SERI/SP--98155-1

SOLAR ENVELOPE CONCEPTS

Moderate Density Building Applications

SERI

SERI/SP-98155-1
UC Category: UC-58a, 58b, 58d

SOLAR ENVELOPE CONCEPTS

Moderate Density Building Applications

Final Report

April 1980

Ralph L. Knowles
Richard D. Berry

School of Architecture
University of Southern California
Los Angeles, California

Prepared Under Subcontract
No. XM-9-8155-1
For The

Solar Energy Research Institute
A Division of Midwest Research Institute

1617 Cole Boulevard
Golden, Colorado 80401

THIS PAGE

WAS INTENTIONALLY

LEFT BLANK

FOREWORD

Solar envelope zoning represents an especially promising approach to solar access protection. Other solar access protection techniques, such as privately negotiated easements, continue to be tested and implemented but none offer the degree of comprehensiveness evident in this approach. Easements rely on agreements between individual landowners while the solar envelope system is applied within an entire zoning district. Also, easements probably would not be negotiated until a solar system is planned or installed; the envelope approach protects access for new development so that it can benefit from a future solar installation. In this way, maximum flexibility is ensured; a quality especially important with a rapidly changing technology.

The Community and Consumer Branch of the Solar Energy Research Institute continues to be interested in solar envelope zoning and is continuing funding to resolve the multitude of issues that arise with this new concept of zoning and property law. In this report, Professors Knowles and Berry and their students at the School of Architecture, University of Southern California treat several issues related to the trade-off between development potential and solar access protection for moderate density commercial and residential development. Their results are very encouraging. In a variety of case study designs for commercial office buildings in Los Angeles, floor area ratios of 2.25 to 4.73 were achieved. For moderate-density housing, averaging results from six different sites, a density of 52 dwelling units per acre was achieved. These findings clearly indicate that urban densities and solar envelope zoning are compatible. The City of Los Angeles, through the Mayor's Energy Office, the City Planning Department, and the City Attorney's Office, has been examining the feasibility of translating the study results into zoning proposals.

Results of this work will be available in the spring of 1980. Currently, SERI is developing a work program with the University of Southern California to continue study of the solar envelope concept, concentrating on the application of the solar envelope to a high-density urban redevelopment project and also to the infill of multi-family housing on sloping sites.

These studies mark a beginning in the effort to introduce solar energy technologies in crowded urban environments where the bulk of U.S. population resides. Solar access protection is a necessary condition for the widespread use of solar energy in cities. We hope that the results of this research project and the others to come will help address some of the concerns regarding development potential and solar access protection, and will ultimately help cities achieve a higher degree of energy self-sufficiency.

Robert Odland, Branch Chief

Peter Pollock, Staff Urban Planner

Community and Consumer Branch
Solar Energy Research Institute
Golden, Colorado

April 1980

THIS PAGE

WAS INTENTIONALLY

LEFT BLANK

PREFACE

The solar envelope concept documented in this report evolved from a two-fold presumption: first, that without long-term assurances of solar access to all properties in a community, there could be little hope for widespread use of solar energy in buildings; second, that access to sunshine would become increasingly important to American society, not only for purposes of encouraging energy conversion, but also as a means for enhancing the quality of urban life. The basic value premise of the study, then, was that access to the sun's rays should and indeed could be guaranteed in an equitable way to everyone living or working in an urban environment.

The envelope concept seems to offer an approach to providing solar access that potentially could be utilized by any community, irrespective of changing economic or technological factors that would affect how the sun might actually be used by property owners. Each land parcel in a community would have its own defined solar envelope and each envelope would determine the maximum building bulk that could be placed on the parcel without casting shadows on any adjoining properties--during specified times of the day throughout the year. In other words, the envelope was conceived to function as a control mechanism to limit building and development on all properties so that predictable amounts of solar irradiation would be available to all properties.

The guarantee of solar access over the useful life-span of buildings requires a legally tenable regulatory mechanism that could first be applied evenhandedly throughout a city and then maintained over a long period of time. To provide for access on raw land undergoing development, the envelope concept probably could be implemented in the context of subdivision regulations. However, since the concern of this study was with solar access in urbanized areas, the solar envelope has been applied as if it were a conventional zoning envelope; and the zoning framework offers some distinct advantages.

If a community wanted to encourage capital investment in new development in general and solar energy applications in particular, then it seems clear that regulatory constraints would have to be applied in a form that would allow property owners and investors to anticipate what was likely to be built on and around any given parcel of land. In built-up cities, zoning has long provided the most widely used and best understood means available for implementing community planning, land use and development policies; and zoning law has been well tested in application at the local level of government. Hence, while there are other strategies that might be used by urban communities to accommodate solar access, none appear to match the level of certainty that would be provided by the envelope-zoning approach: certainty as to the present and future development potential of all land parcels and certainty as to present and future access to the sun.

While the envelope concept and zoning approach are clearly quite simple, the envelope forms and methods for generating them are admittedly not so simple, particularly when applied to an actual urban environment. This study has addressed what appear to be some of the most basic complications, but the report is necessarily limited in its scope. It does not attempt to explore all the regulatory, developmental or economic implications of solar access; nor does it examine all the critical variables that are germane to the envelope-zoning approach, such as hillside conditions, landscaping or highrise buildings which will be covered in future work.

The focus of this research has been mainly limited to testing the applicability of the solar envelope on a variety of typical urban sites, assuming moderate-density objectives for development that would be applicable to almost any city. Earlier studies of the envelope approach (not reported here) clearly indicated that there would be no significant problems in providing solar access at low densities. Moreover, low-density development appeared to have little if any applicability to the in-fill and rebuilding needs of most cities, large or small. At the mid-range of development density, however, significant problems did appear and the research was subsequently focused to examine these problems specifically.

The solar envelope, by definition, constrains building bulk, and hence development density, in order to provide solar access. In applying the envelope concept, it would obviously be necessary for a community first to establish its development and solar access needs, and then to determine generalized envelope-zoning rules that would be appropriate to both needs.

One of the earliest fundamental questions addressed by the research was how to formulate specific envelope-generating rules that would achieve a reasonable balance between development and solar access. Two different approaches were explored in the study. One was established to fit commercial development opportunities in one particular area of Los Angeles, the other to fit residential development possibilities in another part of the city. The rules for both cases and the simulated development results are fully documented in the report. The two approaches used in the study, however, should be considered hypothetical. They illustrate how different land-uses, different urban characteristics and different development objectives could be handled in establishing envelope generating rules. The rules themselves and the resultant envelopes are appropriate in a strict sense to only the two case-study areas, and they should be considered applicable to other urban locales only in a general sense. What might be an appropriate application for one community or land-use could well be wholly inappropriate elsewhere. With this caveat in mind, the material in the report should lead the reader to a better general understanding of the extent to which the envelope varies according to specific land-parcel size, orientation and geometry. The report also describes how the envelope form is influenced by differences in subdivision platting and the nature of surrounding buildings.

Latitude also affects the envelope form. The significance is only briefly noted in the report, but the zoning envelope approach appears to be a generally applicable means for guaranteeing solar access in all parts of the United States. A fully convincing demonstration, however, may ultimately require a replication or extension of this study at differing latitudes. Hopefully, such work will be undertaken in the future; and with this possibility in mind, the hypotheses, the testing strategy, the conceptual premises and the simulation methods have all been fully documented in the report.

Finally, while the solar zoning envelope might provide the means for guaranteeing solar access, it obviously can do so only by constraining development density. Hence, one of the key objectives of the research was to discover the extent to which the envelope might provide other development and design opportunities. This dictated a need for extensive development simulation studies and required the resources of a large number of designers. The building development studies reported here were undertaken by the authors with two groups of young designers studying in the School of Architecture at the University of Southern California. The projects are presented as illustrative examples of development possibilities, but they do not represent exhaustive architectural studies. Although only selected design examples are included in the report, the study conclusions reflect the contributions of all the participants. It was largely their collective interest and sustained efforts that provided the breadth of exploration and the design diversity which were so essential to the research objectives.

The students who participated in the design studies for the commercial office building program were: Rosilyn Alizor, Mojtaba Amanimehr, Fred Assef, Janet Carmichael, Ann Davidson, Kitty Lew, Steve Lowinger, Hector Magno, Ron Mitnick, Roy Murabata, Carl Pelke, Paul Pina, Dan Reza, Mike Semple, Geoffery Sheldon, Scott Steele, and Mark Suberville.

The students who participated in the design studies for the multi-family housing development were: Oscar Aguilar, Alphonso Alonzo, Mike Gehring, Paul Gutierrez, Herman Howard, James Kearns, Jasek Lisiewicz, Patty Liu, Mike Marquez, Russell Meyers, Joseph Pica, Jeannette Quon, Mary Stockus, Tobie Stockwell, Barry Sullivan, and David Wallace.

Dan Reza, who served as the principal research assistant for the study, provided most of the finished drawings that appear in the report. He also assumed much of the responsibility for organizing and compiling the text and graphics in a form suitable for printing. The finished publication reflects his efforts in many ways.

THIS PAGE

WAS INTENTIONALLY

LEFT BLANK

SUMMARY

Solar energy utilization in urban areas requires public guarantees that all property owners have direct access to the sun. The study examines the implications of this premise in relation to the need for cities to also encourage or accommodate rebuilding and future development. The public policy mechanism for guaranteeing solar access is conceptualized as a solar zoning envelope that allows the largest possible building bulk on a land parcel without shadowing neighboring properties during specified times. Step-by-step methods for generating solar envelopes are described with extensive drawings, showing a variety of urban platting and lot configurations. Development and design possibilities are examined on a selected set of Los Angeles sites with typically diverse urban characteristics. Envelope attributes suitable for encouraging moderate-density commercial and residential building are examined in the context of two hypothetical but realistic development programs: one for speculative office buildings and one for condominium housing. Numerous illustrations of envelope forms and prototypical building designs are provided. The results of development simulation studies on all test sites are tabulated to show building bulk, density, land-coverage and open space characteristics obtainable under the hypothesized envelopes.

THIS PAGE

WAS INTENTIONALLY

LEFT BLANK

TABLE OF CONTENTS

SECTION 1.0
INTRODUCTION

1.1 RESEARCH OVERVIEW

The concept of the solar envelope was first developed as a framework for architecture and urban design at the University of Southern California (USC) over the period 1969 to 1971. The results were initially published in **Energy and Form** by Ralph L. Knowles, MIT Press, 1974.

In 1976, a directed research seminar was begun by Knowles at USC to further develop the envelope concept as a public zoning policy. The Planning Department of the City of Los Angeles participated in the seminar and supplied staff working papers being prepared at the time on the topic of alternative approaches to solar zoning. The results of this seminar were first published in an article, "Solar Energy, Building, and the Law," by Ralph Knowles: Journal of Architectural Education; Vol. XXX, No. 3 (1977).

In the fall of 1977, and after a year of research to identify legal alternatives to solar zoning, the first attempt was made to test the envelope concept as a straightforward zoning mechanism. For this purpose, Richard D. Berry joined with Knowles to direct undergraduate architecture students in designing buildings within envelope constraints. For the past two years, Berry has prepared architectural studio programs based on a presumption of solar zoning on real urban sites in Los Angeles.

During the academic year 1977-78, studio design tests of the envelope were based on a variety of building types and different site conditions. The design results of this effort are included in a forthcoming book, **Sun, Rhythm, and Form** by Ralph L. Knowles, to be published by MIT Press. Beginning in the fall of 1978 and ending in the spring of 1979, the studio work shown in this report was accomplished. For this work, the emphasis of programming shifted from a nearly exclusive concern with design issues in 1977-78 to an equal concern for questions of development in 1978-79. This balance between design and development forms the ground for the scope and conclusions of the work that follows.

1.2 SCOPE OF REPORT

This report covers three general topic areas: the solar envelope concept; directions for generating the solar envelope; and the potential for design and development within the constraints of the solar envelope.

Sections 2.0 and 3.0 of this report deal generally with the solar envelope concept based on time (the sun moves by day and season) and space (the constraints of property). Here the implications of the envelope for active and passive applications are described as a function of duration of solar access and site geometry. Also discussed here is the relation between the envelope and the aggregation of separate land parcels.

Section 4.0 is transitional, proceeding from a general description of the envelope to the specific methodologies for solar envelope generation used in the architectural design studio during the year 1978-79. Here the values underlying the studio are discussed and groundwork is laid for the envelope's specific application by describing some conditions of site and context that affected the envelope's shape and bulk during the studio work.

Section 5.0 of the report covers a number of site and context issues in a detailed explanation of the generation of solar envelopes. The strategy here is to demonstrate the steps of generation on several different sites. First, a rectangular site is incrementally rotated to demonstrate the impact of orientation on the solar envelope. Next, the site shape is made irregular to determine what changes this makes in the envelope's form and mode of generation. Finally, the building context of the site is systematically varied to demonstrate the impact on envelope bulk and extent of solar access.

Section 6.0 of the report is an exposition of specific design and development implications of the solar envelope. The studio results from the academic year 1978-79 are reported here in some detail. These results include application of the solar envelope in both commercial and residental areas of Los Angeles. Studio programs for each project are described as are the specific rules of envelope generation. Actual sites, envelopes, and building designs are shown and described. Measures of development potential, residential densities, and commercial floor area ratios are tabulated for each study site. The variable impact of the envelope on such urban qualities as privacy and diversity are presented through specific images. And finally, out of the numbers and images, emerging prototypes are presented that differ from current development practices.

As a point of departure and to help in the reading of this report, some conclusions are next presented about the solar envelope and about its impact on development, new building forms and on urban growth in general.

1.3 CONCLUSIONS OF THE REPORT

The most salient conclusion drawn in this report is that good-quality moderate-density urban development is possible within the constraints of the solar zoning envelope. Specific corollaries to this conclusion can be grouped under three headings: (1) the generation of the solar envelope; (2) the impact of the envelope on individual buildings; and (3) the regulation of urban growth by community-wide application of the solar envelope.

1.3.1 Envelope

The solar envelope is a space-time construct. Its spatial limits are defined by the parameters of land parcel size, shape, orientation, topography, latitude, and the urban context. Its time limits are defined by the hours of each day and season for which solar access is provided to neighboring land parcels, and the time interval will vary according to land use and community attitudes toward the value of solar irradiation.

An appropriate envelope can be generated for any land parcel and for any time interval using any of several methods: the heliodon (sun-simulating machine), descriptive geometry, or high-speed computers. The first two have the advantage of image-ability, the last one has the advantage of speed.

The most practical approach to the zoning application of the envelope appears to be one that would require developers or property owners to provide the envelope description in conjunction with the normal land survey done prior to the preparation of construction drawings and the filing for building permits. Compliance could then be appropriately checked by city building departments.

1.3.2 Buildings

Buildings designed within the solar envelope are likely to have both new and old architectural characteristics. For example, commercial structures designed within the envelope tend to be lower and to fill more of the site than do present-day buildings. To make the best use of the envelope's volume, both commercial and residential buildings are likely to employ terraces and courtyards: architectural elements from an earlier time that have the potential for improving the quality of urban life.

Without some means for guaranteeing a predictable amount of solar irradiation to all buildings, there seems to be little likelihood that developers or property owners will make any significant effort to utilize the sun for energy conversion purposes.

Significant conversion applications, utilizing either active or passive systems, would probably begin to occur in many development projects built under solar zoning requirements because any systems designed into the buildings could then be justified as having long-term utility.

On those urban sites where development would be the most severely constrained by the envelope approach, commercial building densities could be expected to range between an F.A.R. of 2.5 and 5.5, depending on building type, land parcel size, orientation, and surrounding context. Under more optimal conditions, it is reasonable to anticipate an F.A.R. as high as 7.5, particularly on sites adjacent to large open spaces.

On urban land parcels zoned for multi-family residential use, solar envelope zoning would easily allow for rebuilding of between 10 to 60 dwelling units per acre; and there are undoubtedly many land parcels in every city that would provide densities as high as 75 to 80 dwelling units per acre, without a significant loss of amenities.

1.3.3 Urban Growth

Solar zoning can be formulated in such a way as to encourage future development as well as to guarantee future solar access. This conclusion seems applicable to most land parcels in most urban areas. How much development and how much solar irradiation can be provided becomes a problem of balancing one objective with the other: a public policy issue that will have to be determined by each community in the same way that all zoning decisions are reached.

Because the envelope is defined in part by its existing surroundings, it tends to mold and scale new buildings to fit the immediate urban context. Hence, if solar access were regulated by means of a solar zoning envelope, building densities would also automatically be regulated on a parcel-by-parcel basis. This would be particularly applicable to urban areas undergoing rebuilding and infilling.

THIS PAGE
WAS INTENTIONALLY
LEFT BLANK

SECTION 2.0
SOLAR ZONING ENVELOPE

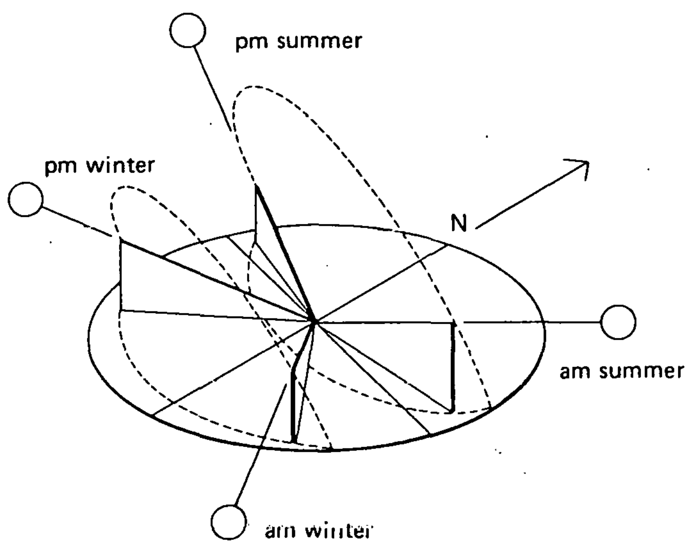
2.1 DEFINITION

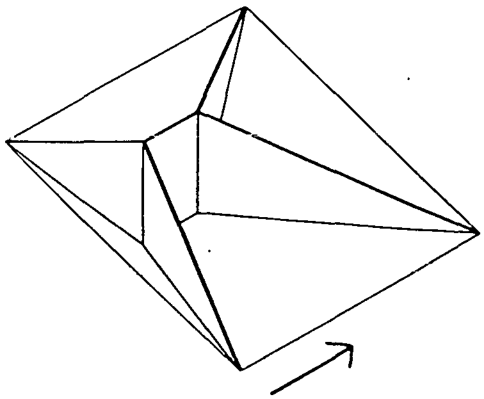
In order to use the sun, we need access to it. This basic point has recently come into focus as a topic of discussion in the United States, principally because rising fossil fuel prices are forcing us to consider the sun as a direct source of energy. Therefore, solar access has come to be viewed as a legitimate area of public policy to regulate the manner in which neighbors may or may not shadow one another.

Alternative approaches to this problem have been explored recently but are largely untested in real communities. One such approach is the solar envelope, modeled on straightforward zoning regulations with the intent of protecting future rights of solar access for buildings and for land parcels.

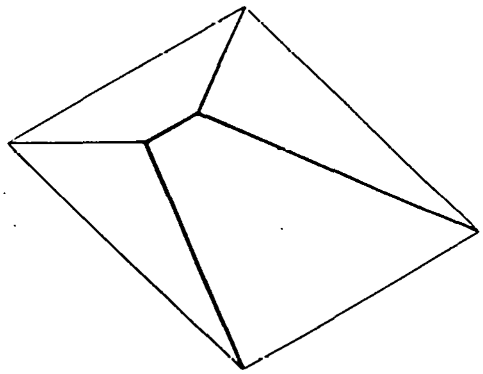
The solar envelope, as it is presented in this work, is a container to regulate development within limits derived from the sun's relative motion. Development within this container will not shadow its surroundings during critical periods of the day. The envelope is therefore defined by the passage of time as well as by the constraints of property.

The time involved is a duration of solar access, a period of direct, line-of-sight approach to solar heat and light. The period of solar access may be conceived as some segment of an arc drawn to represent the sun's path. If access is required year-around, two arcs may be used to represent paths of the sun during summer and winter.

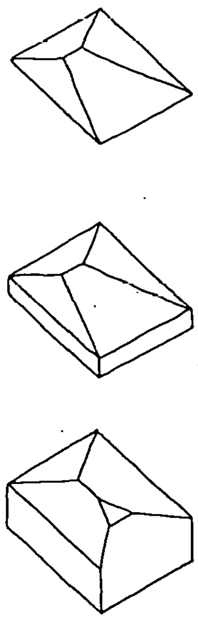




If the resulting angles of the solar azimuth and altitude are transferred to the edges and corners of a land parcel, the consequence is a set of geometric limits that derive their vertical dimensions from the sun's slanting rays.



If the entire volume implied by the vertical limits is drawn as an explicit form, the result is a container with surfaces representing the three-dimensional boundaries of development.

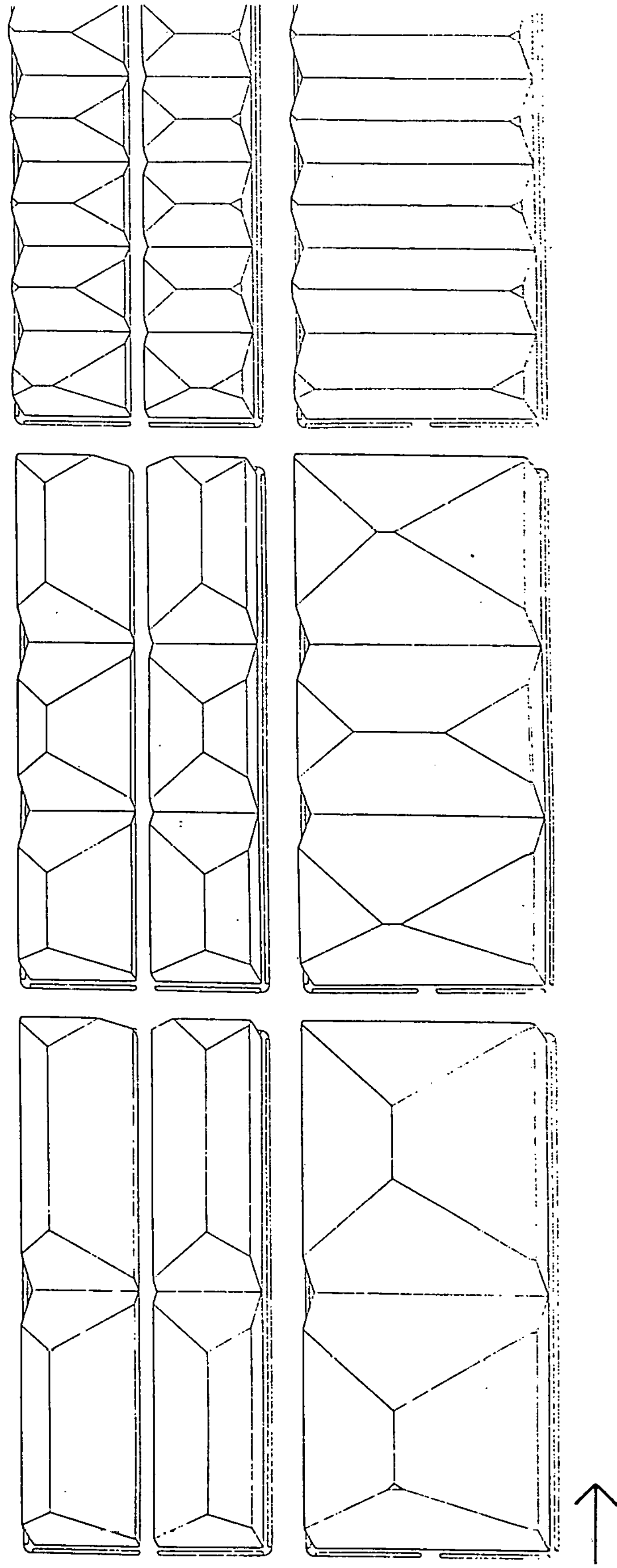


Depending on duration of solar access, land parcel configuration, and surrounding conditions, the size and shape of the envelope will vary. This work is concerned with the impact of the solar envelope on design and development under two quite different sets of urban conditions in Los Angeles.

2.2 URBAN CONTEXT

The solar envelope's size, shape, and orientation are greatly dependent on the urban context. In the United States, that context is usually influenced by a regular system of subdivisions that have geometrized the land. Streets often run with the cardinal points so that rectangular blocks extend in either the east-west or north-south direction.

If shadows are allowed to extend across streets but not onto adjacent land parcels during specified times, solar envelopes over corner lots will always be larger than those over inside lots. Block orientation will significantly influence the solar envelope and land assemblage will have different consequences related to direction.



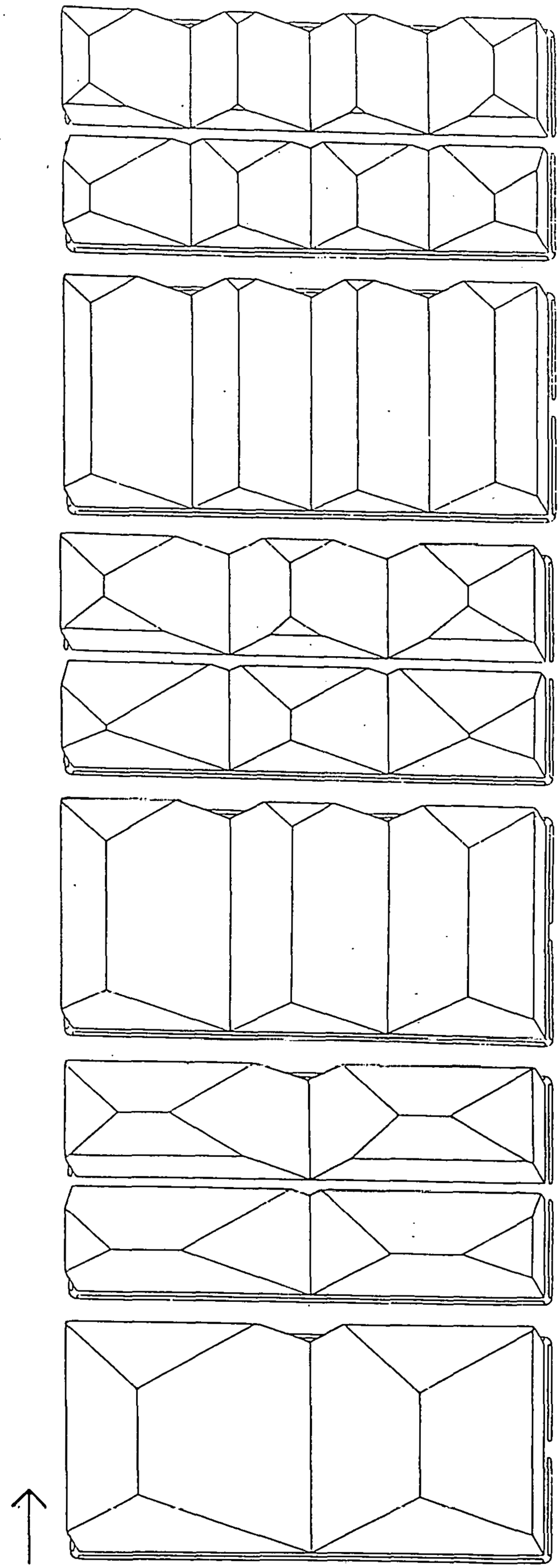
Consider first the example of long north-south blocks, with and without an alley.

Where the block has an alley, the solar envelope extends across the street in front and across the alley in back. Envelopes over corner lots are higher and contain more volume because they can extend across the street in two directions instead of only one.

As small lots are assembled, envelopes become larger and shift polarity; ridges that ran east-west over 100'-frontage land parcels change and run north-south over 200'-frontage land parcels.

This shift of the ridge orientation becomes more pronounced as the land parcels increase to 300' frontages. The same observation can be made of envelopes over land parcels that run the full block depth without an alley.

Land assemblage in east-west blocks produces similar changes of envelope size and shape but significantly different envelope polarities.



Where the block has an alley, 100'-frontage land parcels have envelopes with north-south ridges. As parcels increase to 200' frontages, the ridges begin to peak and 300'-frontage land parcels have ridges with an east-west polarity. Where blocks have no alley, the change of ridge orientation from north-south to east-west would not occur until the land parcel encompassed the entire block.

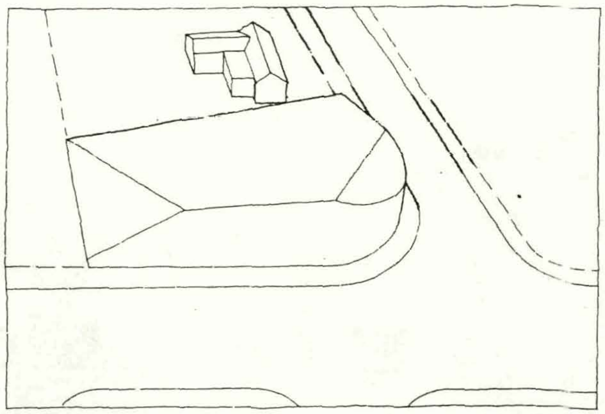
The significance of envelope polarity is related to south orientation and to its advantages for energy conversion by active or passive means. The advantage of south exposure lies with small land parcels in long north-south blocks but shifts to large land parcels in east-west blocks.

A strategy of seeking south exposure in new subdivisions or in urban rebuilding would, over a period of time, result in a differentiation of land parcel size based on block orientation.

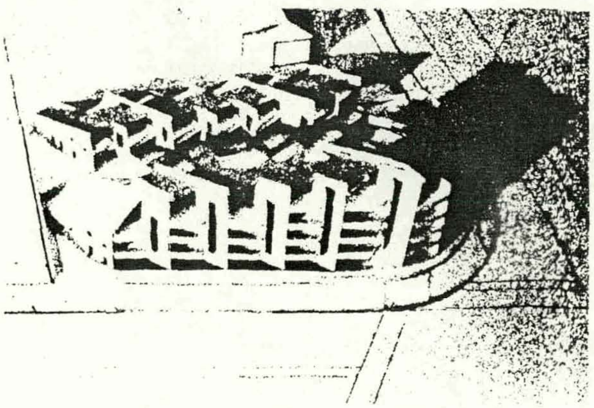
2.3 LAND USE CONTEXT

A second contextual influence on the solar envelope's application is land use. This study looked at both commercial and housing development. Differences between the two appeared because each was located in a quite different part of the city and also because a different attitude toward solar access was taken for housing than was taken for commercial development.

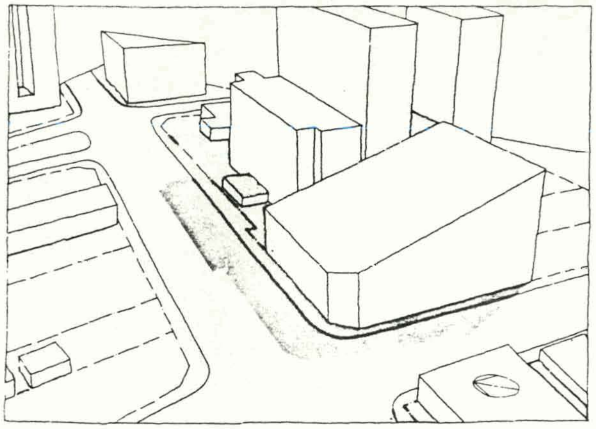
The attitude taken about solar access for housing was that the entire land parcel was to be protected. Such protection was guaranteed above an 8-foot privacy fence. The resulting envelope defined the largest volume possible on residential land parcels without casting shadows over 8 feet in the direction of the neighbor's property line. When the property line fell between adjacent lots, the envelope sloped to 8 feet at the dividing boundary. Where shadows could extend to property lines across the street, the envelope was quite high.



Each envelope's size, shape, and orientation were determined by a specific set of rules. In turn, the contained building's general location and form were regulated by the solar envelope. Within the general limits of the envelope, design variety appeared in the way units were arranged around open spaces. None of the designers used the envelope's entire volume because the quality of life of the inhabitants would have suffered from lack of light and natural ventilation.

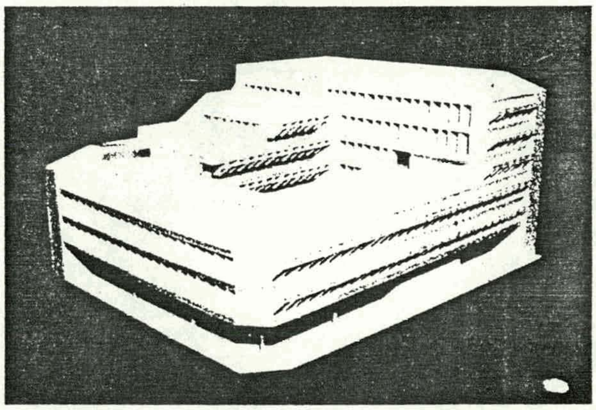


While the study intent was to provide relatively high densities and solar access to surrounding land parcels, high priority was given to the inhabitants' quality of life including solar access, cross ventilation, and open space for all units within each designer's project. The design results demonstrate that these priorities can be met within the solar envelope at densities averaging 47 dwelling units per acre.



The solar envelopes for commercial development were determined by a more complex physical context and by a different attitude about solar access than was the case for housing. Solar access for commercial development was guaranteed with relation to surrounding buildings rather than land parcels. As with housing, shadows could extend across the street within the specified period of access. But unlike housing, where access was guaranteed above 8 feet at the property line, several less stringent conditions were set to provide greater development opportunities.

These different conditions for solar access to commercial buildings allowed some shadowing of existing and of future surrounding buildings. In addition, the solar envelope was extended continuously over adjacent land parcels to allow owners the option of sharing a common wall to gain development potential.



The resulting buildings were designed as speculative commercial structures with retail space at the street level, parking below grade, and office spaces that did not exceed 30 feet in depth. This last requirement, based on the desire for daylighting, resulted in courtyards, terraces, and sunscreens as design elements.

Most designs ranged from three to six stories and were set close to the sidewalk rather than back from it. This was the result of the need for more ground coverage to make up for the lack of height.

While the study intent was to provide solar access to surrounding buildings and to use solar energy, especially for daylighting within the project building, high priority was given to development feasibility. The design results demonstrate that floor area ratios of 3.8, well within the range of moderate-density commercial development, are attainable.

SECTION 3.0
SOLAR ZONING--POTENTIAL

3.1 ADVANTAGES OF ZONING APPROACH

There are two compelling advantages to guaranteeing solar access through zoning rather than through alternative legal approaches.

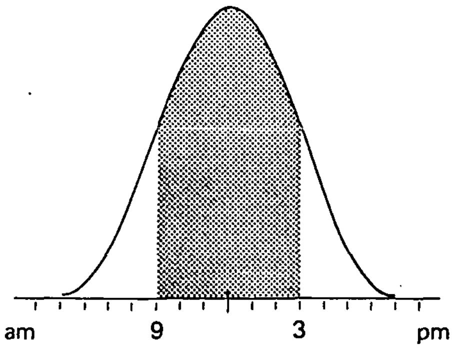
First, zoning is a form of local governmental control that is necessarily sensitive to specific and immediate conditions. Since the envelope for any land parcel is intimately based on surrounding conditions that exist or that may exist in the future, local application seems essential.

Second, solar zoning can be formulated as a relatively simple modification of present zoning precedences that govern building height and bulk. Both concepts are concerned with defining the limits of development by means of a regulating container or envelope.

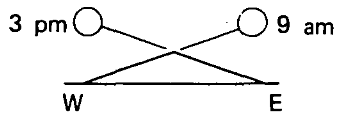
3.2 TIME CONSTRAINTS

The solar envelope differs from conventional zoning envelopes in that time as well as space data are required in its description. In fact, time and space become inversely related: the greater the time interval provided for solar access, the less space there will be under the envelope. This of course is because the sun's angle of altitude defines the slopes of the envelope. Early morning and late afternoon sun angles are relatively low while mid-day angles are correspondingly steeper--at any season of the year. Hence, on a daily basis, progressively increasing the hours of solar access will set cut-off times that provide progressively less and less building volume under the envelope.

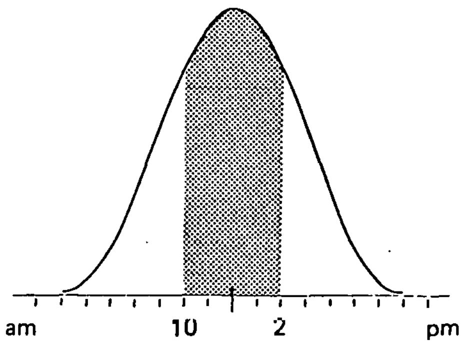
Determining exactly what cut-off times might be used, then, will depend not only on how much solar irradiation is desired but also on how much building volume is required to accommodate development needs. Some comparisons are useful to clarify this inverse space-time relationship that is unique to the solar envelope.



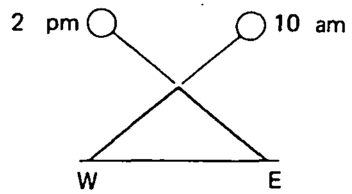
Suppose, for example, it was determined that 6 hours of solar access were needed for energy conversion purposes. And for convenience, the requisite cut-off times were kept symmetrical so that sunshine was guaranteed between the hours of 9 am and 3 pm. This can be described in a graph form that plots available irradiation from sunrise to sunset. The 6 hours of solar access, from 9 am to 3 pm, will contain most of the useful irradiation available during the day (the shaded area under the curve).



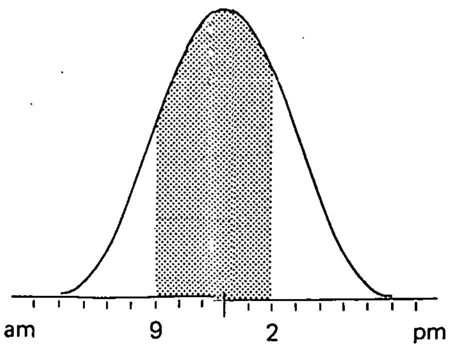
The resulting envelope will be defined and the developable space regulated by the sun's rays as they strike the site from the east in the morning and from the west in the afternoon.

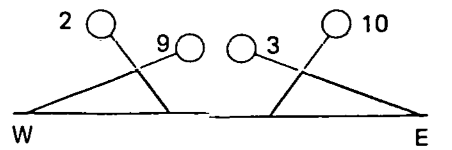


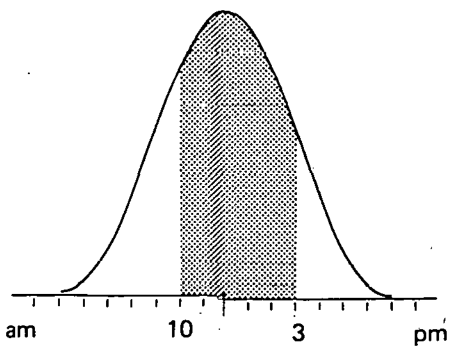
If a shorter period of solar access were to be taken, say from 10 am to 2 pm, the area under the irradiation curve defines less total energy than did the corresponding 6-hour period. But, because the period of access starts later in the morning and ends earlier in the afternoon, the sun's rays will strike the site from higher in the sky at the two critical cut-off times. The resulting envelope consequently will contain more volume. The less the duration of solar access, the more space provided by the envelope.



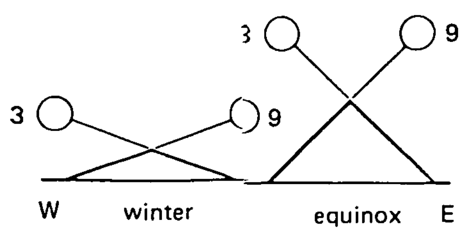
When the period of guaranteed solar access is asymmetrical around noon, the solar envelope will have unequal slopes on the east and the west. For example, if the period were taken from 9 am to 2 pm, the envelope would be steeper on the east than on the west because the sun is higher at 2 pm than at 9 am. Just the reverse is the case if the same duration of access were shifted to extend from 10 am to 3 pm. To keep this relationship clear may require the reminder that it is the morning sun that sets the envelope's western limits. The eastern limits are set by the afternoon's rays.

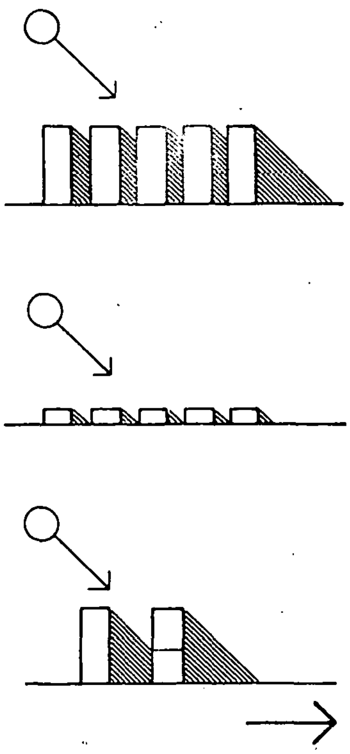






There is also a seasonal counterpart of the relationship between the duration of solar access and volume under the envelope; this seasonal relationship between time and space is also inverse. The larger the number of months of a year for which solar access is provided, the smaller the volume of the envelope. For example, if access were required for a full 12 months of a year, the envelope would contain less volume than if access were required for only 6 months, say from spring equinox through summer to fall equinox. This is due to the much lower angles of the sun's rays in winter than at the equinox.





Ultimately, the question of how to establish the exact relationship between time and space becomes a question of balancing **sun rights** against **development rights.** In any community, the question can only be resolved by informed public debate. A proper balance for one neighborhood or land use is likely to be quite wrong for another. As in all zoning, the establishment of specific public solar constraints should evolve over time to reflect the needs and desires of each city.

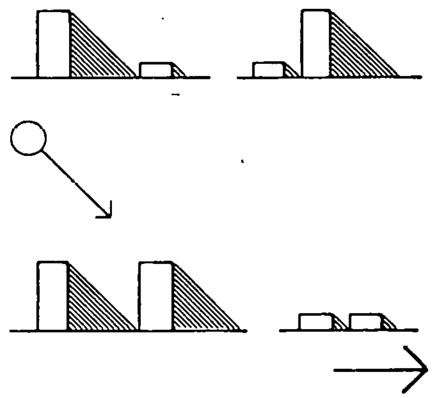
3.3 ENERGY CONVERSION CONSTRAINTS

The energy conversion requirements for solar access can be conveniently categorized in terms of three modes of energy conversion. Each of the modes can be used to describe the interrelationships among development potential, solar access, energy conversion, and land use.

The first mode, termed **roof-top conversion,** characterizes solar access to only the roofs of buildings. This would provide the maximum development potential on any given set of sites but the minimum potential for energy conversion per unit of built volume. Regulation pertaining to the envelope would only need to distinguish between tall buildings that cast large shadows and small buildings that do not. Since the *sun's direct radiant energy* would need only to be guaranteed to building roofs, any shadowing on the outside walls would have to be considered inconsequential. If light, however, were also a desired component of *solar irradiation*, the shadowing might imply a need for different uses between the upper and lower floors of a building.

Use of the roof-top conversion approach obviously has the greatest applicability in high density urban areas and would provide the greatest potential for commercial development. (Single-family residences would reverse the *relationship* between *development* potential and energy conversion but is not included in this study of urban applications of the solar envelope concept.) In many high-density commercial districts, roof-top access might well be sufficient to allow for the use of flat-plate collectors, in either new or existing structures. But such limitations on solar access would not provide for the broader options of using the whole building for energy conversion purposes.

The second approach to solar energy conversion does involve the whole building. Every building is an energy converter by virtue of the specific heat and density of its materials. Those material properties can be organized to receive radiant energy as heat, to be stored and given up over an appropriate period of time and at a useful rate. The potential for responding to daylighting needs also increases in this second approach, which is termed the **whole-building conversion** mode. If this attitude towards energy conversion is followed, differences in building sizes must be recognized in formulating solar envelopes and in regulating solar access. For example, small buildings sited to the south of large buildings would allow closer packing than the opposite case would. Large buildings would have to be spaced farther apart than smaller ones. The certainty the designer or developer would have in planning uses for the roof would, of course, be extended to the whole building.

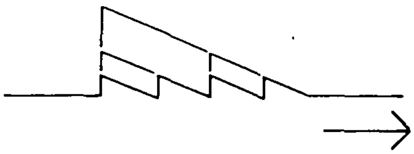


The potential building volume attainable from this approach is less that that attainable from roof-top conversion, but the potential uses of solar energy are increased. The whole building's shape and structure could be adapted to conditions of light and heat for improved quality of life. This approach is probably most applicable to moderate-density commercial and residential development.

The third approach would allow for **whole-site conversion** and therefore requires a guarantee of solar access to the ground surface of adjacent land parcels. This approach is the one that would provide the greatest potential for energy conversion and probably the least volume for development.

The premise of this approach is that all possible users of solar energy–the ground itself, plants, insects, animals, people, as well as buildings--would be guaranteed direct radiant solar energy.

Under this most inclusive approach, solar envelopes would tend to differentiate themselves according to difference of land parcel size. This would result from providing access to the land itself. In general, larger land parcels could be used for larger buildings because the envelopes would be larger.



In cases where more than one building is to be placed on a single site, as in a planned unit development, the proportional relationship between any single building and its immediate surrounds may result in complex sets of buildings in which individual building size and even the sequence of development for solar access might need to be regulated.

The singular advantage of this whole-site approach lies in the generous number of design options that it would provide for improved quality of life, making it especially appropriate to housing in the low- to moderate-density range.

SECTION 4.0
STUDY FRAMEWORK

4.1 VALUE PREMISES

Hindsight suggests that our buildings and cities have been built rather cheaply compared with the high cost of maintaining them. Our standard modes of construction have included the detached, single-family residence and the high-rise commercial building. Both are energy-intensive to regulate. And our spread-out subdivisions have forced a heavy reliance on the automobile as an almost exclusive mode of transportation.

This study has looked at mid-range building densities for both residential and commercial development. We have based this focus on the proposition that by replacing or infilling with moderate-density housing and mid-rise commercial buildings, two broad objectives could, over time, be attained: a reduction in energy costs both for maintaining our urban buildings and also for supporting urban transportation.

Lower transportation costs, on a passenger mile basis, would likely result from increased land densities in many cities, particularly Los Angeles. Lower costs for building heating and cooling would result from several interrelated properties of moderate-density development.

First, moderate-density housing generally exposes fewer heat-transferring surfaces than does the average detached house. Second, lower heights for commercial buildings would require less vertical servicing. Third, and most important of all, to reduce the energy demands of our buildings, it has been demonstrated that solar energy can be used very effectively, by both active and passive means, at moderate densities.

Solar access to moderate building densities does raise new design and development problems. It also raises new opportunities for improving the quality of life; and a major concern of this work was to explore means of using the sun's light and heat directly to enhance the living and work environment. When access to the sun can be guaranteed, many opportunities arise to use windows, skylights, courtyards, and terraces for the natural light and warmth they can bring into buildings.

It is evident in current buildings that the once traditional means of using sunlight and heat have fallen into disuse. We have, of course, become accustomed to a reliance on mechanical support systems; but comfortable environments were created by architectural means long before the advent of central heating, ventilating, and air conditioning. Some of those means are probably worth relearning since they often produced spaces of extraordinary quality. It seems reasonable to expect that a sophisticated integration of machines with a more traditional architectural style could produce buildings that are more efficient in terms of both energy consumption and environmental quality. The prerequisite, however, is in assuring solar access.

4.2 STUDY OBJECTIVES

Two general hypotheses were formulated that could be subjected to testing in different geographic regions, in diverse urban areas and by a variety of research teams, if necessary. The hypotheses paraphrase two recurring arguments that have been raised against the solar envelope concept. (1) The solar envelope would not provide sufficient building volume to encourage new development in urban areas of moderate to high density. (2) The solar envelope would not allow sufficient design freedom to attain good architecture and urban design results.

Preliminary work with the envelope concept clearly indicated that solar access could be achieved under a variety of urban conditions but there were indeed some potentially serious limitations on development density. Hence, the initial research concern focused on how to treat the envelope so as to balance development needs with solar access needs.

The primary objective of the study, then, was to undertake a real-world test of solar zoning that would reflect (as closely as possible) conditions of actual development. Our concern was that development programs, design procedures, and evaluation format should be conservative, straightforward, and consistent with the rebuilding potential of at least two different study areas.

4.3 DEVELOPMENT SIMULATION STRATEGY

The general strategy used to test the development and design implications of the envelope concept can be outlined as a set of steps, stated as procedural imperatives.

(1) Identify a variety of potential development parcels having diverse characteristics of parcel shape, orientation, and urban context.

(2) Establish a set of rules for defining solar envelopes that balance development needs with solar access needs and that fit the land use and planning characteristics of the study area.

(3) Generate solar envelopes for each selected building site, using the established rules as a hypothetical zoning ordinance which is viewed as being applicable to all future development.

(4) Establish a realistic and detailed building program that reflects the actual development potential of the study area and that complies with the objectives common to speculative development.

(5) Apply the building program consistently to all selected sites, instructing a set of independent designers to explore the development possibilities within each site envelope.

(6) Identify the range of acceptable building options and the maximum building volumes that can be generated on each site.

(7) Evaluate the feasibility of all building solutions and the implications for development.

(8) If either development potential or solar access potential is found to be too limited (relative to community values), modify envelope rules and reiterate steps 3 to 7.

Each of these steps involved a number of analytical considerations which influenced both the methods and the results of the study. The first task was to select potential development areas in the Los Angeles region that would be suitable for study purposes.

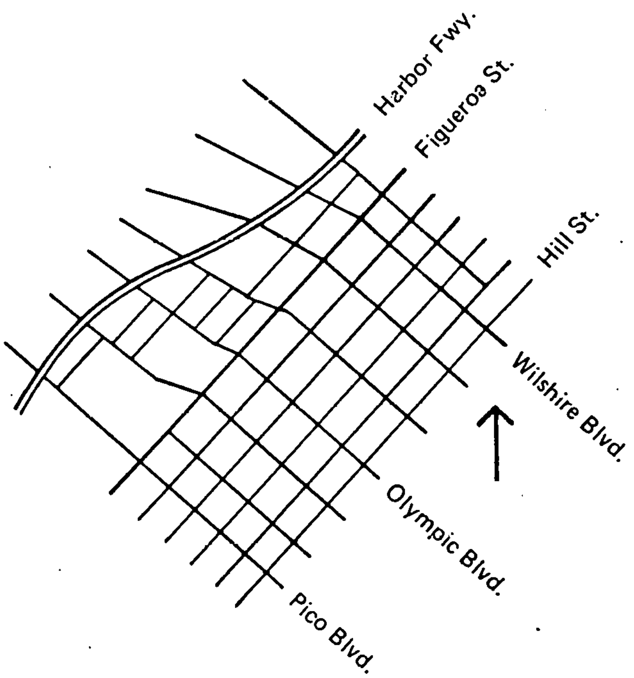
4.4 SELECTION OF DEVELOPMENT SITES

Since it was possible to solicit help from local professionals in land economics, planning, and construction, several areas in Los Angeles--both residential and commercial--were analyzed in terms of their suitability for actual development. Residential densities and commercial floor area ratios could be (and were) matched to prevailing market conditions.

The final decision was to explore the design and development possibilities of two quite different parts of the city, having two different land uses. Working in two areas allowed comparisons to be made and insured a more comprehensive test of the hypotheses than if only one locale and land use had been investigated.

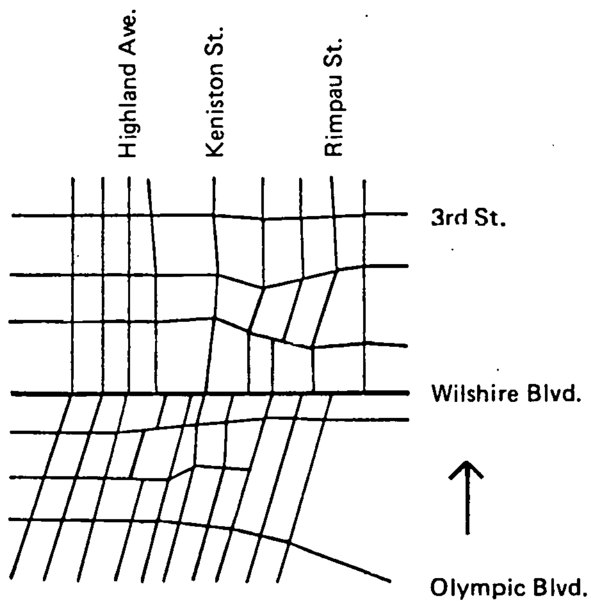
Having two study areas was especially useful because the physical surroundings of each were so different and because their street orientations differed significantly.

The study area selected for moderate-density commercial development was located on the edge of the city core, where the street pattern followed the old Spanish grid that was laid out 200 years ago when the original pueblo was founded. This grid is almost 45° off the cardinal compass points, which has significant implications for development volume under a solar envelope.



The study area for moderate-density housing was located about 5 miles west of the downtown area in a part of Los Angeles that developed much later, when the Jeffersonian grid was more closely followed in laying out major streets and subdivisions. While there is some variation from one subdivision to another, the streets run generally in a north-south and east-west direction.

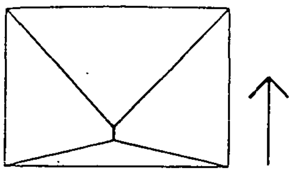
Unlike the Spanish grid, which allows the winter morning and afternoon sun to penetrate all streets, the Jeffersonian grid selectively shadows some streets. During the winter when shadows are long, streets that run east-west will be shadowed all day long. Streets that run north-south will receive sunshine during much of a winter day. These differences of street quality that result from differences of solar exposure are, if only subconsciously, felt by people and they are even acknowledged by real estate experts. But as a design criterion, street orientation is almost never examined as a basis for land use or site planning decisions.



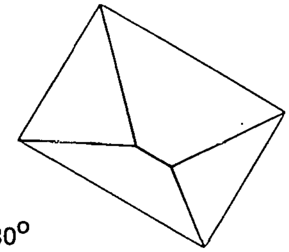
There is an equally significant aspect of grid orientation which can be quantified. It relates land parcel orientation to volume within the solar envelope.

For example, if a land parcel of fixed size (say 150 feet by 250 feet) is rotated at thirty-degree intervals, starting at 0^{o} from north, a solar envelope on that parcel will undergo a change in size and shape, if the period of solar access remains constant.

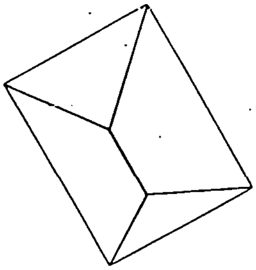
0^{o}



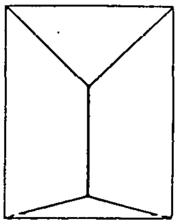
30^{o}

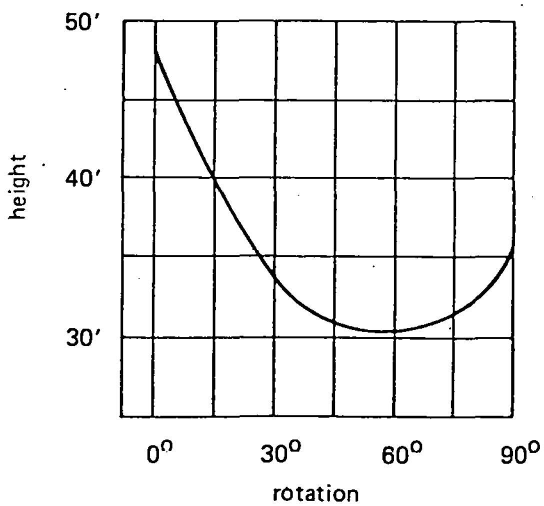


60^{o}



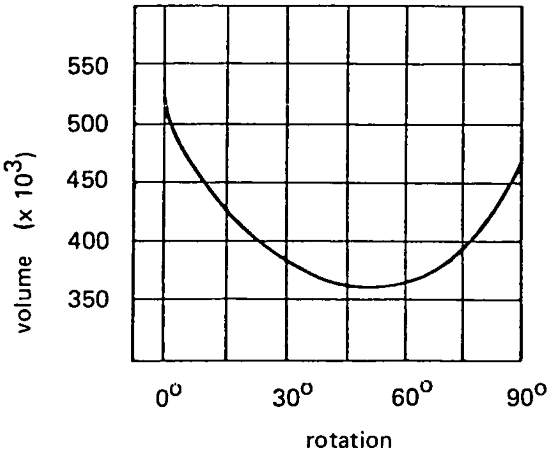
90^{o}





Rotating the land parcel clockwise will successively reduce the envelope's height, reaching a minimum at an angular rotation of about 60^{o}. At this angle, any further rotation will begin to increase the envelope height; and at a rotation of 90^{o}, the envelope height will be midway between that of the 0^{o} and the 60^{o} rotation.

There are two important observations to be made here. First, if a parcel of land is located within a grid orientation of about 60° off the cardinal points, its envelope will provide less development volume than what would be available in any other grid orientation. Second, land parcels that have their long side in the east-west direction will provide a greater volume of development under the solar envelope than will land parcels oriented long in the north-south direction.



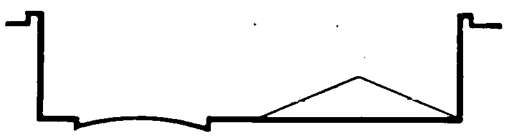
Both observations hold important implications for this study. The downtown study area was in part chosen because it had the inherent advantage of winter sun in all streets. However, the grid orientation of about 45° provided relatively small envelope volumes. The challenge then was to find strategies that could be used to compensate for this inherent limitation in development potential.

On the other hand, the orientation of the housing site provided the advantage of obtaining envelope volumes that were close to the maximum, because of the north-south, east-west orientation of most sites.

One of the major problems in this situation related to the design challenge of dealing with long winter shadows that were cast across east-west running spaces. The other problem was with achieving reasonable densities for sites located on the northside of a street running east-west, because envelopes on the southside of the street have more volume than the northside.

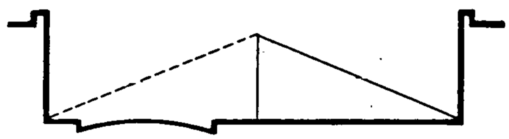
4.5 FORMULATION OF ENVELOPE REQUIREMENTS

In the study's downtown commercial area, a general strategy was devised that both increased the limited envelope volume available for development and maintained solar access to neighboring buildings. The basic problem was how to achieve a reasonable balance between solar access and development potential. In built-up commercial districts, some shadowing of a land parcel's surroundings can probably be tolerated, so long as no existing or future buildings are deprived of their energy conversion potential in a practical sense. This strategy can be illustrated in terms of shadowing conditions that would have little impact on buildings but would allow envelope volumes to be substantially increased.



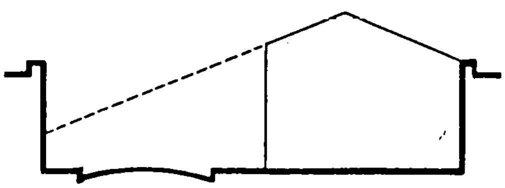
V_1=1.0

The most restrictive envelope condition would allow no shadowing of adjoining land: the whole-site approach to guaranteeing solar access. This means the envelope would touch grade at the site's boundaries. Consider this envelope (V_1) to have a volume of unity for any specified interval of access.



V_2=1.8

The most obvious way to increase the envelope height, and volume, is to allow the envelope shadows to extend across the street. In effect, the envelope (V_2) spans the street. This assumes that solar irradiation on the street has no significant energy conversion potential but this might not always be the case. Land parcels located on the corner of street intersections have the advantage of shadowing in two directions, providing corner sites with more building volume than single-frontage lots. All lots, and envelopes, would still guarantee solar access to all surrounding buildings.



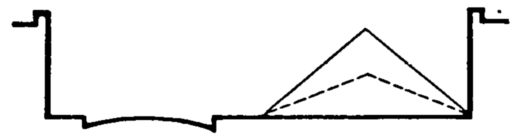
V_3= 4.8

Still another strategy, and the one used for design purposes in this study, is to allow selective shadowing of existing and future buildings as well as streets and alleys. This approach recognized that certain elements of a building, such as roofs, have a clear potential for either active or passive energy conversion. Other building elements, such as fire walls or party walls separating adjacent land parcels, could be entirely shadowed (V_3).

Ultimately, it was found that solar access could be guaranteed for all surrounding buildings, but it was necessary to allow shadowing of 30 percent of all window walls, and 100 percent of all fire walls. This seemed to provide the best attainable balance between guaranteeing solar access and encouraging future development within this particular study area.

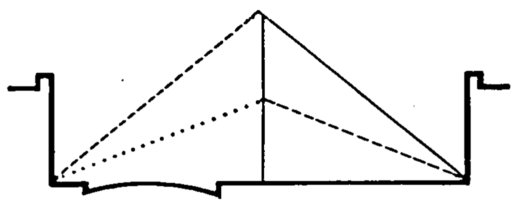
As this strategy was finally applied in the design of commercial office buildings on actual sites, it increased the envelope's volume to almost five times the volume obtainable through the whole-site strategy. The resulting building designs attained gross floor areas averaging almost four times their site areas.

The envelope modifications just described may be seen as variations on a basic attitude about land use, shadowing, and the envelope's relationship with surrounding buildings. A fundamentally different approach might seek to increase envelope or development volume by altering only the period of solar access.

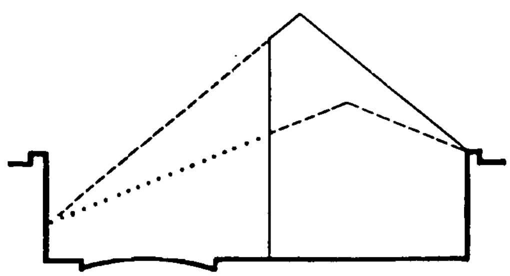


V_4=2.2

One such approach was considered that would guarantee solar access for only 6 months of the year (spring through summer to fall), but it was quickly rejected for two reasons. First, while considerable volume could apparently be gained, the envelope's sloping surfaces became very steep and their shapes in general appeared to be impractical for actual building applications (V_4, V_5, V_6). And second, the idea of guaranteeing solar access for the summer half of the year and not the winter half was inconsistent with our program values and objectives.



V_5=4.0

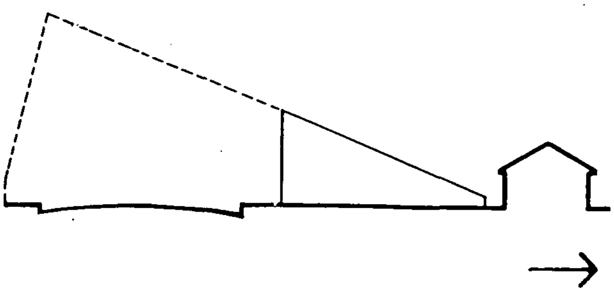


V_6= 6.0

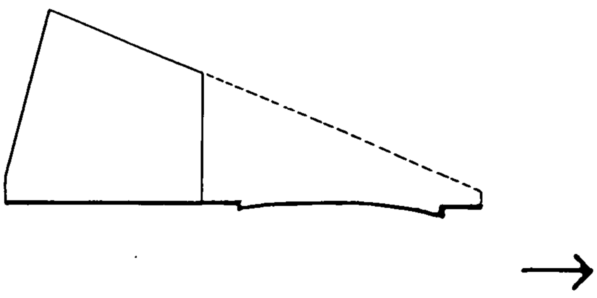
The strategy followed in dealing with residential development was to guarantee year-round solar access to all neighboring sites, allowing shadowing of the streets. Where whole-building access was provided in the commercial study area, whole-site access was provided in the residential study.

However, in order to increase envelope volume and attain more realistic densities, the final strategy used in the residental study area allowed shadowing up to 8 feet above grade at the property line.

The basic principal underpinning this strategy disallowed any construction at the property line that would cast more shadow on the surrounding lots than would a one-story, single-family house set back 5 feet from the property line. An 8-foot wall or fence on the property line produces this extent of shadowing under the conditions found in our residential study area.



These envelope requirements become most restrictive on development sites located on the north side of any street running east-west. Such envelopes are steep on the south face and gently sloping toward the north. In our particular study area, the envelope extends over a wide street on the south side and stops 8 feet above grade at the north property line, beyond which there are existing houses with normal setbacks.



Sites on the south side of the street have larger envelopes because shadows can be cast northward over the street's entire width before striking the opposing property line (raised 8 feet here).

The consequence of this envelope asymmetry produces different development potential. Designers working with the same program were able to achieve higher average densities on the south side of the street (58 dwelling units per acre) than on the north side (48 dwelling units per acre).

4.6 PROGRAMMING AND DESIGN PROCEDURES

The programs that were formulated for both commercial and residential development were generally realistic, relative to a developer's point of view. The normal profit motive was assumed. The market potential and marketability were determined to fit the specific characteristics of the two study areas. Land costs and development economics were also considered.

Each of the two programs also required conformance with local building and fire codes as well as with existing zoning regulations, with the single exception that solar zoning envelopes were to control building height, bulk, and setbacks.

The program for the downtown area specified development of a conventional multiple tenancy office building with ground floor commercial rental space. The residential program specified upper middle income, condominium housing units, having a specific mix of unit types and sizes. Marketability requirements translated primarily as partitioning flexibility in the office building program and as living amenities in the condominium housing. The major objective of both programs was to provide as much usable floor area as the zoning envelopes would allow.

The program for each of the study areas was applied uniformly to the selected sites by a group of designers working more or less independently of one another.

Two separate groups of undergraduate students in the USC School of Architecture, working in design courses under the direction of the study investigators, were asked to explore a relatively broad range of building examples on all of the sites. These student designers were encouraged to follow their own value preference, within the constraints of the program, so that clearly different design approaches would be assured.

The design process itself involved a series of progressive steps, an iterative procedure, which allowed evaluative comparisons of building options to be made as the study progressed. It also allowed for periodic input from experienced developers and practicing design professionals. Each of the development test sites, in both areas, was assigned to a minimum of two and a maximum of four designers. The designers on each site were collectively responsible for site and program analyses. Each set of designers began their studies by generating the solar envelope that was unique to their site, working first with physical models on the heliodon and then with descriptive geometry to establish precise measurements.

A detailed explanation of both drawing techniques and envelope-generation methods is presented in Section 5.0.

THIS PAGE

WAS INTENTIONALLY

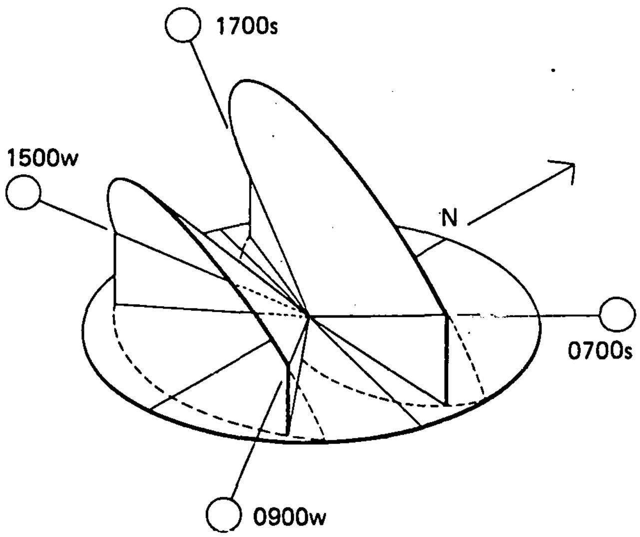
LEFT BLANK

SECTION 5.0
SOLAR ENVELOPE GENERATION

5.1 ELEMENTS OF GENERATION

One way to explain the solar envelope as a space-time construct is by graphically presenting the steps of its generation under a variety of situations. For this demonstration, grid orientation, site shape, and surroundings will be systematically varied. The duration of solar access will be held constant at latitude 35N.

The consequence of holding the period of solar access constant is that the sun's angles of approach to the earth remain a fixed set. The selected cut-off times, their altitude angles (α), and their azimuth angles (θ) are as follows: 0900-1500w ($\alpha = 17.6^o$, $\theta = 137^o$ and 223^o); 0700-1700s ($\alpha = 25^o$, $\theta = 78^o$ and 282^o). Two azimuth angles are given for each season but only one altitude angle need be given. This is because the selected cut-off times are symmetrical around noon, making the morning and afternoon altitude angles constant at a given season.



The consequence of varying site geometry and surroundings is that different combinations of the cut-off times establish the envelope's shape and bulk. To demonstrate this point it is useful to begin with a normal grid orientation, on the cardinal compass points, and then to rotate the grid - generating a new envelope each time.

Each envelope will be generated over a land parcel of 205 feet x 150 feet. Descriptive geometry will be used in a number of steps analogous to those taken in our laboratory work on the heliodon at USC. Since this procedure is based on trigonometry, the steps might be adapted for either conventional surveying practices, on site, or for envelope generation by a high-speed computer. Each method has certain advantages; however, the more descriptive techniques have the initial advantage of image-ability.

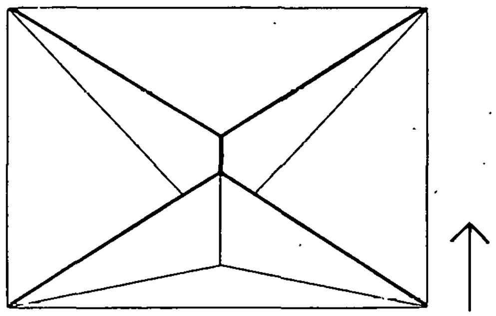
In the discussions that follow, the sun's rays will act as the descriptive elements that generate solar envelopes with reference to a site. Those rays will first be isolated and then, step-by-step, they will be combined to establish the final limits of an envelope that is a specific space-time construct.

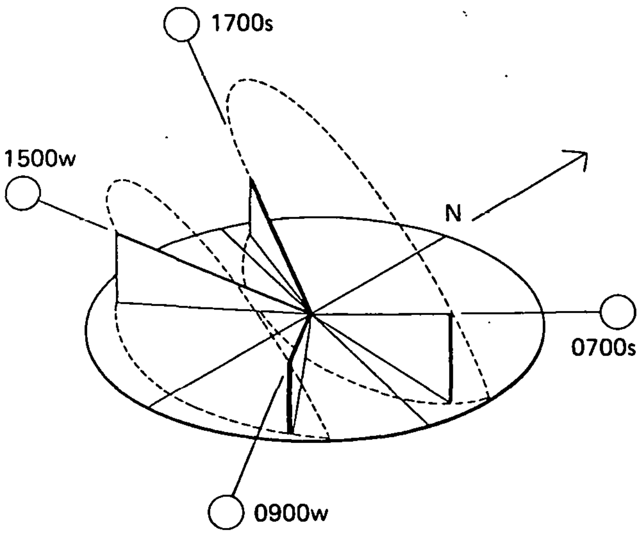
Each envelope will initially be shown in a plan oblique drawing for easy visual reference. Vertical planes will be shown extended from the site to describe the envelope's four sloping hips and single horizontal ridge.

The first envelope will be generated over a land parcel 205 feet east-west and 150 feet north-south. This orientation is referred to as 0^{o}. Each succeeding orientation will be rotated from this reference in 30^{o} intervals.

5.2 GRID ORIENTATION - 0^{o}

The first solar envelope is symmetrical in the east-west direction and asymmetrical in the north-south direction. Its four sloping hips rise to a horizontal ridge, 48.5 feet high. The enclosed volume of the envelope contains 5.3×10^{5} cubic feet.





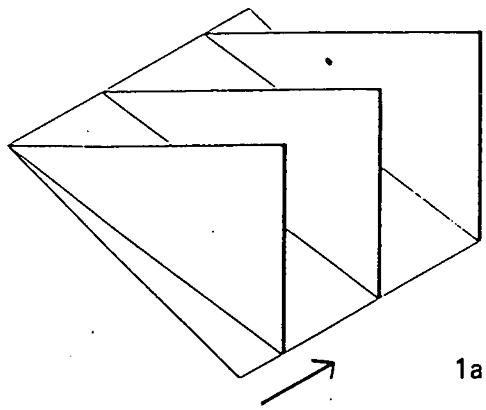
The descriptive steps that follow are all based on measures of the sun's position at those cut-off times for which the envelope is to be generated.

A convenient way to demonstrate these measures is to presume that all solar phenomena occur on the surface of a hemisphere. Where the hemisphere intersects the earth, a circle results, forming the horizon. The middle of the circle represents that point on the earth that concerns us and is identified by the intersection of two normal lines running north-south and east-west. In this construct, the sun moves in circular paths across the surface of the hemisphere. Its position at the cut-off times is shown by triangular planes set vertically, with all meeting at the middle of the circle. The base of each triangle describes the azimuth angle (θ), measured clockwise from north. The hypotenuse of each triangle marks the sun's altitude angle (α), measured above the horizon.

These measures will now be applied to a site using an asymmetrical diametric drawing. (Later demonstrations will all use plan oblique drawings that make measurement easier; but for this first demonstration, the asymmetrical diametric gives a clearer pictorial effect.)

The triangles that represent each cut-off time will be directly transferred from the solar hemisphere to the edges and corners of the site. First morning, then afternoon cut-off times will be transferred. Then the descriptive triangles that mark each time will be systematically combined to define the envelope's upper limits.

To make the sun's measures even clearer, a second description has been included for the first two steps. This second description makes use of vertical planes cut, as from the sides of a box, to cast shadows precisely covering the site.

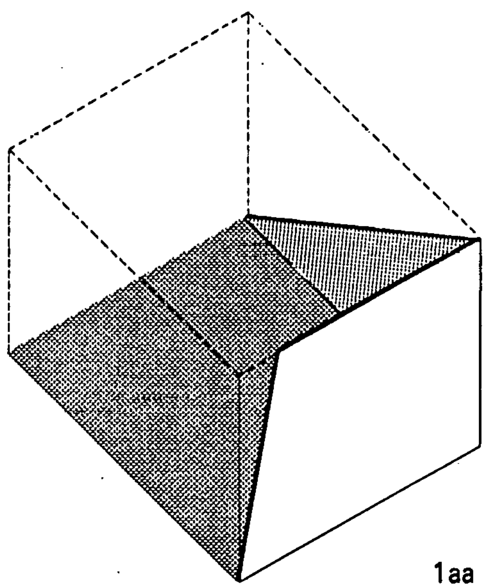


1a

5.2.1 Step 1: Morning Cut-Off Times

The summer morning rays (0700s: $\alpha = 25^{o}$; $\theta = 78^{o}$) would appraoch the site across its north and south boundaries (1a).

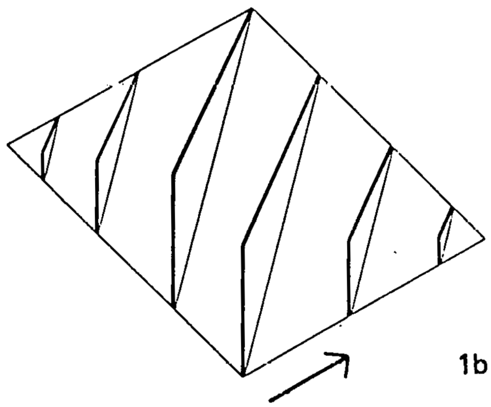
Planes located at those boundaries and cut to precisely intersect the sun's rays as they enter over the site cast shadows to the opposing south and west boundaries (1aa).



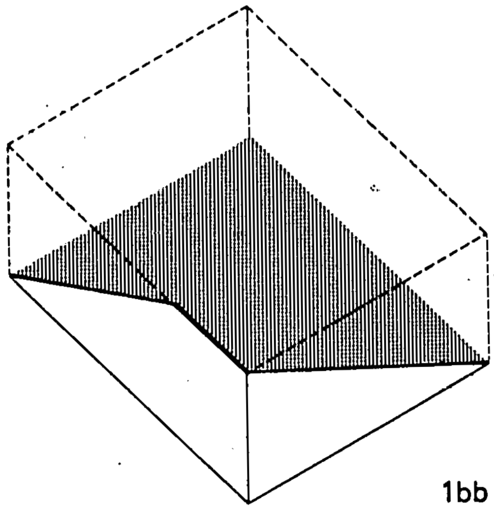
1aa

The winter morning rays (0900w: $\alpha = 17.6^{o}$; $\theta = 137^{o}$) would approach the site from the south and east (1b).

Planes located at those boundaries are shaped to cast shadows to the opposing north and west boundaries (1bb).



1b

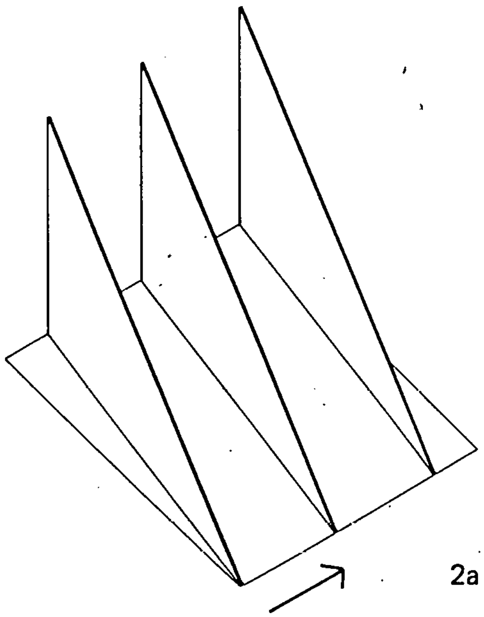


1bb

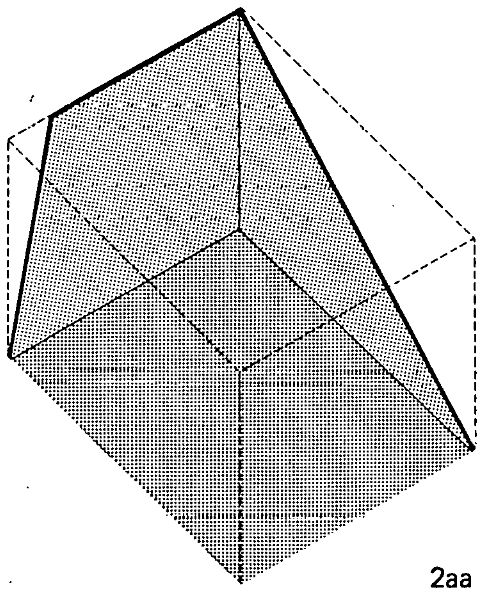
5.2.2 Step 2: Afternoon Cut-Off Times

The summer afternoon rays (1700s: $\alpha = 25^{o}$; $\theta = 282^{o}$) would approach the site across its north and west boundaries (2a).

Vertical planes at those boundaries are shaped to cast shadows to the opposing south and east boundaries (2aa).



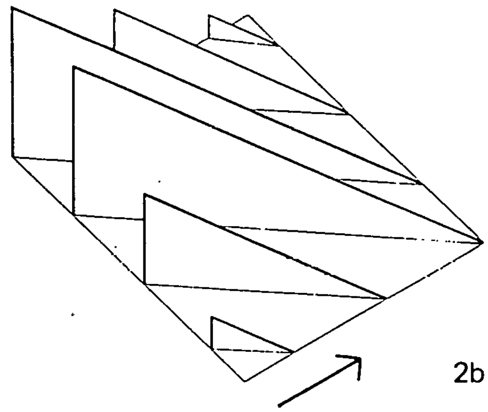
2a



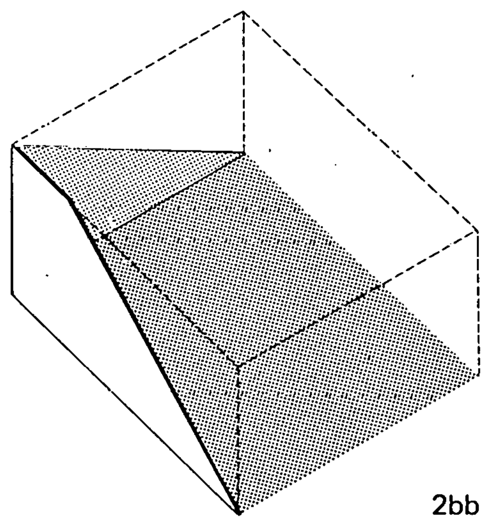
2aa

The winter afternoon rays (1500w: α = 17.6°; θ = 223°) would approach the site across its south and west boundaries (2b).

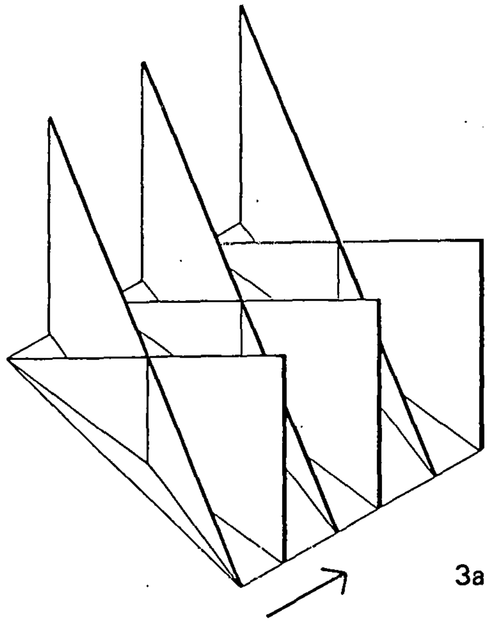
Vertical planes at those boundaries are precisely shaped to cast shadows to the opposing north and east boundaries (2bb).



2b



2bb

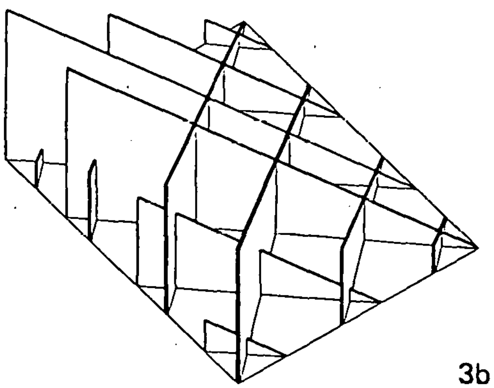


3a

5.2.3 Step 3: Morning and Afternoon Cut-Off Times

The combination of summer rays would slope across the site to strike the south and west boundaries in the morning, the south and east boundaries in the afternoon. They would intersect to define a north-south ridge running symmetrically above the site (3a).

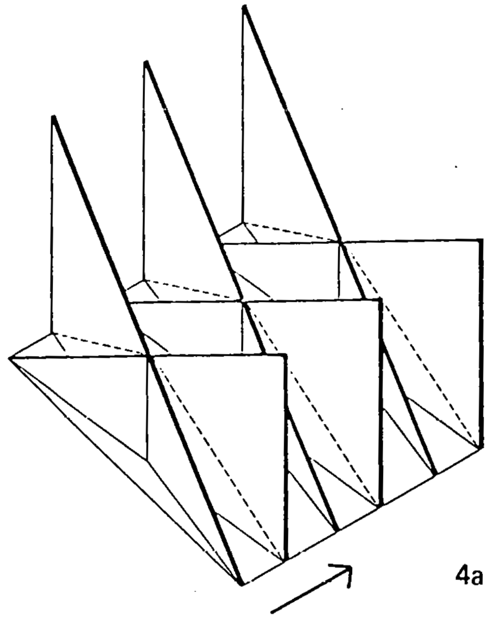
The combination of winter rays would slope across the site to strike the north and west boundaries in the morning, the north and east boundaries in the afternoon. The winter rays do not all intersect in a simple ridge as did the summer rays (3b).



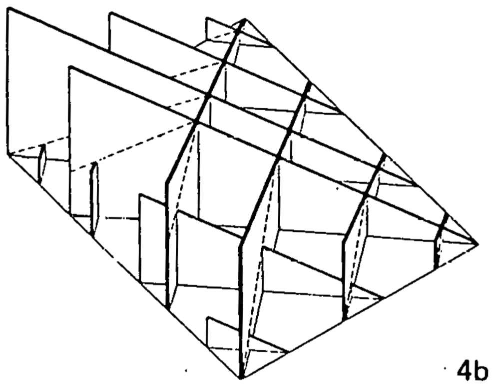
3b

5.2.4 Step 4: Indicate Redundancy

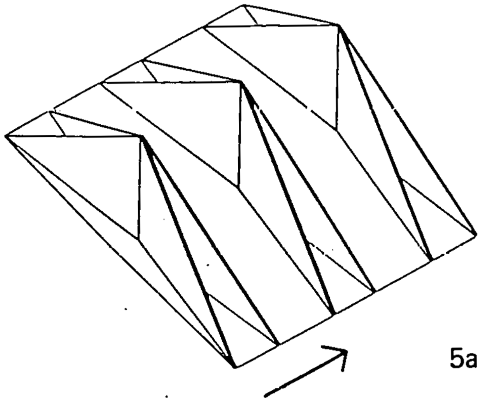
That portion of any triangular plane that rises above an intersecting plane would cast shadows off the site at one or another of the cut-off times. Such portions are descriptively redundant and are shown above the dotted lines (4a,b).



4a



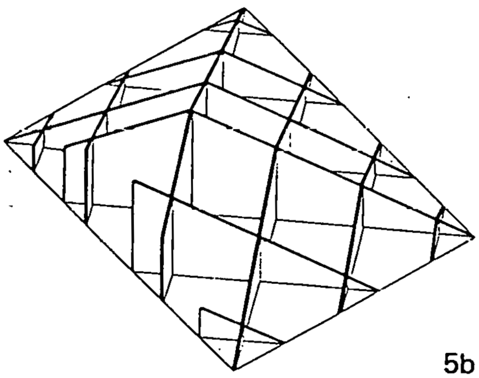
4b



5a

5.2.5 Step 5: Eliminate Redundancy

When redundant portions of triangular planes are cut away, the result is a tent-like shape for the summer solstice (5a) and an imperfect pyramid for the winter solstice (5b). Each, in a sense, describes a solar envelope that functions for one day of the year.

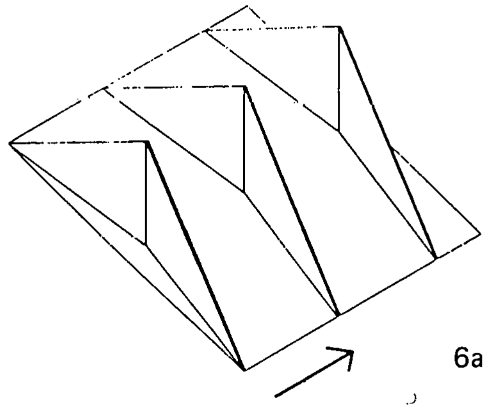


5b

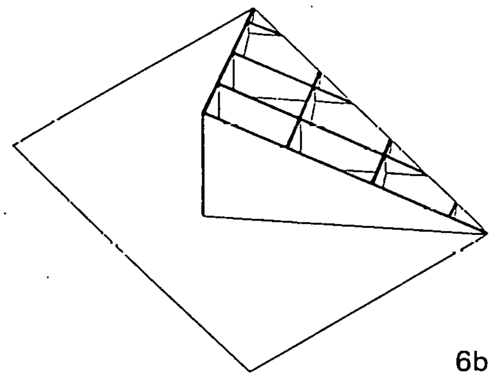
5.2.6 Step 6: Definition of Envelope Hips

External angles, or hips, are defined where two sloping faces of the envelope meet. The essential triangles that define summer faces also indicate two hips that slope from an implied ridge to the site's southeast and southwest corners (6a).

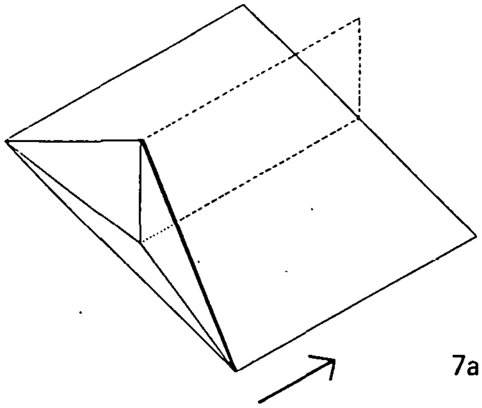
The essential triangles that define winter faces also indicate two hips that slope from a vertex to the site's northeast and northwest corners (6b).



6a



6b



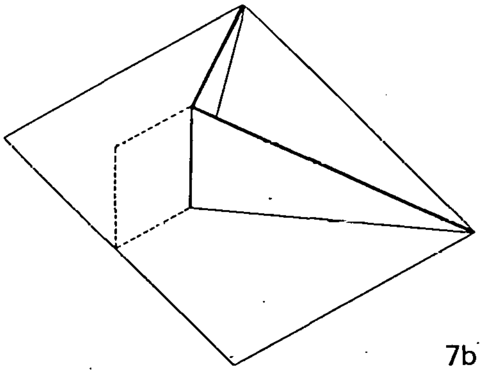
7a

5.2.7 Step 7: Definition of Envelope Ridges

A line of intersection, or ridge, appears where opposing east and west slopes meet at the envelope's top.

One ridge extends northward from the vertex of two intersecting summer hips (7a).

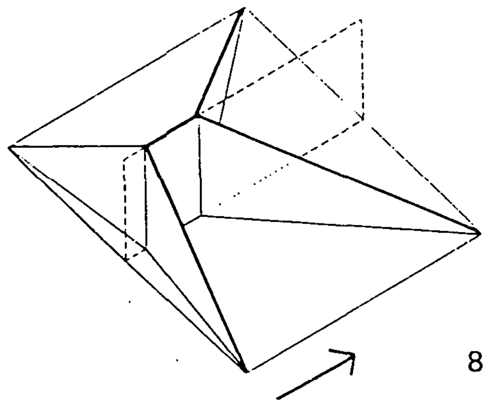
A second ridge extends southward from the vertex of two intersecting winter hips (7b).



7b

5.2.8 Step 8: Ridge Convergence

When the summer and winter ridges are superposed, they precisely contact each other. This convergence is particular to these time constraints and site geometry. The ridges might not occur if these parameters were different.



8

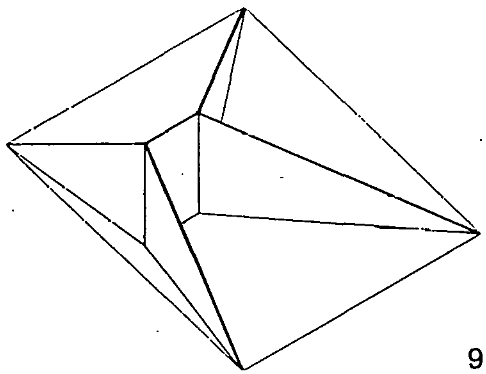
5.2.9 Step 9: Completed Solar Envelope

The final envelope emerges with four hips that meet at a short, north-south ridge.

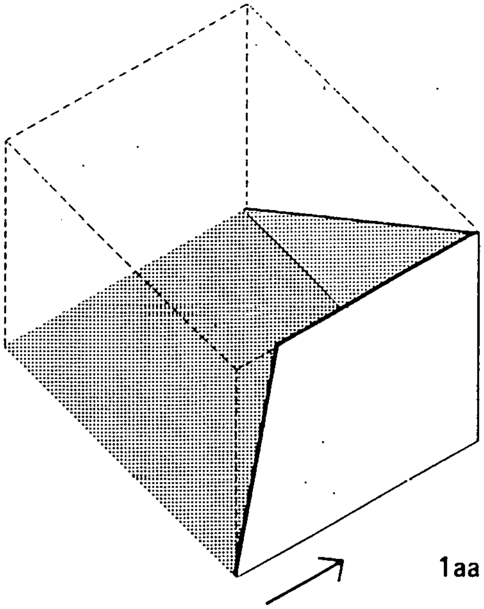
Two hips appear at the site's two southern corners. Their top edges lie parallel to the sun's rays at the two summer cut-off times.

Two complimentary hips appear at the site's two northern corners. Their top edges lie parallel to the sun's rays at the two winter cut-off times.

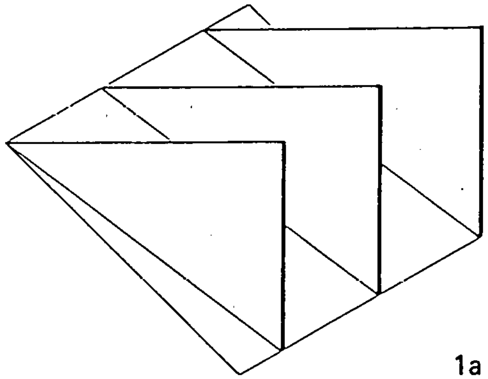
The implied volume could not be larger without casting unwanted shadows, nor could it be smaller and still satisfy basic premises of the envelope definition.



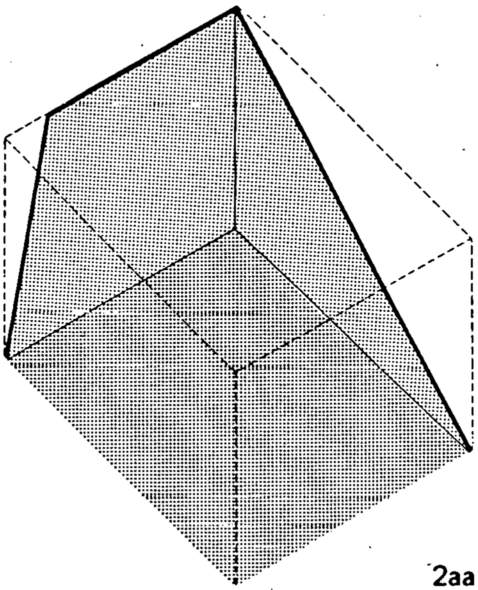
9



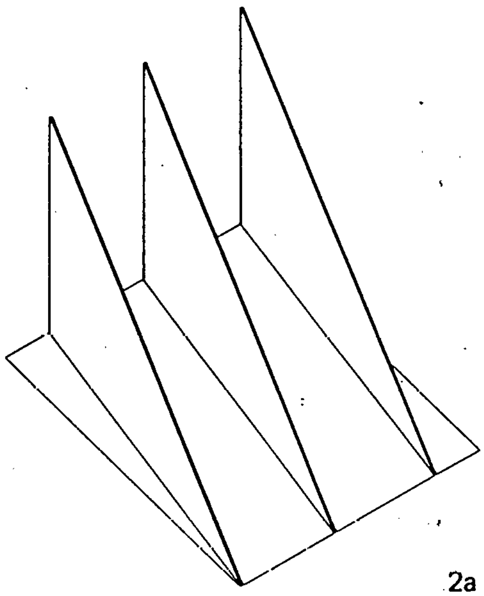
1aa



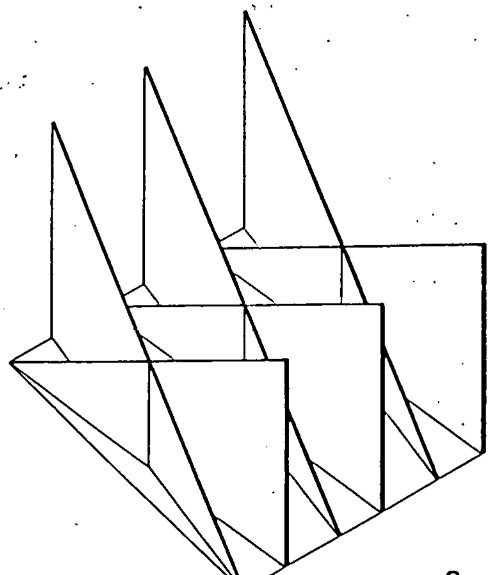
1a



2aa

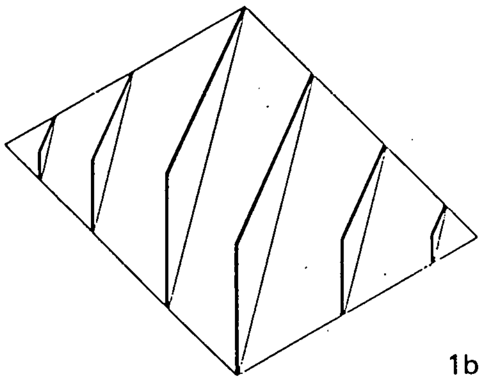


2a

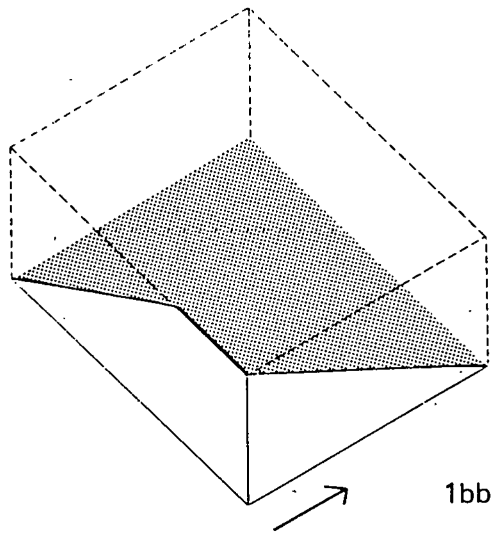


3a

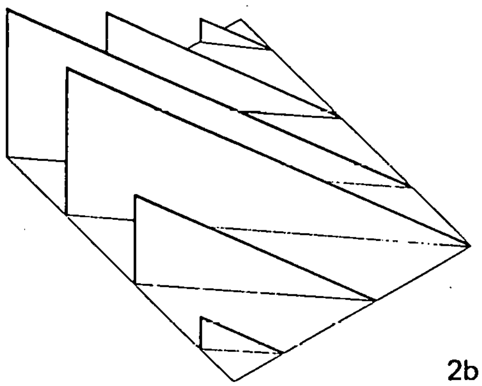
A graphic summary of all steps (1-9) is shown on pages 40 through 43. This procedure will be used in each of the following cases.



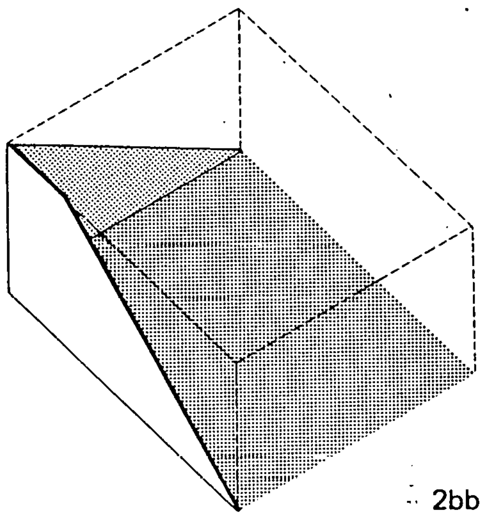
1b



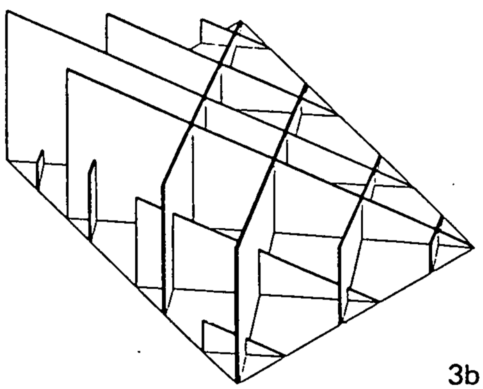
1bb



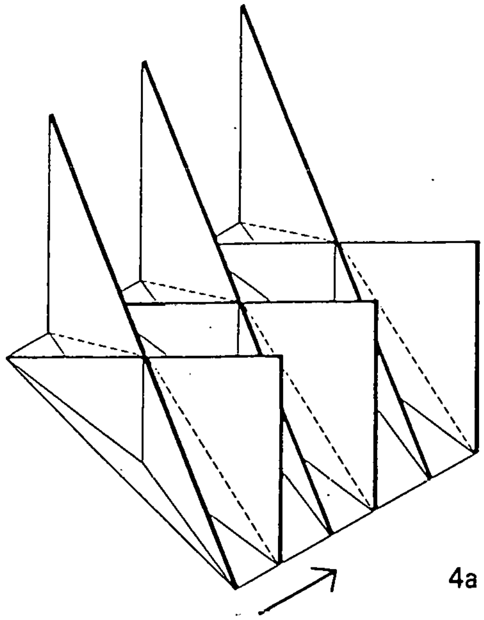
2b



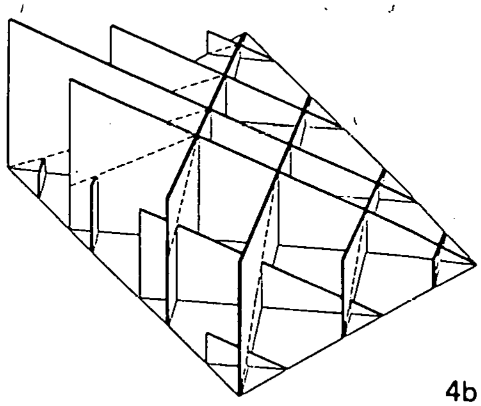
2bb



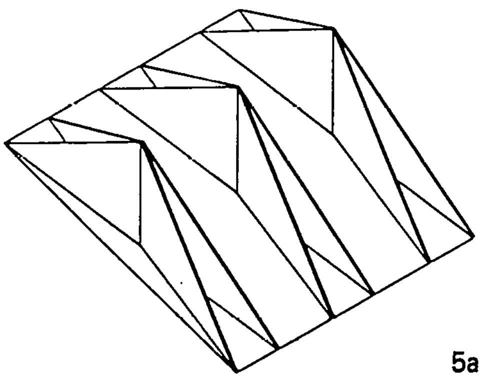
3b



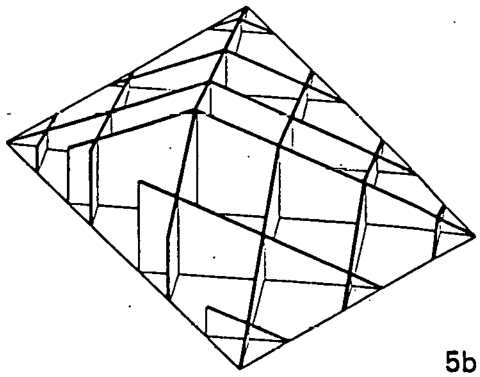
4a



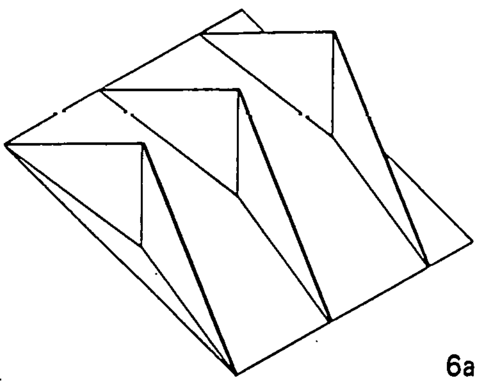
4b



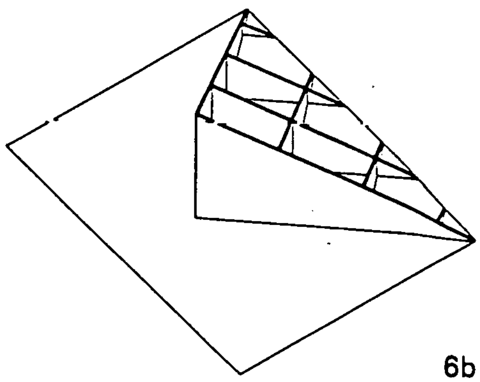
5a



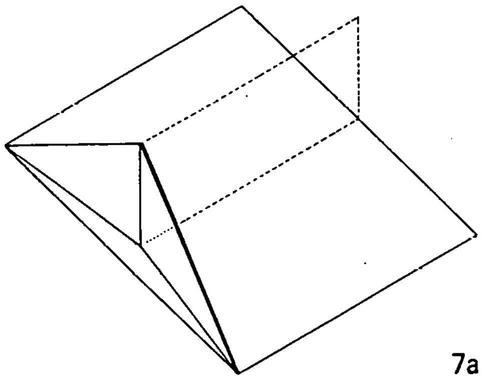
5b



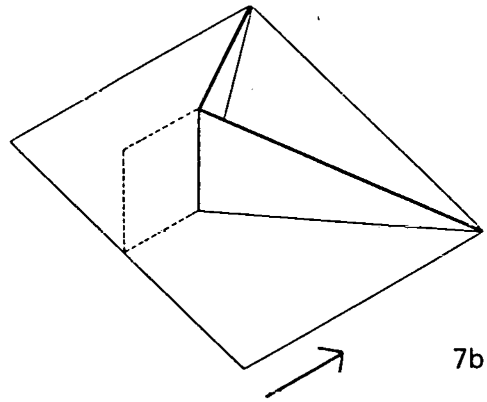
6a



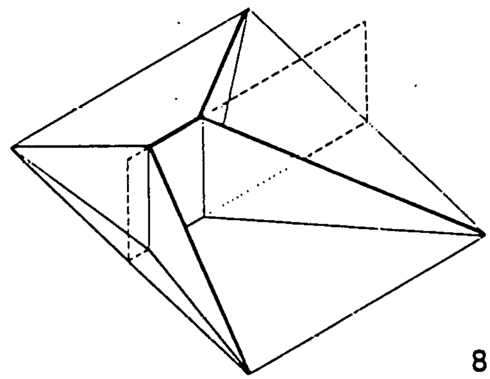
6b



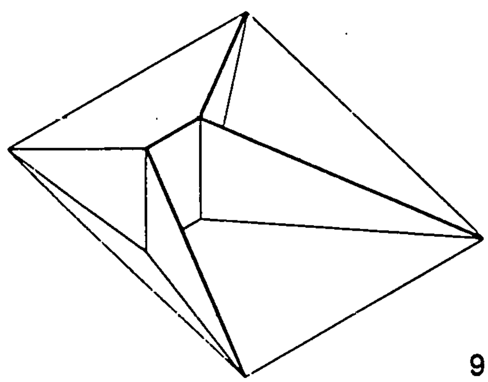
7a



7b



8



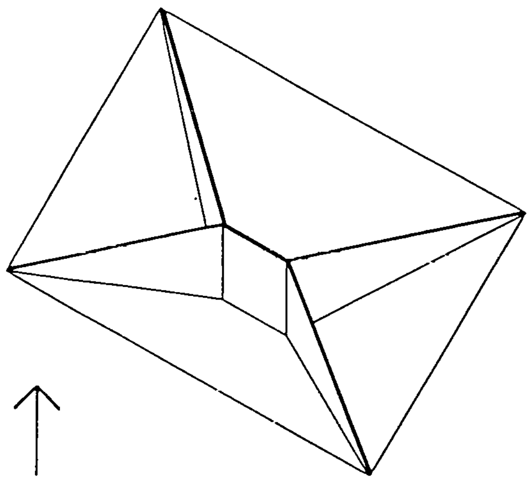
9

THIS PAGE

WAS INTENTIONALLY

LEFT BLANK

5.3 GRID ORIENTATION - 30°



The second solar envelope is generated for the same site, rotated clockwise 30° off the cardinal axis. Its four sloping hips rise asymmetrically to a horizontal ridge, 34.1 feet high, that parallels the site's long edges. The envelope loses volume in this orientation; it contains 3.8 x 10^5 cubic feet compared with 5.3 x 10^5 cubic feet for the first case.

The next three descriptive cases of the envelope generation show the information (as in the 0° case) transferred from the solar hemisphere drawing, but the drawing technique has been modified to what is termed a plan oblique drawing in which north is always directly up. Other than this change, which makes measurement easier, the generation procedure is identical with the first six steps shown in the first example. Beginning with Step 7, the procedure is slightly modified because the change of orientation causes a transformation of the envelope geometry.

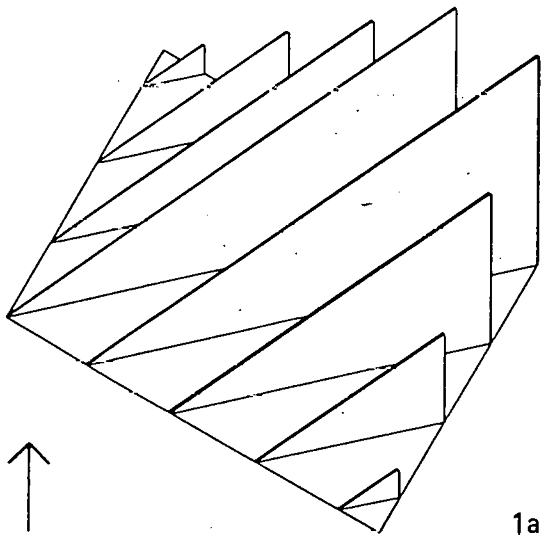
Step 7 and Step 8 show the nature of the departure from the first example. This variation of procedure occurs because the rays of the sun are asymmetrical in their approach to the site's edges at the selected cut-off times which remain constant for all the examples. Since many real-world sites lie off the cardinal compass points, this descriptive procedure may be more generally useful than the first one. It simply requires these two additional steps.

Step 9 through Step 11 follow the original procedure and the completed solar envelope is generated in 11 steps, rather than the original 9.

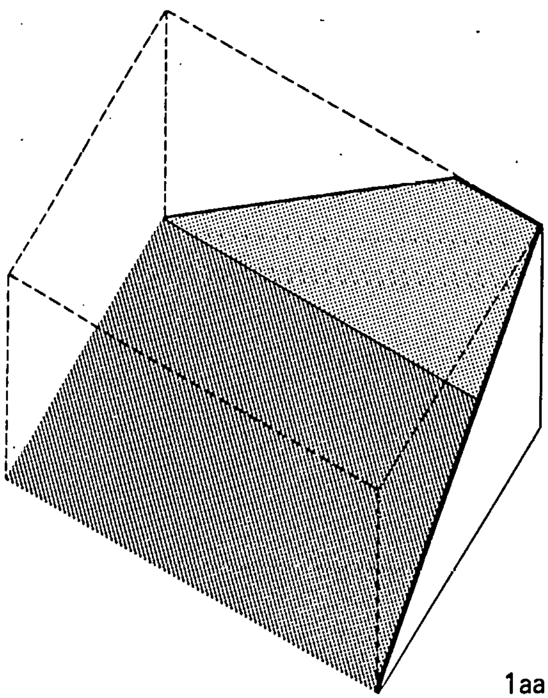
5.3.1 Step 1: Morning Cut-Off Times

Summer morning rays approach the site across its northeast and southeast boundaries (1a).

Vertical planes at those boundaries are precisely cut to cast shadows across the site to the opposing northwest and southwest boundaries (1aa).



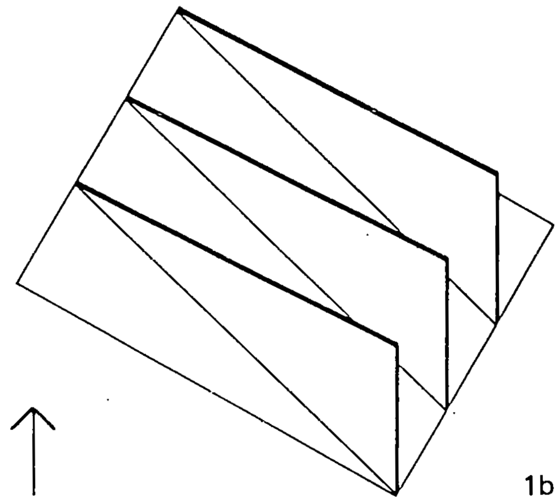
1a



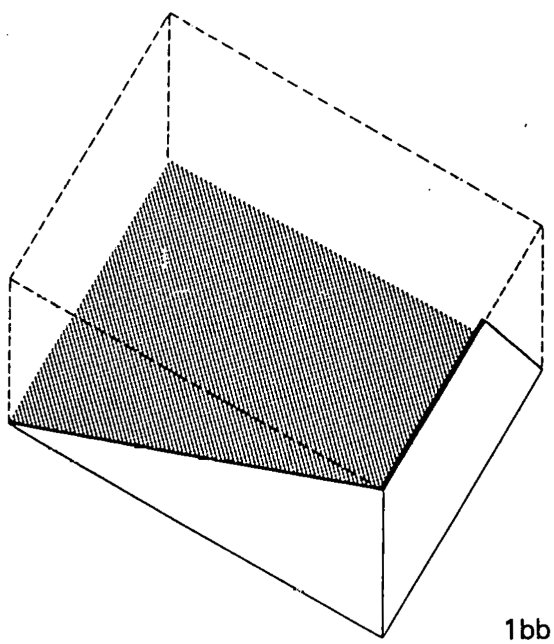
1aa

Winter morning rays approach the site across its southeast and southwest boundaries (1b).

Vertical planes at those boundaries are cut to cast shadows across the site to the opposing northeast and northwest boundaries (1bb).

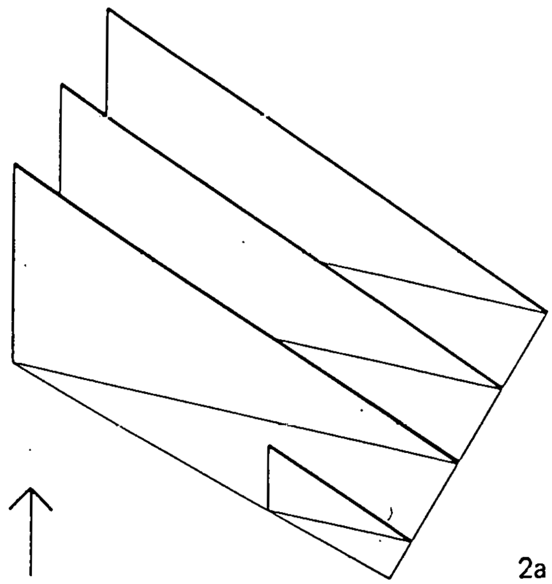


1b



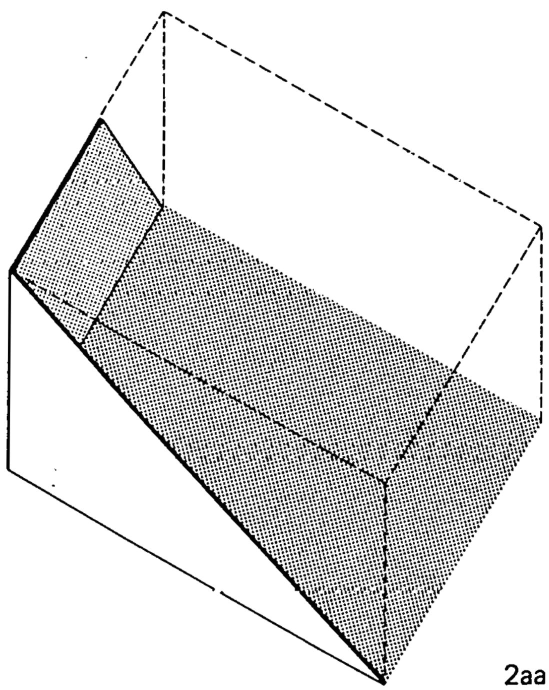
1bb

5.3.2 Step 2: Afternoon Cut-Off Times


2a

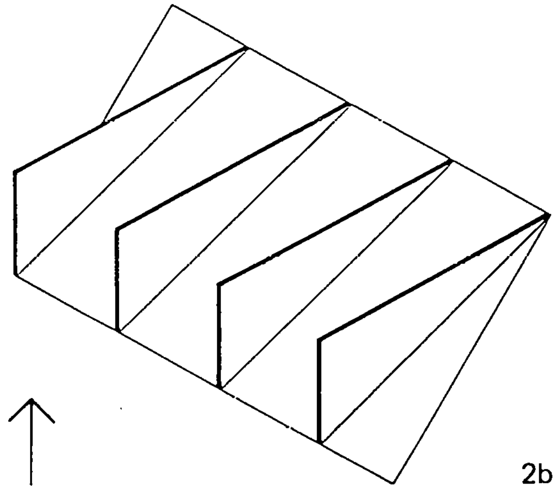
Summer afternoon rays approach the site across its northwest and southwest boundaries (2a).

Shadows are cast to the opposing northeast and southeast boundaries (2aa).

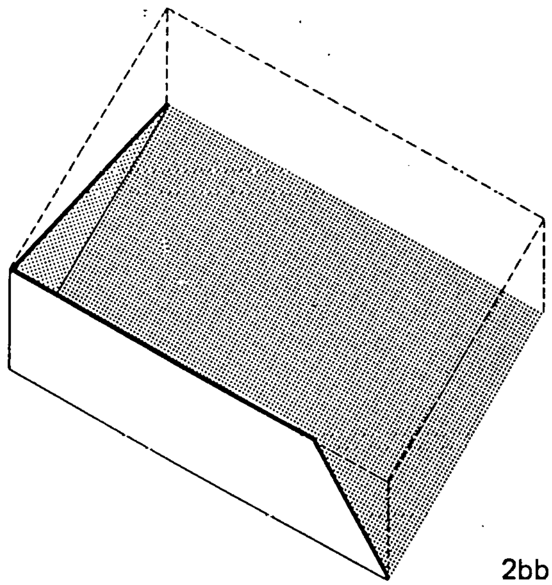

2aa

Winter afternoon rays approach the site across its northwest and southwest boundaries (2b).

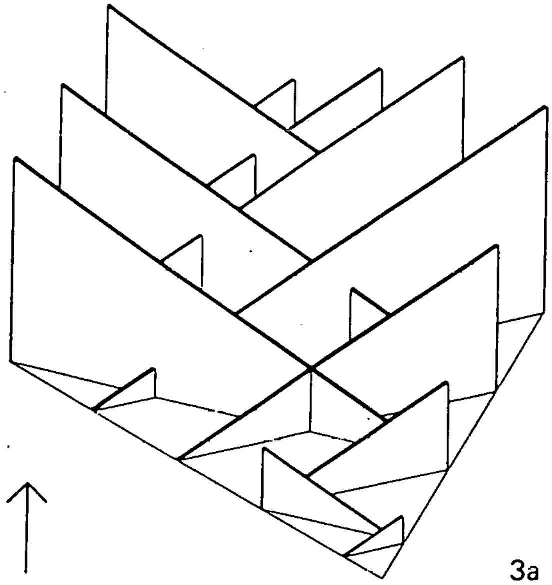
Shadows are cast to the opposing northeast and southeast boundaries (2bb).



2b



2bb

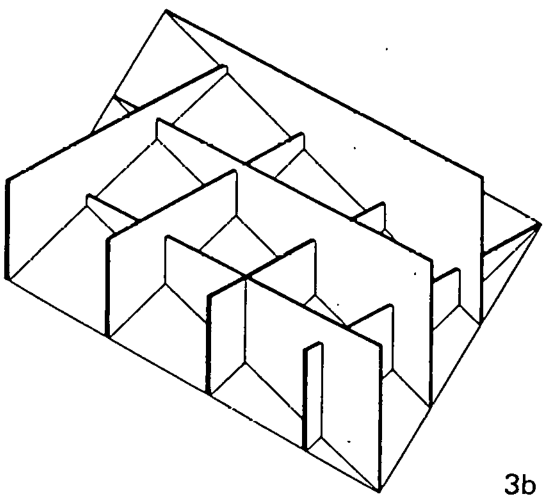


3a

5.3.3 Step 3: Morning and Afternoon Cut-Off Times

The combination of summer rays would slope across the site to strike the northwestern and southwestern boundaries in the morning, the northeastern and southeastern boundaries in the afternoon (3a).

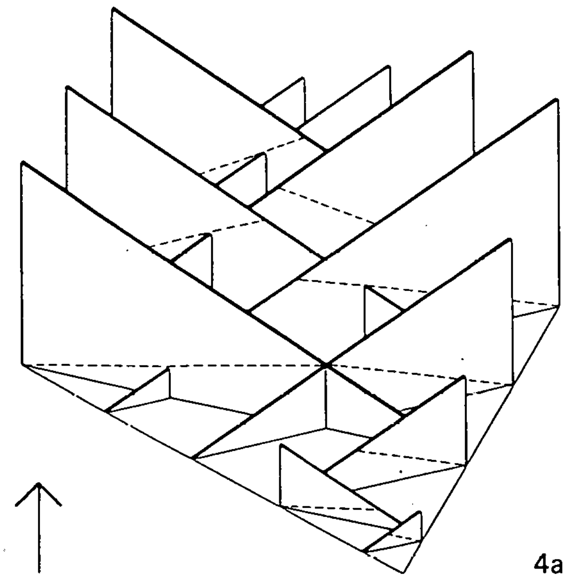
The combination of winter rays would slope across the site to strike the northwestern and northeastern boundaries in the morning, the northeastern and southeastern boundaries in the afternoon. No rays cross the site in such a way that they strike the southwestern boundary (3b).



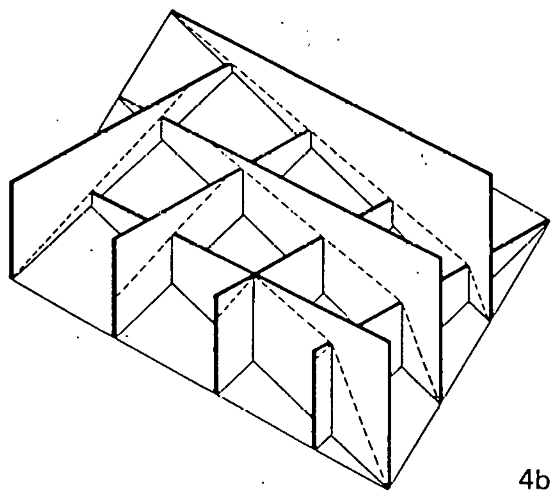
3b

5.3.4 Step 4: Indicate Redundancy

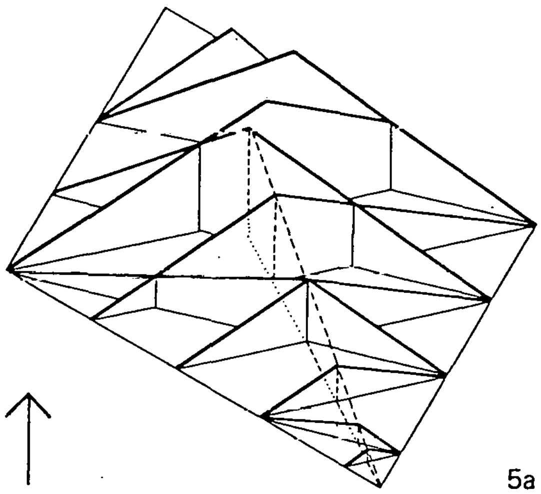
That portion of any triangular plane that rises above an intersecting plane would cast shadows off the site at one or another of the cut-off times. Such portions are descriptively redundant and are shown as the portion of the triangles above the dotted lines (4a,b).



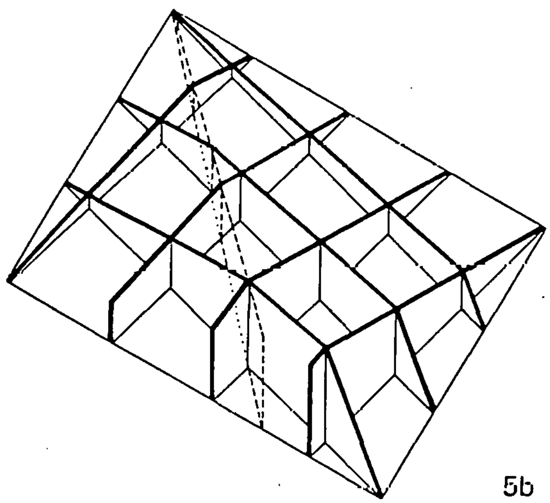
4a



4b



5a



5b

5.3.5 Step 5: Eliminate Redundancy

When the redundant portions of triangular planes are removed, two different solar envelopes appear: one is a summer envelope that would guarantee solar access for the longest day of the year (5a).

The other is a winter envelope that would guarantee solar access for the shortest day of the year (5b).

The shapes of the two seasonal envelopes are somewhat different from the 0° case but they are wholly consistent with the previous demonstration. However, understanding the nature of the differences in the two seasonal envelopes is critical to understanding the next few steps for the 30° site.

The summer envelope differs from the winter envelope in two important respects. First, solar rays cross the site in a way that defines all four boundaries of the summer envelope but they define only three boundaries of the winter envelope, leaving the southwestern boundary unresolved. Second, the locations of the critical hips occur over a different region of each envelope.

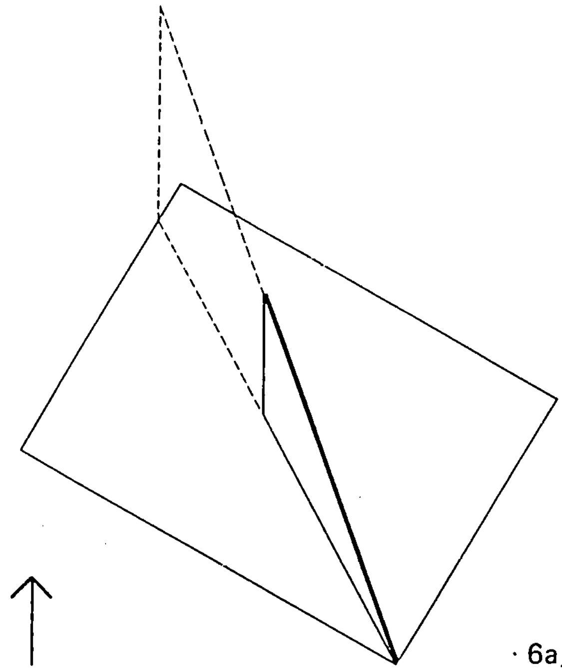
The rotation and resultant asymmetry of this site produce a single hip at the southern corner of the summer envelope, rather than the two hips seen in the 0° case. A visual comparison of the two seasonal envelopes here also shows that this summer hip is below the winter envelope. Therefore, the summer sun controls the envelope's height for solar access over the site's southern region. In other words, the winter envelope is superceded by the summer.

The reverse condition occurs at the site's northern corner. Here the winter hip controls the envelope's height because of the lower angles of the winter sun in the southern sky.

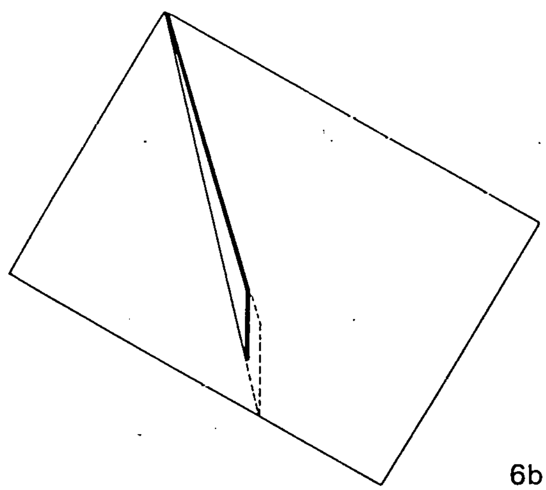
5.3.6 Step 6: Definition of Envelope Hips

The two hips that appeared in the last step are now isolated so that the next step can be taken. The summer hip is shown to the extent that it has been defined and is extended to the site's northern limits for construction purposes (6a).

The winter hip is shown in the same way, extended to the southern limit (6b).



6a

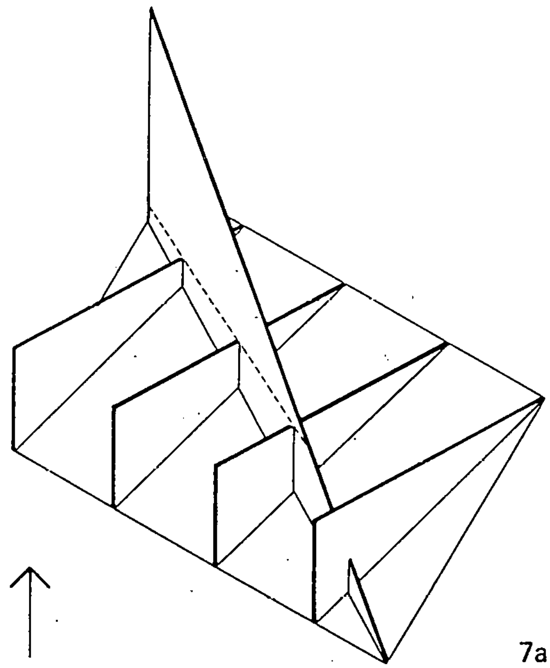


6b

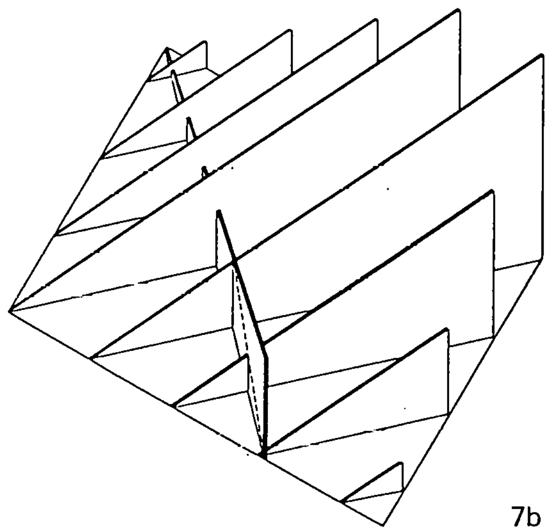
5.3.7 Step 7: Determine Summer and Winter Intersections

This step has no counterpart in the 0^{o} site demonstration. It is based on the simultaneous application of measures derived from the two seasons. The summer hip is intersected by the lateral rays of the winter afternoon sun (7a).

The winter hip is intersected by the lateral summer morning rays (7b).



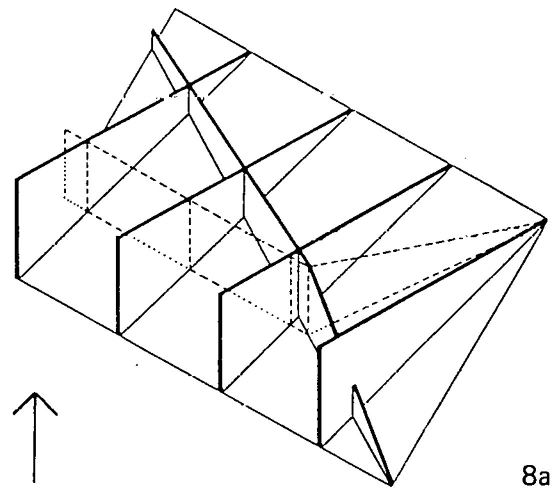
7a



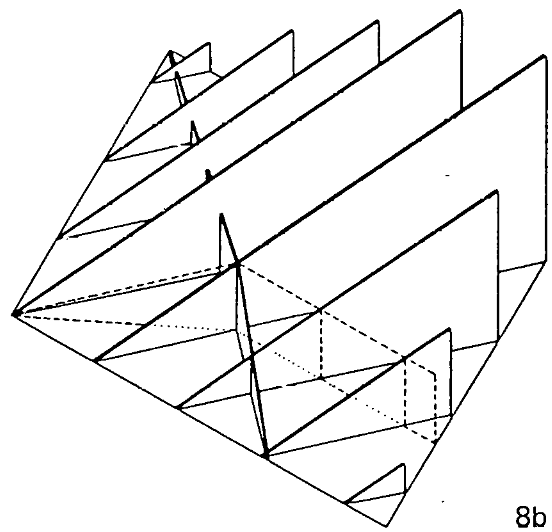
7b

5.3.8 Step 8: Indicate Two-Season Hips

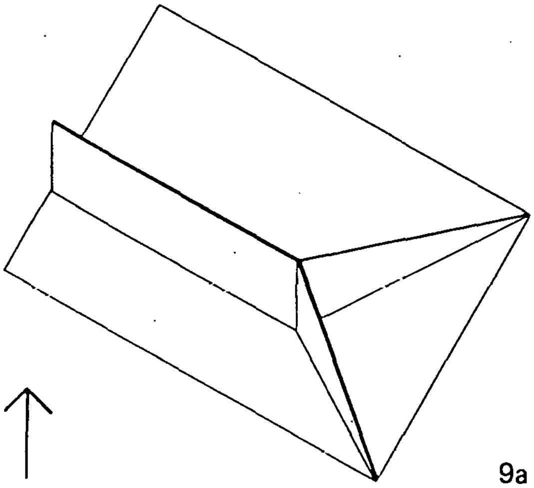
When the redundant portion that would produce shadowing is removed from each seasonal hip, a vertex appears. A second hip must then descend from this vertex to the adjacent corner of the site where a summer face of the envelope will meet a winter face. This becomes a two-season hip, occurring on the east corner after intersecting the summer hip (8a), and on the west corner after intersecting the winter hip (8b). An unresolved horizontal ridge extends from each of these intersections.



8a



8b

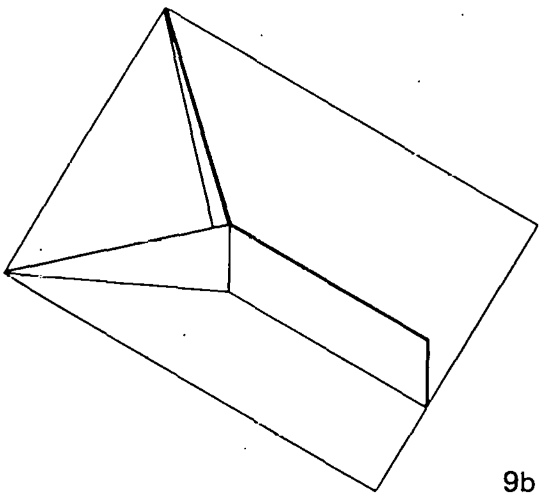


9a

5.3.9 Step 9: Definition of Envelope Hips and Ridges

Each final set of hips and ridges requires two seasons in order to be established. The southernmost hip is set by summer sun's morning and afternoon rays; the easternmost hip and the ridge require the addition of the winter afternoon's rays (9a).

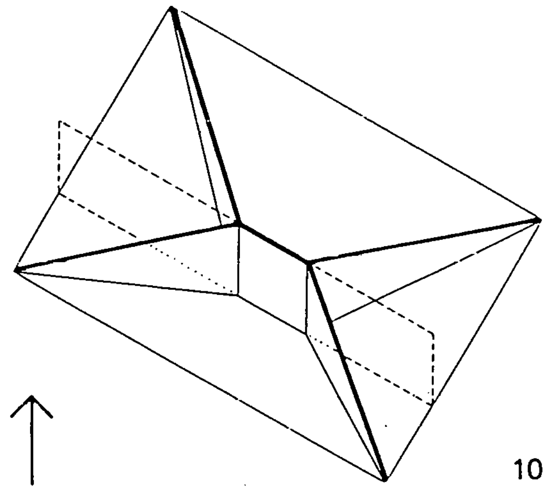
The northernmost hip is set by winter morning and afternoon; and the westernmost hip and the ridge require the addition of summer morning rays (9b).



9b

5.3.10 Step 10: Ridge Convergence

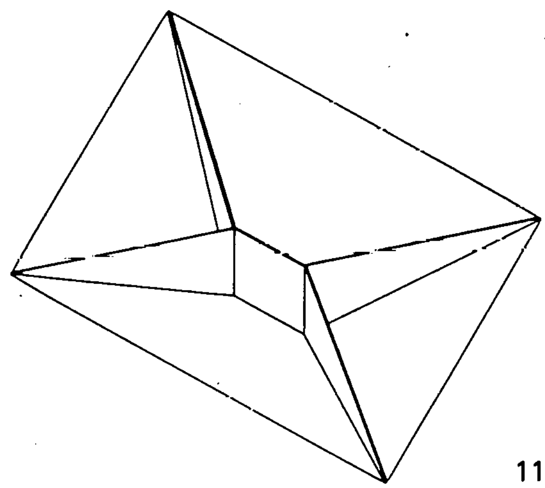
When the two ridges are superposed, they precisely contact each other, as it occurred in the first demonstrations on the 0° site. Also as in the first case, this convergence is particular to the time constraints and site geometry that are being used.



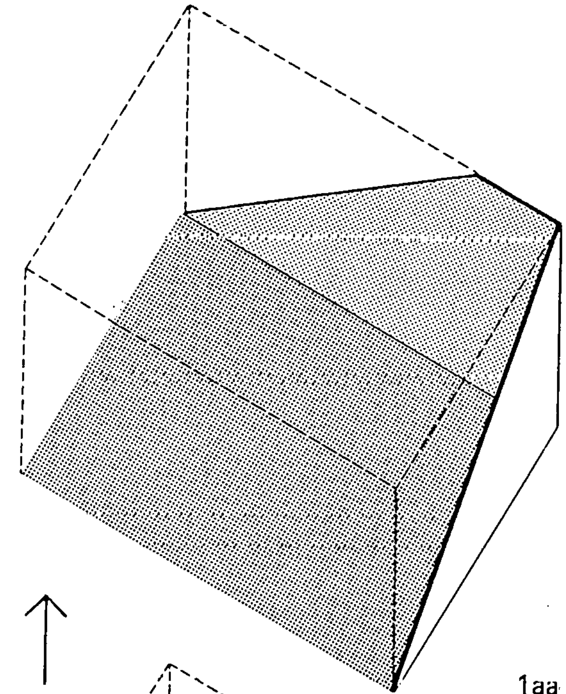
10

5.3.11 Step 11: Completed Solar Envelope

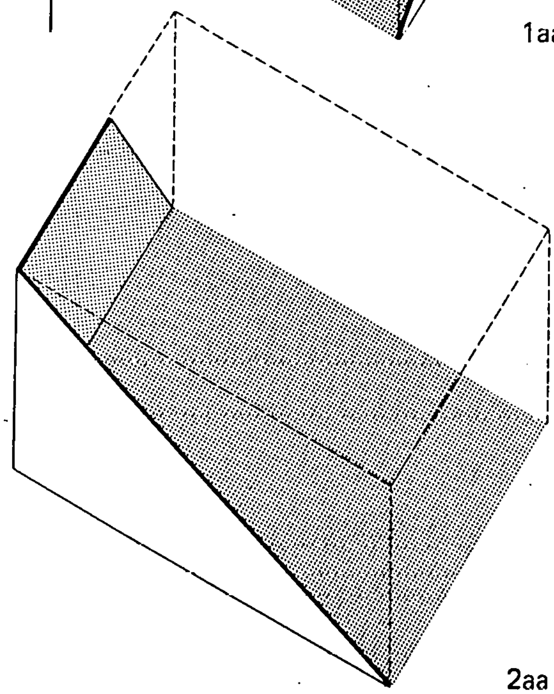
The completed envelope for the 30° site appears to be similar to the envelope for the 0° site, having similar hips and a ridge which define its form. But there are significant differences. This envelope contains 30 percent less volume and is clearly a more complex space-time construct than the preceding case.



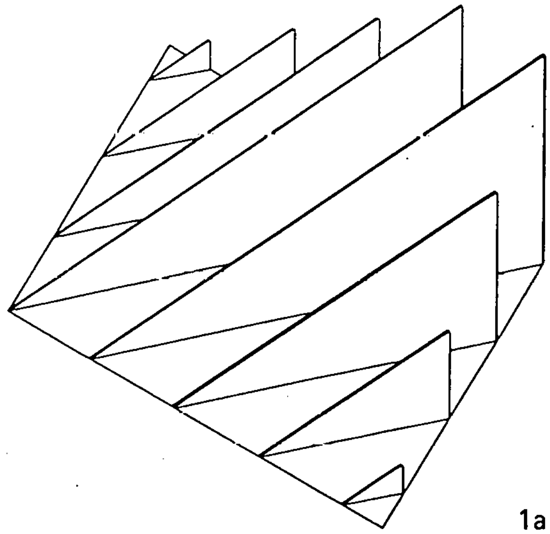
11



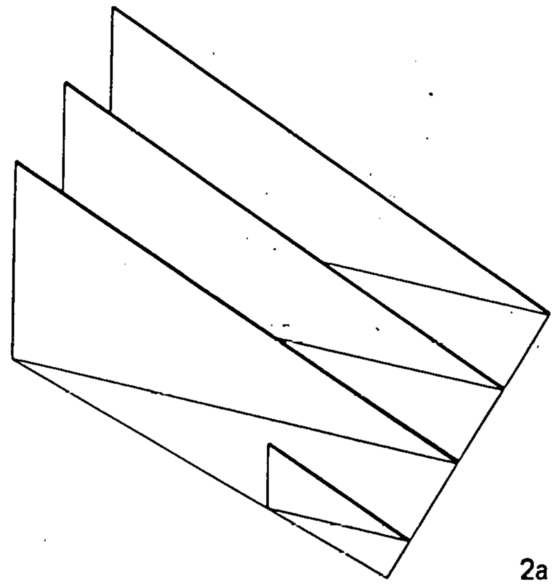
1aa



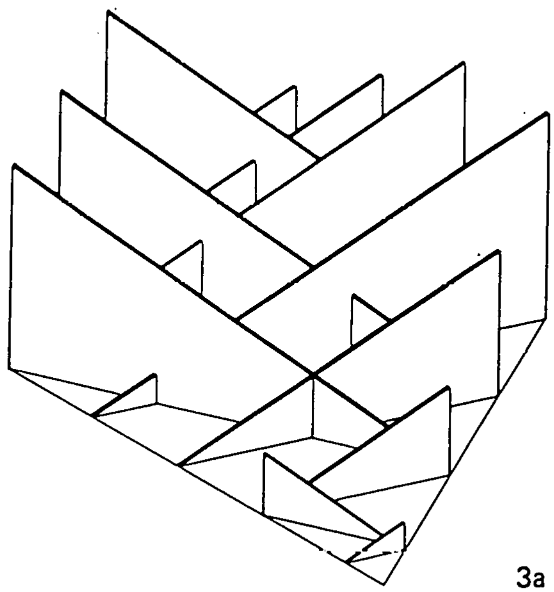
2aa



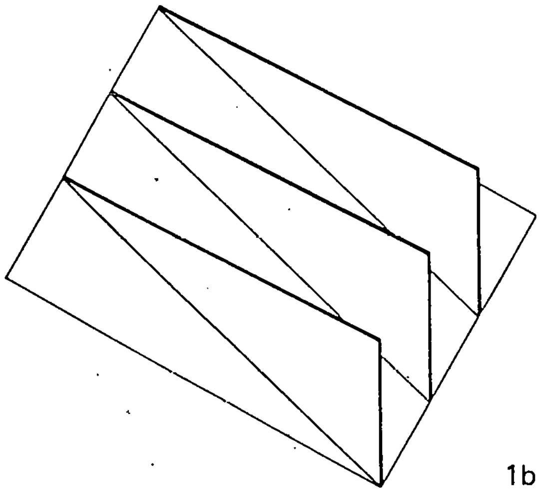
1a



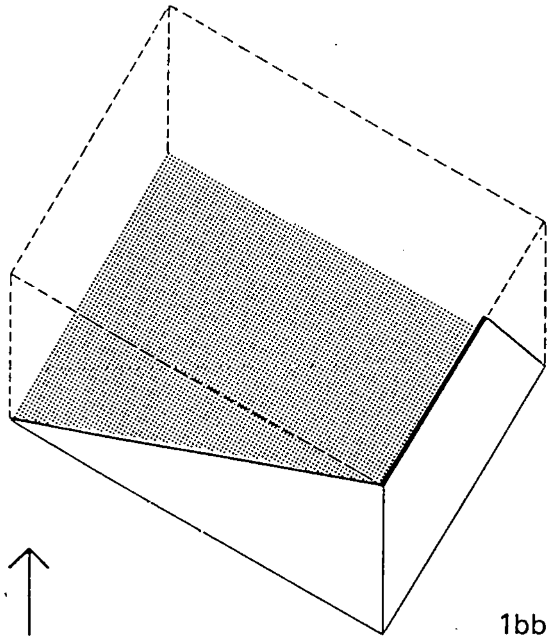
2a



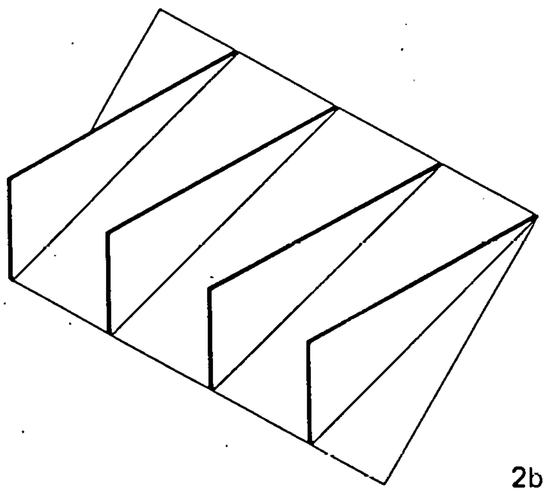
3a



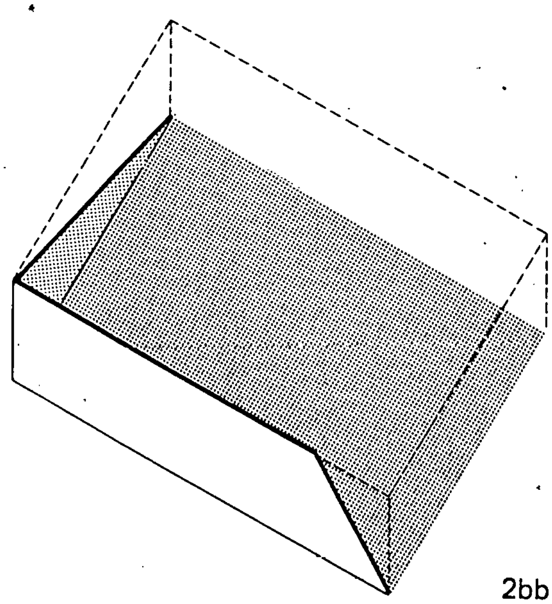
1b



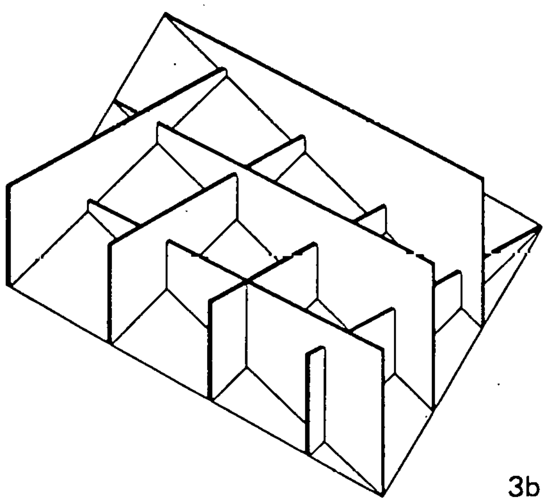
1bb



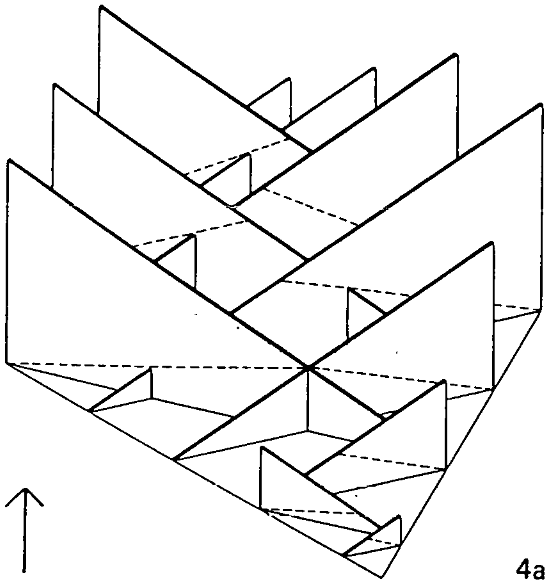
2b



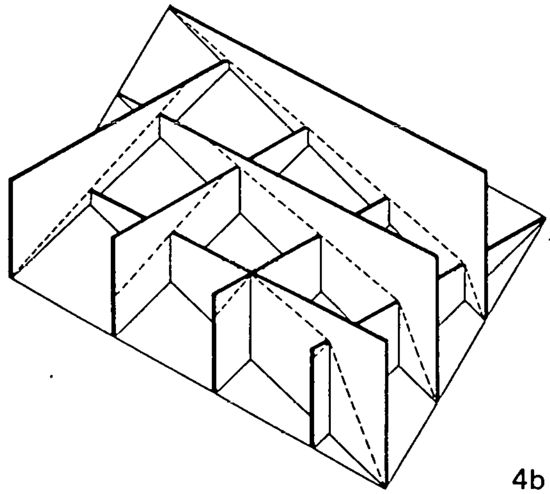
2bb



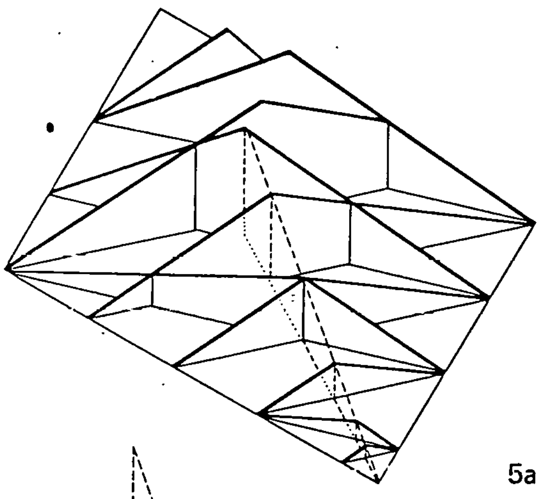
3b



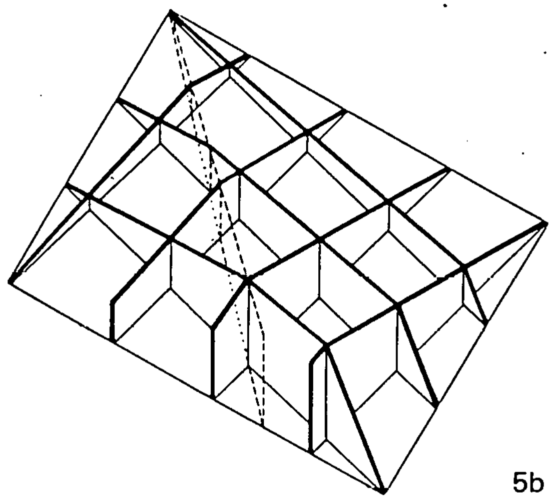
4a



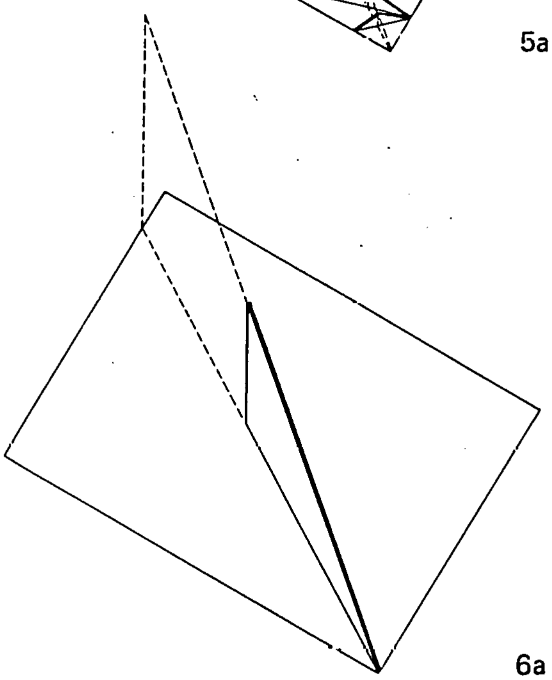
4b



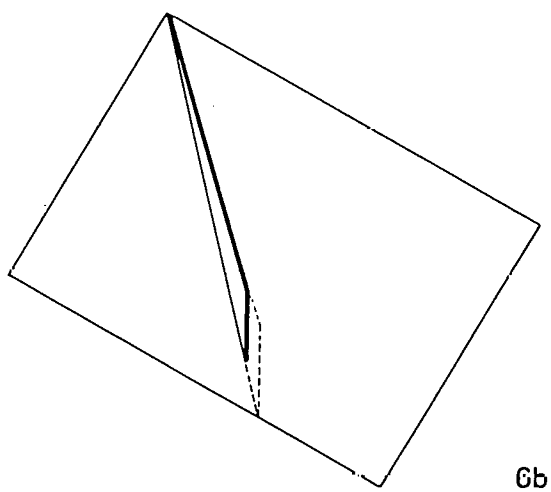
5a



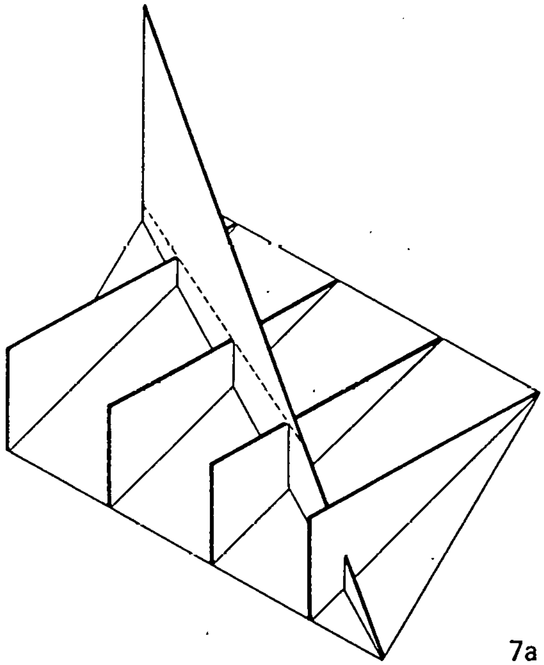
5b

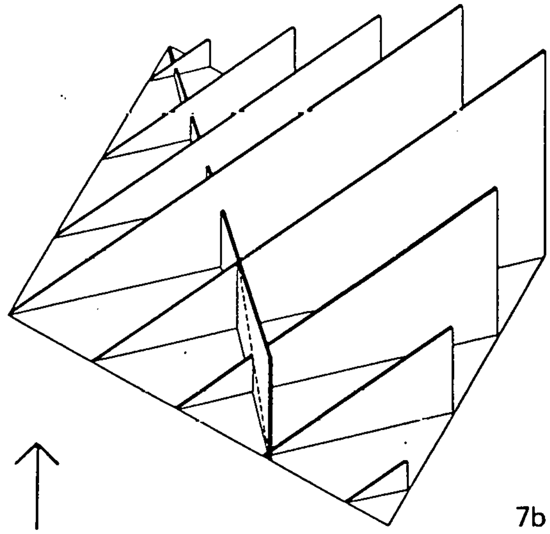


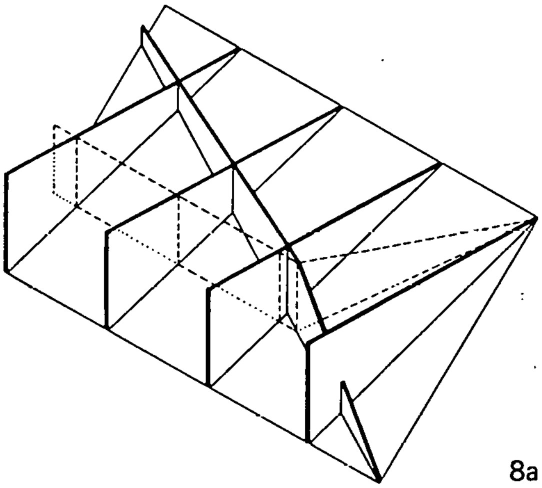
6a

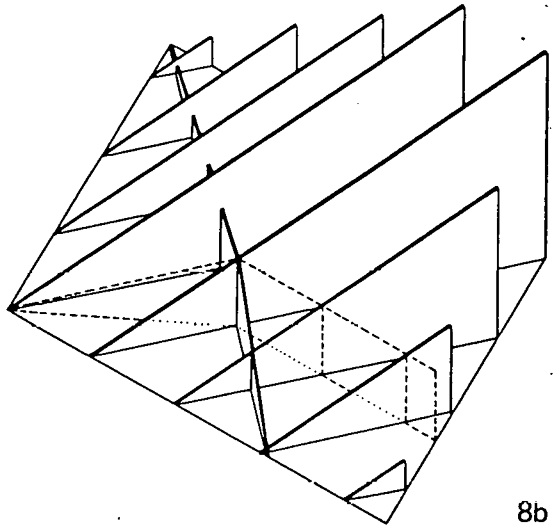


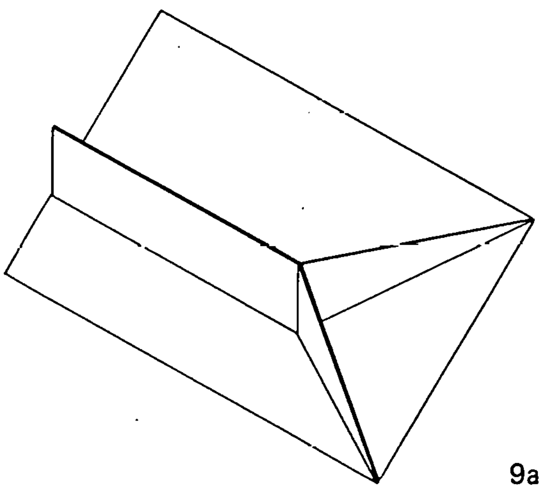
6b

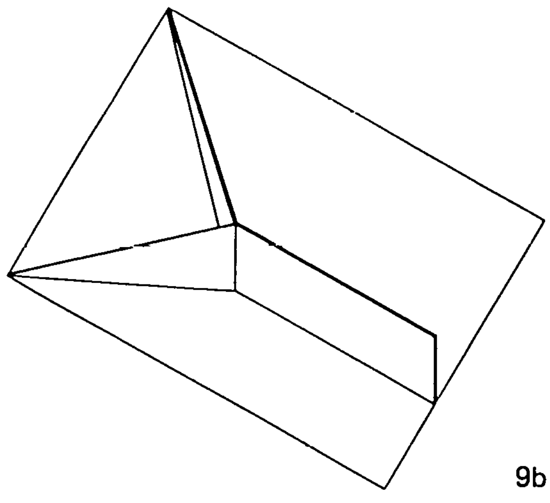

7a

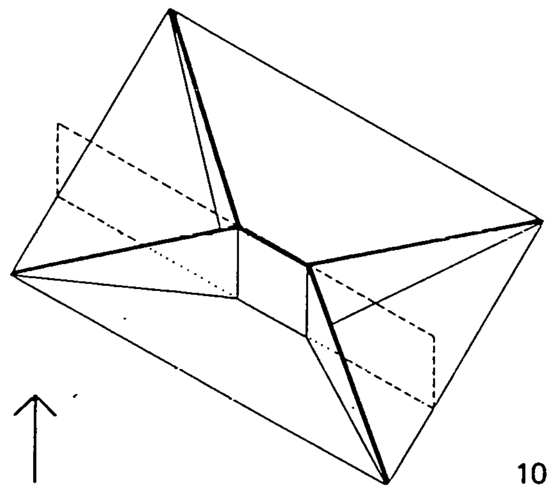

7b


8a

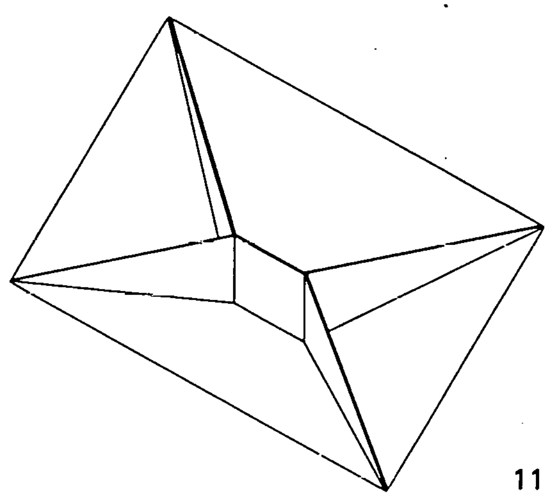

8b


9a


9b

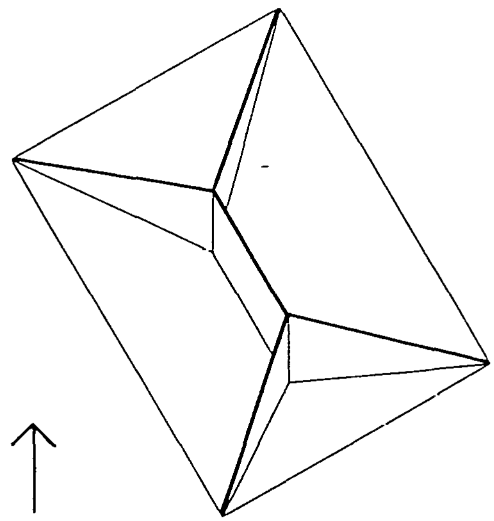


10



11

5.4 GRID ORIENTATION - 60°



The third solar envelope is generated for the same site, rotated 60° off the cardinal axis. Its horizontal ridge is 30 feet high; volume is only 3.6×10^5 cubic feet. Both measures are significantly less than for the prior two cases.

The drawing and generation techniques for this example are identical to those used for the 30° site. Hence, rather than being fully explained, the steps will only be outlined.

There is only one significant difference between this site and the 30° site. The sun's rays at the specified cut-off times cross the site to strike different sets of site boundaries. Those differences are pointed out in the following exposition.

Because of the contracted descriptions of generation steps for this envelope, the drawings are all grouped as a set (on pages 66 through 70).

5.4.1 Step 1: Morning Cut-Off Times

Summer, same as 30° site. (1a)

Same as appeared for 30° site. (1aa)

Winter morning rays cross the northeast and southeast boundaries, a different condition from the 30° site (1b).

Winter morning shadows are cast to the northwest and southwest boundaries, a correspondingly different condition from the 30° site (1bb).

5.4.2 Step 2: Afternoon Cut-Off Times

Summer, same as 30° site. (2a)

Same as appeared for 30° site. (2aa)

Winter afternoon rays cross the southwestern and southeastern boundaries, a different condition from the 30° site (2b).

Winter afternoon rays are cast to the northwestern and northeastern boundaries, a correspondingly different condition from the 30° site (2bb).

5.4.3 Step 3: Morning and Afternoon Cut-Off Times

Summer, same as 30° site (3a).

The combination of winter rays strikes all except the southeastern boundary, a different condition from the 30° site (3b).

5.4.4 Step 4: Indicate Redundancy

Both summer and winter, same as 30° site (4a,b).

5.4.5 Step 5: Eliminate Redundancy

Summer, same as 30° site (5a).

Winter envelope not resolved on southeastern boundary, a different condition from 30° site (5b).

5.4.6 Step 6: Definition of Envelope Hips

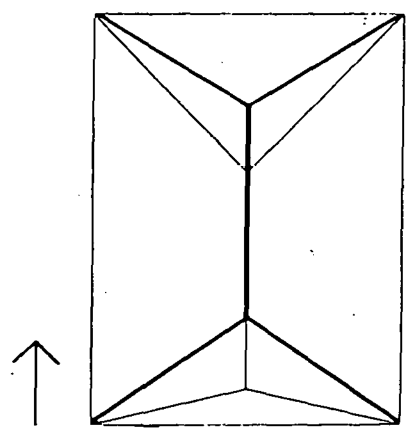
Both summer and winter hips slope to the same corners as on the 30° site but, when extended upward, they touch different boundaries (6a,b).

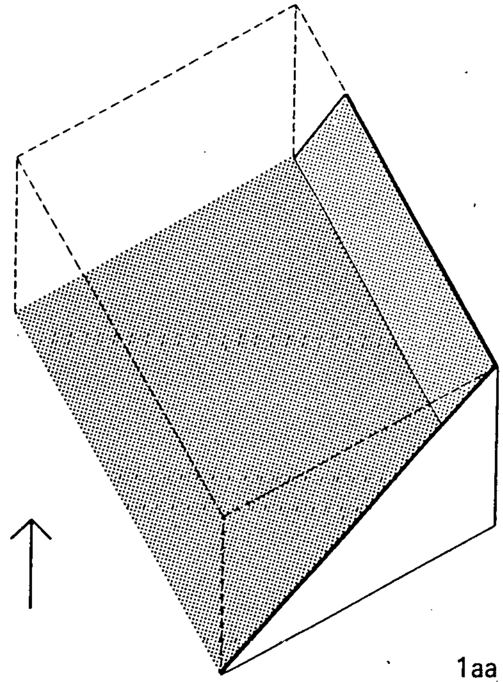
5.4.7 - 11 Step 7 through Step 11

Repeat the procedure of the previous demonstration on a 30° site.

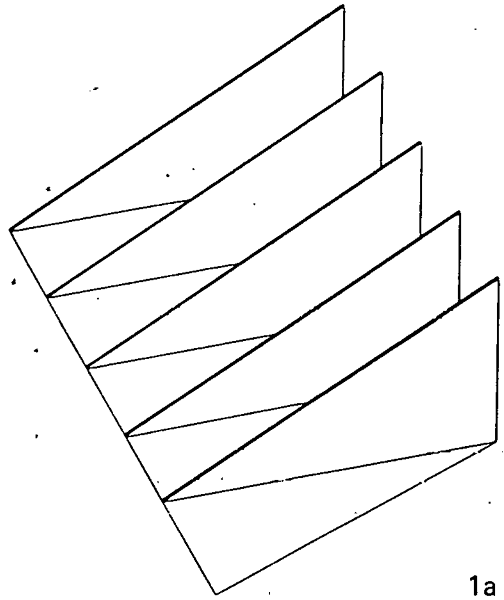
The final envelope has a different size and shape but otherwise is similar to the last case.

Before proceeding to the next demonstration of an irregular site, it should be pointed out that if the angular rotation had been completed to a 90° site, the envelope would again have been symmetrical over the site and would have gained both height (36 feet) and volume (4.6×10^5) over the 60° site.

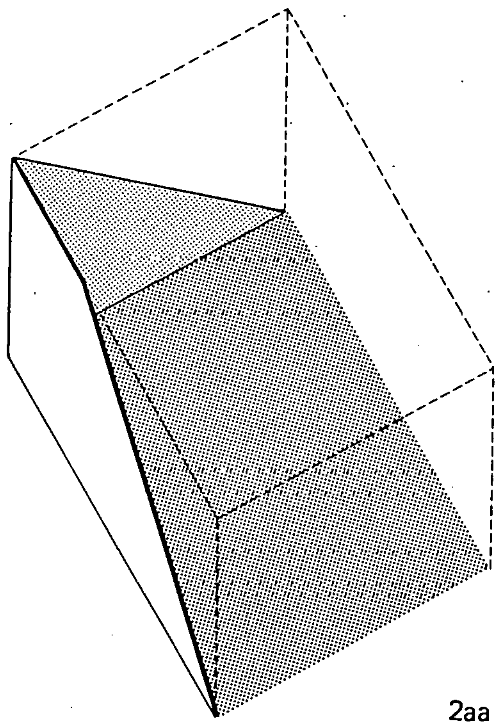




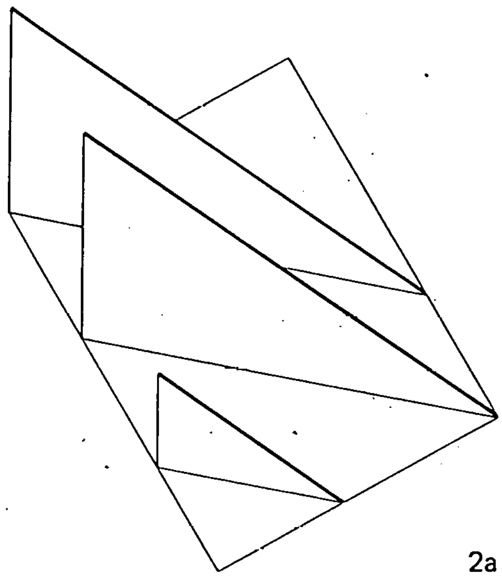
1aa



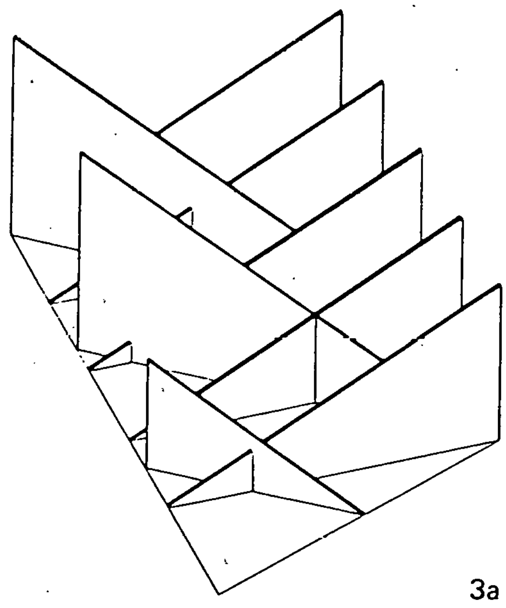
1a



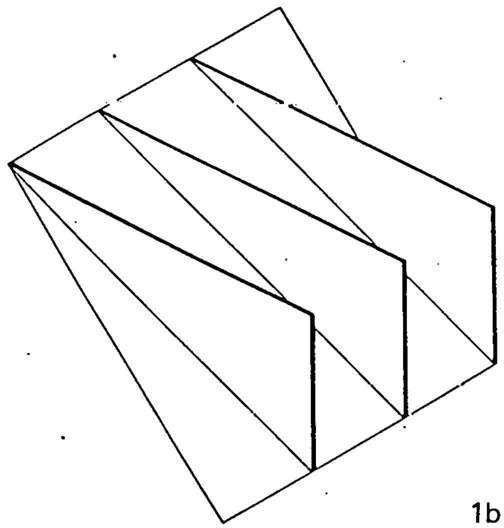
2aa



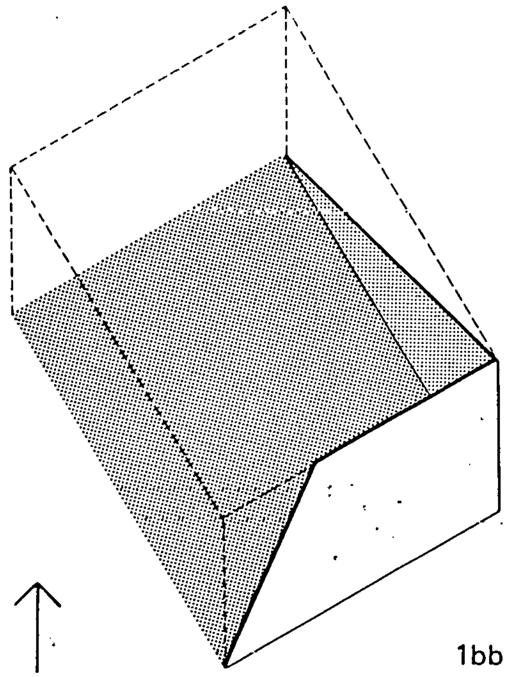
2a



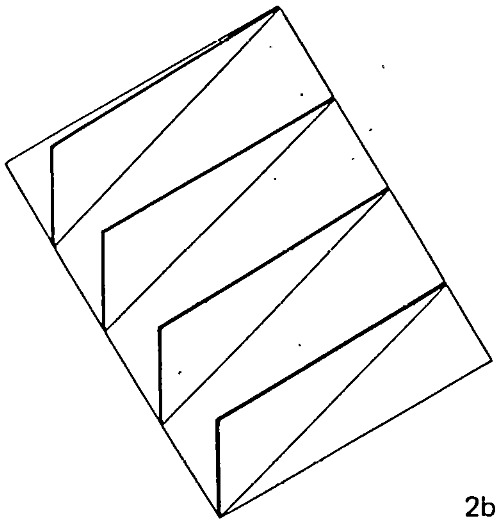
3a



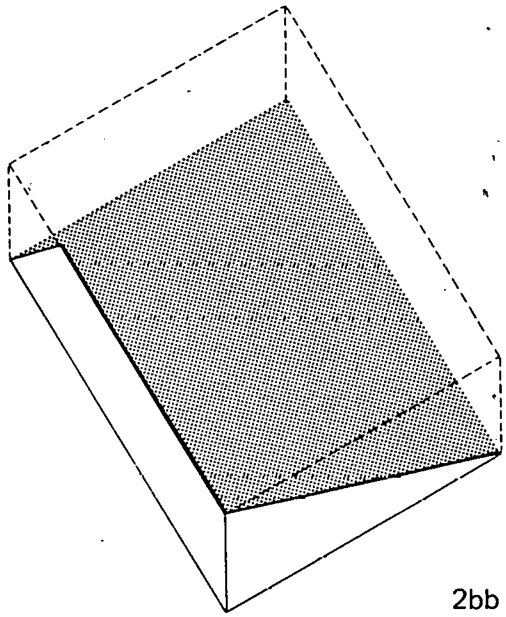
1b



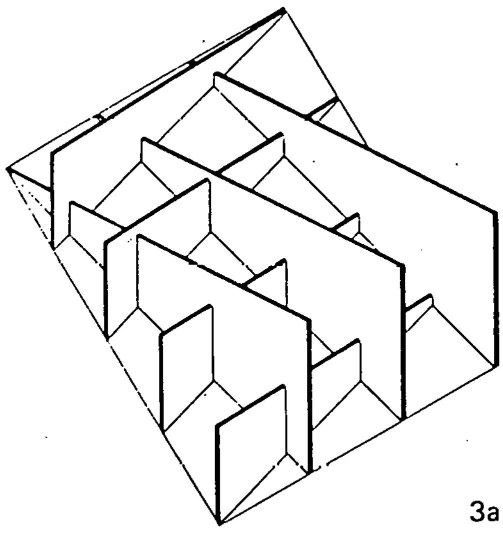
1bb



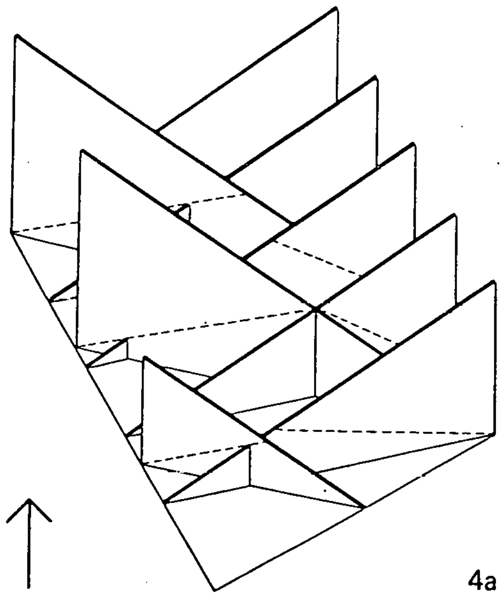
2b



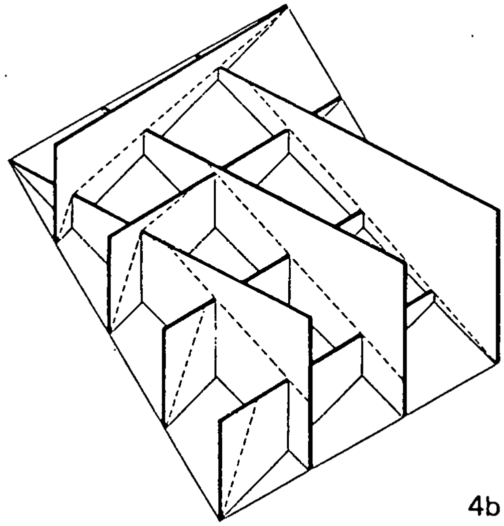
2bb



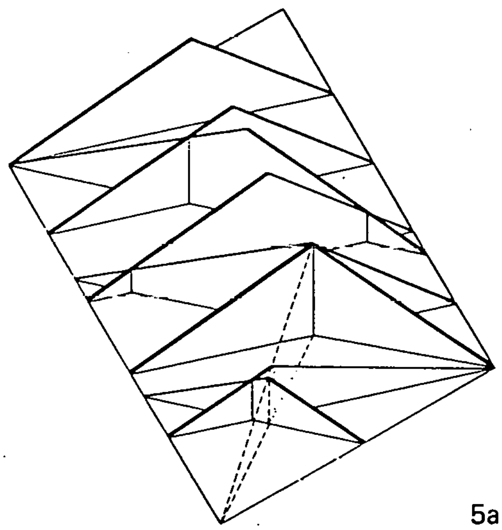
3a



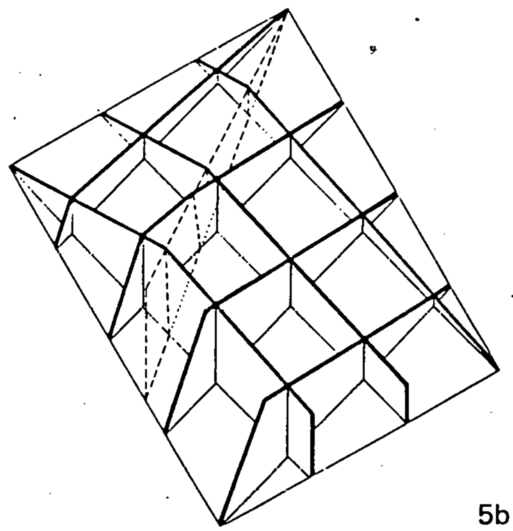
4a



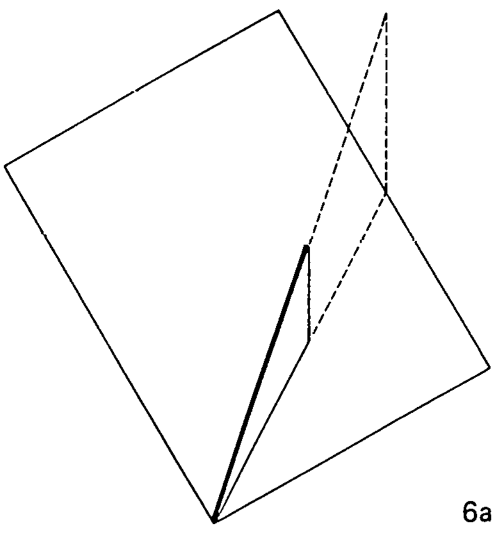
4b



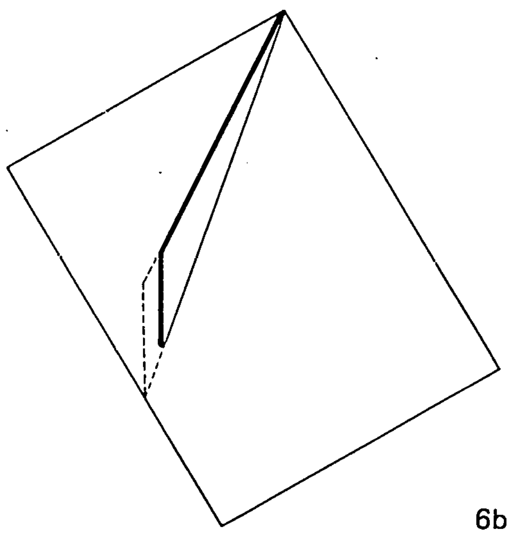
5a



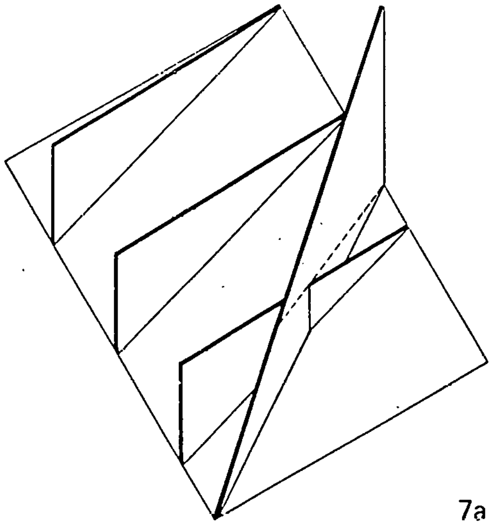
5b



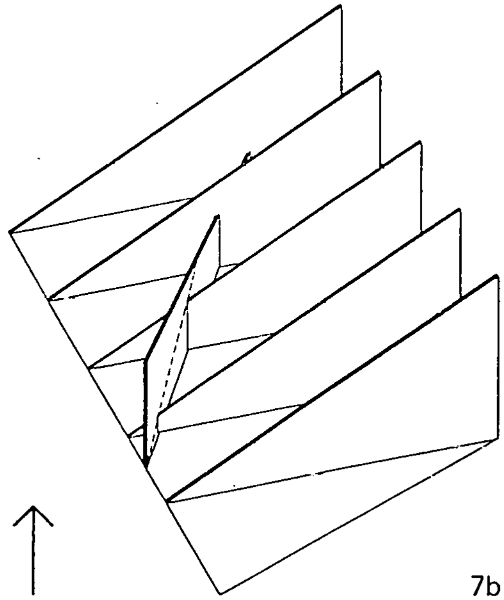
6a



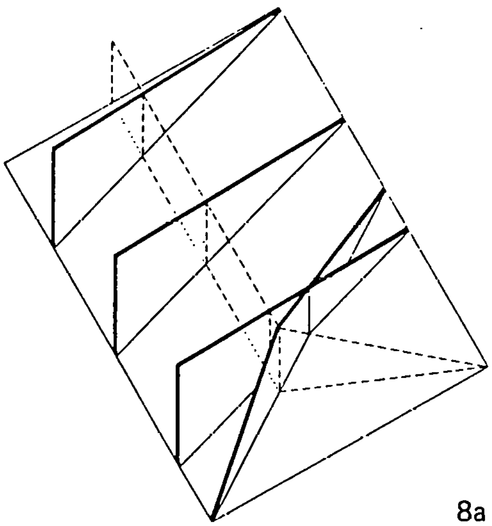
6b



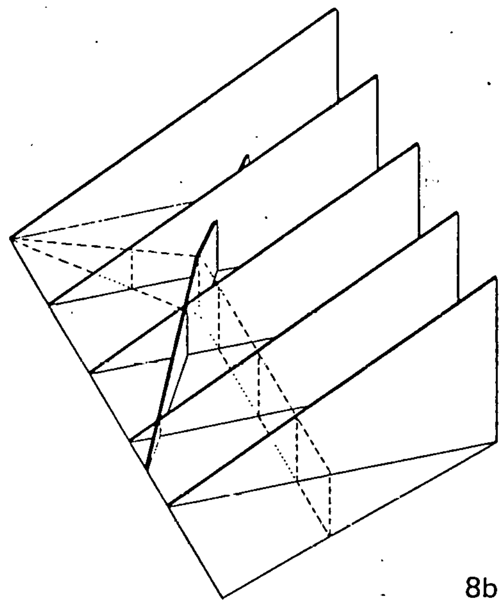
7a



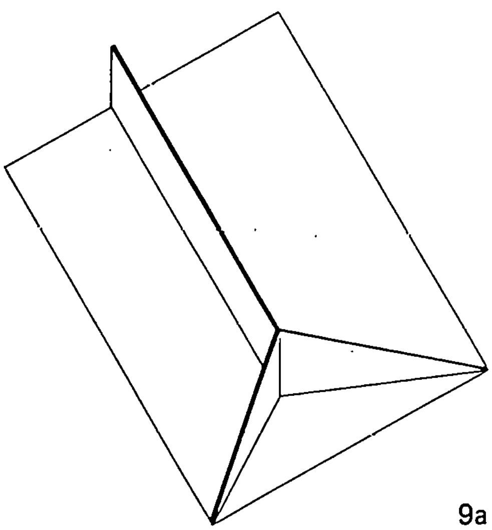
7b



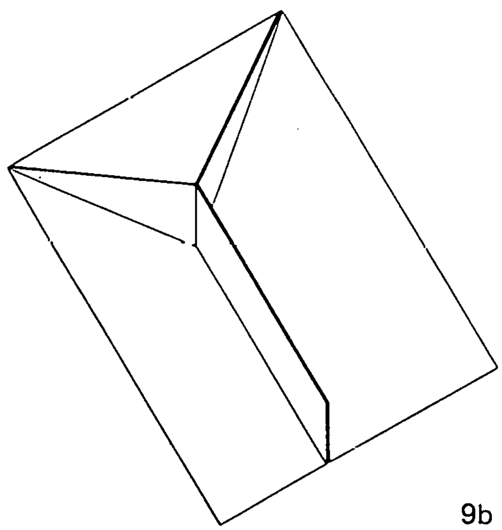
8a



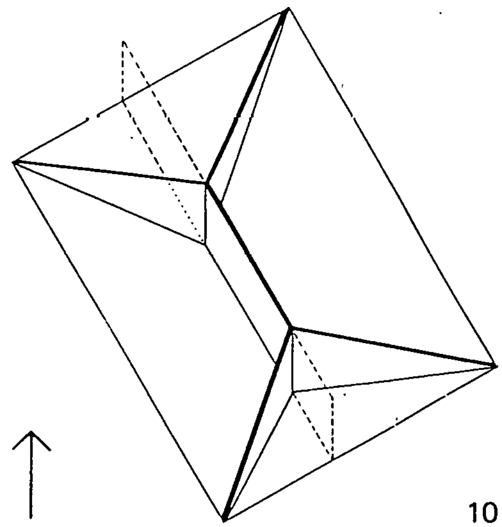
8b



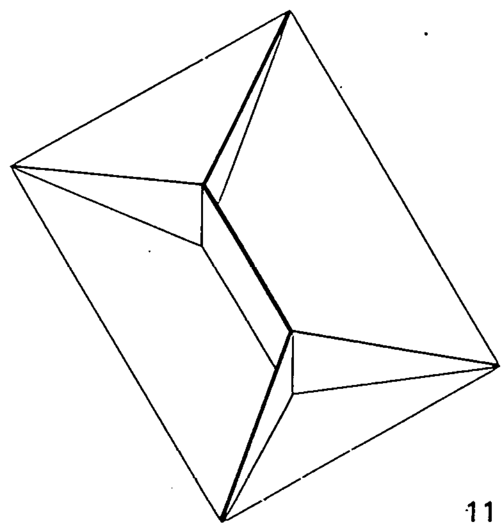
9a



9b

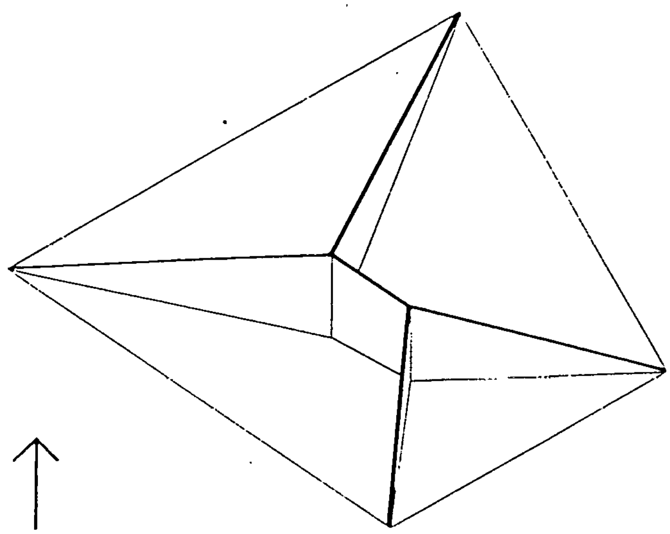


10



11

5.5 IRREGULAR SITE - 60°



The site of the fourth solar envelope is like the third in all respects except that its southwestern boundary is skewed making the site nonrectilinear. This condition is not uncommon and is of special interest because it is similar to sites in the moderate-density housing study reported later in this work.

This single change in the site affects both the envelope's basic shape and the generation procedure. The envelope's shape becomes much less regular on this site, principally because the ridge does not lie parallel to any boundary and, furthermore, it is not horizontal.

Some differences also appear in the generation procedure. They are pointed out where they occur in the following exposition.

Drawings of each step are grouped as a set (on pages 74 through 78).

5.5.1 Step 1: Morning Cut-Off Times

Summer, same as 30° and 60° sites (1a).

Shadow-casting vertical planes at the northeast and southeast boundaries only touch the horizontal top of the box-like reference at a single point (1aa).

Winter morning rays approach the site across three, rather than two, boundaries. This difference from the 30° and 60° sites is the direct result of the skewed southwestern boundary (1b).

Vertical planes at the northeast, southeast, and southwest boundaries cast shadows across the site to the remaining boundary on the northwest (1bb).

5.5.2 Step 2: Afternoon Cut-Off Times

Summer, same as 30° and 60° sites (2a).

Same as appeared for 30° and 60° sites (2aa).

Winter, same as 30^{o} and 60^{o} sites (2b).

Shadow-casting vertical planes at the southeast and southwest boundaries only touch the upper horizontal reference at a single point (2bb).

5.5.3 Step 3: Morning and Afternoon Cut-Off Times

Summer, same as 30^{o} and 60^{o} site (3a).

Winter, the combination of morning and afternoon ray's slope across the site to strike only the northwestern and northeastern boundaries (3b).

5.5.4 Step 4: Indicate Redundancy

Same as 30^{o} and 60^{o} site (4a,b).

5.5.5 Step 5: Eliminate Redundancy

Summer, same as 30^{o} and 60^{o} site (5a).

Winter, the envelope has two unresolved edges that occur where the sun's rays do not strike the southeastern and southwestern boundaries (5b).

5.5.6 Step 6: Definition of Envelope Hips

Same as 30^{o} and 60^{o} site (6a,b).

5.5.7 Step 7: Determine Summer and Winter Intersection

Same as 30^{o} and 60^{o} sites (7a,b).

5.5.8 Step 8: Indicate Two-Season Hips

Same as 30^{o} and 60^{o} sites (8a,b).

5.5.9 Step 9: Definition of Hips and Ridges

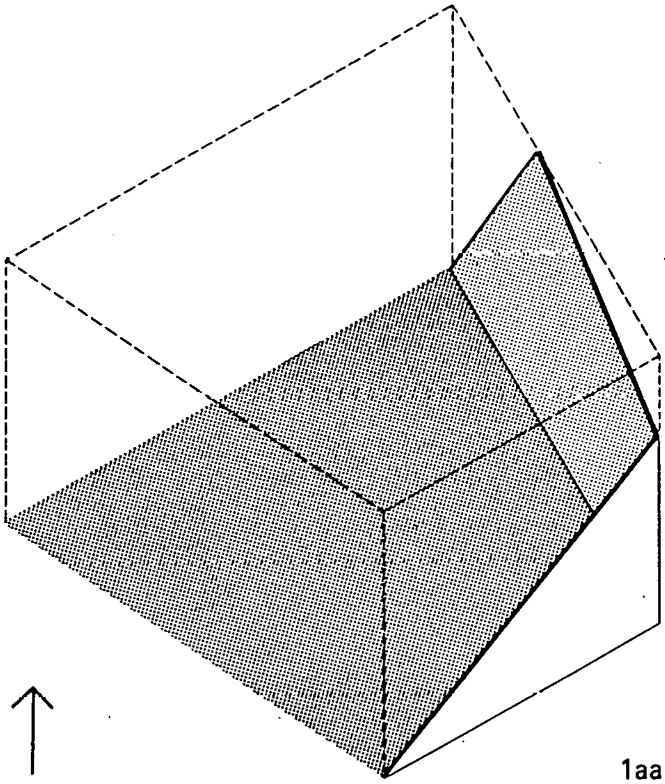
Same as 30^{o} and 60^{o} sites (9a,b).

5.5.10 Step 10: Ridge Convergence

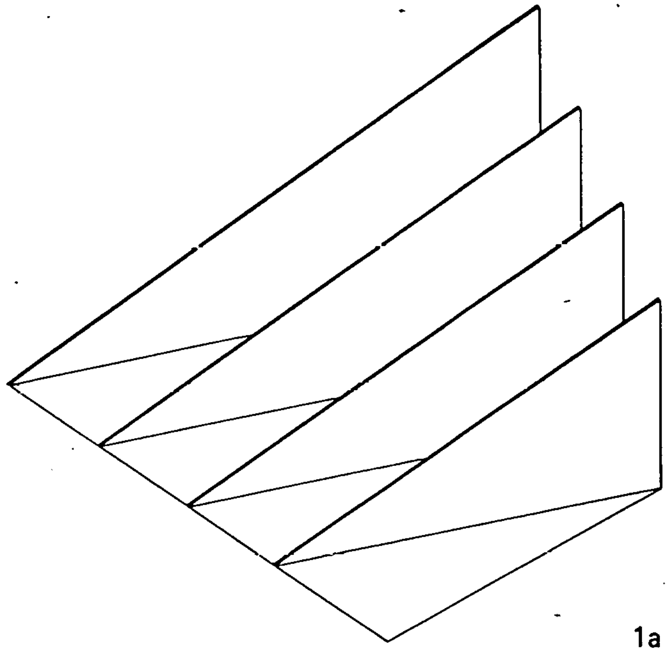
When the two different sets of hips and ridges are superposed, the ridges do not contact each other. Their azimuth angles and height are different.

5.5.11 Step 11: Completed Solar Envelope

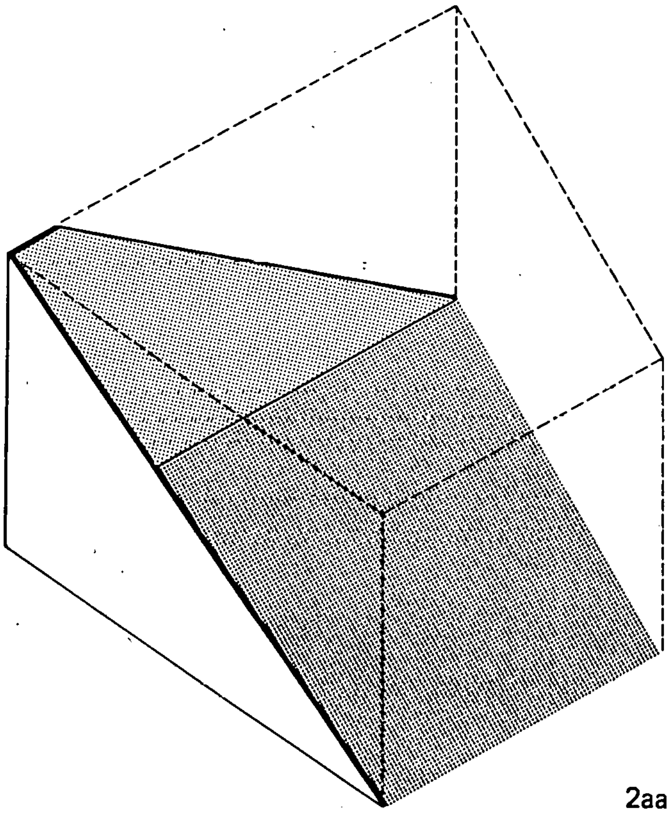
The ridge mismatch is easily resolved in the final step by directly connecting the two vertexes. The two individually derived ridges are replaced with a composite ridge that functions year round during the specified hours of solar access.



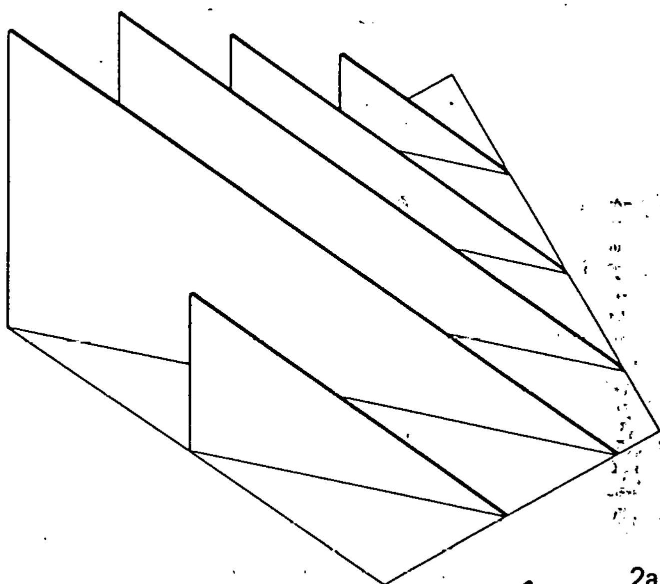
1aa



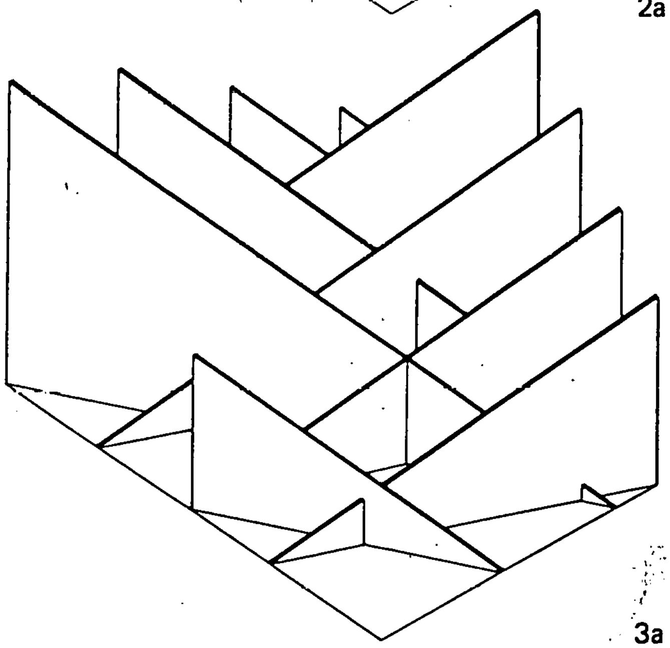
1a



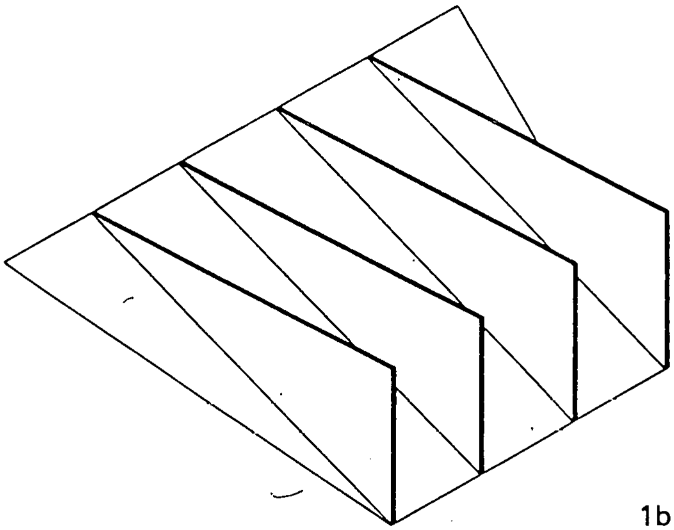
2aa



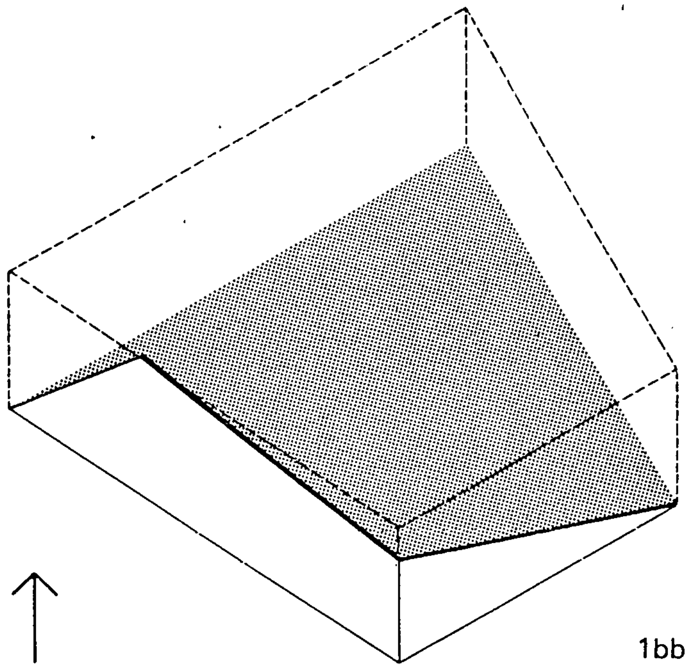
2a



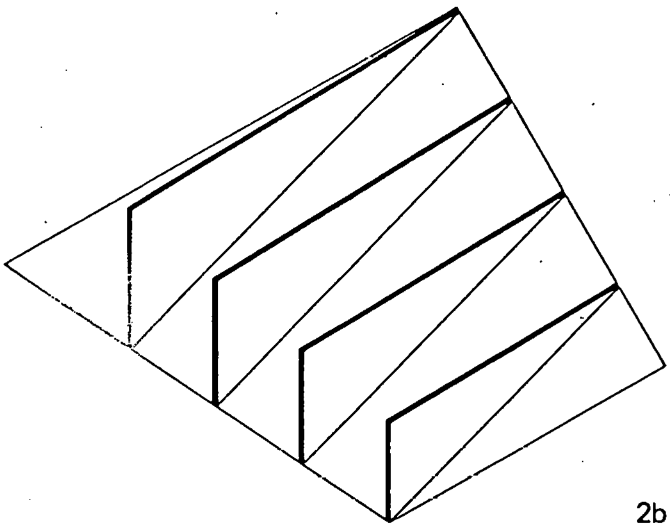
3a



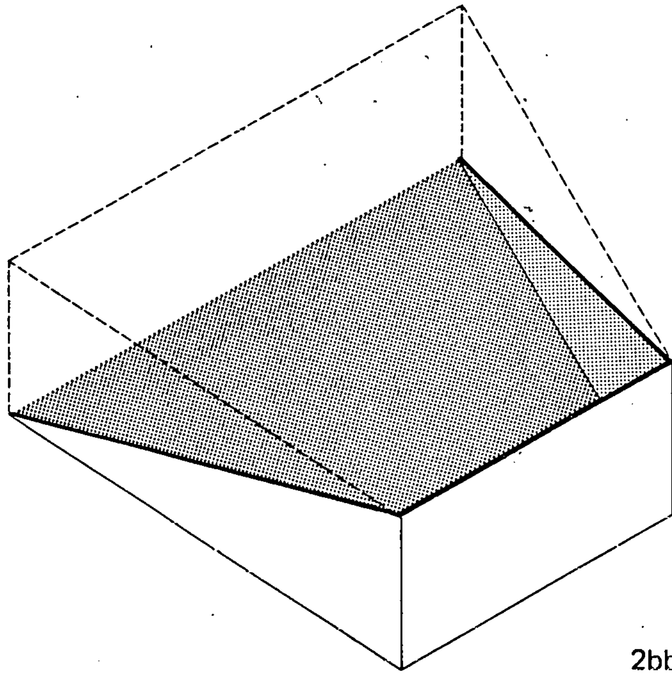
1b



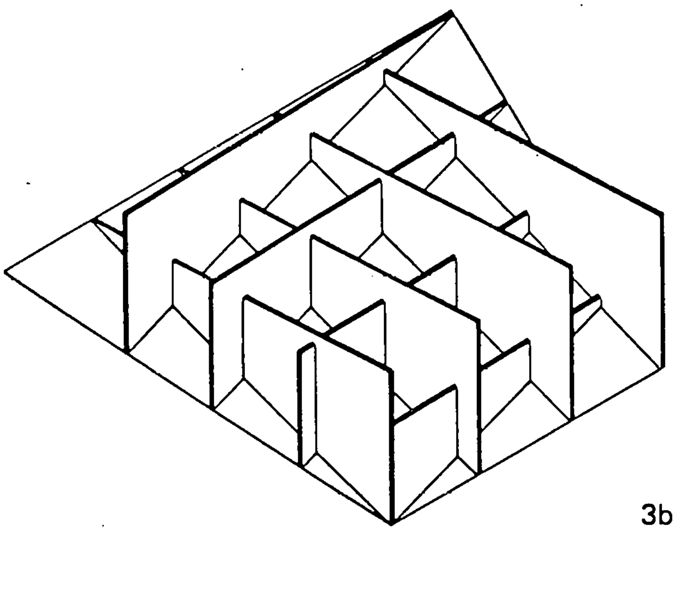
1bb



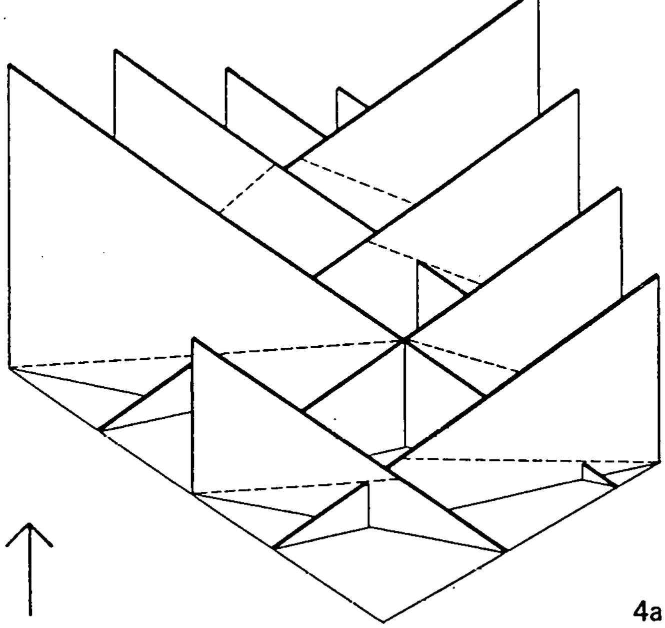
2b



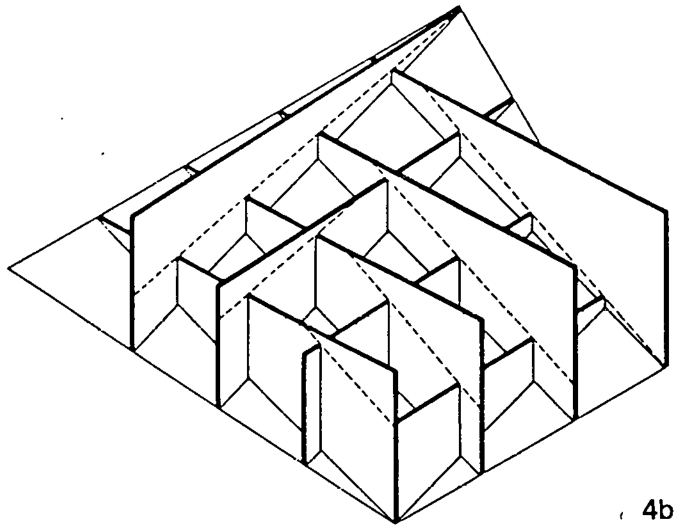
2bb



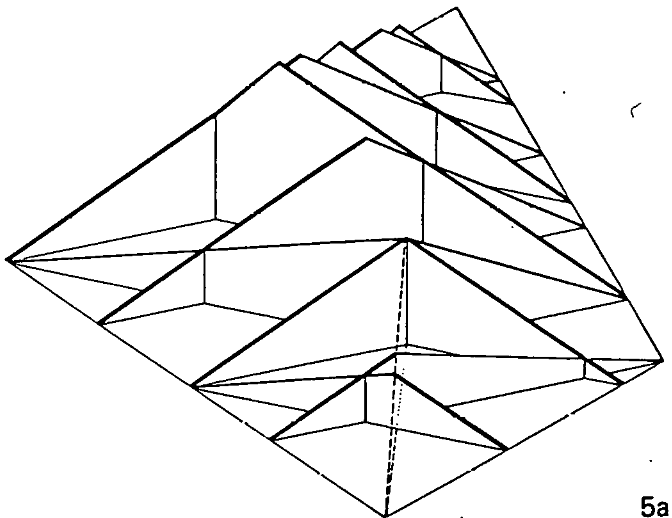
3b



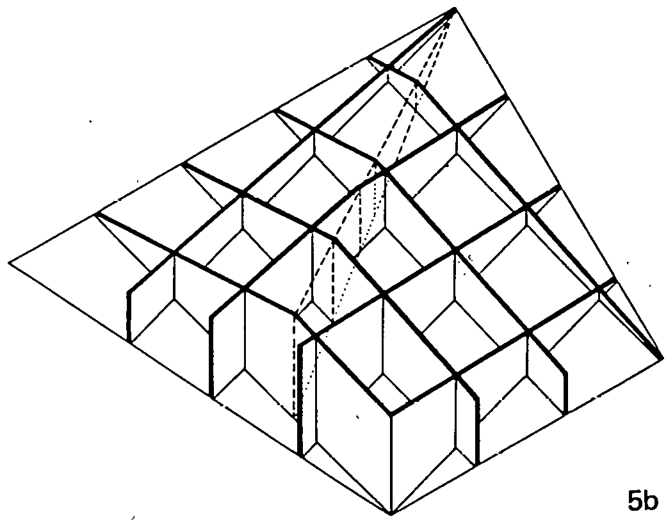
4a



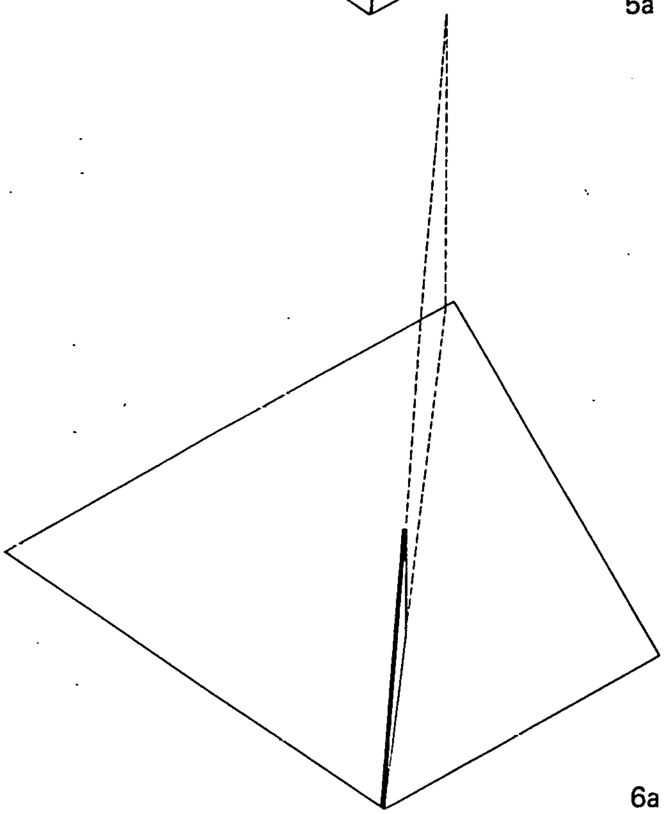
4b



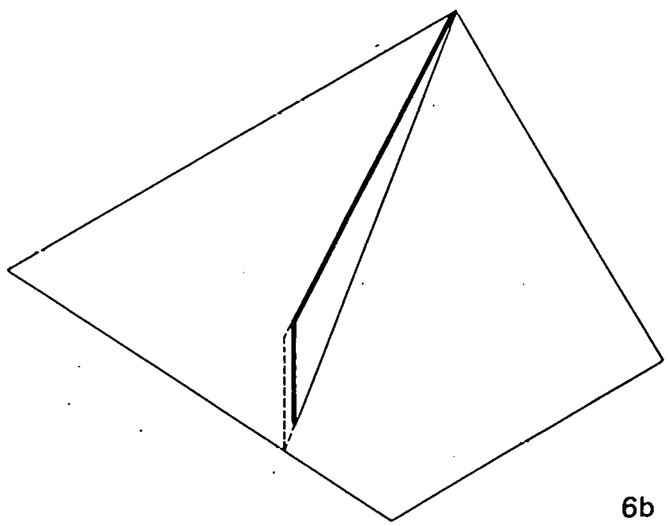
5a



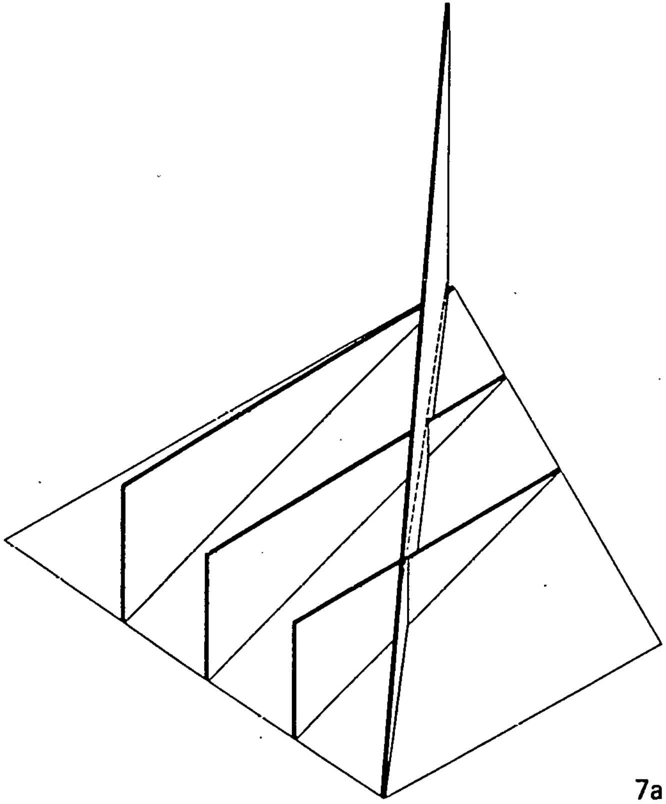
5b



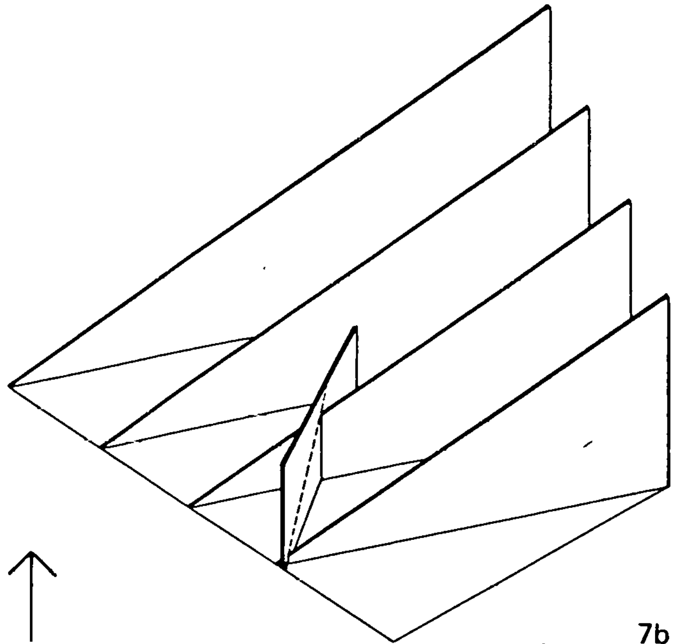
6a



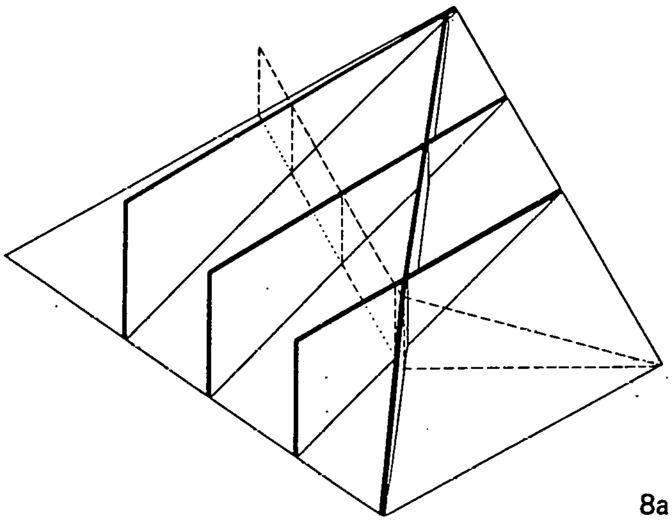
6b



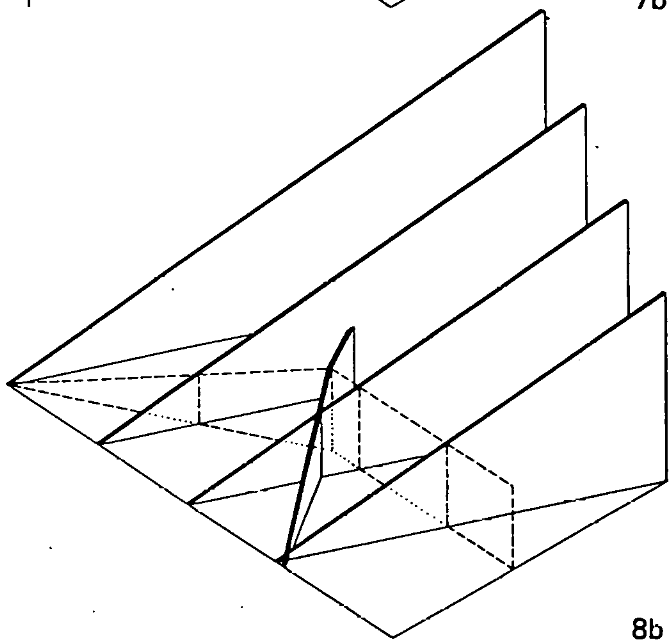
7a



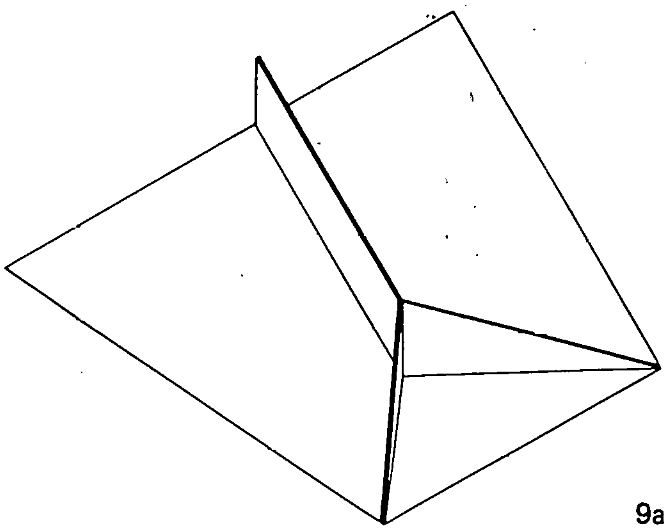
7b



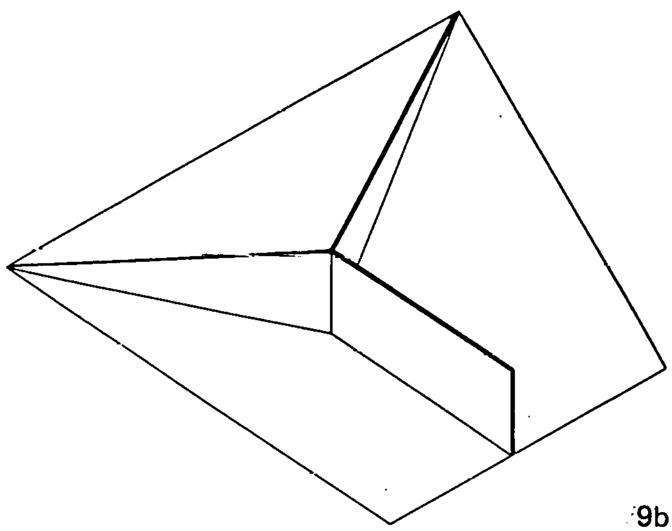
8a



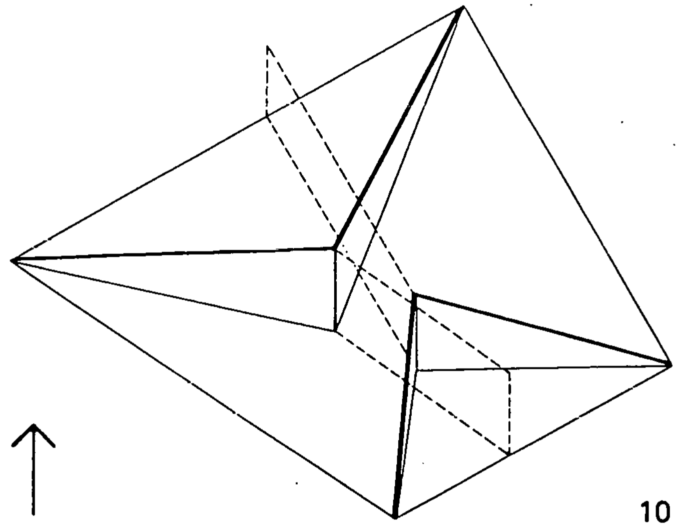
8b



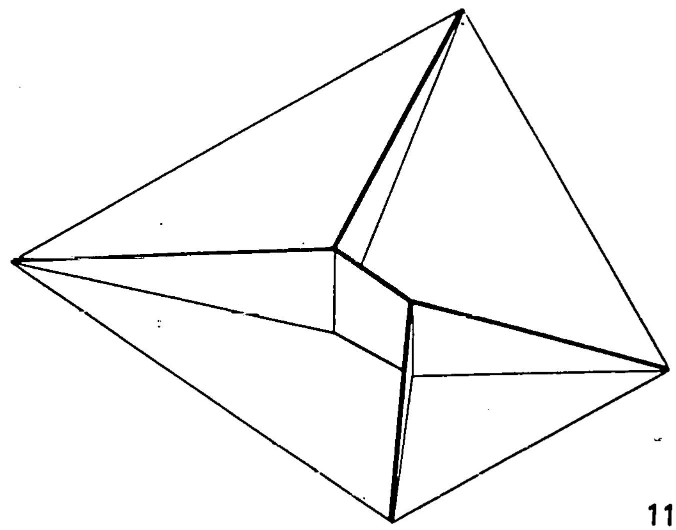
9a



9b

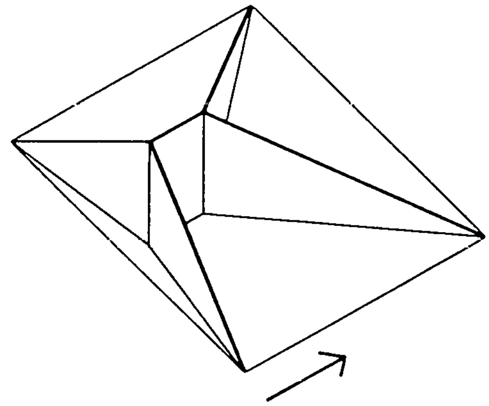


10



11

5.6 VARIABLE CONTEXT

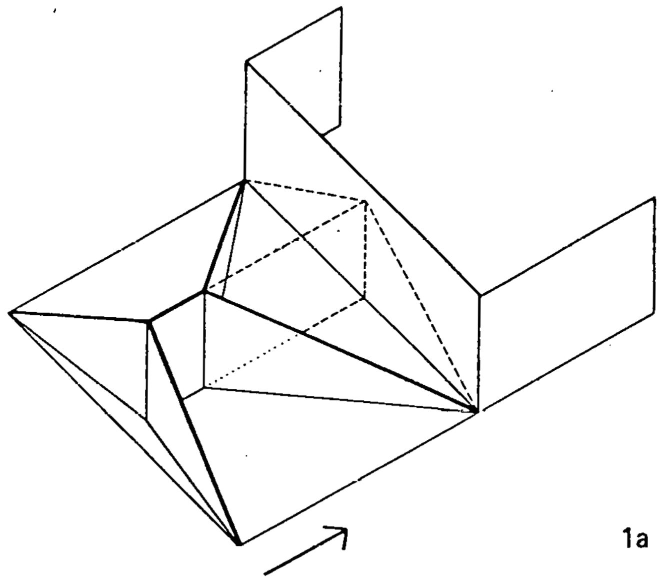


The last demonstration in this series deals with variable conditions surrounding a rectangular site. The size, shape, and orientation of the site are identical to the first case on a 0° grid orientation. The basic envelope, to which transformations will be made, is the same as the one generated for the first case.

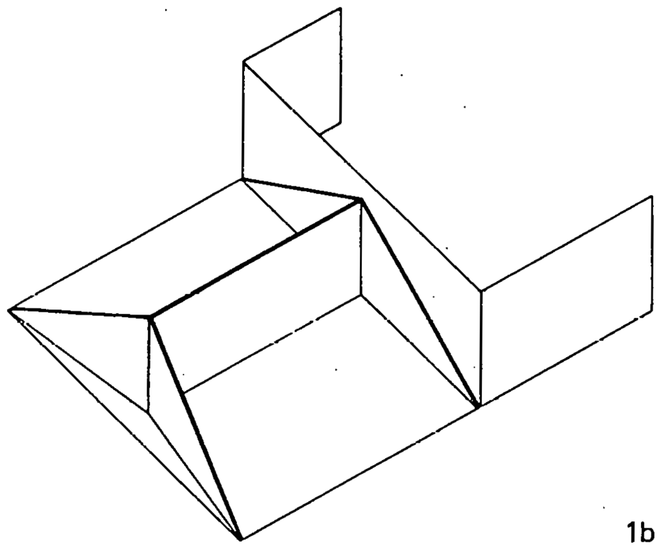
The eastern edge of the site touches a street. The procedure, then, sequentially changes the external conditions along the other edges of the site by adding fire walls. First one, then two, and finally three fire walls are added to enclose the site. Finally, the envelope is extended across the street to touch a building on the opposite side.

Each of these steps progressively adds volume to the envelope; but each step also diminishes solar access to the site itself and to its surroundings. Finally, only the street face of the envelope and the surfaces that slope up from the surrounding fire walls have exposure to the sun. The rest of the added volume is completely enclosed by the site's surroundings.

The essential strategy for obtaining each additional increment of volume is to allow some shadowing of the surrounding walls as follows: 100 percent of all existing or future fire walls; 30 percent of all existing or future window walls. (These particular shadowing assumptions are illustrative of the rules that were applied to one of the study areas).



1a



1b

5.6.1 Step 1: Add North Fire Wall

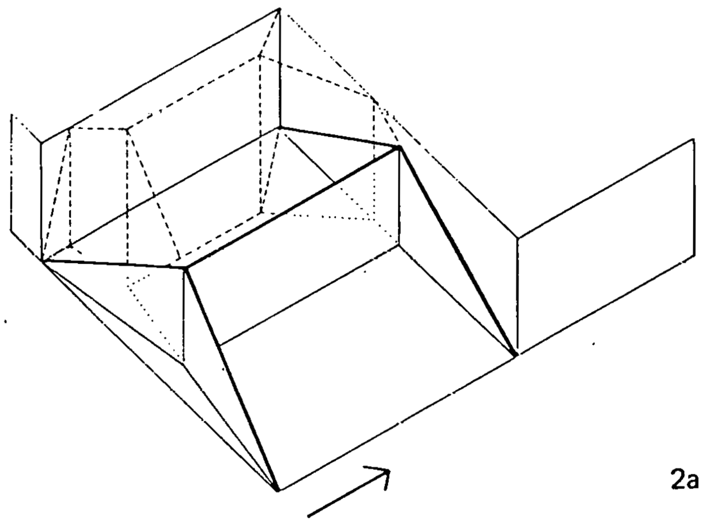
A fire wall is shown on the site's north boundary. Volume is added to the basic envelope by extending the ridge northward until it reaches the wall (1a).

The first modified envelope has three sloping faces on the south, east, and west. The fourth face is hidden by the fire wall on the north (1b).

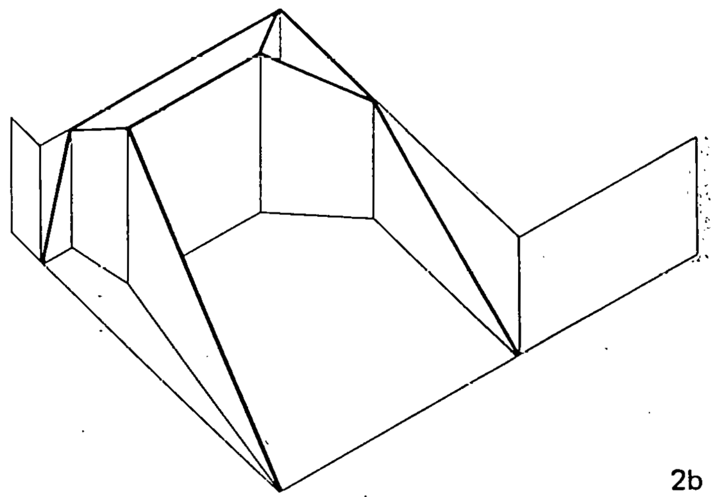
5.6.2 Step 2: Add West Fire Wall

Two fire walls are shown, one on the north and a second on the west boundary. More volume is added to the envelope by moving the ridge up and back toward the west fire wall (2a).

The resulting second envelope remains generally exposed on the south and east but is contained on the north and west. Its exposed south and west faces slope down to grade while two small faces slope to the tops of fire walls on the north and west (2b).

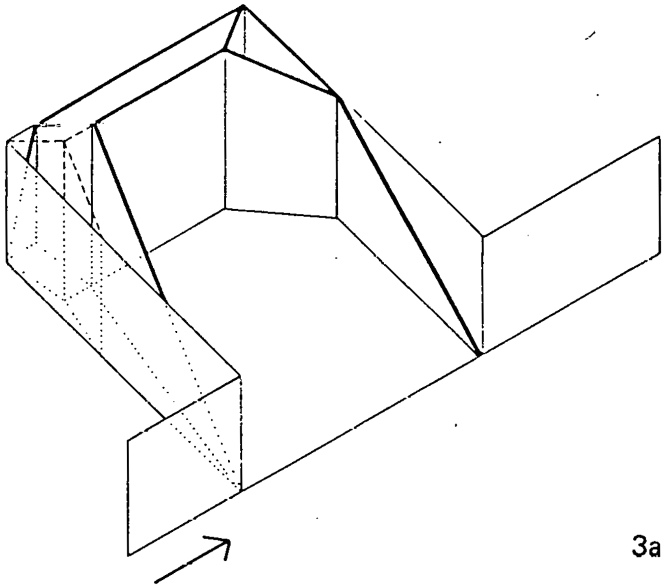


2a



2b

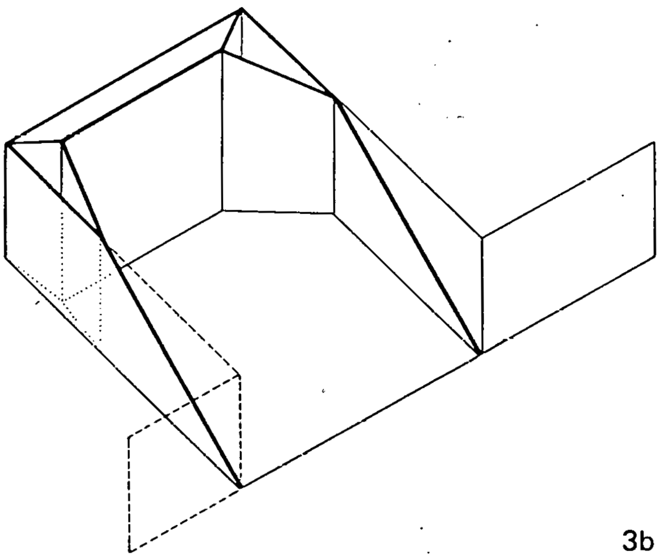
5.6.3 Step 3: Add South Fire Wall



3a

Three fire walls are now shown: one on the north, a second on the west, and a third on the south. Still more volume is added to the envelope by longitudinally extending the ridge toward the south fire wall (3a).

The resulting third envelope is generally contained on three sides and exposed on the fourth side. Its faces slope to the tops of fire walls on the north, west, and south; the east face slopes to grade (3b).



3b

5.6.4 Step 4: Add Buildings Across Street

A window wall is shown across the street to the east of the site. Unlike the fire walls that could be completely shadowed, only 30 percent of the window wall is shadowed, according to the assumed rules. In other words, the envelope may contain all of the fire wall area but only a portion of the window wall area. Under these circumstances, volume is once more added by expanding the envelope eastward until its slope intersects the opposing wall about one-third the distance from its bottom. In this process, the envelope's ridge shifts polarity from north-south to east-west, which increases its height (4a).

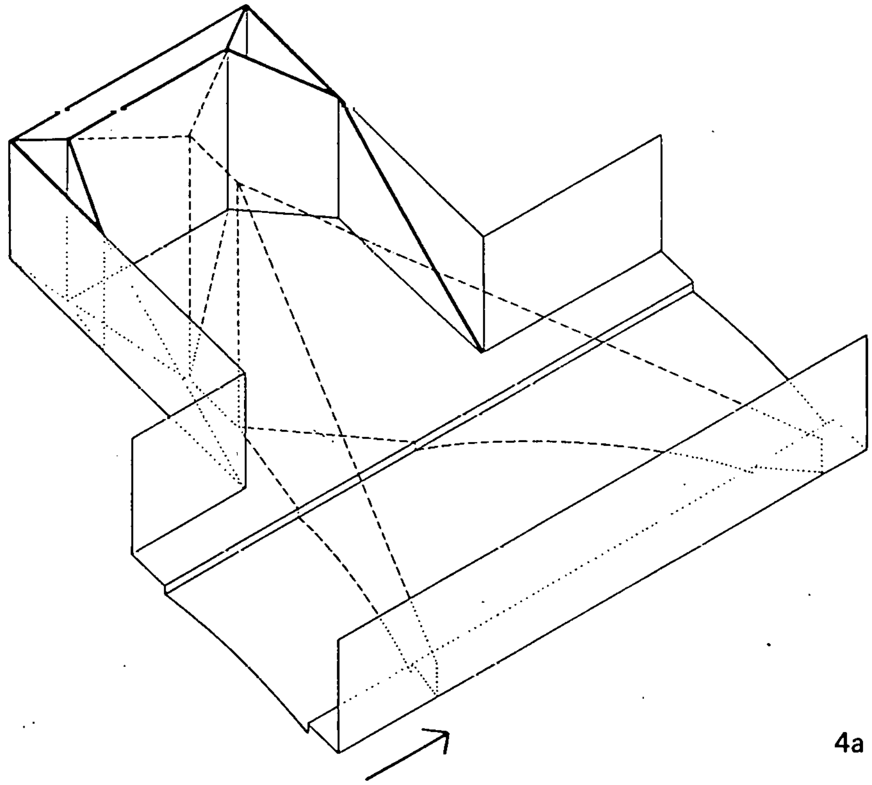
The resulting fourth envelope has a vastly increased volume. It fans out across the street to include all of the fire walls at the site's boundaries and portions of the window walls on both sides of the street (4b).

5.6.5 Step 5: Determine Final Envelope

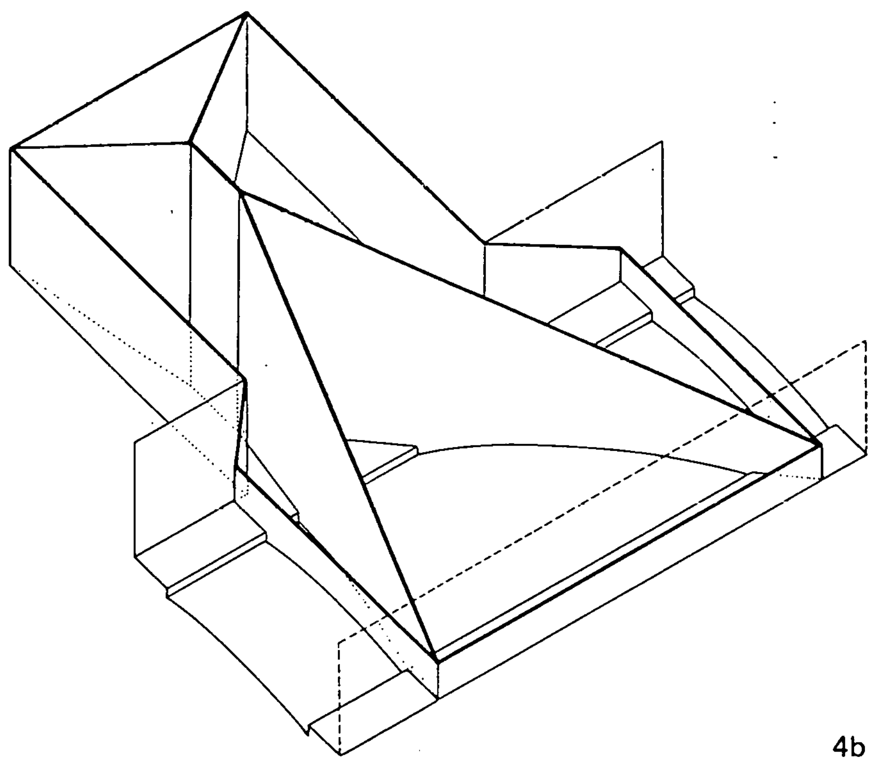
The developable volume must of course stop at the property line. The extent of the buildable volume is indicated by passing a vertical plane through the fourth envelope at the building line abutting the street (5a).

The fifth and final envelope guarantees solar access to the roof tops of adjacent surrounding buildings and to 70 percent of the window wall across the street. In addition, it has more volume under its sloping surfaces than do the presumably flat-roofed buildings surrounding it (5b).

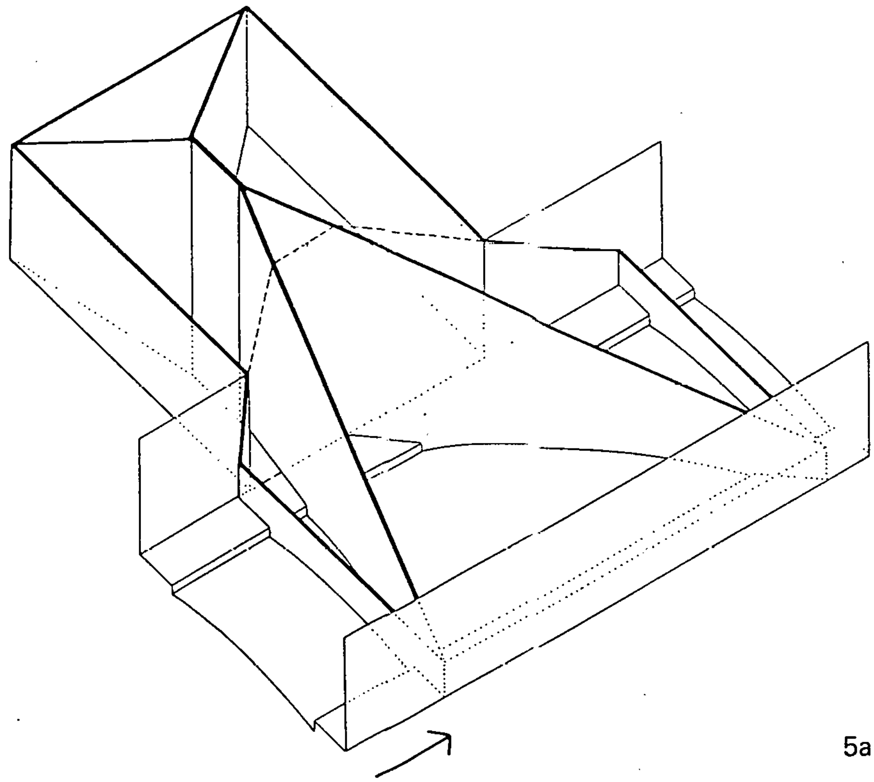
If the solar envelope were now applied in successive stages to the surrounding sites, they too could gain volume by following the same procedure. And of course, if adjacent sites were assembled, the resulting envelope could gain much more bulk without increasing its impact on the surrounds. In this manner, urban growth and change can continuously occur allowing building volume to increase progressively over time while protecting solar access to all buildings, at all times.



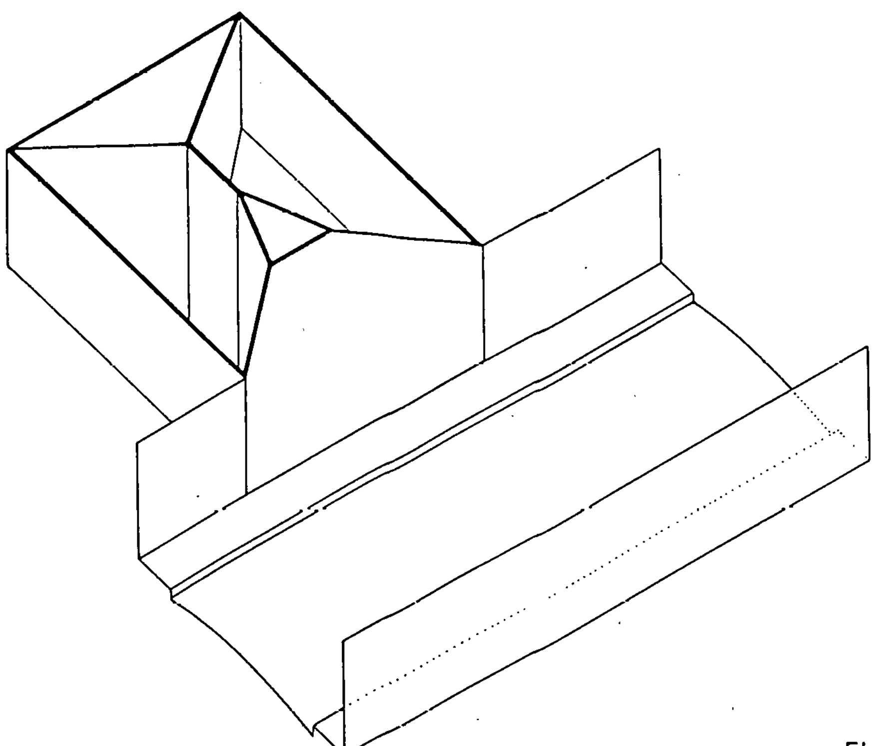
4a



4b



5a



5b

THIS PAGE

WAS INTENTIONALLY

LEFT BLANK

SECTION 6.0
DESIGN STUDIES

6.1 GENERAL APPROACH

This section documents the development simulation studies that were undertaken as a test of the two hypotheses stated in Section 4.2. These hypotheses translated as general, interlocking objectives to guide the site analyses and design efforts that were the core of the simulation strategy.

The first objective was to identify the development potential of both commercial office buildings and multi-family housing on two different sets of sites, complying with the constraints of the solar envelope. The second objective was to explore the design implication of the envelope, within the context of an office-building program and a multi-family housing program and under a variety of site conditions.

Because the site locations, development constraints, building programs, and envelope considerations differed significantly for the housing and commercial studies, the development programs for each were treated as two independent parts of the research. The downtown commercial studies were done in the fall of 1978 by one group of architecture students; the housing studies were undertaken in the spring of 1979 by another. Hence, the results of the work are presented here as two separate aspects of study and of urban development.

The general strategy used to test the envelope concept has already been outlined (Section 4.3). The strategy, as it was applied in the design studio at USC, required students to select and analyze an urban site, generate a solar envelope that met both solar access and development requirements, program a building that reflected these requirements, and finally design a building to be evaluated as an ultimate answer to the program requirement.

For both the commercial and the residential studies, this strategy insured that the student designers would be thoroughly familiar with the development sites. Before design work was initiated, groups of students participated in the analysis and final selection of test sites they would work on as individual designers.

The development program, from which each student worked, reflected typical development objectives and constraints. As presented, the problem was that of a developer seeking professional feasibility studies for a number of land parcels.

The research intent was to generate practical building options for each site so that the development implications could be compared for all sites. Equally important, there was an educational intent to balance the designer's level of experience and need for skill development with the study objectives.

The general charge given to the designers of all the study sites was to explore building alternatives first and then, on the basis of the programmatic criteria, to select one option for detailed study.

Designers were expected to identify specific problems and alternative solutions based on such necessary elements as parking, service access, elevators, fire stairs, corridors, lobby entrances and the like. The building form and architectural character were left to the designer's discretion. Experienced professionals' advice was periodically available as a check on the practicability of the building proposals.

The several designers working on a particular site acted as a team to determine the solar envelope for their own site. While the procedures used for generating an envelope were relatively simple, the building conditions surrounding a site created complications and the resultant forms of the envelope were in some cases relatively complex, particularly in the downtown commercial area.

There were two heliodons (sun simulating machines) at the students' disposal and most design teams were able to construct a model of their envelope, according to the assumed zoning rules, within a matter of a few days. An accurate set of measured drawings entailed several more days.

The zoning rules that were followed in generating the envelopes are provided in Sections 6.2 and 6.4, along with the specific programmatic requirements that guided the individual designers in both the office building and the residential studies.

The result of the design studies are seen in Sections 6.3 and 6.5. The examples shown are representative of a considerably larger body of work. However, what has been selected for inclusion in the report serves mainly to point out some of the important development and design issues that were raised by these particular projects. The building examples are not shown as exclusive solutions, nor even the best solutions to a particular set of development problems; neither are they shown to be emulated as building forms. They are rather shown as alternative answers to new development questions. They may also raise tentative questions to engage planners and designers in a serious consideration of fresh viewpoints, based on the concept of solar access.

6.2 OFFICE BUILDINGS - DESIGN FRAMEWORK

6.2.1 Study Sites

The commercial study area is situated on the southwest fringe of the Los Angeles central business district. This portion of the downtown area contains a large number of vacant land parcels, many of which serve as parking lots. These open land parcels occur among buildings of different sizes, ranging from 1 to 13 stories. The average building density, in terms of floor area ratio (F.A.R.), is close to 3.0, compared with 3.6 for the downtown as a whole. The area contains both new buildings and a significant number that have limited economic viability.

The area as a whole appears likely to attract moderate- to high-density development over the next two decades. Land values are comparatively low and land assemblage appears to be relatively simple to accomplish. Also, the city's planning department recently reduced the allowable F.A.R. from 13.0 to 6.0, in recognition of what was actually being built within the commercial core of the city.

Initially, studies were undertaken for only five sites, rectangular in shape, ranging in size from 22,000 to 35,000 square feet and having different street orientations (Sites A-E). The other four sites (F-I) were subsequently added because they were significantly larger than the first set of sites (about 50,000 square feet) and two of them had the kind of complex shapes that result from major modifications in public rights-of-way or land assemblage (Sites H and I). As a set, the nine land parcels seemed representative of the range of site conditions that potential developers might confront if they were interested in building office space anywhere within this part of Los Angeles, or even within similar commercial areas in other cities.

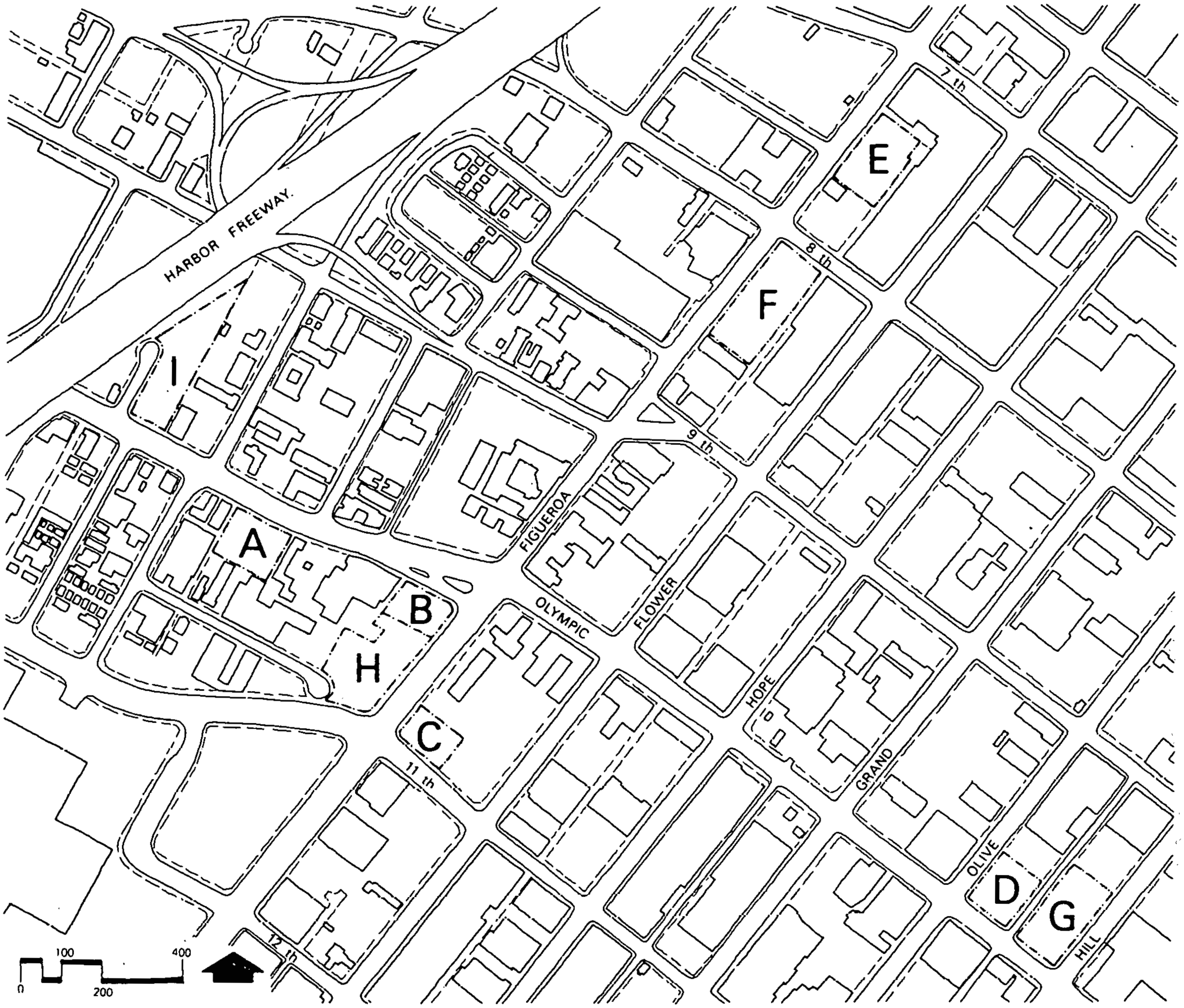


FIGURE 6–1. DOWNTOWN LOS ANGELES – COMMERCIAL SITES A TO I
Two major arterial streets, running at right angles to one another, have been attracting some new development. These two streets, Olympic and Figueroa, were the locus of study attention and about two dozen city blocks that bounded these streets were analyzed as to their development potential. Nine sites were ultimately used for study purposes.

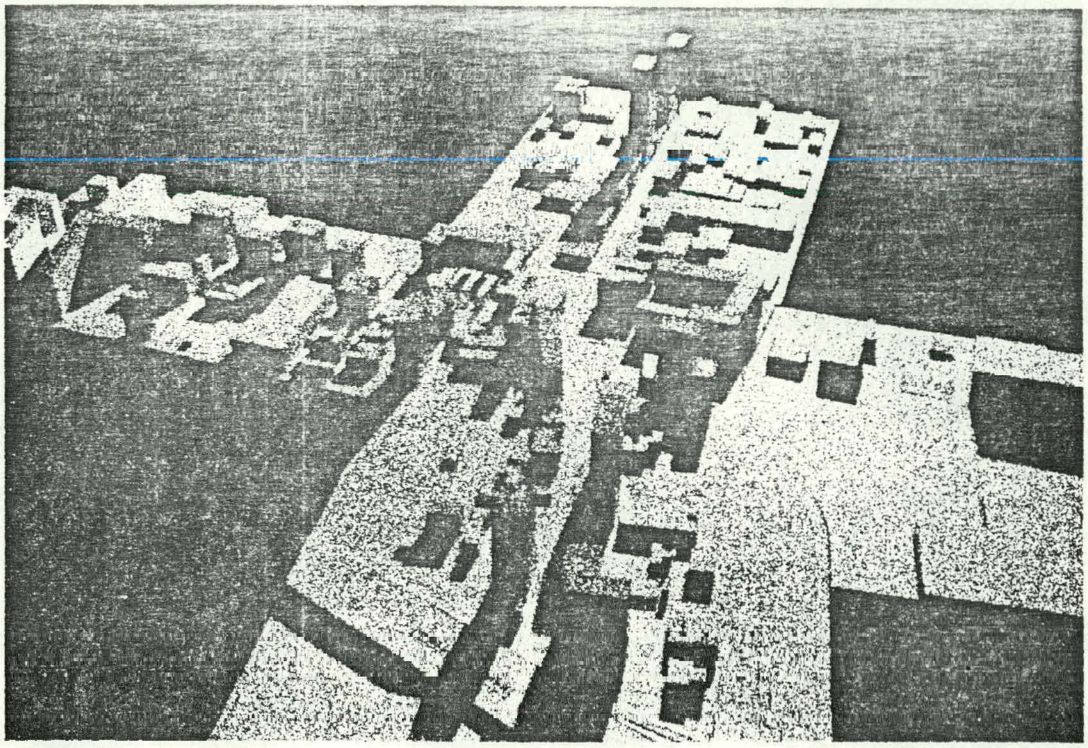


FIGURE 6–2. DOWNTOWN LOS ANGELES – WINTER – 9 AM
This is a view of the study area looking southeast into the winter morning sun at about 9 a.m. Olympic Boulevard is the long vertical street that can be seen receiving direct sunlight for its full length. All streets paralleling Olympic receive morning light. The other study reference street, Figueroa, runs left-to-right across the picture, and is shadowed by the buildings located on its southeast side.

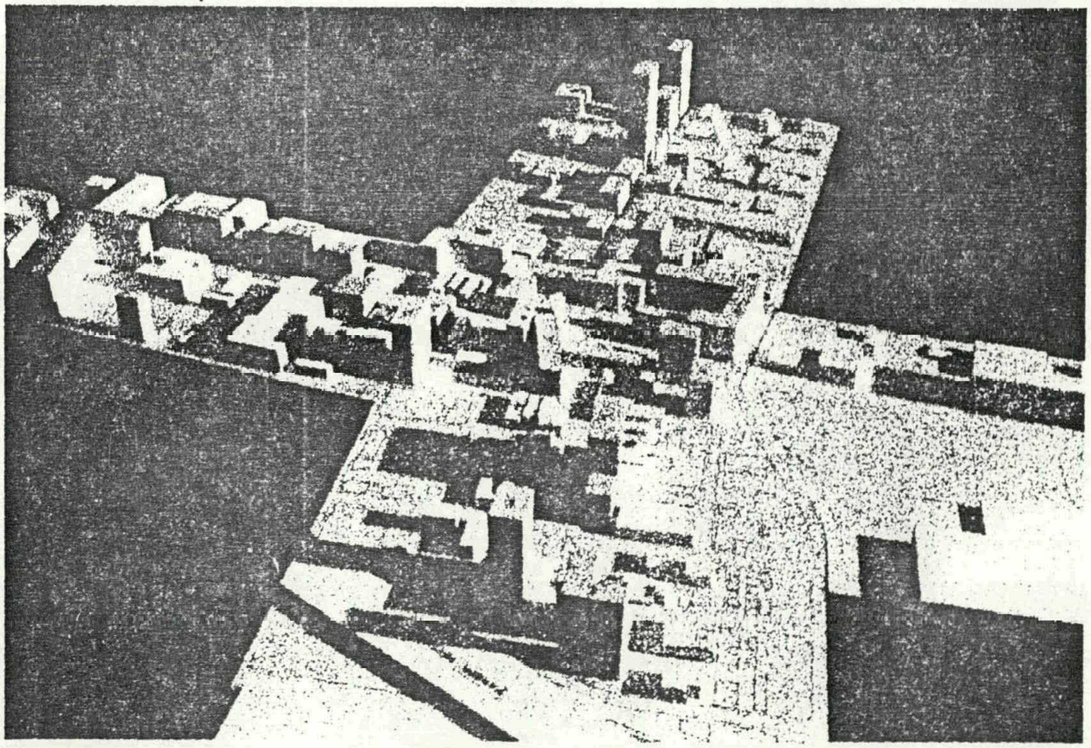


FIGURE 6–3. DOWNTOWN LOS ANGELES – WINTER – 3 PM
This is the same view of the study area, showing the winter afternoon rays of the sun sweeping up the streets from the southwest (from the right). Olympic Boulevard and streets running parallel to it are shadowed during the winter afternoon. Figueroa and the other streets that run from southwest to northeast are the ones bathed in sunshine at this time of day.

The nine sites were actually selected from more than two-dozen possibilities. One of the ways this initial set was analyzed involved the construction, in model form, of conventional office structures as they might be built under present zoning and development attitudes on each of the sites. These hypothetical structures varied in height from about 6 to 30 stories, according to individual designer's predilections, but none of them exceeded the allowable F.A.R. of 6.0. The results are shown pictorially in Figures 6-2 and 6-3, illustrating what might occur in this part of the city over perhaps the next two decades.

A comparison of the two pictures (Fig. 6-2 and 6-3) provides a dramatic illustration of how an urban-scape changes as the sun moves from morning to afternoon, a change that is particularly apparent on the Spanish street grid because of the grid's unique relationship with the sun's geometry. Every street receives the sun's light and heat during some part of the winter day.

There are obvious advantages in providing solar access to a commercial district since shopping and other pedestrian activities relate directly to the quality of the street itself. The portion of the downtown core that already contains 20- to 40-story buildings has seemingly lost most of the qualitative advantages provided by the Spanish planners, along with much of the street life that once existed.

6.2.2 Program Objectives

The specific programmatic objective was to design a rental office building, with ground floor commercial space, that would meet the following criteria, stated as performance specifications: (1) provide the maximum amount of rentable floor area that can be obtained; (2) provide sufficient on-site parking to comply with city zoning requirement; (3) provide natural light to all offices, maximum office depths not to exceed 35 feet; (4) prevent direct penetration of sunlight through windows during normal office hours; (5) provide an appropriate structural framing system; and (6) comply with all fire and building codes.

Solar zoning was of course presumed applicable to all sites. This entailed the formulation of a hypothetical zoning ordinance, which evolved in steps as the nature of the development problems in this area of the city became better understood by both the designers and the researchers. The rules that were finally agreed upon reflected the specific characteristic of the study area and an explicit set of premises.

The stated **objectives** of the hypothetical zoning ordinance were twofold: (1) to assure useful solar irradiation to all buildings, both existing and future; and (2) to encourage, or at least not inhibit, new development over time.

The basic **premises** can be stated as follows:

(1) Consider any building to be a total system having the potential to utilize solar energy through either passive or active mechanical means (sunshine or shadowing on open space is of no relevance).

(2) Solar irradiation must be available at least 6 hours per day in order to provide energy that is sufficient for practical conversion purposes within a building.

(3) The area in the vicinity of Figueroa Street and Olympic Boulevard has characteristics of land use, street orientation, land parcel sizes and geometries, and the potential for new development that seems to make the area suitable for solar zoning.

(4) Existing building patterns in the area plus real estate values suggest floor area ratios (F.A.R.) for new construction should not exceed F.A.R. = 6, but new development probably could be encouraged with a maximum F.A.R. = 4.

(5) Rules for generating solar zoning envelopes must be sufficiently explicit and sufficiently generalized to accommodate any development proposal and to guarantee solar access to all existing buildings that might surround any parcel.

(6) Once a solar envelope has been determined for a specified development land parcel, the zoning envelope is defined, limiting future construction height, bulk, and set-backs: in effect, no building or landscaping element may extend outside the envelope.

(7) Current zoning regulations impose no front, side, or rear yard set-backs on properties zoned "commercial," which will be maintained in the solar zoning applied to the study area.

6.2.3 Envelope Rules

The **rules** that were used in generating all zoning envelopes for the commercial sites can be stated as follows:

(1) Provide solar irradiation to all surrounding buildings at all times of the year between the hours of 9:00 am and 3:00 pm solar time. (In effect, this interval will provide maximum potential heat gain at the winter solstice while mitigating heat gain in the summer: about 77% of the aggregate daily energy that is theoretically available on a winter day and about 45% of what is available on the summer solstice at 34N latitude.)

(2) In order to protect solar collector plates that might in the future be placed on any nearby roof, the solar envelope for a land parcel cannot extend above the roof parapet of any existing building during the specified hours of the day.

(3) If a development parcel adjoins one or more vacant sites, then a single envelope may be constructed under the assumption that fire walls would be built at the common property lines when new building occurred.

(4) Parcels of land containing only temporary structures or having structures whose bulk is 10% or less of the allowed F.A.R. may be treated as vacant parcels for purposes of establishing a solar envelope.

(5) Walls of surrounding buildings that serve as fire walls or that have no significant windows in them have little or no potential for utilizing solar irradiation. Such walls may be totally shaded by a solar envelope.

(6) Walls of nearby buildings that function as window walls or that have window openings that exceed 25% of the wall area may be partially shaded by the solar envelope so long as no more than 1/3 (33 percent) of the wall is shaded during the specified hours of any day of the year. For example, on a mid-winter morning, the lower 1/3 of a nearby office building may be shaded (such shadows are in effect transitory and would allow solar access to most of the building wall most of the day and most of the year).

(7) If a development parcel has nearby vacant land parcels located on the opposite side of a public right-of-way (a street or alley), then the vacant parcels shall be treated as if they had buildings on them (which they will have in time). Any hypothetical future building on the vacant land must necessarily fit within its own solar envelope; hence, generate the solar envelope for the vacant parcel and assume that a full height window wall will eventually be built on the property line that fronts on the right-of-way. Under this condition, the solar envelope for the developable parcel may shadow 1/3 of the assumed window wall. However, if a solar envelope cannot be determined for the vacant parcel, then the envelope for the developable parcel may cast a shadow on the bottom 20 feet of the hypothetical wall.

(8) If the walls or roof of an existing low building are being shadowed by an existing tall building to a greater extent than what is imposed by an intervening solar envelope, then the solar envelope may be raised vertically until its shadow impact equals but does not at any time exceed the existing tall building's impact. In general, the increase in the envelope height will be proportional to the ratio of horizontal distances between shaded building and the solar envelope and between shaded building and the tall building which is producing the shadows.

(9) The solar angles to be used in generating envelopes apply to latitude 34N at 9:00 am and 3:00 pm sun time (bearing angles are for east and west of North at the given cut-off times).

Time of Year	Bearing Angle (θ)	Altitude Angle (α)
Summer	94^{o}	50^{o}
Equinox	120^{o}	35^{o}
Winter	137^{o}	18^{o}

6.2.4 Tabulated Results

The results of the building design studies are presented in the next section (6.3). The quantifiable planning, design and development attributes for each site have been summarized in Table 6-I. The numbers provide a comparative basis for evaluating the development potential of each site, each design solution, and the entire study area for which the sites are representative.

The data provided by the table suggests the wide range of building densities that can probably be expected for in-fill development. For example, the designers on one site (A) achieved an average F.A.R. of only 2.5 on a .66 acre site. A smaller site (B), with only .45 acres, produced an average F.A.R. of 3.5.

To achieve the specified solar access, the zoning envelope must reflect the existing conditions surrounding a site, and these variable conditions are what impose variable limits on the building potential of any site. Site A had buildings on three sides while Site B was situated on a corner.

On the other hand, the highest building F.A.R., about 4.5, occurred on two quite dissimilar land parcels of roughly equal size. Both had the same general orientation but one (Site I) had an unusual site geometry and envelope form.

The buildings on all the combined sites ranged in size from about 65,000 gross square feet up to roughly 230,000 square feet, differing by a factor of 3.5 from smallest to largest. By comparison, land parcel size differed by a factor of only 2.7.

The zoning envelope used clearly regulates density and development potential in ways that are quite subtle but always related to the specific conditions that surround a building site. Why and how this happens is suggested in the next section.

TABLE I -- ENVELOPE, BUILDING AND DEVELOPMENT DATA FOR PROTOTYPE DESIGN STUDIES OF COMMERCIAL OFFICE BUILDINGS ON NINE LAND PARCELS

DEVELOPMENT PARCEL		SOLAR ZONING ENVELOPE (Max. Development Potential)[1]			BUILDING DESIGN AND DEVELOPMENT FEASIBILITY STUDIES[2]				BUILDING/ENVELOPE RELATIONSHIPS	
SITE NO.	LAND AREA (sq.ft.)	GROSS FLOOR AREA	FLOOR AREA RATIO (F.A.R.)	ENCLOSED VOLUME (cu.ft.)	DESIGNER'S NAME	GROSS BLDG. FLOOR AREA (sq.ft.)	FLOOR AREA RATIO	BUILDING VOLUME (cu.ft.)	FAR (Bldg.) / FAR (Env.)	VOL. (Bldg.) / VOL. (Env.)
A	28,675	90,900	3.17	1,022,289	Alizor	66,154	2.31	793,852	.73	.776
					Carmichael	64,563	2.25	884,916	.71	.866
					Lew	81,167	2.83	908,802	.89	.889
					Magno	80,180	2.80	962,160	.88	.941
B	19,435	94,000	4.84	1,158,107	Assef	68,784	3.54	931,464	.73	.804
					Suberville	67,308	3.46	876,076	.71	.756
C	21,650	113,313	5.23	1,407,250	Murabata	80,630	3.72	1,075,998	.71	.765
					Steele	98,116	4.53	1,298,436	.87	.923
D	27,630	136,940	4.95	1,801,400	Mitnick	129,295	4.68	1,605,580	.95	.891
					Lowinger	97,589	3.72	1,328,568	.75	.738
E	35,200	156,200	4.44	2,440,047	Reza	131,835	3.75	1,694,020	.84	.594
					Pina	141,200	4.01	1,888,800	.90	.774
F	53,664	288,756	5.38	3,890,640	Reza	236,448	4.41	3,143,748	.82	.808
					Pina	206,863	3.74	2,633,745	.69	.677
					Alizor	194,724	3.63	2,608,074	.67	.670
G	49,500	295,000	5.96	3,579,425	Suberville	222,146	4.49	2,931,360	.75	.818
					Assef	229,854	4.64	3,137,697	.78	.877
					Lowinger	224,250	4.53	2,962,512	.76	.828
H	50,702	224,010	4.42	5,799,813	Steele	210,951	4.16	2,821,206	.94	.486
					Mitnick	196,473	3.88	2,536,468	.88	.437
					Murabata	184,465	3.64	2,401,712	.82	.414
I	49,500	310,875	6.28	4,746,833	Magno	233,899	4.73	3,103,788	.75	.654
					Carmichael	188,349	3.81	2,172,072	.61	.457
					Lew	232,867	4.70	2,819,232	.75	.594

1. Potential buildable floor area and FAR calculated for above-grade building bulk, assuring constant floor-to-floor height of 12 feet.

2. Building floor area, FAR and building volume excludes below-grade parking.

6.3 OFFICE BUILDINGS – DESIGN EXAMPLES

The results of the building design studies presented in this section are representative of both the design exploration procedures and the development alternatives that were identified for each site. The eight sets of drawings illustrate the progression that was actually followed by the student designers in moving first from a raw land parcel to a solar envelope and then from a development translation of the envelope to the generation of building options.

Several examples of completed building models are included to illustrate the range of design possibilities and the nature of the design problems that were dealt with.

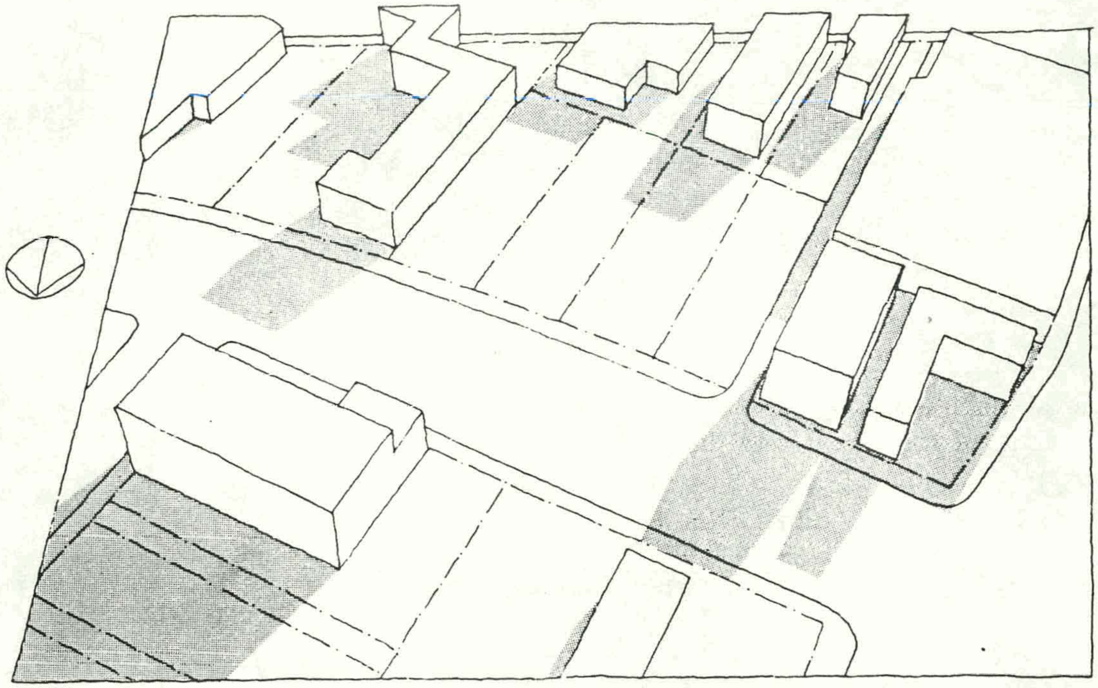


FIGURE 6–4. SITE A – PARCEL BOUNDARIES, WINTER – PM
This site is located mid-block on the southwestern side of Olympic Boulevard. An alley runs along the site's westerly boundary. This 28,675 square feet land parcel is surrounded by two- and three-story buildings.

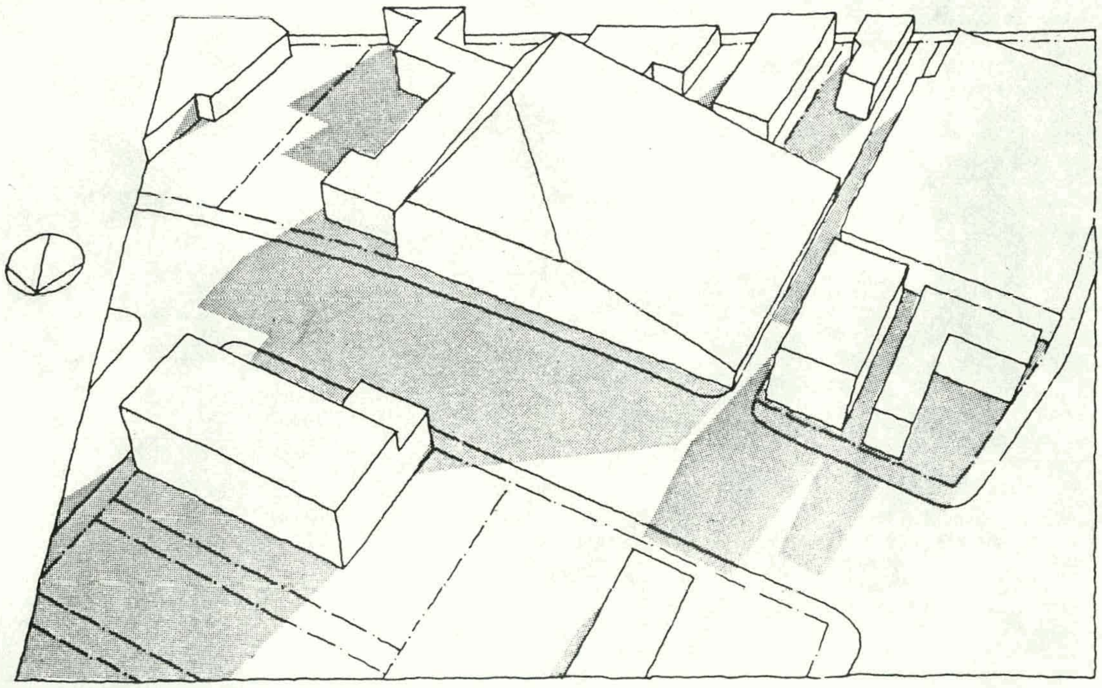


FIGURE 6–5. SITE A – ENVELOPE, WINTER – PM
The site's solar envelope contains 1.0 million cubic feet. It is generated to protect the roofs of all surrounding buildings. The envelope presumes fire walls on the southeast and southwest site boundaries. Window walls on buildings across the alley and the street are partially protected, based on the rules used to assure solar access. The envelope's principal feature is a broad, sloping northwest face.

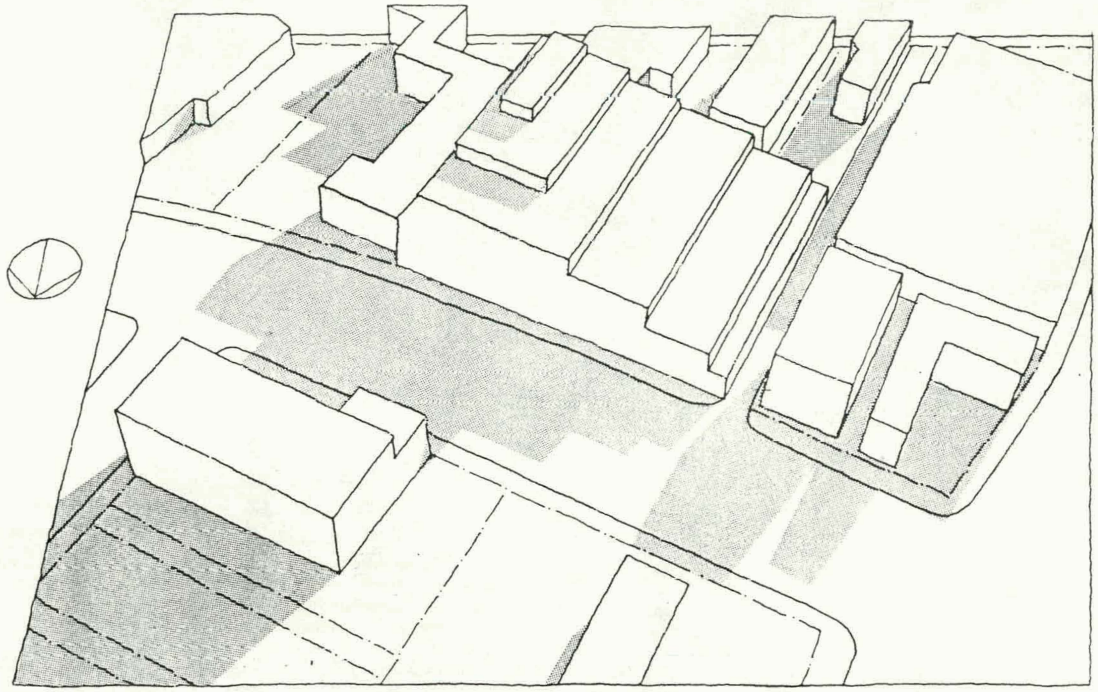


FIGURE 6–6. SITE A – ENVELOPE BUILDING TOPOGRAPHY, WINTER – PM

The envelope here is sliced horizontally at 12-foot intervals to represent the floors of a hypothetical building. This topographic interpretation provides a useful measure of the envelope's potential building bulk. The procedure on this site produces a gross floor area of 90,000 square feet; and from this number, it is determined that the envelope provides a potential floor area ratio of 3.17 (F.A.R. = 3.17).

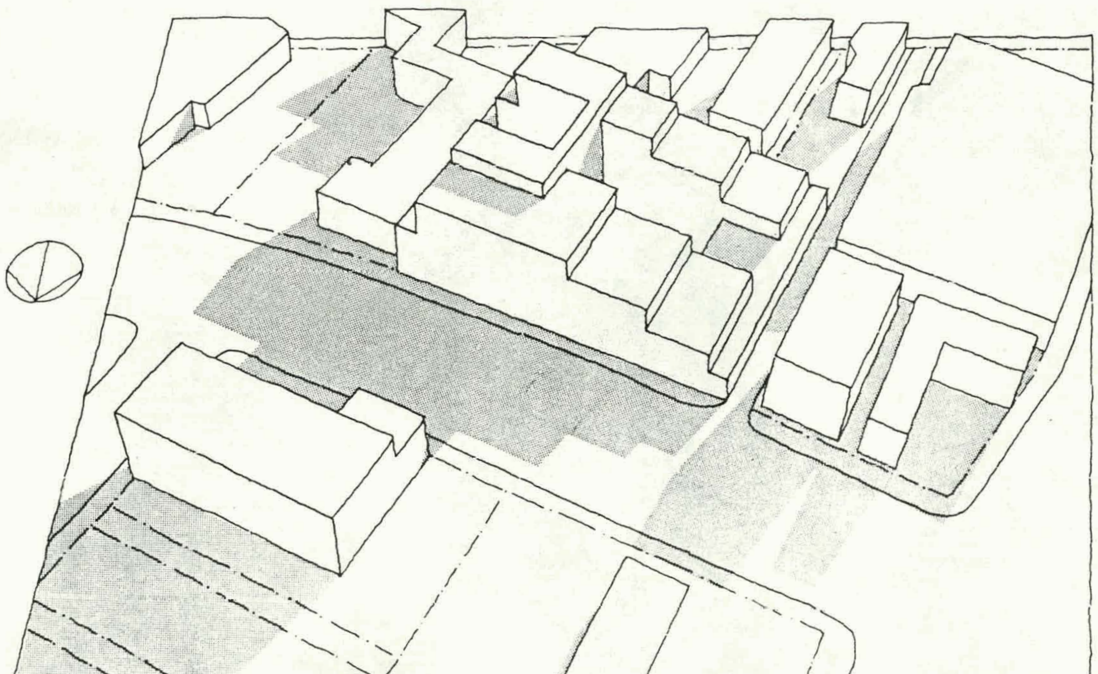


FIGURE 6–7. SITE A – DESIGN OPTION, WINTER – PM

To establish the actual development potential of the envelope requires general building design options for a development program. This particular design drops the first commercial floor half a level below grade, providing 962,000 cubic feet within the building. This represents 94% of the envelope's volume. The designer has cut into the envelope to create courts that provide natural light to the office spaces. The gross floor area obtained in this design is 80,000 square feet, or 88% of the envelope's potential floor area. F.A.R. = 2.80. (Designer: Hector Magno.)

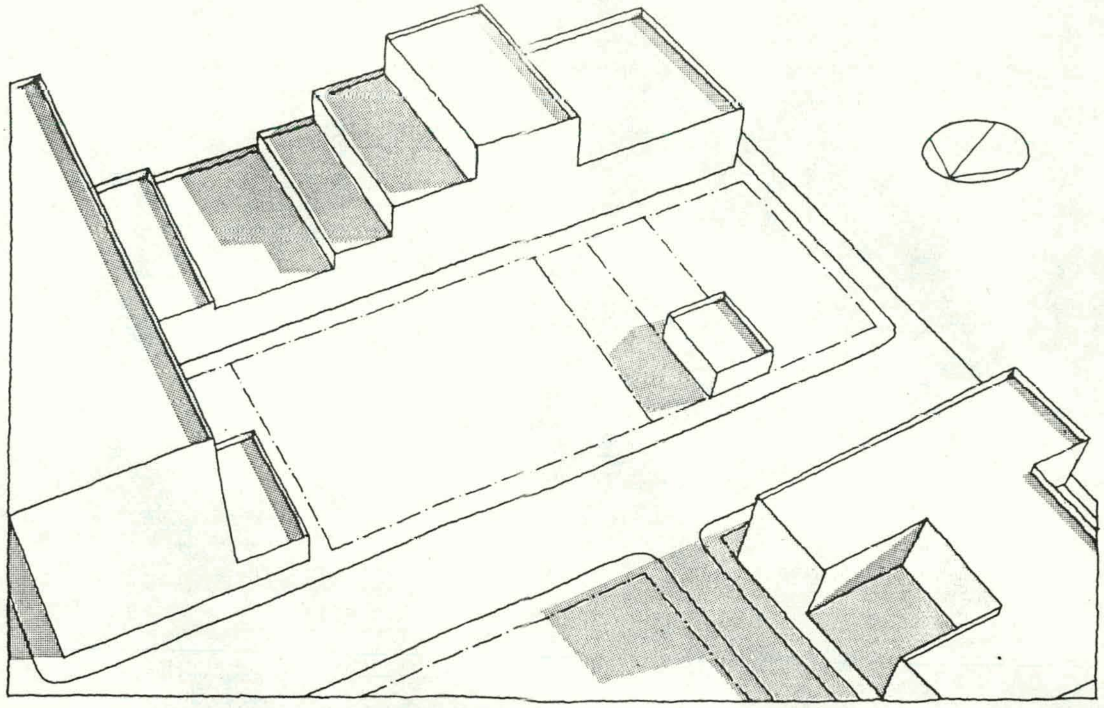


FIGURE 6–8. SITE E – PARCEL BOUNDARIES, WINTER – PM

This second mid-block site is located on the southeastern side of Figueroa Street. An alley runs along the site's southeastern boundary. The parcel contains 35,200 square feet of land and is surrounded by a complex set of one- to six-story buildings.

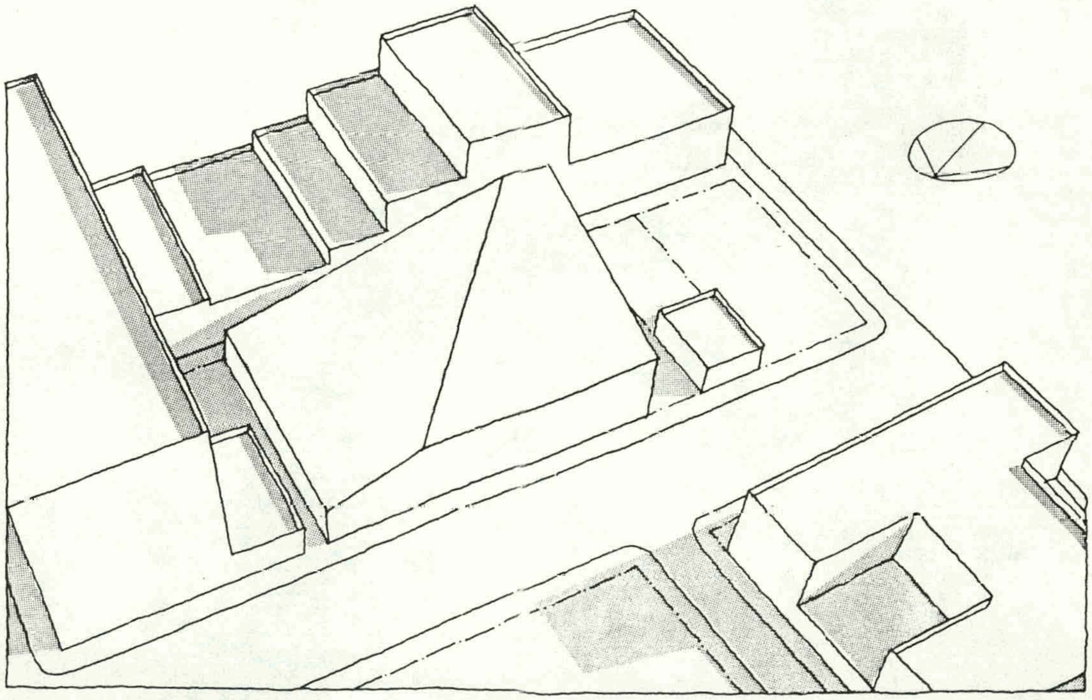


FIGURE 6–9. SITE E – ENVELOPE, WINTER – PM

The envelope for this site contains 2.4 million cubic feet. It is generated to protect the low roofs of the existing buildings to the northeast and southwest of the site and a window wall on the building across the alley on the southeast. The envelope's principal features are two broad sloping faces that intersect to form a north-south running hip which rises to a high peak on the south corner.

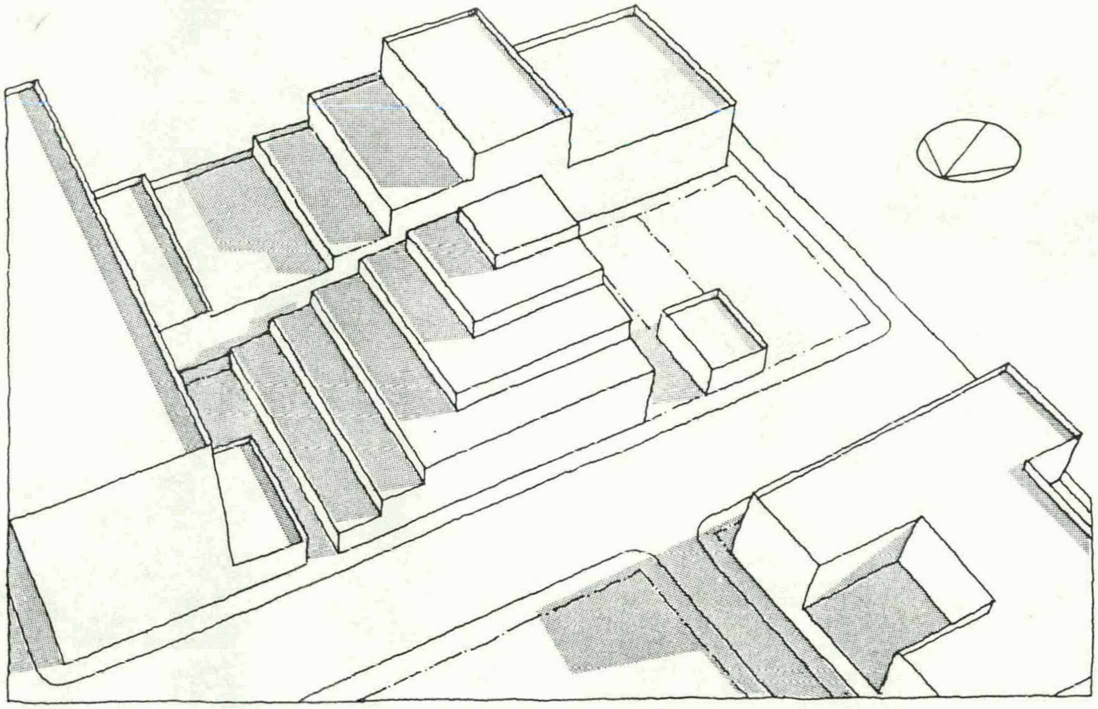


FIGURE 6–10. SITE E – ENVELOPE BUILDING TOPOGRAPHY, WINTER – PM
The topographic interpretation of the envelope indicates the potential buildable floor area for this site is 156,000 square feet. This number corresponds to a potential F.A.R. of 4.44.

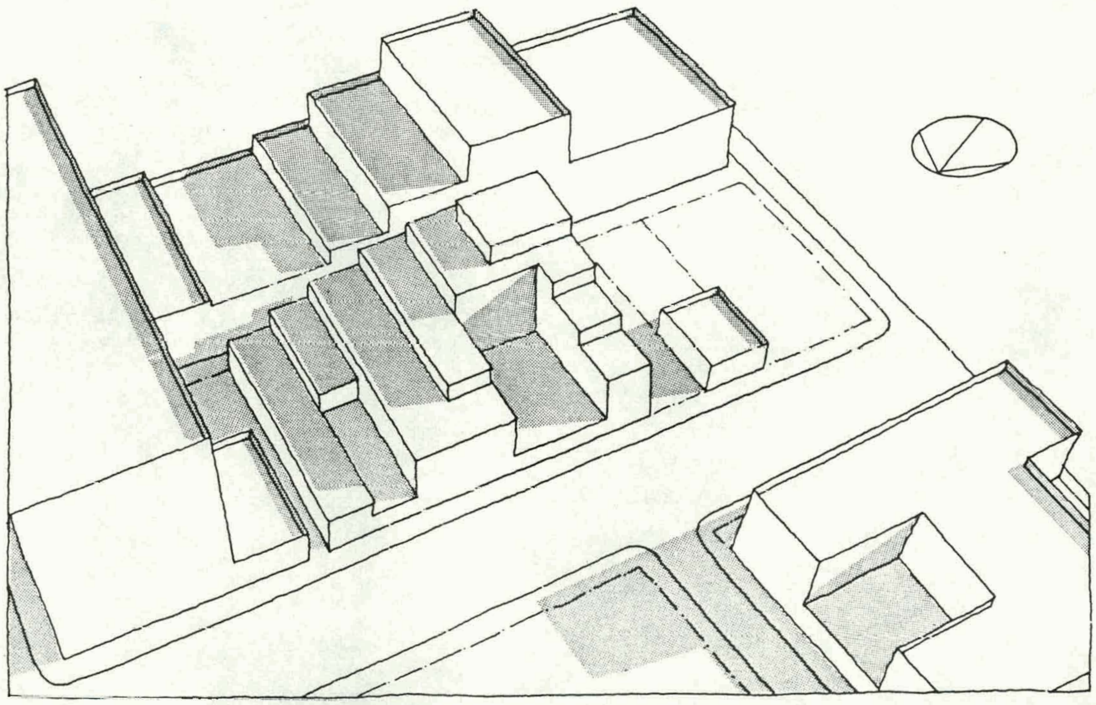


FIGURE 6–11. SITE E – DESIGN OPTION ONE, WINTER – PM
This first approach to a building design under the envelope opens two courts to the street. The larger court serves as the building's major entrance. Retail facilities are located at street level. The design provides 1.7 million cubic feet of space, which represents 70 percent of the envelope's volume. The gross floor area excluding subterranean parking is 132,000 square feet or 84 percent of what is potentially available within the envelope. F.A.R. = 3.75. (Designer: Dan Reza.)

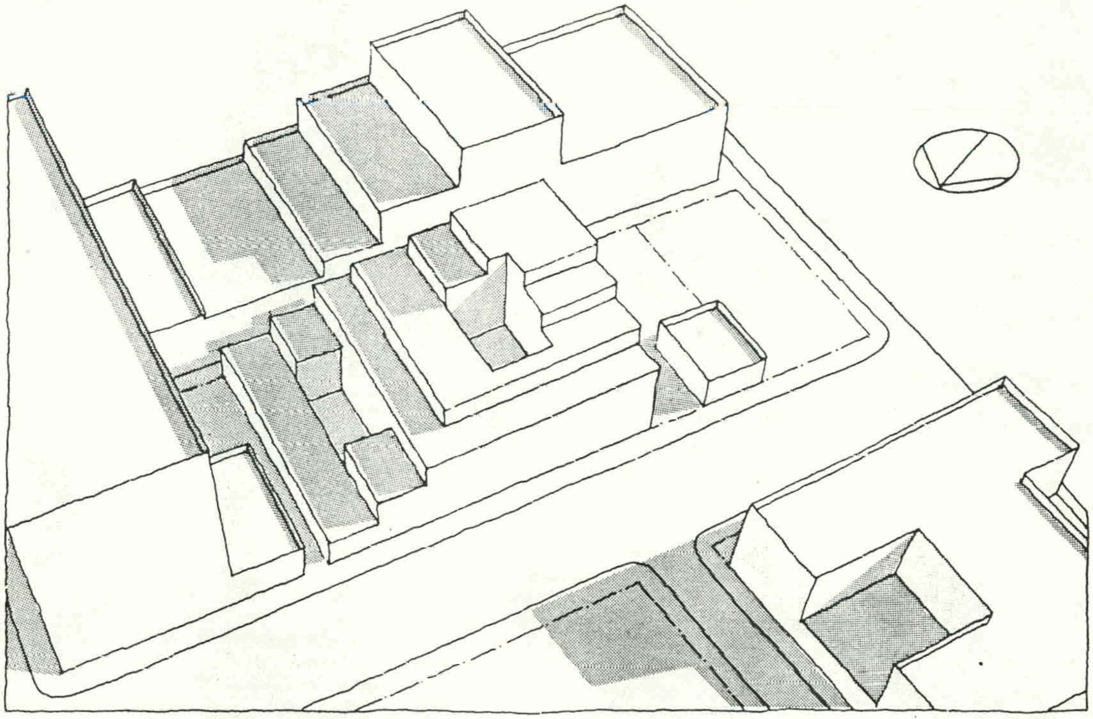


FIGURE 6–12. SITE E – DESIGN OPTION TWO, WINTER – PM

A second design on the site uses interior courts that are somewhat smaller. Consequently, the designer is able to obtain 1.9 million cubic feet of building, which represents 77 percent of the envelope's volume. The gross floor area (excluding below-grade parking) is 141,000 square feet or 90 percent of what is potentially available within the envelope. F.A.R. = 4.01. (Designer: Paul Pina.)

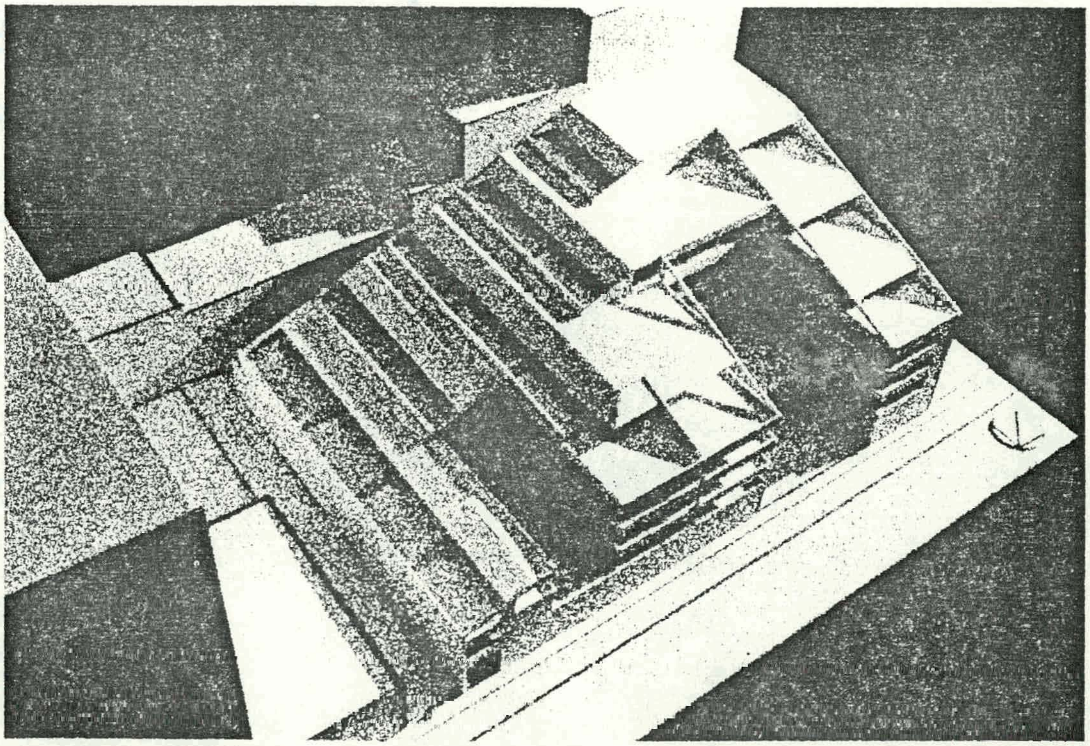


FIGURE 6–13. SITE E – BUILDING MODEL, DESIGN OPTION ONE, WINTER – PM

The terraces are seen here partially enclosed under sloping roofs. Office spaces are extended by this technique, providing added leasable floor area. Some offices open onto private roof terraces, others open into courtyards; a few look out to the street. (Designer: Dan Reza.)

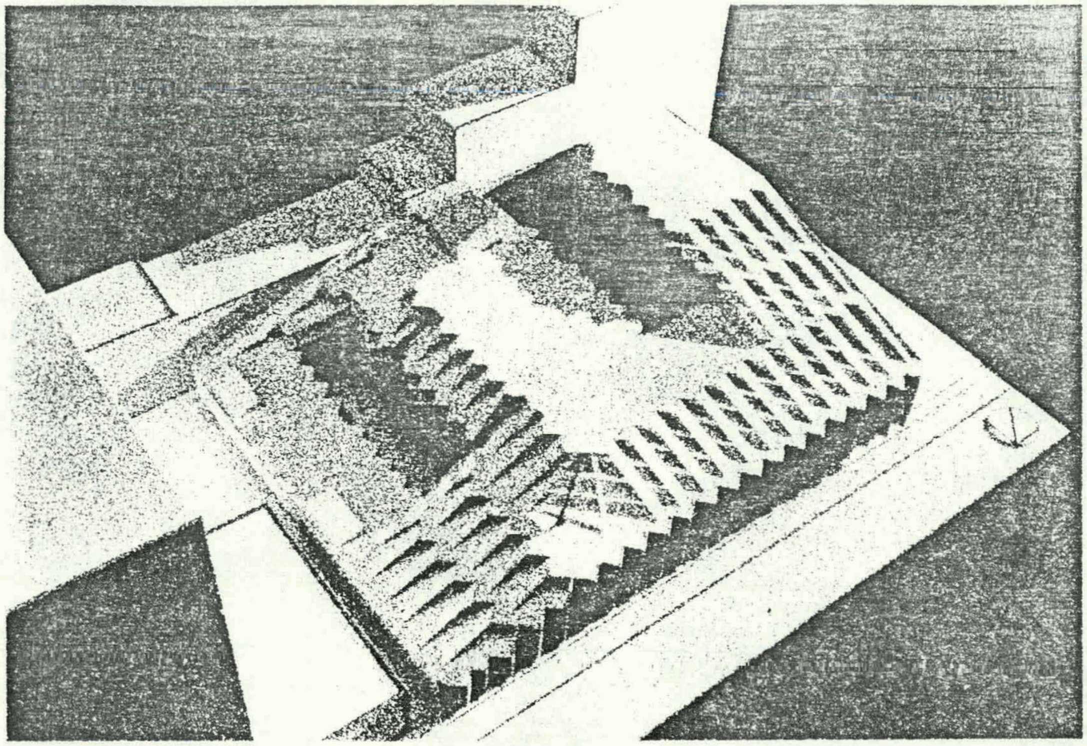


FIGURE 6–14. SITE E – BUILDING MODEL, DESIGN OPTION TWO, WINTER – PM
The terraces in this case are completely enclosed under sloping roofs that act to control and admit daylight. This technique adds still more leasable office space, but of an unconventional character. (Designer: Paul Pina.)

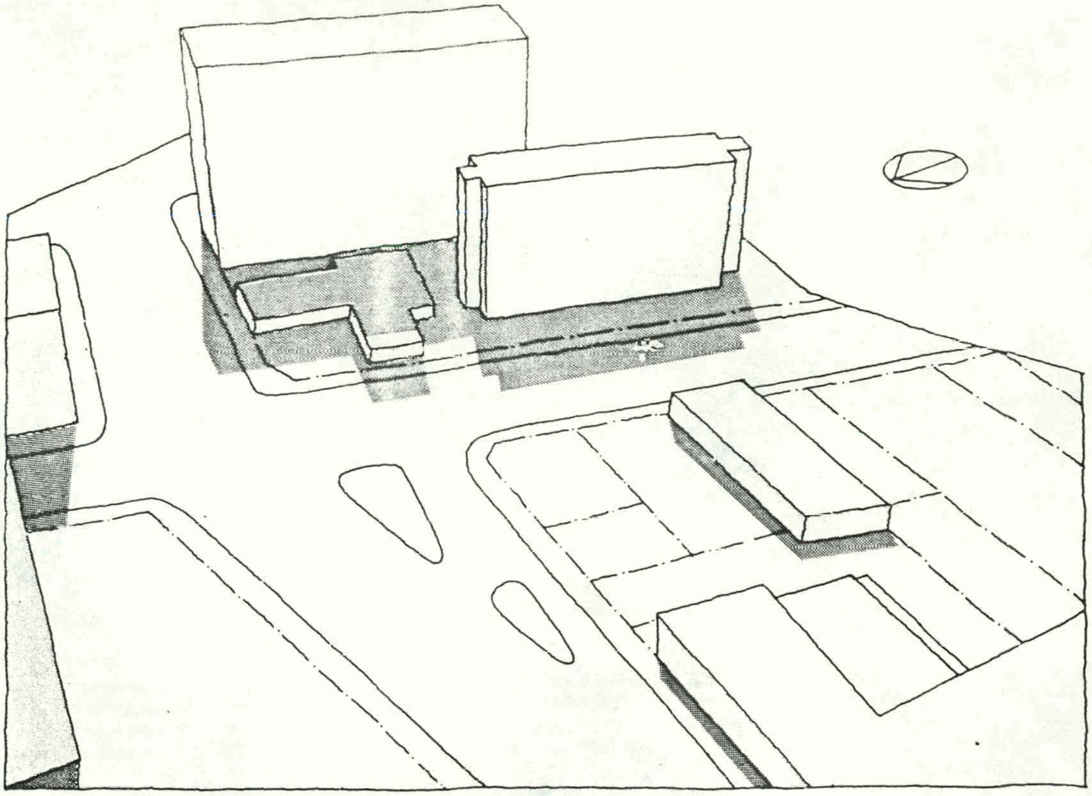


FIGURE 6–15. SITE B – PARCEL BOUNDARIES, SUMMER – AM
This site is located at the western corner of Olympic Boulevard and Figueroa Street. The parcel contains 19,435 square feet of land area. The low buildings immediately adjacent to the site vary from one to three stories in height. The buildings across the street to the north and east are eight to thirteen stories in height.

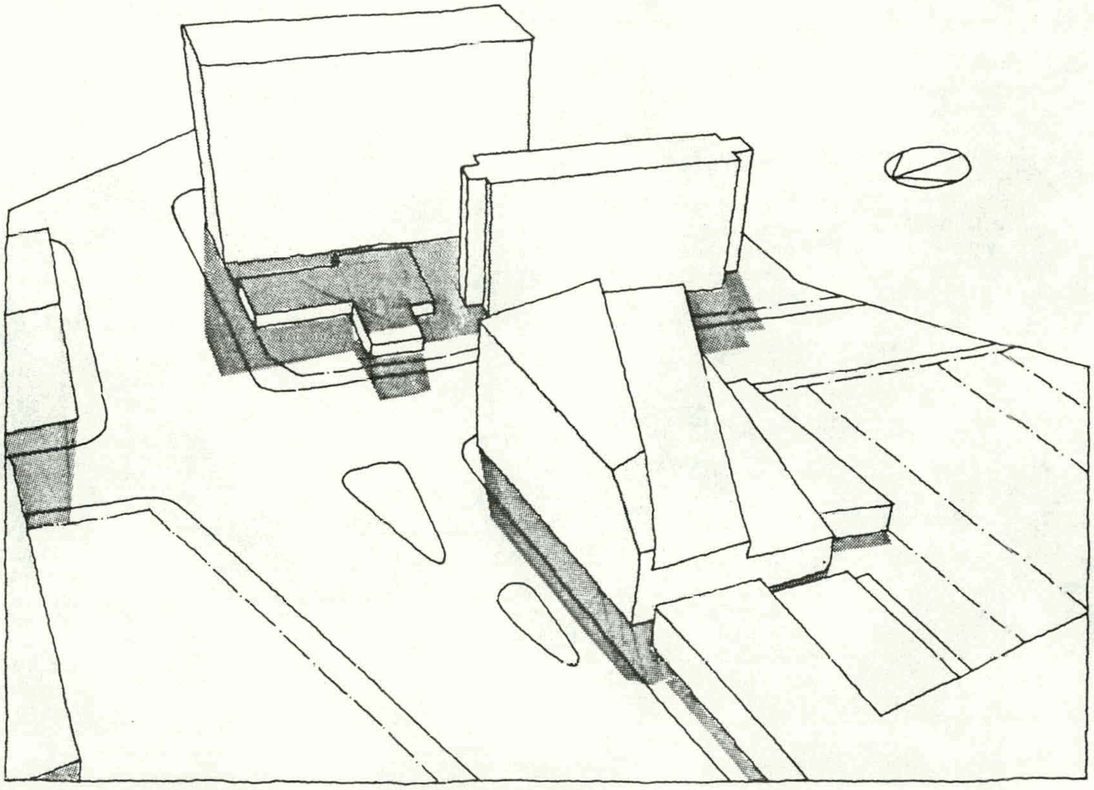


FIGURE 6–16. SITE B – ENVELOPE, SUMMER – AM
The envelope is somewhat complex in its form. Its principal feature is the series of faces that are separated by vertical cuts which provide an exact fit with the variable building heights surrounding the site. The envelope also has high vertical faces on the street sides because its shadows are allowed to project across both streets and the broad intersection. There are 1.2 million cubic feet of volume within the envelope.

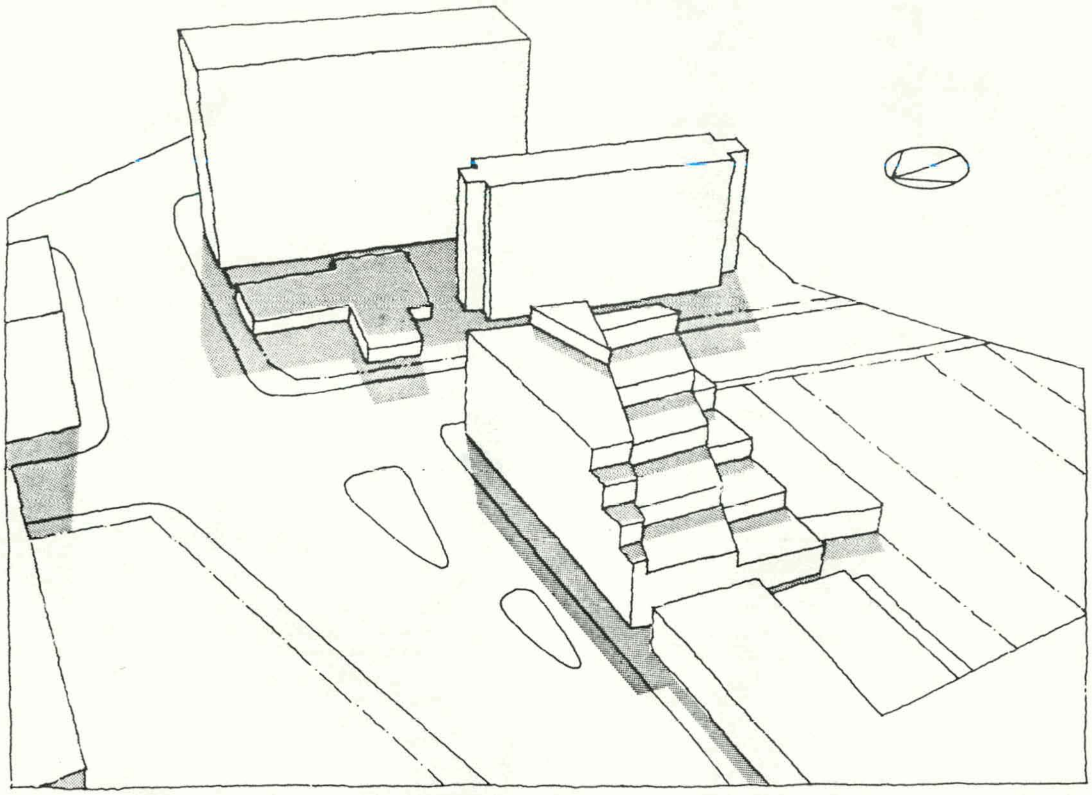


FIGURE 6–17. SITE B – ENVELOPE BUILDING TOPOGRAPHY, SUMMER – AM
The envelope's topographic interpretation as a building form provides a maximum potential floor area of 94,000 square feet. This translates to a potential F.A.R. of 4.84.

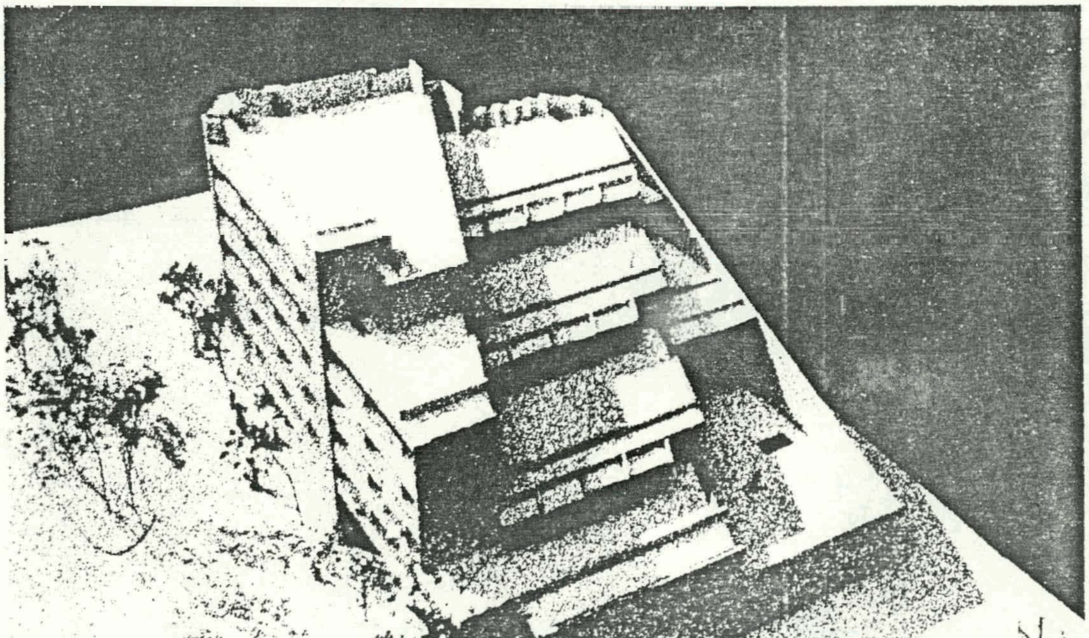


FIGURE 6–18. SITE B – BUILDING MODEL, DESIGN OPTION ONE, SUMMER – AM
The first design is a nearly literal translation of the envelope form. Where the envelope has sloping surfaces, the designer has used terraces to meet the slopes. Also, the building walls closely match the envelope's vertical cuts. The design encloses 876,000 cubic feet or 76 percent of the envelope's volume. The gross floor area (excluding subterranean parking) is 67,000 square feet or 71 percent of the envelope's potential. F.A.R. = 3.46. (Designer: Mark Suberville.)

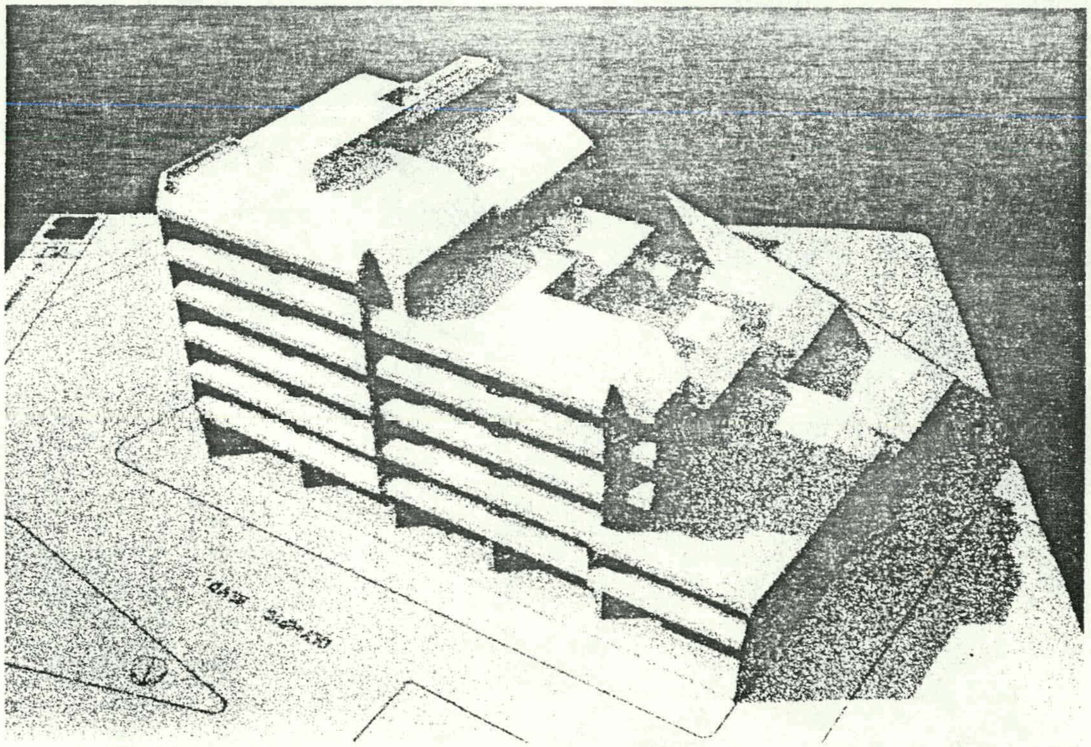


FIGURE 6–19. SITE B – BUILDING MODEL, DESIGN OPTION TWO, SUMMER – AM
This second design follows a more traditional, rectilinear building geometry, but the floor area and building bulk obtained by this design are almost identical with those of Option One. (Designer: Mojtaba Amanimehr.)

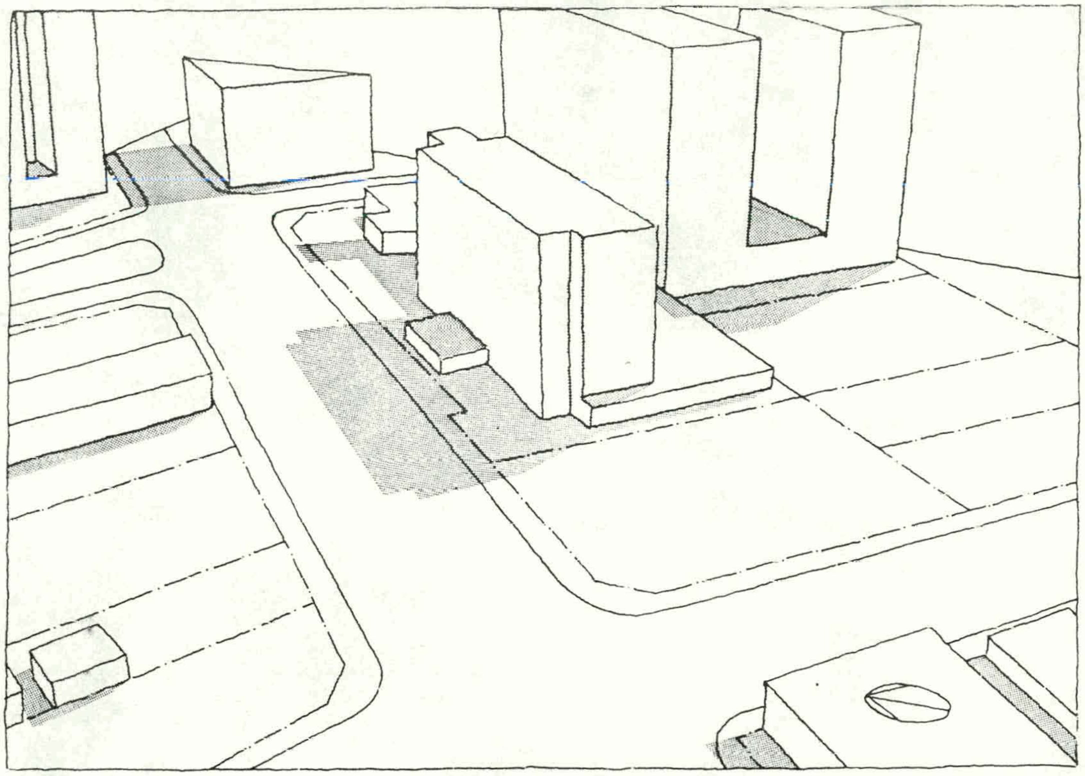


FIGURE 6–20. SITE C – PARCEL BOUNDARIES, SUMMER – AM

This site, like the preceding one (Site B), is situated on a street corner, at Figueroa and 11th Street. The parcel area is 21,650 square feet. There is a high fire wall on the end of the existing building to the northeast of the site. The properties to the southeast of the site and across the street to the northwest are vacant.

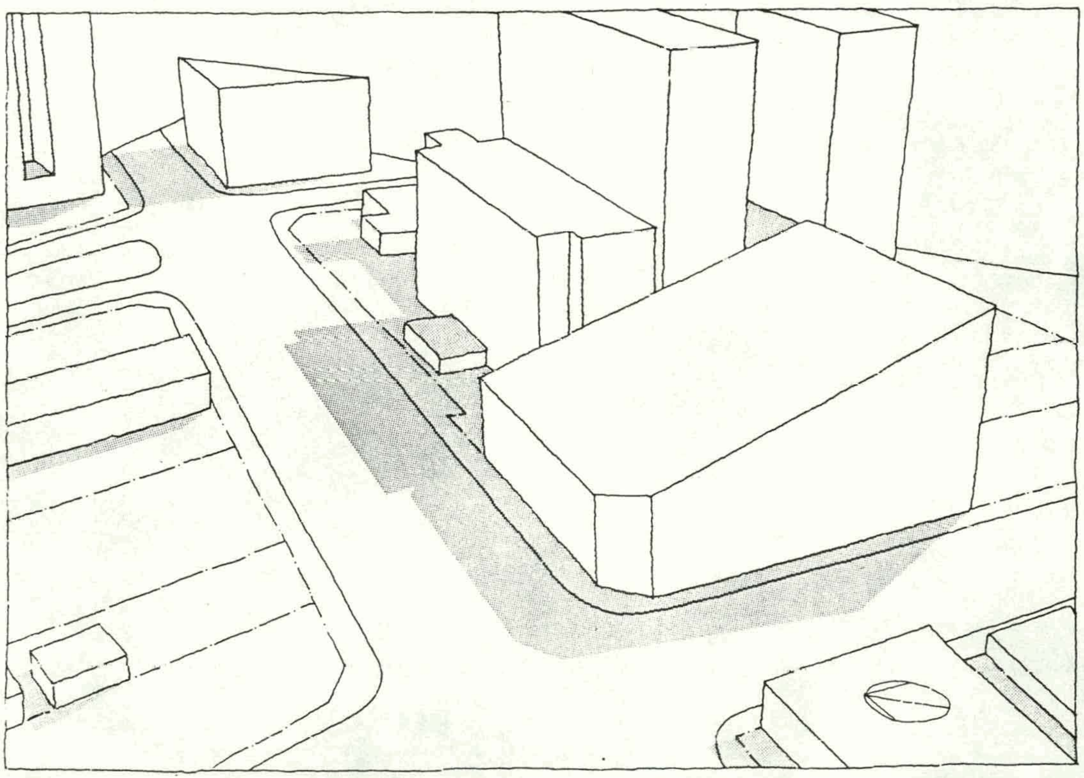


FIGURE 6–21. SITE C – ENVELOPE, SUMMER – AM

This envelope contains 1.4 million cubic feet. Its principal feature is the high vertical face at the interior, southeast boundary where the adjacent site is included under an extension of the same envelope. From this high side, the envelope slopes down to Figueroa Street. The height of the street face is determined by first generating an envelope for the vacant site across the street and then generating the envelope for Site C, assuming that there will be window walls on any future buildings across the street.

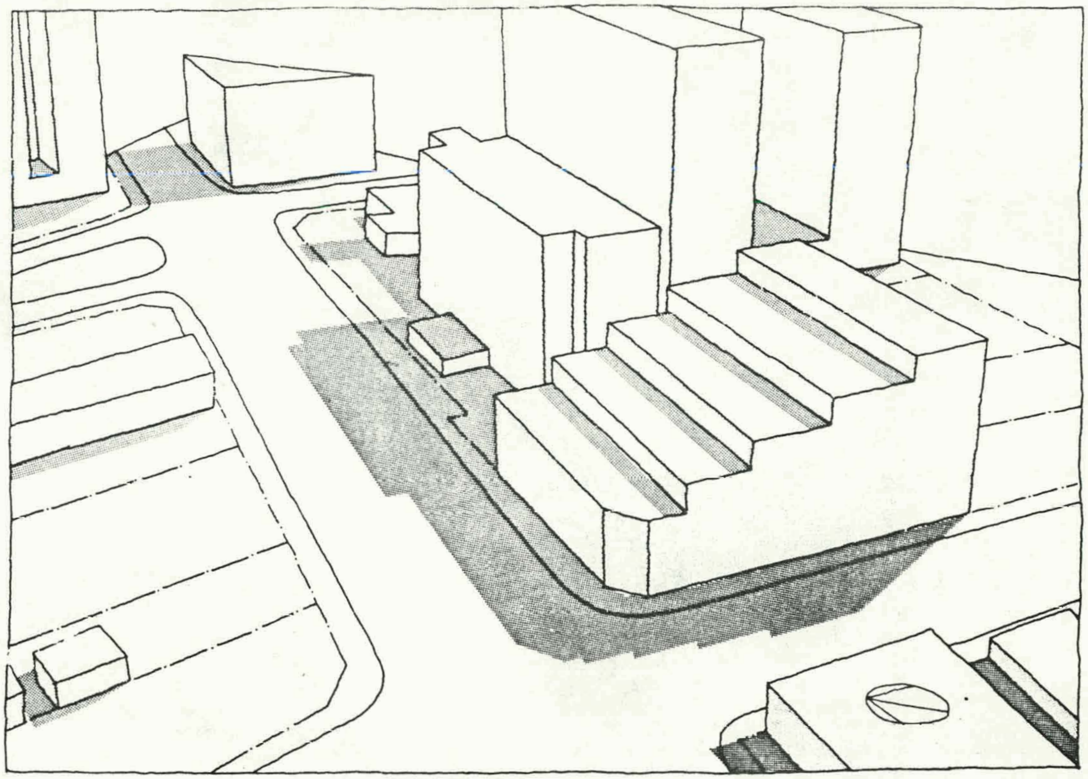


FIGURE 6–22. SITE C – ENVELOPE BUILDING TOPOGRAPHY, SUMMER – AM
The topographic interpretation of the envelope for building purposes provides a relatively high gross floor area of 113,000 square feet. This converts to a potential F.A.R. of 5.23.

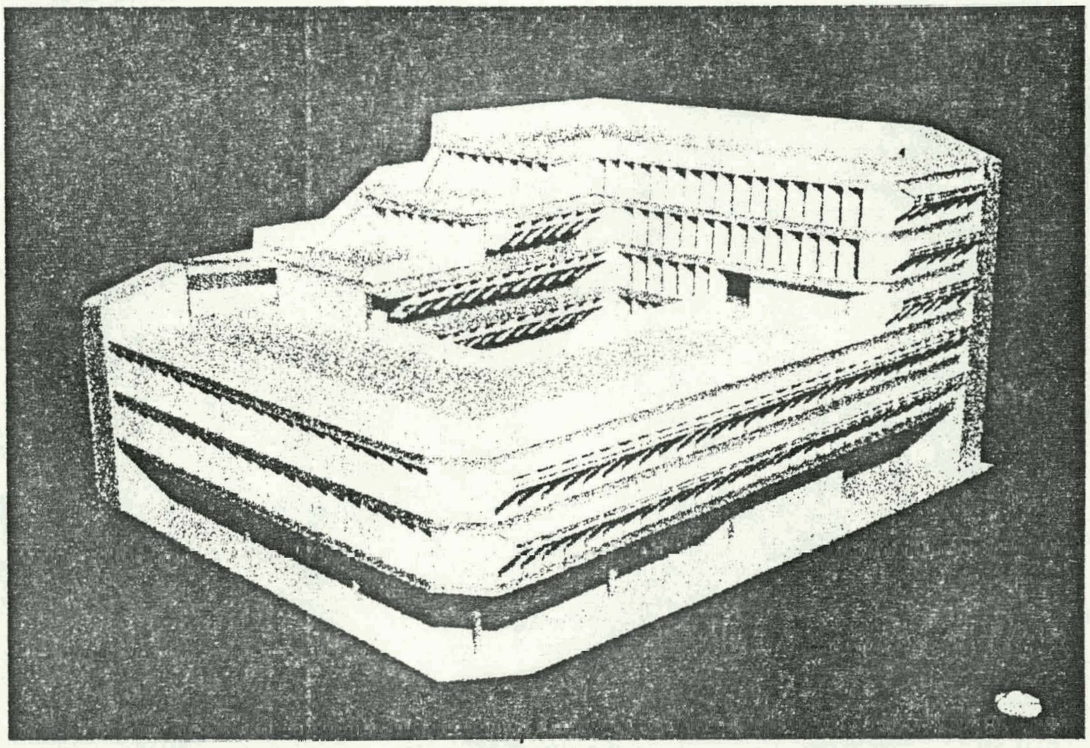


FIGURE 6–23. SITE C – BUILDING MODEL, DESIGN OPTION ONE, SUMMER – PM
The designer has used a large central court to provide light and ventilation to office spaces above street-level retail stores. Sunscreens act to admit light, but no direct solar rays, during normal office hours from 9 a.m. to 5 p.m. throughout the year. The building contains 1.0 million cubic feet or 76 percent of the envelope's volume. The gross floor area above street level is 80,000 square feet or 71 percent of the envelope's potential. F.A.R. = 3.72. (Designer: Roy Murabata.)

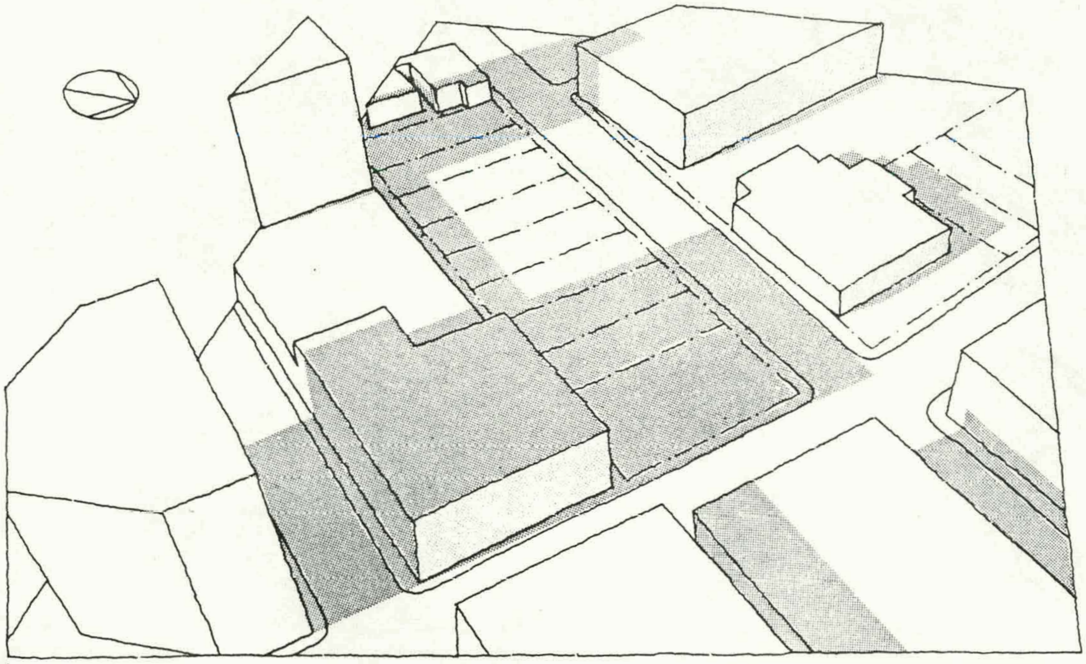


FIGURE 6–24. SITE F – PARCEL BOUNDARIES, WINTER – AM

This site, an assemblage of smaller lots along the southeast side of Figueroa, is the largest of the study sites. The parcel contains 53,600 square feet. Typical of many urban sites, this one is impacted during the winter by the shadows of an existing building. Here, the shadow is produced by a 13-story building located a full block away.

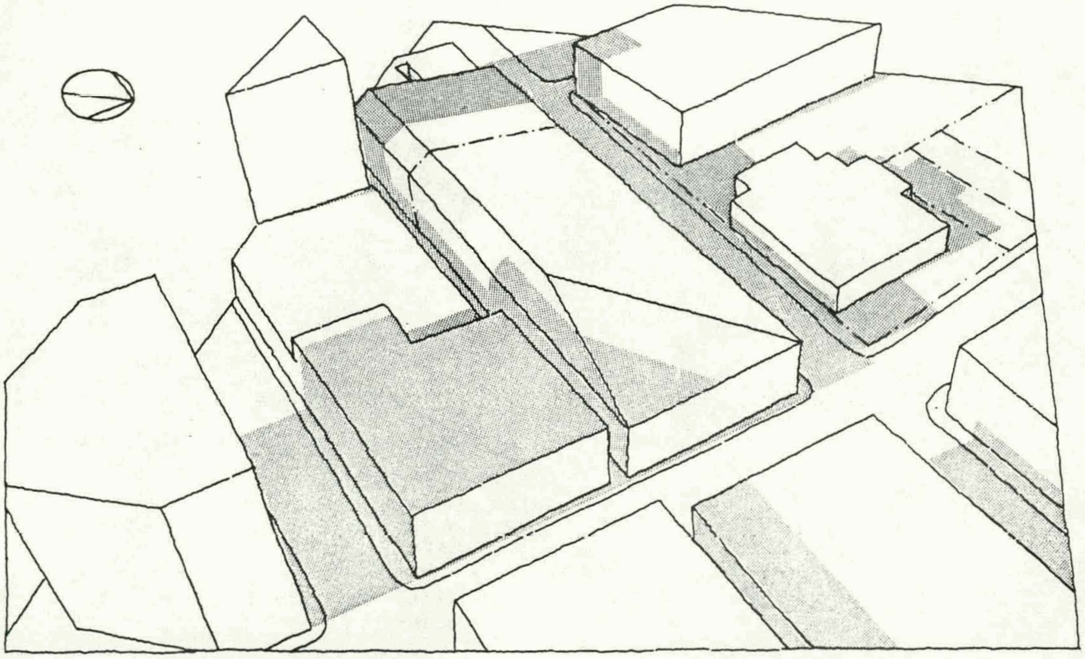


FIGURE 6–25. SITE F – ENVELOPE, WINTER – AM

This envelope contains 3.9 million cubic feet. It is shown extended to the southwest over an adjacent site that is also vacant. A presumed fire wall would separate the two future buildings. The top surfaces of the envelope are only minimally shadowed by the tall building because of the envelope's height.

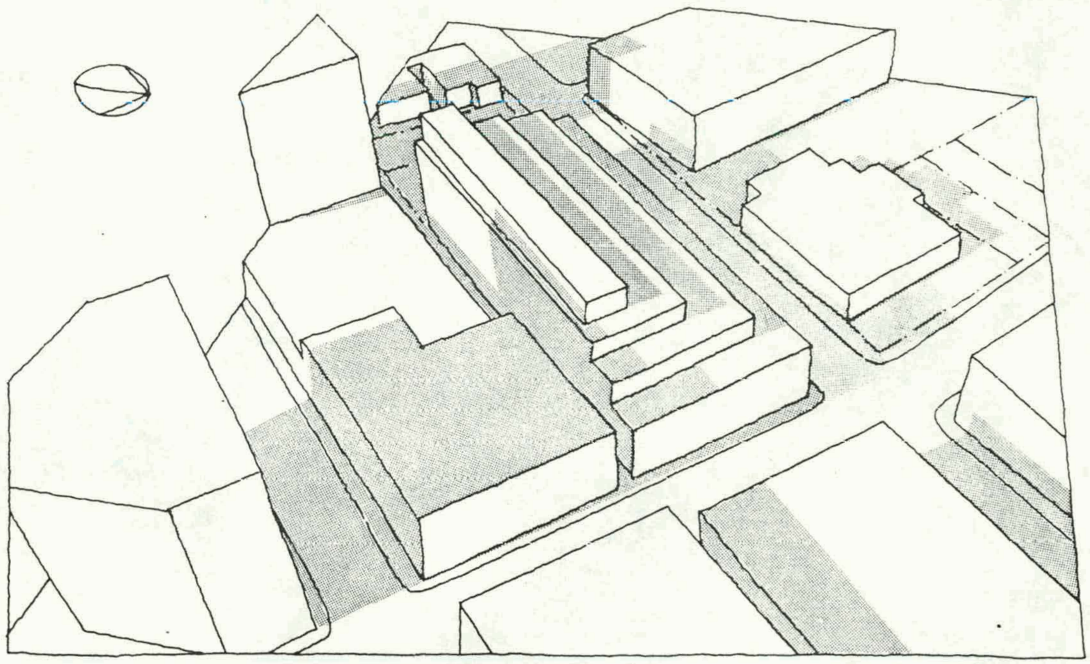


FIGURE 6–26. SITE F – ENVELOPE BUILDING TOPOGRAPHY, WINTER – AM

The topographic interpretation of the envelope provides a relatively high gross floor area of 288,750 square feet, which converts to a potential F.A.R. of 5.38.

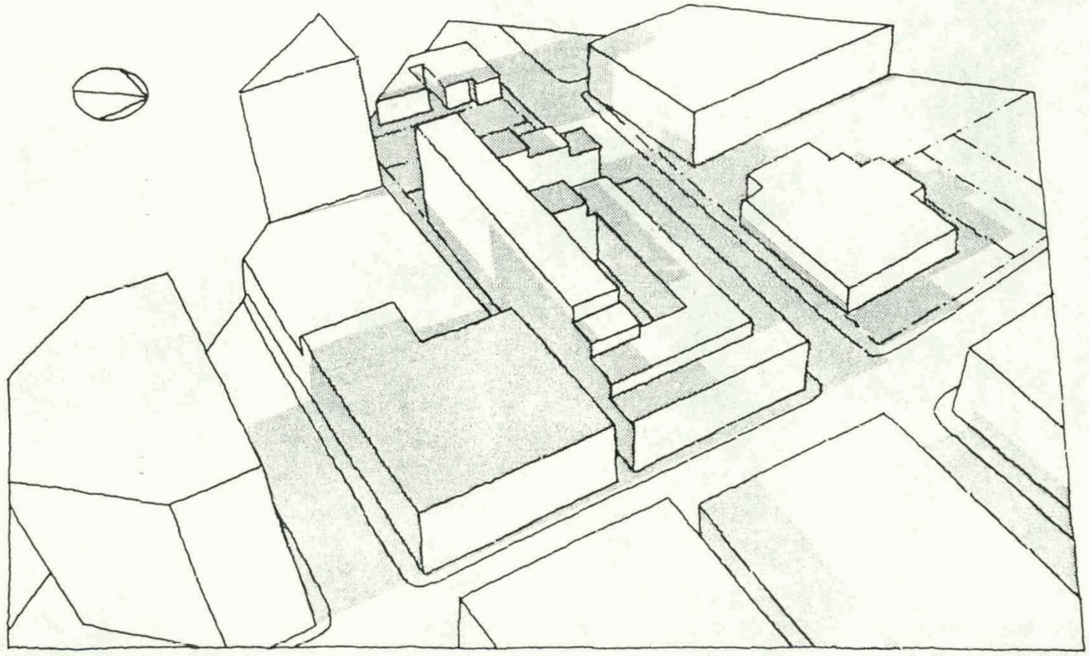


FIGURE 6–27. SITE F – DESIGN OPTION ONE, WINTER – AM

This design relies on two courts, one of them interior, to provide light and ventilation to the office spaces. Provision is made for retail uses at the ground floor. The building encloses 3.1 million cubic feet, which is 80 percent of the envelope's volume. The gross building floor area (excluding parking) is 236,000 square feet or 82 percent of the envelope's potential. F.A.R. = 4.41. (Designer: Dan Reza.)

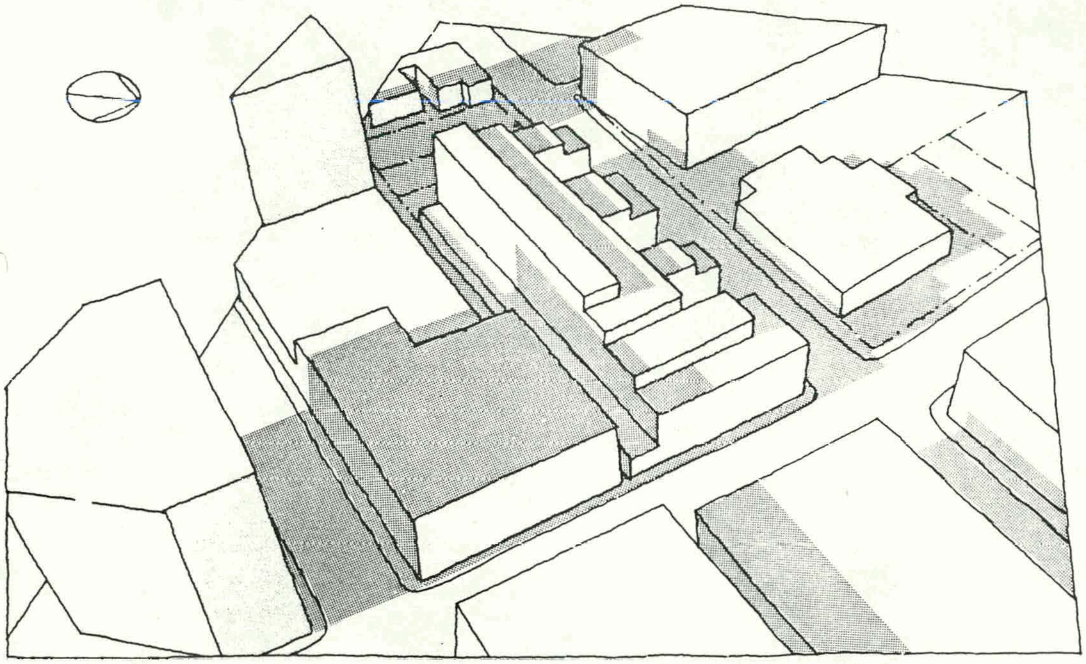


FIGURE 6–28. SITE F – DESIGN OPTION TWO, WINTER – AM

In this second design approach, three courts open out to the street. The development numbers are quite close to those of Option One. (Designer: Dan Reza.)

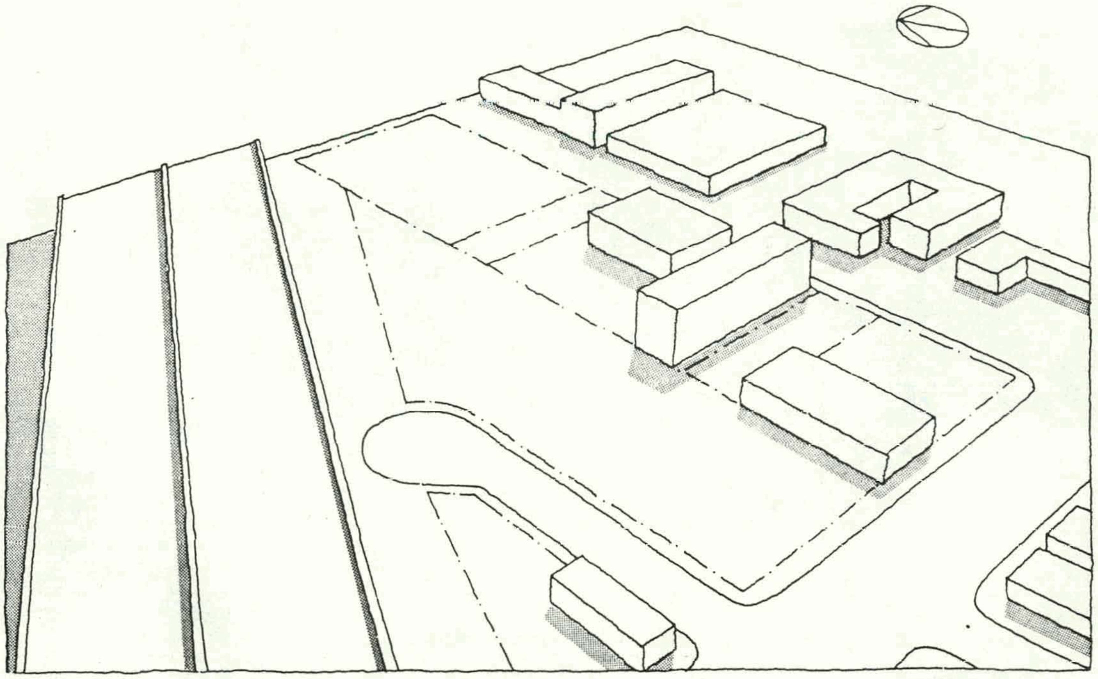


FIGURE 6–29. SITE I – PARCEL BOUNDARIES, SUMMER – AM

This site is shown above with summer morning shadows and below with winter morning shadows. These two views provide a comparison of the shadow impacts at each season. This site contains 49,500 square feet. It has an 8-lane elevated freeway on the northwest, a large vacant site, assorted small buildings on the southeast, and one small but relatively new building across the cul-de-sac to the west.

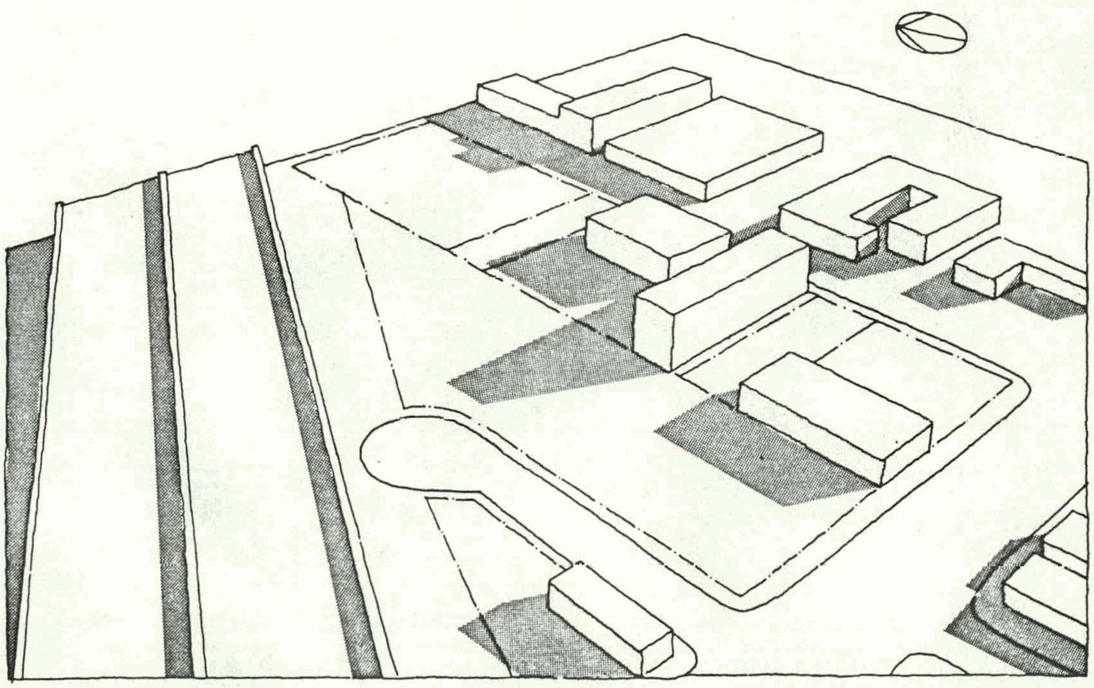


FIGURE 6–30. SITE I – PARCEL BOUNDARIES, WINTER – AM

The irregular geometry of the site is a consequence of the freeway's right-of-way cutting diagonally across the original street and subdivision lay-out. This is a condition that can be found in most cities and that often poses difficult development problems.

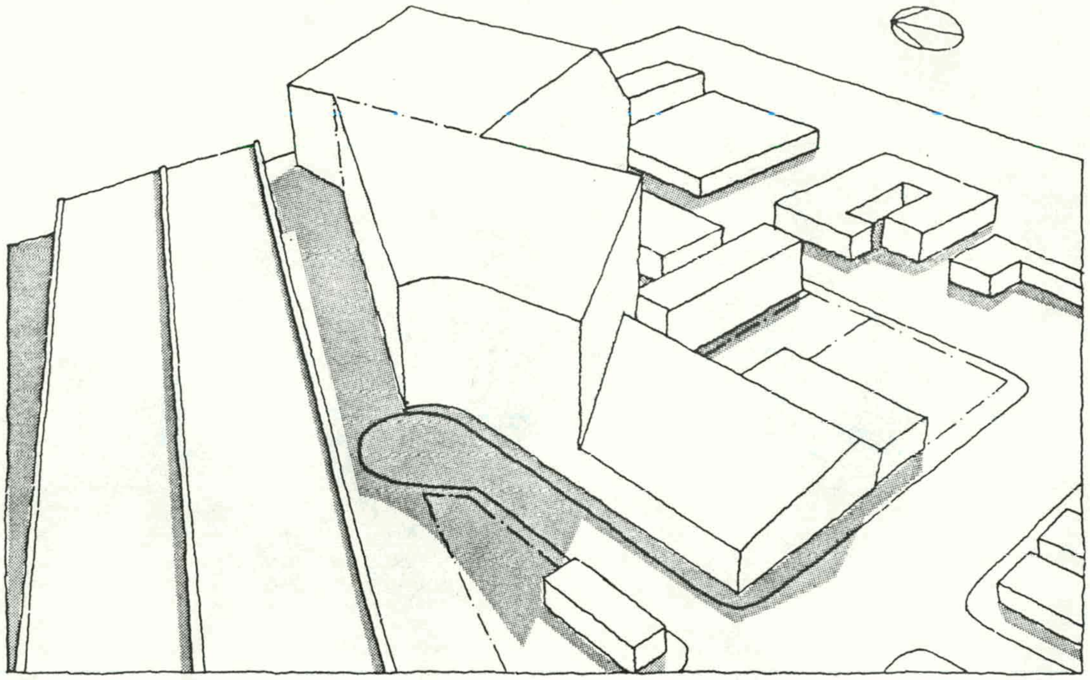


FIGURE 6–31. SITE I – ENVELOPE, SUMMER – AM

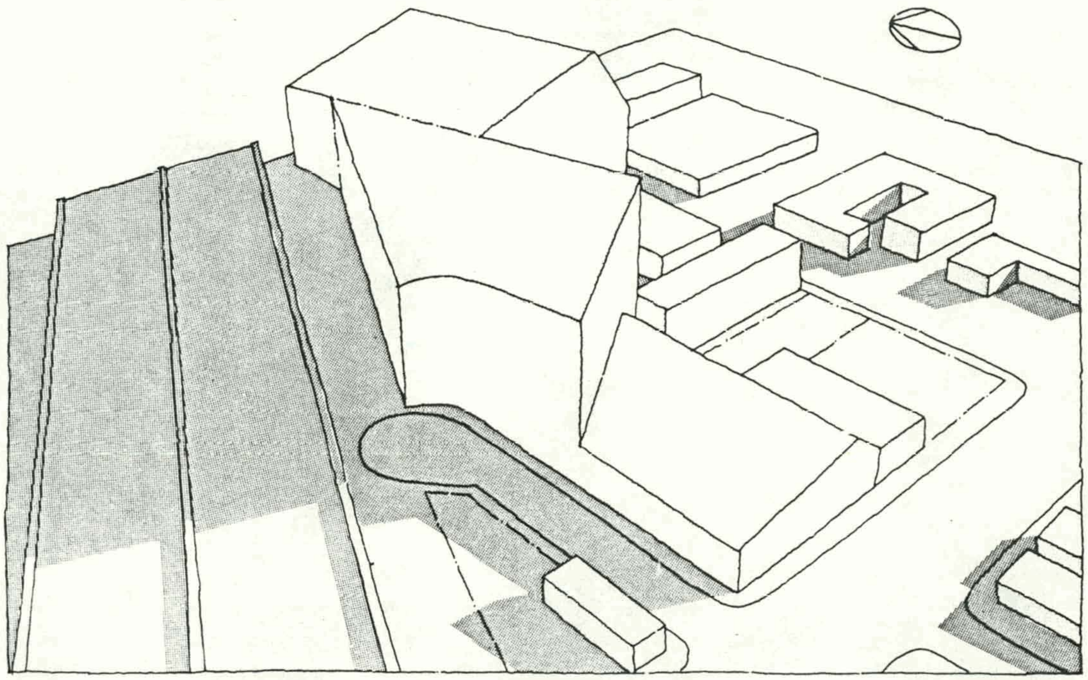


FIGURE 6–32. SITE I – ENVELOPE, WINTER – AM

This envelope is depicted under two sun conditions in order to make its unique form more understandable. The envelope is shown above with summer shadows and below with winter shadows. The envelope, which contains 4.7 million cubic feet, is quite large for two basic reasons. As seen in the lower drawing (Fig. 6–32), winter morning shadows can cross the freeway which gives the envelope additional height. Also, the large adjoining land parcel to the northeast allows the envelope to be extended, unbroken, over two sites with the assumption that fire walls would be built on the common property line when development occurs. The upper drawing (Fig. 6–31) shows how the envelope form has been sliced vertically so that a small existing structure will not be shadowed. The summer morning sun angle is critical here and the consequence is a substantial loss of volume over the southwestern portion of the site.

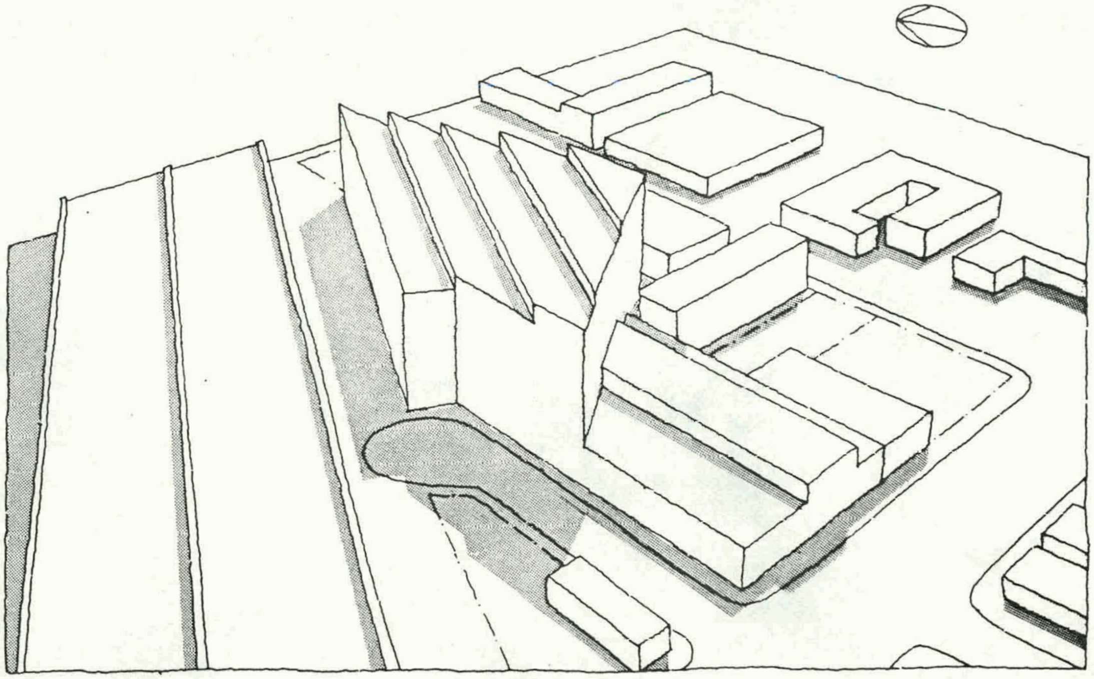


FIGURE 6–33. SITE I – ENVELOPE BUILDING TOPOGRAPHY, SUMMER – AM

The topographic interpretation of the envelope provides a gross floor area of 310,875 square feet, which converts to a potential F.A.R. of 6.28. This represents the largest potential building volume found on any of the study sites.

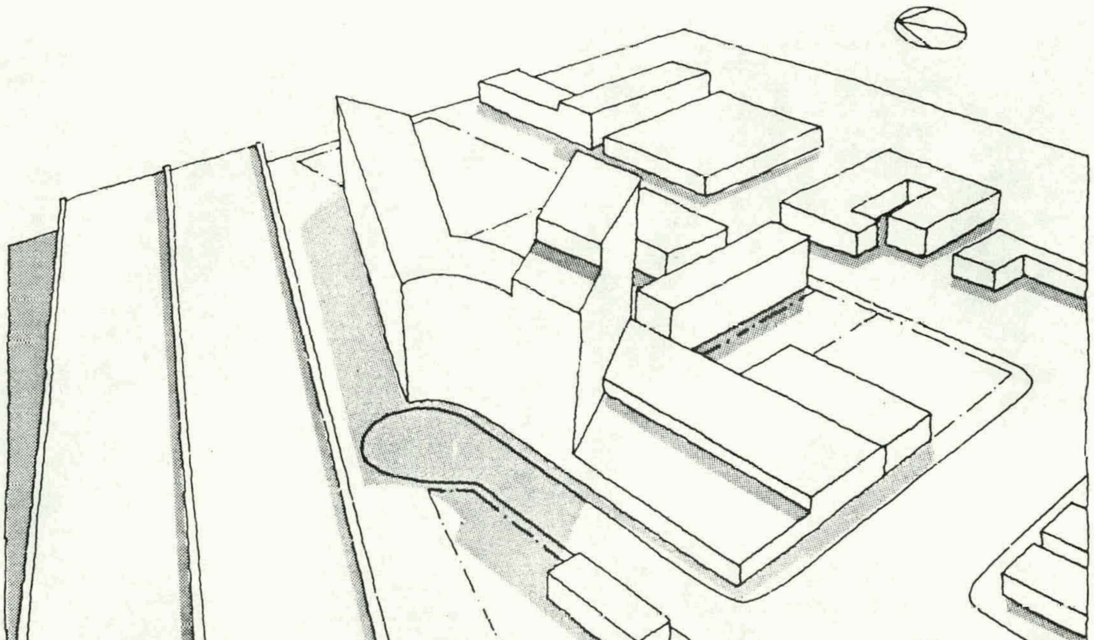


FIGURE 6–34. SITE I – DESIGN OPTION ONE, SUMMER – AM

This design places a low retail section next to a higher office block built around an open court. The designer utilizes a single-loaded corridor as a means for insulating the offices from the freeway. As a result, the design is relatively inefficient in its use of the envelope's development potential. The building contains 3.1 million cubic feet or 65 percent of the envelope's volume. The gross floor area is 234,000 square feet or 75 percent of the envelope's potential. F.A.R. = 4.74. (Designer: Hector Magno.)

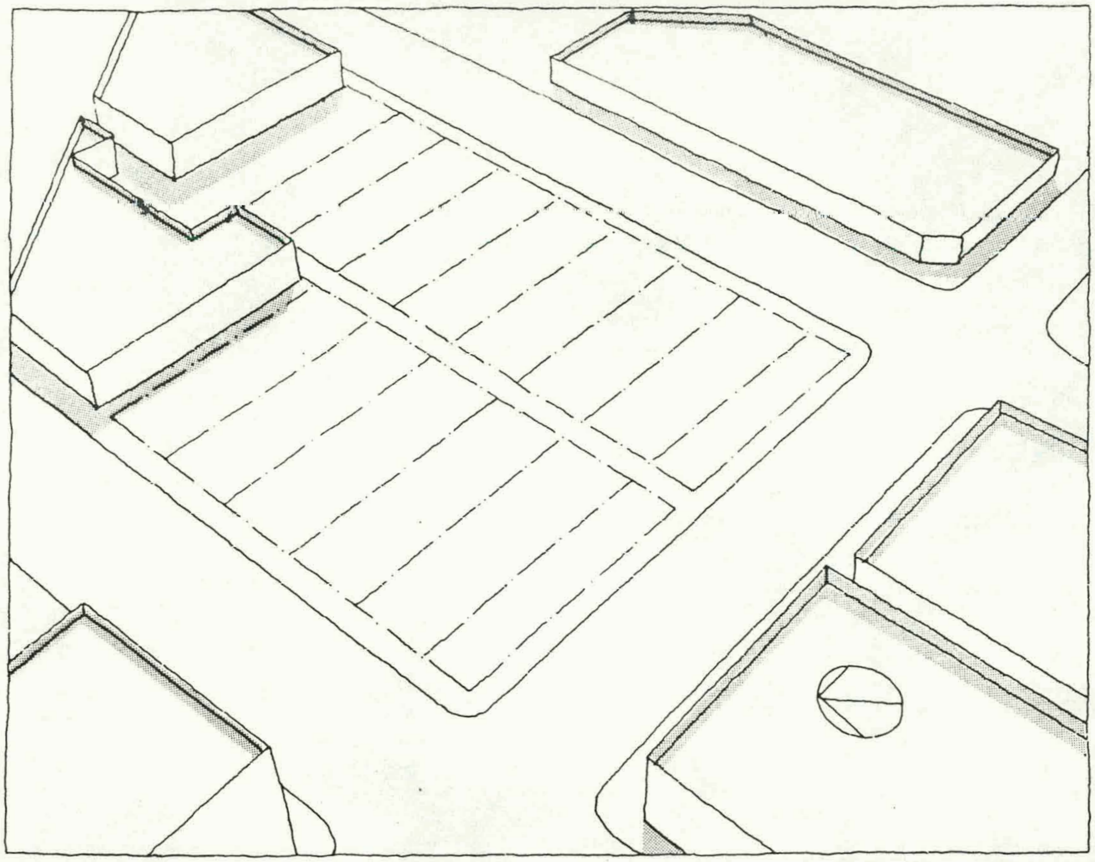


FIGURE 6–35. SITES D AND G – PARCEL BOUNDARIES, SUMMER – AM

Two large vacant sites occur within the same block off Olympic Boulevard between Flower and Hope Streets. An alley separates Site G, the larger parcel, from Site D, the smaller.

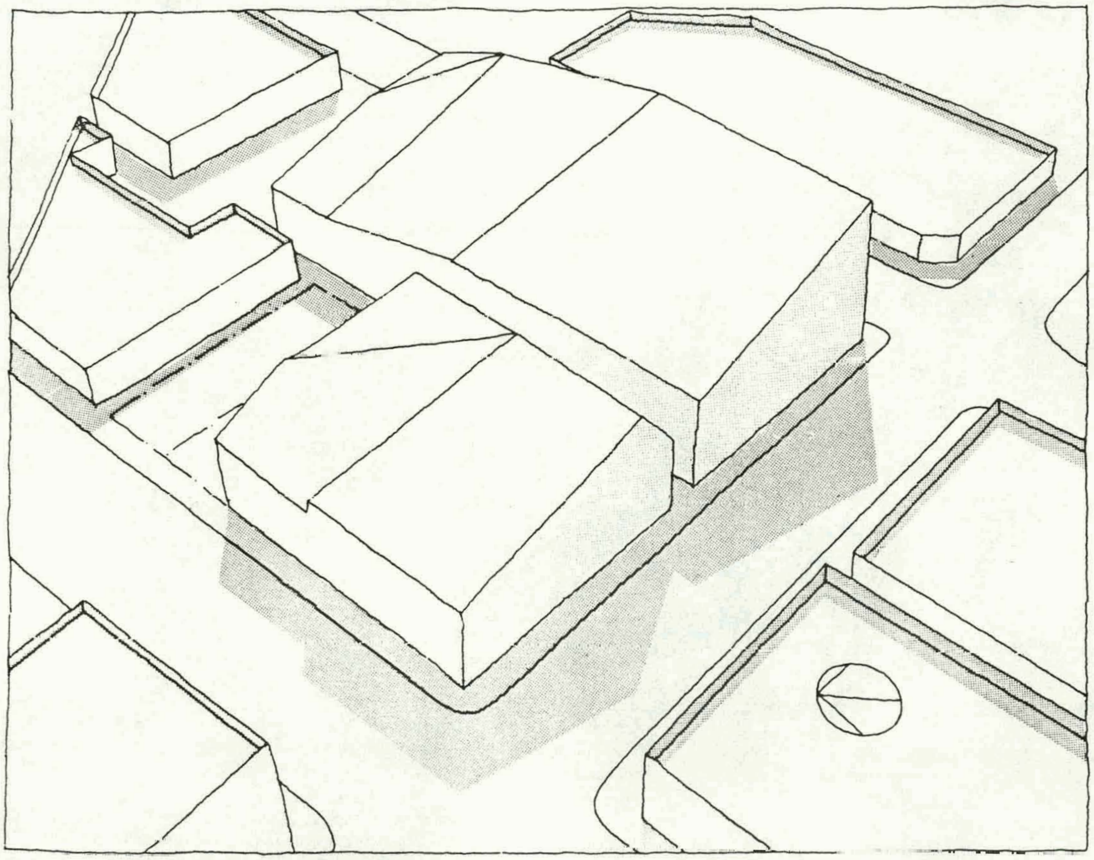


FIGURE 6–36. SITES D AND G – ENVELOPES, SUMMER – AM

Each envelope provides solar access to the other based on the presumption of window walls on the alley. And as with all previous cases, both envelopes protect the roofs of surrounding buildings.

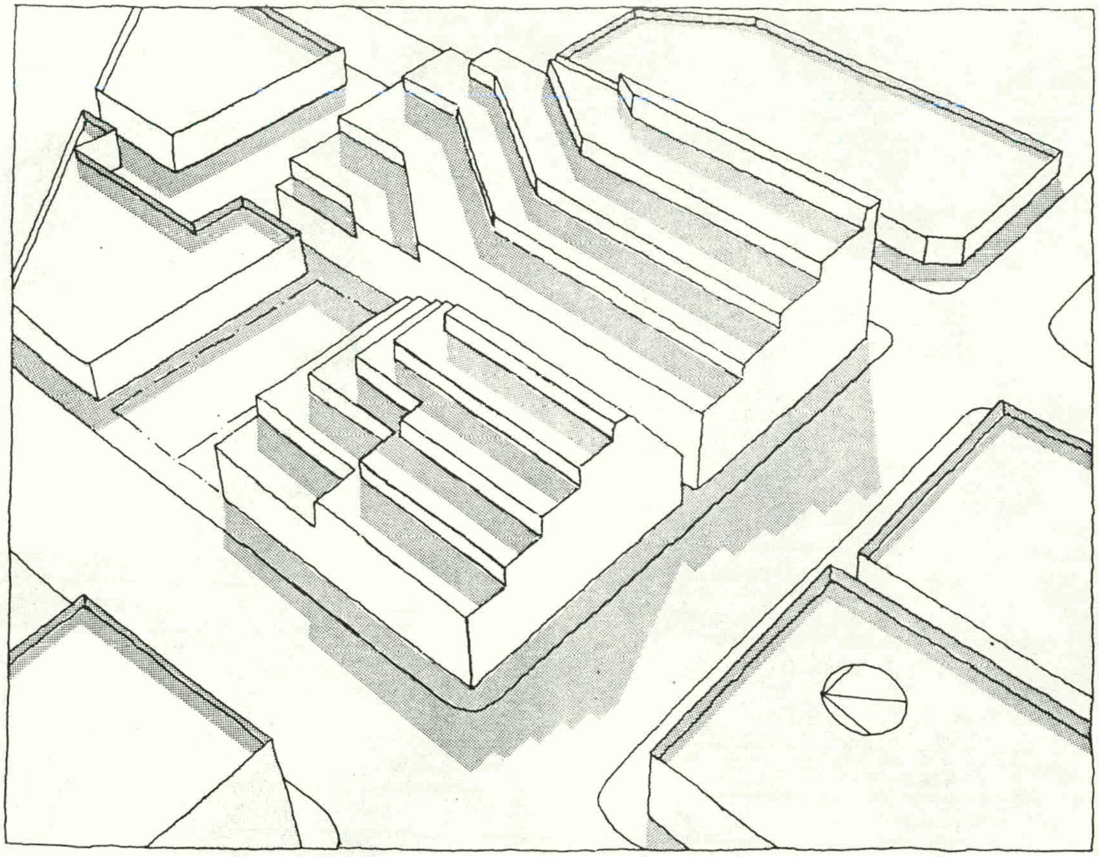


FIGURE 6–37. SITES D AND G – ENVELOPE BUILDING TOPOGRAPHY, SUMMER – AM

The main characteristic of the topographic interpretations of these envelopes is the set of terraces that consistently step down to the northwest. The direction and pitch of the slope that produces the terracing is determined by the winter morning sun. Under summer sun conditions, however, the terraces receive substantial sunshine in the morning and throughout the day. For site D (the smaller), gross floor area is 137,000 square feet and the F.A.R. is 4.95. For site G, the potential floor area is 295,000 square feet and the F.A.R. is 5.96.

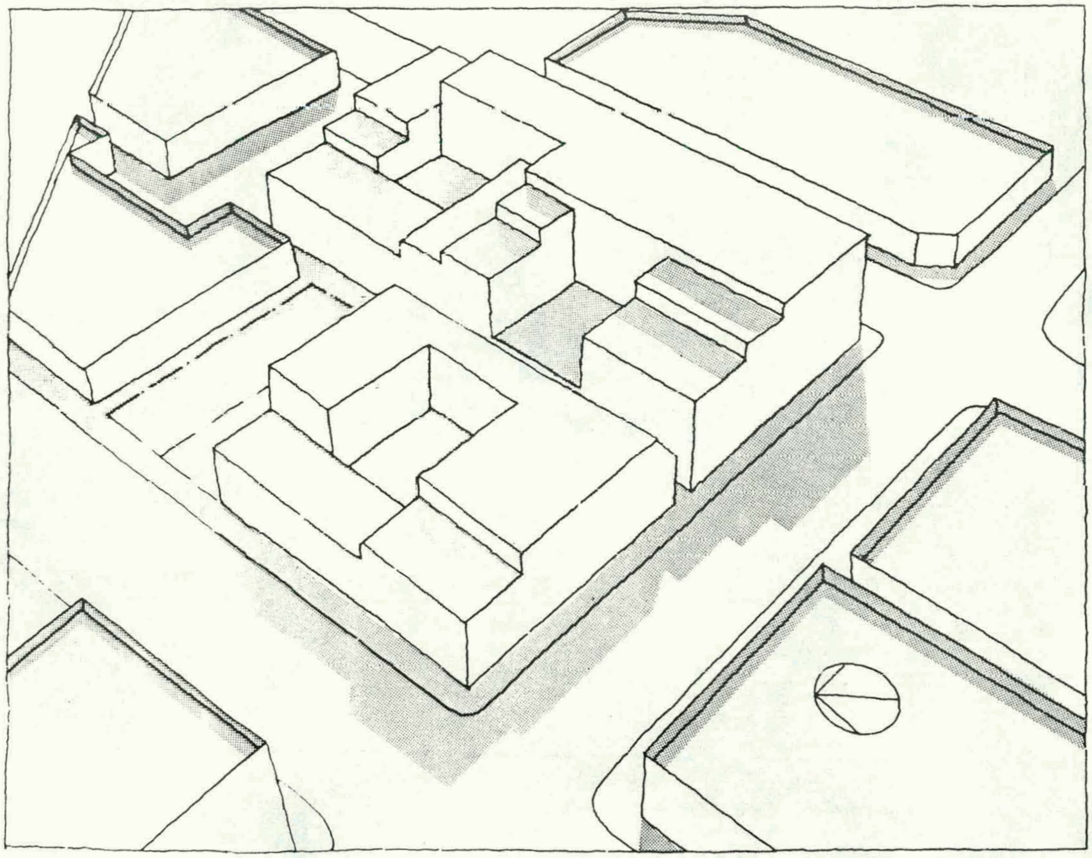


FIGURE 6–38. SITES D AND G DESIGN OPTIONS, SUMMER – AM
The building designs shown have an average F.A.R. of about 4.0, which is a clearly reasonable development potential for the study area. The repeated appearance of courts in adjacent buildings suggests the potential for re-examining building forms and design approaches used successfully in earlier periods to provide light and ventilation without reliance on extensive energy inputs. (Designer: Steve Lowinger – both sites.)

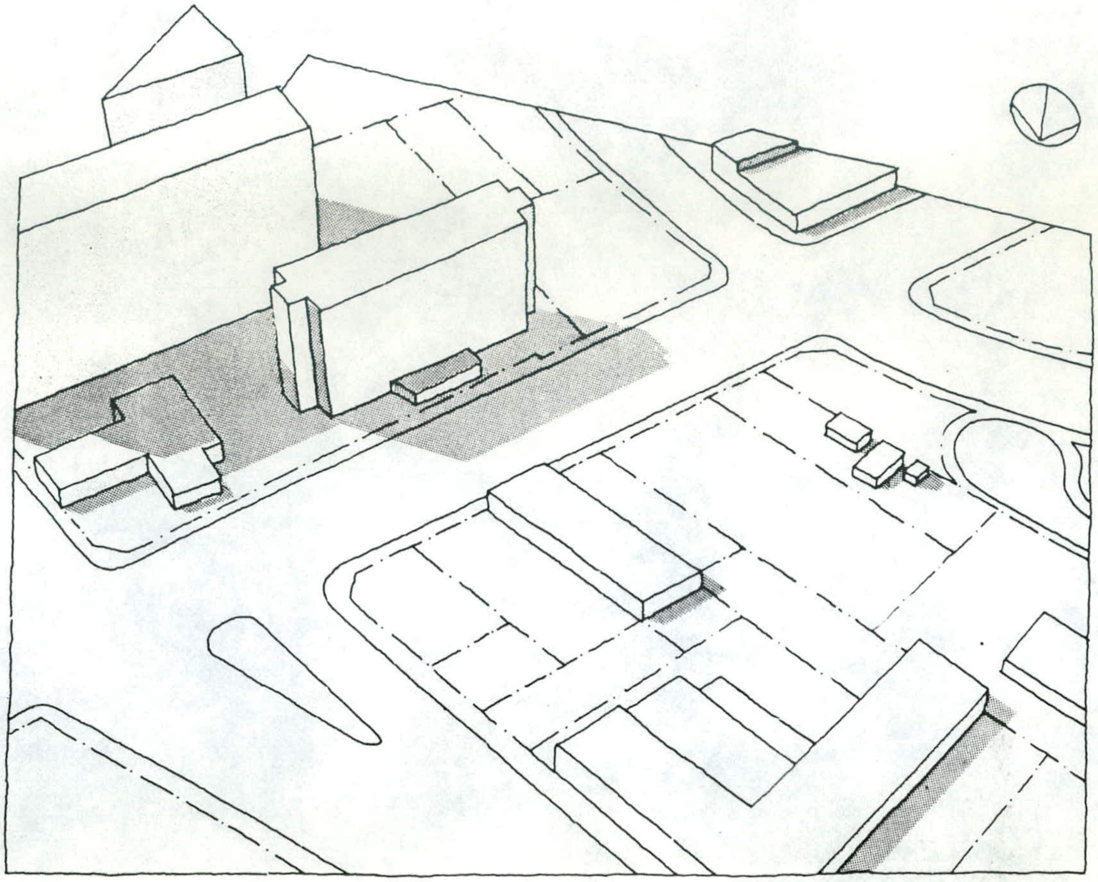


FIGURE 6–39. SITES B, H, AND C – PARCEL BOUNDARIES, SUMMER – AM

By removing a few small buildings, two adjacent sites, B and H, are formed that extend a full block along Figueroa. Site B, at the northern end of the block, has already been analyzed. Across Figueroa Street, to the southeast of Site H, is Site C, which has also been separately analyzed.

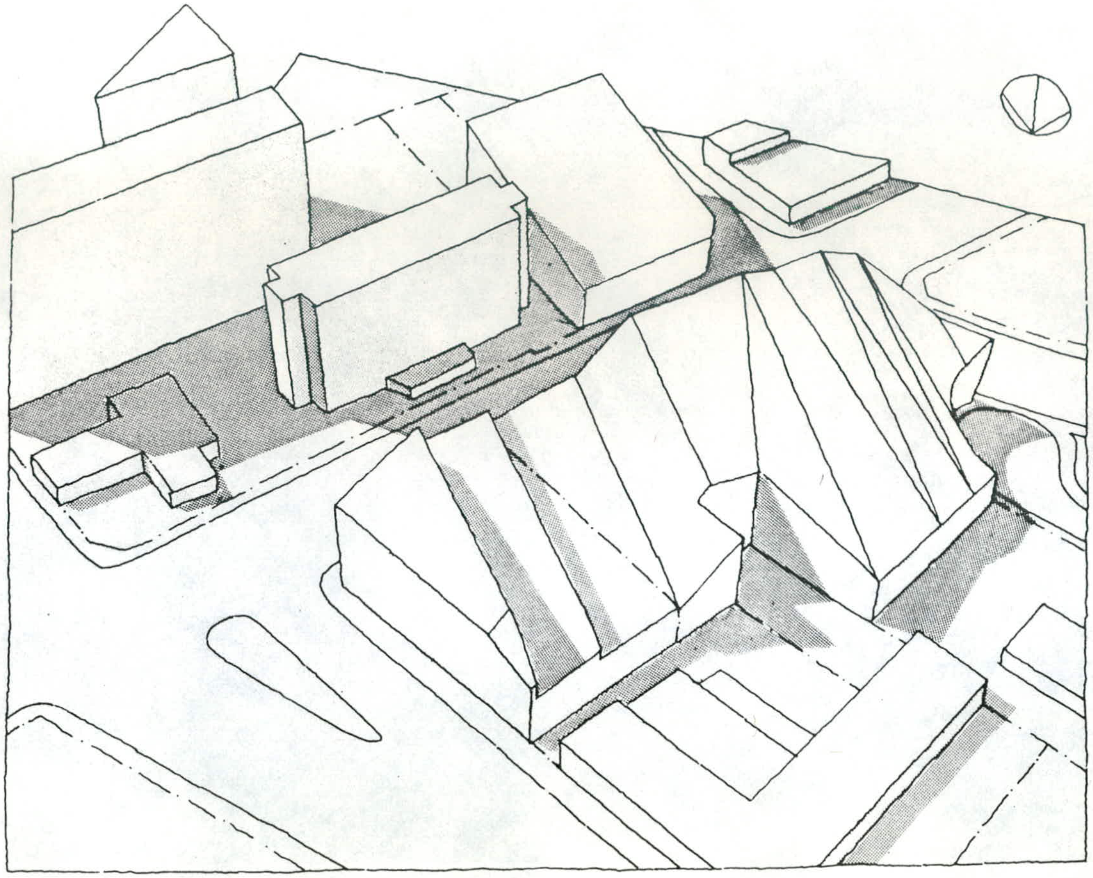


FIGURE 6–40. SITES B, H, AND C – ENVELOPES, SUMMER – AM

The envelopes for sites B and H together generate a combined volume of 7.0 million cubic feet. If it could all be used, this would represent a considerable development potential. The long sloping surfaces on all three sites are determined by the winter morning sun. The most important feature of the Site B and H envelopes is the surface complexity which results from the variable heights and locations of the existing building roofs that must be protected.

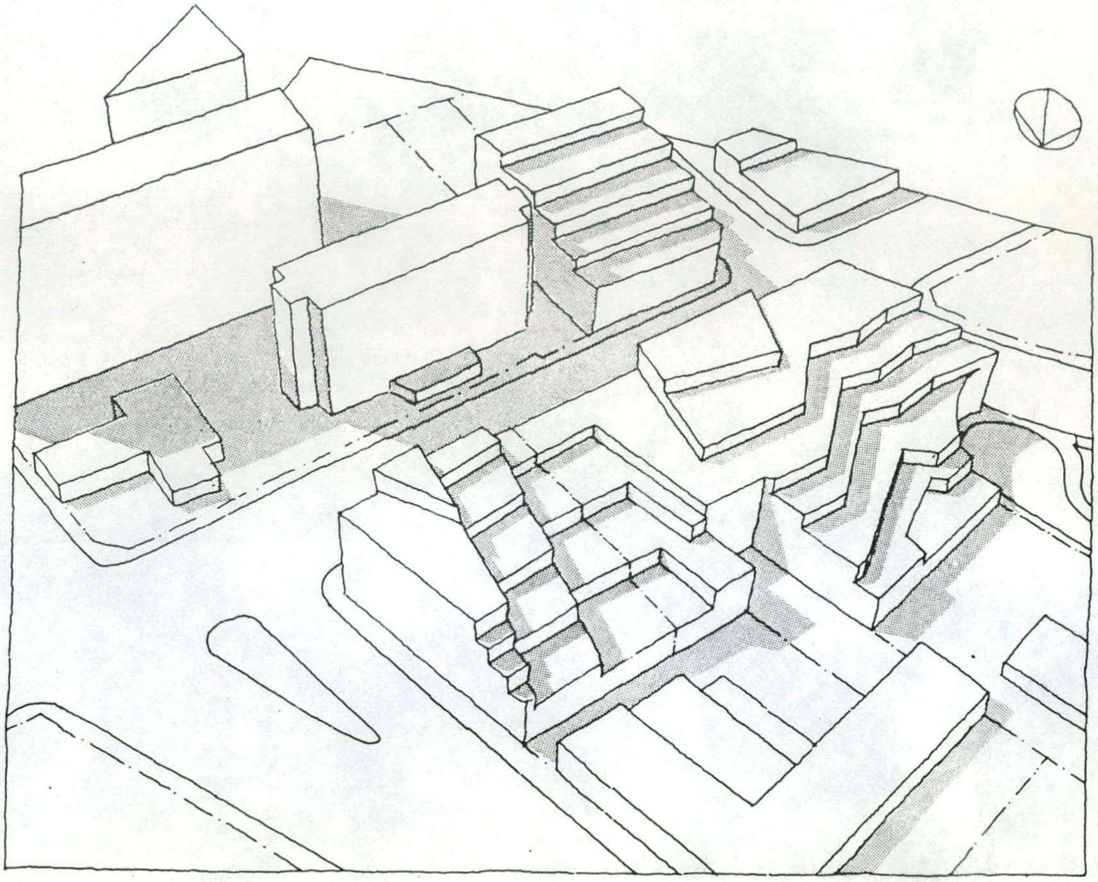


FIGURE 6–41. SITES B, H, AND C – ENVELOPE BUILDING TOPOGRAPHY, SUMMER – 9 AM

The topographic interpretation of the three envelopes shows how variable and complex envelopes can become in a typical urban context. It suggests both a need for architectural innovation and the potential for variety in building forms.

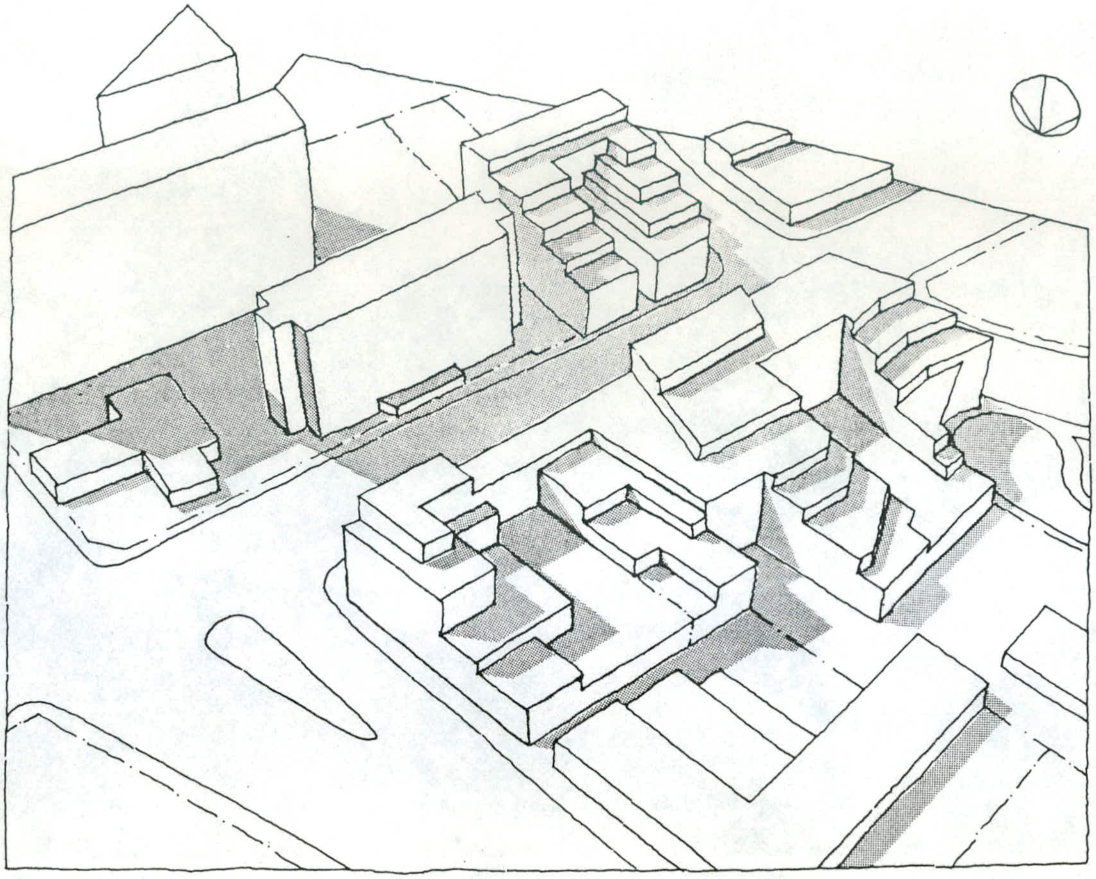


FIGURE 6–42. SITES B, H, AND C – DESIGN OPTIONS, SUMMER – AM

The designs on all three sites employ courtyards to get light and ventilation into the office spaces. The terraces reflect the envelope form but also have significant potential as an urban amenity. All of the designs consistently press building walls out to the property line, creating a relatively continuous building facade along the streets. The building scale that results seems clearly comfortable to pedestrians at the street level. One problematic design issue arises from the fact that the sloping envelopes produce less building height on the southeast side of the street than on the opposite, northwest side. In other words, over time the street would tend to acquire an asymmetry related to solar orientation. From a development point of view, the average F.A.R. is about 4.0 which is significantly greater than the existing building density.

6.4 HOUSING – DESIGN FRAMEWORK

6.4.1 Study Sites

There are undoubtedly countless areas within a city the size of Los Angeles that would have been suitable for testing the envelope's applicability to moderate-density housing, but the locale selected had several unique attributes.

First, a number of land parcels in close proximity to one another were vacant and under pressure for development. Second, the parcels fronted on or related to a major boulevard that has become an important transit link between downtown Los Angeles and the city of Santa Monica on the ocean. This boulevard has historically been a prestige address for both apartment and commercial structures, ranging in height from 1 to 20 stories.

Third, the land parcels were surrounded by single-family housing of high quality and the residents of the area were adamantly opposed to high- or even moderate-density development, particularly commercial structures. At the same time, the city planners were under enormous pressure from developers to allow relatively high-density housing, commensurate with land costs.

The obvious compromise for these sites seemed to be moderate-density housing projects that would have minimum impact on the surrounding neighborhood: a perfect fit with the solar envelope testing objectives.

It can be seen from the site map that Wilshire Boulevard is clearly a major traffic and bus artery, having been progressively widened over the years. The study parcels C through F were obviously part of the original residential platting, having the same geometry and being only somewhat larger than the surrounding lots.

The relative sizes of the houses on both sides of Wilshire can be seen from their outline. The large building at Wilshire and Hudson (upper right corner) is one of several office buildings in the area, built under zoning variance permits and having sufficient height, 6 to 10 stories, to severely shadow the properties to their north.

As a set, the six sites provided the constancy of size plus the variety of parcel geometry and orientation that was needed to obtain a meaningful test of solar zoning, applied to multi-family housing projects.

6.4.2 Program Objectives

The basic objectives, as they were stated to guide design studies on each site, were threefold: (1) to provide the maximum number of dwelling units; (2) to provide a quality living environment; and (3) to minimize negative impacts on the surrounding single-family houses.

Land values, site locations, and neighborhood characteristics all suggested that the development objective should be condominium housing rather than rental units. The subsequent particulars of the development program, as they evolved, related mainly to marketability considerations that were specific to the site location and other economic factors, including estimated construction costs.

The unit mix was established accordingly, with the average unit size set at about 1,300 square feet. The Efficiency Units were sized to average 850 square feet, 1-Bedroom Units were to be 1,100 square feet; 2-Bedroom Units were 1,350 square feet and 3-Bedroom Units were set at 1,650 square feet.

This programmatic framework, as it was finally formulated, reflected the collective analyses of the design group as a whole, with considerable input from experienced developers as well as the study researchers. Compliance with local building, fire, and parking codes established many of the spe-

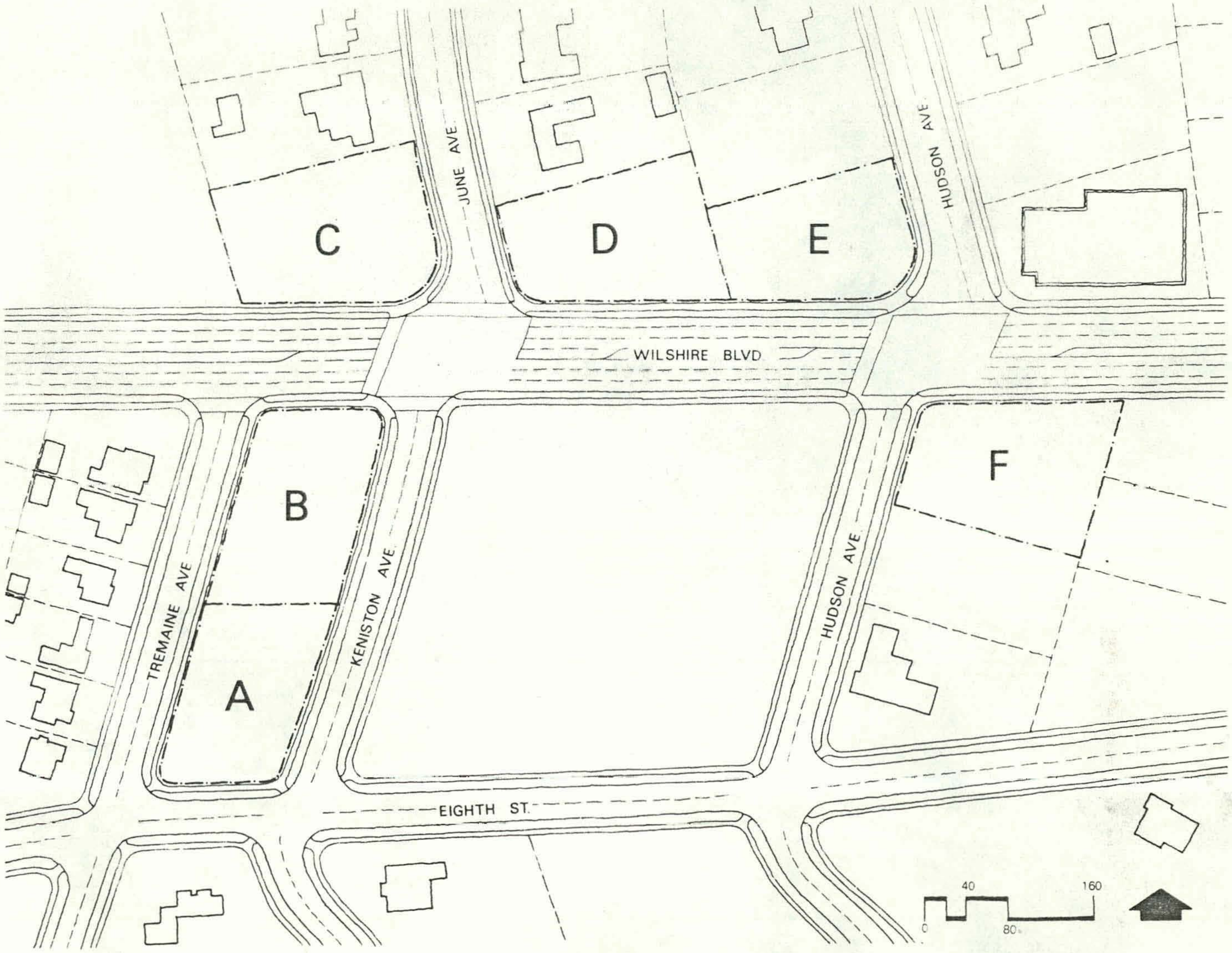


FIGURE 6–43. WILSHIRE BLVD. – HOUSING SITES, A THROUGH F
Six vacant sites were finally selected for design studies. Each parcel is close to half an acre in size. (The full block between sites B and F is also vacant land but it was deemed too large for design purposes.) The irregular geometry of the parcels is typical of the variability often confronted by designers working with urban in-fill development.

cific design constraints; but other constraints derived from what potential purchasers of the units would desire in condominium housing.

For example, the life style and climate of the region suggested that private outdoor space should be included as a design requirement, and it was.

Of course, the zoning envelope was given, but there were no restrictions imposed on the building for set-backs and side yards. So long as fire and safety requirements were met in principle, each designer was free to pursue his own objectives as to the form and architectural character of the building.

Design concerns for life quality in general and liveability in particular did impose a requirement that all units be given at least two exposures: two outside walls, facing different directions. The objective of such a specification was to insure that all units would have cross ventilation and that the designers would have two options for utilizing solar irradiation. The specification ultimately provided the designers with additional options for dealing with the internal organization of the units as well.

Like the downtown office study, the building designs were undertaken as a series of discrete steps with recurring evaluations along the way. Ultimately, each building design was carried far enough to describe qualities of space, light, and architectural scale as well as to justify the pragmatics of parking, unit lay-out, structure, construction, and building codes.

6.4.3 Envelope Rules

Unlike the envelope rules that were needed for the downtown study sites, the housing sites could be handled by zoning rules that were quite simple because the conditions surrounding all the sites were more or less the same. However, the general premises regarding the envelope remained the same as for the commercial sites (Section 6.2).

Because of the neighborhood's residential characteristics, it was appropriate to take a whole-site attitude in providing solar access to the surrounding properties, where a whole-building approach had been appropriate for the commercial area.

There was of course the need to provide sufficient development volume under the envelope to attain densities of 40 to 60 dwelling units per acre. Hence, some minimal shadowing of adjoining ground surfaces was necessary. But, it was generally agreed that any such shadows should not exceed what would be produced by a 1½ story, detached single-family residence with a normal sideyard. In effect, this degree of shadowing was what an 8-foot wall or fence would produce, located directly on the property line.

The specific rules that were used in generating the solar envelopes over the residential sites can be stated as three simple zoning requirements.

(1) Provide solar irradiation to all surrounding properties at all times of the year between the hours of 9:00 am and 3:00 pm solar time, the same as for the downtown study area. (The solar angles are the same as those given for the office building envelopes: Section 6.2).

(2) Public rights-of-way may be shadowed by buildings at any time of the day, all year; hence, the solar envelope for any parcel will span adjoining streets or alleys (essentially the same as for the commercial envelopes).

(3) The base of the solar envelope for any land parcel will be set at a height of 8 feet above existing grade, at the parcel boundary or the property line on the opposite side

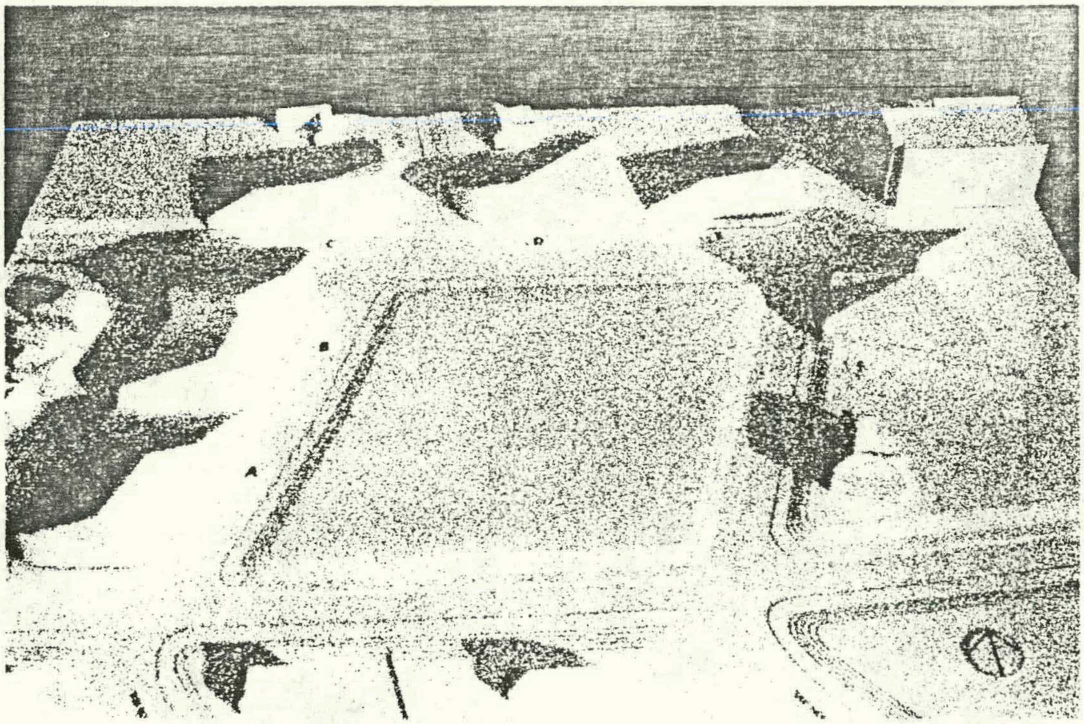


FIGURE 6–44. WILSHIRE BLVD. – WINTER – 9 AM

The solar envelopes for all sites guarantee access to surrounding properties between the hours of 9 am and 3 pm, at all times of the year. Seen under the winter morning sun's rays that normally determine the envelopes' north and west sloping surfaces, it is apparent that the three site envelopes on the north side of Wilshire (top of picture) have similar forms; this is because the sites all have similar orientation and geometry. The two long envelopes (on the far left) cast their shadows across two streets but the existing houses remain in full sun.

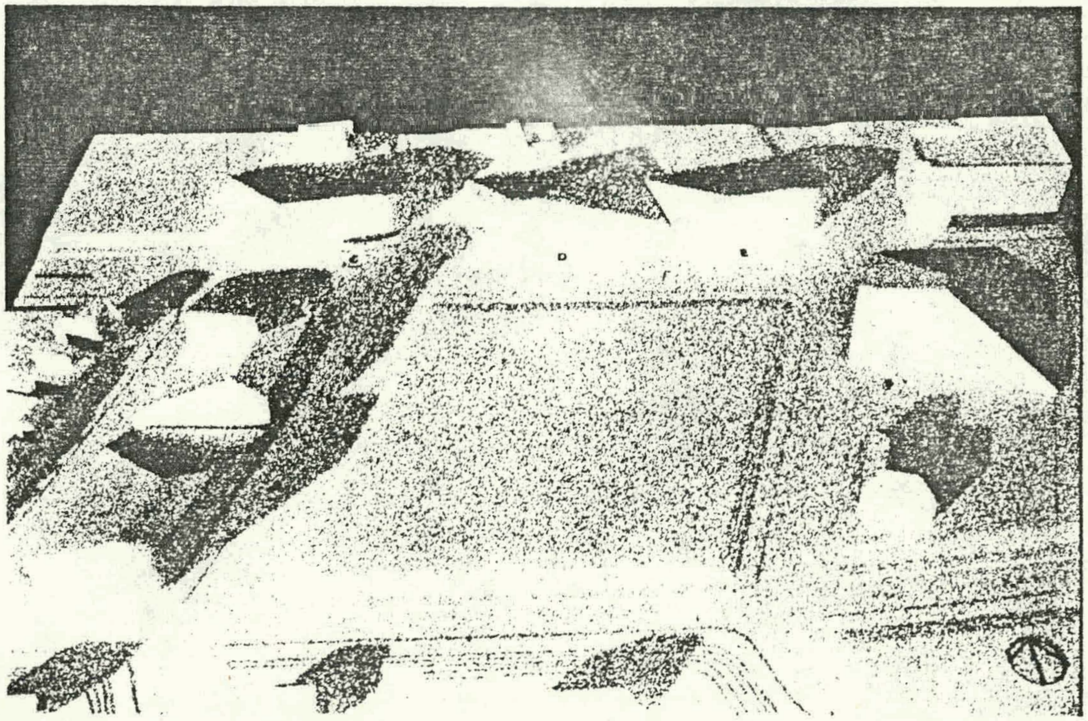


FIGURE 6–45. WILSHIRE BLVD. – WINTER – 3 PM

Seen under the winter afternoon sun's rays that generally determine the north and east slopes of the envelopes, it is apparent that the envelopes on the north side of Wilshire (top of picture) have less ridge height and volume than those on the south side. The envelopes on the south cast shadows across Wilshire to an 8-foot height on the vertical surfaces. (The form in the upper right-hand corner is an existing 6-story office building.)

of any public right-of-way adjoining the parcel. Where the existing grade along a property boundary has significant slope, the average height of the envelope base may be set at 8 feet but at no point may the base extend more than 10 feet above the grade of the adjoining property. (This rule is unique to housing but analogous to two of the commercial envelope rules.)

Just as in the downtown study, each design team generated the envelopes unique to their particular development parcel, working first with models on the sun machine and then with descriptive geometry to establish the true measurements of the envelope form. Since the sites were located in close proximity to one another, it was possible to construct a study area model that showed all the envelopes in scale with the surrounding houses and streets (Figures 6-44 and 6-45).

6.4.4 Tabulated Results

It was not initially clear what densities might actually be achieved on these particular sites under the specific zoning rules that were being followed. Averaging the building results of all the designers, on all six sites, gives a density figure of 52 dwelling units per acre of land: the low end of what is presently allowed by the City under R-4 zoning.

The average number of units for each development parcel, taken as a whole, was 28, not very large by some standards but sufficiently large to encourage active development interest.

The trade-off usually required to attain such densities in low-rise structures (2 to 6 stories) is to increase land coverage and decrease open space. In this the student designers' results were surprising. The "average" building covered only 56 percent of its site area. The total open space, counting private terraces and patios as well as set-backs and courtyards, averaged 67 percent of the site area.

Such figures can of course be equalled by the conventional high-rise strategy, but only by ignoring energy conversion concerns and solar access needs. However, most low-rise development done at R-3 densities, roughly 35 dwelling units per acre, provides far less open space.

It would seem that once designers are forced to deal with providing sunshine to people around a project, they may become concerned with providing sunlight to the people who will live in their building. This entails careful thought about how the living units are organized as well as thoughtfulness about all the qualities, such as open space, that people appreciate in a living environment.

The quantitative results for all the building examples are summarized in Table 6-II, in a form that allows detailed comparisons to be made among sites.

TABLE II -- BUILDING AND DEVELOPMENT DATA FOR PROTOTYPE DESIGN STUDIES OF MULTIFAMILY CONDOMINIUM HOUSING ON SIX LAND PARCELS

DEVELOPMENT PARCELS			COMPARISON OF DWELLING UNIT DENSITIES ACHIEVED IN DESIGN STUDIES[1]				AVERAGE SIZE OF DWELLING UNITS[2]		ON-SITE PARKING[3]	OPEN SPACE CHARACTERISTICS[4]	
SITE NO.	AREA (sq.ft.)	AREA (acres)	DESIGNER'S NAME	TOTAL NO. OF D.U.s	LAND COVERAGE AS % OF SITE	D.U.s PER NET ACRE	ENCLOSED SPACE (sq.ft.)	OUTSIDE SPACE (sq.ft.)	AVERAGE STALLS PER D.U.	TOTAL OPEN SPACE (sq.ft.)	TOTAL SPACE AS % OF SITE
			Alonzo	25	54	49	1,540	380	1.9	17,700	69
A	22,430	.51	Myers	30	62	58	1,270	250	1.6	16,300	67
			Pica	26	48	50	1,270	250	1.6	20,200	89
B	23,970	.55	Gehring	32	43	58	1,180	145	1.9	18,000	75
			Aguilar	27	55	45	1,200	240	2.3	14,600	56
C	26,000	.60	Gutierrez	29	50	48	1,080	370	1.9	18,400	70
			Quon	25	52	42	1,350	330	1.8	19,700	75
			Liu	22	55	44	1,310	320	2.4	18,100	76
D	23,700	.54	Stockus	27	65	49	1,360	300	2.1	13,700	56
			Sullivan	26	70	50	1,280	360	2.2	13,600	57
E	20,000	.46	Marquez	25	65	54	1,240	330	1.8	10,800	54
			Stockwell	25	59	54	1,180	180	2.4	10,400	52
			Kearns	30	50	55	1,160	270	1.8	17,000	71
F	23,960	.55	Lisiwicz	40	55	73	1,200	130	2.0	17,200	72
			Wallace	27	65	49	1,280	230	2.3	15,100	68
AVERAGES FOR ALL SITES	23,340	.535		28	56	52	1,260	272	2.0	16,000	67

1. Land coverage is based on building bulk above grade and excludes subterranean parking and building overhangs above the first floor.
2. Program requirements specified a mix of unit sizes, ranging from efficiency to 3-bedroom units, and all units were specified to have some private outside space: decks, balconies or patios.
3. All parking was placed below grade and conformed to current L.A. zoning requirements for on-site parking.
4. Total open space includes private outdoor spaces as well as courts, walkways and setbacks.

6.5 HOUSING – DESIGN EXAMPLES

The design examples presented in this section are limited in number, but they were selected as those that best illustrate the nature of both the envelope constraints and the design possibilities.

Site C (Fig. 6–46 to 6–50) is typical of all three of the sites located on the north side of Wilshire, and the building examples reflect approaches that were also taken by other designers on sites D and E.

Site F (Fig. 6–51 to 6–53) is typical of many corner lots as well as development parcels located on the south side of a street that runs east-west.

Site B (Fig. 6–54 to 6–56) is perhaps unique in that it is surrounded by streets on three sides and seems more typical of the very old parts of eastern cities, where block size is significantly smaller than that found in mid-west or west coast cities

Finally, the urban design inplications are suggested (Fig. 6–57 to 6–59) by some examples of how Wilshire Boulevard would appear if all the sites along it were developed under solar zoning envelopes.

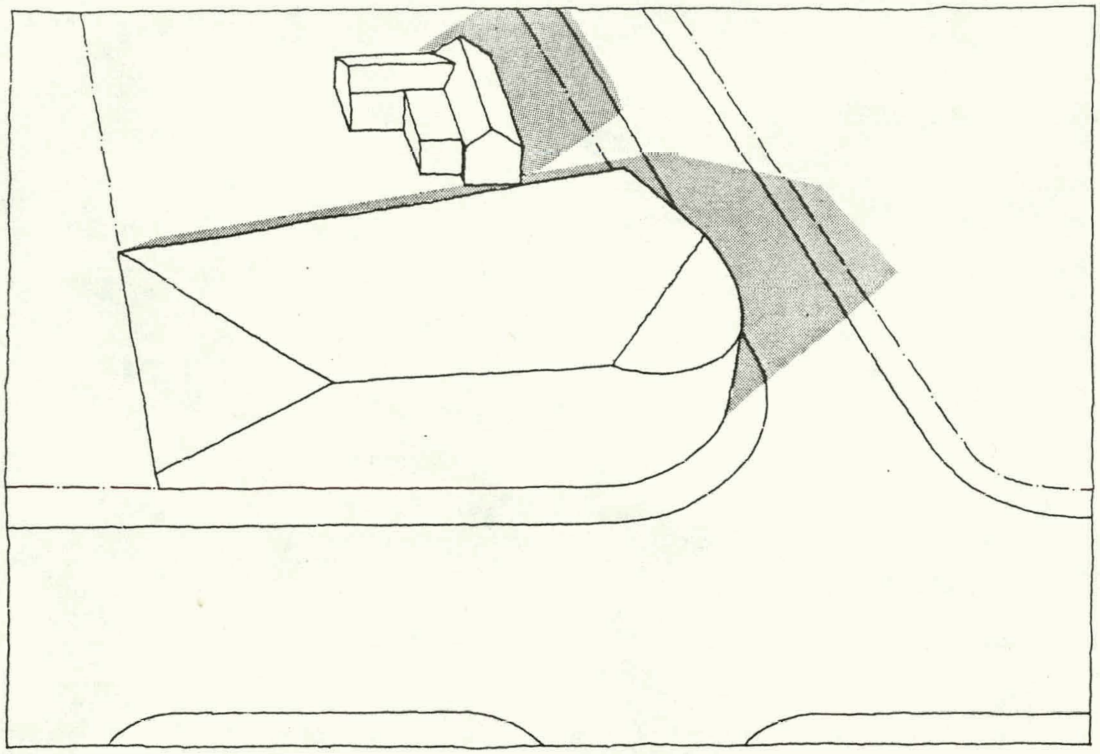


FIGURE 6–46. SITE C – ENVELOPE, WINTER – 3 PM
The envelope over Site C is characteristic of all study sites on the north side of Wilshire Boulevard. The envelope's south or street side is high; the north side is low to protect the single-family residence from winter shadows. The envelope also has small sloping faces on the east, to protect sites across June Avenue, and on the west, to protect adjacent property. The principal feature is the large face that slopes down to 8 feet above grade on the site's north boundary. This is a characteristic of envelopes over Sites C, D, and E, setting stringent development and design limits on all three sites.

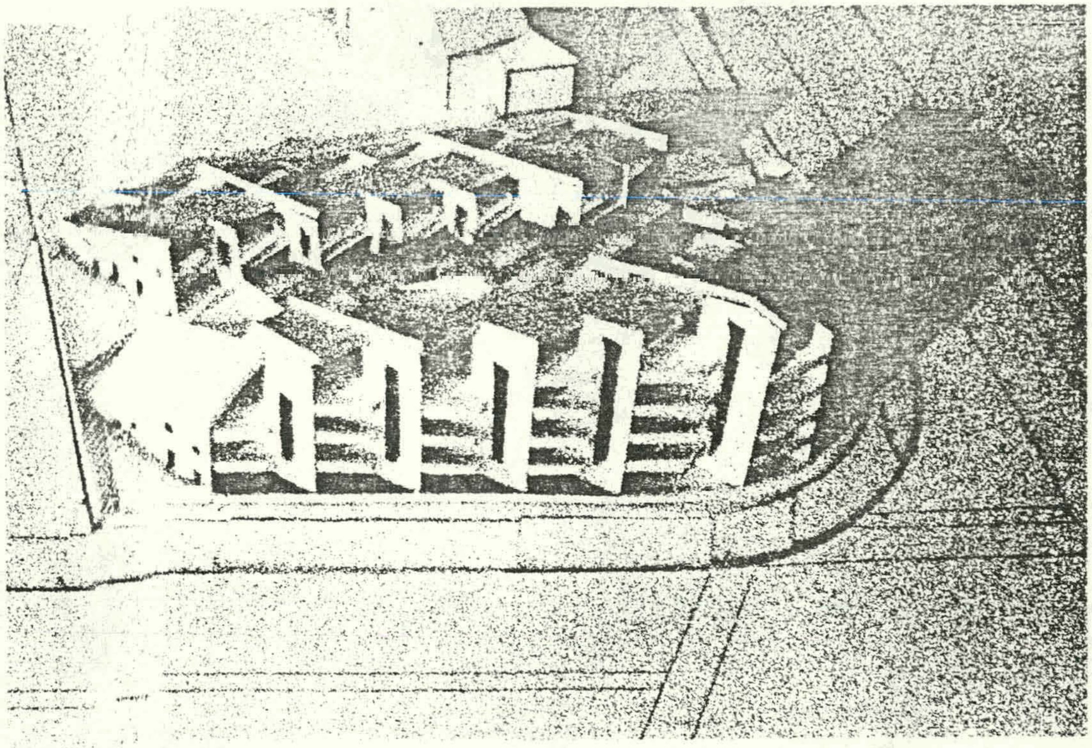


FIGURE 6–47. SITE C – DESIGN OPTION ONE, WINTER – 3 PM

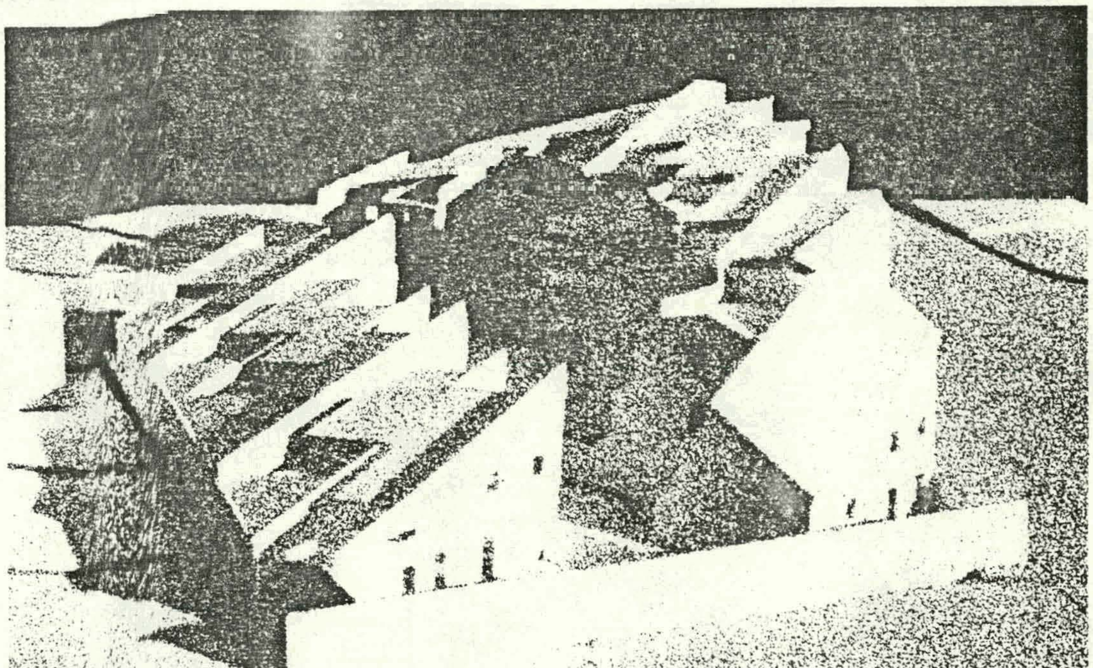


FIGURE 6–48. SITE C – DESIGN OPTION ONE, WINTER – 3 PM
Two views of this design are shown. The upper is seen from the south and the lower is seen from the west. The designer has followed one of two basic strategies found applicable for arranging units under this envelope. All living units are located in two rows to provide south and southeast sun exposure. The courtyard width varies relative to building height so that winter sun reaches major portions of the northern row of units from 10 am to 2 pm. (This period is 2 hours shorter than the guaranteed period of access for the solar envelope.) This strategy has a development price. Significant envelope volume is lost to the large court, but the building achieves twenty-five condominium units, producing a density of 42 dwelling units per net acre. A second design strategy on the site achieves more units. (Designer: Jeanette Quon.)

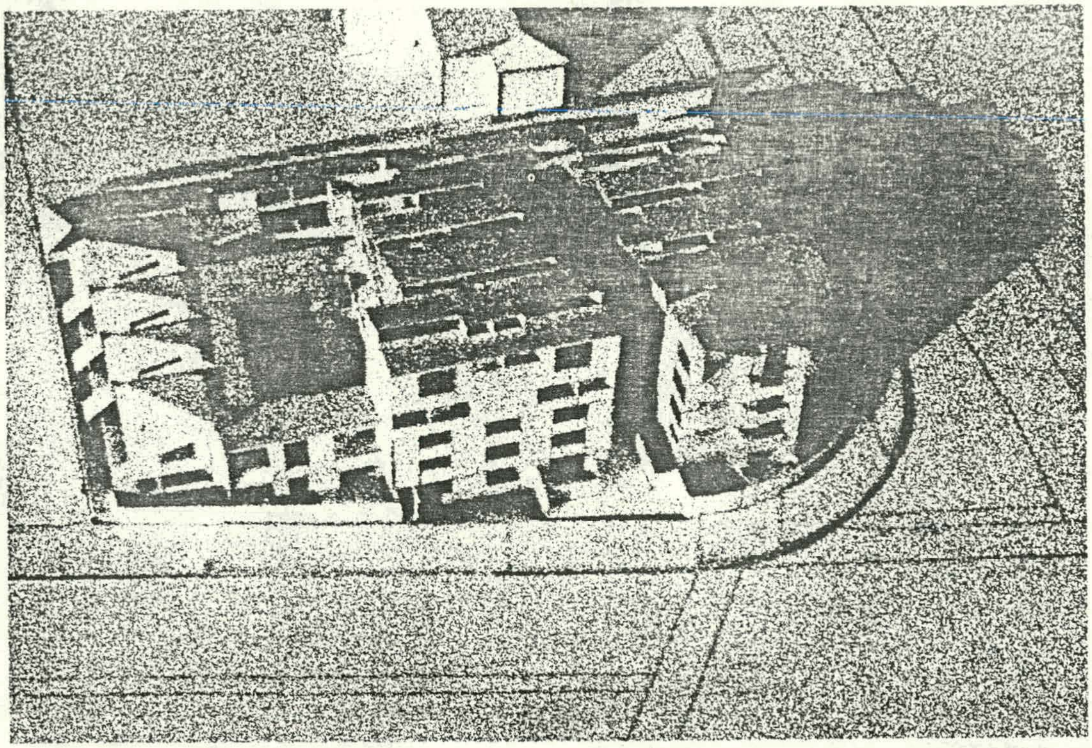


FIGURE 6–49. SITE C – DESIGN OPTION TWO, WINTER – 3 PM

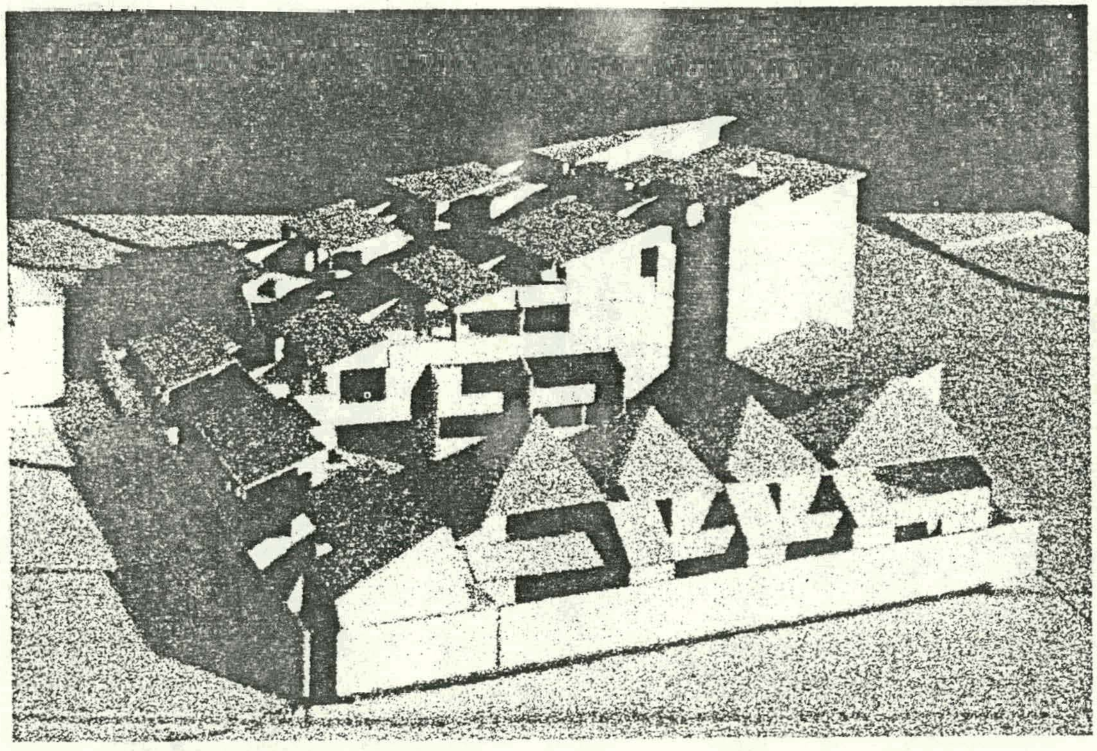


FIGURE 6–50. SITE C – DESIGN OPTION TWO, WINTER – 3 PM

A second design approach is seen in two views. The upper one is from the south and the lower is from the west. This designer has followed a different organizational strategy in which almost all units are located in three north-south rows instead of two east-west rows as in Option One. By a combination of clerestories and terraces, some south exposure has been provided to every unit but the units have their major exposures on the east and west. While this orientation does not have the energy conversion advantage of a major south exposure, there are development advantages. Twenty-nine condominiums are obtained at a density of 48 dwelling units per net acre. (Designer: Paul Gutierrez.)

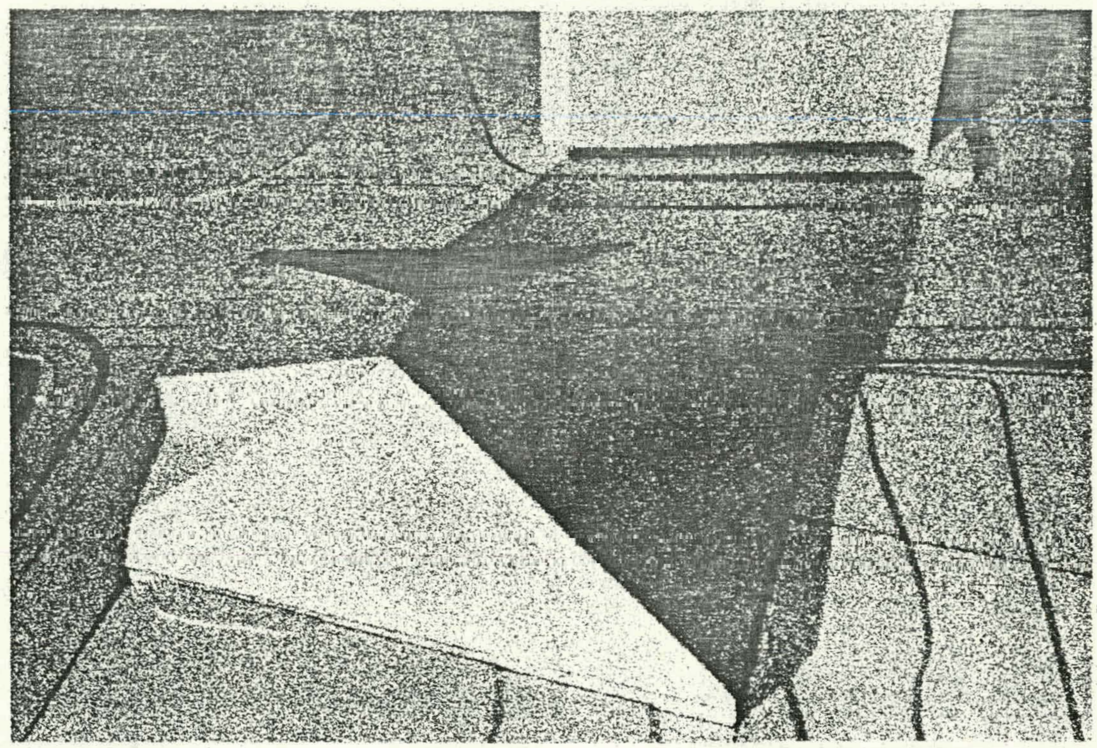


FIGURE 6–51. SITE F – ENVELOPE, WINTER – 3 PM

This site has a shape similar to site C but it is somewhat smaller in area. The envelope form is quite different, however, because of the site's location. This site is south, rather than north, of Wilshire Boulevard. And because shadows can be cast across the entire street width, the envelope bulk increases to provide 20 percent more actual development potential than envelopes over northern sites.

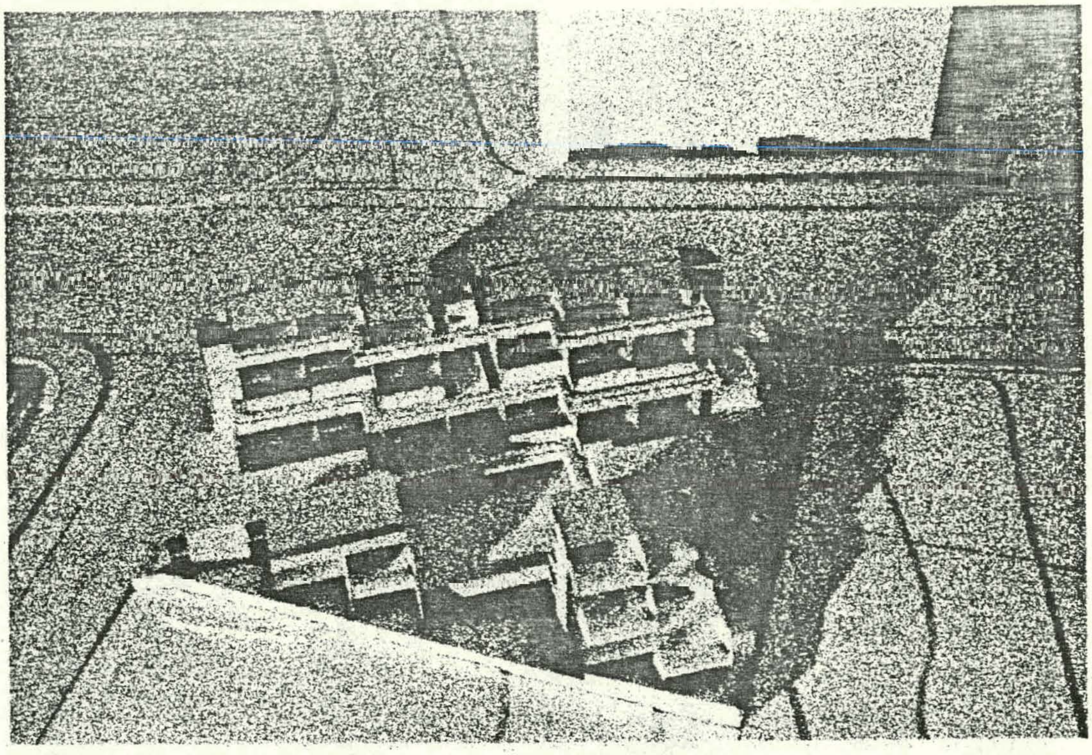


FIGURE 6–52. SITE F – DESIGN OPTION ONE, WINTER – 3 PM

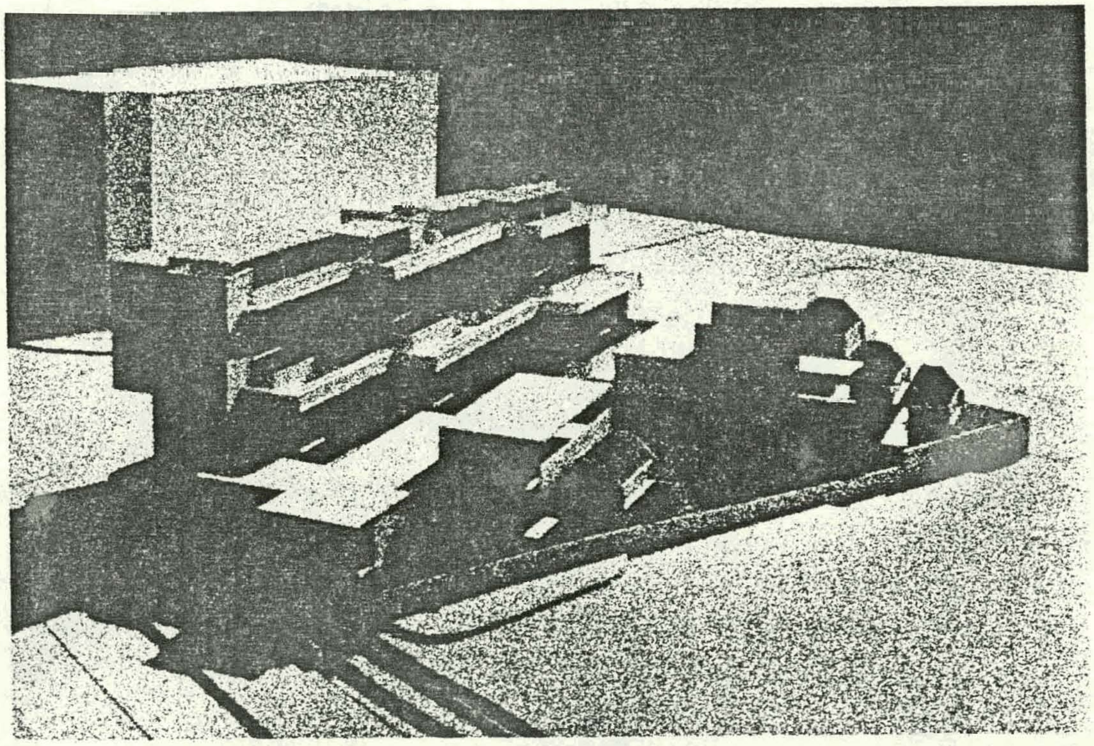


FIGURE 6–53. SITE F – DESIGN OPTION ONE, SUMMER – 9 AM

Two views of one building design are shown. The upper view is from the south and the lower one is from the west. The designer has followed a strategy of providing south exposure for all units. The taller block of living units is located along the site's northern boundary where the long winter shadows extend across the street without impacting the existing building. The southern row of units are kept low and arranged around a court that opens directly to the south. No unit shadows another during the winter between the hours of 9 am and 3 pm. Even though the designer sacrificed volume for south exposure, a relatively high density is achieved because of the envelope's bulk. Twenty-seven condominium units are obtained, providing a development density of 49 dwelling units per net acre. (Designer: David Wallace.)

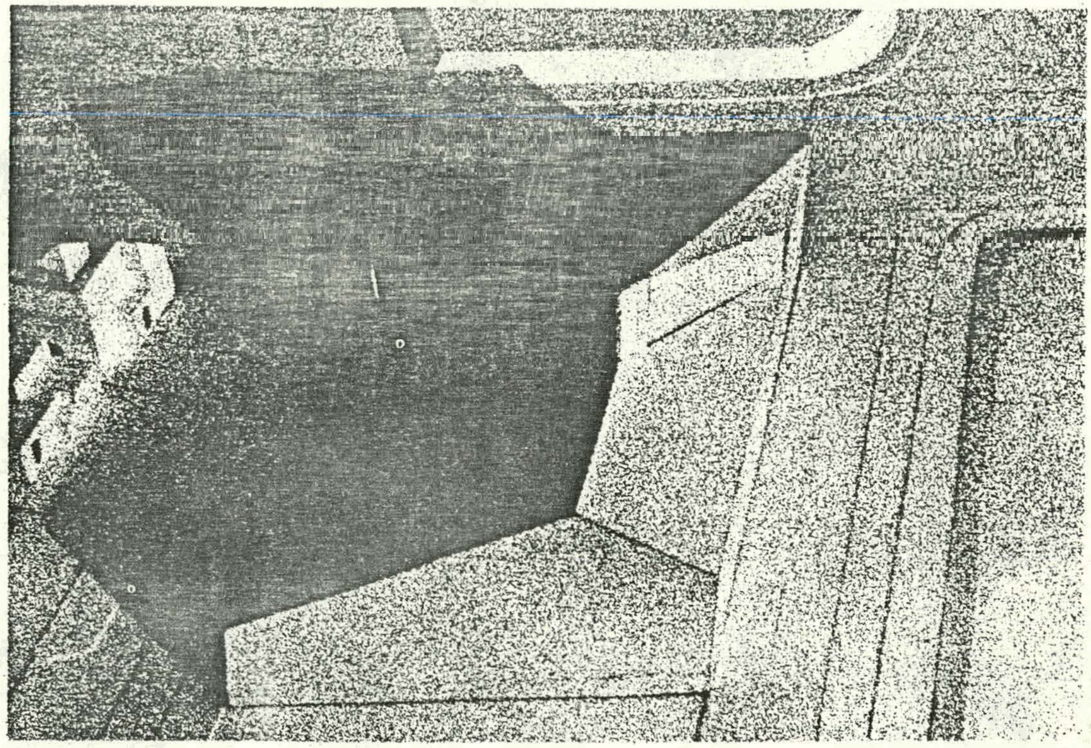


FIGURE 6–54. SITE B – ENVELOPE, WINTER – 9 AM

The winter morning shadow seen in the figure provides the clue to this envelope's unusual shape. The site is south of Wilshire, so shadows may extend quite far to the north. The resulting envelope, as it faces north to Wilshire, is relatively high. Across Tremaine to the west are single-family residences that must be protected from shadow impact. A similar condition, assuming future development, occurs across Keniston to the east. These two situations require that the envelope's southern portions be dropped below the northern portion.

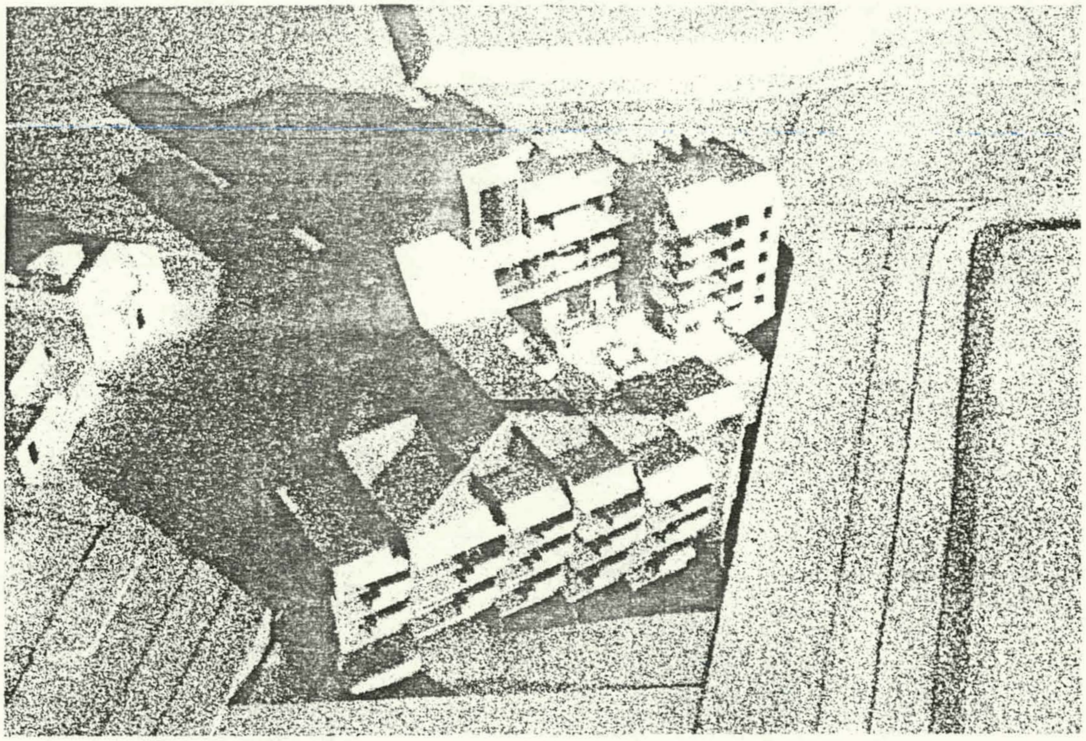


FIGURE 6–55. SITE B – DESIGN OPTION ONE, WINTER – 9 AM

FIGURE 6–56. SITE B – DESIGN OPTION ONE, SUMMER – 9 AM

Two views of the building are shown. One is from the south on a winter morning (Fig. 6–55) and the other on a summer morning (Fig. 6–56). The winter morning shadows cast by the building indicate how closely the designer came to approximating the envelope's outline. Shadows from the buildings closely approximate shadows from the envelope. If the winter (above) and summer views (below) are compared, the importance of a south orientation becomes clear. This designer has oriented almost all units to the southeast so that the winter morning sun penetrates deeply into the main living spaces of every unit. The summer morning sun does not penetrate interior spaces at all, a condition that persists during the rest of the day. By the skillful use of courtyards, terraces, and overhangs, this designer is able to achieve both high-quality spaces and good development results. Thirty-two units are obtained, providing a development density of 58 dwelling units per net acre. (Designer: Michael Gehring.)

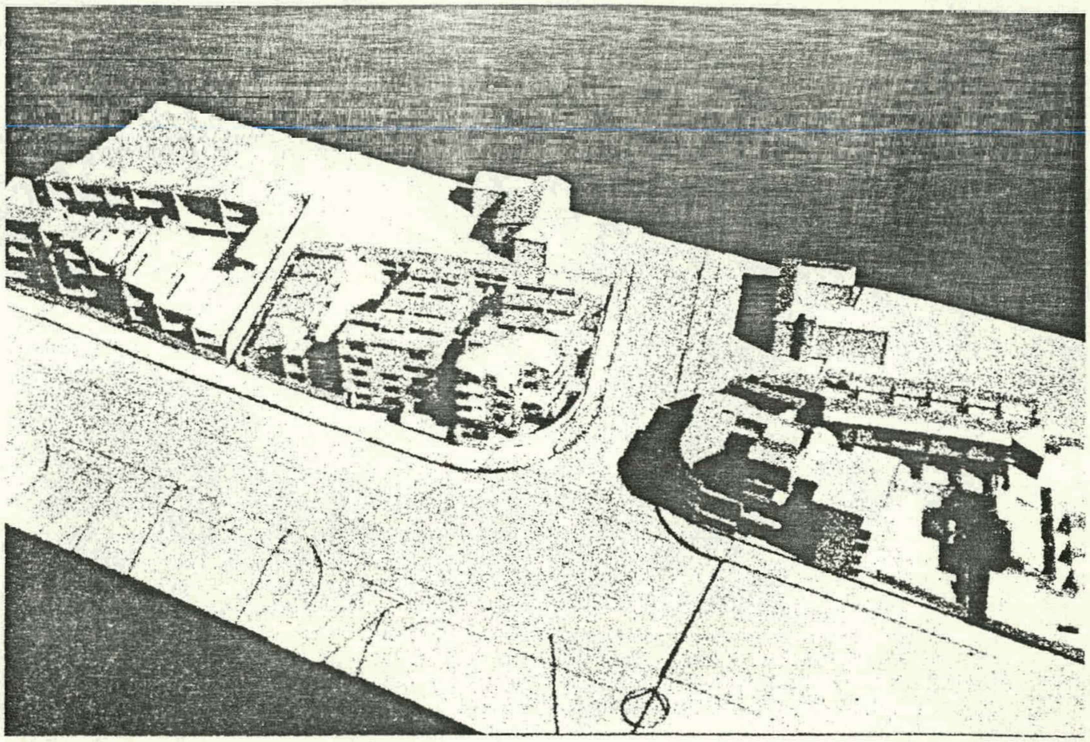


FIGURE 6–57. Sites C, D, AND E – SUMMER – 9 AM

Building designs for several adjacent land parcels are shown in Figures 6–57, 58 and 59. These indicate the character of the study area as it might develop over time. The resulting images suggest a distinctly pedestrian scale and an urban quality that seems richly diversified. The solar envelope allows the individual designer ample latitude for self-expression while meeting the stringent demands of both solar access and development economics. (Designers, from left to right: Mary Stockus, Paul Gutierrez, Barry Sullivan.)

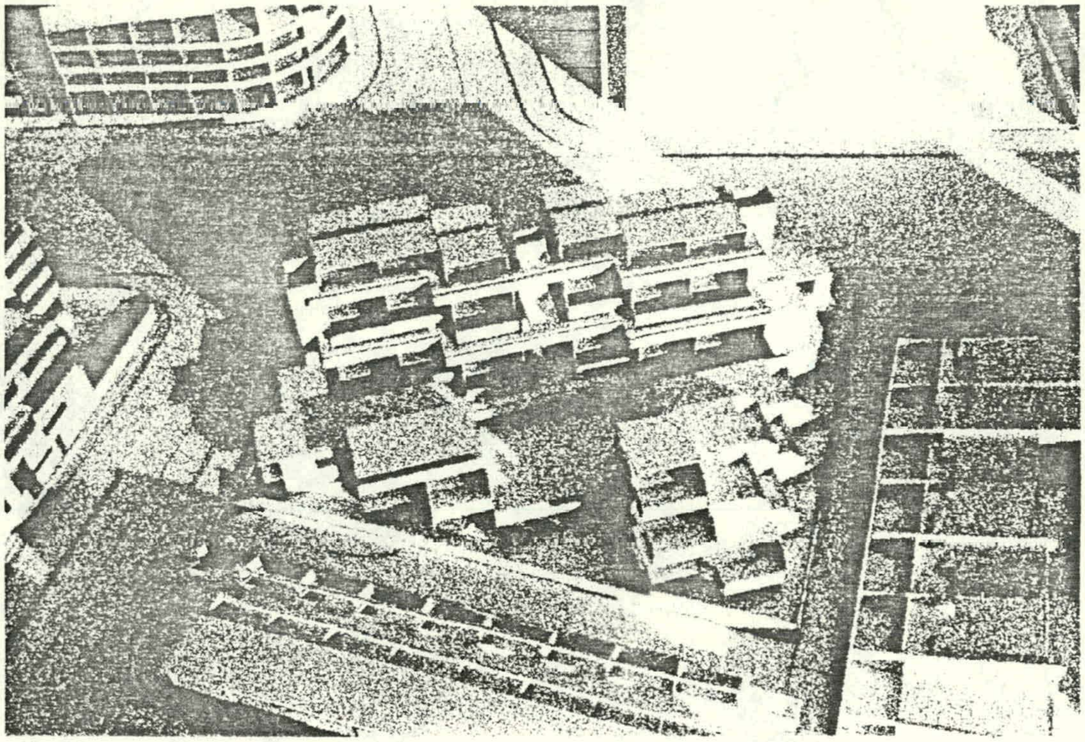


FIGURE 6–58. SITE F & SURROUNDING PARCELS – WINTER – 9 AM

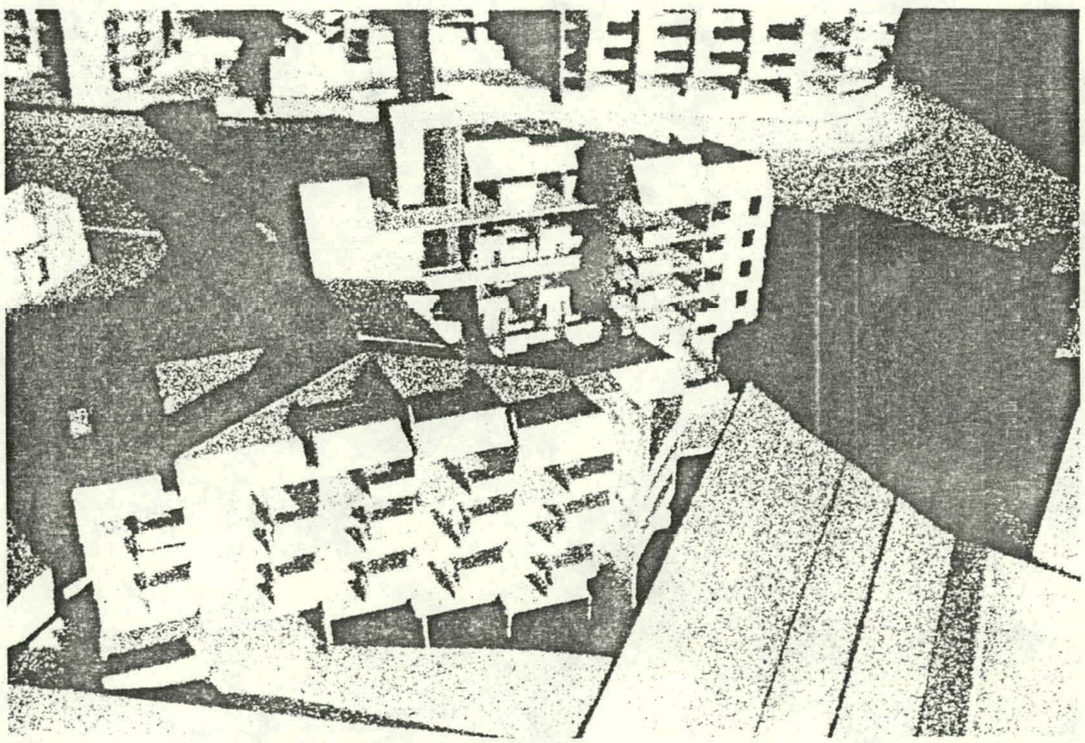


FIGURE 6–59. SITE B & SURROUNDING PARCELS – WINTER – 9 AM

Document Control Page	1. SERI Report No.	2. NTIS Accession No.	3. Recipient's Accession No.
	SERI/SP-98155-1		

4. Title and Subtitle	5. Publication Date
Solar Envelope Concepts; Moderate Density Building Applications	March 1980
	6.
7. Author(s)	8. Performing Organization Rept. No.
Knowles, Ralph L.; Berry, Richard D.	
9. Performing Organization Name and Address	10. Project/Task/Work Unit No.
School of Architecture University of Southern California Los Angeles, CA	5641.20
	11. Contract (C) or Grant (G) No. (C) XM-9-8155-1 (G)
12. Sponsoring Organization Name and Address	13. Type of Report & Period Covered
Solar Energy Research Institute 1617 Cole Boulevard Golden, Colorado	Special Report
	14

15. Supplementary Notes

16. Abstract (Limit: 200 words) Solar energy utilization in urban areas requires public guarantees that all property owners have direct access to the sun. The study examines the implications of this premise in relation to the need for cities to also encourage or accommodate rebuilding and future development. The public policy mechanism for guaranteeing solar access is conceptualized as a solar zoning envelope that allows the largest possible building bulk on a land parcel without shadowing neighboring properties during specified times. Step-by-step methods for generating solar envelopes are described with extensive drawings, showing a variety of urban platting and lot configurations. Development and design possibilities are examined on a selected set of Los Angeles sites with typically diverse urban characteristics. Envelope attributes suitable for encouraging moderate-density commercial and residential building are examined in the context of two hypothetical but realistic development programs: one for speculative office buildings and one for condominium housing. Numerous illustrations of envelope forms and prototypical building designs are provided. The results of development simulation studies on all test sites are tabulated to show building bulk, density, land-coverage and open space characteristics obtainable under the hypothesized envelopes.

17. Document Analysis

a. Descriptors Solar Envelope; Buildings; Residential Buildings; Houses; Zoning; Design; Heliodon; Geometry; Computers; Simulation

b. Identifiers/Open-Ended Terms

c. UC Categories

58a, 58b, 58d

18. Availability Statement	19. No. of Pages
National Technical Information Service U. S. Department of Commerce 5285 Port Royal Road Springfield, Virginia 22161	144
	20. Price $7.25

Form No. 8200-13 (6-79)

U.S. GOVERNMENT PRINTING OFFICE: 1980 - 677-175 REGION NO. 8