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Earth Sheltered Housing in Warren County, Kentucky: Description of Housing Units & Determinants of Residents' Satisfaction

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EARTH SHELTERED HOUSING IN WARREN COUNTY, KENTUCKY: DESCRIPTION OF HOUSING UNITS AND DETERMINANTS OF RESIDENTS' SATISFACTION

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EARTH SHELTERED HOUSING IN WARREN COUNTY, KENTUCKY: DESCRIPTION OF HOUSING UNITS AND DETERMINANTS OF RESIDENTS' SATISFACTION

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The known population of earth sheltered houses in Warren County, Kentucky were studied (a) to document building materials and techniques utilized, (b) to describe the residents demographically and document their attitudes regarding satisfaction with earth sheltered housing, and (c) to determine reasons for building and resources utilized in financing and planning, as well as problems encountered in regard to the earth sheltered house.

Data on 21 housing units were collected through personal interviews. Data analysis was accomplished using contingency tables, chi-squares, Pearson's product-moment correlation, and multiple stepwise regression.

The earth sheltered house found to provide residents with high satisfaction was generally a chambered elevational structure which had cast-in-place concrete walls at the earth contact points with an exposed wood frame roof and a concrete floor. Amounts of soil coverage on the exterior varied, as did the use of insulation below grade. Waterproofing systems usually included drainage tile, swale(s), plastic sheeting, and a built-up asphalt or pitch coating applied to the exterior walls. A wood stove and central heating system were the most frequently used sources of heat. Air conditioning was utilized by most residents in the summer, although a window air conditioning unit often provided adequate cooling of the entire house. Ventilation was not a concern and dehumidification was seldom a concern for the residents. All 19 original owners (90% of the house owners in the study) acted as their own contractors, hiring professionals for such tasks as soil testing and subcontracting, and most reported no difficulty with financing and planning the earth sheltered house. Information on building the earth sheltered house was most often obtained from family and friends. The most common reasons for choosing this housing alternative were energy conservation and low cost.

Resident satisfaction was high for most aspects of the earth sheltered house included in the study. All residents reported high overall satisfaction with the earth sheltered house and most of the housing systems investigated. Significant ($p \leq .01$) contributors to residents' computed total satisfaction score (TSS) were satisfaction with lack of mildew and satisfaction with natural lighting in the house (90% of variance explained). The addition of satisfaction with lack of condensation on windows,

satisfaction with exterior appearance, and satisfaction with performance of the waterproofing system to the regression equation brought the explained variance to 98%. Significant ($p \leq .01$) to residents' self-reported overall satisfaction with their earth sheltered houses were satisfaction with heating and cooling expenses and satisfaction with interior surface temperature (59% variance explained). None of the other variables, housing related or demographic, added significantly to explained variance in the TSS or self-reported overall satisfaction with earth sheltered housing.

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Warmest thanks are conveyed to the author's husband, Jim, who will agree that "...we have this treasure in earthen vessels, that the excellency of the power may be of God, and not of us." II Corinthians 4:7

TABLE OF CONTENTS

LIST OF TABLES

Chapter One

Introduction and Purpose

Although earth sheltered housing has existed for centuries, not until the early 1970s did builders and home owners seriously consider this alternative to conventional housing. Today almost every state includes examples of this housing form that utilizes the soil as a barrier to isolate the house from its environment ("Earth Shelters," 1984). In Minnesota, Oklahoma, and certain other locations, extensive studies have been conducted on the construction and physical aspects of earth sheltered houses (Underground Space Center, 1979; Impson & Impson, 1984; Aiken, 1979; Chester et al., 1983). However, information is lacking regarding the attitudes of people who live in these structures toward this housing alternative. This was confirmed by J. Carmody of the Underground Space Center (personal communication, June 12, 1984). Earth sheltered house designs that are psychologically acceptable and the characteristics that make them attractive and acceptable in established neighborhoods were areas of research suggested by Combs (1985). Also, there is a dearth of information regarding characteristics of earth sheltered housing in Kentucky.

The primary reason for building earth sheltered housing in Minnesota has usually been isolation from cold weather (Underground Space Center, 1979) while in Oklahoma this housing form has most often been used to protect its occupants from high winds and storms (Rivers, Helm, Warde, & Grondzik, 1981). What reasons do Kentuckians give for building earth sheltered housing in this geographic locality with its unique climatic conditions?

The purpose of this research was to compile data on existing earth sheltered houses in Warren County, Kentucky and to examine the attitudes of occupants toward this housing form.

Specific objectives of the study were as follows:

1. To develop profiles of the physical characteristics of each earth sheltered house;

2. To describe the occupants of earth sheltered housing and their attitudes regarding satisfaction with this housing form;

3. To examine the relationship between the residents' satisfaction with the performance of earth sheltered housing systems and components of the systems;

4. To ascertain reasons for building earth sheltered housing;

5. To examine the relationship between reasons for building and overall satisfaction with the housing form;

6. To identify resources utilized in financing and planning the earth sheltered house and potential problems encountered.

Definition of Terms

Earth sheltered house--any completed dwelling in which a major living area is isolated from the environment by soil. Soil may isolate a portion or all of the exterior wall(s) and/or roof.

Bermed earth sheltered house--an earth sheltered house built on grade with soil banked against the exterior wall(s) or a portion of the wall(s).

Chambered earth sheltered house--an earth sheltered house built below existing grade. Soil is excavated from the building site to create a recess in the earth in which to construct the house.

Elevational plan earth sheltered house--an earth sheltered house in which one or more walls is exposed.

Penetrational plan earth sheltered house--an earth sheltered house in which only door and window openings are exposed.

Atrium plan earth sheltered house--an earth sheltered house in which a central courtyard is exposed, allowing entrance to the dwelling and generally admitting light to the interior.

Swale--a human-made drainage ditch to route surface water to desired location.

R-value--the insulative quality of a material. The higher the R-value, the greater the ability of the material to insulate.

Limitations

The study was limited to earth sheltered housing, as defined in the study, in existence in Warren County, a single county in Southcentral Kentucky. The study was limited to the opinions and perceptions of the respondents obtained through a structured questionnaire in an interview setting.

Chapter Two

Review of Literature

Humankind has always sought basic needs of food, clothing, and shelter from the earth. Early peoples obtained comfort and protection from the elements in caves. According to Roy (1982) earth sheltered dwellings have provided shelter from harsh heat and cold, as evidenced in Cappadocia, Turkey, where people have been living in underground towns and cities since before Christ. Roy (1982) has also described contemporary apartments "supplied with electricity, tile floors, and all the creature comforts" (p. 6) nestled in soft rock cliffs in Gaudix, Spain and France's Loire Valley.

The Underground Space Center (1981a) has documented underground residences carved from soft rock in Matmata, Tunisia to protect the residents from the extreme temperatures of the climate. The Center (1981a) has also described courtyard-type houses constructed within loess soil in China where farming takes place on the roofs of the houses in order to conserve space.

In the United States ancient Indians occupied dwellings in the face of southwestern cliffs (Chester et al., 1983). American settlers used underground cellars for food storage and as storm shelters as they moved westward across the continent. Sod houses and dugouts were constructed in the midwest during the 1800s to provide shelter in a region barren of trees and conventional building materials (Chester et al., 1983).

These early examples of earth sheltered structures are unsatisfactory by today's standards because of "drawbacks associated with the ground: dampness, insects and vermin, difficulty keeping them clean, lack of view and so forth" (Underground Space Center, 1981a, p.16). When given the opportunity, the inhabitants of these early structures usually moved into a conventional housing form.

Preference for conventional housing was also true of homeowners who built basement houses. This type of housing was popular following World War II as it provided a living space while the remainder of the house was being constructed. The houses were often left unfinished for many years and detracted from the appearance of the landscape until zoning ordinances were enacted to prevent the construction of these houses (Underground Space Center, 1981a).

The design for an aesthetically pleasing environment was also a concern shared by such contemporary architects as Phillip Johnson, John Barnard, and Malcolm Wells. These builders solved the problem of blending the house with its environment by placing earth around the exterior of the house. The oil embargo of 1973 gave ecomonic impetus to energy efficient earth sheltered housing. Since that time, others have chosen earth sheltered housing for various reasons, including privacy, structural stability, low maintenance, and isolation from noise (Campbell, 1980). Impson and Impson (1984) noted the ability of earth sheltered houses to protect against fire, wind, hail, and vandalism. Decreased infiltration resulting in protection from air pollution and decreased dust accumulation are advantages reported by Swayze (1980).

Literature pertinent to the present study was reviewed and categorized as follows: the structural shell of the earth sheltered house, waterproofing, insulation, ventilation and dehumidification, codes and finance, solar heating, and earth cooling.

The Structural Shell of the Earth Sheltered House

Structures against which earth is placed must not only be constructed to bear the load of the structure itself and its contents, but also the lateral pressure of the surrounding soil. Roofs that are earth covered must bear vertical earth loads. Massive materials that can support such loads are generally used for the earth contact walls and roof. According to the Underground Space Center (1979), concrete is one of the most frequently used materials. When cast-in-place, concrete is usually available at a low cost, has high compressive and shear strengths, resists uplift and sliding due to water and earth pressure, and is durable and fire resistant. It is generally watertight, unless cracks develop, and can be formed into unique shapes. Plain concrete is commonly used for "floors on grade, nominal footings and walls with less than about 6 feet of cover" (Sterling, 1978, p.77). Reinforced concrete is used to advantage in "structural floors, roofs and walls; for large footings, beams and columns; and for arch and shell roof systems" (Sterling, 1978, p.77). Reinforcement may be used to increase the water resistance of concrete by reducing the width of cracks caused by its shrinkage during the curing time or by structural movement.

Masonry units are another alternative for earth contact structures. These units are mass produced and widely available, but have the disadvantage of being more susceptible to water penetration through cracks which are easily formed (Underground Space Center, 1979). Sterling (1978) has pointed out that a potential leakage path also exists along mortar joints between the concrete masonry units.

All concrete products mentioned have the disadvantages of low tensile strength which may result in cracks. They also require large foundations and footings to support the weight of the structure. Other difficulties include problems in working with concrete in cold weather and a lengthy curing time which may slow the construction of the structure and cause excessive moisture in the interior of the structure for several months. Curing time and attendant moisture problems can be eliminated by using precast concrete. However, heavy equipment may be required to move it to the job site and place it in the structure, thus adding expense (Underground Space Center, 1979).

Earth sheltered building specialists at the Underground Space Center (1981a) described one successful example of a group of 12 earth sheltered residences, constructed of precast concrete, known as the Seward town houses. These houses were constructed using precast concrete planks for the intermediate floor and roof, and reinforced concrete block for the structural walls. Located immediately adjacent to a busy freeway in Minneapolis, Minnesota, the earth shelter not only isolates this housing complex from the weather, but also from the freeway noise (Underground Space Center, 1981a).

Steel, because of its good strength, is another material often used for load-bearing members of earth sheltered houses, such as beams and columns. The Underground Space Center (1979) reports that steel is very water tight, it can be formed into arch shapes, and building is not restricted by cold weather. Disadvantages of steel include the need for fire and corrosion protection and, often, a greater cost than concrete.

Corrugated steel culverts have traditionally been used underground for drainage ditches, spanning creeks, and roadwork. Hermann J. von Fraunhoffer, president of Concept 2000 Inc., an architectural and engineering firm in Phoenix, Arizona, reportedly uses 10-gauge corrugated steel culvert pipes as the structural shell of earth sheltered houses (Smay, 1981). In the hot Phoenix climate, Fraunhoffer omits insulation in the earth sheltered house, allowing the steel to conduct heat from the interior of the dwelling to the soil. Using this type of structure, the temperature at floor level is approximately 75 degrees on a day when the outside air temperature is 115 °F.

Chemically treated wood that resists decomposition is a third building material that can be used below grade. Although it must be used in well-drained earth to remain dry, it is light weight and can be assembled quickly by standard construction crews. The cost of a wood structure is low, but this type of structure is combustible (Underground Space Center, 1979).

The Underground Space Center (1981a) reported successful use of chemically treated wood in the Wild River State Park House in the tongue and groove wood decking of the roof. Functioning also as the second floor ceiling, the wood roof was covered by a waterproof membrane, rigid insulation, and 18 in. of earth cover. Advantages of the house design include widely familiar construction methods and building materials which are readily available throughout the United States.

<u>Waterproofing</u>

A major concern associated with earth sheltered housing is waterproofing. The first consideration is the site chosen for the structure. A high water table is to be avoided. It is also wise to avoid low lying areas although drain pipes and sump pumps may be used to assist in draining these areas (Underground Space Center, 1979). The site should also not be located in the path of surface runoff which may occur during heavy rains or snow melt. These considerations are more critical to chambered dwellings than bermed housing since chambered dwellings are built below grade.

The first line of defense in waterproofing is to route the water away from the house. This can be done by sloping the surface of the soil away from the house. If the soil surface naturally slopes toward the house, a swale or drainage ditch should be formed to divert water around the structure (Underground Space Center, 1979). Other landscaping techniques for water control include

> surface contours, type and compaction of fill, erosion controls on slopes, hardy planting materials, drainage of semipermeable or impermeable surfaces (e.g., driveways, patios, decks, overhangs, walkways), enclosed atrium drains or drywells, drainage conduits, and roof runoff devices (e.g., gutters, downspouts, scuppers, splash courses) (U.S. Department of Energy, 1980, p. 2).

The second component in the waterproofing system is the means of dealing with the subsurface water that reaches the structure. The water may be diverted with drainage techniques that include drainage ducts placed within porous granular backfill material. This is usually placed around the perimeter of the structure, and sometimes it is also placed under the floor of the structure. Thought should be given to the outlet of the water as well as to the maintenance of the drainage ducts which may need to be cleaned of accumulated debris. A slight surface slope (1% to 8%) will encourage proper drainage of earth covered roofs. A porous granular backfill material and a waterproofing layer adjacent to the roof are also necessary for an earth covered structure. Concrete floors should be cast-in-place over a plastic vapor barrier beneath which has been placed several inches of porous fill. Additional drain tile may be placed within this porous fill to drain water to perimeter tiles, thus removing any accumulated soil moisture.

The third component of a successful waterproofing system is the waterproofing skin of the structure. It protects the structure from vapor pressure, capillary draw, and hydrostatic pressure. Because each situation is unique, there is no best waterproofing material (U.S. Department of Energy, 1980). Site, soil type, climate, weather conditions, construction scheduling, cost, lifespan, availability, application and installation, surface conditions, and the structure itself are factors involved in choosing the proper waterproofing material and system.

Latex emulsions, cement parging, and asphaltic and pitch foundation coatings are considered dampproofing materials. They should be used only on structures in which some dampness and moisture can be tolerated. While they are able to withstand water and moisture, they are brittle and easily cracked. The water and moisture then enter the structure though these cracks (U.S. Department of Energy, 1980).

Liquid elastomers, on the other hand, are able to bridge small cracks. "These products are applied by spray, trowel, squeegee, roller or brush to form a monolithic membrane" (U.S. Department of Energy, 1980).

Modified bitumens are a compound of tar or asphalt and synthetic rubber which is manufactured in rolls. The sheet goods are bonded to the structure with primers or adhesives and seams are bonded with mastic adhesive.

Also manufactured in rolls or sheets are vulcanates which are fully cured elastomers, polymers, and rubber compounds. They may be seamed at the factory or at the job site. Each compound has specific advantages and disadvantages.

Bentonite clay products expand when they come into contact with water, forming a waterproof barrier. Available for spray, panel, or trowel application, this product has no seams or joints except for panel application.

While plastic sheeting, such as polyethylene, is not a waterproofing material, it can be used in the waterproofing system to act as an underground umbrella to shed water to drainage routes and away from protected areas. It is also sometimes used directly over the waterproofing material on the structure, but has the disadvantages of being easily punctured and impossible to seal at the seams.

Insulation

In cold climates insulation is desirable to isolate the living space from the cool earth. Even though earth temperatures 10 ft below grade in central Kentucky do not fall lower than 50 F (Smay, 1977), this temperature is too cool for human comfort. Insulation may be placed outside a concrete earth sheltered house so that the concrete mass can help to store and reradiate the interior heat (Underground Space Center, 1982). This position of placement is the most desirable (Underground Space Center, 1979). However, insulation placed this way works best if it has high compression strength, high resistance to water, is long lived when placed in contact with soil, has good dimensional and R-value stability over a long period of time, is available in tongue and groove configuration to reduce cold spots and water movement between the insulation sheets, is easily available at low cost, and is easily handled (Underground Space Center, 1979).

Extruded polystyrene performs well when placed in contact with soil and ground moisture and has been found in testing to retain a high percentage of its insulating value for a 10-year period. Although expanded polystyrene is less expensive, it is weaker than the extruded version and will absorb moisture more readily, thereby reducing the R-value of the material. Moisture absorption can be reduced by protecting the insulation from ground moisture with a polyethylene sheet or by some other measure. Polyurethane is the insulating material with the best initial R-value, but it loses a larger percentage of this quality as it ages and as it is exposed to ground moisture. While it is usually the most expensive insulation material, polyurethane can be applied by spraying, making it a good choice for curved surfaces (U.S. Department of Energy, 1981a).

Where exterior walls do not provide ample thermal mass, as in the case of a wood structure, insulation is best placed within the walls of the structure. Insulation placed within the exterior walls of an earth sheltered house should not emit toxic fumes, should have good dimensional and R-value stability over a long period of time, should be low cost, and should be easily obtained and installed. One such material is glass fiber (U.S. Department of Energy, 1981a).

In warm climates where cooling the interior environment is a major concern, insulation may be omitted from the floors and lower portion of the walls or may be omitted entirely (U.S. Department of Energy, 1981b). This permits the warmth of the living area to transfer to the surrounding soil. Because the proximate soil is almost always cooler than the air temperature within the earth sheltered structure, condensation may occur on interior surfaces. It is brought about by moisture-laden air coming into contact with a surface which is below the dew point. The likelihood of this occurring depends on the local climate and on the manner and degree of transference of exterior air to the interior. Although this phenomena may occur on uninsulated walls, it is more likely to occur if the insulation is placed on only part of the walls and it ends abruptly, rather than tapering off in R-value. This situation creates a cold spot where the insulation ends, thus increasing the chance of condensation (Underground Space Center, 1982). Insulation is sometimes omitted from the floor and/or parts of the walls when heating the interior is at least as important as cooling the interior.

Ventilation and Dehumidification

Energy efficient structures are built tighter than conventional structures in order to limit the amount of air infiltration. This type of structure also allows a greater amount of humidity to accumulate in the interior which may cause condensation on building elements, such as windows, exposed to both the cold outside air and the warm interior. Adequate ventilation within the building will usually rectify this problem (Underground Space Center, 1982). An electric dehumidifier may be used to lower the humidity level, especially during the early months of occupation of the building. Air conditioning also lowers the humidity level as it cools the air (Campbell, 1980).

Codes and Finance

Building codes and zoning ordinances vary from region to region, but most do not apply to earth sheltered structures. However, some limit the construction of this type of structure. Because earth sheltered construction is relatively new, some experts predict that these codes will be changed or amended in time. In instances where conflicts exist, building officials should be contacted before construction has begun so that they can better understand the project and its problems. These officials may offer alternative solutions for unconventional housing forms (Underground Space Center, 1981b).

Another difficulty often encountered by earth sheltered house builders is financing. Considered by some to be the largest single obstacle to more widespread construction of earth sheltered housing, financing for earth sheltered housing is sometimes difficult to obtain. Reportedly, this is because many financial agents at lending institutions do not understand the concept of this housing form. Another concern is resale potential which is difficult to estimate because of the short time contemporary earth sheltered housing has been in use

(Underground Space Center, 1981b).

Concern for resale potential is shared by building contractors. In a study by Combs (1985), many Nebraska contractors believed that it was difficult to obtain earth sheltered designs that were viable as well as acceptable, both to the occupants and to the surrounding neighborhood.

Solar Heating

The most commonly used method of space heating conservation for earth sheltered housing is a passive solar system (Underground Space Center, 1982). The passive solar system requires few, if any, components that would not ordinarily be found in the housing structure. In order for a passive solar system to be effective, the interior must be exposed to solar radiation. This is generally achieved by placing adequate windows on the south side of the structure. These windows may be placed to form a greenhouse or a sunspace located within the living area. A form of insulation, such as insulating draperies, is provided for this expanse of glass in order to reduce heat loss at night and on cloudy days. A second type of shading device, such as awnings, is desirable to block solar radiation in the summer (Mazria, 1979).

The large thermal mass inherent in earth sheltered housing having a concrete shell is often used for the advantage of solar heat storage. The heated interior air warms the concrete slowly. When the interior air temperature falls, the heat is released slowly by the concrete, thus warming the living space. Earth sheltering also reduces the amount of air infiltration of a structure thereby reducing the amount of cool air seeping into the interior in the winter and warm air in the summer. (Underground Space Center, 1982).

Earth Cooling Techniques

Earth cooling techniques make use of the naturally cool subsurface ground temperatures to cool the interior of a building. Interior air is circulated through passageways, usually pipes, in the ground. As the air circulates, it loses heat to the soil and thus reenters the structure at a lower temperature. Fans or other mechanical devices may be used to circulate the air, or it may circulate by natural convection (Smay, 1981).

Chapter Three

Methodology

Population

The population of earth sheltered houses included in the study was restricted to all known existing earth sheltered houses in Warren County, a single county located in Southcentral Kentucky. The choice of Warren County was based on the fact that it is the most populous and fastest growing county in the area, and its residents have a reputation for being somewhat progressive and receptive to new ideas (Urban Studies Center, 1987). Because all new housing units built since 1979 must be inspected by a city or county inspector, both building inspectors were contacted to determine the number and location of such structures in Warren County and Bowling Green, its county seat.

The Bowling Green city building inspector cited only one earth sheltered structure within the city limits. This structure was an apartment complex originally built as a bomb shelter, and it was rejected from the study because it was not built for the purpose of permanent housing. The county building inspector cited the location of 18 possible earth sheltered houses. Six of these houses did not qualify as earth sheltered houses because the earth sheltered part of the house was not intended to be used as a major living area, either at the present time or in the future. The resident of a seventh structure agreed by telephone to be interviewed, but could not be contacted at a later date for the interview. Two other houses were not included in the study because the residents declined to be interviewed. Each of the nine remaining earth sheltered house residents were interviewed and asked if they knew of other examples of this housing form. Twelve additional structures were located in this way for a total of 21 earth sheltered houses. With the exception of one earth sheltered house built by a classmate of the researcher, who responded to a pretest of the questionnaire, and the three earth sheltered structures mentioned earlier whose residents were not interviewed, this was assumed to be the entire earth sheltered housing population of Warren County, Kentucky.

Data Analysis

Computations and data printout were accomplished through the Academic Computing and Research Services Center at Western Kentucky University. Statistical procedures were obtained from the Statistical Package for the Social Sciences (SPSS) (Nie, Hull, Jenkins, Steinbreuner, & Brent, 1975). Frequencies and percentages were computed for all variables. Chi-square analysis was used to compare (a) occupants' satisfaction with the waterproofing material/system and the components used in the waterproofing system, (b) satisfaction with the ventilation of the house and the components used in ventilation and air quality control, (c) satisfaction with heating/cooling expenses and the type of heating and cooling systems used, (d) satisfaction with the lack of mildew and the humidity control method used, (e) satisfaction with the professional help received and the percentage of building that was constructed by professionals, and (f) overall satisfaction with the earth sheltered house and the most important reason cited for building an earth sheltered house.

A total satisfaction score (TSS) was computed for each subject by summing the ratings on all individual components of satisfaction. Pearson's product-moment correlation was utilized to test the significance of the relationship between the overall satisfaction rating of the earth sheltered house and the TSSs of earth sheltered house residents.

Stepwise multiple regressions were computed to determine which variables made significant contributions to overall satisfaction with the earth sheltered house and those most determinant in the TSSs of earth sheltered house residents.

Development of the Questionnaire

The questionnaire (see Appendix A) was developed and organized into five parts. Questions regarding description of the earth sheltered house and construction of the housing form comprised Parts I and II and provided data to achieve objective one. The questions were formed using the information obtained from Earth Sheltered Structures: Fact Sheet, Numbers 1 through 12 (U.S. Dept. of Energy, 1980, 1981). The Fact Sheets were inclusive, but general in nature because they were intended to be used "as a checklist and a reminder of site considerations for site responsive design in general, and the earth sheltered structure in particular" (U.S. Department of Energy, 1981c, p. 1).

Part III of the questionnaire, Financing and Planning the Earth Sheltered House, was developed to fulfill objective four and six. The questions were derived from a thorough investigation of the literature. Earth Sheltered Housing: Code, Zoning, and Financing Issues (Underground Space Center, 1981b) and transcripts of selected presentations from Going Under to Stay on Top--Housing: 1978-1979 Earth Sheltered Conference Series (Underground Space Center, 1980) were especially helpful sources.

Part IV of the questionnaire, Satisfaction of the Resident, and Part V, Demographic Description of the Resident, fulfilled objectives two, three, and five. Satisfaction questions were based on physical aspects of construction addressed in Parts I through III, as well as literature citations of problems residents of earth sheltered housing have encountered relative to this housing form.

A Likert-type scale was used for the satisfaction ratings and a 10 point scale was chosen because it offered no middle choice. In addition to the Likert-type ratings on satisfaction, open ended questions were asked to provide free responses regarding construction components that may have been unsatisfactory, as well as aspects of satisfaction/dissatisfaction with the earth sheltered house which may not have been tapped in the structured questions.

Finally, the demographic questions were included to obtain information for developing profiles of earth sheltered housing residents. The Two Factor Index of Social Position (Hollingshead, 1957) was used to compute the social class based on occupation and education for each person interviewed.

The questionnaire developed for the survey was critiqued by two housing and design specialists at Western Kentucky University, and revisions for clarity and length of the instrument were made. The questionnaire was then pretested by the researcher by conducting a telephone interview of an earth sheltered house resident who was somewhat familiar with the intent of the research. Minor changes were made in parts of the format of the questionnaire to further improve clarity and insure accuracy of data.

The researcher then contacted all other known earth sheltered house residents in Warren County. Only the location of each earth sheltered house was given by the building inspector, so each house location was plotted on a map. The researcher then drove to the house and requested an interview with the male or female head of household. If both were present during the interview, the demographics were recorded for the person who chose to rate the satisfaction questions. If the residents were not at home, an introductory letter asking the resident to contact the interviewer by telephone was left at the house (see Appendix B). One occupant responded to the researcher's letter of introduction by telephone and requested a telephone interview, which was successfully administered. The researcher also successfully administered the survey to residents of 20 houses in person, for a total of 21 earth sheltered houses. The survey was given orally, with the researcher recording all data. The researcher judged the house building type based on the definitions adopted for the study. All other information was provided by the occupant.

Chapter Four

Findings and Discussion

The data for the study were obtained from personal interviews with the head(s) of households of 21 earth sheltered houses in Warren County, Kentucky. Analysis of the data resulted in findings which are presented under the following headings: (a) Description of Respondents, (b) Description of Housing Forms, (c) Respondents' Recommendations for Future Earth Sheltered House Builders (d) Comparison of Satisfaction with Systems and Components Used in the Systems, (e) Variables Contributing to the Total Satisfaction Score, (f) Variables Contributing to Overall Satisfaction, (g) Comparison of Overall Satisfaction and Reasons for Building Earth Sheltered Housing, and (h) Financing and Planning the Earth Sheltered House.

Description of Respondents

The residents of the entire known population of earth sheltered houses in Warren County, Kentucky (25) were contacted. One house was excluded from the study because the residents had been involved in pretesting the interview schedule. Residents of three earth sheltered houses failed to respond to contact or declined to be interviewed. Data were obtained from residents of 21, or 88%, of the known earth sheltered houses in the study area.

The 21 respondents included 10 males and 11 females. When both husband and wife were present for the interview, the sex of the respondent was that of the person who volunteered the satisfaction ratings. Demographic characteristics of the respondents are given in Table 1.

The ages of earth sheltered housing dwellers ranged from 28 to 61 years. The mean age was 42 and the mode was 43. Nineteen of the respondents were married and two were single, divorced. The number of children living at home ranged from none (9) to three (2).

Respondents were classified into social classes according to Hollingshead's Two Factor Index of Social Position (1957) using occupational and educational rankings of the head of the household who rated satisfaction questions. In cases where the social score of the spouse was known to be higher, the higher social class score was used. The social class of respondents ranged from Class Five (lower) to Class Two (upper middle) with the majority (11) in Class Four, lower middle.

For six of the respondents the earth sheltered house was the only house ever owned. Four respondents had previously owned one house, four had previously owned two, and seven had previously owned three houses.

Nine respondents had graduated from high school; four had attended college or vocational school; and another two had attended graduate school. Three respondents completed

Table 1

Demographic Characteristics of Respondents

Age	Sex	Mar. stat.	Number of children at home	Soc. score	Number prev. houses	Education	Income in thousands[a]
28	M	married	0	3	0	voc. school	36-40
29	F	married	2	4	2	high school	21-25
29	F	married	3	5	0	high school	21-25
33	F	married	1	5	0	grade 7-9	21-25
34	M	married	1	4	3	high school	36-40
34	F	married	0	5	2	high school	41-45
35	F	married	0	3	2	grad. school	46-50
41	F	married	2	2	3	voc. school	31-35
42	F	married	2	4	3	high school	26-30
42	F	married	3	4	3	high school	46-50
43	F	married	2	5	1	grade 10-11	10-15
43	F	married	0	4	1	high school	31-35
43	M	married	2	2	1	grad. school	31-35
43	M	married	2	4	0	voc. school	21-25
46	M	divorced	1	3	0	high school	10-15
47	M	married	0	4	1	high school	36-40
50	M	married	0	4	0	grade 7-9	26-30
51	F	divorced	0	4	0	some college	16-20
53	M	married	1	4	3	grade 7-9	36-40
60	M	married	0	4	3	grade 10-11	10-15
61	M	married	0	3	2	grade 10-11	21-25

Note. Social class score was derived from education and occupation of the respondent according to Hollingshead's Two Factor Index of Social Position (1957) (Class Five, lower, to Class One, upper).

[a]Annual household income refers to income from all sources for all family members before taxes.

high school through grades 10-11, and another three completed high school through grades 7-9.

Approximate annual household income from all sources ranged from $10,000-$15,000 to $46,000-$50,000. The modal income category was $21,000-$25,000 with 24% of the respondents reporting incomes within this range. Occupations included several factory workers, managers, business owners, fire fighters, and teachers. One resident representing each of the following occupations was also included: truck driver, bookkeeper, industry instructor, maintenance worker, secretary, salesman, building contractor, real estate manager, and decorator.

The typical earth sheltered house owner in Warren County, Kentucky was most likely to be 43 years of age, married, with two children living at home, a high school graduate, a member of the lower middle social class, with annual household income in the $21,000-$25,000 range, and to have owned houses previously.

Description of Housing Forms

Twenty (95%) of the 21 earth sheltered housing units included in the survey were chambered earth sheltered houses. These structures were built by removing soil from the building site and building the house in the excavated area. The berm technique was used for some of these houses in that the excavated soil was placed on the exterior of one or more walls. One (5%) of the earth sheltered housing units was constructed using only the berm technique. This structure was built on grade and soil was placed around the exterior to form a berm. Elevational plans, having one or more walls exposed, were used for all 21 houses.

All 21 of the houses included in the study were built between 1966 and 1986. Most of the houses (95%) were built in the '70s and early '80s, with one or two built in 1970, 1974, 1976, and 1978 through 1986. The most houses built in one year was five (24% of the sample) built in 1980. The earliest structure studied was built in 1966, predating the energy conservation movement of the 1970s as well as Phillip Johnson's earth sheltered Grier house of 1969. The builder reportedly was inspired to construct an earth sheltered house by the coolness of her mother's root cellar in the summer and its warmness in the winter. She learned many building techniques as she built the house; friends and family were her primary sources of building information. As this occupant was building by trial and error, she made some mistakes. Consequently, in 1985, she replaced the flat felt and pitch roof that leaked with a wood frame gable roof. The resident of this house indicated an interest in new earth sheltered building materials and techniques and plans to build another earth sheltered house in the future.

Because an earth sheltered house is integrated with its site, the house may be as unique as the site. Thus a profile of each earth sheltered house was developed and integrated with the resident's satisfaction with the house.

The first house. This house was the oldest earth sheltered house in the study and was built of concrete block walls with a placed concrete floor and a wood frame roof with 75% of all walls covered with soil. Glass fiber batt insulation placed in the ceiling was the only insulation. Waterproofing consisted of plastic sheeting under the floor and built-up asphalt or pitch on the exterior walls below grade. Cement parging was applied to the interior of the perimeter walls as a secondary waterproofing. On a scale of 1 to 10, overall satisfaction with this house was rated a 10 (high) by the occupant. Satisfaction with specific aspects of the earth sheltered house ranged from 5 to 10. The lowest ratings given were 5s for satisfaction with natural lighting of the house, lack of condensation on windows, and lack of mildew in the house.

The second house. This house was completely soil covered except for the south wall which was exposed to create a sunspace within the structure. The estimated average roof soil depth was 24 in. and the entire structure was constructed of cast-in-place concrete. Built in 1985, this house had no insulation and used built-up asphalt or pitch in addition to a rubber membrane as a waterproofing system. The drainage system was comprised of trenches of gravel with drainage tile and surface swales. The resident/builder gave a rating of 10 to each aspect of satisfaction, as well as overall satisfaction.

The third house. Constructed of concrete block to grade, this house exhibited wood frame above grade and a wood frame roof. The south wall was also wood frame and exposed, while the other three walls were 75% covered by soil. Glass fiber batt insulation was placed in the ceiling only. Waterproofing included plastic sheeting under the placed concrete floor and built-up asphalt or pitch on the exterior walls below grade. The resident was pleased with a centrally located wood burning stove which supplied most of the heat required by the household. Because the current resident purchased the house from the builder, the question of satisfaction with the professional help received did not apply. All other satisfaction questions were given a rating of 10, including overall satisfaction.

The fourth house. Built in 1980, this house consisted of first floor living space, completely earth sheltered on the west and north walls and covered 40% on the east wall, with an exposed second floor garage/storage area under a gambrel roof. All first floor perimeter walls were concrete block filled with vermiculite insulation, while the second story was wood frame. Inside the structure, rigid extruded polystyrene was used to insulate the earth sheltered walls and glass fiber batt was used to insulate the remaining walls and roof. Surface water was carried from the house by swales, while ground water and moisture were deflected using built-up asphalt or pitch on the exterior of the walls and cement parging on the interior of perimeter walls. The resident also stressed the importance of placing drainage tile in gravel, because of his success with this type of drainage. The resident was highly satisfied with all aspects of his house, rating each a 10, except for a 9 on satisfaction with lack of mildew in the house. Mildew was present only during the first year of use of the house, possibly due to excessive moisture released from the curing concrete.

The fifth house. Built in 1984 into a steep hillside, the first story of the house had 75% of the north wall, 45% of the east wall, and 50% of the west wall covered in soil. No soil coverage was used on the south wall or on the walls of the second story of the house, which contained a second living room, an extra bath, and bedrooms. The first story floor and walls were 8 in. thick cast-in-place concrete while the roof and second story were wood frame. The first story contained a family room, kitchen, laundry room, bathroom, food storage room, and three bedrooms. No insulation was used below grade. Rigid extruded polystyrene foam insulation was used on walls above grade and glass fiber batt insulation was used in the ceiling. All satisfaction ratings were high, the lowest being a 6 for satisfaction with the natural lighting of the house. According to the resident, there was not enough natural light in the kitchen/family room. Satisfaction with the ventilation system received a score of 9, and the resident recommended that other earth sheltered house builders install extra attic vents. However, overall satisfaction was given a perfect rating of 10.

The sixth house. This structure was built in 1978 and faced west. All walls were constructed of concrete blocks and the roof was wood frame. All walls had some soil coverage, ranging from 20% on the west wall to 75% on the east wall. Drainage tile, plastic sheeting, and built-up asphalt or pitch comprised the waterproofing system. Insulation was loose fill cellulose placed between perimeter concrete block walls and one and one-half inch furring strips to which wall board was attached. The resident expressed satisfaction with the fact that windows were included in every room and gave the house a rating of 10 on overall satisfaction. The aspect of this house receiving the lowest satisfaction score was the exterior of the house which received a score of 5. This was due to the fact that the house was painted concrete blocks with mortar joints which had not been struck, as they should have been.

The seventh house. This house was begun in the early 1980s and completed in 1986. The structure was covered completely with soil on the north and south walls and chambered in the soil 4 ft deep with 10 ft of additional soil berms. The east wall had 80% soil coverage and allowed a rear entrance. The west wall was completely exposed and contained a door and windows. The roof was covered with 30 in. of soil and the resident/builder planned to increase the roof soil coverage to a total of 36 in. The entire shell of the house was placed concrete, as was the floor. The soil covered walls and roof were insulated with rigid extruded polystyrene while the exposed wall contained vermiculite in a 4 in. cavity between the concrete wall and brick veneer. Drainage tile, swales, plastic sheeting, and neoprene (a vulcanate) comprised the waterproofing system.

The overall satisfaction rating for this house was a 10. The aspect receiving the lowest satisfaction rating (6) was the lack of mildew in the house. The resident explained that the rear corner bedroom was seldom used and mildew formed on the walls. All other satisfaction questions received high satisfaction ratings, except satisfaction with the exterior of the house which was not rated since the house had not been completed. The resident, who was a contractor, indicated that he recommended building other earth sheltered houses the same as he had built this one.

The eighth house. This house was built in 1970 and contained three levels. The first level included a kitchen, a sitting room, a dining room, a bath, and a bedroom. The structure was chambered in a hillside and the south wall was covered 100% with soil, while soil coverage on the east and west walls was 45%. The north wall was completely exposed. The second level contained three bedrooms, a living room, and a bath. The third level was tucked under the gambrel roof and contained two bedrooms. When asked if the earth sheltered portion of the house was a major living area, the respondent replied, "The basement, that's where we live."

The first level walls were constructed of concrete block, and the floor was cast-in-place concrete. The second and third levels, and the roof, were wood frame construction. No insulation had been used in the earth sheltered portion of the house, but it had been waterproofed with drainage tile, plastic sheeting, and built-up roofing tar.

The overall satisfaction rating given by the resident was a 9. A rating of 2 for satisfaction with the lack of mildew was given because the resident reportedly experienced a problem with mildew growth in the house. The skeletal material was listed as unsatisfactory by the respondent who would recommend using cast-in-place concrete rather than concrete block in future construction.

The ninth house. The earth sheltered portion of this house was the only living area from the time it was built in 1981 until the summer of 1987 when an above grade story and split-level entry were added. The first level included a master bedroom, a bath, a utility room, a library, and a two car garage. Chambered into a wooded hillside, the north wall was 90% soil covered, while the east and west walls were 75% covered with soil. The exposed south wall contained two units of 8 ft wide glass sliding doors to create a solar sunspace which was effective according to the owner. The first level floor was concrete and all first level walls were concrete block. The second level and roof were wood frame construction. No insulation was used below grade, but drainage tile, swales, built-up asphalt or pitch, cement parging, and sheetrock with a vapor barrier for use in basements, were used to protect the interior from ground water and moisture.

The resident gave an overall satisfaction rating of 7, since the roomy second level was completed. She was dissatisfied with the cast-in-place concrete floor, as well as with mildew and moisture-related problems. While using only the passive solar heating during a period of several cold, winter days, the interior air temperature reached no lower than 55 °F. She recommended passive solar heating to other earth sheltered house builders. The resident also noted that the earth sheltered part of the house was quiet compared to the above grade part because less outside noise entered below grade.

<u>The tenth house</u>. A chambered structure built in 1980, this house utilized total soil coverage on the west wall while the north and south walls were 95% covered with soil. The exposed east wall, as well as the gable roof, were wood frame. The other walls and floor were

cast-in-place concrete. Batts of glass fiber insulation were placed on the inside face of the exterior walls which were finished with sheetrock. Drainage tile and plastic sheeting comprised the waterproofing system. The resident was dissatisfied (rating of 1) with the waterproofing system and with mildew in the house. She stressed the need for sloping the drainage tile for easy drainage and the possibility that a dehumidifier might be needed. Other low ratings were given to satisfaction with lack of condensation on walls and the natural lighting of the house. Three double hung windows and one door were the only openings connecting the interior of the house with the outdoors. The occupant would have preferred a bay window, which would have increased the window area, but chose double hung windows because of economy. Despite problems with the house, the resident rated overall satisfaction with the dwelling a score of 9.

The eleventh house. This house was a chambered dwelling built in 1982. The west wall was 80% earth sheltered, while the south and west walls were 45% covered with soil. The walls and floor were constructed of cast-in-place concrete and a wood frame roof completed the structure. The walls were not insulated, but were covered with plastic sheeting and built-up asphalt or pitch for the purpose of waterproofing. Drainage tiles were used to supplement the waterproofing system. The resident's most important reason for building an earth sheltered house was protection from tornadoes. Overall satisfaction with the housing form was given a rating of 10.

The twelfth house. From a distance, this house appeared to be a conventional ranch style house, but was actually a bermed earth sheltered house. The current resident was the second owner of the house which was constructed in 1979. Soil coverage on the north wall was 70% and the east and west walls were 35% each. The exposed south wall and roof were wood frame and the rest of the structural skeleton was cast-in-place concrete. Glass fiber batt insulation was used on the inside of the exterior walls which were finished with sheetrock. Drainage tile, swales, and plastic sheeting were used to deter water from the structure while built-up asphalt or pitch was used for waterproofing. An overall satisfaction rating of 10 was given by the resident. His recommendation to future earth sheltered house builders was to "put a back door in" the structure. Three doors in the exposed wall provided safety for the occupant, but the lack of a door to the rear was considered inconvenient at times.

The thirteenth house. This house was a chambered structure, built in 1980 by the residents. It was totally sheltered on the west wall, with 80% of the south wall, 75% of the north wall, and 15% of the east, or front, wall earth sheltered. Wood frame construction was used for the east wall and roof. Concrete was used for the floor and walls. The latter were 12 in. concrete masonry units filled with cast-in-place concrete having reinforcement every 6 ft. Extruded polystyrene sheets were placed outside the structure for insulation. The waterproofing system included built-up asphalt or pitch on the exterior of the shell below grade and cement parging on both sides of the exterior walls below grade. Drainage tile, swales, and plastic sheeting completed the waterproofing system which the occupants gave a performance rating of 10. An overall satisfaction rating of 8 was given for this house. Low satisfaction ratings of 2 were given to the exterior appearance of the house, as well as satisfaction with professional help received. The resident/builders cautioned other builders not to be concerned with a conventional appearance, but to build the house to meet the needs of the occupants and, when changes occur in the building plans, to consider how they will affect the total plan. The residents also cautioned future earth sheltered house residents to allow for light in the interior. A central atrium and light interior wall color were used to enhance lighting in this dwelling.

The fourteenth house. This house contained two levels, the first of which was totally earth sheltered except for the west wall which was completely exposed. The entire structure was built in 1980 and housed the main living area on the first level, with an additional family room, a computer room, and a bedroom on the second floor. The exposed wall, upper level and roof were wood frame, with the balance of the shell being cast-in-place concrete. Rigid extruded polystyrene insulation was used to protect the house from outside temperatures, and a waterproofing system of drainage tile, swales, plastic sheeting, and built-up asphalt or pitch was utilized to shield it from water and moisture. A dehumidifier was used for the first two years of residence until the concrete was cured. Satisfaction ratings for all questions administered were 10s, except satisfaction with the natural lighting of the house which received a 6.

The fifteenth house. The lower level of this house was built in 1980. The upper level was started in 1985 and completed in 1987. Complete living space was built into each level. The resident/builder indicated that plans included sleeping in the upper level and using the kitchen, living room, and dining room in the lower level. One level may be rented to another occupant after the two children leave home; however, the builder and his wife disagreed as to which level they preferred for their own use. The husband was comfortable living in the lower level, while the wife expressed a preference for the upper level for prestige reasons, according to the husband.

The entire upper level and the west wall of the lower level were completely exposed, while the east, north, and south walls had, respectively, 100%, 90%, and 60% coverage with soil. The lower level walls were constructed of concrete block and the lower level floor was cast-in-place concrete. The roof and upper level walls were wood frame. The interior of the exterior walls below grade were covered with 1 in. rigid extruded polystyrene insulation. Plastic sheeting was placed only under the floor and built-up asphalt or pitch was the singular waterproofing used on the walls below grade. Drainage tile was used at the perimeter of the structure.

Dissatisfaction was expressed by low ratings of 3 for two variables. The natural lighting of the earth sheltered level was given a low rating because only two windows and one door served that level. Satisfaction with professional help received was rated low because the sub-contractor had built the concrete block walls 2 in. too high on one side of the house. This problem had to be corrected by the builder before proceeding with the construction of the house. High satisfaction ratings, ranging from 8 to 10, were given for the other aspects of the house with a rating of 8 for overall satisfaction.

The sixteenth house. Built in 1983, the south wall of this house was completely covered with soil and the west and east walls were 50% covered, with the north wall completely exposed. All exterior walls of the house were concrete block, the roof was wood frame, and the floor was made of cast-in-place concrete. No insulation was used on the walls below grade, but built-up asphalt or pitch had been applied to the exterior walls as waterproofing. Drainage tile was used to route ground water from the structure.

The occupant indicated that the dwelling lacked sufficient window area and this was reflected by the 3 rating given satisfaction with the natural lighting of the house and the 5 rating given satisfaction with the ability to ventilate the house. The house, which was painted concrete block, also received a rating of 5 on satisfaction with exterior apperance. All other satisfaction ratings were above the midpoint of the rating scale, including a rating of 7 for overall satisfaction.

<u>The seventeenth house</u>. Built in 1979, this house was unique in that the lower 4 ft of all exterior walls were constructed of 8 in. concrete blocks and veneered with 4 in. of poured concrete on the exterior. Standard wood frame construction with sandstone veneer on the exterior was used for the upper parts of all walls. The resident was dissatisfied with the concrete block construction and would recommend cast-in-place concrete walls instead. The north, west, and east walls were chambered into a hillside so that 50% of each wall was earth sheltered, but still permitted windows in all exterior walls. The entrance to the house was situated in the totally exposed south wall. The house had no insulation below grade and the waterproofing system was comprised of drainage tile, plastic sheeting, and built-up asphalt or pitch.

The highest satisfaction rating was a 10 for satisfaction with the natural lighting of the house. The lowest rating was a 6 for satisfaction with lack of condensation on windows, which the resident believed may have been related to the absence of storm windows. Overall satisfaction received a rating of 9. The recommendation cited by this earth sheltered house owner/builder was for adequate waterproofing. Since satisfaction with the waterproofing material/system was rated 9, the method used by the builder worked well for the hillside site selected for the house.

The eighteenth house. Built circa 1974, this house consisted of a lower level containing the kitchen, living room, bath, and bedrooms and an upper level containing a bath and a recreation room. All walls except the south wall were chambered on the lower level with 75% soil coverage. The lower level walls were concrete block with a concrete floor and the upper level walls and roof were wood frame construction. Glass fiber batt insulation was placed inside the structure. Drainage tiles were placed around the perimeter of the building, but, since the current owner was not the builder, additional information on waterproofing was not available.

The resident expressed dissatisfaction with the natural lighting of the house (rating of 2) and the ability to ventilate the house (rating of 5), but rated each of the other satisfaction components 10. Although it would reduce further the natural lighting of the house, the owner recommended complete soil coverage on three exterior walls of a structure for better energy efficiency.

The nineteenth house. The current resident had occupied this house since it was built in 1970. The perimeter walls were 16 in. thick, constructed of concrete and field limestone. The main living level was chambered, being earth sheltered 80% on the north wall and 100% on the west wall. A second level consisting of five rooms was tucked under a wood frame gambrel roof. The first level floor was concrete with a plastic vapor barrier and 10 in. of gravel beneath it. Cast iron drainage pipes were laid within the gravel layer, although the owner/builder conceded that polyvinyl chloride (PVC) pipe now available would be less likely to clog. Plastic sheeting and built-up asphalt or pitch were used to waterproof walls below grade and drainage swales were incorporated to divert surface water.

Satisfaction ratings were high (7 to 10) except for satisfaction with the natural lighting of the house (5). Overall satisfaction was rated 9. Recommendations included gravel filled trenches with drainage tile and a well drained lot for waterproofing, as well as good attic ventilation, even with flat roofed structures.

The twentieth house. This house was built in 1983 and was exposed entirely on the south wall to create a solar sunspace within the structure. The north wall was completely chambered and 30% of the east and west walls were soil covered. All four perimeter walls were concrete block, and a concrete floor and wood frame roof completed the shell. The only insulation was the glass fiber batt in the ceiling. The waterproofing included plastic sheeting and tar on the exterior and cement parging on the interior of the walls. Circulation fans installed in the walls over bedroom doors moved the air heated by the woodstove in the winter. Baseboard electric heaters were installed, but they were seldom used. On one occasion, the house was reportedly unheated by mechanical means for three days while unoccupied. Only passive solar heating was used. When the residents returned, the interior air temperature was 54 °F, although the outside air temperature had remained near zero. All satisfaction ratings given by the resident were 10s.

The twenty-first house. The final house in the study was built in 1979 using concrete block construction for the lower level and having a concrete floor. This level was chambered 40% on the north and west walls and 10% on the east wall. The upper level was placed under a wood frame gambrel roof. Each level contained complete living quarters. The owner/builder lived in the upper level and rented the lower level to another occupant. Although the earth sheltered walls were insulated on the inside of the structure with glass fiber batts, little or no insulation in the upper level walls was the reason given for a rating of 5 on satisfaction with heating/cooling expenses.

Drainage tile in gravel which drained to underground dry wells were the component of the waterproofing system the owner/builder recommended to potential builders. Swales, plastic sheeting, and cement parging completed the waterproofing system which was given a satisfaction rating of 3. Satisfaction with the exterior appearance of the house and satisfaction with the lack of condensation on the windows received low satisfaction scores of 3 and 4, respectively.

The resident gave high satisfaction ratings of 9 for satisfaction with the lack of condensation on the walls and satisfaction with the lack of mildew in the house. The resident of this house gave it an overall satisfaction score of 6 and was, at the time data were collected, building a two-story conventional house into which to move. In retrospect, he stated that he would have preferred building the earth sheltered house using cast-in-place concrete walls with a waterproof additive in the concrete. Also, he would have sprayed an asphalt coating on the walls as a waterproofing, in addition to using the gravel and drainage tile leading to dry wells.

Respondents' Recommendations for Future Earth Sheltered House Builders

Several recommendations for future earth sheltered house builders were given by present owners included in the study. Special consideration for allowing natural light in the interior was recommended by five residents. Another five residents advocated including drainage pipe and gravel in the waterproofing system, while three residents specified drainage tile in conjunction with a good waterproofing on the exterior of the structure. Cast-in-place concrete was recommended as a better material for earth sheltered house perimeter walls than concrete masonry units (concrete block). Two residents recommended furring the inside of the exterior concrete or concrete masonry walls and placing insulation between the wall and the finish, such as sheetrock. Two residents cautioned that the attic must be ventilated so that moisture can escape from the house.

Comparison of Satisfaction with Systems and Components Used in the Systems

Chi-squares were computed to test the relationship between resident satisfaction with certain housing systems and the components used in each system. Satisfaction ratings 7 through 10 were considered "high" and ratings 1 through 3 were considered "low" in order to decrease the number of cells in the contingency tables. However, the results must be interpreted cautiously since data were obtained from only 21 earth sheltered house owners and expected cell frequencies were sometimes low. Chi-squares were not computed if resulting cell frequencies would have been too low to give a valid chi-square. Frequencies and percentages were examined to determine which system components were most often chosen by residents who were most satisfied and those who were dissatisfied with a given system.

The waterproofing system is a critical element of the earth sheltered house since one or more walls will be partially or completely covered with soil. Chi-square analyses were used to compare satisfaction with the performance of the waterproofing system and the components included in the system. The results of these analyses are shown in Table 2.

The only significant chi-square was for satisfaction with performance of the waterproofing system and choice of waterproofing material ($p < .01$). Sixteen of the 19 respondents describing the waterproofing material used on the exterior walls below grade indicated they used built-up asphalt or pitch and reported high satisfaction with the performance of the waterproofing material/system. Of the 16, three also used cement parging and one added a rubber membrane to the built-up asphalt or pitch. One respondent included in the 16 reported using built-up asphalt or pitch, cement parging, and a sheet rock with a vapor barrier on the interior of the exterior walls. Using three types of waterproofing, none of which was highly recommended by authorities on earth sheltering, resulted in a satisfaction score of 7.

One respondent used only a rubber membrane to waterproof the below grade walls and roof, but gave a

Table 2

Frequencies and chi-squares for satisfaction with performance of waterproofing system and components used in system.

Components used in system	Overall satisfaction with waterproofing system							
	Low		High		Row totals		df	x^2
	N	%	N	%	N	%		
Drainage tile								
With	2	12	15	88	17	90		
Without	0	0	2	100	2	10		
Col. totals	2	10	17	90	19	100		
Swale								
With	1	10	9	90	10	53		
Without	1	11	8	89	9	47		
Col. totals	2	10	17	90	19	100		
Plastic sheeting							2	1.887*
With	2	18	9	82	11	55		
Without	0	0	6	100	6	30		
Don't know	0	0	2	100	2	10		
Col. totals	2	10	18	90	20	100		
Waterproofing material[a]							3	19.000**
Cement parging	1	100	0	0	1	5		
Built-up asphalt or pitch	0	0	16	100	16	84		
Vulcanates	0	0	1	100	1	5		
Don't know	0	0	1	5	1	5		
Col. totals	1	5	18	95	19	100		

Note. Only significant chi-squares are shown in table.

[a]Only the first type of waterproofing material used on below grade exterior wall(s) is shown. Some systems included more than one type.

*$p \leq .05$ **$p \leq .01$.

rating of 9 for satisfaction with the performance of the waterproofing material/system. Another respondent used only cement parging and gave a low satisfaction score of 3. One resident was not able to answer the materials section of the survey as he had purchased the house after it had been built and was not certain of the materials used. The final respondent, of the 21 surveyed, chose not to rate the performance of the material/system but did use built-up asphalt or pitch.

Built-up asphalt or pitch is not generally recommended for use below grade because of its inability to self-heal cracks at low temperatures such as those found in the earth. However, the majority of the earth sheltered house owners interviewed used the product and reported high satisfaction levels.

Only one person in the study used no waterproofing material, only drainage tile and plastic sheeting as a waterproofing system, and gave a 1 (low) rating for satisfaction with the performance of the system. The respondent expressed extreme dissatisfaction with the waterproofing aspect of the house. The dissatisfaction was due to a crack in an exterior earth sheltered wall which resulted in flooding of the interior during heavy rains.

Several earth sheltered houses had drainage tile, swales, or plastic sheeting as components of the waterproofing system. None of these components resulted in a statistically significant difference in the performance of the waterproofing system. Examination of contingency tables revealed that 15 residents, 88% of those responding to this question, reported having drainage tile at the perimeter of their earth sheltered house and high satisfaction with the waterproofing system. Two highly satisfied residents rated the waterproofing system a perfect score of 10, but did not use drainage tile in the waterproofing system. The other two residents who responded to this question included drainage tile in the waterproofing system but reported low satisfaction with the system.

The incorporation of a drainage swale into the waterproofing system was not significantly related to resident satisfaction. Nine residents reported having swales and rated satisfaction high, while eight residents reported not having swales and also rated satisfaction high. It may be assumed that some housing sites had good natural drainage and did not require additional contouring of the surface.

The use of plastic sheeting as a barrier to ground water and moisture was not a factor in satisfaction with the waterprooofing material/system. Plastic sheeting was utilized by 45% (9) of those responding to this question, and these residents were highly satisfied. However, 33% (7) did not incorporate plastic sheeting into the waterproofing system, yet were highly satisfied.

None of the earth sheltered houses surveyed made use of a sump pump to transfer water from the house. Although this device is used in this locality for non-living spaces, it was either not acceptable or unnecessary for earth sheltered housing living spaces.

Satisfaction with the ventilation system of the earth sheltered house was compared with ventilation components used in the system. No significant difference existed in ratings of residents on satisfaction with the ability of the ventilation system and the components included in the system (see Table 3). Differences were not significant regardless of whether or not the system included exhaust fans, circulation fans, or greater than standard 8 ft ceiling heights. All respondents reported satisfaction with the ability of their system to ventilate the house.

Satisfaction with lack of mildew in the house was compared with components used in the humidity control system. These data are shown in Table 4. The only significant chi-square was for the satisfaction with lack of mildew in the house and whether or not a portable dehumidifier was used ($p < .01$). The majority of the residents (15 of 21) were found to be highly satisfied, although they did not use a dehumidifier to control household moisture. Perhaps the earth sheltered houses were constructed so as to avoid a damp interior, thereby eliminating the need for a dehumidifier. No significant differences were found between the use of window or central air conditioning units or the use of humidifiers and

Table 3

Frequencies and Chi-Squares for Satisfaction with Ventilation of the Earth Sheltered House and Type of Ventilation Used.

Components of ventilation system	Overall satisfaction with ventilation of house: Low		High		Row totals		df	x^2
	N	%	N	%	N	%		
Kitchen exhaust fan							5	3.578
With	2	17	10	83	12	57		
Without	3	33	6	67	9	42		
Col. totals	5	24	16	76	21	100		
Bath exhaust fan							5	7.643
With	1	8	12	92	13	62		
Without	4	50	4	50	8	38		
Col. totals	5	24	16	76	21	100		
Circulation fan							5	1.851
With	4	21	15	79	19	90		
Without	1	50	1	50	2	10		
Col. totals	5	24	16	76	21	100		
Greater than 8 ft ceilings							5	2.543
With	2	33	4	67	6	29		
Without	3	20	12	80	15	71		
Col. totals	5	23	16	76	21	100		

Table 4

Frequencies and Chi-Squares for Satisfaction with Lack of Mildew in House and Components of Humidity Control System

Components of humidity control system	Satisfaction with lack of mildew							
	Low		High		Row totals		df	x^2
	N	%	N	%	N	%		
Portable dehumidifier							1	7.14**
With	3	60	2	40	5	24		
Without	1	6	15	94	16	76		
Col. totals	4	19	17	81	21	100		
Central air conditioning							1	0.031
With	1	17	5	83	6	29		
Without	3	20	12	80	15	71		
Col. totals	4	19	17	81	21	100		
Window air conditioning unit							1	0.103
With	2	17	10	83	12	57		
Without	2	22	7	78	9	43		
Col. totals	4	19	17	81	21	100		
Humidifier							1	0.283
With	0	0	1	100	1	5		
Without	4	21	15	79	19	90		
Col. totals	4	19	17	81	21	100		

$^{**}p \leq .01$.

resident satisfaction with the the lack of mildew in the house.

Theoretically, earth sheltered residents might be more satisfied with their dwellings if they utilized professional help in planning and constructing their houses. Residents were asked the proportion of professional help received in six categories: soil testing, engineering, sub-contracting, architectural services, landscaping for drainage, and contracting. None of the earth sheltered house owners used the services of a contractor, because all 19 original owners acted as their own contractors.

All of the earth sheltered houses in the study were built for use by the owner rather than for speculative sales. One contractor, who worked in Warren County at the time data for the present study were collected and who was interested in earth sheltereed houses, was contacted by the researcher. He cited lack of knowledge of earth sheltered housing building techniques with no incentive to learn and uncertain public acceptance of this housing alternative as reasons why contractors do not build earth sheltered housing in the region studied. The latter reason was supported by Combs (1985), who noted perceptions of uncertain public acceptance of this housing alternative by speculative builders in Nebraska.

The amount of professional help received in the other five categories was cross-tabulated with ratings for satisfaction with professional help received in respective categories. Results of these analyses are shown in Table 5. None of the chi-squares were statistically significant.

Professional help with soil testing was utilized by half of the 18 responding owner/builders, and only one of these gave a low satisfaction rating for this help. Low satisfaction was also reported by one resident who utilized little or no professional help with soil testing. The majority (89%) were highly satisfied regardless of the amount of help utilized.

Only four (22%) of the respondents reported professional assistance from an engineer. High satisfaction with professional help was reported for this group, as well as the majority (12 of 14) who utilized little or no services of an engineer. Two respondents (11%) reported little or no assistance from an engineer and low satisfaction with professional help received.

The term subcontracting was used to refer to the installation of systems within a structure such as plumbing and electrical wiring. The majority of the earth sheltered house builders (55%) hired professional subcontractors for some, most, or all installations, and most (9 of 10 in this group) were highly satisfied with the professional help received from subcontractors. However, many of the residents (83%) accomplished at least part of the subcontracting themselves.

Table 5

Frequencies and Chi-Squares for Satisfaction with Professional Help Received and Types of Professional Help Utilized.

Types of Professional help utilized	Overall satisfaction with professional help utilized							
	Low		High		Row totals		df	x^2
	N	%	N	%	N	%		
Soil testing							2	0.320
Little or none	1	14	6	86	7	39		
Some	0	0	2	100	2	11		
Most or all	1	22	8	88	9	50		
Col. totals	2	11	16	89	18	100		
Engineering							1	0.650
Little or none	2	14	12	86	14	78		
Most or all	0	0	4	100	4	22		
Col. totals	2	11	16	89	18	100		
Subcontracting							2	1.570
Little or none	1	12	7	88	8	44		
Some	1	25	3	75	4	22		
Most or all	0	0	6	100	6	33		
Col. totals	2	11	16	89	18	100		
Architect							1	0.020
Little or none	2	12	15	88	17	94		
Most or all	0	0	1	100	1	6		
Col. totals	2	11	16	89	18	100		
Landscaping for drainage							1	1.420
Little or none	2	18	9	82	11	65		
Most or all	0	0	6	100	6	35		
Col. totals	2	12	15	88	17	100		

Of the 18 residents who responded to the question on satisfaction with help received from an architect, 17 reported little or no use of architectural services. The one builder who hired an architect rated satisfaction with professional help received a perfect score of 10, as did 10 of those who did not hire architects.

The questions regarding the use of landscape professionals to provide proper site drainage were answered by 17 residents. Most residents (15 of 17) were highly satisfied with professional help received regardless of whether or not they used the services of a professional to provide landscaping for drainage. Neither of the two residents who indicated low satisfaction on this variable actually utilized professional help.

It may be that some building sites drain well naturally and these sites may not require human-made drainage systems. This may explain why many of the earth sheltered house builders were highly satisfied regardless of whether or not they utilized the services of professionals in landscaping for drainage.

Satisfaction with heating/cooling expenses was compared with components included in the heating/cooling system. No statistically significant differences were found (see Table 6). Of the 21 people interviewed, 18 rated satisfaction with heating/cooling expenses 9 or 10, highly satisfied. Twelve of these used wood stoves to supplement other heat, and two used wood stoves as their

Table 6

Frequencies and Chi-Squares for Satisfaction with Heating and Cooling Expenses and Components Used in the System

Components of heating/cooling system	Satisfaction with heating/cooling expenses							
	Low		High		Row totals		df	x^2
	N	%	N	%	N	%		
Solar							8	7.051
Sunspace	1	33	2	66	3	14		
None	1	6	16	94	17	81		
Hot water								
Circ. system	0	0	1	100	1	5		
Col. totals	2	10	19	90	21	100		
Earth cooling techniques							4	0.328
Pipes	0	0	1	100	1	5		
None	2	10	18	90	20	95		
Col. totals	2	10	19	91	21	100		
Stove							2	0.268
Gas	0	0	1	100	1	7		
Wood	1	7	13	93	14	93		
Col. totals	1	7	14	93	15	100		
Central forced air							8	10.625
Electric	1	17	5	83	6	60		
Natural gas	0	0	1	100	1	10		
Bottled gas	0	0	1	100	1	10		
Wood	0	0	1	100	1	10		
Oil	1	100	0	0	1	10		
Col. totals	2	20	8	80	10	100		

only heat source. One respondent used only electric radiant heat and gave a satisfactory rating of 7. Another respondent who used only an oil gun furnace and gave a satisfaction rating of 5, explained that the above grade walls and roof were not well insulated. The only unsatisfactory rating given was a rating of 1 by a respondent who used electric central air as the primary heat source, and electric radiant heat in the ceiling of bathrooms, a wood stove, and a sun space as secondary heat sources. This respondent had recently added a second level to the earth sheltered house to include above grade living space and was expecting to be dissapointed with the increase in heating and cooling expenses.

A total of three respondents used solar heating in the form of a sunspace and one respondent used earth pipes to cool the interior of the house when desired. This earth sheltered house resident also used a hot water circulation system buried in the concrete floor and around door and window openings of the exposed wall to supplement the one electric radiant wall heating unit. A satisfaction rating of 10 for heating/cooling expenses was given by this innovative resident/builder.

Ten earth sheltered houses included in the study utilized insulation, while 11 (52%) did not use insulation. Ten of the 11 who did not use insulation rated satisfaction with heating/cooling expenses a perfect 10. However, only 6 of the 10 residents of insulated earth sheltered houses gave a perfect satisfaction rating of 10 for satisfacton with heating/cooling expenses. Perhaps insulation interferes with the natural cooling effect of earth sheltering in the hot summer months. Or, perhaps, insulation is not a critical factor in determining satisfaction with heating and cooling expenses in this temperate climate.

Variables Contributing to the Total Satisfaction Score

Multiple stepwise regressions were computed to determine which variables made statistically significant contributions to satisfaction with earth sheltered housing. The total satisfaction score (TSS) for each resident was computed by summing ratings given on the 10 questions concerning satisfaction with specific aspects of the earth sheltered house. The TSS was used as the independent variable and all other variables included in the survey were used as independent variables. All blank data were assumed to be means in analyzing the data using the SPSS program (Nie et al., 1975). Results of the analysis are shown in Table 7. The significance level for all steps was very high ($p = 0.000$).

The variable making the greatest contribution to the TSS was satisfaction with lack of mildew in the earth sheltered house. Scores ranging from 1 to 10 were given for this question as some houses did contain mildew. This variable gave a highly significant standardized beta

Table 7

Multiple Stepwise Regression of Variables Contributing to Total Satisfaction Scores

Independent variables	Standardized Beta	Multiple R	R^2	F	pF
Step 1					
Satisfaction with (S w/) lack of mildew	0.872**	.872	.760	60.357	0.000
Step 2					
S w/lack of mildew	0.776**				
S w/natural lighting	0.379**	.946	.895	76.849	0.000
Step 3					
S w/lack of mildew	1.028**				
S w/natural lighting	0.315**				
S w/lack of condensation on windows	0.334**	.973	.947	101.865	0.000
Step 4					
S w/lack of mildew	0.996**				
S w/natural lighting	0.290**				
S w/lack of condensa tion on windows	0.318**				
S w/exterior appearance	0.148**	.984	.968	119.763	0.000
Step 5					
S w/lack of mildew	0.942**				
S w/natural lighting	0.261**				
S w/lack of condensation on windows	0.235**				
S w/exterior appearance	0.147**				
S w/performance of waterproofing system	0.140**	.991	.982	163.850	0.000

Note. Five additional steps produced significant ($p \leq 0.01$) F values, but made minimal contributions to explained variance.

**$p \leq 0.01$.

coefficient and explained 76% of the variance in the computed TSS variable.

The second variable entering the regression equation was satisfaction with the natural lighting of the house. The addition of this variable resulted in a highly significant standardized beta coefficient and the two variables explained 90% of the variance in the computed TSS variable. The actual amount of natural light in the earth sheltered houses of the respondents did not appear to be a function of the amount of soil coverage of exterior walls of the earth sheltered houses. Careful planning allowed for adequate windows in most elevational plans.

Step three of the multiple regression brought the explained variance in the TSS variable to 95% with the entry of satisfaction with lack of condensation on windows into the equation. An explained variance of 97% was achieved by the entry of satisfaction with the exterior appearance of the house in step four of the analysis. Satisfaction with the performance of the waterproofing material/system was entered in step five of the analysis. The addition of this variable brought the explained variance to 98%. In steps 6 through 10, satisfaction with the professional help received, satisfaction with the ablilty to ventilate the house, satisfaction with the heating/coooling expenses, satisfaction with the lack of condensation on walls, and satisfaction with the interior surface temperature were added to the regression equation in the order listed. These final five steps accounted for only 2 percent of the variance in the TSS.

It is notable that even though all 10 variables included in the computed TSS made highly significant contrubutions to explained variance, two variables--satisfaction with lack of mildew and satisfaction with natural lighting--accounted for 95% of the variance in the TSS. The third variable added only 2%, the fourth and fifth variables contributed only 1% each, and the other five variables added only 1% to the explanation of variance in the TSS computed variable. None of the other housing related or demographic variables were statistically significant.

Pearson product-moment correlation was used to measure the strength of the relationship between the overall satisfaction ratings and the TSS. A coefficient of 0.8531 was computed with a significance of 0.000. Therefore, a highly significant relationship exists between the TSS and the overall satisfaction rating.

Variables Contributing to Overall Satisfaction

Stepwise multiple regression was used to determine which variables made statistically significant contributions to residents' overall satisfaction with earth sheltered housing. Overall satisfaction was used as the dependent variable and all other variables included in the survey were used as the independent or predictor variables. The analysis was executed using the SPSS program (Nie et al., 1975) and assuming all blank data were means. Results of the analysis are shown in Table 8.

The variable making the greatest contribution to overall satisfaction with earth sheltered housing was satisfaction with heating and cooling expenses. This variable gave a highly significant standardized beta coefficient and explained 35% of the variance in overall satisfaction.

Generally the response to "How satisfied are you with the heating/cooling expenses?" was an immediate reply, "Very satisfied" or "I'd rate that a 10." Of the 21 respondents, 19 experienced high satisfaction (7 to 10) with heating/cooling expenses, with 16 of those giving a perfect satisfaction rating of 10. All residents surveyed expressed moderate to high overall satisfaction with the earth sheltered house (6 to 10), and 12 (57%) gave overall satisfaction a perfect score of 10.

The second variable entering the regression equation was residents' satisfaction with interior surface temperature of the earth sheltered house. The addition of this variable resulted in highly significant beta coefficients and brought the explained variance in overall satisfaction to 59% (see Table 8). Residents' satisfaction ratings for the interior surface temperature ranged from 7 to 10, with 67% of respondents giving a rating of 10. None

Table 8

Multiple Stepwise Regression of Variables Contributing to Overall Satisfaction

Independent variables	Standardized Beta	Multiple R	R^2	F	pF
Step 1					
Satisfaction with heating and cooling expenses	.592**	.592	.351	10.264	0.005
Step 2					
Satisfaction with heating and cooling expenses	.523**				
Satisfaction with interior surface temperature	.493**	.768	.589	12.919	0.000

**$p \leq 0.01$.

of the other variables contributed significantly to explained variance in residents' self-expressed overall satisfaction with earth sheltered housing.

Comparison of Overall Satisfaction and Reasons for Building Earth Sheltered Housing

All respondents reported an overall satisfaction rating of 6 to 10, indicating moderate to high satisfaction with the earth sheltered house. Chi-square was used to compare overall satisfaction with the earth sheltered house and the reasons residents gave for choosing this housing alternative. There was no significant difference between overall satisfaction and reasons for building the earth sheltered house (see Table 9).

Nine respondents gave "energy conservation" as the most important reason for building an earth sheltered house and gave an overall satisfaction rating of 8 to 10. Eight respondents gave "low cost" as their reason and their satisfaction ratings ranged from 6 to 10. "Protection from weather" was the primary reason given by two residents who rated overall satisfaction 7 and 10. "Security and low maintenance" was the reason given by one owner/builder whose overall satisfaction rating was 10. Another perfectly satisfied resident said he built an earth sheltered house "Because it would last [a long time]."

Reasons for building the earth sheltered house were examined relative to overall satisfaction because

Table 9

Frequencies and Chi-Squares for Overall Satisfaction Ratings and Reasons for Building the Earth Sheltered House

Reasons for building the earth sheltered house	Overall satisfaction with the earth sheltered house					
	Med.		High		Row totals	
	N	%	N	%	N	%
Energy conservation	0	0	9	100	9	43
Low cost	1	12	7	88	8	38
Permanence[a]	0	0	4	100	4	20
Col. totals	1	5	20	95	21	100

df = 2

$x^2 = 1.704$

[a]This category included protection from weather (2), security and low maintenace (1), and "lasts a long time"(1).

satisfaction with a particular choice is generally tempered by the reason for the choice. The most popular reason for building an earth sheltered house was energy conservation which, in this study, resulted in high satisfaction with the housing form. The second most frequent reason given for building was "low cost" which may have resulted in less highly satisfied residents because of lower quality building materials used in the construction in the house. The durability of the earth sheltered house accounted for the balance of those surveyed, who valued the permanence of this type of structure.

Financing and Planning the Earth Sheltered House

Questions were asked about financing and planning the earth sheltered house to determine whether or not problems were encountered in constructing this relatively new housing form, as literature had indicated. The majority (57%) of the 21 home owners surveyed obtained a loan to finance the earth sheltered dwelling. Four residents obtained loans from federal savings and loan institutions, two of these purchased the houses from previous residents. Another three residents obtained financial assistance through a state bank and trust company, and four residents obtained loans through national banking institutions. One resident obtained a loan from his father-in-law to finance his house, so he did not attempt to secure a loan from a conventional source. Another earth sheltered house resident was required to make a larger than usual down payment on his house because the loan officer was concerned about the resale of the unconventional house. Still another resident was encouraged, by the lending institution, to build a house instead of buying a trailer, as he had originally planned. Apparently this lending officer considered the earth sheltered alternative housing form preferable to a manufactured home.

One resident found it impossible to sell an earth sheltered house because, according to the builder/owner, "first of all, people in this area do not like this style of house." One couple reportedly was interested in buying the house but could not obtain financing because the house was considered a "basement house." The same resident explained that insurance was also difficult to obtain. Above grade rooms were later added to the house by the original owner and other improvements were made to the structure, so that the resident's satisfaction improved in all areas except the heating and cooling expenses.

Two owner/builders had to alter their building plans in order to meet local building codes. One used roof trusses for the conventional roof in order to meet clear-span requirements. This change was not related to the fact that the house was earth sheltered and would have been required regardless of the housing form. The other resident did not specify what changes were made in the building plans.

Although some of the potential earth sheltered house owners had to make adjustments in their financial plans for their house or make larger down payments, all were able to obtain financing. This may be related to the fact that none of the earth sheltered structures were located within the city limits of Bowling Green; all were in rural areas of the county. Combs (1985) noted that "greater deviation in housing designs, in terms of appearance and acceptability within the neighborhood, may exist in rural areas" (p. 145).

Eight of the residents interviewed stated that it was difficult to find information on earth sheltered housing, while 10 residents reported that finding such information was not difficult. Information on earth sheltered housing was found through books, magazines, other earth sheltered house owners, equipment leasers, concrete companies, and, most frequently, family and friends. One person relied on past experience with building houses.

Because 44% (8) of the earth sheltered house owner/builders reported difficulty in obtaining information on earth sheltered housing, and some who reported no difficulty used only basement construction techniques, it can be concluded that more information on earth sheltered housing construction needs to be available to interested persons. Disseminating the information may be difficult since the earth sheltered house builders included in this study most frequently relied on the advice of family and friends, rather than on a scholarly source of information.

Chapter Five

Summary, Conclusions, and Recommendations

Summary

The purpose of the study was to compile data on existing earth sheltered houses in Warren County, Kentucky and to examine the attitudes of residents toward this housing form. Specific objectives were developed to guide the study.

Literature on earth sheltered housing was surveyed and used as the basis for questionnaire development. House plan types were divided into three categories: elevational, penetrational, and atrium. House plan sections were divided into two categories: chambered and bermed. A variety of building materials and methods were noted. No literature was found on satisfaction of residents with this housing form.

The male or female head of household for each of the 21 earth sheltered houses in the study was interviewed to obtain a description of the housing unit and to rate satisfaction with the housing form using a 10 point Likert-type scale. The same scale was also used to determine the extent to which housing construction professionals' services were utilized in construction of the house.

All earth sheltered housing in the study was elevational in plan and all but one example were chambered. Soil coverage varied from 40% on each of two walls and 10% on a third wall to total coverage on three walls and the roof. The housing units were built between 1966 and 1986, using a variety of methods and materials. The earth sheltered portion of all structures was either cast-in-place concrete, concrete block, or field stone; however, the structures also included wood frame construction. The floor was, in all cases, cast-in-place concrete.

Fifty percent of the dwellings in the study were insulated in the earth sheltered area (a) internally using glass fiber, extruded polystyrene, or cellulose within the wall cavity, or (b) externally using extruded polystyrene placed between the exterior of the structure and the surrounding soil.

Drainage tile, swales, and plastic sheeting were often used in conjunction with a damp-proofing or waterproofing coating applied to the earth sheltered portion of the exterior of the structure. The use of tile, swales, and sheeting appeared to have little effect on resident satisfaction; however, high satisfaction resulted when built-up asphalt or pitch was applied to the exterior of the structure in conjunction with the above materials. High satisfaction with the performance of this type of waterproofing material/system was reported for 16 of the 19 households responding to this question. Built-up asphalt or pitch is not generally recommended for use below grade because of its poor ability to reseal cracks at below grade temperatures, but it was found to be the most frequently used waterproofing material for earth sheltered structures in this study.

Primary heating systems consisted of electric radiant heat or central systems powered by electricity, oil, or natural or bottled gas. Most supplemental heat was provided by wood stoves, although a gas stove, an electric space heater, and two wood burning fireplaces were also utilized. A solar sunspace was included in the heating system of three dwellings. A hot water circulation system within portions of the floor and walls for heating, and cooling tubes for cooling, were also utilized in one structure. Eighteen respondents (86%) reported high satisfaction with heating and cooling expenses.

Satisfaction with heating and cooling expenses and satisfaction with the interior surface temperature were the variables which were most determinant in overall satisfaction with the earth sheltered house. Conversely, these variables were much less important in explaining variance in the total satisfaction score (TSS) obtained by summing ratings on individual aspects of satisfaction with earth sheltered housing. Satisfaction with lack of mildew, natural lighting, and lack of condensation on windows were the most significant determinants of the TSS. Perhaps the residents experienced dissatisfaction with particular aspects of the earth sheltered house, but were still willing to give the houses high overall satisfaction ratings.

Resident satisfaction with the ventilation of the house was not significantly different regardless of whether or not ventilation devices were utilized. Although 15 respondents (71%) did not use a dehumidifier, high satisfaction with lack of mildew was reported by this group. Mildew was found in some houses; however, proper building methods, such as waterproofing and surface drainage provisions, appear to be the best way to avoid costly correction of water and moisture problems.

Financing earth sheltered housing was not a problem in the present study as has sometimes been reported in the literature. Twelve respondents (57%) obtained loans to finance the earth sheltered house, and most reported no difficulty in doing so.

Obtaining information on the construction of earth sheltered housing was reported to be difficult by 8 of the respondents answering this question. Sources of information utilized included literature, equipment leasers, concrete companies, other earth sheltered house owners, and, most frequently, family and friends. The latter source seemed to encourage the utilzation of basement construction technology in building the earth sheltered house. In some instances this met the needs of the occupants. In other instances, problems with the site itself, such as poor drainage, or problems with design specific to earth sheltered housing, such as window placement for natural lighting, could have been corrected or at least reduced, by having knowledge of materials, their performance, and careful planning before construction began. Based on these results, there is a need for information on earth sheltered housing which is readily available and understood by the owner/builder.

The reason cited most often for building the earth sheltered house was energy conservation. Since most residents (86%) were satisfied with heating and cooling expenses and two-thirds (67%) were completely satisfied with the interior surface temperature, energy conservation was, apparently, a realistic expectation. Low cost was the second most frequently given reason for building an earth sheltered house. The initial cost of the structure, in 43% of the cases, was the same as expected. However, the initial cost of the earth sheltered house was not included in this study. The initial cost of the structure may have been reduced by the owner/builder acting as contractor since all the original owners surveyed acted as their own contractors. Professional help hired most frequently in the construction of the dwelling was for soil testing and subcontracting.

The earth sheltered house residents included in this study were demographically diverse. Although most were married and slightly more than half were lower middle social class with one to three children at home, the ages, educational levels, and income varied.

Conclusions

The Warren County, Kentucky earth sheltered house providing residents with high satisfaction was generally a chambered elevational structure which had cast-in-place concrete walls at the earth contact points with an exposed wood frame roof and concrete floor. Amounts of soil coverage on the exterior varied as did the use of insulation below grade. The placement of insulation inside or outside the exterior wall, depended on the insulation material and the design of the structure, although insulation was not always utilized in the earth sheltered house. Waterproofing systems generally included drainage tile, swale(s), plastic sheeting, and a built-up asphalt or pitch coating applied to the exterior walls. The most common reasons for choosing this housing alternative were energy conservation and low cost. A wood stove and central heating system were generally used to provide heat for the house. Most residents also used air conditioning to cool the interior in the summer, although a window air conditioning unit often cooled the entire house adequately. Ventilation was not a concern and dehumidification was seldom a problem for the resident.

Most owner/builders reported no difficulty with financing and planning the earth sheltered house. Information was most often obtained from family and friends. All owner/builders served as their own contractors, but most hired professionals for such tasks as soil testing and subcontracting. Resident satisfaction was high for most aspects of the earth sheltered house included in the study. All residents reported high overall satisfaction with the earth sheltered house and reported high satisfaction with most of the housing systems investigated in the present study.

Recommendations

Cast-in-place concrete appears to be a better material than concrete masonry units for the exterior walls of the earth sheltered house since it was less likely to develop cracks. A good waterproofing system must be provided. Each housing site requires a unique waterproofing system, but the system must include provision for surface water drainage and subsurface water drainage. Swales and drainage tile may provide the necessary drainage for these functions, respectively. A skin or coating on the exterior of the structure itself, such as built-up asphalt or pitch, protected the interior from ground moisture and water. Plastic sheeting functioned well to divert underground water from the structure.

Extruded polystyrene insulation placed on the exterior of the earth sheltered house received slightly higher ratings for satisfaction with heating and cooling expenses than did glass fiber batts placed within the structure; although both were highly satisfactory methods of insulation. Residents, who did not utilize insulation in their earth sheltered houses, also reported high satisfaction with heating and cooling expenses. Perhaps insulation in earth sheltered housing is not of major importance in a temperate climate.

Since all new earth sheltered houses in the study were constructed by the owner/builder, information easily understood by this group should be made available. Knowledge of proper building techniques and materials for this housing alternative could improve resident satisfaction by eliminating potential problems.

Mildew was reported by eight respondents, generally occurring in a windowless, earth sheltered corner room of the house. The researcher was not able to determine why some earth sheltered houses tended to support the growth of mildew while others did not. Perhaps interior ventilation to the exterior, as well as within the structure, in addition to adequate waterproofing and insulation would alleviate the problem. Further research in this area is recommended.

Research should be conducted to explain why a high overall satisfaction rating was given by some residents, even though certain aspects of the earth sheltered house were undesirable, such as water leakage and mildew, and obviously affected the quality of living conditions. Perhaps the resident accepted some problems because the house was owner-built or because less quality was expected from this housing alternative.

Satisfaction of earth sheltered housing residents in other geographic areas should be investigated since the present study was limited to one county in Southcentral Kentucky.

APPENDICES

Appendix A

SURVEY OF EARTH SHELTERED HOUSING RESIDENTS

Western Kentucky University

Col. #

01, 02 _____ Respondent number

Name:

Address:

I. DESCRIPTION OF THE EARTH SHELTERED HOUSE

A. Building type:

03 _____ 1. Section: 1) chamber 2) berm

04 _____ 2. Plan: 1) elevational

2) penetrational 3) atrium

B. Soil coverage for each wall: give estimated percentage.

05, 06, 07 _____ 1. South wall

08, 09, 10 _____ 2. West wall

11, 12, 13 _____ 3. North wall

14, 15, 16 _____ 4. East wall

17, 18 _____ 5. Estimated average soil depth on roof in inches

19, 20 _____ 6. Year built: 19__

II. CONSTRUCTION OF HOUSING UNIT

A. Skeletal material: 1) wood frame 2) cast-in-place concrete 3) concrete masonry units 4) steel frame

5) prestressed concrete panels 6) other ____________________________ 7)don't know

21 ____ 1. South wall

22 ____ 2. West wall

23 ____ 3. North wall

24 _____ 4. East wall

25 ____ 5. Roof material

26 _____ 6. Floor material

B. Insulation:

27 _____ 1. Type: 1) none 2) rigid foam 3) foamed-in-place 4) loose fill 5) batt 6) other ____________________

28 _____ 2. Placement: 1) outside structure 2) inside structure

29 _____ 3. Material: 1) glass fiber 2) extruded polystyrene 3) expanded polystyrene 4) polyurethane 5) cellulose 6) other _______________________ 7) don't know

C. Waterproofing:

1. Methods:

30 ____ a. Drainage tile: 1) yes 2) no 3) don't know

31 _____ b. Swale(s): 1) yes 2) no 3) don't know

32 _____ c. Plastic sheeting: 1) yes 2) no 3) don't know

33 _____ d. Sump pump: 1) yes 2) no
3) don't know

34 _____ 2. Materials: 1) latex emulsion

35 _____ 2) cement parging 3) built-up asphalt

36 _____ or pitch 4) liquid elastomers
5)modified bitumens (rubberized
asphalt) 6) vulcanates (butyl, EPDM,
neoprene, hypalon) 7) bentonite clay
products 8) other _______________

D. Heating system: match fuel source with mechanical system used.

1. Primary: 1) electric 2) natural gas
3) bottled gas 4) wood 5) coal
6) other _______________________

37 ____ a. Central forced air

38 _____ b. Radiant heat

2. Supplemental: 1) electric 2) natural
gas 3) bottled gas 4) wood 5) coal
6) kerosene 7) other _____________

39 _____ a. Space heater

40 ____ b. Stove

41 ____ c. Fireplace

42 _____ 3. Solar: 1) none 2) sunspace
3) greenhouse 4) water wall
5) trombe wall 6) other___________

43 _____ E. Earth cooling techniques: 1) none 2) cooling tube 3) reduced insulation at lower depths 4) other ________________

F. Ventilation:

1. Exhaust fan(s):

44 _____ a. kitchen: 1) yes 2) no

45 ___ b. bath: 1) yes 2) no

46 _____ 2. Circulation fans: 1) yes 2) no

47 _____ 3. Central/portable air cleaning device: 1) yes 2) no

48 _____ 4. Air-to-air heat exchanger: 1) yes 2) no

49 _____ 5. Greater than standard 8 ft ceiling height

50 _____ 6. Other (indicate air cond. below)

G. Dehumidification:

51 ____ 1. Dehumidifier in central heating system 1) yes 2) no

52 _____ 2. Portable dehumidifier: 1) yes 2) no

53 _____ 3. Central air conditioning: 1) yes 2) no

54 _____ 4. Window air conditioning unit: 1)yes 2) no

55 _____ 5. Other ______________________________

III. FINANCING AND PLANNING THE EARTH SHELTERED HOUSE

56 _____ A. If you obtained a loan to finance the house, what was the source of the loan? ______________________________

57 ____ B. Did the fact that it was an earth sheltered house make it difficult to obtain a loan? 1) yes 2) no 3) don't know

58 _____ C. Did you alter your building plans? 1) no 2) yes, due to building codes 3) yes, to qualify for loan 4) don't know, describe: ____________________

59 _____ D. As you were planning the house, was it difficult to obtain information on earth sheltered housing? 1)yes 2)no 3) don't know

60 _____ E. Where was the information found? 1) books 2) magazines 3) utility company 4) cooperative extension service 5) family/friend 6) building supply center 7) other______________

61 ____ F. What is the most important reason you built an earth sheltered house? 1) energy conservation 2) low cost 3) environmental ecology

4) aesthetics 5) protection from weather 6) other ____________________

G. On a scale of 1 to 10, how much professional help did you receive in the following categories?

1	2	3	4	5	6	7	8	9	10
None									A lot

62, 63 ___ 1. Soil testing

64, 65 _____ 2. Engineering

66, 67 _____ 3. Contracting

68, 69 _____ 4. Sub-contracting

70, 71 _____ 5. Architect

72, 73 _____ 6. Landscaping for proper drainage

74 _____H. Was the initial total cost of the house: 1) higher than expected 2) lower than expected 3) same as expected 4) don't know

IV. SATISFACTION OF RESIDENT

In the next part of the survey you will be asked to rate resident satisfaction regarding features of the earth sheltered house. A 10 point Likert-type scale will be used to rate the features from 1 (low) to 10 (high).

1 2 3 4 5 6 7 8 9 10
Low High

75, 76 _____ A. How satisfied are you with the natural lighting of the house?

77, 78 _____ B. How satisfied are you with the exterior appearance of the house?

79, 80 _____ C. How satisfied are you with the performance of the waterproofing material/system?

81, 82 _____ D. How satisfied are you with the ability to ventilate the house?

83, 84 _____ E. How satisfied are you with the heating/cooling expenses?

85, 86 _____ F. How satisfied are you with the interior surface temperature?

87, 88 _____ G. How satisfied are you with the lack of condensation (sweating) on walls?

89, 90 _____ H. How satisfied are you with the lack of condensation (sweating) on windows?

91, 92 _____ I. How satisfied are you with the lack of mildew in the house?

93, 94 _____ J. How satisfied are you with the professional help received?

95, 96 _____ K. Which rating would you give for overall satisfaction with the earth sheltered house?

97, 98 _____ L. Were any of the following construction components unsatisfactory? If so, describe briefly.

99 ______ 1. Skeletal material: 1) yes 2)no

100 ______ 2. Insulation: 1) yes 2) no

101 ______ 3. Waterproofing: 1) yes 2) no

102 ______ 4. Heating system: 1) yes 2) no

103 ______ 5. Earth cooling tech.: 1) yes 2)no

104 ______ 6. Ventilation: 1) yes 2) no

105 ______ 7. Dehumidification: 1) yes 2)no

106 ______ 8. Other ________________________________

M. List aspects with which you are satisfied and/or would recommend to other earth sheltered house builders.

107 ______ 1. Skeletal material

108 ______ 2. Insulation

109 ______ 3. Waterproofing

110 ____ 4. Heating system

111 ______ 5. Earth cooling techniques

112 ______ 6. Ventilation

113 ______ 7. Dehumidification

114 ______ 8. Other ________________________________

V. DEMOGRAPHICS

115 _____ A. Sex of respondent: 1) male 2) female

116, 117 ______ B. Age of respondent

118 ______ C. Marital status: 1) single, never

married 2) single, divorced

3) married 4) widowed

119 _____ D. Number of children living at home

120 _____ E. Occupation of male head of household

121 _____ F. Occupation of female head of household

122 _____ G. Number of houses previously owned

123 _____ H. Education (How far did you go in school?):

1) graduate school

2) graduated from 4 year college

3) some college/vocational school

4) graduated high school

5) grade 10-11 6) grade 7-9

7) grade 6 or less

124 _____ I. Which of the categories shown on the chart would best fit your approximate annual household income from all sources? 1) under 10,000

2) 10,000-15,000

3) 16,000-20,000

4) 21,000-25,000

5) 26,000-30,000

6) 31,000-35,000

7) 36,000-40,000

8) 41,000-45,000

9) 46,000-50,000

10) over 50,000

Appendix B

Western Kentucky University
Bowling Green, Kentucky 42101

August 21, 1987

Hello,

I am a graduate student in Housing and Interior Design at Western Kentucky University. I am interested in earth sheltered housing, especially the construction of the house and the satisfaction of the residents.

I would like to ask you some questions about your house. Your responses will be analyzed only in group data to assure confidentiality. If you would like, a copy of the results of the study will be available to you after the study is complete. A summary of the major findings will also be given to the president of the Bowling Green Home Builders Association so that others interested in earth sheltered houses will benefit from the information.

If this is an inconvenient time to interview, I will be glad to arrange a meeting at a later date. Thank you for your help.

Sincerely,

Peggy Wallace

Peggy Wallace

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CORRECTION

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PRECEDING IMAGE HAS BEEN REFILMED TO ASSURE LEGIBILITY OR TO CORRECT A POSSIBLE ERROR

B10, F9