illegible]	158 900	248 200
1 1	171 800	231 000
[illegible] 5	191 300	223 200
[illegible] 2	209 300	223 400
[illegible]	243 400	231 500
[illegible] 4	273 800	243 400
[illegible]	301 300	256 000

This information was applied to determine the optimum shape for each climate zone. This application revealed that: 1. The square house is not the optimum form in any location. 2. All shapes elongated on the north-south axis work both in winter and summer with less efficiency than the square one. 3. The optimum lies in every climate zone in a form elongated somewhere along the east-west direction. (Olgyay, pp. 87-89).



174. Basic forms and building shapes in different regions.

CLIMATE MODIFICATION

TOWN LAYOUT

Transportation Percentage of Energy Efficiency	A study simulating a hypothetical situation found that communities having two-thirds of the total industrial employment facilities of a metropolitan area dispersed within a seven-mile radius (assuming residential development to be scattered), to be from 10-20 percent more energy-efficient than those in which 90 percent of the employment was concentrated within a one-mile radius of the center. (Harwood, p. 13.)
Transportation Percentage of Energy Savings	A study found that arranging a few large employment centers in clusters throughout a simulated metropolitan area, creating low density residential villages around the centers, would result in a transportation energy savings of 20 and 35 percent over the most energy intensive development pattern would be possible by the years 1985 and 2000, respectively. 25 and 30 percent savings by 1985 and 2000, respectively, were also thought possible with high density residential developments and dispersed employment opportunities. (Harwood, pp. 13-14.)
Road Reduction Cost Savings	A developer in Berks County, Pennsylvania, found a 30 percent reduction in roads required a cost savings of $720,720, when it built a large planned unit development with linear contour clustering and compared it with a conventional single family development in a grid pattern. (Harwood, pp. 24, 35.)
Road and Utility Percentage of Cost Savings	The Cost of Sprawl estimates that a planned communities can save 15 percent of the road and utility cost incurred by sprawling communities. (Harwood, p. 146.)

STREET DESIGN:

Cost Savings from Street Width Reduction

Estimates of possible savings were given for streets 24 feet wide, as opposed to the standard 40 feet wide streets. A street with 8 houses on 50 feet lots was used to demonstrate this savings.

	40 feet	24 feet
Land Use in Streets	9,600 sq.	4,800 sq.
Percentage of Lot Area	24%	12%
Land Cost - $1/sq. ft.	$ 9,600.00	$4,800.00
Construction Cost		
Street $ .50 sq. ft.	$ 4,200.00	$4,800.00
Curb $8.50 ln. ft.	$ 3,200.00	$3,200.00
Sidewalk $8.50 ln. ft.	$ 3,200.00	0.00
TOTAL	$10,400.00	$5,600.00

	CASE 1	CASE 2
Temperature 100° day	110°	100°
Air Conditioning Efficiency	x + 15%	x
Internal Temperature	75°	75°
To	35°	25°
Average Trip/week (miles)		
Auto	60	56 @ 13¢/mi
Bike	0	4 @ 3¢/mi

Assume that the interest rate possible on investment is nine percent, the interest rate on a construction loan is nine percent, and a typical air conditioning bill is $300/year.

Annual Unit Cost for Wider streets

Air Conditioner increase cost	$150	(300 x 50% = 150)
Interest on construction cost	$ 54	($10,400 - $5,600/8 x 9%)
Value of Land Cost	$ 54	($4,800/8 x 9%)
Auto vs. Bike	$ 20	(200 mi/yr. x 10¢ mi)
Maintenance	$ 20	(300,000 / 7,000 x 4800 / 9600
TOTAL	$298	

Degrees of Temperature Reduction

Parking lot shading can provide economic and energy benefits. Maximum temperatures can be kept 10 degrees F. cooler with tree shade and evaporative cooling due to transpiring leaves. (Living Systems, Final Draft Report, 76.)

Lower air and surface temperatures reduce the heat load on buildings significantly and the difference in temperature from inside to outside is reduced. A 10 degree F. reduction from 110 degrees to 100 degrees F. represents almost a 30 percent reduction in heat load, and a 40-50 percent reduction in the use of energy for air conditioners. (Living Systems, Final Draft Report, 76.)

Regulatory Policy

Land costing $10,000 per acre is roughly as valuable as pavement is per spuare foot. The effects of wider street widty for right-of-ways can be shown by comparing lot yields for 60 by 125 foot lots:

R.O.W. Width in feet	Lots Per Acre	Cost Per Lot
50	4.609	$2,169
54	4.549	2,198
60	4.461	2,241

(NAHB, Land Development Manual, p. 69.)

<u>Street Design</u>

Cost Reduction Per Lot From Narrower Streets

A subdivision proposed for North Davis was review to determine how land was allocated:

Houses	15%
Garages	5
Front Yard	19
Side Yard	11
Back Yard	22
Driveway	5
Street	18
Sidewalk	5
	100%

It was revealed in a cost breakdown that 57 percent of the lot cost was for site work (roads, lights, sewers, drainage, etc.)

$4,181	Site work
2,342	Land work
833	City fees
$7,356	Total cost to developer.

By reducing street widths 50 percent, the total site work would be $3,484, and the land saved from narrower streets would allow 8 more lots, thus reducing the land cost of each lot to $2,181.

$3,484	Site work
2,181	Land cost
812	City fees
$6,477	or, a savings of $879 per lot.

This savings represents a minimum of 12 percent in the cost to the developer, or approximately a $7.83 savings per month to the home owner on mortgage payments. (Hammond, et al., p. 28.)

Number of Miles Reduction	It was found in one study that individuals in cities over one million commute to work on the average of 14.1 miles, compared to 7.8 miles in cities under 100,000. (Harwood, p. 7.) Measurements associated with the private auto versus public transportation, Harwood, pp. 12-13.
Fraction of Transportation Energy Savings	A study using Sioux Falls, South Dakota, as a model, concluded that by increasing the density (which locates employment closer to residential areas and allows more efficient public transportation use), a city would require one-tenth the transportation energy than that required by more dispersed developments. (Harwood, p. 13.)

CLIMATE MODIFICATION

General:

Cost Savings for Energy Efficient Plan

The City of Davis, California, has adopted an energy-efficient land use plan. It has been demonstrated that there is a substantial savings to the individual resident and to the community as a whole: up to $150,000 per thousand homes for utility bills ($150 a home); up to $1,000,000 per year for every 10,000 automobile owners and at the presnet, an unquantifiable amount to the taxpayers for a reduced cost for city services. (McGregor, July 1977).

CLIMATE MODIFICATION

General:
Percentage BTU's of Heat Loss Reduction

For each of the various climate zones, a square (35' X 35') house with a floor area of 1,225 sq. ft. was compared with a house modified by: orientation, shape, and rearrangement of openings ; shading of glass surfaces; partial shading of walls; double-pane south windows; roof alteration by color and ventilations; and ventilation effect for heat created indoor, since the under heated period prevails only 12% of the year in this region. (For purposes of this Report, only those measures relating to Environmental planning and Design will be mentioned in further detail. The material presented to support the conclusion was extensive and illustrated by charts, tables, diagrams, etc. The table below was constructed to highlight the findings. Note that only those measures underlined above are included in the table. The remainder of the Total Reduction in Heat Loss and Heat Gain represent the measures not included. For example, in the cool zone, the total reduction of heat loss of all measures is 75%-65% of which is represented by orientation, shading and rearrangement of openings (8%); shading glass (54%) and shading walls (3%). Thus, the remaining 10% is a result of other measures mentioned above, but not included in the table. For complete documentation on these studies, see Olgyay, 132-52.

	WINTER		SUMMER			
	ORIENTATION, SHADING REARRANGEMENT OF OPENINGS	TOTAL REDUCTION OF HEAT LOSS OF ALL MEASURES	ORIENTATION SHADING REARRANGEMENT OF OPENINGS	SHADING GLASS	SHADING WALLS	TOTAL REDUCTION OF HEAT LOSS OF ALL MEASURES
COOL	82.631 BTU 12%	42%	-19.650 BTU 8%	-141.330 BTU 54%	-9.573 BTU 3%	75%
TEMPERATURE	86.429 BTU 19%	49%	-21.938 BTU 8%	-132.408 BTU 48%	-12.468 BTU 4%	71%
HOT-ARID	58.951 BTU 89%	--	-9.820 BTU 2%	-85.000 BTU 16%	-118.454 BTU 22%	42%
HOT-HUMID	Not* Evaluated	--*	-84.913 BTU 24%	-40.680 BTU 11%	-7.355 BTU 2%	55%

* Since the under heated period prevails only 12% of the year in this region.

APPENDIX D POLICY

Key to Policy Descriptors

Action

site selection (proximity to existing shopping centers, schools, offic[e]
recreation land).

- o clustering
- o lot size reduction
- o mixed land use
- o density, increase (direct growth)
- o building height restriction (for solar access)
- o building height restriction, reduction of (for density increase)
- o contiguous development (versus leapfrog development)
- o public transportation lines, adequate
- o bicycle and pedestrian paths, provision of
- o number of through streets, reduction in
- o street widths, reduction of
- o street lengths, reduction of
- o street layout and arrangement
- o site orientation, flexible
- o building orientation
- o building position on slope
- o lot requirement, reduction in
- o setback requirement, flexible
- o public facilities location (in clusters near high density areas and along transportation lines).
- o utilities layout
- o exterior shading devices, use of
  vegetation shading
  - for streets
  - planting more mature trees
  - planting appropriate vegetation
  - in existing developments
- o wind protection
- o tree removal restriction
- o recreational land, creation of (neighborhood parks, etc.)
- o low rise and small high rise multi-family structures, construction of
- o floor to area ratios, increase in
- o single family homes into multifamily homes, conversion of
- o multiple use buildings
- o mixed building types (to accommodate various incomes)
- o land use regulations and comprehensive plan, coordination of
- o states to conform to local comprehensive plan.

Means
(administrative tools/techniques, implementation strategies)

* land use policy
  state land use legislation
* building codes
  standards, prescriptive
  standards, performance
* zoning
  open space zoning
  - large lot zoning
  - agricultural zoning
  - sensitive area and other environmental zoning
  - scenic area zones

high density zoning
spot zoning
exclusionary zoning
cluster zoning
incentive zoning
* ordinances
subdivision ordinance (subdivision impact)
PUD ordinance
zoning ordinance (local jurisdiction)
public facilities ordinance
* comprehensive land use plan (comprehensive planning)
* master plan (general plan, development guide)
* site plan review
* state or regional agency review
* capital facilities plan (urban containment)
* tax policies
* impact statements
* land acquisition program
land banking
* transfer of development rights
* special permits
* state law/act
* density bonuses (financial incentive to developer, nonregulatory)
* annexation agreement (financial incentive to developers, nonregulatory)

Savings

construction
transportation
space heating and cooling

Descriptors	Policy proposed or implemented
* comprehensive planning	As of 1973, Eugene, Oregon, includes energy conservation as one of the goals in the "Goals & Policies Document," a supplement to its metropolitan area plan. (Harwood, 38-9.)
* comprehensive planning	Albuquerque/Bernalillo County, New Mexico includes a statement in its comprehensive plan/policy for 1975 to maximize the potential for energy conservation in land use planning. (Harwood, 39.)
* state land use legislation	Vermont requires promoters of all major developments and promoters of some minor developments without zoning controls to obtain state permits before beginning development. The applicant must demonstrate that principles of energy conservation are reflected in the design of the subdivision or development as well as incorporate technology for efficient use or recovery of energy. (Harwood, 40.)
* state land use legislation	Florida Environmental Land and Water Management Act of 1972 requires that developments of regional impact be approved by the local government in the area in which they would be located. The project must comply with the state land development plan and as of 1972 is assessed in terms of energy impact for approval. (Harwood, 41-2.)
* state land use legislation	Oregon's 1973 land use legislation regulates projects of broader than local scale. All projects of statewide significance (such as planning and siting of public transportation facilities, public sewage and water supply systems, public solid waste disposal facilities and public schools) cannot be undertaken without a permit. The permits are issued if the proposed activity complies with statewide goals (which includes energy conservation) and the comprehensive plan of the county in which the activity is to be located. (Harwood, 42.)
* state or regional agency review	The California government Code and the Oregon Review Statute include provisions for state or regional agency review of boundary changes in order to overcome obstacles to regional cooperation such as fiscal zoning and exclusionary land use regulations. (Harwood, 44-5.)
* state energy conservation goals	Oregon in 1975-76, established a Land Conservation and Development Commission (LCDC). LCDC developed statewide land use goals and guidelines which included energy conservation as one of Oregon's goals. Local comprehensive plans can be developed by the localities but they must comply with statewide goals. Planning activities (housing, employment centers, transportation and utility lines)

which affect county land use must be coordinated by the county. (Harwood, 46.)

* local comprehensive planning proposal
* state law

States can encourage local governments to develop comprehensive land use plans (partially designed to save energy) by enacting legislation which would authorize local comprehensive planning and include provisions for technical and financial support within the legislation. States can condition grants of specific state benefits and allocate specific planning powers on the basis of localities' adoption of comprehensive plans. (See Harwood, p. 47 for a review of the states which have passed various legislative measures.) (Harwood, 46.)

o coordinating land use regulations with the comprehensive plan

Land use regulations such as zoning, subdivision ordinances, regulations, etc. must conform with the adopted comprehensive plans in order to ensure effective energy conservation measures. Only county and city zoning ordinances in California are required to be consistent with the comprehensive plan whereas in Florida, all land development regulations (zoning, subdivision, building and construction regulations) must be consistent with the adopted comprehensive plan. (Harwood, 50-51.)

o requiring states to conform to local comprehensive plans

* statute

* comprehensive planning statute

Not only must localities conform to adopted comprehensive plans but also the reverse is true--state activities must conform to local comprehensive plans. A statute in Virginia requires local government and state agencies to cooperate during the preparation of comprehensive plans. Florida, Idaho and Virginia statutes require state agency action to be compatible with or conform to approved local plans. Idaho allows some flexibility by stating those instances in which the state is excused by the statute. Oregon requires state agencies and special districts to follow the same statewide goals and guidelines that localities are required to follow in preparing comprehensive plans. In addition, Oregon requires "state and federal agencies and special districts to review local comprehensive plans in order to identify and to resolve conflicts between plans and projects of agencies and local comprehensive plans." (Harwood, 50-52.)

o high density development--multifamily structures mendment

Oregon in 1975 adopted an amendment to its tax laws which insures that property assessments conform to the density permitted by zoning. Thus, developers are required to put multifamily housing on land zoned for dense development. (Harwood, 70.)

o high density development - height restriction modification * ordinance # transportation	Montgomery County, Maryland on January 29, 1974 adopted an ordinance which authorizes the creation of transit station development zones for high density, multistory buildings within walking distance of transit stations. This ordinance recognizes that congestion which might accompany increased density can be lessened by integrating the more intense land use with transportation planning. This encourages individuals to use conveniently located public transit. (Harwood, 70.)
o high density development - lot size reduction proposed	It has been proposed that rigid lot size requirements be reduced to encourage more dense development. It is argued that some regulations specifying front, back and side yard requirements are so modest that they serve no useful purpose. An example mentioned is that a side yard requiring eight feet does not greatly reduce congestion, guarantee a nice view, or always enhance privacy. (Harwood, 71.)
o high density development - floor-to-area ratios, increase in	Floor-to-area ratio (FAR) refers to the amount of lot space a building can occupy based on the total square footage of all the floors. If the floor-to-area ratio is .5 or 50 percent, then a one story structure can occupy one-half of the lot space whereas a two story structure can only occupy one-fourth the lot space. Some communities use FARs because traditional setbacks, yard and height requirements are eliminated and flexibility of building shape and orientation is allowed which permits new buildings to use energy conserving techniques. (Harwood, 71-72.)
o high density development - multi-family structures proposed * special permits # transportation	Converting single family structures into multi-family structures increases density by allowing spaces such as basements and unused rooms to be converted into a rental unit or an apartment. This offers the opportunity for individuals employed in the Urban Center to eliminate long trips if located in the suburbs. A special permit could allow for the conversion of single family structures into multi-family structures. (Harwood, 72.)
o setback requirement, flexible * ordinance # space heating and cooling	Increasing density may cause a loss of privacy. To compensate, Davis, California proposed an ordinance which deregulates fence setbacks. The common practice is to locate fences 18 feet from the sidewalk whereas the proposed ordinance will allow a 7' high fence to be located four feet from the sidewalk (except where they might interfere with traffic signage and signals). (Living Systems, March 16, 1977, 19-21.)

* exclusionary zoning high density, compact development * local zoning ordinance # transportation # space heating and cooling	Pennsylvania, New Jersey, and New York prohibit exclusion of multifamily housing from communities, however, Ohio gives its residents the right to deny rezoning to allow high density residential development, by popular vote. High density, compact development promotes energy savings in both transportation and space heating and cooling. Localities can encourage high density compact development through zoning ordinances which reduce "minimum lot requirements, permit additional multifamily housing and modify maximum height limits and the FAR" (floor to area ratio). (Harwood,74-6
* mixed use zoning o mixed land use * transit station - residential zone * transit station - mixed zone # transportation	Mixed use zoning can imply 3 types of mixed use: 1) combining buildings with different uses in the same zone; 2) mixing uses within the same building; 3) combining residential areas of varying sizes and prices in the same area. Montgomery County, Maryland has a variety of economic levels within walking distance of transit stations and consumer stations. "Another zone, the transit station-mixed zone (TS-M), also provides for mixed uses, but is intended for locations near transit stations where substantial commercial or office uses already exist." The TS-M zone minimizes the use of the auto and also eliminates rigid height, bulk and layout requirements. (Harwood, 76-7).
o multiple use building * zoning ordinance # transportation	Multiple use buildings, in addition to providing greater operating efficiency and rejuvenating the downtown areas, reduce transportation requirements. Local zoning ordinances can be modified to permit multiple use of buildings. Many cities (e.g., New York, Chicago, Baltimore, Washington, D.C., San Francisco, Little Rock and White Plains, New York) and many localities have implemented this strategy. (Harwood, 80-81.)
o mixed building types for various incomes * ordinance * incentive zoning # transportation	Ordinances and zoning restrictions that ban multifamily housing in communities or that require a fixed percentage of low and moderate income housing, can enable blue collar workers to locate closer to their jobs. However, this particular type of legislative act has been considered as "being a taking of property without just compensation" in an ordinance in Fairfax, Virginia, but a similar ordinance in Montgomery County, Maryland "remains intact." (Harwood, 82-3).

* cluster zoning subdivision ordinance o clustering # space heating and cooling # transportation * special permit * site plan review	Permitting the clustering of buildings allows developers to take advantage of energy conserving techniques such as efficient building layout (shelter each other from the wind in winter yet allow summer breezes), orientation and landscaping (less grading is required and more existing trees can remain). These create a savings in space heating and cooling costs. There is also a savings in transportation since clustered developments typically have shorter roads and utility lines and also can be located near various activities (places of employment, shopping, schools, etc.) thus minimizes individual trips and encouraging public transportation. Cluster zoning or subdivision ordianances relaxes yard, setback and lot size requirements. To insure that the developer does indeed take advantage of energy conserving techniques, a special permit or a site plan review can subject the developer to energy efficient standards mentioned above (building orientation, street and building arrangement, and landscaping). (Harwood, 85-6.)
o street design * subdivision laws proposed space heating and cooling	Street layout determines the orientation and shape of the lot. This in turn, determines the orientation and the shape of the building on the lot. Flexible subdivision laws could ensure street design which is energy efficient; i.e., would allow buildings to be oriented for optimum solar radiation and to be arranged to protect one another from harsh winds. (Harwood, 88.)
o orientation, flexible * zoning ordinance # space heating and cooling	A zoning ordinance in Buchanan, New York allows for a variation in the orientation of structures for the benefit of climate control provided certain requirements are met. (Harwood, 89.)
* zoning ordinance o shade trees o planting appropriate vegetation o planting trees in existing developments o planting more mature trees # space heating and cooling	An ordinance in Davis, California requires shading for parking areas, existing developments and new commercial development. Shading of these areas must conform to minimum standards. Some of the criteria which must be met include: the tree planting design must shade a minimum of 50% of the parking area at noon on August 21 within 51 years of the planting and the trees selected must cast moderate to dense shade, be long lived (over 60 years), do well in an urban environment, require little maintenance and be able to survive one year with no irrigation after establishment. (Living Systems, March 16, 1977, 76-79.)

* zoning ordinance tree removal restriction # space heating and cooling	Fairfax County, Virginia adopted an ordinance which requires developers to secure a permit from the county for tree removal if five or more acres are intended to be cleared. This can have an impact on energy demand if large shade trees and wind buffer trees are intended to be removed. (Harwood, 90.)
o recreational land, convenient- ly located proposed # transportation	It is proposed that conveniently located recreational land (urban parks, neighborhood parks, regional parks) be required by localities (for small parks) and by developers (within subdivisions or other conveniently located areas). Large regional parks should be located close to metropolitan areas. All would encourage walking or bicycling and discourage use or reduce length of trips by the automobile. (Harwood, 93.)
* statutes * ordinances o dedication of recreational space # transportation	"Some states and localities have passed statutes and ordinances incorporating dedication [of parks and recreational space] and fees-in-lieu provisions". It is found that the dedication of land for park and recreational uses will be supported by most states. This measure serves to provide recreation close to home, thus saving in transportation costs. (Harwood, 95.)
bicycle and pedestrian paths, provision of * state law # transportation	In 1971, Oregon enacted a bicycle and footpath law which "requires one percent of state highway funds awarded to a city or county be used to establish footpaths and bicycle trails along highways, roads and streets that are being constructed or relocated. (Harwood, 97-98.)
o bicycle and pedestrian paths, provision of * state act # transportation	California's Bikeway Act establishes the provision of a bikeway transit system. The selected routes are based on the need of employees, students, businessmen and shoppers and must be designed for the physical safety of the bicyclists and the bicycles property as well as accommodate bicycle users of all ages. The construction of bikeways and related facilities receive priority and bikeways serving mass transit terminals receive top priority. (Harwood, 98.)
o bicycle and pedestrian paths, provision of proposed # transportation costs	A proposed method of ensuring bicycle and pedestrian paths is to require developers of large-scale projects to include bike and pedestrian paths connecting residential areas with activity centers within the project. (Harwood, 98.)

bicycle and pedestrian paths, * ordinance # transportation costs	Davis, California, has adopted an ordinance which requires: developers to submit a map showing pedestrian and vehicular circulation systems (which encourages energy conserving transportation systems) and that these systems be orderly and convenient (providing the most direct route possible for the pedestrian and the bicyclists). (Hammond, <u>et al.</u>, 36.)
o street widths * subdivision ordinance proposed # transportation # space heating and cooling	Streets that are wider than they need be consume large amounts of energy. Additional energy is expended not only on the initial cost of construction but also for the continued cost of cooling the buildings in the summer. Large areas of asphalt increase temperatures in the microclimate. Subdivision ordinances could be changed to require street width reductions. (Harwood, 98-99.)
* zoning * ordinances o clustering o utility layout o slope orientation building orientation o building position on slope o wind protection o natural ventilation o shading # space heating and cooling # transportation	Vermont requires state development permits for all major developments. A checklist of energy efficient site planning objectives is used by the reviewing agency to determine whether or not the development permit should be issued. These energy conserving techniques listed in the site planning objectives are specific to Vermont's climate; i.e., they stress the minimization of heat losses. Other localities could provide a checklist appropriate to their climate (Harwood, 100.)
* subdivision ordinance proposed o density, increase o mixed land use o site selection # space heating and cooling # transportation	It is proposed that in addition to efficient site planning objectives, that a subdivision ordinance could also include density, mixed use locational and design considerations. An ordinance should be designed according to the environment of the region involved. It should be flexible allowing developers to make trade-offs if other strategies can be shown to be more energy saving. (Harwood, 103.)

zoning ordinance
site location
construction
proposed

Ramapo, New York uses an approach which withholds permits for subdivisions and developments until a project accumulates a fixed number of energy conservation points for employing various land use features based on site location to facilities. These "points could be granted for proximity to transportation lines, proximity to other developments, cluster zoning, percentage of multifamily homes, self-sufficiency of the development, availability of bikeways, etc." (Harwood, 103-4.)

* PUD ordinance
o clustering
o vegetation shading
o vegetation ventilation
o street lengths, reduction in
o utilities, reduction in
o building orientation
o layout and arrangement mixed land use
o site selection
o road layout
transportation
space heating and cooling
construction
* zoning ordinances local governments

Planned unit developments (PUD) are "characterized by a single,integrated plan for an entire project." They offer an opportunity for all energy efficient techniques mentioned in the margin. Eliminating rigid lot size use and relaxing density regulations allows: a mixture of building types and uses; clustering of buildings; utilizing vegetation for shading and ventilation, efficient road and utility systems, and optimal building arrangement and orientation. These energy conserving techniques are assured to be met since PUDs are subject to site plan review. Existing PUD ordinances can be amended to include energy conservation by simply inserting appropriate phrases (such as optimization of siting, orientation, layout and utilization of natural cooling and ventilation) or by changing phrases to explicitly state energy saving techniques. Several states have included a PUD ordinance in the zoning ordinance. "Local governments will be primarily responsible for adopting and implementing PUD ordinances." It is estimated that some 18 states now have some form of PUD enabling legislation. (Harwood, 107-9, 114-15, supra note 122.)

* incentive zoning - density bonuses
o density, increase in
space heating and cooling
transportation

High density in development can reduce heating and cooling costs, transportation and construction costs. Developers can be encouraged to build at higher densities than normally allowed (if they provide suitable amenities to compensate for the problems caused by increased density) by providing bonuses (economic benefits). These can be mandatory or voluntary. Of course, maximum density allowance must be established. Several states have utilized bonuses to achieve energy efficient project designs and locations. Some of these states and the amenities specified are: Eugene, Oregon, dedication of land for bike paths; San Francisco, proximity of buildings to transit stations or provision of rapid transit; and Prince George's County, Maryland, provision of pedestrian paths linking housing to major transportation terminals, provision of common open space for recreation and preservation of stands of trees. (Harwood, 116-122.)

* annexation conditions proposed
# clustering
# mixed land use
# road layouts

Conditioning annexation is another non-regulatory techniques which can be used to ensure energy-efficient developments. When a developer applies for annexation of property outside municipal boundaries, the municipality can provide services (such as utilities, lighting, etc.) on the basis of whether the developer employes energy efficient techniques (clustering, multifamily housing, mixture of land uses, transportation layout, etc.). (Harwood, 122-3.)

* public facilities ordinances
o contiguous development
o site location
construction
transportation

An ordinance that requires developments to show that a project will be served by adequate public facilities in order to be issued a permit will promote energy-efficient growth. Ramapo, New York, is one area which utilizes a public facilities ordinance to guide residential developments. A permit is required for residential development in Ramapo and is issued only if a developer shows that the site has existing facilities (sewers, drainage facilities, public parks, public schools, roads, and firehouses) that are adequate. A total of fifteen points, acquired from the quality of the facilities and their location to the proposed project, must be attained in order to be issued a permit. Developers are made aware of the timing and location of future facilities and services from reviewing the town's capital facilities and services program. Other localities have adopted similar ordinances to control the location and sequence of growth. (Harwood, 136-142.)

* open space zoning
o contiguous development
* large lot zoning
* agricultural zoning
# transportation
# construction

Open space zoning is a technique used to prevent or minimize land development in areas remote "from employment, shopping and other traffic-generating destinations." Large lot zoning is one kind of open space zoning which can be used to promote energy conservation. For example, large lot zoning can be required for the urban fringe which would leave smaller lots closer to the urban core for development. Environmental zoning can prevent or limit the development on land ecologically sensitive or unsafe for development. (Harwood, 154-59.) Open space zoning may be implemented at the local level but should be supported by states to prevent leapfrogging to areas with less stringent development controls. (Harwood, 163.)

land acquisition
* land banking
o site selection
transportation

Land acquisition programs can be used to restrict or prevent developments permanently or temporarily. States can enact legislation permitting acquisition of various land uses such as agriculture and scenic easements. It is proposed that land be authorized for acquisition for the purpose of directing growth toward the urban center. Land banking is an extension of this proposal in that it involves placing restrictions on the land when it is allowed to be developed. (Harwood, 164-166.)

* Transfer of Development Rights (TDR)
o contiguous development
transportation
construction

Transfer of Development Rights can be used to promote orderly, compact growth. A TDR by building structures on the land, transfers the right to modify the natural environment from one parcel of land to another. Some TDR's are similar to the concept of clustering; i.e., they only allow transfer of development rights between contiguous development. (Harwood, 173.)

* energy impact statements

space heating and cooling
transportation

"Energy impact statements provide a means for state and local governments to assess the overall energy impacts of a proposed project and to determine whether efforts have been made to reduce the energy demands that the project may generate." They serve as a check on the changes that would occur as a result of a proposed project and also inform the public and developers of energy conservation. "Twenty-five states have adopted environmental impact legislation or regulation modeled on NEPA" (National Environmental Policy Act of 1969). Nine of these states "explicitly require analysis of the energy demand generated by the project and of the sources of energy that will meet the demand." All projects in California that may have a significant effect on the environment (except those involving a "ministeral" act by the government) prepare an environmental impact report. The guidelines as they now stand allow flexibility for the state and local governments in assessing the energy impacts of the proposed projects. The author suggests that detailed standards should be outlined in order to give the developers a better idea of the importance of various measures and in turn reinforce the attention given them by the agencies responsible for creating them. Florida's energy impact statements are designed to encourage energy conservation on a regional level. (Harwood, 193-196.)

Future Research Needs and Suggestions

RESEARCH NEEDS AND GOALS

All of the environmental design fields involved with site design for energy conservation, with the exception of engineering, have operated with a shortage of research data on which to make objective decisions. Landscape architects, architects, planners, builders, landscape nurserymen and contractors have traditionally been somewhat subjective in their approach to land use or land design problems. This has been because of a lack of hard substantive available factual data on which to base design solutions as much as it is on the traditional reliance on the sensitive and aware trained designer. The design fields have always been deeply involved in application and in problem solving with little applied research capability from within the professions. Therefore, even if each of the fields develop specific research activities there is going to be a shortage of research, researchers and research capabilities in and related to environmental design. Of necessity, then, some or a great deal of the necessary research may have to be done by some of the traditional research entities which exist locally, regionally or nationally throughout the United States. This research, however, has to be more oriented toward land planning or design for energy conservation than has been the case in the past. This may entail the involvement of design oriented personnel in the employment and the work programs of these research institutions.

In all of these suggestions for further research activity a very idealistic, visionary and theoretical approach has been taken. The resources or inclination to undertake all of these programs will undoubtedly not exist. These are, however, the suggestions from the vantage point developed during the course of this study as to what needs to be done to fill the research void which now exists. This lack of objective data on which to base design or planning decisions is causing actions to be taken which use increasingly greater amounts of scarce and expensive energy in a variety of forms. In years to come research costs to develop this data base would be amply repaid in energy savings through more efficient and effective land planning for energy conservation.

The approach to an exposition of these concepts is at the same time simple and complex. The approach deals with developing answers to the following questions:

> What needs to be done in the way of research in regard to land planning for energy conservation?
>
> Why?
>
> Who needs this sort of research?
>
> In what form should it be developed or presented?
>
> Who should or could be doing this sort of research and who should or could be supporting or funding research of the type which is needed?

Obviously it is not possible within the limits of this study and the summary report to completely and exhaustively cover each of these areas of answers.

An approach to defining the full scope of research which is needed or desirable would follow to a certain extent and yet at the same time expand upon the efforts undertaken in this specific study. Any listing of research needs in this particular field would be at best superficial and would be to a certain extent platitudinous. This total listing of needs, however, is essential in that it may point the way in the future to some individual or entity to undertake sections or portions of this overall program. In addition to certain things which need to be done in relation to land design and land planning for energy conservation, probably more important is the undertaking of research related to design for human users and human activities. The research in this overall area needs to be divided into at least five basic areas or activities based on the land planning or design process. These areas of research relate to:

> optimum site selection

- guidelines and criteria
- building siting design and orientation
- site planning and design criteria and guidelines for energy conservation
- optimum site construction techniques, methods and installation practices for optimum energy conservation, and
- site management or grounds maintenance practices to encourage energy conservation in the site on an on-going basis.

It seems that all of the research needs should be predicated with a suggestion for the establishment of a clearinghouse mechanism and role for updating research activities in a specific or particular field. This may entail the development of the Land Planning Center in the Energy Conservation Program at the Department of Energy or at the Argonne National Laboratory. Such an entity should have an on-going survey mechanism or technique to gather and disseminate information and material relating to land planning and design for energy conservation. The various research needs may be outlined as follows:

1. Literature Search. A much more extensive literature search should be undertaken than the one that was possible in the course of the study. Such a literature search would include foreign and national publications and periodicals and would entail the breaking down of gathered information and materials into segments or sections. Such a literature search might be undertaken not just by one governmental library, but might be undertaken by the Library of Congress in addition to libraries in the fields of agriculture, at the Department of Housing and Urban Development, and at the National Science Foundation. Such material might be coordinated through the Council of Planning Librarians.

2. Agency or Organization Contact. Beyond the work undertaken in this specific study, on-going agency or organization contacts should be made to gather examples, illustrations or material from professional and trade associations and government agencies at all levels to be made available to larger audiences. It may be necessary or possible to contact agencies

and organizations dealing with other climatic regions of the world to develop more complete information in land planning and design data for use in the major geographic regions of the United States.

3. Quantification. One of the great shortcomings discovered during the course of this study was the lack of numerical data or measurement techniques relating to the effectiveness for the relative options in land planning for energy conservation. At the present time there are no uniform measurements or measurement techniques to quantify the relative effectiveness of land planning and design and thus to give it the same parity as engineering and technical data available from other professional fields or areas of interest. This sort of quantification methodology or technique is essential for the field to have acceptance and to show that there is in fact some measurable difference between adequate and inadequate land planning, site selection, building, siting and orientation or site planning and design from an energy conservation standpoint.

4. Case Studies. A much more extensive and ongoing technique for gathering information and evaluating data on various case studies for projects dealing with land planning and design needs to be undertaken, implemented and organized in some uniform format. These need to be case studies of effective processes, completed products or projects and programs reported by builders, developers or designers. These case studies and the reporting and evaluation technique utilized in reporting needs to be systemized so as to be most effective.

5. Predictive Modeling. A great deal of additional research needs to be undertaken in regard to predictive modeling techniques for various alternative directions or actions on specific projects. There exists at the present time a great deal of capability to utilize remote sensing data and to couple this with various programs and techniques for computer mapping and modeling so that computer generated options or alternatives might be projected for use by designers and decision makers for specific options or sites. By utilizing some of the newer technology it is possible to project options or alternatives, uses, site orientations or planning and design alternatives relatively quickly and effectively to show the energy conserving values of certain approaches or techniques. This sort of

predictive modeling would be usable to local communities as well as the builders, developers and designers from a variety of fields. The computer and computer mapping capabilities lend themselves to this sort of activity and are able to show it in a way which is convincing to a larger audience and at a much more reasonable cost than now exists by manual forms.

6. Interpretation. There is a great research need at the present time for interpreting basic information and material as it relates to land planning for energy conservation. In many instances research data is available, but it does not now relate to energy conservation. It seems essential in any future research activities to enlist the assistance and support of persons who are able to take basic climatic or meteorological data and to interpret this in terms of the energy conservation potential. For instance, on a specific structural type what impact does a winter wind reduction have on energy conservation in that particular structure? By the same token it would be helpful to have some sort of interpretation as to the relative effectiveness of the summer shade on the south side of a structure which is provided by a tree or a group of trees on the energy conservation made possible by decreased air conditioner usage.

7. Translation. In future research activities it would seem advisable to provide for a more extensive translation either from other languages or from one technical "jargon" to a language or a graphic format more easily understood by designers. It is even within English sometimes necessary to translate information or material from a form used by a physicist or an engineer or a meteorologist to a "graphic language" which is uniformly able to be understood by designers from a variety of fields. By the same token some of the most significant current writing in this and related fields is often in German, Russian or Japanese and there is inadequate translation of this material into English.

8. Field Testing or Evaluation. Some sort of methodology should be developed for actually field testing or evaluating or developing measurement techniques for the relative energy conservation effectiveness of various land planning or design alternatives. Over the years the Highway Research Board has employed a variety of research firms to

actually field test various environmental factors in relationship to the highway environment. It seems like someone should be working toward the developing either of a case study or a field testing methodology to actually evaluate the relative effectiveness of inadequate or adequate land planning and design alternatives.

9. Energy Impact Statements. Even though such governmental criteria may never be developed or undertaken it would seem advisable in future research to develop at least a framework for energy impact statements which might be developed or utilized by local communities or others in evaluating the various energy conservation options in specific projects. At least the land planning, site selection and siting orientation aspects should be developed in future research to give parity to those factors as they relate to mechanical or engineering factors or functions in energy conservation or usage.

As mentioned previously this list is by no means definitive as to the research needs which exist or perceive to exist at the present time relating to land planning and land design for energy conservation. This does give, however, a broad overview of the needs which exist and which must be met in the years to come if designers, builders, administrators and other decision makers are to have objective data to utilize in land planning for energy conservation.

Why? Who Needs It?

The question that must be asked in regard to future research dealing with land planning for energy conservation must obviously be, why? who needs it? There is a need for research because designers and developers involved in land planning decisions which affect energy conservation use research data and at the same time they do not have intrinsically in their own field or profession the capabilities of performing the necessary studies or research. Land designers and developers involved in land planning for energy conservation base their decisions on "facts" or research data of readily available information. The decision which these individuals or groups make is no better than the "facts" or research data which is readily available to them. It is necessary then to pinpoint to a certain extent the precise audience which would need or use such information and from that to deduce a certain form that the research data must be presented in to be most usable to that precise audience. In dealing with any research or decisions made by planners, designers or developers, the ripple effect of such input data must be understood or at least accepted. The design, planning, building and building community consists of a very small number of persons or of users of such research data. This limited number, however, does have through their design, planning and building decisions an effect on a larger number of persons who use those designs over the lifetime of the projects. The audience or the groups who would use expanded research data dealing with land planning or design for energy conservation would include the following groups:

<u>Designers</u>--These would consist in most cases of
landscape architects
architects
nurserymen
landscape contractors, or
planners.

<u>Builders</u>--home builders
community developers
mobile home park developers
industrial park developers

<u>Administrators</u>--local communities
state agencies
regional authorities
federal agencies

Administrative personnel dealing with park, highway, housing, urban development, energy and defense would be able to use research data for

- decision making
- guidance of local citizen groups
- review and evaluation

<u>Planners</u>--urban
regional
physical

<u>Faculty and schools of environmental design</u>--
landscape architecture
architecture
planning

Students in schools of environmental design.

Research Form

The ultimate users of the material and their needs would dictate to a certain extent the ultimate form of the presentation of the research data. It must be kept in mind when evaluating the ultimate form of research for use by this audience that most designers are not conversant or fluent in a number of foreign languages or in a technical "jargon" of other fields such as physics, meteorology, climatology, forestry or engineering and they should not have to be in order to use basic research data. Most designers or planners express themselves graphically, therefore they understand and can utilize and communicate information graphically. Designers are usually intermediaries between the researchers and the user-clients of design projects. Many times land planners, builders, developers, and designers are eclectic appliers of concepts or ideas. In most cases some designer at some point on the project is almost always on a limited fee basis, therefore the designer and the planner need information which is easily applied, explained and defended. Most of this material will be most effective if it is in the form of books, pamphlets, audio-visual or continuing education materials which can be easily utilized and absorbed. Future research on land planning for energy conservation should be

- diagrammatic in that it bridges the gap from theoretical to practical
- it should be graphic
- it should be readily understandable or usable by the designer or planner
- it should be profusely illustrated with charts, diagrams and drawings
- it should be current or in an updatable form or format
- it should be related to design decisions or processes and should be
- pragmatic and not highly theoretical.

Who Should Do or Support the Research?

The final question then arises in regard to research relating to land planning for energy conservation. Who should or could be doing or supporting the necessary research that would be more pertinent and usable in regard to land planning for energy conservation? There is, obviously, no one group, organization or entity that could or should be doing all of the necessary background research to make land planning decisions for energy conservation.

As a summarization of any discussion of future research needs and directions dealing with land planning or landscape design for energy conservation, it is essential to outline, however broadly or generally, those organizations and entities who should be conducting research on this particular subject, or who should be supporting research which is undertaken in this general area. There are at least two types of entities which could be involved in such a research activity. The first of these are a series of new organizations who have developed in the past few years dealing specifically either with energy conservation or land planning and design for energy conservation. An example of such an institution is The Living Systems organization of California which has been deeply involved with providing guidance to local communities throughout the State of California on energy conservation options. In addition some of the existing research organizations will have to develop or devise orientation or inclination in order to meet these research needs if they are to be met. Many existing organizations have the research capability, background, personnel and experience, but have not in the past seen fit to conduct research in this particular area. Among the organizations, agencies and groups which should rightfully be involved in conducting or supporting the necessary research on site design for energy conservation would include the following:

Federal governmental agencies:
- Department of Energy
- National Science Foundation
- Department of Housing and Urban Development
- Department of Agriculture
- Department of the Interior
- General Services Administration
- Department of Commerce
- The National Bureau of Standards

Associations:
ASLA, AIA, NAHB, ULI, ASPO and AIP.

State governmental agencies involving the following program:
- Energy
- Housing
- Parks
- Transportation
- Building
- Construction

Regional research entities:
- Tennessee Valley Authority
- The Bonneville Valley Authority
- The Oak Ridge National Laboratory
- The Argonne National Laboratory

Local communities such as in Davis, California
- professional and trade associations
- schools and universities
- professional offices
- independent research entities
- new town developers
- industrial companies
- utility companies
- development and building firms

Individuals

Undoubtedly, much of this outline research will not be conducted nor developed. It should be and certainly could be within the framework of existing institutions, but with existing priorities. Hopefully this overview will provide some guidance to future researchers to show the relative needs in the fields and to establish some sort of relationship and priority among the various institutions and organizations who could or should be involved in such activity.

FUTURE RESEARCH NEEDS AND POTENTIAL IMPLEMENTING ENTITIES Land Planning and Design for Energy Conservation RESEARCH TASK / POTENTIAL IMPLEMENTING ENTITY	Federal Government Agencies LIBRARY OF CONGRESS	Federal Government Agencies ENERGY	Federal Government Agencies NAT'L SCIENCE FOUNDATION	Federal Government Agencies HOUSING & URBEN DEV.	Federal Government Agencies AGRICULTURE	Federal Government Agencies INTERIOR	Federal Government Agencies GENERAL SERVICES ADMIN.	Federal Government Agencies NAT'L ACADEMY of SCIENCES	Federal Government Agencies FED. POWER COMMISSION	Federal Government Agencies DEFENSE	Federal Government Agencies NAT'L BUR. of STANDARDS	STATE GOV'T AGENCIES	REGIONAL RESEARCH INSTITUTIONS	LOCAL COMMUNITIES	ASSOCIATIONS	UNIVERSITIES	PROFESSIONAL OFFICES	INDEPENDENT RESEARCH ORGANIZATIONS	NEW TOWN DEVELOPERS	INDUSTRIAL COMPANIES	UTILITY COMPANIES	DEVELOPMENT FIRMS	INDIVIDUALS
Literature Search	●		●	●									●			●		●					●
Agency Contact													●		●	●	●	●					●
Organization Contact																●	●	●					●
Quantification		●			●		●	●			●		●					●		●			
Case Studies				●	●	●	●	●	●	●		●					●		●		●	●	
Predictive Modeling		●				●		●	●		●		●			●		●		●			
Interpretation		●						●	●		●		●			●		●					●
Translation	●		●		●			●			●		●			●	●	●					●
Field Testing		●		●	●					●	●		●		●		●		●	●		●	
Energy Impact Statements		●	●			●	●		●	●		●		●						●			
[illegible]ing House Development	●	●	●									●	●		●	●							

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