1994

Greenhouse grows in Missoula| Urban sustainable living in theory and practice

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A GREENHOUSE GROWS IN MISSOULA: URBAN SUSTAINABLE LIVING IN THEORY AND PRACTICE

by

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B. A., Alfred University, 1986

Presented in partial fulfillment of the requirements
for the degree of
Master of Science in Environmental Studies

University of Montana

1994

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December 29, 1994
Date

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INTRODUCTION

In this paper I explore the area where ideas and ideals meet actual situations. I document the construction of a straw-bale solar greenhouse on the site of the Missoula Urban Demonstration Project. The greenhouse project was a particular, tangible response to the large and murky problem of human degradation of the natural environment. By documenting the process in which broad guiding ideas were manifest in very specific actions, I hope to demonstrate the possibility that consciously taken action, even at relatively mundane levels, brings large and murky problems into better focus and guides us toward their resolution.

Chapter One outlines the broad problem that prompted the project by examining the ecologically harmful nature of U.S. urban development and suggests the notion of sustainable urban living as a reasonable response. Chapter Two discusses the structure and guiding ideas of the Missoula Urban Demonstration (M.U.D.) Project, an organization formed to allow experimentation with techniques in sustainable urban living in Missoula, Montana. Chapter Three details the rationale behind the straw-bale greenhouse project built at the M.U.D. Project site, showing how the ideas guiding M.U.D. and sustainable urban living were manifest in the methods and materials employed in this experiment and model. Chapter Four describes the nature and history of the institutional barriers to the greenhouse project and how they were surmounted. Chapter Five is an account of the day-by-day process of the construction of the building by amateurs, with notes on what lessons were derived during this process. Chapter Six assesses the results of the project, evaluating the degree to which the project met the goals set for it, and suggesting criteria for assessing the performance of the finished building.

CHAPTER ONE - WHAT'S A GREEN CITY? (AND WHAT ISN'T?)

CITIES ON SHAKY GROUND: HOW URBAN AREAS ARE JEOPARDIZING THEIR OWN FUTURE (AND EVERYBODY ELSE'S)

Like most people in the U.S., I learned in a public school social studies class that "America is becoming a nation of city dwellers". In 1950, I heard, two-thirds of North Americans lived in cities and towns with more than 25,000 people. By 1986, the proportion had increased to 75%.[1] While these figures accurately reflect U.S. demographics, my school lessons ignored the larger implications of such a state of affairs. This blind spot (not unique to my school) is interesting, because from a practical perspective, the idea of a "nation of city dwellers" presents obvious and striking problems.

The way our cities now work is a good primer of these problems. Diminishing numbers of people remain in the rural areas that these cities depend upon for the raw materials of their existence. Urban centers rely on distant sources of food, water, energy and materials to survive, and these sources are shrinking. As cities make ever-increasing demands on the country for support, the health of rural lands begins to suffer. Cities dry up lakes and rivers to quench their thirst. The chemical-intensive, high-production agriculture used to feed the dependent people in the cities depletes

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[1]Peter Berg, Beryl Magilavy and Seth Zuckerman, A Green City Program for San Francisco Bay Area Cities and Towns ((San Francisco: Planet Drum Books, 1989), p. xii.

soils and pollutes waterways. Urban economies demand the mining of the plains and the mountains for wood, minerals and fossil fuels.

Like any human settlement, cities are part of a biological system. They occupy a place in the web of natural energy flows that characterize the systems of life on this planet. Biological systems on earth consist of constantly cycling matter and energy. Any imbalance in these cycles cannot continue indefinitely. A component of the energy web that draws matter and energy out of another part of the system without recycling any back will damage the health of the entire system.

We support urban centers in a manner that's out of balance with the natural systems that cities ultimately rely upon. While urban areas are utterly dependent on rural areas for survival, the nature of their dependence is damaging the rural areas' ability to continue supporting cities over the long term. The burden that cities are placing on the natural systems that they are part of will eventually make these systems incapable of supporting them. Cities are on a downward spiral as they make ever-increasing demands on outlying lands that have an ever-diminishing ability to meet them.

To get off of this downward spiral, we need to find ways to support our cities that don't jeopardize future generations' ability to do so; a way that is sustainable for an indefinite time. We need cities for human habitation, for the rural and wilderness lands would disappear if all city dwellers dispersed into them. But cities need to become ecologically healthy and stable living places. We need to find ways for our cities to become integrated into the web of life, to "begin building a dwelling in life instead of on top of it."[2] Urban dwellers need to find ways to provide some of their own basic needs - food, water, energy and materials - without relying on a constant input of matter and energy from other places. We need urban areas that are regenerative instead of parasitic.

BROTHER, CAN YOU PARADIGM? THE CULTURE OF ECONOMICS

Our cities aren't sustainable because of the dominant cultural view that modern western civilization "has emancipated itself from dependence on nature."[3] A money-dominated notion of reality pervades in our political, social and technological paradigms. The prevailing ethic of economics relentlessly favors short-term monetary gain over the long-term stability and sustainability of natural and human communities. Classical economic theory posits that production and prices are determined by the choices of consumers and producers who act "in accord with some timeless human nature" that maximizes utility and profit.[4] This theory of consistent economic behavior justifies the classical economic proposition that social benefit is maximized by a "natural" result of

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[2]Peter Berg, Figures of Regulation: Guides for Re-Balancing Society with the Biosphere (San Francisco: Planet Drum Foundation, 1982), p.3.
[3]E. F. Schumacher, Small is Beautiful: Economics as if People Mattered (New York: Harper & Row, 1973), p. 97.
[4]George Tukel, Toward a Bioregional Model: Clearing Ground for Watershed Planning (San Francisco: Planet Drum Foundation, 1982), p. 4.

simple economic choices. The current economic paradigm fails to consider that damage to the biotic systems that support society (and the economy) might eventually be damaging to the social fabric (and the economy).

Classical economics' conclusion about simple economic behavior is the rationale behind our current industrial society - that we must continually and increasingly maximize consumption and profit. Exploitation rather than care is the operating standard. Wealth rather than health is the goal. The economic paradigm places the highest value on the goods produced, not on the humans that produced them. Its emphasis is therefore sub-human; humans and human values are of small importance. John Maynard Keynes, the dominant figure in modern economic theory, was quite conscious of the pernicious nature of his economic paradigm. Keynes claimed to believe in "traditional virtue," that avarice is a vice, that "extraction of usury is a misdemeanor," that "love of money is detestable."[5] However, he also believed that these unsavory vices were necessary to "solve the problem of economics", that is, to reach a point in the (presumably near) future where all of the necessities of human existence would be provided. Once society had reached this point, said Keynes, we could then, and only then, value ends above means and prefer the good to the useful. But until then we must hold onto a value system that Keynes believed was unethical. "For at least another hundred years," he wrote in 1930, "we must pretend to ourselves and to

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[5]John Maynard Keynes, Essays in Persuasion (New York: Harcourt, Brace and Company, 1932), p. 372.

everyone that fair is foul and foul is fair; for foul is useful and fair is not. Avarice and usury must be our gods for a little longer still."[6]

Keynes and his many disciples in the field of economics based the authority of their theories upon claims of scientific objectivity. Because their theories could be stated and manipulated mathematically, they were presented as something akin to natural law, obscuring the ethical assumptions (or lack thereof) underlying them. Critics of Keynesian theory assert that this claim of scientific objectivity is spurious, that although one can state and manipulate the theories mathematically, one must substitute constants for preferences, judgments and decisions.[7]

Given the low status of natural and human communities in the dominant economic paradigm, it's inevitable that preferences, judgments and decisions in economic behavior and policy will tend to harm these communities. The notion of humans as value-free, rational economic beings masks the harmful assumptions and consequences of the prevailing economic ethic. If we are interested in considering the long-term health of the natural systems that support human communities, we must examine the values that underlay our economic, political and technological paradigms.

Since the primary value underlying the present system of urban development is simple economic growth, the development of urban centers is guided mostly by the profits of businesses and

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[6]Keynes, p. 372.

[7]W. H. Hutt, Keynesianism - Retrospect and Prospect: A Critical Restatement of Basic Economic Principles (Chicago: Henry Regnery Company, 1963), p.1.

developers, and by politicized land use issues. The well-being of the community and its citizens, and the health of local ecosystems are considered incidentally, if at all. Since the primary goal is economic growth, humans and natural communities become simply means of production.

In order to bring the issue of the health of the natural and human communities that comprise cities to the forefront, we must distinguish between ends and means to ends. Is production and consumption an end in itself, or merely a means to an end? If production and consumption is an end in itself, the land and the beings on it (including humans) are then means to this end. If production and consumption are a means to an end, what is the end?

Our current paradigm treats production and consumption as ends in themselves, and treats the land and the beings on it as means to this end. The resulting harm that is done to the land and to the people on it is a compelling reason to reconsider our patterns of urban development.

NOW AND FOREVER: A DIFFERENT GOAL FOR URBAN COMMUNITIES

In reconsidering our economic and political paradigm, we should look critically at the assumption that the land and the people and animals on it are merely factors of production - means to an end - and consider the possibility that the land and the beings on it are ends in themselves. It isn't logical for us to treat the natural "resources" (land and beings) of a place in the same manner that we treat other man-made factors of production. These "resources" can't be made by man, and can't be replaced once they are damaged. They should be considered outside the realm of economics, perhaps above the realm of economics.

History tells of entire civilizations that collapsed due to the heedless destruction of the resources that they were based upon. Most traditional teachings recognize the significance of "the generous earth," that it is much more than an economic entity. Questions about the proper use of land are not economic, but metaphysical. Instead of asking how much the land can give us right now, we should ask what kind of relationship must we have with the land in order that it might sustain us over the long run.

A biogeographical framework is a useful tool for thinking about the kind of relationship our cities and communities must have with the land in order to be sustainable. Thinking in terms of the biological "constraints" of a particular place can guide us to different paths of urban development. The criteria for success in such a framework would be, in E.F. Schumacher's words, the production of "health, beauty and permanence" rather than simple economic growth.[8] This way of thinking about the problem would pay attention to "balance points between human needs and the

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[8]Schumacher, p. 19.

requirements of the natural community that ultimately supports us."[9]

A useful concept in this biogeographical framework is the bioregion. A bioregion is a geographical area "known for its distinctive climate, landforms and plant and animal life."[10] Territory is divided by natural rather than human boundaries. The bioregion is " a place defined by life forms, its topography and biota, rather than by human dictates, a region governed by nature, not by legislature."[11] A bioregion is made up of individual ecosystems and watersheds. The word "ecosystem" comes from the Greek "oikos," meaning house or home. Webster's Ninth Collegiate Dictionary defines an ecosystem as a "complex of a community and its environment functioning as an ecological unit in nature." A cluster of ecosystems arranged topographically and climatically comprise a watershed, and groups of watersheds comprise a distinct bioregion.

Bioregions can be seen to be "like chinese boxes, one within another."[12] For example, one can consider a bioregion that we might call the Headwaters, or the Northern Rockies Region. This area has been called the spine of North America because it contains the high-country headwaters of major river systems that drain to the Pacific, the Gulf of Mexico and to Hudson Bay. This bioregion comprises an

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[9]Berg, Figures of Regulation, p. 7.
[10]John Todd, Reinhabiting Cities and Towns: Designing for Sustainability (San Francisco: Planet Drum Foundation, 1981), p.8.
[11]Kirkpatrick Sale, Dwellers in the Land: The Bioregional Vision (San Francisco: Sierra Club Books, 1985), p. 43.
[12]Ibid., p. 56.

enormous land area over five or six states and provinces, but is identifiable by a distinctive array of flora, fauna, climate, and landforms. Within this unit we can identify a smaller and slightly more uniform bioregion that we could call the Clark Fork River Basin. This region in western Montana and northern Idaho comprises one tributary to the Columbia River System. Within this region we can consider a yet smaller and more homogeneous unit we could call the Five Valleys Bioregion, containing the five small watersheds that drain into the Missoula Valley of western Montana.

Bioregions have been characterized as being "easy to recognize, but hard to define."[13] Indeed, while it's easy to recognize a region of distinctive vegetation and climate (the Pacific Northwest, the Clark Fork basin, etc.), it's hard to draw concrete boundaries for these regions or keep them entirely separated. The transition between bioregions is gradual and blurry, and there are multiple levels of biological organization that can be considered at once. However, it isn't necessary to nail down a hard boundary in order to recognize the biological constraints of a region where a city is located. More easily than political boundaries, a bioregion can serve as a terrain in our consciousness, one that we consider ourselves belonging to, and having a responsibility toward.

A bioregional model has as its guiding idea the maintenance of the health and diversity of the biosphere. In this context, for a city to be sustainable, its functions should mimic the biological processes of

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[13]Todd, p. 8.

its region. The functions of the city should tap into existing energy and matter flows. For example, human energy needs should come from the available, renewable energy sources of the region, and should be tapped in such a way that the health of the bioregion is not imperiled. Methods of production should strive to cycle material back into the biosphere instead of turning matter into "waste" that is no longer usable in the biosphere.

The concept of a sustainable urban area has been termed a "green city." The impetus for working to make our cities "green" comes from the recognition that the old economic model for development is inadequate. It treats the production and consumption of goods as the ultimate goal for our society, doing harm to society and the natural systems that support society. If we look at the production and consumption of goods as a means to an end, we can begin to think about the crucial question of what we want our lives, and the life of our society, to be. We can strive for a "green" city not merely as a survival strategy, but in recognition that cities must be conducive to "a becoming existence." Defining what it is that makes for a becoming existence is the proper goal of a healthy society.

CHAPTER TWO - APPLYING THEORY - THE MISSOULA URBAN DEMONSTRATION PROJECT

We need to think about the problem of sustaining cities in new ways, but thinking alone will not begin to move us in new directions. At some point, we must act. To move toward a green city, we need to try out our ideas and stay committed to them.

Some of the impetus for acting on these ideas comes from a momentum that builds from the act of thinking about a problem. Wendell Berry referred to this condition as "being responsible for what one knows."[14] Once one has thought through these issues, one is no longer comfortable continuing along in ways that one knows are harmful. Responsibility for what one knows can provide the energy needed to undertake necessary action. The health of individuals and of communities is enhanced when people take on this responsibility.

Applying concepts of urban sustainability in real situations is also important as a method for sharing the idea of a green city with the community. Concrete applications of green city theory can demonstrate to the community that these concepts can work. The impact of a working model on community consciousness is many times greater than any theoretical discussion. If we believe that green city concepts are valid, we must take on the task of showing

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[14]Preface to Masanubu Fukuoka, The One-Straw Revolution (Emmaus, Penn.: Rodale Press, 1978), p. xi.

our fellow community members that validity, and work toward making the concept a reality.

IDEAS IN MOTION: THE M.U.D. PROJECT

The Missoula Urban Demonstration (M.U.D.) Project is one attempt to apply ideas of self-reliant, sustainable urban living in the real world. The project serves as a site for people to explore projects in urban self-reliant living. An outgrowth of the Down Home Project,[15] the M.U.D. Project was established in 1990 by five individuals interested in trying out ideas in self-reliant, urban sustainable living. The M.U.D. site consists of three contiguous lots on Missoula's Northside, a low-income neighborhood located between Interstate 90 and the Northern Pacific railroad switching yard. The site contains two small residences and several utility buildings, as well as a small solar greenhouse. The rest of the site is mostly given over to garden space. M.U.D. residents are considered project staff, and are responsible for maintaining the activities of the Project.

M.U.D. runs the Northside Community Gardens nearby, which provides about thirty garden plots to individuals and families who

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[15]The Down Home Project was incorporated as a non-profit organization in 1982, with the mission of fostering self-reliant living skills in Missoula. Its activities were based at the Phillips Street Properties now occupied by the M.U.D. Project. Some of the original people started Garden city Seeds on the property, an enterprise which outgrew the limited space there. The seed company and the Down Home Project moved to the Bitterroot Valley to continue their work, leaving the Northside properties available to a new group of people interested in self-reliant and sustainable urban living. The M.U.D. Project is currently a subsidiary of the Down Home Project.

lack space to garden. M.U.D. staff also use the Community Gardens to grow food for the local food bank and for the Poverello Center - an emergency shelter and soup kitchen. The Gardens include a wheelchair-accessible gardening bed, which M.U.D. builds for others upon request. M.U.D. staff run the Gardening Program, which provides seeds, tools, skills workshops, and, if necessary, garden space at the Community Gardens to people with limited incomes. The Head Start Program gives preschool kids a chance to learn about gardening at a plot reserved for them at the Community Gardens. The staff conducts weekly classes during the spring and fall. M.U.D. conducts school outreach programs for local schools and youth organizations, exploring self-reliance and urban sustainable living topics with kids both in the classroom and on field trips to the M.U.D. site. The Project also sponsors open-to-the-public workshops on topics related to urban sustainable, self-reliant living.

On-site demonstrations are an ongoing part of the M.U.D. Project. The M.U.D. site's organic vegetable, fruit, and herb gardens date back to the Down Home Project days in the early 1980's. Other ongoing demonstration projects include a small solar greenhouse and the use of other solar power technologies, native plant landscaping, low-cost, energy-efficient home improvement, and bicycle carts for transportation and hauling.

At M.U.D., self-reliance and sustainable urban living go together. As citizens of Missoula become more self-reliant, they begin to disengage from the systems of urban support that are harmful to the natural systems of the region. For example, as a community gardener develops the ability to provide some of his own food, he becomes less dependent on centralized corporate agriculture (with its attendant environmental and social costs) and perhaps becomes less dependent on government agencies to assist him.

HERE AND NOW: GUIDING IDEAS FOR SUSTAINING PEOPLE AND PLACES

Inherent in the mission of demonstration projects at the M.U.D. Project are the goals of involving people in the natural systems that they are part of, and empowering urban dwellers economically, politically, and personally.

.Putting People in Their Place

Since M.U.D. seeks to involve residents of Missoula in the natural systems of their particular place, the projects are small-scale and site specific. These projects strive to pay attention to the biological constraints of the urban ecosystem of Missoula. While many of the general concepts can be applied to other bioregions, staff conceive projects with the idea of tailoring them to the conditions they find in Missoula. M.U.D. Project people concern themselves with the relationship of themselves and those in the community to the environment and the forces at work in it. Attempting to understand this relationship necessitates proceeding from a specific piece of ground.

The nature of the M.U.D. Project dictates that the projects be on a small scale. To involve themselves and others in the urban ecosystem, M.U.D. Project staff takes on projects on a scale that is small enough to be understandable to non-experts, and can be tackled without a large amount of capital and specialized skill or equipment. Small-scale projects thus are less intimidating prospects, which has an encouraging effect on the staff and on others who might be interested. A project undertaken at M.U.D. doesn't attempt to tackle the entire problem of urban sustainability, but is undertaken in the belief that single projects, though modest in impact, can have a cumulative effect.

Power Where You Need It

In your pocketbook

In economic terms, the M.U.D. Project demonstrates how the urban household can be a center of production as well as a center of consumption. The dominant economic paradigm views a household only as a center of demand for products and services. Householders must generate a large cash income to maintain such a situation. For the median U.S. worker, there has been no increase in constant dollar take-home pay since the late 1960's, and real incomes are dropping for Americans in the bottom fifth of the income distribution.[16] A continuously increasing amount of human time and energy is devoted to generating the cash to maintain wasteful habits. By showing alternatives to these habits (energy saving, providing for some of one's needs), projects at M.U.D. can show how urbanites can begin to get free from the economic treadmill of wage dependence. They can demonstrate that much wealth is not connected to money, and that frugality can translate into independence and power.

In your neighborhood

Related to the notion of the household as merely a center of consumption is the householder's condition of dependence on so-called experts and specialists to manage the complex centralized technologies that support her urban home. Radical architect Ken Kern termed this "a sub-human condition of dependence and ineptitude."[17] Dependence and ineptitude do not make for citizens who can form and maintain strong local communities. Most urban centers are at the mercy of large, centralized government agencies and corporations to provide for most of their needs. By encouraging increased self-reliance on the part of urban residents, the M.U.D. Project hopes to foster a stronger, more autonomous local community. This political empowerment can make it more possible

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[16]Paul Krugman, The Age of Diminished Expectations: U.S. Economic Policy in the 1990's (Cambridge, Mass.: M.I.T. Press, 1990), p. 1.
[17]Ken Kern, The Owner-Builder and the Code: Politics of Building Your Home (Oakhurst, Ca.: Owner-Builder Productions, 1976), p. 172.

for the interests of the human and natural communities of a particular place to be served.

In your own head

Urban dwellers' economic and political empowerment can also become a personal empowerment. Our current notion of work is responsible for much personal unhappiness. Western economics views work as a necessary evil. A person performs labor in order to obtain the money necessary to purchase the staples and luxuries of her existence. In our highly specialized, high-technology economy, most of this "labor" involves performing a small task within a very large structure. Quite often, it is difficult for the laborer to perceive meaning in this isolated task-performing. In a literal sense, this laborer is a cog in a machine, whose motivation for continuing to perform is his utter dependence on a cash income to survive. Since we spend the majority of our waking hours working, many people become despondent that they are spending their lives at work that lacks a sense of worthiness and meaning. The only solace that seems to be available is escape in consumption - of food, drugs, entertainment, and material possessions.

A different notion of work could ease the personal toll that many people's work takes on them. E.F. Schumacher outlined such a notion in his essay on Buddhist economics.[18] Schumacher saw that the Buddhist's idea of the function of labor was positive rather than

[18]Schumacher, pp. 50-58.

negative. Instead of laboring meaninglessly to pick up a paycheck, one can strive to create an economy in which labor enhances people's lives. Schumacher outlined three life-enhancing functions of labor in a Buddhist economy.

First, labor is a chance for an individual to develop and utilize her abilities. The human mind and body is capable of many and varied tasks. The stunting of the impulse to utilize these capabilities inherent in highly specialized Western "labor" is life-stunting. Taking on the task of urban self-reliance requires an individual to utilize her mind and body creatively, tackling problems that fall into many different areas of knowledge. M.U.D. hopes to put the knowledge of many so-called experts into the hands of "average" people, and enhance their experience of labor.

Second, Buddhist economics sees labor as enabling an individual to overcome ego-centeredness by joining with others at a common task. Most of the work of any society requires the labor of many people working in some kind of coordination. The specialization of Western-style labor is one kind of coordination, but it is a coordination that keeps the individuals involved disconnected from each other. It is difficult for such an individual to have a sense of a common goal with the greater society. The resulting sense of isolation is unhealthy for the individual and the society. In small-scale, site-specific projects, specialization is minimized, enabling an individual to become involved in a cooperative labor that connects him to goals outside his narrow self-interest. Putting his labor toward a tangible goal in common with others in his community can ease the sense of isolation that is common to many urban-dwellers. By serving as a medium where small-scale community projects can develop, M.U.D. can draw people into such cooperative labor, empowering the urban community as well as the urban individual.

The third Buddhist view of labor is as a means of providing individuals and the community with the goods and services that are needed for "a becoming existence." As noted in Chapter One, the Western economic paradigm treats the production and consumption of goods as the goal of society, the end that we are striving for. I have suggested that we might think of the production and consumption of goods as simply a means to an end, and that defining the "end", or the ultimate goal of the society, was the proper task of a healthy society. The task is no less than to answer the question "What is the best way to live?", and it must be answered first by individuals in the society.

One of the reasons that modern workers find their work so lacking in meaning is that nothing about the isolated, specialized task that they perform seems connected to any ultimate purpose for their lives. The worker only has the vague assurance that her contribution of labor is furthering the goal of ever-increasing production, and that her reward will be ever-increasing consumption. Many people find that ever-increasing consumption is unsatisfying as a meaning for their existence. If, however, this worker has begun to answer for herself the question of what makes for a "becoming existence," and can see her labor as contributing to the fulfillment of that goal, her labor will be invested with meaning and fulfillment. Rather than being a chore to be endured, her labor will become a part and parcel of her life's goals.

If we look at the production of goods and services as a means to a larger end, than we see that we need not strive always and forever to increase our production and consumption. The path to "the good life" doesn't involve constant consumption, but merely the provision of goods and services that allow us to pursue a deeper notion of "the good life." The fact that this involves a much lower rate of production and consumption has profound implications for the sustainability of cities, and also for the individuals who live in the cities. If people's labor serves a larger purpose in their life, the activity that consumes much of their waking existence will be a source of sustenance instead of a source of anguish for them. This alone can be a big step toward a good life.

The nature of projects and activities at M.U.D. can personally empower the inhabitants of Missoula. By re-focusing the question of what the purpose of labor is, M.U.D. hopes to help those involved bring their efforts more in line with their goals and values. M.U.D. projects and activities can demonstrate the ways in which labor expended in the service of personal goals and values contributes to personal well-being and power. A community of such empowered people is well equipped to tackle the question of what constitutes a becoming existence for its citizens.

CHAPTER THREE - AN EXPERIMENT AND A MODEL - THE M.U.D. SOLAR GREENHOUSE

Much of M.U.D.'s work focuses on ways that people of limited means can provide food for themselves, their families, and the larger community. Small-scale intensive organic gardening has been central to the organizations's vision of urban self-reliance and sustainability. This focus is a recognition that the food system that supports most urban areas is not sustainable over the long run.

TACKLING A SPECIFIC PROBLEM: THE URBAN "FOOD SYSTEM"

Currently our cities are completely dependent on the countryside to feed the increasing urban population. The current economic and technological paradigm dictates that this food be produced by large-scale, capital- and energy-intensive agriculture. In this framework, agriculture is treated as an industrial process, where the only priority is maximizing productivity and profits. In 1930, John Maynard Keynes accurately predicted that the technological revolution that was occurring in heavy industry and vastly increasing productivity "may soon be attacking agriculture. We may be on the verge," he wrote, "of improvements in the efficiency of food production as great as those which have already taken place in mining, manufacture, and transport"[19] In this view,

[19] Keynes, p. 364.

efficiency is the standard. Care and health, of the land and the people on it, don't compute.

A Cycle of Displacement

Industrial agriculture is by definition carried out on a large scale. It achieves high production and low consumer cost by taking advantage of economies of scale familiar to manufacturers of automobiles, computers, and the like. In order to produce food as efficiently as possible, industrial agriculture employs large and expensive machines which "work" large tracts of land. Since this method has the effect of driving crop prices down, a small (perhaps family owned) farm has difficulty staying economically viable. Small operators can't afford to buy the machines which allow them to produce at industrial rates (they often try to do so by carrying enormous debt), yet per-bushel crop income steadily declines. Obeying the instructions popularized by the government agricultural establishment in the 1950's, they must "get big, or get out."[20] This economic situation is a large cause of the population flight from rural to urban areas. Rural people are compelled by the economic paradigm to leave the countryside and become dependent upon the urban food system that has driven them off the land. Here we have a feedback loop in which industrial agriculture becomes self-justifying. Apologists for the status quo argue that the social costs of crowding

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[20]Wendell Berry, The Unsettling of America (San Francisco: Sierra Club Books, 1977), p. 41.

more and more people into cities, which is in large part caused by industrial agriculture, must be borne because industrial agriculture is the only method in which a very few people can feed the many.

Mining the Land

If social costs were the only problem with industrial agriculture, this line of argument would be stronger. But the argument assumes that the land can be "worked" industrially forever. There is much evidence that indicates otherwise.

An efficient large-scale agricultural operation must produce the highest yield now for the lowest monetary cost. Doing so requires large machines working large tracts of land planted in a single crop. Crop yields are further increased by the use of pesticides and chemical fertilizers, which accumulate in ground and surface water. Often, pushing the soil to produce a single crop at such high rates causes nutrients to be depleted, which increasingly requires chemical fertilizer to produce at the same rate - a case of diminishing returns. Traditional methods of preventing soil erosion - crop rotation, wind breaks, contour plowing - necessitate keeping certain land out of production at different times, which is not conducive to "efficiency." In Iowa and Missouri, the heart of agricultural production in the U.S., the annual soil loss on average is 35 times the natural replacement rate.[21] Maximum agricultural efficiency also dictates that land in dry

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[21]G. Tyler Miller, Jr., Environmental Science: Sustaining the Earth, Fourth Edition (Belmont, Ca.: Wadsworth Publishing Company, 1993), p. 283.

climates be put into production of crops that historically have been grown only in very wet climates. Growing, for instance, cotton in west Texas is only possible by tapping groundwater aquifers at rates that far exceed replacement rates.

Current trends in industrial agricultural land use point to a coming crisis in which the land will no longer support the use to which it is being put. Boosters of industrial agriculture believe that the soil depletion and erosion, aquifer mining, and water pollution that result from current methods of food production can be solved by as-yet-undiscovered technology. While this is possible, it is a position based not on reason but on faith. In the guise of hard-nosed common sense, such people are advocating a metaphysical faith in our salvation through technology.

The Problem of Energy

Any technological salvation will also have to solve the problem of energy in industrial agriculture. The methods of modern agriculture require inputs of non-renewable energy sources that far exceed the energy value of the food that is produced. On-farm energy requirements include fossil fuels to run the large machinery, and the energy and materials used to produce pesticides and fertilizers. Yet these on-farm energy requirements represent only 18% of the energy consumption of the U.S. food system. Processing and distribution account for 40% of the energy used by the system.[22] The average food molecule is hauled 1300 miles in the U.S. before someone eats it.[23] Food preparation accounts for the remaining 42% of energy consumption in the food system.[24] In the U.S., a little over two calories of energy is invested per calorie of food obtained for all agricultural production. Accounting for agricultural production that is consumed in the U.S. rather than exported, a bit more than three calories of energy is invested per calorie of food obtained. Adding the energy costs of processing, transportation and preparation nets a total energy cost of 9.8 calories of energy invested per calorie of food consumed in the U.S.[25] Since nearly all of these 9.8 calories invested to yield one food calorie are derived from diminishing non-renewable energy sources, it is clear that this form of industrial agriculture has a limited future.

The degradation of the land and of the people on the land that characterizes the food system that supports cities can't continue indefinitely. Aside from its unsustainable patterns of energy consumption, the system is destructive to the health of rural communities and of the land. We who live in cities are dependent on this unhealthy system. If the question of proper land use is

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[22]Amory B. Lovins, L. Hunter Lovins and Marty Bender, "Energy and Agriculture," in Meeting the Expectations of the Land: Essays in Sustainable Agriculture and Stewardship, eds. Wes Jackson, Wendell Berry and Bruce Coleman (San Francisco: North Point Press, 1984), p. 75.
[23]Ibid., p. 68.
[24]Ibid., p. 75.
[25]Ibid., p. 68.

addressed as a question of the type of relationship we should have with the land, then we ought to look at the natural systems of our place for answers. Most relationships in nature are characterized not by dependence but by interdependence. We need to look at ways that can provide us with food that fit into these interdependent relationships without destroying them. We need to have cities that don't need industrial agriculture to feed their inhabitants. We need to look outside the conventional economic framework to begin to move in this direction.

ASKING THE RIGHT QUESTIONS: PUTTING THE NEW FRAMEWORK INTO PRACTICE

The M.U.D. solar greenhouse project was an attempt to approach the problem of urban food supply within the framework of urban sustainability. Since urban areas are destructively dependent on outlying areas for food, we must ask how individuals can produce some of their own food in this specific place.

Keeping in mind the goals of self-reliant, sustainable projects at M.U.D., we wanted any potential solution to be small-scale, to keep it manageable and understandable to non-experts. We didn't try to tackle the entire problem in one step. We wanted to apply general principles of urban sustainability to our specific place. Doing so required us to pay attention to the biological constraints of the Missoula urban ecosystem, and to take advantage of natural energy flows to produce food. We wanted a method that made a minimal demand on so-called natural resources for its execution. The project needed to be low-cost in order to be repeatable by urban dwellers lacking large cash incomes. We wished to demonstrate the possibility of partial disengagement from the dominant economic pattern.

Biological Constraints Point the Way

The easiest, and most common way that urban dwellers produce food for their household is by growing it in gardens. It isn't surprising that the M.U.D. Project spun out of a large urban gardening project. Gardening comes immediately to mind when one thinks in terms of self-reliance in the city.

For human food production, the strongest biological constraint of the Missoula urban ecosystem is the region's short growing season. Generally, the city has only ninety continuous frost free days during the summer months, and many recent seasons have seen considerably fewer. Finding ways to extend this growing season within a framework of urban sustainability would make it easier for Missoula residents to become more self-reliant, and more independent from the food system.

One way to extend Missoula's growing season is through the use of a greenhouse. A greenhouse creates an environment that allows plants to grow in colder months. This structure extends Missoula's growing season by creating a place where seedlings can be started in late winter for later transplanting, and a place where plants can be placed in the fall to protect them from frost. The greenhouse can also be used to grow very warm weather plants throughout the warm months, and to grow cold weather tolerant plants during cold months. People involved with this project at M.U.D. conceived it within the framework of self-reliance and urban sustainability.

A Really Green Greenhouse

Figures cited refer to Appendix A for plan drawings of the M.U.D. greenhouse.

Any greenhouse extends the growing season by providing a hospitable environment for plants to grow. When we speak of a "solar" greenhouse, though, we are speaking of a special kind of structure. All greenhouses are solar - they take advantage of the nature of reflected ultra violet sunlight to trap heat as well as light. A conventional greenhouse is designed to allow the maximum amount of light into the structure, and is usually all-glass (or "glazing," - any translucent material.) Since glazing is an extremely poor insulator, a conventional greenhouse requires a supplemental heat source to keep the temperature from falling too low for plants during cold months. What we call a solar greenhouse is a structure designed specifically to collect and then to store existing solar energy income in such a way that little or no supplemental heat is required.

To avoid the use of fossil energy to grow food plants, the M.U.D. design uses straw and straw bales to create "super-insulated" walls. (Figures A-1, A-3, A-4) Super-insulation makes use of very thick walls to trap large amounts of air. With conventional wood stud wall construction, a super-insulated design has high initial material costs and puts a strain on local wood resources. A double stud wall is twice as thick as a conventional stud wall, and requires much more wood to build. Besides putting more strain on the wood resources of this region, a super-insulated structure costs more to build, making it necessary to have a lot of cash up front to begin realizing energy savings. Taking into account these savings, the life-cycle costs of super insulated designs are lower, but most people cannot afford the initial cost.

Fabricating walls from straw bales yields thick super-insulated walls without requiring a lot of wood and at low cost. Straw is a cheap and locally available resource (in many places, it is a waste product that is hard to dispose of), and the straw fiber is a direct substitute for wood fiber. Substituting straw for wood fiber in more structures in this area would reduce current pressures to log intensively this region's forests. The bales for many structures can be grown in one year in a sustainable production system instead of the 50 to 120 (or 1,000) years required to grow wood fiber.

Straw bale walls have the added advantage of being relatively easy to construct. Building this type of wall isn't difficult for non-experts, so the technology remains accessible to most people. By allowing the "owner" of a structure to also be the "builder", straw walls can make any structure much cheaper. Material costs represent less than 20% of the costs of a wall system, so supplying one's own labor allows an owner-builder to realize large savings.[26]

While straw bale walls can be used by themselves as load-bearing structures, the M.U.D. greenhouse used salvaged lumber and other material as a load-bearing "skeleton," known as a timber frame. (Figures A-1, A-5, A-6) Timber frame construction allows the greenhouse to be designed for optimal solar heat gain. Using a wood frame allows the angles of the south glazing wall to be tilted to more precisely capture the meager winter sunlight. By making use of wood salvaged from old buildings that would normally have become waste, the structure minimized its need for new wood fiber and prevented the wood used from becoming a disposal problem.

This greenhouse has foundation walls that serve as both an anchor for the above-ground super-structure and as thermal mass to aid in heat retention. (Figures A-1, A-2, A-7) These walls were constructed with concrete and the glacial rock that is abundant in the soils of the Missoula valley. Anyone who has dug a garden plot in the valley knows that these rocks are a resulting waste product. Utilizing this material in the greenhouse was intended to further reduce material costs and the need for new materials.

Producing food in one's own greenhouse enhances individual health as well as the health of the urban community and ecosystem.

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[26]David Bainbridge, Plastered Straw-Bale Construction (Canelo, Az.: The Canelo Project, 1992), p. 7.

Vegetables produced in such a greenhouse are cheaper and fresher than those purchased in a typical supermarket. Commercial produce loses flavor and nutritional value during transit and while sitting on the market shelf. Vegetables raised in a backyard greenhouse can be raised to the peak of ripeness for immediate eating. They can also be grown without the use of chemical pesticides and fertilizers, which are found in varying amounts in commercial produce, and which may well have detrimental effects on human health.

AN EXPERIMENT AND A MODEL: ENGAGING THE URBAN COMMUNITY

The M.U.D. greenhouse project was intended to serve as an experiment and a model in urban self-reliant, sustainable technologies. Building this structure within the context of the M.U.D. Project allowed us to try out our notions of urban sustainability, and yielded information as to the feasibility of the ideas embodied in it. The completed structure was intended to serve as a model, demonstrating our ideas in practice to the Missoula community.

Missoula Is Our Laboratory

The experiment that is the M.U.D. greenhouse project served several purposes. It was conceived as an example of the way that we might approach solutions to the large problem of human degradation of the environment, specifically as related to urban settlements. We attacked a specific problem (urban food supply) in a specific place (Missoula) with a proposal addressing a single way in which the problem may be lessened. It is hard to make a city lot into a self-sufficient farm, but we can explore ways to be less dependent on the conventional food system. Thus we attempted to keep the problem within the realm of our ability to understand it while using broad issues (the requirements of the natural systems that support us) as guiding ideas.

The greenhouse experiment allowed us to apply our theoretical understanding in an actual situation. The theories were specific to our particular project and also were more general regarding urban sustainability. Seeing how well the project met the goals set for it (general and specific) gave us information that will be useful in working toward urban self-reliance and sustainability.

Conducting the greenhouse experiment helped to set a precedent in the community that eliminated institutional barriers to unconventional solutions to the problem of making cities more self-reliant. Since our framework for thinking about these problems is different from the economic framework in which most of the institutions were established, some of the solutions we arrive at fall outside of conventions that community institutions are accustomed to working with. These institutions then become barriers to trying out new solutions to our urban problems.

The Missoula city building department deemed straw bale construction "not acceptable" as a building method. This rejection of the technology wasn't based on experience, the technique simply fell outside of convention. Since we wished to promote this technology in the community as a way toward becoming more sustainable, we had to do the necessary bureaucratic wrangling to help to eliminate this barrier for others. For the M.U.D. greenhouse, we obtained the first city building permit for a straw-bale structure. This permit legitimized the straw bale technique in the eyes of the Missoula building department. Our contacts with this institution will help to make the people in it aware of different methods of urban living that are alive in their community.

A Broader Notion of Construction

Conducting the greenhouse experiment helped to involve community members in the natural systems that they are a part of. We wanted the greenhouse to be an integral part of the natural communities of the Missoula urban ecosystem, and we wanted it to be an integral part of the human community. Thus the process of building the greenhouse was as important as the realized structure. The greenhouse could have been constructed completely through conventional industrial building practices. We could have hired a contractor to build the structure using our unconventional building methods. But we wanted this project to entertain a broader notion of construction. We wanted to learn how to build a greenhouse by actually building one, and we wanted to share the learning with others in our community. By making the building process a public forum, we attempted to construct connections to the wider community as well as constructing a simple building.

The project involved numerous Missoula citizens throughout the construction process. We held a public work party to publicize our project, to tap into interest in the issues involved, and to help those interested to develop skills that can help them realize their own vision of urban self-reliance.

A Model From Which to Work

While we were interested in the process of the experiment that created the M.U.D. greenhouse, we were also interested in how the realized structure would serve as an ongoing model of urban self-reliance and sustainability. The existence of the greenhouse in a public setting like M.U.D. demonstrates the ideas embodied in its design. It shows the community the possibilities inherent in thinking within a new framework. It reinforces the ideas of urban sustainability that M.U.D. promotes, and encourages community members to apply these ideas to their own lives. The ideas can be a point of departure for citizens of Missoula to create their versions of a sustainable urban life.

We also publicized the project by producing a short video document for Missoula Community Access Television and other outlets. The video documents the construction of the greenhouse, publicizing the concept of urban greenhouses and urban self-reliance and sustainability, and publicizing the M.U.D. Project's overall mission. We hope that through this publicity we can bring more people in Missoula to the idea of a sustainable community.

RULES OF THUMB: USING GENERAL PATTERNS IN A SPECIFIC PLACE

The M.U.D. solar greenhouse followed basic rules of thumb guiding the design of such structures. All acts of building are based on rules of thumb. Christopher Alexander referred to these rules of thumb as "patterns" in his visionary books on building and design.[27] The patterns have developed through long experience, evolving and changing over time. To be useful to a design process, the patterns must be specific but not too restrictive. All principles involved in a solar greenhouse are simple and logical. One need not be an expert to understand them. However, the nature of a solar greenhouse - one that gathers and retains heat without reliance on supplemental fossil fuel heat - requires more care and thought than a conventional greenhouse in its design and more labor and care in its building. The benefit that we hoped to derive from the extra work involved in designing a solar greenhouse - being involved with design decisions and building tasks - was a greater understanding of the functions of

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[27]Christopher Alexander, The Timeless Way of Building (New York: Oxford University Press, 1979) and Christopher Alexander, et. al., A Pattern Language: Towns, Buildings, Construction (New York: Oxford University Press, 1976).

our greenhouse. We think that this knowledge helped us to maintain and operate the greenhouse more effectively when it was complete.

Solar Greenhouse Principles

The design decisions that we made for our greenhouse were guided by principles of capturing and storing solar radiation (or insolation). The "greenhouse effect" describes the behavior of solar insolation. Insolation is energy that falls on the earth's surface in short waves. Visible light is of a wavelength that falls between very short wave ultra-violet (UV) radiation and long wave infra-red radiation. Glass (or glazing) is transparent to visible light, so this energy passes through it to heat objects behind the glazing. This heat is re-radiated at longer infra-red wavelengths to cooler surrounding areas. The glazing is essentially opaque to infra-red radiation, so the sun's energy is trapped behind the glazing.

A solar greenhouse is sited and oriented in such a way that it most efficiently captures incoming solar radiation.

One must choose a site that has exposure to the south, especially in colder months. Other buildings and coniferous trees that block large amounts of sun from the structure will compromise its heat and light gathering abilities. However, deciduous trees at the southern exposure can be a benefit. Since they lose their leaves in the colder months, they don't greatly compromise the sunlight reaching the greenhouse, but can serve as needed shading during hot months when overheating can be a problem.

The structure must be oriented on the site such that the glazing faces the incoming sunlight most effectively, and that the exposures to the north, and, to a lesser extent, the east and west, consist of well-insulated, opaque walls. To gather sunlight efficiently, the glazing should face something approximating due south.

Other critical design decisions are guided by the goal of storing the captured solar heat as efficiently as possible. Airtight construction, proper insulation, and inclusion of heat storage media are rules of thumb that accomplish this goal.

Greenhouses lose their gathered heat by conduction, radiation, convection, infiltration, and evaporation

Conduction is the direct transfer of heat energy through the greenhouse "skin" to cooler outside air. Energy is passed from one excited molecule to an adjacent one. Insulation slows this process by creating a large amount of "dead" (uncirculating) air space to lessen direct contact between warm air molecules inside and the cooler air molecules outside.

Radiation heat loss occurs as heat transfer by electromagnetic waves from an object of greater temperature to an object of lesser temperature. Greenhouses are susceptible to nocturnal, or clear sky, radiation. Warm earthly bodies lose heat to the sky and to outer space. This occurs most profoundly on clear nights. Clouds are a barrier to radiant heat loss from earth.

Convective heat loss is the transfer of heat by the movement of individual excited molecules in fluids and gases. Most commonly, the circulation of air near the skin of the greenhouse carries away heated molecules, accelerating the process of conduction. Siting the greenhouse out of the direct flow of prevailing local winds helps to slow conductive heat loss.

A greenhouse loses heat through infiltration. Air leaks around glazing, doors, vents or badly constructed joints allows cold drafts to enter the structure and allows warm are to escape. Taking care to build the greenhouse with tight joints, seams, and openings will minimize infiltration.

Evaporation is the conversion of water from a liquid to a vapor. In a greenhouse, solar radiation drives this process, but heat energy is taken up by the vapor. In a closed greenhouse, this heat should largely be contained within the structure. Evaporative heat loss can be effective in cooling a greenhouse during hot months by strategic opening of the structure.

The design of a solar greenhouse should efficiently collect solar energy, should be able to store the collected energy and should prevent its loss during and following the collection periods. Unlike conventional greenhouses, a solar greenhouse minimizes the amount of glazing to allow it to store the heat that is gathered. The less uniform light distribution on the plants can be somewhat made up for by reflecting light off of the inside walls, particularly the north wall.

A solar greenhouse must include heat storage media to store the excess heat. On a sunny day, a greenhouse will collect much more energy than it needs to provide a healthy environment for plants. A heat storage medium absorbs this excess heat, keeping the greenhouse cool on warm, sunny days, and releasing this heat back into the structure at night and on cloudy days. In most solar greenhouses, the heat storage medium is placed so that it absorbs heat by direct radiation. The amount of heat stored depends on the temperature of the surrounding air, and on the color, texture, conductivity, and thermal mass of the material.

Thermal mass of a material is its density times its specific heat. The specific heat of a substance is the amount of energy required to raise the temperature of 1 gram of the substance 1 degree Celsius. A substance with a low specific heat will increase in temperature with a relatively low input of energy, but as a result will not have the capacity to store a large amount of heat for later re-radiation. A substance with a high specific heat will require more energy to raise its temperature, but has a large capacity for heat storage. In the greenhouse we are dealing with relatively large amounts of energy (in the form of solar radiation), so we want a substance with a high density and specific heat to absorb and release larger amounts of energy and thus moderate extremes of temperature.

Common materials that are used as heat storage medium in solar greenhouses are water, masonry, rock, and soil. The masonry, rock and soil are often integral parts of the greenhouse structure.

Dark colored containers filled with water can be placed in strategic locations for additional heat storage capacity. Dark colors reflect less radiation, and therefore absorb more total radiation than light colors. Water has one of the highest specific heats of any common substance, and so makes an excellent heat storage medium.

PATTERNS REALIZED: DESIGN DECISIONS FOR THE M.U.D. GREENHOUSE

Bringing the rules of thumb that guide the design and construction of solar greenhouses to the M.U.D. Project site yields a unique structure. While the M.U.D. greenhouse resembles other solar greenhouses, the demands of the Missoula urban ecosystem and the particular piece of ground we have to work with give the structure its unique form. The characteristics of our chosen place guide design decisions related to siting and orientation, energy storage, and temperature regulation.

Siting and Orientation

A primary design consideration for a solar greenhouse is its siting, or location on the piece of land one has to work with. Facing the glazed wall of the greenhouse to the south is the most basic siting requirement. While a greenhouse facing due south will gather the maximum amount of solar insolation, a structure can be oriented within 15 degrees of south without losing appreciable solar radiation.[28]

The M.U.D. greenhouse is sited between the two primary residences of the site. (Figure 3.1) This gives it a glazing orientation close to due south, and the residences on either side shelter it from prevailing westerly winds, and from episodic arctic Hellgate winds from the east, which are especially severe in this area of Missoula.

The M.U.D. greenhouse site has a good "sun path," - few obstacles obstruct the sun for most of a typical winter day, while two deciduous trees provide shade during summer afternoons.

The sun path is the apparent movement of the sun through the sky as seen from a particular spot. Since the earth's axis is tilted relative to the plane of its orbit around the sun, the northern hemisphere is tilted toward the sun during the summer and away from the sun during the winter. From our point of view, the sun is higher in the sky in the summer and lower in winter. The sun path altitude is the height of the sun in degrees from the true horizon as it moves through the sky during a given day and month. In western Montana, the sun will be 47 degrees higher in the sky at noon on June 22 than on January 22.[29]

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[28]Ron Alward and Andy Shapiro, Low-Cost Solar Greenhouses: A Design and Construction Guide (Butte, Mont.: National Center for Appropriate Technology, 1980), p. 30.

[29]Dale Horton, "Solar Heating Guide for Western Montana," Master's Thesis, Univeristy of Montana, 1978, p. 6.

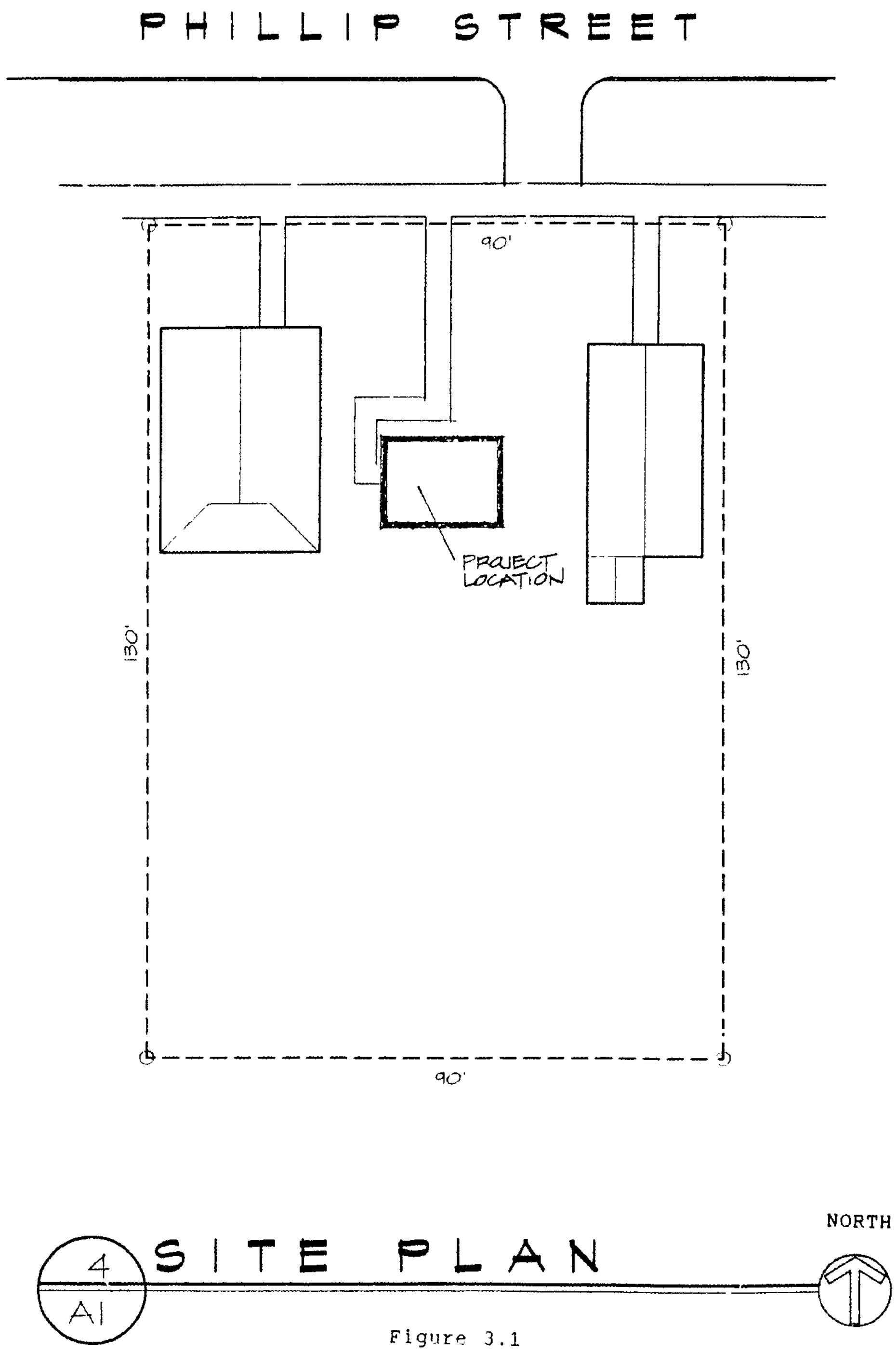

PHILLIP STREET
90'
PROJECT LOCATION
130'
130'
90'
4
A1
SITE PLAN
NORTH

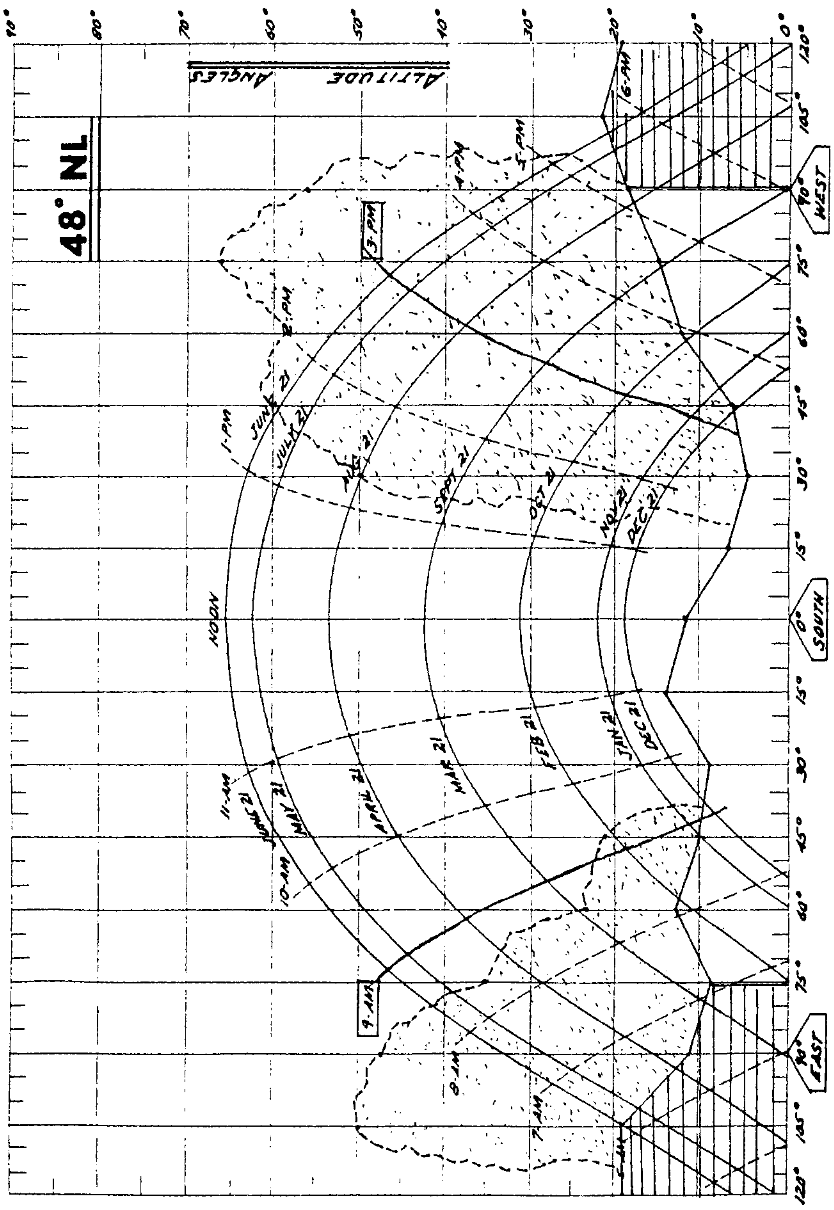
Figure 3.1

Completing a sun path chart for a potential site will show the location of objects that prevent the sun from reaching the greenhouse during certain times of the day and year. Nearby hills, certain trees, and buildings between the sun and the structure will affect the light and heat gathering abilities of a solar greenhouse. We obtained a blank sun path chart for our latitude from a solar greenhouse handbook.[30] The chart shows the sun path for the 21st day of each month for 48 degrees north latitude (the M.U.D. site latitude is approximately 46.5 degrees north). By surveying the proposed site with a compass, we plotted the location of the apparent horizon and the buildings and trees that were located between the sun's path and the glazing of the greenhouse. (Figure 3.2) The chart shows these objects as viewed from the front of the greenhouse. The shaded portions of the chart indicate deciduous trees, and the crosshatched portions indicate buildings. The chart reveals that the two residences don't affect the winter sun exposure to the greenhouse, but shade it in the early morning and late evening in summer. The trees that stand between the structure and the sun shade it in summer during the early morning and for most of the afternoon hours. Without leaves in the cold months, they allow early

[30]Alward, p. 172.

Figure 3.2

Sun Path Chart for M.U.D. Greenhouse Site



spring and late autumn light to reach the greenhouse for most of the day.

The angle of the glazing of the greenhouse is designed to collect the maximum amount of low-angle sunlight in late winter and late fall, and to reflect high-angle summer sun. Aside from the fact that the sun is in the sky for a shorter time in winter, the sun's rays must pass through a greater amount of the earth's atmosphere to reach the surface, due to its low angle. The greater distance the sun must travel through the atmosphere to reach the surface, the less energy is available at the surface, due to reflection off of dust, moisture, and clouds.

For reasons discussed below, we won't attempt to grow in our greenhouse during the months of December, January and February. In Missoula, fall and winter months are often cloudy. In the spring and fall months, western Montana receives about 80 percent of the sunshine received by relatively sunny Denver, Colorado. In January, however, Denver receives more than twice the amount of sunshine as western Montana.[31] Also, the Missoula valley traps low clouds and air pollution, which further reduce the available solar energy. On a cloudy winter day, solar energy is available, but in small amounts. To capture weak late winter rays, the glazing should be perpendicular to the sun's rays during the coldest months of the year. An angle of incidence (the angle at which the sun's rays strike a surface) that is

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[31]Horton, p. 5.

perpendicular (normal) to solar rays allows for the most effective transmission of solar energy.

Since we were not trying to capture these weak winter rays, we concentrated on not having the greenhouse glazing perpendicular to the high summer sun. The glazed south wall of our greenhouse is nearly vertical at about 12 degrees. Having nearly vertical glazing also creates more space inside the structure and eases installation of insulating curtains if we choose to do so in the future.

Energy Storage

Having chosen a site and an orientation that maximizes the greenhouse's ability to collect solar energy, we need to incorporate into the design ways to store the collected energy to maintain a warm environment between collection periods.

To insulate the foundation, we used foam-core door scraps as forms for the concrete foundation walls. Leaving these in place after we poured the wall insulated the subterranean portions of the walls as well as the foot or so of the above-ground foundation.

The superstructure of the greenhouse is designed to be super-insulated and as airtight as possible. Straw-bale side walls and salvaged cellulose fiber for the north-facing roof should provide excellent heat retention, while extra care in constructing the joints and seams of the structure should result in little heat loss to infiltration.

We want to use water in dark containers for added thermal mass, since water stores between three and four times more energy per pound as rocks and masonry.[32] Different solar greenhouse designers recommend slightly different amounts of water for thermal mass, depending on the climate and the intended use for the greenhouse.[33] For a season-extending greenhouse in a cold climate like Missoula's, we'll shoot for a ballpark figure of three gallons of water per square foot of glazing.[34]

This water resides in large black plastic barrels salvaged from a local market. Some are used as supports for planting beds, but most are placed along the back wall of the structure so that they receive direct exposure to sunlight. Heat absorption by direct solar radiation is most effective, but thermal mass that receives indirect radiation is also useful. The containers need to be placed such that air can circulate around them. This allows convection currents to transfer heat from the warm thermal mass to cooler areas of the greenhouse between collection periods. Air space around heat storage medium that is not exposed to direct sunlight is especially important.

The final component of energy storage is the actual soil in the planting beds. While soil doesn't store heat as effectively as water or

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[32]See Alward, p. 123; Rick Fisher and Bill Yanda, The Food and Heat Producing Solar Greenhouse (Santa Fe: John Muir Publications, 1976), p. 57.
[33]See Fisher and Yanda, p. 11; Edward Mazria, The Passive Solar Energy Book: A Complete Guide to Passive solar House, Greenhouse, and Building Design (Emmaus, Penn.: Rodale Press, 1979), p. 209.
[34]See Alward, p. 126.

masonry, it's thermal mass is an added benefit to its main function as a plant growing medium.

Temperature regulation

Overheating is a common problem of solar greenhouses that are not carefully designed. In warm months, the structure collects solar radiation so well that a design that doesn't include some kind of temperature regulation can literally become an oven. Inclusion of adequate thermal mass greatly helps to regulate extremes of temperature in a greenhouse. The more thermal mass that is included in a greenhouse, the more excess heat that can be stored. It's also important to include ventilation and other types of cooling in a solar greenhouse design so that you can get excess heat not stored in thermal mass outside and away from the greenhouse.

Warm air is less dense than cool air and therefore rises. Placing vents that can be opened in hot weather high in the greenhouse helps to get this hot air outside. Having vents low in the greenhouse can help to create a chimney effect in the structure. Hot air will rise out of the top of the greenhouse and cooler ground air will be drawn in at the lower vents. A rule of thumb for solar greenhouse design states that the total area of exterior vents should be about one-sixth of the greenhouse floor area.[35]

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[35]See Alward, p. 106; Fisher and Yanda, p. 12.

Since the M.U.D. greenhouse is shaded during the hot summer afternoons, we've designed in low vents below the south glazing, and high vents at the top of the north wall. A doorway on the east side and a window on the west side also serve as vents in very hot weather, remaining open to increase the ventilated area enough to keep our plants from premature cooking.

Strategically placed vents that take advantage of natural properties of heated air constitute "passive" cooling of the greenhouse. "Active" cooling is forcing air in or out of the structure with some kind of fan. Since we don't want to have to use fossil fuels to heat or cool our greenhouse, we make use of a direct-current fan that draws electric power from photo-voltaic (PV) cells. The fan can be placed in a vent, with the PV cells mounted on the south side of the greenhouse. Besides drawing no fossil-fuel power, the fan only operates when it is needed, without human supervision. When the sun is beating down on the greenhouse, the PV cells spin the fan to life and force hot air out of the interior. When the sun goes away, so will the fan's power supply. Then the greenhouse hoards the heat it has collected.

We believe that the combination of tree shading during summer afternoons and passive and active venting of our greenhouse is sufficient to keep it from becoming a giant solar food dryer. However, should we end up needing additional cooling in the summer, we have the option of employing evaporative cooling. Evaporating water will absorb a large amount of heat while changing from a liquid to a vapor. On hot days, opening the vents and hosing down the greenhouse floors and walkways at noon can add a good measure of cooling during the afternoon. We might also employ a simple evaporative cooling unit if the need should arise. Placing pans of water in front of the low vents with a burlap sack dangling into the water and tacked over the vent allows water to wick up the burlap and evaporate. The evaporatively cooled air is pulled through the greenhouse if vents on the opposite side of the structure are opened.

To be free or to be attached? and other sundry decisions

The heat gathering abilities of a solar greenhouse can be used to add heat to a dwelling if the structure is added to the south side of the building. Such attached solar greenhouses can make an existing house warmer, sunnier and more pleasing to live in. The greenhouse is vented into the house in such a way that the living space of the house receives some of the excess heat produced by the greenhouse, and the extra sunlight and plant-filtered air make winters a bit easier to take. Attached greenhouses also tend to be less expensive, since the north wall already exists.

After careful consideration, however, we decided to build a freestanding greenhouse at M.U.D. Neither of the two houses on the property lend themselves well to a sizable attached greenhouse. One house has a narrow southern wall and a funkily-constructed series of additions that impede an easy greenhouse design. The other house's southern wall is mostly blocked by our older, above-ground freestanding greenhouse, creating an eight foot high wall about fifteen feet due south of the house.

An attached greenhouse would also complicate matters with the city building department. In the following chapter I'll discuss the process that we went through to obtain a city permit to build our unconventional structure. While we wanted to set a precedent in the city for straw-bale wall construction, we also wanted to get the structure built in this century. An attached greenhouse would be considered an occupancy structure, which is subject to much more intense regulation and scrutiny by building department personnel. The daunting prospect of tackling this issue was another factor that argued against designing an attached greenhouse.

Building a freestanding greenhouse allowed us to site and orient the structure to collect solar energy most effectively, and allowed us to build a larger structure. Since there are fixed costs associated with building any greenhouse, smaller greenhouses tend to be expensive relative to the amount of usable space that's realized. We can somewhat make up for the added expense of a freestanding structure by increasing the size to realize more growing space for the money invested.

We decided not to include electric and water utility hookups in the completed structure. While these are convenient additions, they add cost and further complicate matters with the city building department. The presence of electric outlets in the greenhouse might also tempt us to use electric heaters to keep the structure operational even in the depths of a Missoula January, compromising our vow to keep the structure independent of fossil energy sources.

Economics and extra labor of the diminishing-returns variety also weigh against trying to keep the greenhouse operational all year long. Given the sparse sunlight and low temperatures in Missoula during December, January and February, it's almost impossible to keep the greenhouse temperature above freezing without using supplemental heat. Since the very short days mean that actual photosynthetic time for plants is short, the cost of heating the building won't return much in the way of plant production.

Letting the greenhouse go fallow during the coldest months has the advantage of freezing out mold and insect pests. Pests can thrive in a greenhouse, since they're protected from predators and cold temperatures. Nailing them with a deep freeze every year is one of the easiest ways to manage this problem.

The winter months can also be used to compost and fertilize the bedding soil in the greenhouse, and to give the soil a rest from constant production. This slack time is also a good time to do basic maintenance that's better done in the absence of plants, like painting, caulking, and wood preserving.

CHAPTER FOUR - INSTITUTIONAL BARRIERS - GOVERNMENT REGULATION AND UNCONVENTIONAL BUILDING

Working toward urban self-reliance and sustainable cities requires change. Change involves overcoming the inertia of the status quo - in one's own mind and in the larger society. By far the most difficult of these problems is overcoming the inertia of the ingrained patterns in one's own life. Sincere and lasting changes in our behavior and habits can only come from within each individual. Arriving at the point where one is ready to commit to new patterns of living is usually a long and very personal journey of the heart and mind. One must come to see the probable consequences of continuing certain behaviors and thus the worthiness of making the changes.

A far easier, but by no means trivial, barrier that must be overcome to make changes in urban living are the rules and regulations that govern the infrastructure of city living. These laws evolved under the prevailing assumptions about how cities should work. Since they have been in place for a long time, these regulations have taken on aspects of custom and tradition, and are therefore usually hostile to modes of building and living that fall outside of the scope of their own convention.

An important goal of the M.U.D. greenhouse project is to engage the Missoula city building code regarding straw-bale construction. By tackling the work of obtaining a city building permit for our straw-walled structure, we want to help to eliminate this particular barrier for others in the community. We hope to make the prospect of constructing unconventional, environmentally sustainable buildings in Missoula a bit less daunting for those who are ready to take the plunge.

FROM PROTECTION TO OPPRESSION: THE EVOLUTION OF BUILDING CODES

The earliest building code is contained in the Code of Hammurabi, the ruler of Babylon in the eighteenth century, B.C.[36] One section of this code that must have been of keen interest to the builders of Babylon read, "if a builder has built a house for a man and his work is not strong, and if the house he has built falls in and kills the householder, that builder shall be slain."[37] The first national building code in the United States was established in 1905, the Recommended Building Code, prepared by a group that represented the insurance industry.[38] The Uniform Building Code (UBC) was prepared and enacted in 1927 by men involved in the building industry - manufacturers, building materials suppliers, and labor organizers.[39] The National Building Code is in effect mostly in the Eastern U.S., while the Uniform Building Code applies mostly in the Western U.S. There also exists the Basic Building Code and the

[36]Kern, p. 12.
[37]Ibid.
[38]Ibid., p. 15.
[39]Ibid., p. 15-16.

Southern Standard Building Code. Most city building codes are based largely on one of these codes, but most cities codes have individual variations or additions to the standard code. As it now stands, there are thousands of different building codes in the U.S.[40]

The rise of extensive building codes in this country accompanied the change in the manner in which housing was created following the industrialization of the U.S. Most houses in the world are still built by those who will occupy them. It is only in the industrialized nations that a professional building industry constructs the majority of dwellings. Even so, in rural areas of the U.S., 40% of all new houses are "owner-built," and more than 20% of all new single family housing in America are built by their eventual occupants.[41]

The building codes were originally a response to the industrial-age phenomenon of the dwelling as consumer commodity. As more people began to purchase their housing from a building industry, the speculative builder arose, mass producing houses to be sold to people who were in no way involved beforehand in the home's design and construction. Inevitably, unscrupulous builders became a part of this market, cutting corners in the construction of their houses to increase their profit margins. Uninformed or unlucky customers ended up with houses that were uncomfortable and often unsafe. Building codes attempted to set a minimum standard of comfort and safety

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[40]Kern, p. 16.
[41]Ibid., p. 3.

for speculation houses to protect the unwitting home-buyer from the sneaky purveyor of homes.

"The Code" wasn't originally intended to make it difficult for people to build houses for their own occupancy. It was assumed that someone who was building her own home would have a compelling reason to ensure that it was comfortable and safe. If for some reason she failed to build a decent house, the consequences would be hers to bear.

The building industry has an interest in promoting the idea that a safe and comfortable home can only be had by purchasing it from the experts. They've pushed the attitude that housing is yet another commodity, and they have been well represented on committees that draw up building codes. As a result, building codes favor mass-production home builders and hinder the owner-builder interested in an unconventional (and usually cheaper and more efficient) design.

Building codes have evolved from protecting home buyers to oppressing owner-builders. While many code standards address safety issues, many others dictate standards that have nothing to do with safety. For example, the code specifies minimum sizes for various rooms as well as the number and size of windows that each room in a new house must have. While this standard may be useful for mass-produced speculative houses, it seems onerous to dictate this arbitrary preference to a builder who will inhabit his own structure. Again, he will be the one who will live with his design, and he should be free to make his own decisions regarding the windows in his rooms.

The codes also discourage new building techniques. They've tended to institutionalize the prevailing conventions of building, and disallowed building practices that fall outside of these conventions. The owner-builder who wishes to employ straw-bale walls to save building costs and materials (and eventually heating and cooling costs) must take on the expense of proving compliance to the building department. Generally, the owner-builder must pay an architect or an engineer to draw up plans and certify that the design meets the "intent" of the building codes, with no guarantee that the plans will be accepted. The code contains a section (Section 106) that allows building officials to use their judgement in approving alternative designs and materials.[42] The owner-builder must ultimately rely on the judgement of one official to approve or disallow her plans. While Section 106 allows the possibility for a building official to exercise flexibility in the face of unique circumstances, it also allows the possibility for that official to exercise arbitrary judgement against an individual or a technique.

In the case of very low-cost buildings like our greenhouse, the actual building permit fee represents a small but not insignificant proportion of the cost of construction. Our city building permit cost $72.00, which represented 6 percent of total construction costs.

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[42]Kern, p. 34.

The result of the strict regulation of building codes is to discourage innovation and lower costs in housing design. The fact that a diminishing number of people in the U.S. are able to purchase housing (and then heat and cool it) speaks to the need to change the way that houses are built and sold. Working to remove unnecessary institutional barriers to techniques that help to solve this problem is crucial to the task of making urban areas livable and sustainable.

REMEDIES: WAYS TO REMOVE THE BARRIERS

Those who are interested in loosening the restrictions that the building codes place on cheap and ecologically sustainable housing can work to amend and revise the codes, and can engage their local building departments in a dialogue about the alternative building technique of their choice.

Amending the building code is difficult. The process is geared toward building industry suppliers who are looking for acceptance of a new marketable product or construction method, and is expensive and time consuming. Legislative action to amend the codes is even more difficult. Amending building codes is usually a low priority for a state or local legislative body, and one encounters the usual array of interest groups and their entrenched lobbyists.

Appealing a code decision can work, but the odds are not stacked in favor of the alternative owner-builder. Most appeals boards are comprised of contractors and engineers associated with the local building industry. It's rare to find a lay person on a building code appeals board.

Rather than taking on the monolith of the standard building code and its amendment and appeals process, an alternative builder can engage his local building department in a dialogue about his specific building proposals. In California, when the San Luis Solar Group sought code approval for unusual building techniques such as straw-bale walls or composting toilet and greywater systems, successful code approval was reached by this sort of communication.[43] The builder presented his ideas to the building officials, who then responded with questions about the viability of certain aspects of the construction. The builder then responded with supporting facts and data to answer the questions and concerns of the officials. At times doing so required that the builders assemble their own facts and data by conducting tests. Other times the questions could be answered using existing information, which the builder was compelled to gather and present. This process then repeated until the building officials were satisfied that the new techniques met the intent of the codes, and they issued a permit.

This method of gaining code approval is time consuming, and involves a lot of work. Fortunately, after the initial work is done, others have an easier time of it. The precedent is set for the particular techniques in that community and others. Local building

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[43]Kenneth Haggard and Greg McMillan, "First California Approved Straw-Bale Construction," Earthword, Issue Number Five (January 1994), pp. 38-40; and telephone interview with Kenneth Haggard, April 1993.

departments are often willing to speak with building officials in other communities about alternative construction methods that have been approved in another community. Thus the work of those who engage their building departments in a dialogue about unconventional construction techniques has a ripple effect. The work of a few people benefits many who follow.

Engaging the local building department can lead to meaningful reform of building departments, and can lead to greater visibility and understanding of alternative ways of urban living. It's important for people who want to change patterns of urban development by living there in different ways to take the initiative to explain their alternative lifestyle to others in the community. Expecting the existing institutional framework to spontaneously accommodate your alternative vision is naive. But by bringing aspects of this vision into the social and political framework of the urban community, we can begin to bring our vision of green cities into the life and the consciousness of our community.

THE M.U.D. GREENHOUSE AND THE BUILDING CODE

On Missoula's Northside, where the M.U.D. Project is located, the building codes are rarely enforced. It's a poor neighborhood, with a lot of frayed-looking railroad worker houses that date from the late nineteenth century. Although the city codes technically apply here, in practice people make additions to their houses and put up utility buildings at their own discretion. This is most likely possible because people don't complain when their neighbor starts to put up a new building. The prevailing ethic seems to be libertarian. It's not common for Northsiders to bring the local government into the affairs of their neighbors.

We at M.U.D. wanted to get a building permit for our greenhouse so that we could pave the way for other people in Missoula to employ straw-bale construction in greenhouses, and eventually in dwellings. Our permit application was the first to propose using straw-bale construction technique inside the Missoula city limits. Although it will take more work with the building department to gain code approval for a residence with straw-bale walls, and for Nebraska-style load bearing straw-bale walls, we think that getting this initial permit has helped to open the way for more straw-bale buildings in Missoula by exposing the concept to the building department.

Our initial application was rejected on several grounds. The building official wanted our plans to be more specific in regards to raftering and framing details, but most significantly, he stated that straw-bale construction was not an "acceptable" building technique and that we would need a Montana licensed architect or engineer to certify that our straw-bale walls met the intent of the building code.

Finding a local architect or engineer who was willing to make such a certification proved to be difficult. At this time (Spring 1993) no municipality in the U.S. had approved straw-bale construction in their building codes. We were aware of efforts to include the technique in Austin, Texas and Tucson, Arizona codes, but these efforts had yet to bear fruit. Some local architects expressed interest in our project, but declaimed having enough knowledge about straw-bale building to be able to make the certification. Adding to our difficulties, we had no money with which to hire any of these people. We were asking these very busy people to donate their time and expertise, and were therefore a very low priority in their work schedules..

The permit application languished until the Winter of 1994, when the Tucson, Arizona building department approved standards for straw-bale buildings into their municipal codes. These revisions included provisions for load-bearing, Nebraska-style houses, as well as timber-frame designs. A Tucson-area business that promotes straw-bale building, Out on Bale, Unlimited, sent us the names and phone numbers of building officials in Tucson who were willing to take calls from building officials in other cities, and answer questions about approving permits for straw-bale buildings.

Then commenced a period of many months in which we waited while a local architect (who generously agreed to draw plans from our working drawings and put his stamp of approval on the plans - free of charge) was able to squeeze this work into his schedule. Finally in late July 1994 we had approved plans in hand to submit to the building department. Within a week, building department personnel gave us verbal assurance that the plans would be approved and the first-ever Missoula building permit for a straw-bale structure would be issued. Two weeks later, we had this permit in hand, and immediately began excavating for foundation work.

CHAPTER FIVE - BUILDING THE EXPERIMENT - THE INSTRUCTION OF EXPERIENCE

The M.U.D. Project Staff and others who pitched in to build the straw-bale greenhouse lacked extensive building experience. When we turned the first shovels of dirt to excavate the greenhouse foundation, our ideas and ideals met the here and now. At this intersection of theory and practice lies potent learning potential. Where Theory meets Practice is where the real work and the real lessons occur at the M.U.D. Project.

What follows is an account of the process of building the greenhouse employing ideas of urban sustainability, and what we learned along the way. Note that discussions of the time required for different steps are based upon our being able to devote only part of our time to this project, the rest of it being allotted to wage-earning and other projects and activities. Thus, when speaking of "several weeks" to complete a step, I'm speaking about time elapsed start to finish, not actual time spent working on the step. We did work regularly at it the entire time, though. It was rare for more than a day or two to pass without work being accomplished; often we were at it many days in a row.

EXCAVATION

Several people not involved in the greenhouse project who visited the construction site were incredulous that we were excavating the foundation with picks and shovels. By any conventional economic standard, hiring a backhoe for an hour or two would have made much more sense. Although it would have required several hundred dollars in cash, the time saved would make up the difference if we valued our time by normal monetary standards. But we lacked cash, and possessed our time. Also, we wished to substitute human energy for fossil fuel power as much as we could, and perhaps learn a thing or two by doing it ourselves.

The excavation required several weeks worth of hard, sweaty labor. A straw-bale building requires a perimeter foundation wall that is eighteen inches wide to support the bales. A greenhouse foundation must be very well drained, since the plants within it get watered often. Thus we needed a trench eighteen inches wide and three feet deep so that we could place river rock under the foundation walls. Since we needed to place forms to hold concrete mix, the width of the excavated trench had to be twenty-four inches. We also needed to dig five holes for the concrete piers to set posts that would support the weight of the roof and winter snow loads. To ensure stability, these piers needed to extend below the winter frost line, forty-two inches below grade level.

Although we managed to do most of the digging during a Missoula August that set records for heat and lack of rain, we were forced to teach ourselves surveying techniques that resulted in a remarkably square-cornered and level excavation. We also developed fashionably-toned biceps' and stylish tans. Excavating did take us much longer than we'd anticipated (a pattern to which we became accustomed) and so pushed construction farther into autumn.

FORM SETTING

Conventional concrete walls are poured into forms fashioned from plywood and two-by-fours. The M.U.D. Project had been given some battered used forms which we used to form the inside edge of our perimeter wall. To insulate the outside edge of the perimeter wall (and preserve the masonry as thermal mass for the finished structure) we used pieces of foam-core doors - scrap from a local manufacturer that otherwise would have ended up in the county landfill. These outside forms remained in place after the walls were poured.

Figuring out a method to set the forms square and level atop piled river rock required some time and head-scratching, but the time that we took to get the forms set and ready was due more to our inexperience than to our unconventional materials. There seemed less of a time penalty at this stage for employing sustainable methods and materials.

As with excavation, we went much against conventional wisdom by mixing and pouring our own concrete. Once the forms were set, we could have called in a ready-mix cement truck to fold down its chute and fill the empty forms in less than one hour. Again, though, doing this would have required another hefty check. I know this because - even by doing the mixing and pouring ourselves - our foundation ate up a lot more cash than we expected.

Our eighteen inch wide, twenty-four inch high wall stretched sixty-eight linear feet and consumed a tremendous volume of concrete. We had planned to mitigate this by making a rubble wall - placing river rock and salvaged concrete fragments in the concrete as we built up the walls. Even doing so we were surprised at how fast our materials were being consumed.

At this step again we vastly underestimated the time we needed to complete the task. We spent a full month pouring concrete into the perimeter walls and the pier tubes. We did become very adept at mixing concrete with the optimal ratios of mix, aggregate (sand & gravel) and water to suit our needs. Again we were able to maintain good muscle tone. So although we invested a large chunk of time, we gained much practical knowledge and skill in the bargain.

Another unconventional aspect to our foundation was our decision to use fly ash instead of Portland as the main cement for our perimeter walls. The production of Portland cement creates pollution, and it is expensive - about $6.50 for a bag that makes perhaps three wheel-barrow loads of finished concrete. Fly ash is a waste product of coal burning. If one lives close to a coal-fired power plant, it can probably be obtained free of charge. We were initially under the impression that fly ash would be significantly cheaper than Portland cement. It turned out to be only slightly cheaper. (See Table 6.1)

Besides anticipating monetary savings, we were originally enthused about making use of what otherwise is a waste disposal problem. After working with the stuff, though, I have serious reservations. Just before we began mixing and pouring (but after we'd bought a pallet of fly ash bags) we met a woman who had worked extensively with fly ash concrete as an alternative building material. She told us to treat fly ash dust as we would asbestos dust. The dust is loaded with heavy metals and if inhaled in large enough quantities is carcinogenic. And shoveling fly ash powder into a mixer raises a prodigious amount of dust. The shoveler had to wear a respirator and anyone else within thirty feet or so had to wear a dust mask. After the concrete hardens these metals are held inert, but meanwhile one is kicking up a toxic cloud.

Using fly ash also raises knotty ethical and practical questions. What are the implications of helping to rationalize (and maybe perpetuate) an environmentally destructive unsustainable fossil fuel production process by finding ways to get rid of its pesky hazardous waste? And what are the ethical implications of creating a "sustainable" soft-technology demonstration project using the hazardous by-products of the fossil fuel economy?

Along with these questions, I was left feeling like I was imperiling my health and creating airborne pollution while we worked with fly ash. I don't think I would use it again.

FRAMING

When at long last our foundation was poured and set, we set to work fashioning a timber frame from salvaged lumber. Most of the dimensional lumber we used we had gathered over a period of years. Some we saved when in 1991 we razed the old building that stood on the greenhouse site, other pieces came from different renovation projects around town. Certain citizens and contractors know about the M.U.D. Project and are kind enough to put us on to sources a good salvaged lumber.

For very large pieces like the main beam, we purchased timbers from the contractor who was tearing down the old Champion lumber mill beside the Clark Fork River in Missoula. This building yielded very clean and massive timbers from early in this century for very little money. The two four-by-twelve-inch timbers for the main beam cost us about $30. This size dimensional lumber is essentially unavailable today, as it requires old-growth trees which are nearly extinct in North America. Glue-laminated beams are now substituted, but these are expensive. I priced one big enough to span the length of our greenhouse - $180.00.

An institution problem arose when we realized that the Missoula building inspector would not approve framing that used salvaged lumber unless the timbers were graded by a certified lumber grader. Lumber grades determine the suitability of lumber for various applications using criteria like the number of knots per foot, splits, etc. There is a single certified lumber grader for western Montana, who normally charges a minimum of $200.00 to come and grade old lumber. Fortunately, he agreed to perform this task gratis for us because we were a non-profit group and we agreed to credit him publicly for his work in any publicity associated with the greenhouse project.

Obviously, this presents an obstacle for those who wish to used salvaged lumber for buildings inside city limits that are legal and up to code. The large expense of paying for the grading of salvaged lumber negates the economic advantage of salvaged lumber. A solution to this dilemma lies in setting up used building material clearing houses. Such a center gathers salvageable materials from construction and demolition sites, sorts it and sells it to the public at lower prices than new materials. In areas subject to building codes, a certified grader could grade old lumber at these centers in large quantities, and the cost could be spread out over many people. Used building material centers are beginning to sprout up here and there as the costs of new materials escalates (the Down Home Project in the

Bitterroot Valley has started one near Hamilton). In the meantime, though, in Missoula the lumber grading problem remains to be solved for the recycling builder.

Setting the four corner posts (four-by-four or four-by-six salvaged timber) was straightforward. The front center post was more complicated, because we felt that a wooden post here would quickly rot from all of the humidity and plant watering spray inside the greenhouse. We used a salvaged steel post with a custom fabricated top bracket. A lot of head-scratching and several phone calls were required before we figured out a way to set this heavy piece into a wet concrete pier and have it end up straight and true to the other posts. When we'd accomplished this, our five posts were in place.

Before we could install the roof rafters, we needed to put the north wall in place. Our design combines a timber frame with straw-bale infill walls and a load-bearing north wall. To avoid having to support the roof weight across the rear twenty-foot span with more large posts and beams, the rafters at the rear rest on the straw-bale wall, as in the Nebraska style bale buildings.

Emerging conventional wisdom on straw-bale buildings advises against combining load-bearing walls and post-and-beam construction in the same building, since load bearing bale walls are subject to a certain amount of settling. At the time that our plans were drawn, we weren't aware of this advisory. Time will tell if the differential settling will be severe enough to create problems with our building. At this time we feel that at worst we will end up with a slight bow in the center rear edge of our roof, since our roof is lighter than that of a conventional house roof, and the span that is load bearing is relatively short.

This sort of uncertainty is inevitable when working with new or unconventional building techniques. It reminds us that we are conducting an experiment. We'll have to wait a few years to see if bucking the conventional wisdom of straw-bale construction on this point was successful or not. Rod Miner of Darby, Montana built a Nebraska style straw-bale greenhouse with a shed roof like ours - no timber posts at all. Although this too bucks the advice of the new straw-bale builders, he feels that his building is strong and safe. When asked if he thought his greenhouse would stand the test of time, he replied "We'll see."

STRAW-BALE INSTALLATION

On October 29, 1994, M.U.D. held a public workshop and work party to stack the walls of our greenhouse. About two-dozen people showed up to ask questions and to help us with our work.

Here was where we reaped benefits from using straw-bales for walls. The foundation took longer and was more difficult due to our use of the straw-bale technique, but the walls themselves went up quickly and easily. The large back wall was up in a day, as well as large parts of the two side walls.

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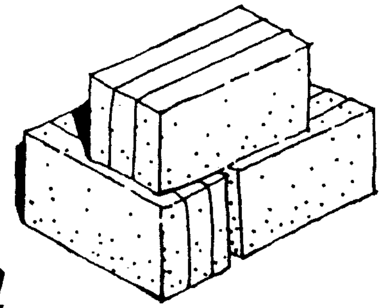
Straw - Bale Construction Workshop



... SEE HOW TO MAKE CHEAP & ENERGY EFFICIENT BUILDINGS WITH STRAW BALES - EASY TO BUILD WITH, EASILY RENEWABLE, AN ALTERNATIVE TO WOOD!

Saturday, October 29th, 10 am

Missoula Urban Demonstration Project

629 Phillips St.

...on the Northside, near Whittier School (Head Start)

for information call

721-7513

It's important to use bales that are tight and as straight as possible. Although there's a lot a forgiveness to the straw-bale technique, very loose or very crooked bales make for bulgy walls that can be unstable. We rejected some of the bales from our pile that were crooked, loose or moldy.

The bottom row of bales were speared onto the rebar set in the perimeter rubble wall. Subsequent rows of bales were offset stacked in the manner of bricks. We then speared rebar or wooden stakes through these bales vertically to prevent the wall from "blowing out" sideways. After "adjusting" these rows for straightness by kicking and pounding, we had a strong, thick wall.

RAFTERS AND ROOFING

When the north wall was finished, we installed a top-plate of two-by-six timbers. This plate was attached by cables to the foundation wall with large screw eyes placed in the concrete before it set up. Turnbuckles on the cables were then tightened to compress the wall and further stabilize it. Since the Montana winter was coming on, we next began to install rafters and roofing to protect the unplastered bales from moisture. With cold weather setting in, plastering was out of the question until springtime, so we wanted to have a roof installed before the snows set in for good.

We used salvaged two-by-six timbers on twelve inch centers for raftering. To achieve greater insulation thickness for the roof, we "furred out" the underside of the rafters by attaching six inch lengths of two-by-two blocks at two foot intervals. We rip sawed other long two-by-six planks into two-by-two strips. Attaching these to the smaller blocks increased the rafter thickness to nine inches.

This procedure again illustrated the pros and cons of using salvaged materials. Using the old timbers and furring them out took much more time and effort. But buying two-by-ten timbers at fifteen and a half foot lengths requires a fat wallet and the sacrifice of large trees.

Before we placed metal delta rib roofing over the rafters, we filled the spaces between them with salvaged cellulose fiber pulled from the walls of the Missoula Central School during a recent remodel. Before hard winter sets in, we'll try to finish the east and west walls, with its windows and doorways, as much as the weather will permit us.

As I write this, it's late November and the roof is complete. The bulk of our work is finished. Early next spring we'll be able to put the finishing touches on the building and begin our first growing season with it. I'm looking forward sitting inside it on a cold but sunny March day with a cup of coffee and a good book, in the light and warmth, with the smell of soil and seedlings in the air.

CHAPTER SIX - ASSESSING THE RESULTS OF THE EXPERIMENT

Now that most of the work is finished on the project, it's possible to assess the results of our experiment in applying theoretical principles of urban sustainable living. I'll assess the degree to which the process of realizing the structure met the goals set for it, and I'll suggest criteria for future monitoring of the greenhouse after it is in use as a functioning part of the M.U.D. Project.

THE PROCESS

The main goals we aimed for when we took on the project were to employ low-cost, low-technology materials and methods and minimal energy consumption in the construction, to set a precedent with the building department in Missoula to allow straw-bale structures inside city limits, to involve local citizens in the building process, and to publicize the M.U.D. Project and the concept of self-reliant, sustainable urban living.

The effort to keep costs and energy consumption down were largely successful. As I've discussed above, we substituted time and human energy for cash and fossil energy. While the extra time required was much in excess of what we anticipated, we gained a concrete sense of the amount of time we needed to dedicate when making this substitution.

Table 6.1 details the construction cost breakdown of the M.U.D. greenhouse.

As is typical of many construction projects, costs in some areas were unexpectedly higher. For example, we did not know when we began the project that we'd have to have our salvaged lumber graded by a certified grader to comply with building code regulations. If we had to pay for this service, our monetary savings using salvaged lumber would have been nearly erased.

The amount of money we saved by using salvaged materials was made clear when we looked at how much costs rose when we had to buy new materials. Table 6.2 shows how some of these new materials came to represent large proportions of the cost of some components of the greenhouse.

The biggest single expense in the building was the foundation, due to the thick concrete walls we needed to fashion for the straw-bale design. Foundation costs represent 45% of total expenses. (Table 6.1) The money spent making this kind of foundation offsets to a degree the monetary savings gained by using straw-bales instead of wood and insulation for the walls. Since material costs represent a fraction of labor costs in a building, and wall systems are also a small part of a building's cost, one only gains a real monetary savings by taking advantage of the ease of bale construction and supplying one's

TABLE 6.1
M.U.D. GREENHOUSE COST BREAKDOWN

Foundation		
Excavation (by hand)	$ 0.00	
Sonnotubes (post piers)	66.69	
Rebar (for bale attachment)	6.10	
Fly ash cement mix (50 bags @ $6.09/ea.)	300.00	
Portland cement mix (13 bags @ $6.57/ea.)	85.44	
Aggregate (sand & gravel)	84.00	
anchor bolts (for glazing attachment)	1.50	
Eye bolts (for wall compression)	1.96	
Stakes (for form setting)	3.95	
Concrete forms (salvaged)	0.00	
Fill (salvaged)	0.00	
TOTAL [proportion of Grand Total]		$549.64 [45%]
Frame		
Lumber		
salvaged	$ 0.00	
purchased from salvager	44.00	
Lumber grading (donation)	0.00	
Post brackets (to attach posts to piers)	50.00	
Center post custom-welded bracket	30.00	
TOTAL [proportion of Grand Total]		$124.00 [10%]
Walls		
Straw bales (donation-waste)	$ 0.00	
Rebar	12.38	
Chicken wire (for plastering)	42.90	
Plaster (estimated)	100.00	
TOTAL [proportion of Grand Total]		$155.28 [13%]
Roof		
Rafters		
salvaged	$ 0.00	
purchased from salvager	20.00	
Insulation		
salvaged cellulose fiber	0.00	
purchased cellulose fiber	15.00	
Vapor barrier (salvaged)	0.00	
Interior sheathing (OSB board)	80.00	
Roofing (metal delta-rib)	115.00	
TOTAL [proportion of Grand Total]		$230.00 [19%]
Glazing		
Glass (salvaged)	$ 0.00	
Channel iron (purchased from salvager)	15.00	
Framing lumber		
salvaged	0.00	
purchased (estimated)	40.00	
TOTAL [proportion of Grand Total]		$ 65.00 [5%]
Door & framing lumber (salvaged)	$ 0.00	
Side window & framing lumber (salvaged)	$ 0.00	
Miscellaneous hardware [proportion of Grand Total]		$ 31.92 [2%]
Building permit [proportion of Grand Total]		$ 72.00 [6%]
GRAND TOTAL		$1227.84 [100%]

TABLE 6.2

SELECTED MATERIALS COSTS

Walls		
Total cost		$155.28
cost of plaster (estimated)	$100.00	
proportion of total	65%	
cost of chicken wire	$ 42.90	
proportion of total	28%	
Frame		
Total cost		$124.00
cost of four post brackets	$ 50.00	
proportion of total	40%	
Roof		
Total cost		$230.00
cost of OSB board (interior sheathing)	$ 80.00	
proportion of total	35%	
cost of delta-rib roofing	$115.00	
proportion of total	50%	

own labor. If the labor is hired out, the monetary savings of using straw-bales for the walls would probably be negligible.

Of course, the savings in resources and in eventual energy consumption for the finished building would still hold. Therefore, even if a person hired out labor for a straw-bale building, he would enjoy a savings in resource consumption. Making considerations outside of purely monetary ones is at the heart of sustainable urban living, and we want to promote it with projects like these.

We also were successful in setting a precedent in Missoula for permitted straw-bale buildings. Obtaining the first permit for a straw-bale structure delayed the project for more than a year, but the delay was mostly due to our lack of cash rather than excessive balkiness on the part of the building department. If we'd had cash to pay an architect to draw up plans, we wouldn't have had to wait for one to make room in a busy schedule and do the work as a favor to us.

Our building is not a residence and doesn't have plumbing or electricity built into it. If one desires to build a straw-bale residence inside the Missoula city limits, he still has some work to do. This person will probably have to hire a state certified architect to draw plans and certify that the building meets the intent of the more stringent code requirements for residential construction. This process will have been made somewhat easier, though, by our having exposed the building department to the idea and the specifics of the straw-bale technique.

Our wall stacking workshop publicized the project and involved local citizens in the building process. We publicized the workshop with posters around town and with press releases to local media outlets. The local paper ran an item on the morning of the workshop which brought a fair percentage of the twenty-five to thirty people who participated. Since then, individuals have come by the construction site to ask questions and sometimes lend a hand, so the word is beginning to get around. The local weekly ran a feature story about the M.U.D. Project in July, which mentioned the upcoming straw-bale building, and a reporter for the local daily has expressed interest in writing a feature article about the greenhouse in the springtime when it is operating.

The contacts we make with workshops, publicity and word-of-mouth information allow us to expose the work we do at the M.U.D. Project to an ever-widening audience. Through such contact, we teach, and we learn. Many who come to the project have skills and information to share, so the Project becomes a kind of clearing house for learning about urban self-reliant, sustainable living.

In sum, the process of bringing the project to fruition met the goals set for it. While things did not always happen exactly as we'd anticipated, the over-arching goals weren't compromised, and we gained knowledge from our minor mistakes and miscalculations.

THE REALIZED STRUCTURE

When the greenhouse begins functioning next spring as a part of the M.U.D. Project garden operation, we can begin to assess how effective the finished design is in creating a hospitable environment for food plants during cold months, and in providing more food self-reliance for M.U.D. Project residents.

To make such an assessment, we can compare conditions in the new greenhouse to those in the older greenhouse on the M.U.D. property. The old greenhouse is smaller, has less insulation because of its conventional wood stud walls, has less thermal mass because of its very light foundation, and has a much less steep glazing angle.

We designed our greenhouse to be most effective in gathering and storing heat during early spring and late fall - roughly March first to November 15th. I suggest monitoring three criteria in both the old and new greenhouses in order to assess how well the new structure serves as a model for an effective greenhouse design.

The high and low temperatures throughout the year should be recorded in both structures. We can compare the lows to see how much of a season extension we gain with each building without adding supplemental heat. It will be particularly instructive to observe the first below-freezing temperatures in each building in late Fall or early Winter, and to observe when each building regains consistent above-freezing temperatures in late Winter or early Spring.

Recording high temperatures in warm months will show how effective the venting of each building is, and will show the degree that super-insulated walls and large thermal mass regulate temperature extremes.

The other two criteria to be monitored will show how well the finished greenhouse is serving as a vehicle for food production for M.U.D. residents. Germination rates and harvest levels of food plants started in the straw-bale greenhouse can be compared to those in the old greenhouse. Observed differences will show how well the new structure has improved upon the old not only in gathering and storing heat and light, but in its size. It will be especially interesting to see the relationship of relative size of each building to harvest levels. I suspect that differences in harvest levels will exceed the size difference.

Monitoring the new greenhouse is an ongoing project. As the seasons go by, M.U.D. residents will incorporate the structure into the seasonal routines of the gardens. The performance of the greenhouse over time constitutes the final results of our experiment.

APPENDIX A: GREENHOUSE PLAN DRAWINGS

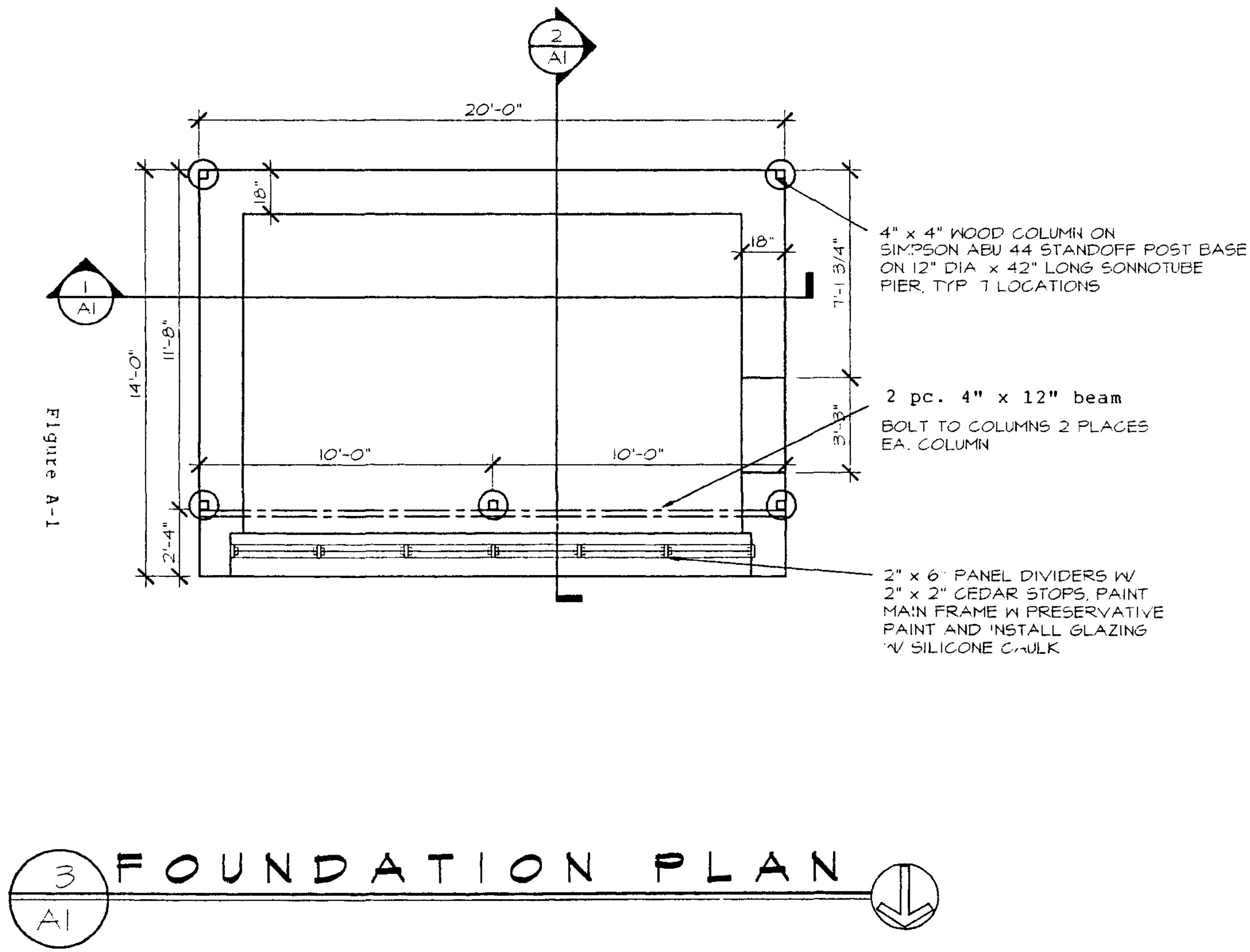
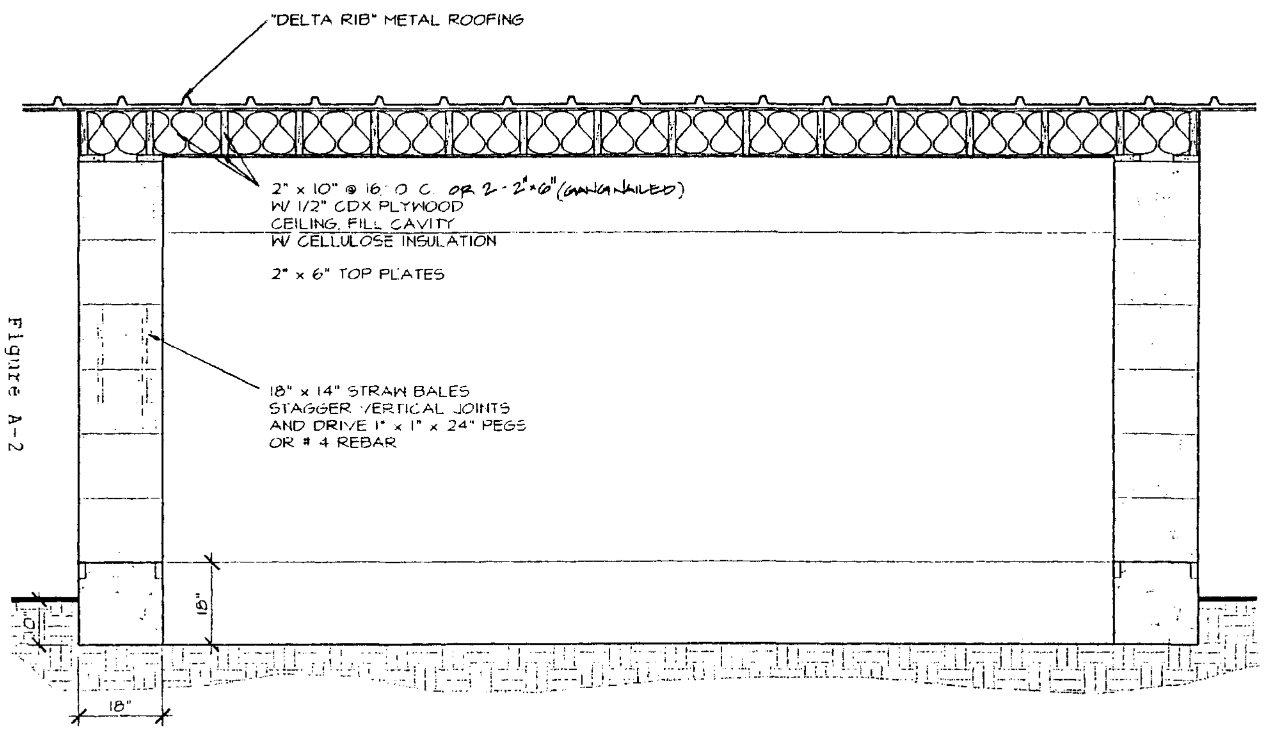

2 A1
20'-0"
18"
18"
1 A1
14'-0"
11'-8"
2'-4"
7'-1 3/4"
3'-3"
10'-0"
10'-0"
4" x 4" WOOD COLUMN ON SIMPSON ABU 44 STANDOFF POST BASE ON 12" DIA x 42" LONG SONNOTUBE PIER, TYP 7 LOCATIONS
2 pc. 4" x 12" beam
BOLT TO COLUMNS 2 PLACES EA. COLUMN
2" x 6" PANEL DIVIDERS W/ 2" x 2" CEDAR STOPS, PAINT MAIN FRAME W PRESERVATIVE PAINT AND INSTALL GLAZING W/ SILICONE CAULK
3 A1
FOUNDATION PLAN

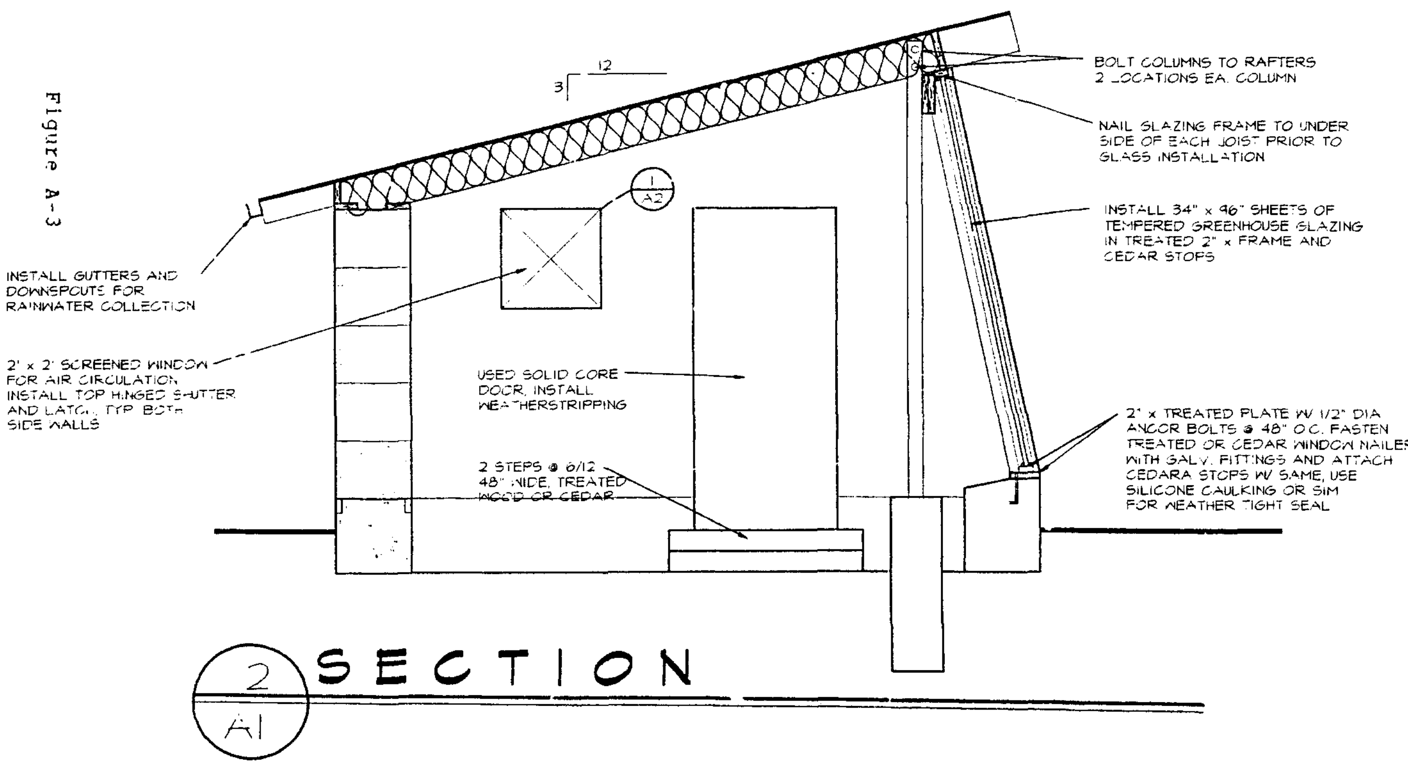
Figure A-1



1/A1 SECTION

Figure A-2

Figure A-3



12
3
BOLT COLUMNS TO RAFTERS
2 LOCATIONS EA. COLUMN
NAIL GLAZING FRAME TO UNDER SIDE OF EACH JOIST PRIOR TO GLASS INSTALLATION
INSTALL 34" x 96" SHEETS OF TEMPERED GREENHOUSE GLAZING IN TREATED 2" x FRAME AND CEDAR STOPS
1
A2
INSTALL GUTTERS AND DOWNSPOUTS FOR RAINWATER COLLECTION
2' x 2' SCREENED WINDOW FOR AIR CIRCULATION INSTALL TOP HINGED SHUTTER AND LATCH, TYP BOTH SIDE WALLS
USED SOLID CORE DOOR, INSTALL WEATHERSTRIPPING
2 STEPS @ 6/12 48" WIDE, TREATED WOOD OR CEDAR
2" x TREATED PLATE W/ 1/2" DIA ANCOR BOLTS @ 48" O.C. FASTEN TREATED OR CEDAR WINDOW NAILERS WITH GALV. FITTINGS AND ATTACH CEDARA STOPS W/ SAME, USE SILICONE CAULKING OR SIM FOR WEATHER TIGHT SEAL
2
A1
SECTION

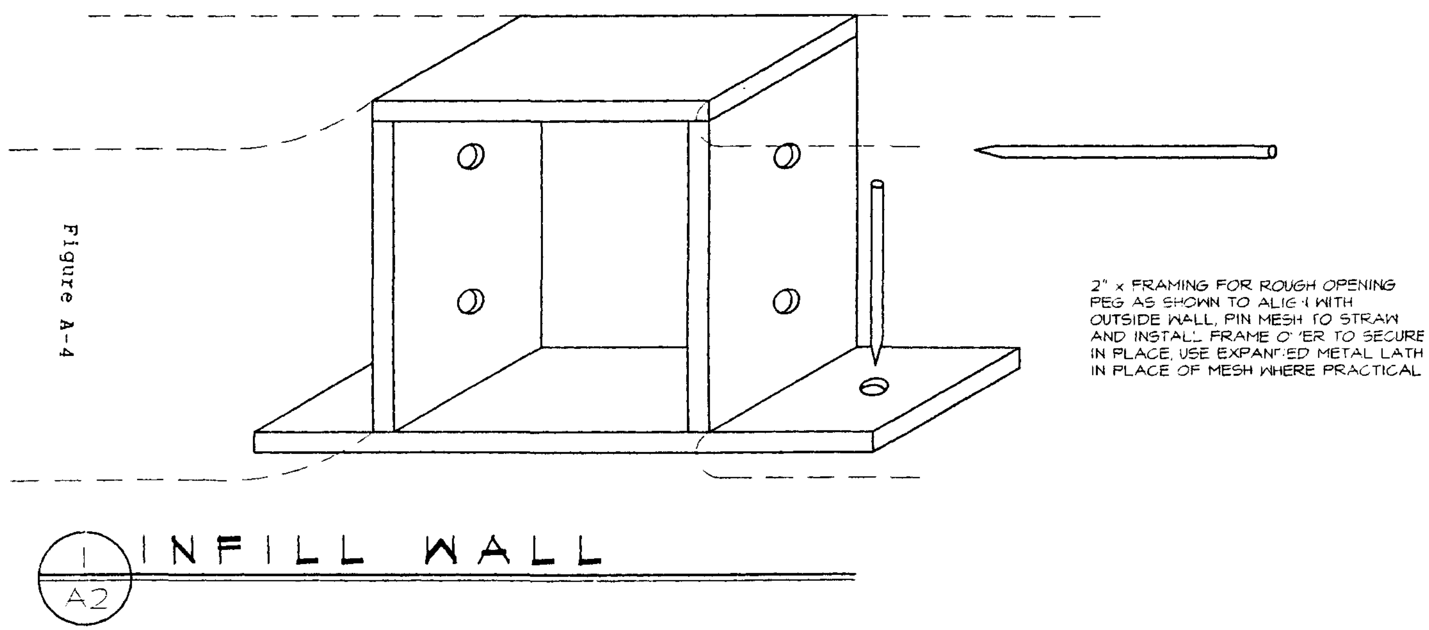

2" x FRAMING FOR ROUGH OPENING
PEG AS SHOWN TO ALIGN WITH
OUTSIDE WALL, PIN MESH TO STRAW
AND INSTALL FRAME OVER TO SECURE
IN PLACE, USE EXPANDED METAL LATH
IN PLACE OF MESH WHERE PRACTICAL
1
A2
INFILL WALL

Figure A-4

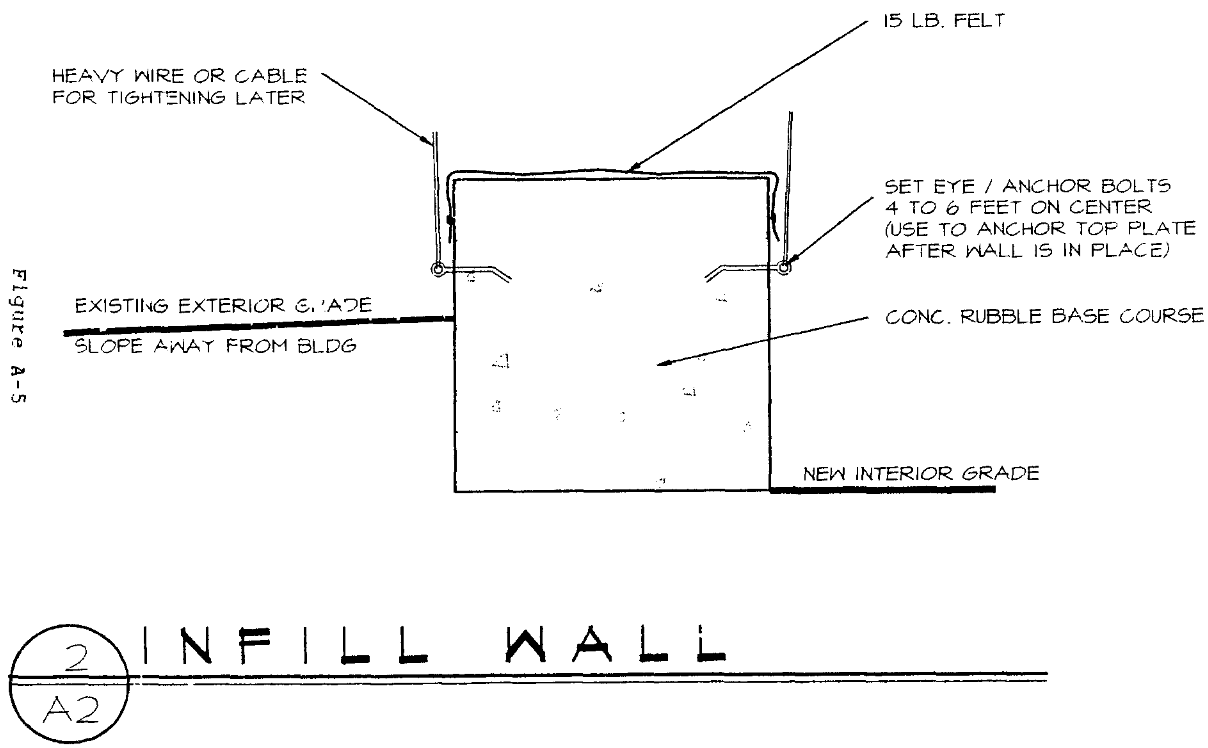
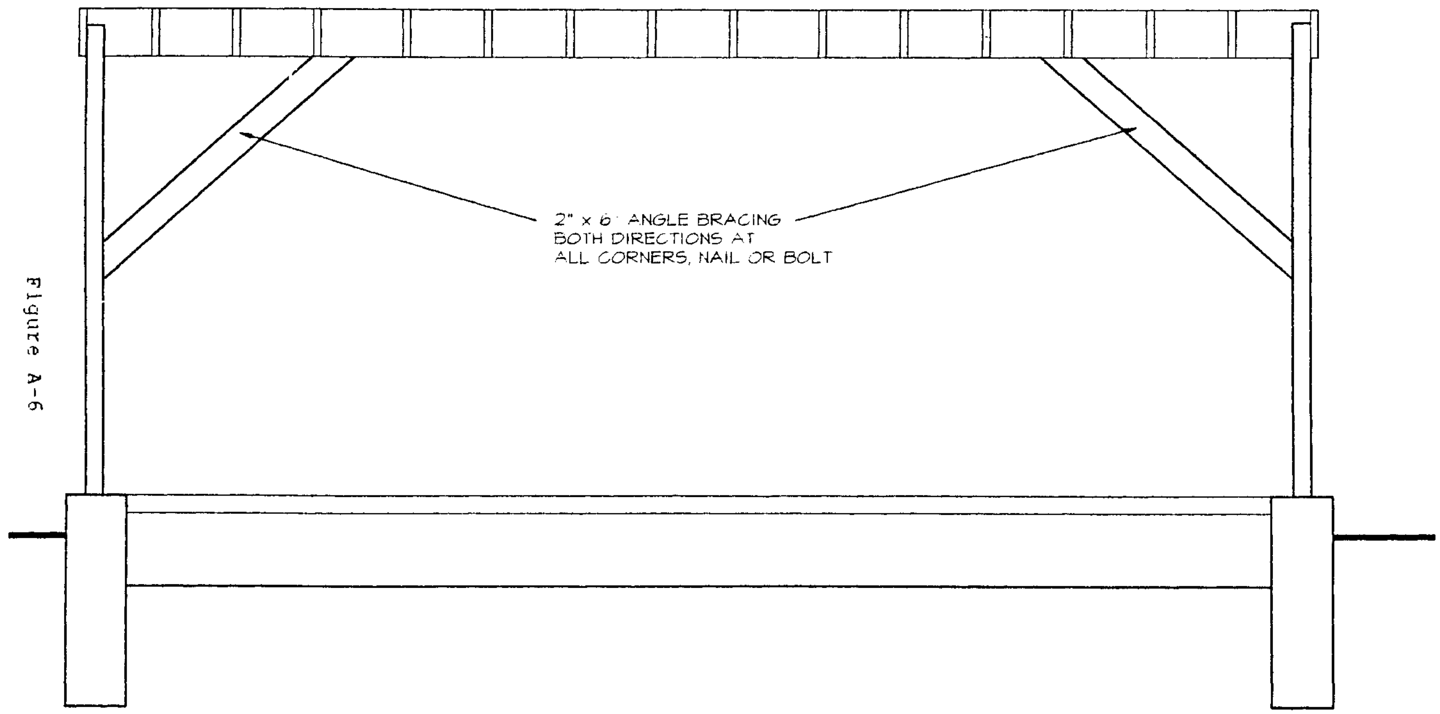
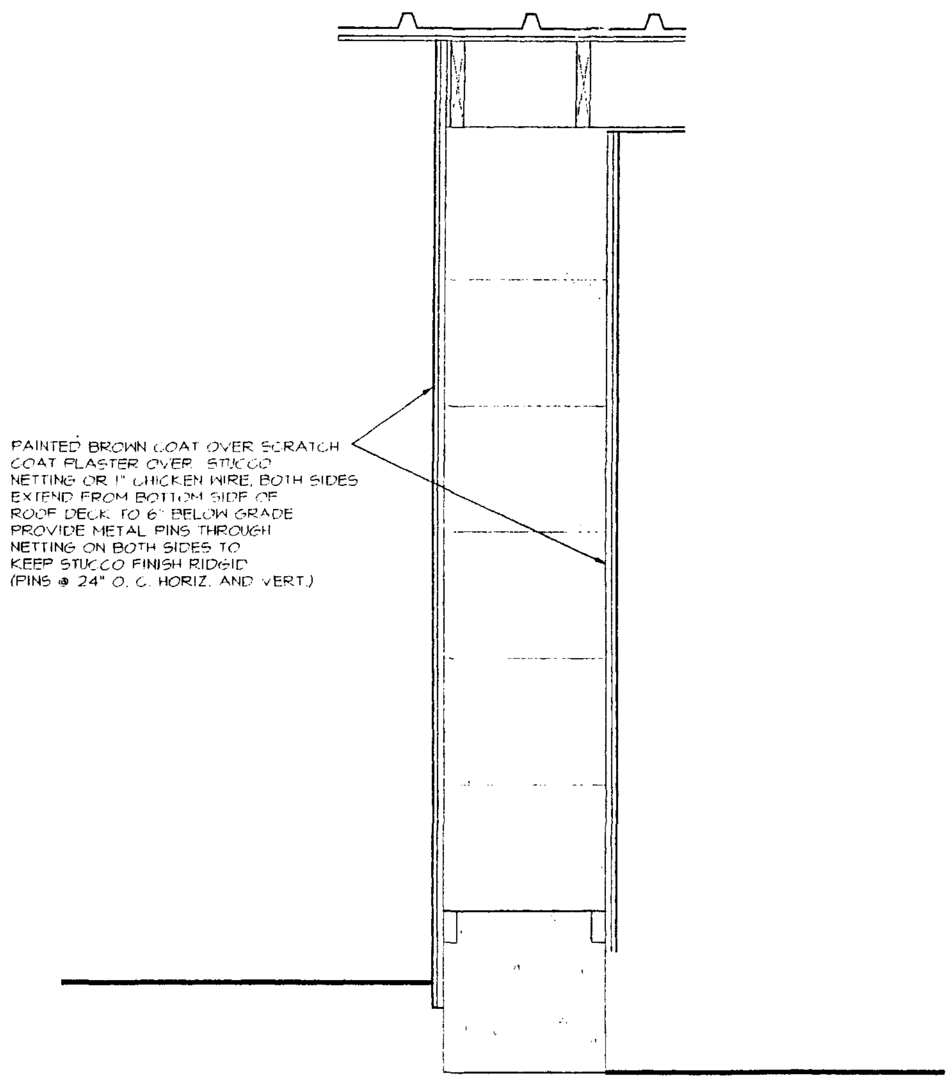

HEAVY WIRE OR CABLE
FOR TIGHTENING LATER
15 LB. FELT
SET EYE / ANCHOR BOLTS
4 TO 6 FEET ON CENTER
(USE TO ANCHOR TOP PLATE
AFTER WALL IS IN PLACE)
EXISTING EXTERIOR GRADE
SLOPE AWAY FROM BLDG
CONC. RUBBLE BASE COURSE
NEW INTERIOR GRADE
2
A2
INFILL WALL

Figure A-5

Figure A-6

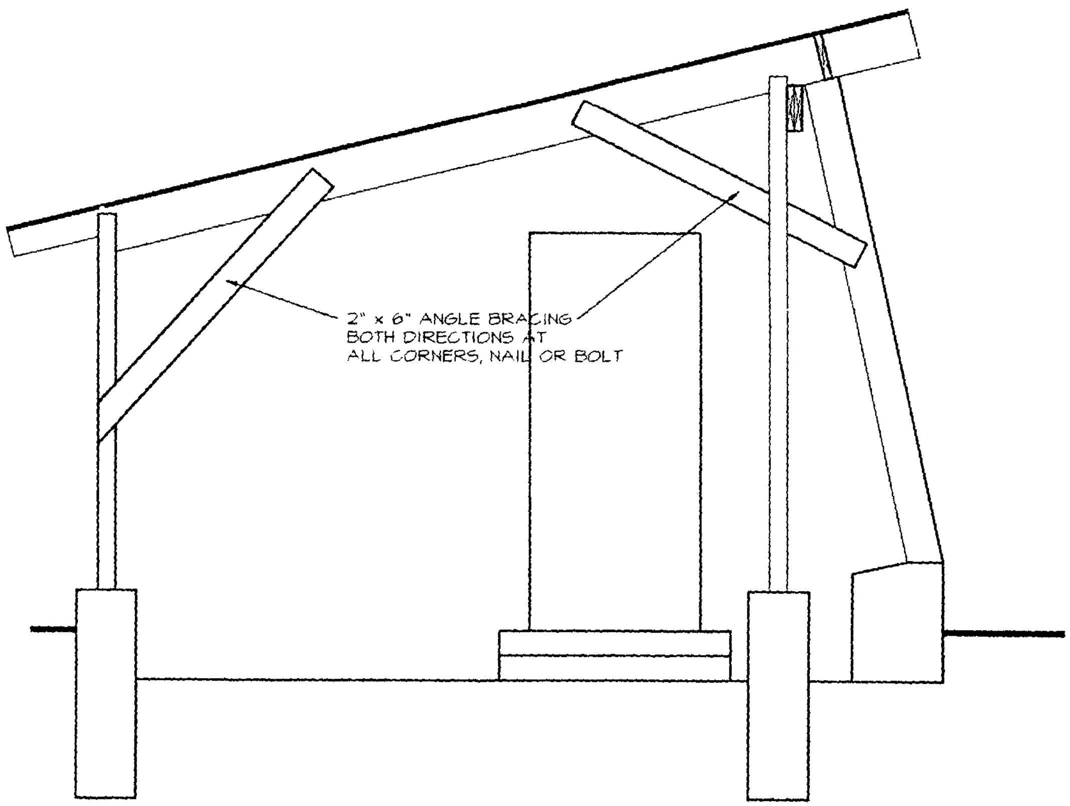


3
A2
BRACING



4 / A2 WALL SECTION

Figure A-7



5 / A2 BRACING

Figure A-8

APPENDIX B: VIDEO SCRIPT

I wrote, videotaped, and produced a short video document to help publicize the M.U.D. Project, the straw-bale greenhouse, and the idea of straw-bale structures. I filmed at various steps in the construction of the building in order to show the process as it unfolded. The final videotape runs about twelve minutes.

Open to MUSIC and SHOTS OF GARDEN PLANTS AND GARDENS

NARRATION:

Most of us learn in school that the United States is changing from a rural nation to a nation of city dwellers. Currently about three-quarters of the U.S. population lives in cities & towns with more than 25,000 people.

MISSOULA FROM THE HILL

These urban folks depend on rural areas for nearly all the food and raw materials they require to survive. As cities and towns continue to expand, they eat up rural land at the same time that they increase their demands for food and raw materials from these lands.

93 STRIP, WALL MART, RESERVE STREET, ETC.

Eventually, the cities' demands on rural and wild lands will become greater than these lands' ability to meet them. Recognizing this problem, some urban city folk are beginning to look for ways to meet some of their own needs without such heavy reliance on resources from elsewhere.

To this end, many city people grow some of their own food in a garden.

SHOTS OF LETTUCE, BEANS, ETC.

In a place like Missoula, Montana, though, cold weather presents a real challenge to the urban food grower.

SHOT OF SNOW COVERED MTNS. IN RATTLESNAKE/LETTUCE WITH SNOW ON LEAVES/SHRIVELLED TOMATOES ON BROWN VINES

With less than three frost-free months, growing many garden vegetables from seeds to fruition is impossible outside. Using a greenhouse to creates a warm and light environment for plants from early spring to late fall makes extensive food growing possible in Missoula.

MORE SHOTS FROM HILL.

Some Missoula residents created a demonstration project to experiment with ideas and techniques in self-reliant urban living.

FRONT OF MUD PROPERTY BEFORE GREENHOUSE. BACK GARDENS. SOLAR PANELS, ETC.

When we decided to build a greenhouse on this site, we looked for ways to do so that were cheap, easy and saved energy and materials. Our search led us to the technique of straw-bale construction. This is the story of how a few Missoulians with little construction experience undertook the task of putting up a straw-bale building.

CLOSE-UPS OF STRAW PILES/STACKED BALES WITH TITLES OVER

MUSIC RISES

TITLE: "A GREEN HOUSE GROWS IN MISSOULA"

TITLE: "Do-It-Yourself Low-Cost Energy Saving Building"

TITLE: "With Straw!"

MUSIC FADE OUT

When most people first hear about making buildings out of straw, they envision flimsy structures that offer little protection from the elements and other dangers.

'THREE LITTLE PIGS" BOOK ON BALE, PAN UP TO WOLVES SIGN

But it's possible to make strong buildings with straw bales, and ones that are cheap and fairly easy for amateurs to make. What's more, the finished structures end up with thick walls that insulate the building more than a conventional wood stud wall, and don't use up wood from forests in our region.

PAN FROM TOWN TO CLEAR-CUT ABOVE LOLO

The greenhouse project sprang from the "ideas in practice" philosophy of the Missoula Urban Demonstration Project - MUD Project for short.

PROJECT SIGN

The folks at the MUD Project look for ways to experiment with and demonstrate self-reliant living skills in Missoula.

PAN FROM "M" TO PROPERTY

On MUD's Northside Missoula property, MUD residents maintain extensive vegetable, herb, flower and fruit tree gardens

SHOTS OF THESE

These organic gardens are largely fertilized from the compost bins on-site

STEVE SHOVELING STEAMING COMPOST

Project staff also run the Northside Community Gardens

GARDEN SIGN, PAN OVER GARDEN

for folks without home garden space. These gardens include a wheelchair-accessible garden bed

SHOT OF THIS

and plots where Project staff grow food for the Food Bank of Missoula and the Poverello Center

GARDEN PLOTS

MUD Project residents work with energy-saving technologies like solar electric systems

PANELS

and home-built bike carts

"MUD PUPPY" CART

When the old greenhouse at MUD began to show its age

OLDGREENHOUSE

we decided to replace it with a straw-bale structure. Besides obtaining a new, bigger, better greenhouse, we wanted to promote the idea of straw-bale buildings for people in Missoula. The MUD Straw-bale greenhouse is the first straw-bale structure to be approved by the Missoula Building Department.

BUILDING PERMIT POSTED

We wanted to construct our greenhouse as cheaply as possible, using as little energy and materials as we could manage.

GROUNDBREAKING, EARLY DIGGING

We excavated the foundation entirely by hand.

ME DIGGING/MARK DIGGING

A straw-bale walled building requires a thick perimeter wall to support the bales. And, since greenhouse plants get watered often, the foundation must be well-drained.

FINISHED HOLE, SHOWING ROCKS IN TRENCH

We filled the trench that will be under the walls with river rock from a large pile of waste rock at the Northside Community Gardens.

Our building uses salvaged lumber to form a wood frame to bear the weight of the structure. Five posts rest on concrete piers set to below the frost line.

POST SONNOTUBES

The walls under the bales don't have to support as much weight, so to save money and materials we made a "rubble" wall, mixing rocks and concrete fragments into our cement mix.

FORMS GOING UP

We want these walls to act as thermal mass and gather and store heat. To prevent this heat from being transmitted to the ground, the outside forms act as insulation. These waste pieces of foam-core door fragments

DOOR PIECES BEFORE INSTALLATION

will remain in the ground after the wall is poured. The inside forms get pulled away after the cement hardens.

FINISHED FORMS

We mixed our own concrete to save money.

MOVING CEMENT MIXER

For the perimeter walls, we substituted fly ash for portland cement.

BAGS OF FLY ASH

Fly ash is a waste product of coal burning. It's cheaper than portland cement, and uses up waste material.

STEVE SHOVELING INTO MIXER

The cement was mixed a wheelbarrow at a time.

CEMENT GOING INTO WHEELBARROW

As we poured the cement into the forms, we added river rock to fill volume.

JUD & STEVE POURING CEMENT. JUD PLACING ROCKS AFTERWARD

Before the concrete set, we placed rebar posts. These will hold the bottom row of bales when we build the walls.

JUD PLACING REBAR/REBAR ALREADY SET

The front wall includes vent tubes to help cool the greenhouse in hot weather.

VENTS

When the foundation was complete, we set the five posts on the piers.

POSTS

The front center post is a salvaged steel post. Since it will be inside the moist greenhouse environment, we used steel instead of wood to avoid rotting problems.

The corner posts are salvaged wood, as is the main cross beam.

BEAM PAN SHOT

The straw-bales get stacked after we lay tar paper on the concrete to keep the bales from wicking moisture. The bottom bales get impaled on the rebar set in the perimeter wall

JUD IMPALING A BALE/STOMPS IT TO GET "FINISHED" FIT

The bales get stacked like bricks, each row is offset

SHOT OF SIDEWALL PARTWAY DONE

Some bales have to be custom made to fill gaps at the ends of rows.

JUD MAKING A SHORT BALE/INSTALLING

and some have to be notched to fit around the posts.

NOTCHED BALE, INSTALLATION

Subsequent rows of bales have rebar and wooden stakes driven through them to stabilize them.

STAKES GETTING PUSHED THROUGH ROWS

The finished walls are surprisingly solid

FINISHED BACK WALL W/ BUELL PARKED ON TOP

With the roof on

RAFTERS GOING IN/SHOT OF FINISHED ROOF

our greenhouse is nearly complete. We'll finish the side walls, install glass on the south side, and spread plaster over the exposed bales to prevent decay and animal infestation.

SLEEMAN GULCH BALE HOUSE IN PROGRESS

Structures built with this technique in Nebraska have been continuously occupied for over sixty years. We expect this greenhouse to last many decades, helping Northside gardeners in Missoula be more self-reliant.

SHOT OF STRAW PILE

The straw bale technique is becoming more popular as folks find out how inexpensive and energy efficient the completed buildings can be. Many who thought they couldn't afford their own home have realized that they can afford a straw-bale home and can tackle most of the work themselves.

SLEEMAN GULCH BALE HOUSE FROM ANOTHER ANGLE

MONTAGE OF GREENHOUSE CONSTRUCTION WORK THROUGH THE STAGES/MUSIC COMES UP

Now that the first building permit has been issued in Missoula for a straw-bale building, the door is open to Missoula residents to tackle projects like these themselves. If you want to become more independent in providing for your gardening and shelter needs, consider a straw-bale structure. We did it, and so can you.

STILL SHOT OF BALE GOING IN. FADE TO BLACK.

CREDITS OVER GARDEN AND PLANT SHOTS.

END.

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