An Appropriate Technology
Working Atlas
For the State of Texas

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Pliny Fisk, 1978

Introduction

The Resource Atlas for the State of Texas is intended to be a reference tool for individuals concerned about resource conservation in the built environment. It acquaints Texans with their relationship to the distribution of various indigenous building materials, water resources, and to climatic patterns which must be dealt with or can be exploited in the built environment. Information sources related to resource conservation in the State of Texas are also mapped. The purpose of the Atlas is to aid individuals in the creation of resource-efficient, low impact living environments. To encourage this effort the Atlas goes beyond the mapping of natural resources to include a brief explanation of resource utilization and references to more detailed information which will allow a prospective builder to wisely create a specific resource conserving system.

The Atlas has been developed in response to a number of pressures and perceptions resulting from the world's continuing ecological and energy crisis. The acute pressure of increasingly higher costs and diminishing resource supplies, most apparently energy, has prompted widespread concern. It is, in fact, only a symptom of a far more difficult problem than merely the balancing of resource supply and demand. This problem, the squandering and misuse of natural resources, is in turn a result of a basic perceptual error which dominates "modern" man's relation to nature. The elaborate technologies which generations of people have developed have created a predominant perception of man's independence from and dominance over the environment. This blindness to the interdependence of man and nature can only lead to disaster. The purpose of the Atlas is on a small scale, to re-acquaint people with the capabilities and limitations of their surroundings. It describes and encourages the use of systems which work with nature rather than in opposition to it. The Atlas is not intended merely as a compilation of techniques, but also as an introduction to a particular approach to resource usage. The result of this collaboration is microenvironments which satisfy the needs of man and respect the limitations of their particular ecosystem. It also encourages a decentralization of control over the building process and perhaps, in time, the independence and self-sufficiency of individuals within our society.

The Atlas is structured in an attempt to achieve these rather lofty goals. Regional resources, such as geologic building materials, water supply resources and climatic factors are mapped on a statewide basis in order that a person may determine roughly what resources are locally available for use, and what environmental factors must be contended with or may be harnessed. In order that a person may use these regional resources effectively, schematic descriptive and instructional material is included on ways in which they can be incorporated into building systems as structural components, passive microclimate systems, and means of providing for physiological needs. This information, however, in its brevity can not explain the processes and systems sufficiently enough so as to allow their fully informed use.

To fill this information gap two strategies have been developed. First, in addition to regional resources, point resources are mapped. Point resources are individuals, firms, or institutions which supply a particular resource or can provide information about resource utilization in the form of skills, first hand experience or written information. Point resources may also be working examples of ways in which resources can be of service to man. Names and locations of these resources are given when possible in order that interested persons may get in touch with other persons knowledgable in a given field or see for themselves the possibilities of resource utilization. The point resources mapped are only a small portion of the actual resources in the state. Individuals would be well advised to investigate the sources of information which are available in their area.

In addition to point resources, bibliographic data and a centralized reference source also are incorporated into the Atlas. The bibliographic references draw on the extensive technical literature which has developed over the years. They are provided so that individuals may obtain information about specific areas of interest. Key aspects of resource conservation dealt with in the Atlas are used to organize the bibliographic material at the end of the Atlas. These words may also be referred to in correspondence with the Center for Maximum Potential Building Systems (Max's Pot) to obtain information on these specific topics. This material may take the form of zeroxed articles, reports prepared by the Center, or instructional manuals for specific processes. The Center will serve as a regional information bank. It will, hopefully, in the course of years develop or locate information sources or people capable of addressing many specific questions related to resource conservation in the built environment.

This central information source is intended to do more than provide information. It will be a central node in a network of communication which will link individuals interested in resource conservation. People who use the Atlas will through their efforts become point resources themselves, and foster participation in the process by other individuals. As the network grows, Max's Pot will decrease in importance. We are proposing to transform and revolutionize man's relationship to the world around him and as with any successful revolution, the institution which fostered it should fade away or take on different responsibilities. The success of this revolution (or reformation) is dependent on individuals. Decentralization cannot be accomplished by a central source. People must become personally involved in the process of reource conservation and encourage its use by others.

If this Atlas is to be a valuable part of the process, it must change and expand continually. If it is to be responsive to the needs and concerns of its users, its users must be responsible for its growth. You, the user must share your knowledge and experience with others. The Atlas is one viable medium for this exchange of information. Others are being developed. The Atlas as it appears now is merely a seed which needs continual nourishment if it is to flourish and bear fruit.

Acknowledgements

This Appropriate Technology Working Atlas is a continuing effort that parallels our lab work at the Center for Maximum Potential Building Systems. Its growth to this point has been sponsored by various individuals and organizations who have helped the Center over the years. Special thanks are due to the people who have been working for the Center for little or no pay. Particular thanks should be given to Daria Fisk for her inspiration and good ideas. Thanks also to the Energy Institute at the University of Houston for hiring Bruce Phillips and Darby Hixson to bring the Atlas together in its present form. We hope this Atlas is as useful to the everyday person as it has been to us.

We first got the idea of mapping appropriate technology during the winter of 1975, when we began work on it with students at the University of Texas' School of Architecture. This first work produced an early vision of the organizational meaning of mapping resources. Later, network resource mapping was added where semiformal organizations of people communicating about the use of an indigenous resource was developed and could be mapped in a form useful for regional analysis. The concept of using areas, points, and networks is still under development with networks having little to do yet with the format of the present Atlas although we hope the Atlas helps generate a network of communication.

Briefings on the regional use of appropriate technology thru the mapping process have been presented to subcommittees of the United States House of Representatives and Senate on invitation from the National Center for Appropriate Technology. It is the hope of this study that the information may be read and used by individuals and institutions alike. This effort is a natural outgrowth of a long standing environmental ethic in this country focussed here on the everyday processes around us. We hope that the operating of the built environment can perform less antogonistically than it has in the past. We feel that the initial building process, the working metabolism of structures, even the final death of these artifacts, can work in harmony with the natural world around us.

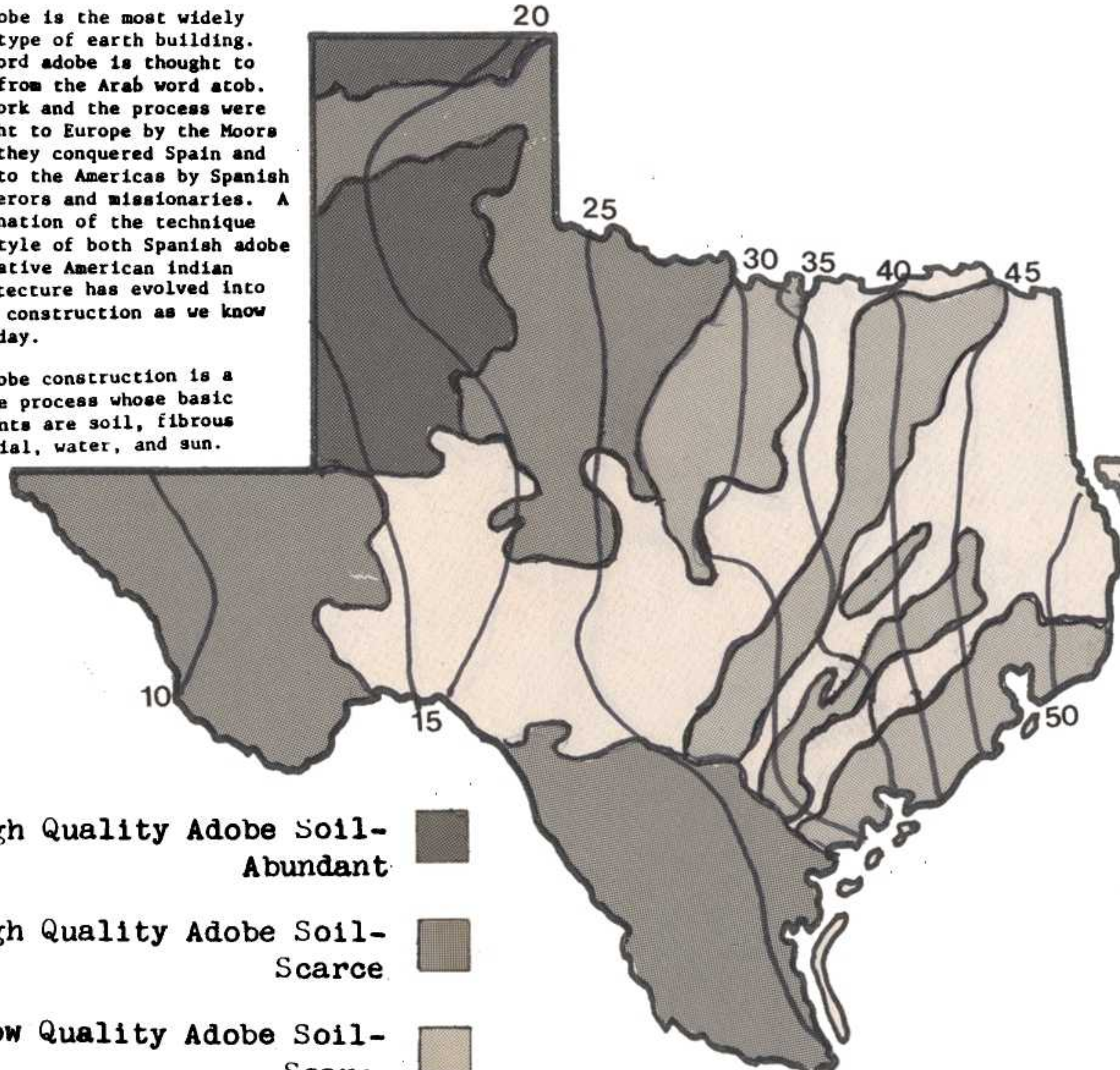
Finally, it is hoped that individual personal responsibility among the population can be catalysed and work in unison with a holistic planning process that respects individuality. It should be realized too that we assume in this study that proper ecological land planning is a prerequisite for the type of work outlined here. The study is meant to be an outgrowth to these well accepted practices. Until now we have been shown where and where not to build. Hopefully we can begin to develop tools to help us decide how to build.

Pliny Fisk
President
Center for Maximum
Potential Building Systems

Adobe

Adobe is the most widely used type of earth building. The word adobe is thought to come from the Arab word atob. The work and the process were brought to Europe by the Moors when they conquered Spain and then to the Americas by Spanish conquerors and missionaries. A combination of the technique and style of both Spanish adobe and native American indian architecture has evolved into adobe construction as we know it today.

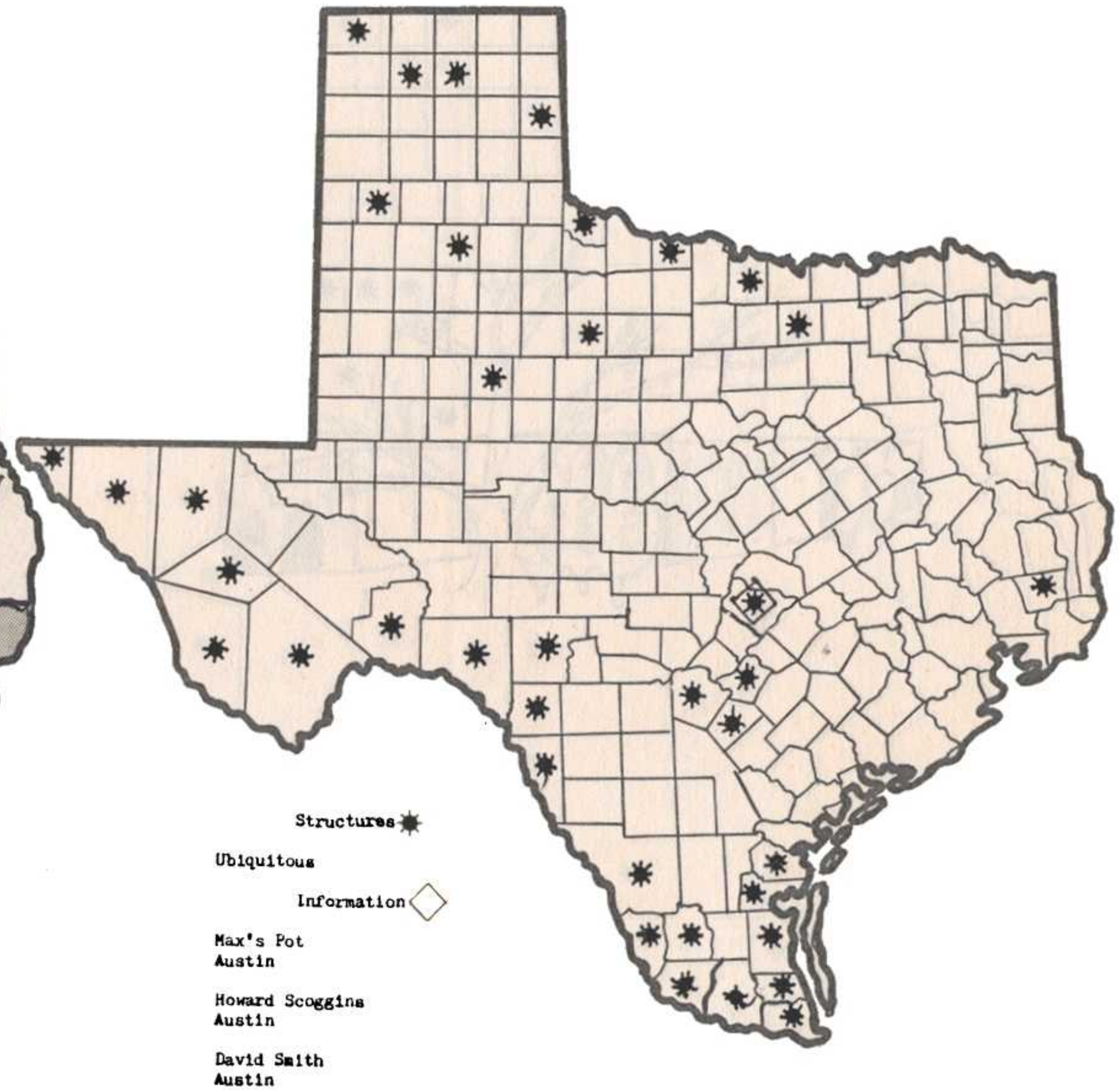
Adobe construction is a simple process whose basic elements are soil, fibrous material, water, and sun.

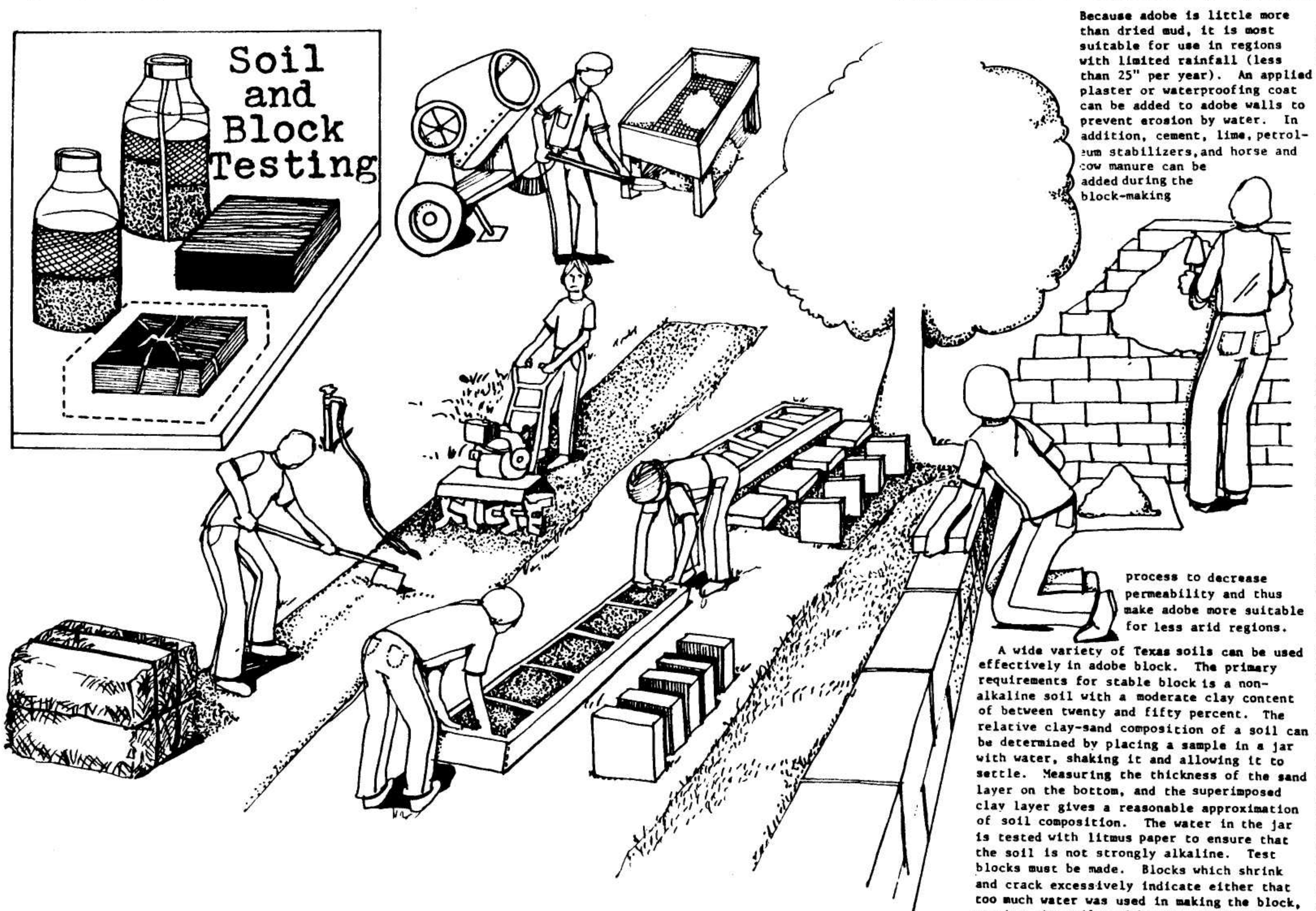


High Quality Adobe Soil- Abundant

High Quality Adobe Soil- Scarce

Low Quality Adobe Soil- Scarce





Because adobe is little more than dried mud, it is most suitable for use in regions with limited rainfall (less than 25" per year). An applied plaster or waterproofing coat can be added to adobe walls to prevent erosion by water. In addition, cement, lime, petroleum stabilizers, and horse and cow manure can be added during the block-making process to decrease permeability and thus make adobe more suitable for less arid regions.

A wide variety of Texas soils can be used effectively in adobe block. The primary requirements for stable block is a non-alkaline soil with a moderate clay content of between twenty and fifty percent. The relative clay-sand composition of a soil can be determined by placing a sample in a jar with water, shaking it and allowing it to settle. Measuring the thickness of the sand layer on the bottom, and the superimposed clay layer gives a reasonable approximation of soil composition. The water in the jar is tested with litmus paper to ensure that the soil is not strongly alkaline. Test blocks must be made. Blocks which shrink and crack excessively indicate either that too much water was used in making the block, or that the soil used has an unacceptably high clay content.

Adobe mix is traditionally prepared directly in the soil from which the block is made. An area of soil is broken up to which water is added and allowed to set in order to assure even moistness of the soil. Fibrous material such as straw is strewn on top of the soil About one pound of fiber is used for every fifty pounds of soil. Stabilizers in solution with water can also be added. The mix is then mixed by foot. Shovels, hoes, roto-tillers, and tractor drawn harrows are more suitable mixing techniques today. The adobe mix can also be made in a concrete mixer or other suitable mechanical agitator. In any case, it must be thoroughly mixed.

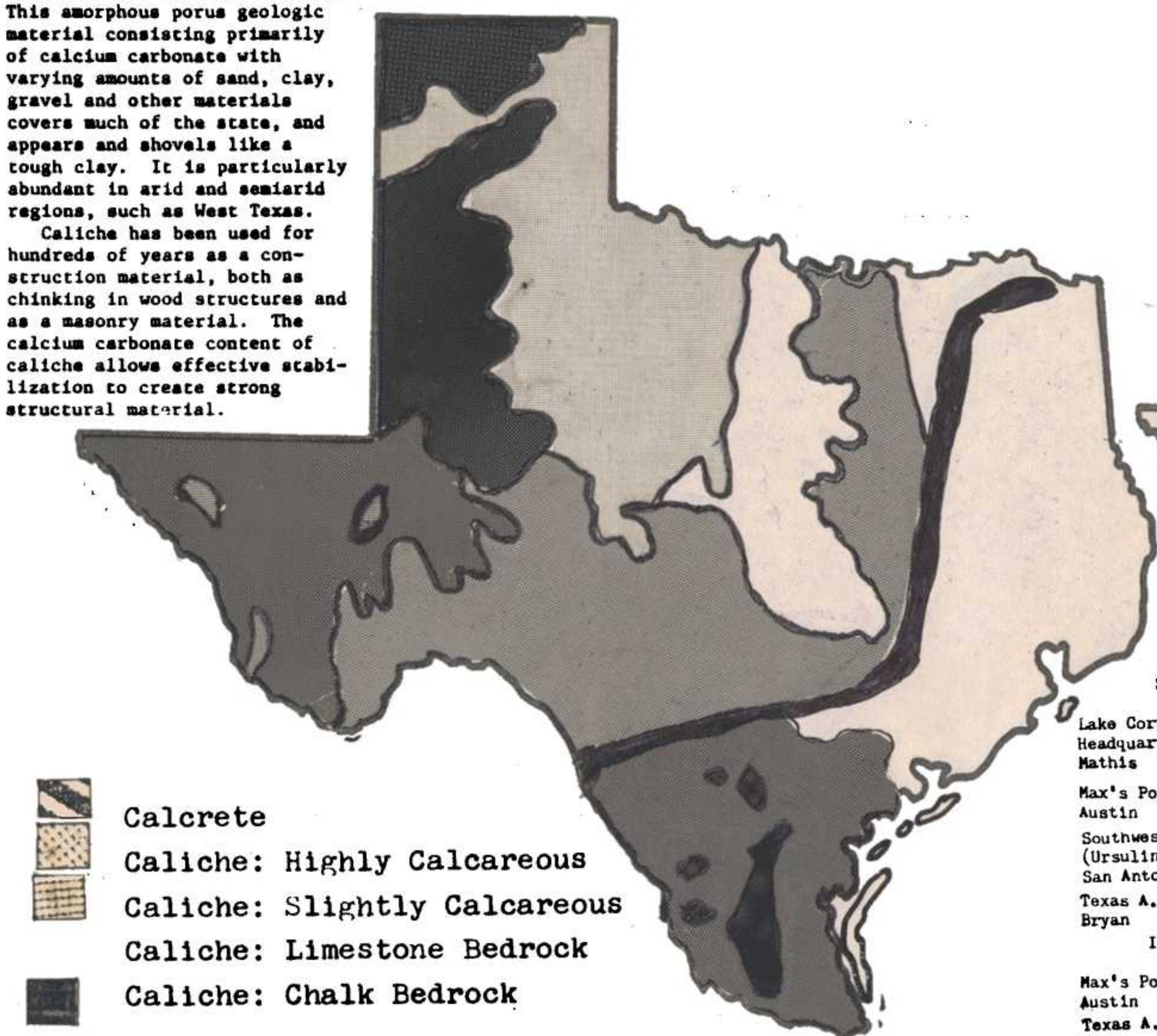
Adobe is puddle formed in multiple forms. (Standard adobe blocks are 18" x 12" x 4" or 24" x 18" x 6"). These multiple forms are placed directly on the ground or on sheets of plastic. The adobe mixture is placed in the mold, tamped, smoothed, and the forms are removed. The blocks are shaded for two or three days to prevent uneven drying and then are stacked on edge to facillitate drying. The blocks are protected from rain and allowed to cure for three to four weeks.

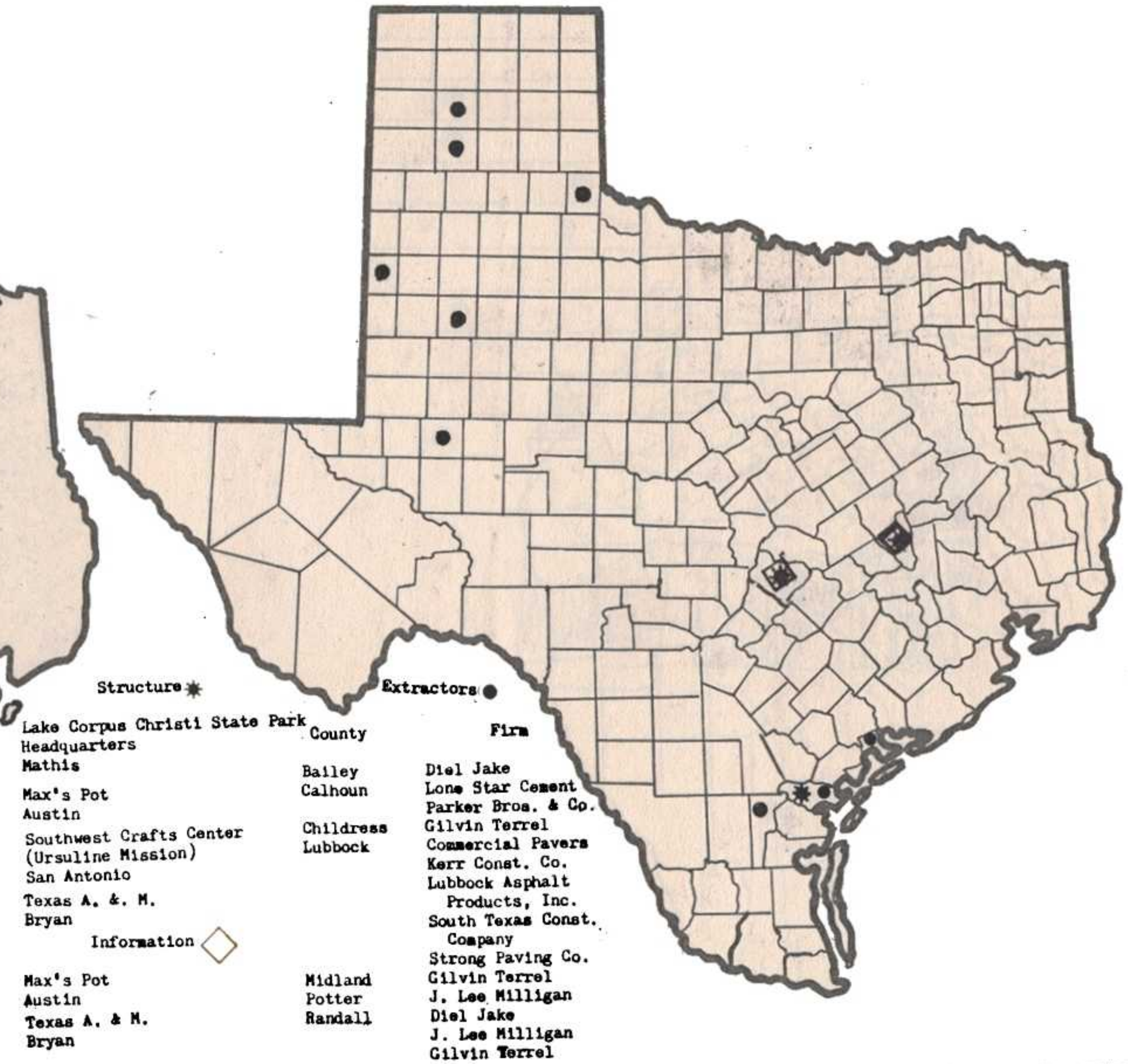
Reliable adobe structures must have firm foundations, due to the great mass of the walls, and must be situated on a site which is safe from flooding. Dried blocks are laid in a mud mortar. The walls should be at least ten inches thick and exterior bearing walls should be no thinner than one tenth the height of the wall. Care must be taken to break joints between courses, and to further ensure the integrity of the walls a continuous concrete bond beam is poured above the final course. The walls are then plastered or treated with a waterproofing agent, and the roof is put on. With care in construction and minimal maintenance, adobe structures can last for centur'

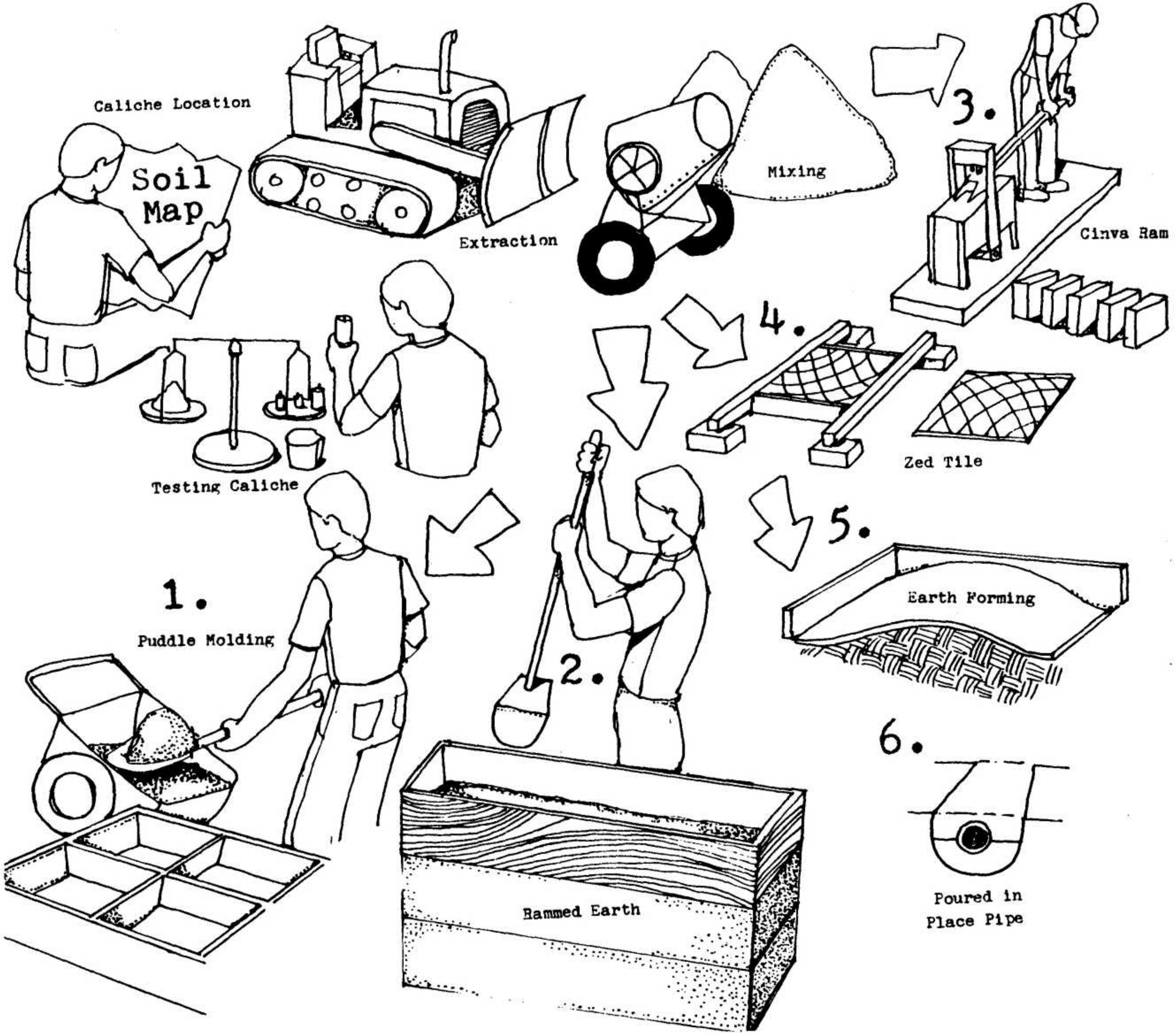
Caliche

Throughout Texas, farmers, gardeners, and ditchdiggers find occasion to curse caliche. This amorphous porus geologic material consisting primarily of calcium carbonate with varying amounts of sand, clay, gravel and other materials covers much of the state, and appears and shovels like a tough clay. It is particularly abundant in arid and semiarid regions, such as West Texas.

Caliche has been used for hundreds of years as a construction material, both as chinking in wood structures and as a masonry material. The calcium carbonate content of caliche allows effective stabilization to create strong structural material.







The first chapel of the Ursuline Academy in San Antonio (now the Southwestern Crafts Center) has rammed earth walls of caliche and is the largest caliche building in the state. Numerous caliche buildings dot the state and are often inconspicuous farm buildings. County agricultural agents are often aware of their presence. Today, caliche is used primarily as a road bed building material. For this reason it is a relatively inexpensive earth material.

The first step in building with caliche is locating a sufficient quantity of the raw material. Geologic and soil maps aid this search. If a suitable caliche deposit is not found on site, caliche should be tested for its suitability for construction purposes. Soil testing can be rather involved but can be done by most laymen.

When suitable caliche is located, test blocks are made with varying ratios of caliche, sand, cement, and water to determine a suitable calcrete mixture for a particular purpose. The mix will vary depending on the caliche, the structural demands which will be made on the calcrete, and the forming technique. These methods are:

1) Puddle Molding: Calcrete mix is placed in wooden molds. The mixture is tamped into each mold, the top of the blocks levelled, and the mold removed. The blocks are then allowed to cure for about a month before use. They should be shaded and kept moist for the first three or four days to insure uniform drying.

2) Rammed Earth: A low water, low cement calcrete mix is shovelled into formwork and compacted with a blunt instrument. Movable formwork can be used to minimize the cost of wood.

3) Cinva Ram: This simple mechanical device produces blocks under 40,000 pounds of pressure with only seventy pounds of applied pressure. Exceptionally strong blockes of various configurations and compositions can be made with this ram.

4) Zed Tiles: Burlap is stretched across a rectangular frame. Calcrete is poured into the form and smoothed. The form is lifted off the ground and placed on blocks allowing the burlap to sag in the center. In a couple of days when the calcrete is relatively strong the tile is removed from the form and a domical tile with greater bearing capacity then a flat tile is formed.

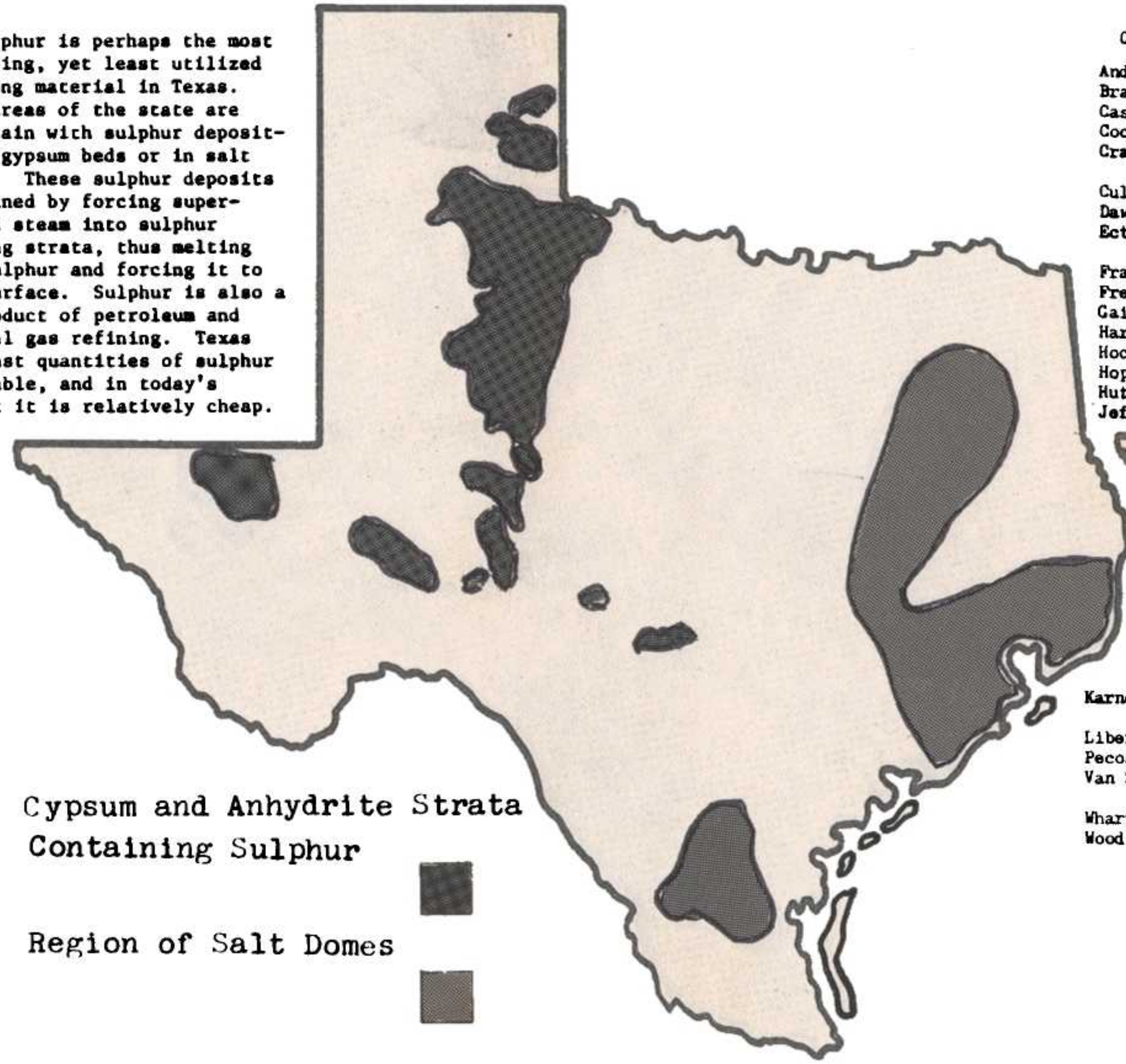
5) Earth Forming: Sand or earth is piled into a desired form. Reinforcing is placed over it, and calcrete is poured and spread over the reinforcing. After curing, the panel is lifted into position, or the sand is excavated from underneath. Large complex shells can be made in this way.

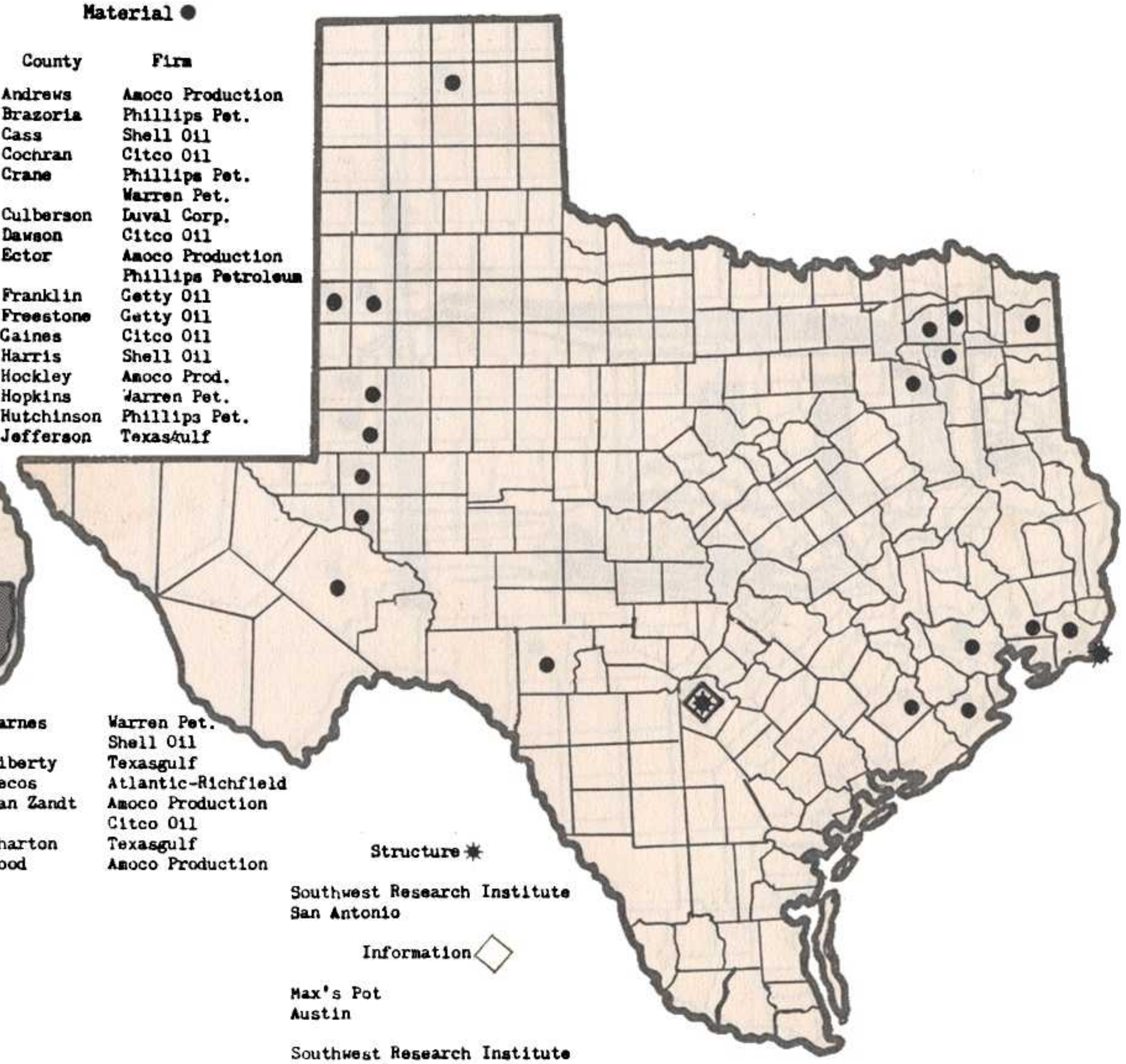
6) Poured in Place Pipe: A trench is dug and a layer of calcrete poured. Cylindrical water bags are placed linearly in the center of it. Another layer of calcrete is then poured over the bags. When the calcrete has set, the bags are popped and removed, leaving a continuous pipe.

There are other applications of caliche. Generally, as with other earth building systems, they are labor intensive and they are most economical for owner-builder or cooperative projects.

Sulphur

Sulphur is perhaps the most promising, yet least utilized building material in Texas. Huge areas of the state are underlain with sulphur deposited in gypsum beds or in salt domes. These sulphur deposits are mined by forcing superheated steam into sulphur bearing strata, thus melting the sulphur and forcing it to the surface. Sulphur is also a by-product of petroleum and natural gas refining. Texas has vast quantities of sulphur available, and in today's market it is relatively cheap.





Material ●

County	Firm
Andrews	Amoco Production
Brazoria	Phillips Pet.
Cass	Shell Oil
Cochran	Citco Oil
Crane	Phillips Pet.
	Warren Pet.
Culberson	Duval Corp.
Dawson	Citco Oil
Ector	Amoco Production
	Phillips Petroleum
Franklin	Getty Oil
Freestone	Getty Oil
Gaines	Citco Oil
Harris	Shell Oil
Hockley	Amoco Prod.
Hopkins	Warren Pet.
Hutchinson	Phillips Pet.
Jefferson	Texasgulf
Karnes	Warren Pet.
	Shell Oil
Liberty	Texasgulf
Pecos	Atlantic-Richfield
Van Zandt	Amoco Production
	Citco Oil
Wharton	Texasgulf
Wood	Amoco Production

Structure ✳

Southwest Research Institute
San Antonio

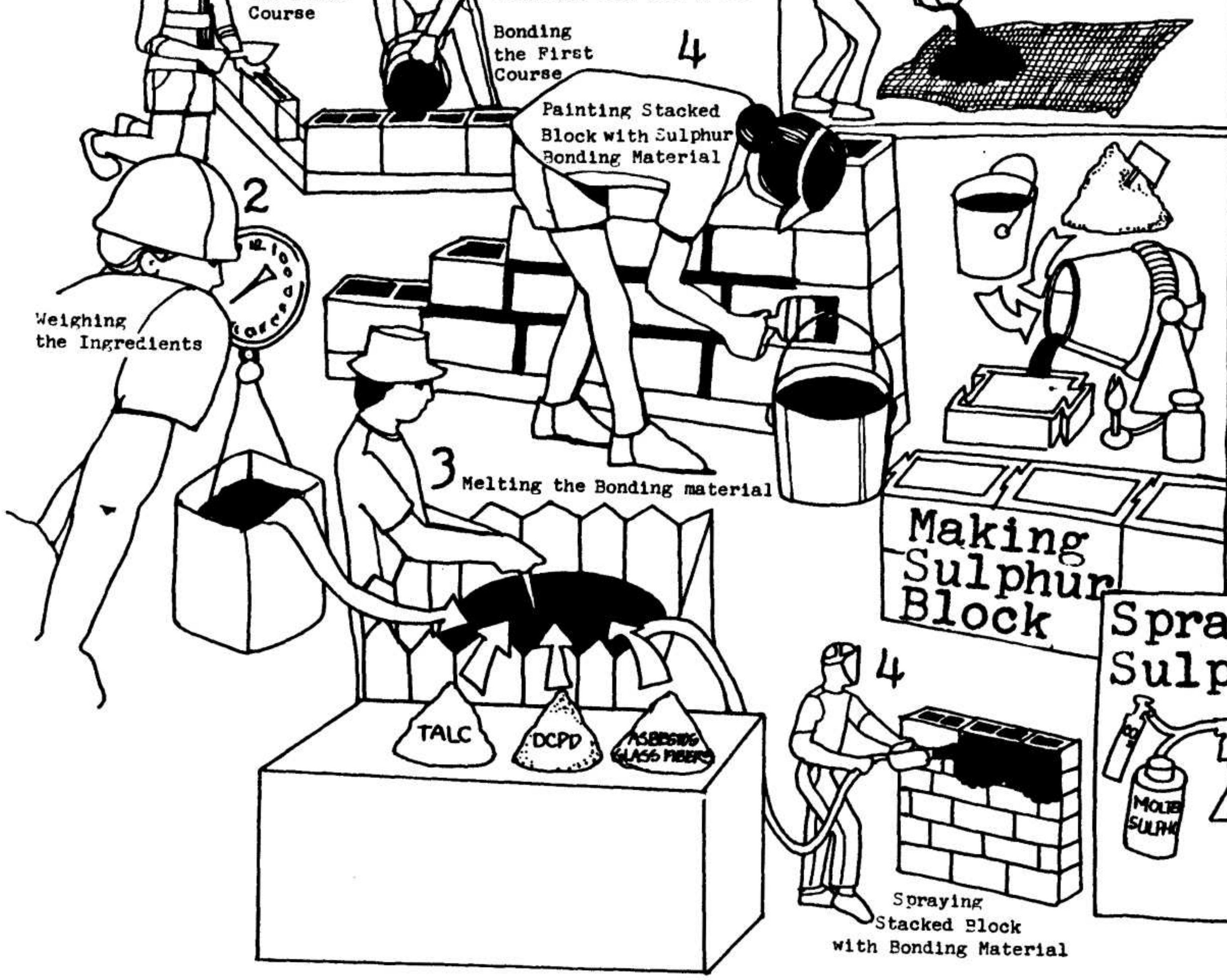
Information ◇

Max's Pot
Austin

Southwest Research Institute
San Antonio

Texas A. & M.
Dept. of Structural Engineering
Bryan

Sulphur has many properties which make it suitable for use in constuction. It is strong, durable, waterproof, insulating, hygenic, verminproof and is easily melted and formed. Although sulphur building techniques date back to the nineteenth century, only recently has sulphur been given serious consideration as a low-cost building material. Many buildings have been built around the world, including one on the San Antonio campus of the Southwest Research Institute, an organization which has pioneered sulphur building research.



Southwest Research Institute has developed a method of bonding building block with a low cost sulphur adhesive which makes walls with far greater strength, and durability than traditional mortared walls. The block bonding system can be effectively used by unskilled labor as has been shown by the low cost housing project in Columbia.

After a foundation is built, the walls are laid out, their first course levelled in a bed of mortar and bonded to the foundation with melted sulphur. Blocks are then stacked to form the wall. Sulphur is melted, together with one of a number of possible combinations of talc, glass fiber, asbestos, and dicyclopertadiene, a relatively inexpensive industrial chemical. Unfortunately the cost of these additives often far exceeds the cost of sulphur. The block bonding mixture is then either brushed or sprayed over the surface of the block, creating a strong impervious wall.

The Minimum Cost Housing Group at McGill University in Montreal has experimented with two promising building technologies using sulphur. For the first, sulphur is used with an aggregate to make building block. Sulphur is melted and poured into a mixer in which sand has been heated. The sulphur concrete mixture is then poured into a mold from which it can be immediately removed as a building block, due to sulphur's quick solidification. The MCAG block is designed to be interlocking so that no mortar is needed. These blocks can be readily recycled by merely melting them.

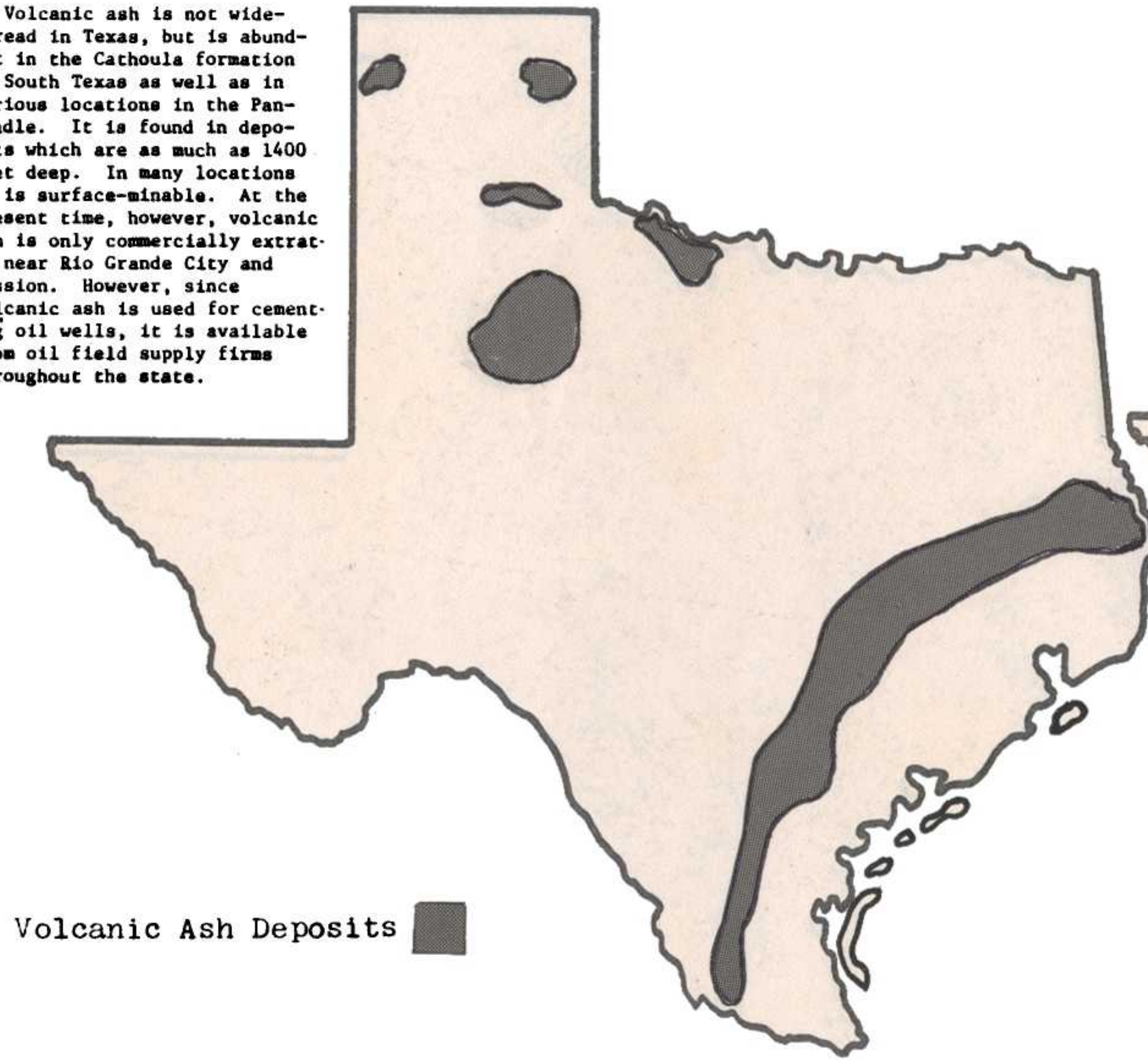
MCAG has also experimented with the impregnation of cloth and paper with sulphur. The fabric is formed in whatever configuration desired, and is then soaked with sulphur, creating a rigid lightweight structural member. If a fabric is allowed to sag in the middle and then impregnated with sulphur, a dome shaped roof panel results.

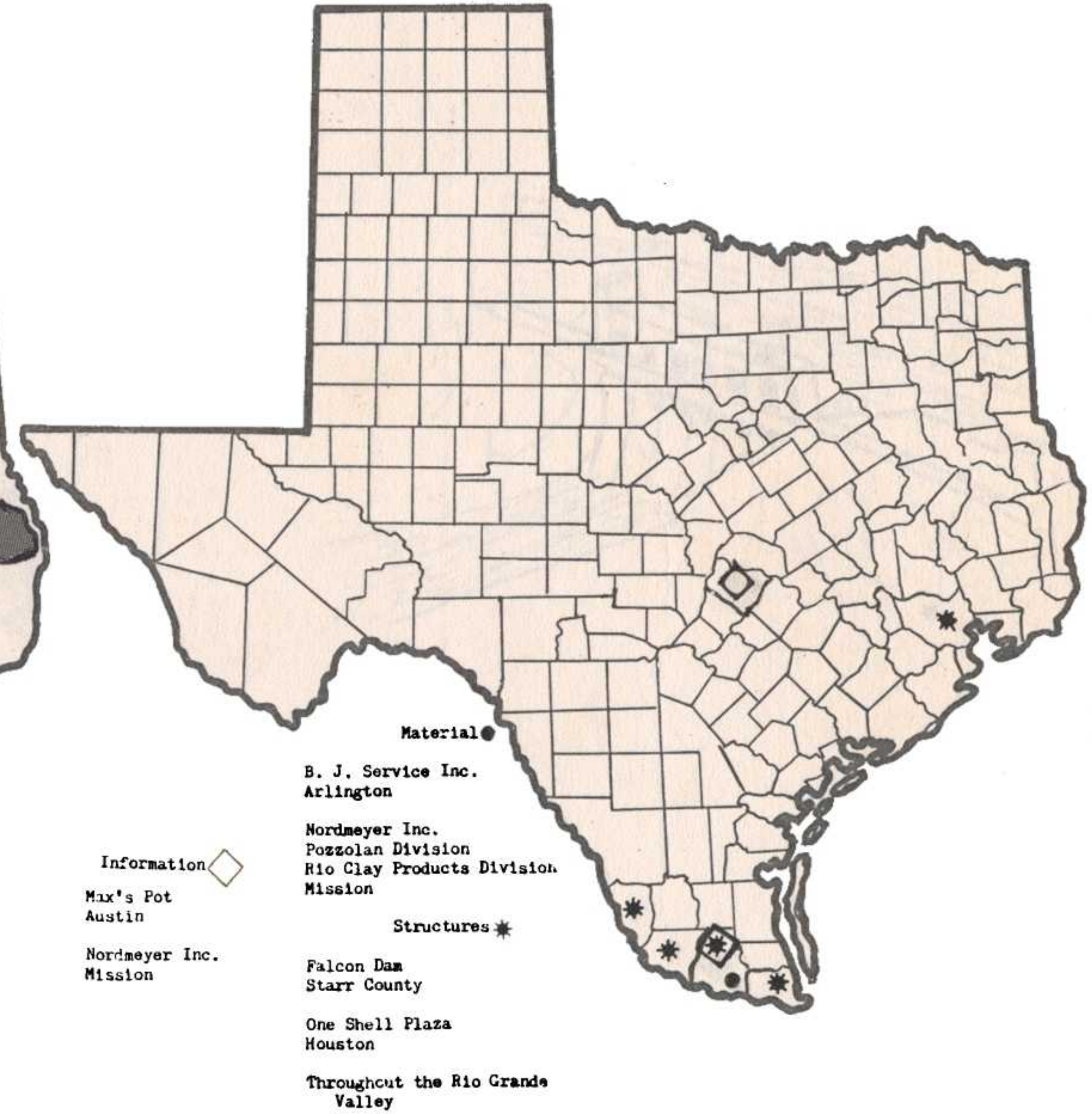
Finally, work has been done with rigid sulphur forms. These forms have the same sort of structural, insulating, and forming properties as other plastic foams, but can be fabricated less expensively. A standard foam gun can be used with only minor modification.

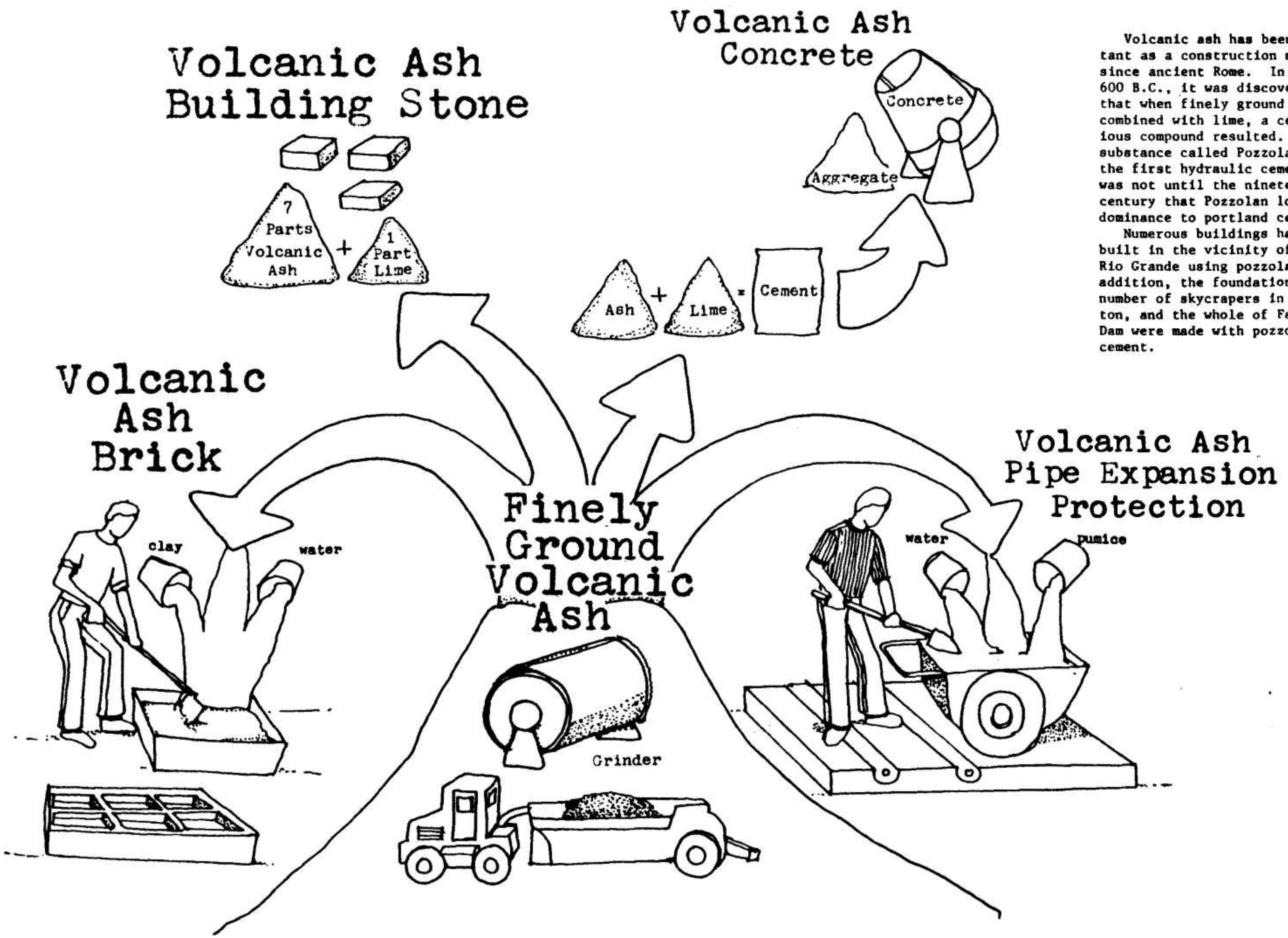
Sulphur building is not without its drawbacks. Sulphur melts at 240° and thus workers' must be protected to prevent burns. Also, melted sulphur has a powerful odor, which although it soon dissipates, makes construction work a smelly job. These, however, are minor problems compared with the potentials of sulphur as a building material.

Volcanic Ash

Volcanic ash is not widespread in Texas, but is abundant in the Cathoula formation in South Texas as well as in various locations in the Panhandle. It is found in deposits which are as much as 1400 feet deep. In many locations it is surface-minable. At the present time, however, volcanic ash is only commercially extrated near Rio Grande City and Mission. However, since volcanic ash is used for cementing oil wells, it is available from oil field supply firms throughout the state.







Volcanic ash has been important as a construction material since ancient Rome. In about 600 B.C., it was discovered that when finely ground ash was combined with lime, a cementious compound resulted. This substance called Pozzolan was the first hydraulic cement. It was not until the nineteenth century that Pozzolan lost its dominance to portland cement.

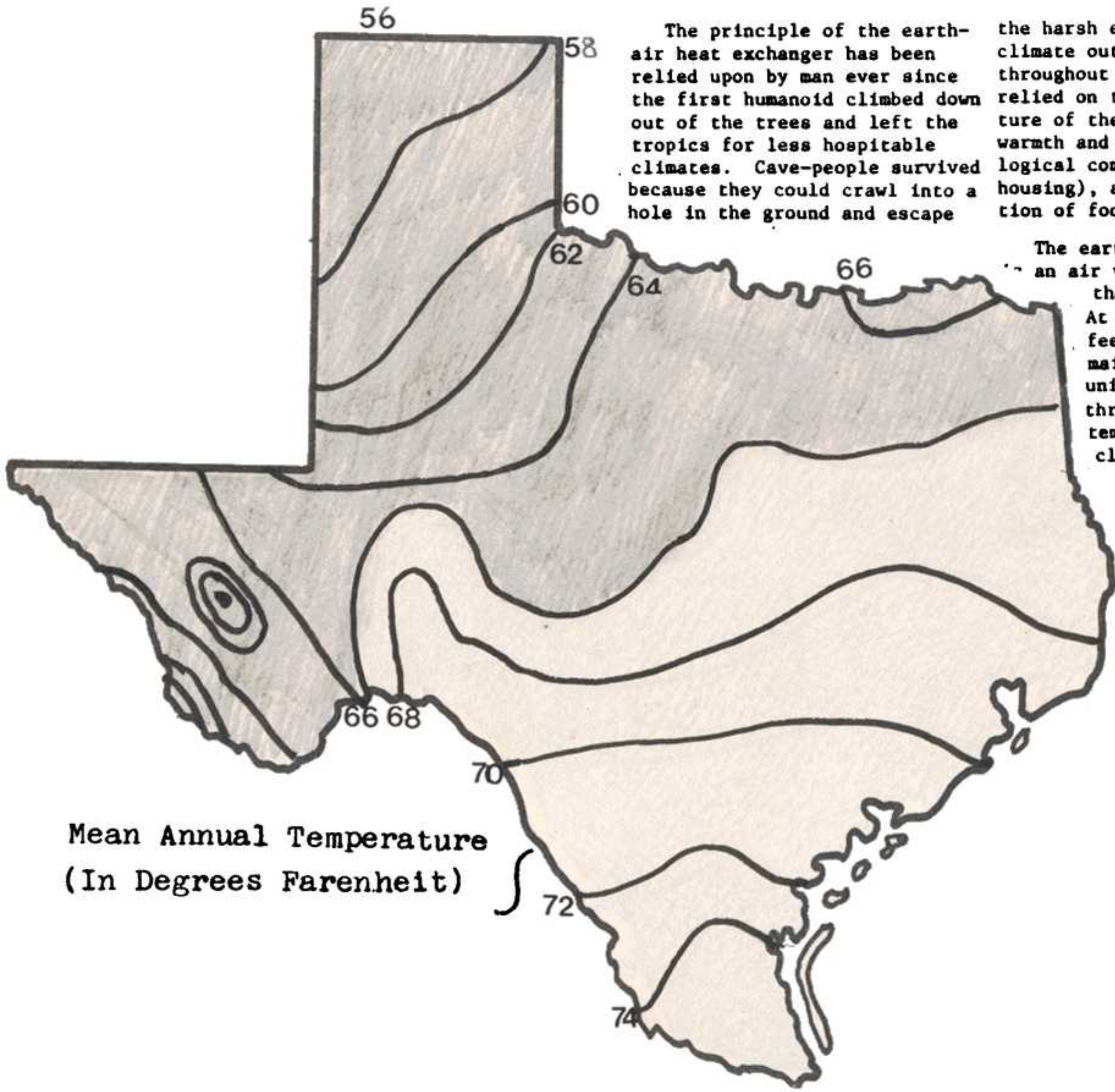
Numerous buildings have been built in the vicinity of the Rio Grande using pozzolan. In addition, the foundations of a number of skycrapers in Houston, and the whole of Falcon Dam were made with pozzolan cement.

Pozzolan is used in many capacities today. Pozzolan concrete in which pozzolan and lime are substituted for some or all of the traditional cement has a number of advantages over neat concrete. It is often cheaper to use, particularly since pozzolan is substituted by volume for cement, but is less dense than cement. Pozzolan concrete has a finer texture than normal concrete and is thus more impervious to water and more tolerant of freeze-thaw cycles. It is also more resistive to chemical action, particularly to sulfates which are normally quite damaging to concrete. Pozzolan also cures more slowly than portland and since curing is accompanied by heat, is less likely to crack during curing.

Ash can be used to make bricks, when mixed with a plastic clay, and water. It can also be mixed in a seven to one ratio with lime to form a stone-like building block. Both of these blocks are stronger and more resistive than similar blocks made with portland cement. Pozzolan, mixed with vermiculite or pumice is useful in the installation of hot water pipes in concrete slabs. When applied as a coating to a pipe, this mixture allows the pipe to expand and contract without damage to the slab. This can be particularly important for solar heating systems which rely on hot water circulating through the slab.

Fly ash, a by-product of the burning of coal for elecrical generators has properties similar to volcanic ash. It is often more available than volcanic ash and since it is at present considered a waste product it is often very cheap. Fly ash can be used in the same ways as volcanic ash.

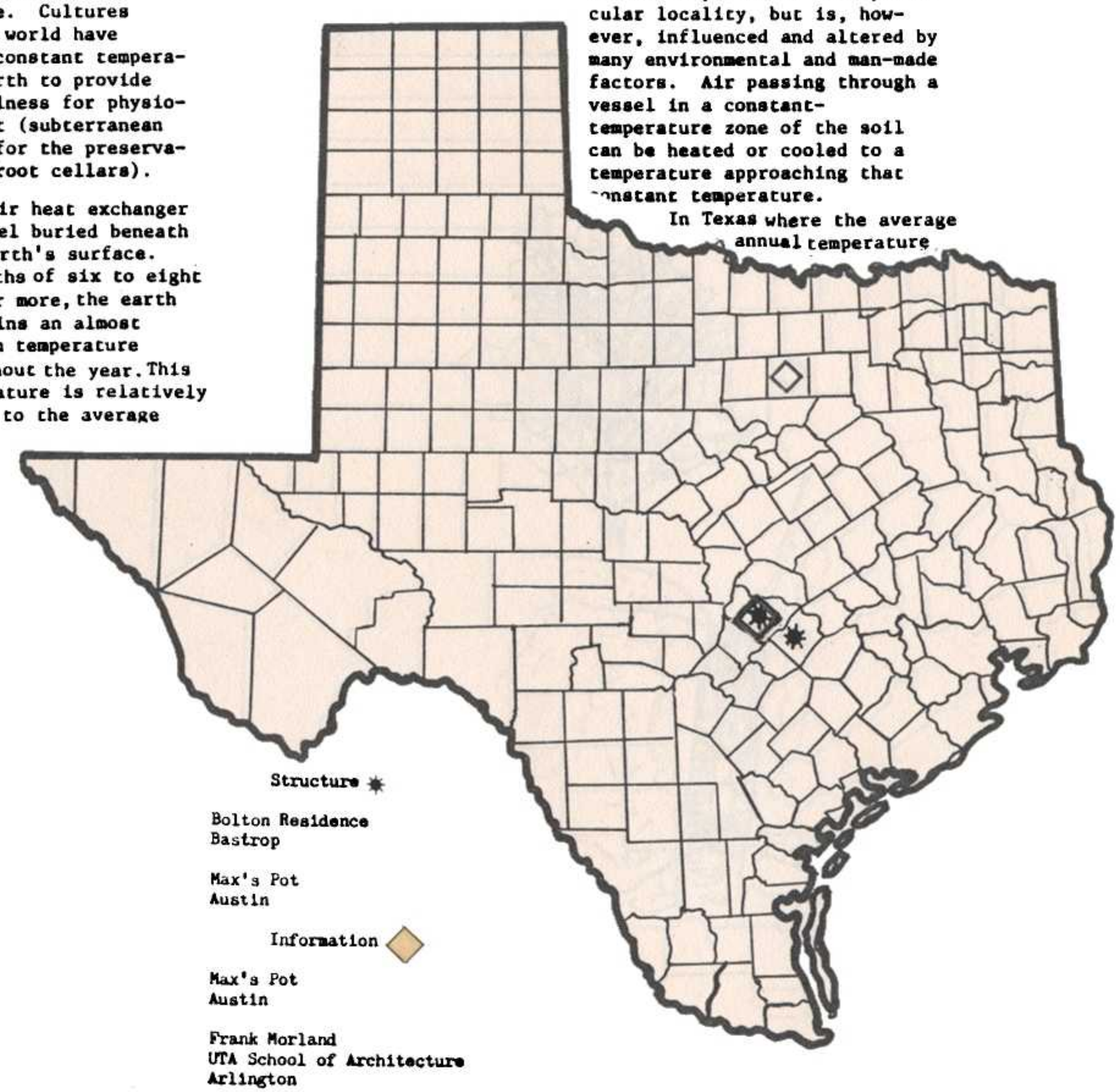
Earth-Air Heat Exchanger

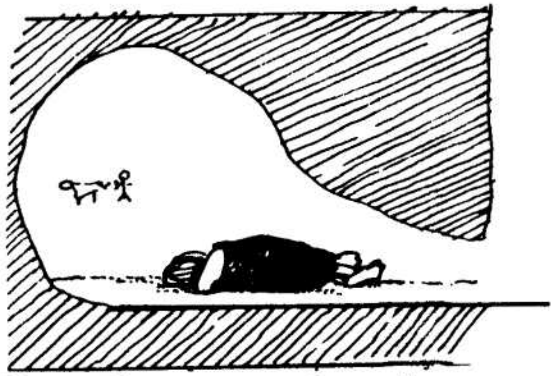


The principle of the earth-air heat exchanger has been relied upon by man ever since the first humanoid climbed down out of the trees and left the tropics for less hospitable climates. Cave-people survived because they could crawl into a hole in the ground and escape the harsh extremes of the climate outside. Cultures throughout the world have relied on the constant temperature of the earth to provide warmth and coolness for physiological comfort (subterranean housing), and for the preservation of food (root cellars).

The earth-air heat exchanger is an air vessel buried beneath the earth's surface. At depths of six to eight feet or more, the earth maintains an almost uniform temperature throughout the year. This temperature is relatively close to the average annual temperatures of a particular locality, but is, however, influenced and altered by many environmental and man-made factors. Air passing through a vessel in a constant-temperature zone of the soil can be heated or cooled to a temperature approaching that constant temperature.

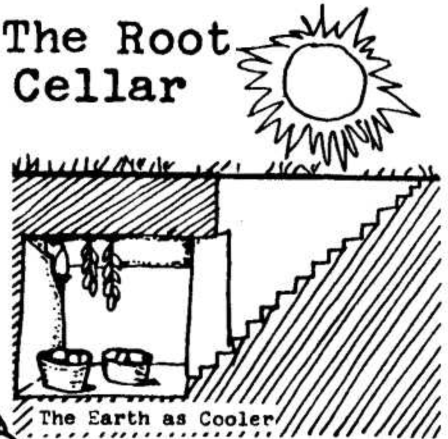
In Texas where the average annual temperature

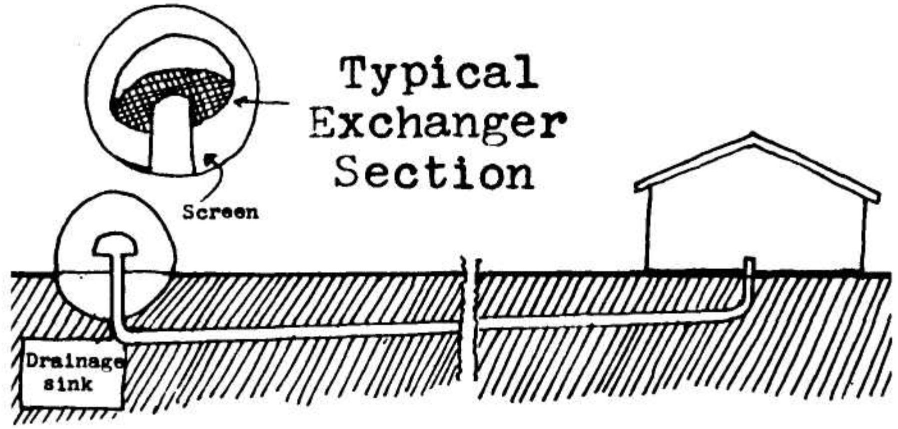




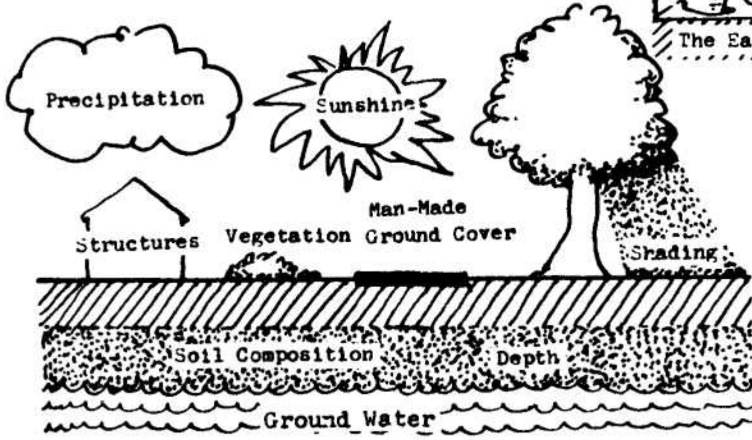
The Caveman's Cave

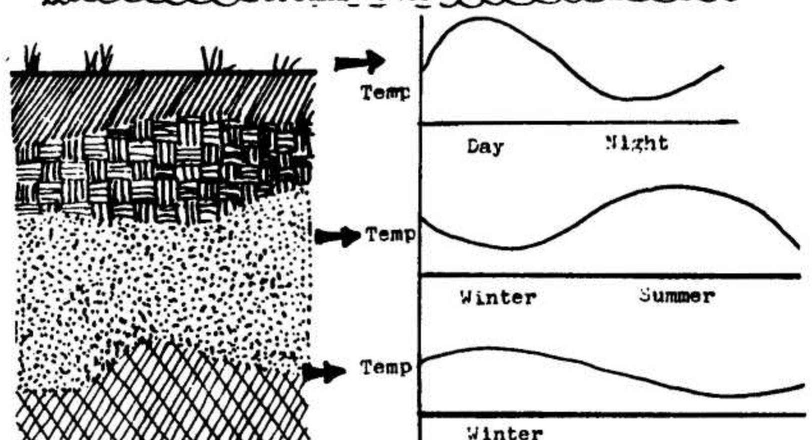
The Root Cellar





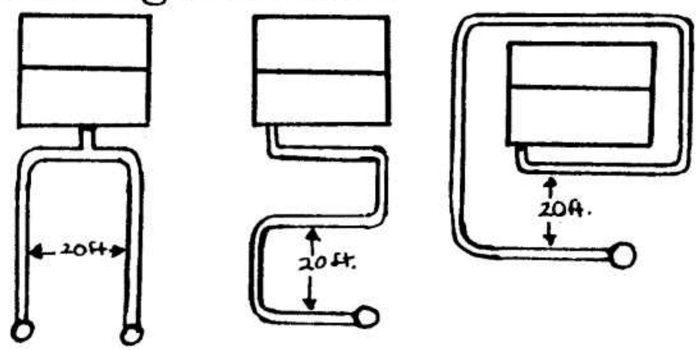
Typical Exchanger Section



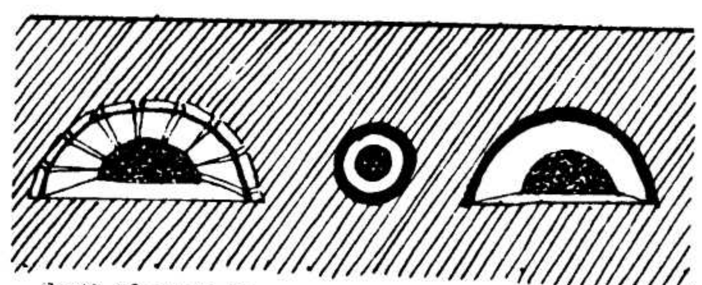


The Relationship of Depth to Soil Temperature Fluctuation

Possible Exchanger Configurations



Types of Exchanger Vessels



Earth Block Vault

Pipe

Vaults Formed Over Bisected Steel Drums

ranges from 56° to °, an exchanger can provide a eat deal of the necessary ating and cooling for a house roughout the year.

The difficulty with earth-r heat exchangers at this int is determining the proper ze for a particular applica-on. An earth-air heat exchan-r must have a great enough rface area to provide suffi-ent heat transfer between air d soil. Thus, the air vessel st be either large in cross-ctional area and relatively ort, or of small diameter and latively long. The air ssel must also be a good nductor of heat like metal, sonry, or concrete. There st also be sufficient air ow through the exchanger to ovide the heating or cooling eds of the house. This quires either mechanical owers or an arrangement such a solar chimney. Earth-air at exchanger sizing is an volved and uncertain process ich must be carefully consid-ed.

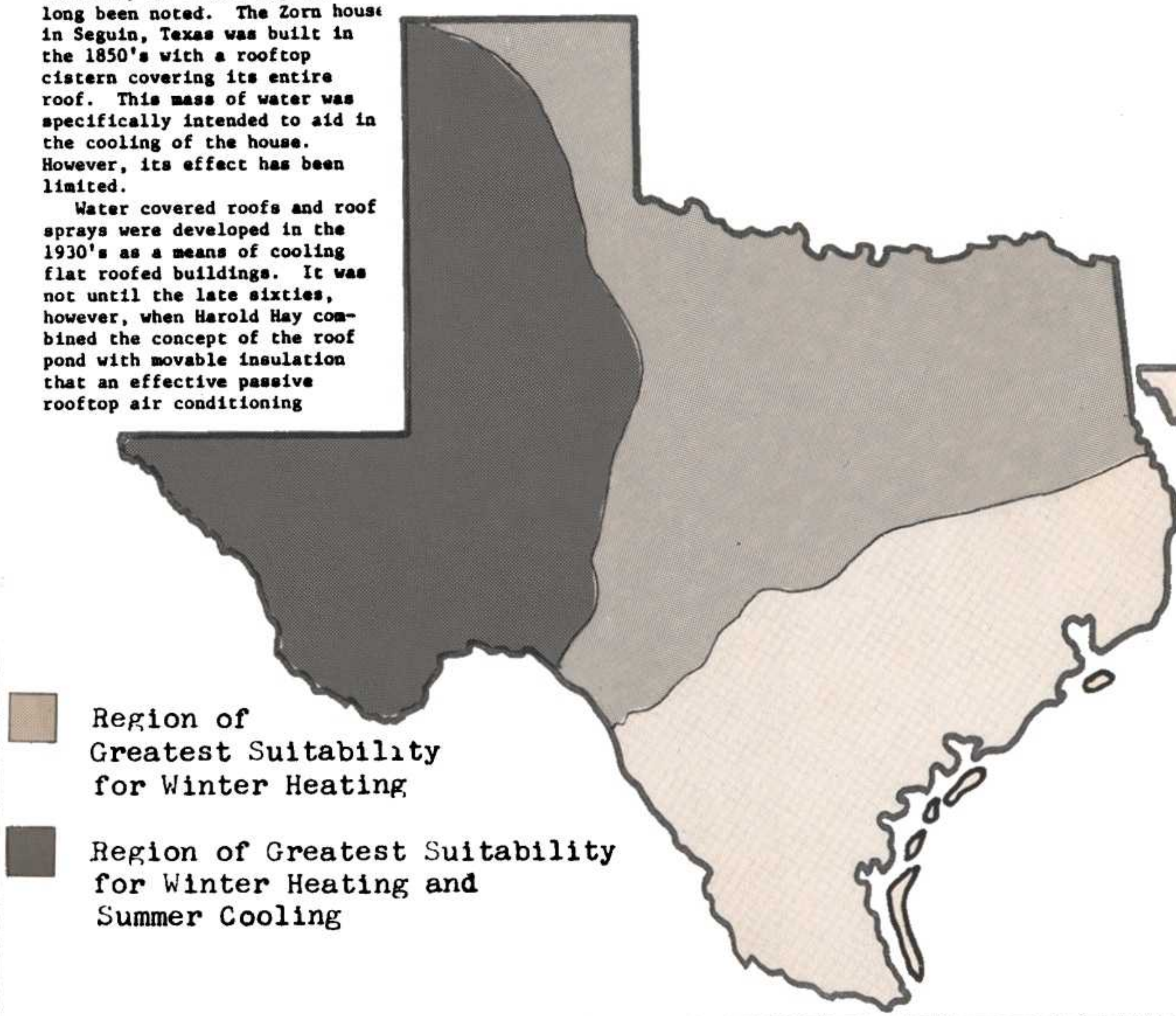
A number of exchanger air ssels have been tested, cluding prefabricated piping, efabricated vaults, and in situ fabricated vaults. Metal and concrete pipe suitable for individual use is generally of small diameter (6"-12") and thus an exchanger must be relatively long. In a site constricted by property lines or soil conditions, the installation of a long pipe can be difficult for to prevent permanent alteration of soil temperature by the exchanger itself, these pipes should be no closer than twenty feet from each other. Vaults on the other hand can be built with large cross-sectional areas and can thus be shorter. They can be built of indigenous materials, but require much labor time to construct and are difficult to waterproof.

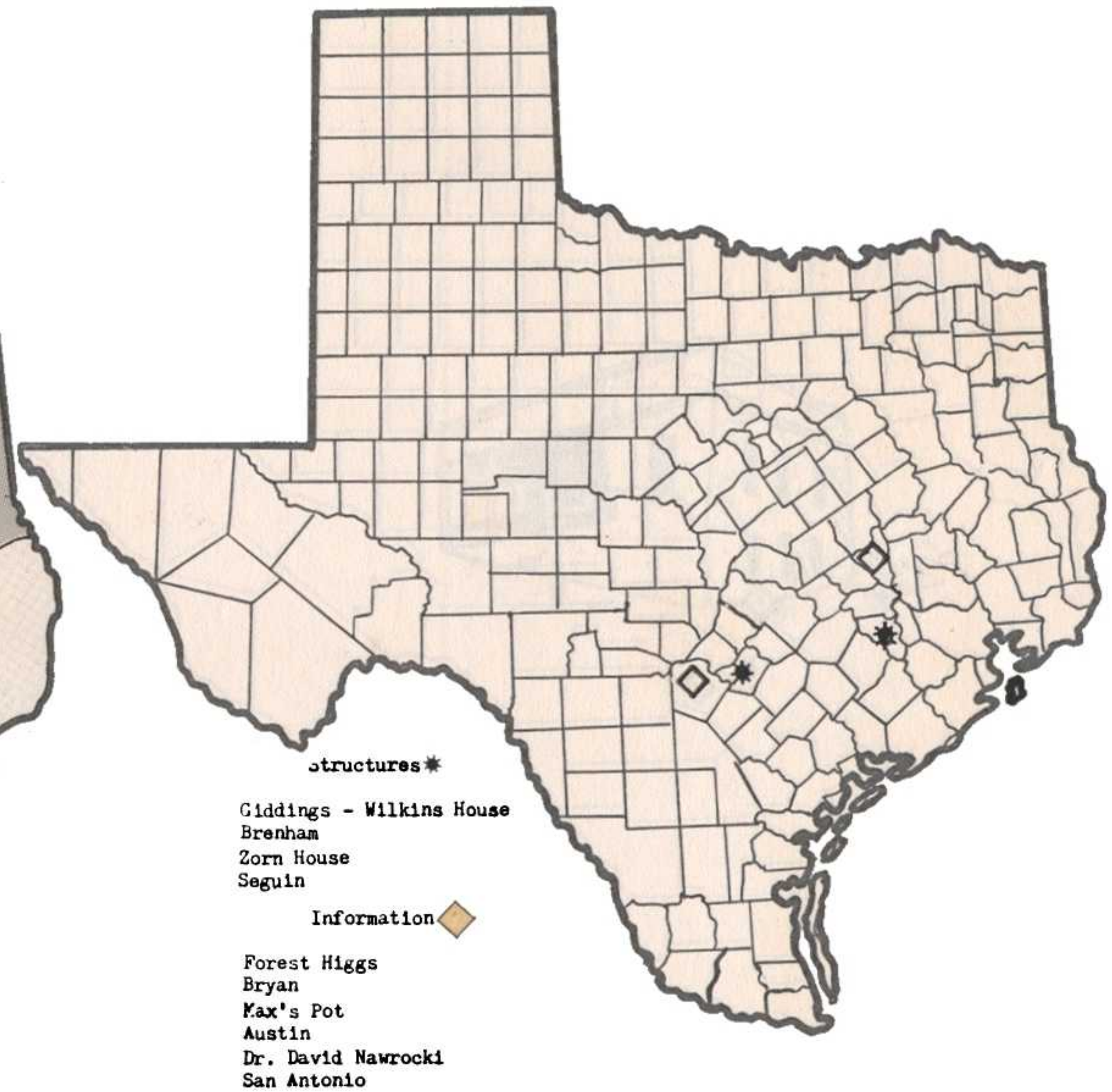
To insure the economic feasibility and proper functioning of an earth-air heat exchanger, a number of factors must be considered. First, the exchanger must be easy to bury, i.e., there must be six to eight feet of soil above bedrock. Secondly, the air vessel must be kept relatively dry and must therefore be properly drained and situated above the water table. If the exchanger is below the water table, provisions must be made to pump out the water. In this case, the exchanger could well serve as a source of water. Thirdly, the air vessel must be unobstructed and allow as free a flow of air as possible in order to minimize the size of air moving devices. Finally, the exchanger must be sealed to prevent the intrusion of insects or animals which could well cause offensive odors and health hazards. A screening of the air inlet of the exchanger is therefore essential. If carefully considered, an earth air heat exchanger should provide a long lasting maintenance free, low energy-use source of air conditioning.

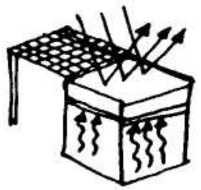
Skytherm

Rooftop cisterns have been used for centuries in many parts of the world, and their contribution to the thermal stability of a dwelling has long been noted. The Zorn house in Seguin, Texas was built in the 1850's with a rooftop cistern covering its entire roof. This mass of water was specifically intended to aid in the cooling of the house. However, its effect has been limited.

Water covered roofs and roof sprays were developed in the 1930's as a means of cooling flat roofed buildings. It was not until the late sixties, however, when Harold Hay combined the concept of the roof pond with movable insulation that an effective passive rooftop air conditioning

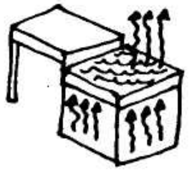






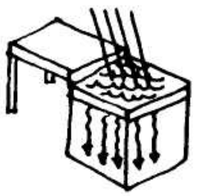
Summer Day

Insulation is Positioned Over Water Bags To Prvent Solar Heat Gain. Interior Radiates Heat to The Roof.



Summer Night

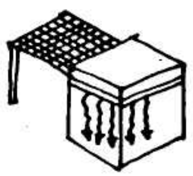
Insulation is Removed From Water and the Roof Radiates Heat to the Clear Night Sky



Winter Day

Water Bags Are Exposed to the Sun and Absob Heat Which

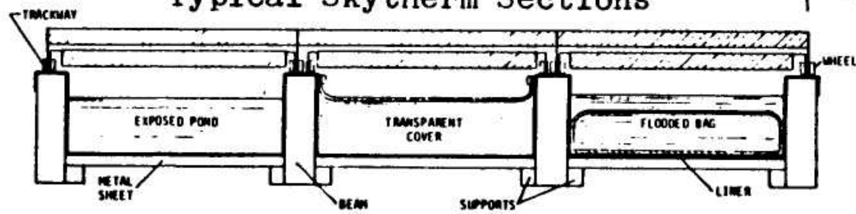
Water Bags Are Exposed to the Sun and Absorb Heat Which is Radiated to the Interior.

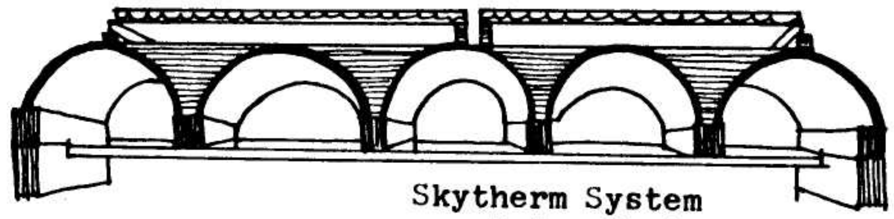


Winter Night

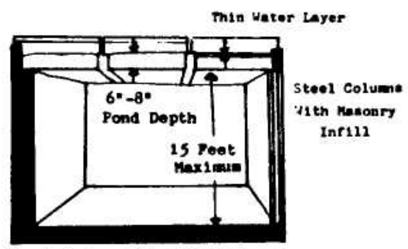
Insulation is Positioned Over the Water, Limiting Heat Loss. The Roof Radiates Heat to the Interior.

Typical Skytherm Sections

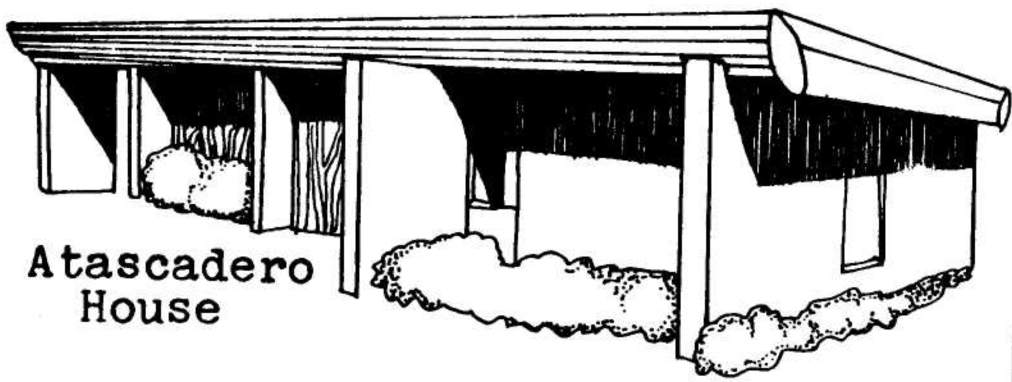




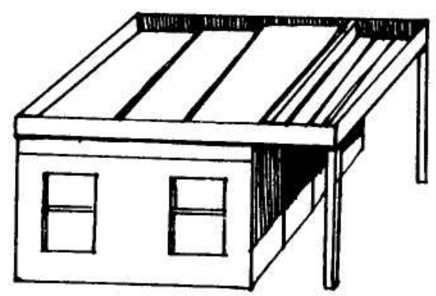
Skytherm System Using Cast Earth-Cement Vaults

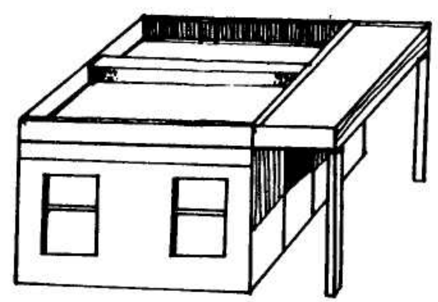


Critical Design Factors

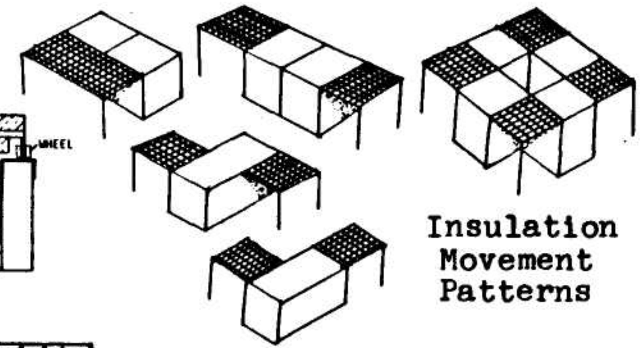


Atascadero House





Typical Skytherm House Configuration



Insulation Movement Patterns

system was developed. He patented his system under the name Skytherm and built the first skytherm residence in Atascadero, California.

The skytherm system relys on water confined in roof ponds by black plastic liners or plastic bags which are in direct thermal contact with the spaces below for its operation. The panels are the sole heat collection, storage, and distribution elements, and provide uniform air conditioning to the area below.

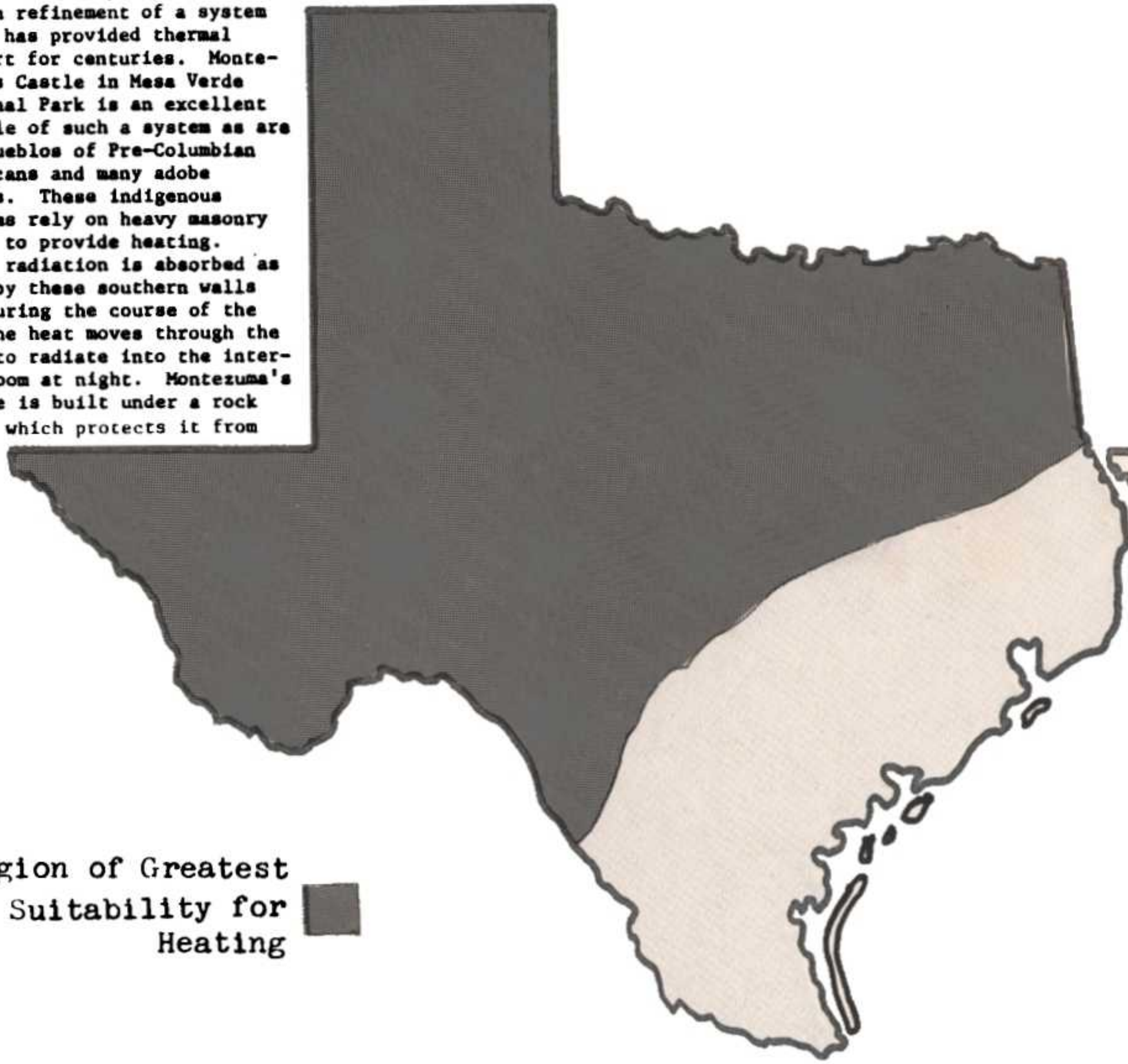
Movable insulation panels above the ponds serve as thermal valves, controlling the flow of heat between the environment and the ponds. During the winter the ponds are exposed to the sun during the day and absorb heat. At night the insulation is moved over the ponds to prevent heat loss, and the ponds radiate heat to the space below. In the summer this process is reversed. At night, the ponds are exposed and loose heat to the clear night sky by both evaporation and radiation. This process can only occur effectively in areas of low humidity. During the day the insulation is moved over the ponds and the water absorbs heat from the room below. The only external energy necessary for the operation of the system is a small electic motor to move the insulation twice a day, and if desired this function can be performed by a hand crank.

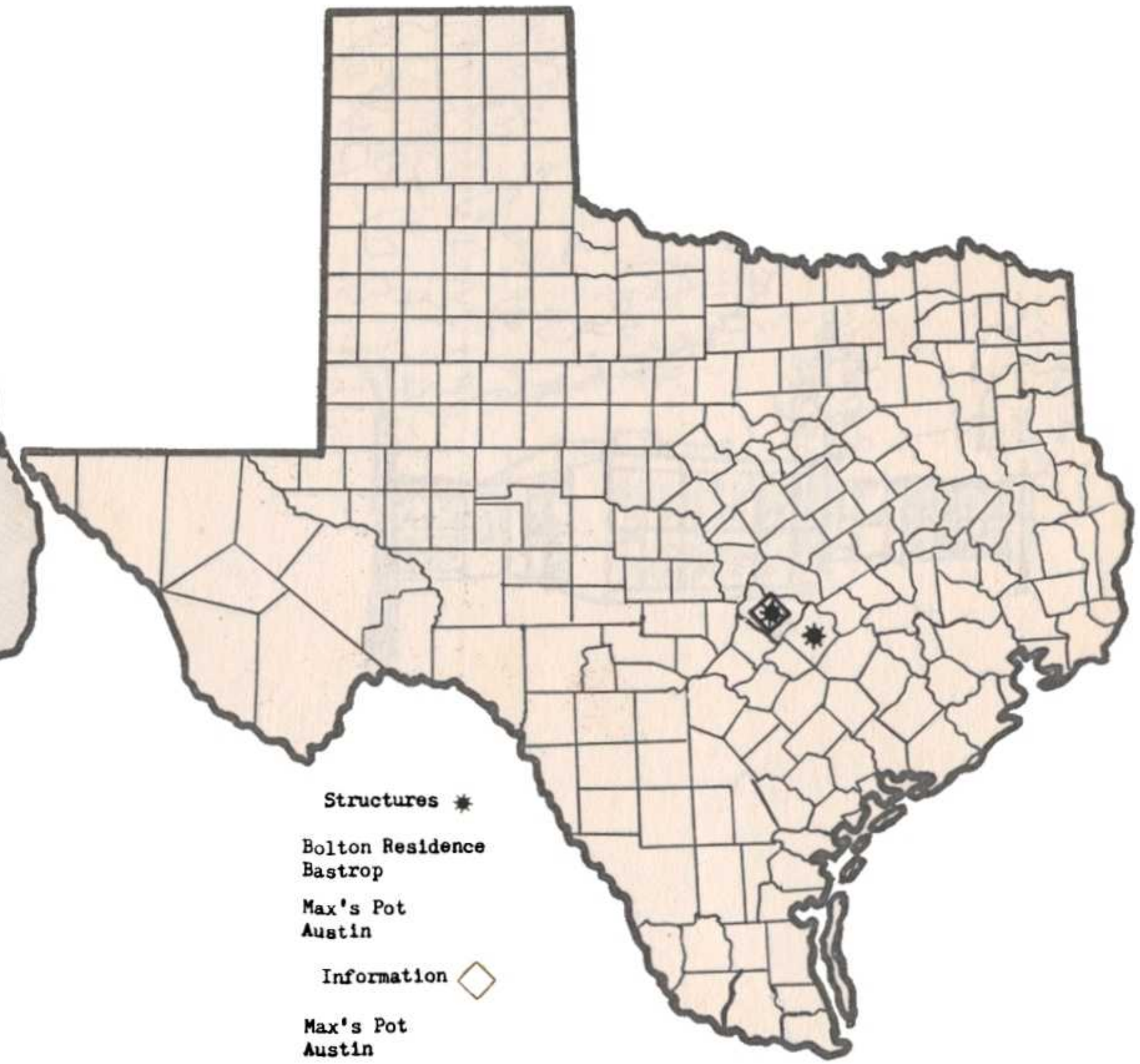
The movable insulation which is the key to Skytherm's operation is also its major limiting factor. Special tracks must be constructed on which to move the insulation panels, and a mechanical system devised to move it. Also, there must be an area to which the insulation can be removed when the roof is in its open configuration. The necessity provides a number of possibilities for the form of the house. The skeletal structure which supports the removed insulation can be used as a carport, or a frame for a solar still or water heating or as a shading device. The mechanical movement of the insulation as well as the flat roof necessitated by the Skytherm prevent its use in areas of relatively heavy snowfall, where ice and snow could jam the mechanism.

Another limitation of the system is the necessity of supporting the great weight of the roof ponds. Steel decking rests on strong beams which in turn rest on strong columns or thick heavy masonry walls. A possible alternative to the decking system is a system of earth-cement barrel vaults although this is a totally untested concept. The thermal mass of heavy masonry walls is complementary to the system's functioning and is thus preferable to a steel or wood column system with infill. Well built thick earth walls provide sufficient strength to support the roof ponds. A Skytherm system on a heavy thermal mass house which is well insulated should be able to supply most if not all of the heating and cooling requirements in a large area of West Texas, and the heating requirements in more humid eastern Texas. Its use in the Gulf Coast area is questionable due to the short heating season in this region.

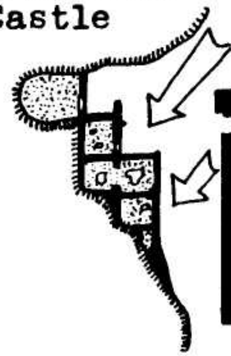
Trombe

The Trombe system is a modern refinement of a system which has provided thermal comfort for centuries. Montezuma's Castle in Mesa Verde National Park is an excellent example of such a system as are the pueblos of Pre-Columbian Americans and many adobe houses. These indigenous systems rely on heavy masonry walls to provide heating. Solar radiation is absorbed as heat by these southern walls and during the course of the day the heat moves through the wall to radiate into the interior room at night. Montezuma's Castle is built under a rock ledge which protects it from

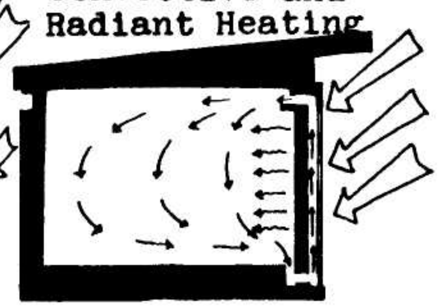




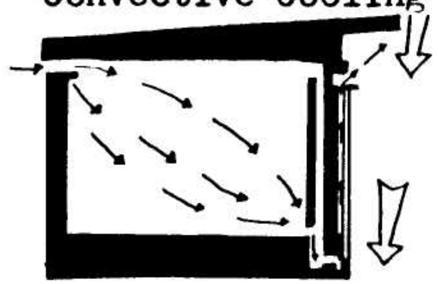
Montezuma's Castle



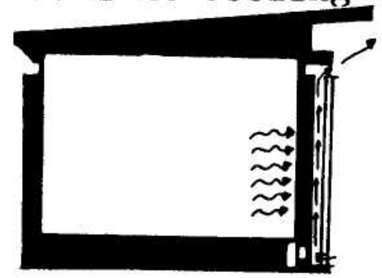
Winter Convective and Radiant Heating



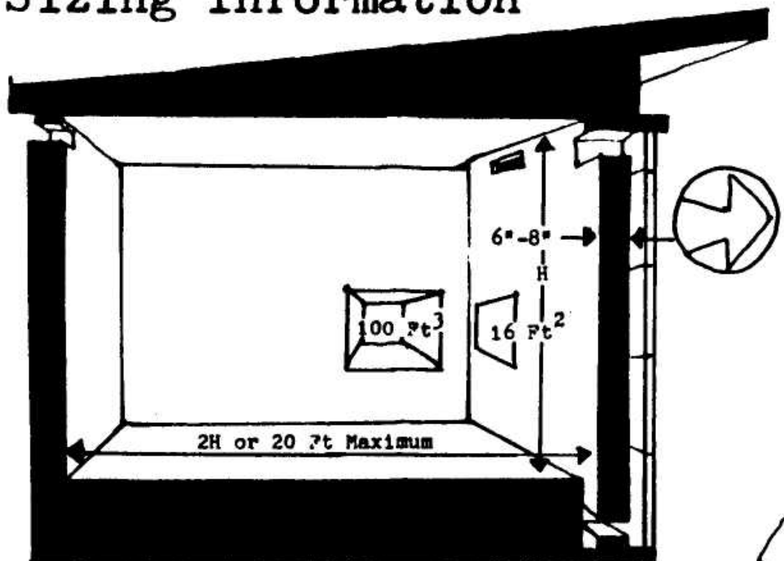
Summer Convective Cooling

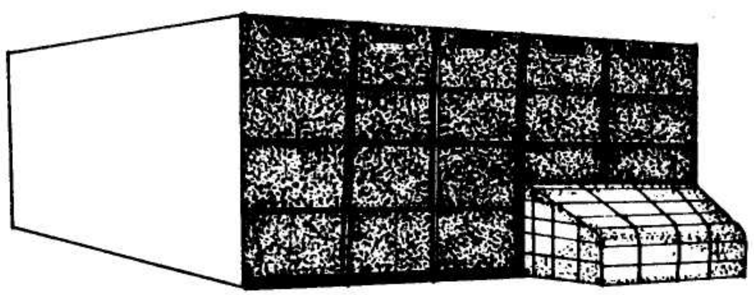


Summer Radiant Cooling

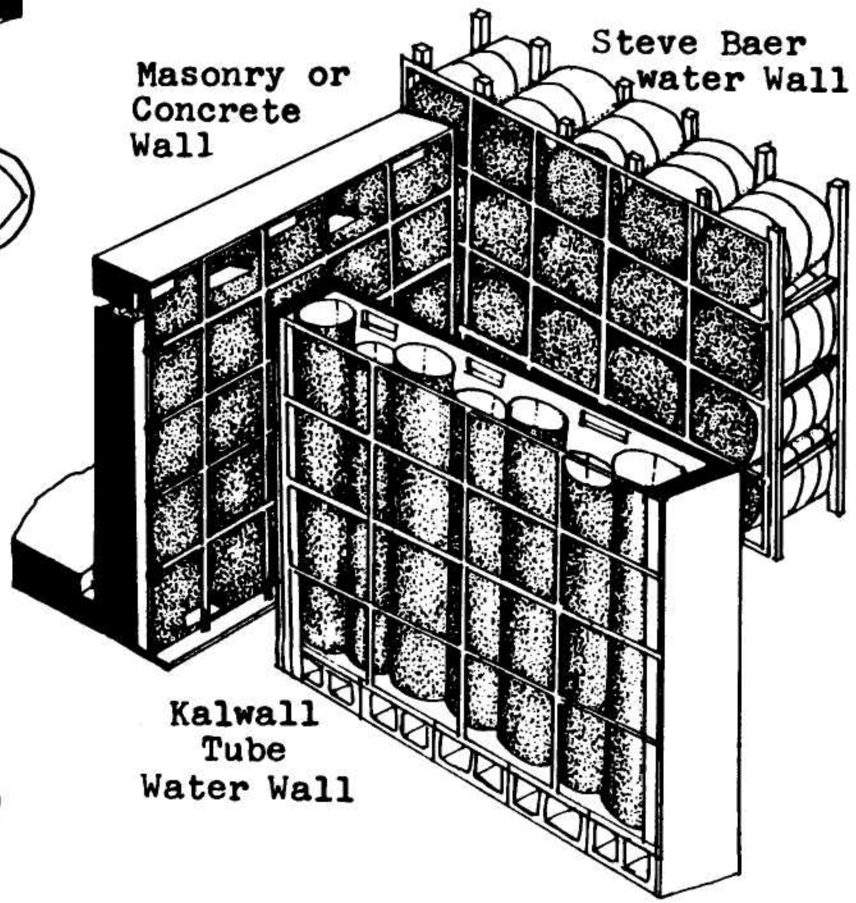


Sizing Information





Kelbaugh House



the summer sun. The thermal mass of these buildings moderates the diurnal temperature fluctuation during the summer, thus keeping the interiors relatively cool.

The Trombe system improves on this theory by putting glazing in front of the wall and painting the wall black. This glazing system first proposed in 1882 produces the "green-house effect" which allows the solar radiation to penetrate, but prevents its reradiation as heat energy. Trombe's innovation was to put adjustable vents in the top and bottom of the wall. This allows a convection loop to be set up, directly heating the air in the space behind the wall. This plenum in front of the wall also provides convective ventilation during the summer when the wall is protected from direct heat gain by a roof overhang. This air flow can in some cases be used to cool the wall itself. Nonetheless, some Trombe wall configurations provide interior movable insulation to prevent radiant heat transfer during the summer.

Trombe walls built up to this time, such the first U.S. Trombe wall in the Kalbaugh residence in Princeton, New Jersey or the Trombes in the Bolton residence in Bastrop, Texas, have been cast concrete. However, masonry block walls are equally suitable. Water in containers is a far better heat storage substance than concrete or masonry, but it lacks its structural strength. The Steve Baer drum wall, while not a Trombe system, has proven the technical suitability and aesthetic desirability of using water in steel drums as a south facing collector wall.

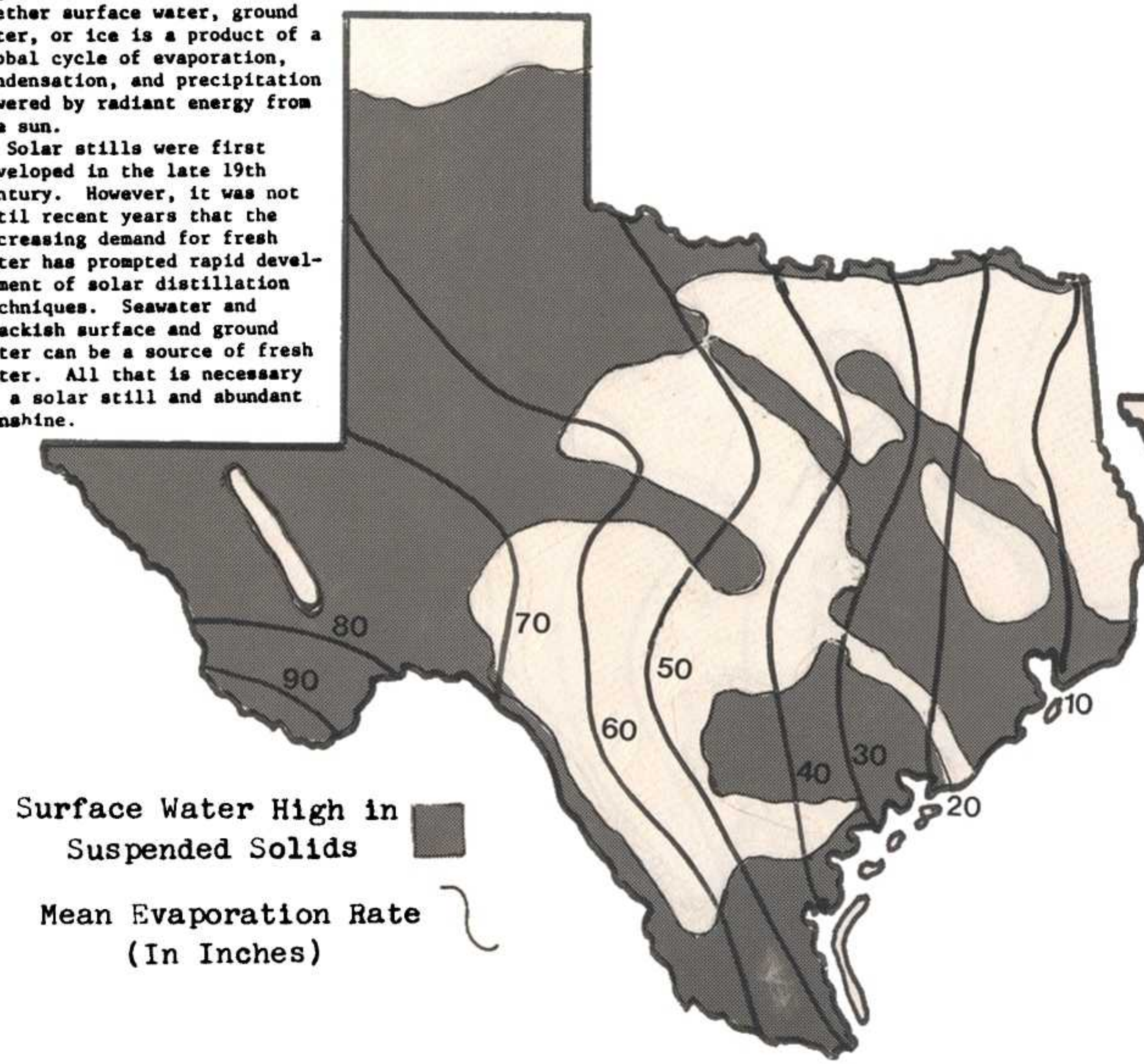
The Trombe system, for all its technical elegance, severely limits the form of the house with which it is integrated. For optimum collection of solar energy, the Trombe wall must be erected on an east west line with a possible variation of about ten degrees. While windows may be placed in the thick wall, they must be limited in order to maximize collection area. The current rule of thumb for trombe sizing is sixteen square feet of wall for every one hundred cubic feet of interior volume. This rule is, however, based on houses built in the Pyrennes Mountains of France. To insure an effective convection loop through the space, it should be no wider than twice the height of the walls with a maximum of twenty feet. The space must be relatively unobstructed so as to allow free air circulation. For this reason Trombe houses should be only one room deep unless other means are provided to heat the northern rooms.

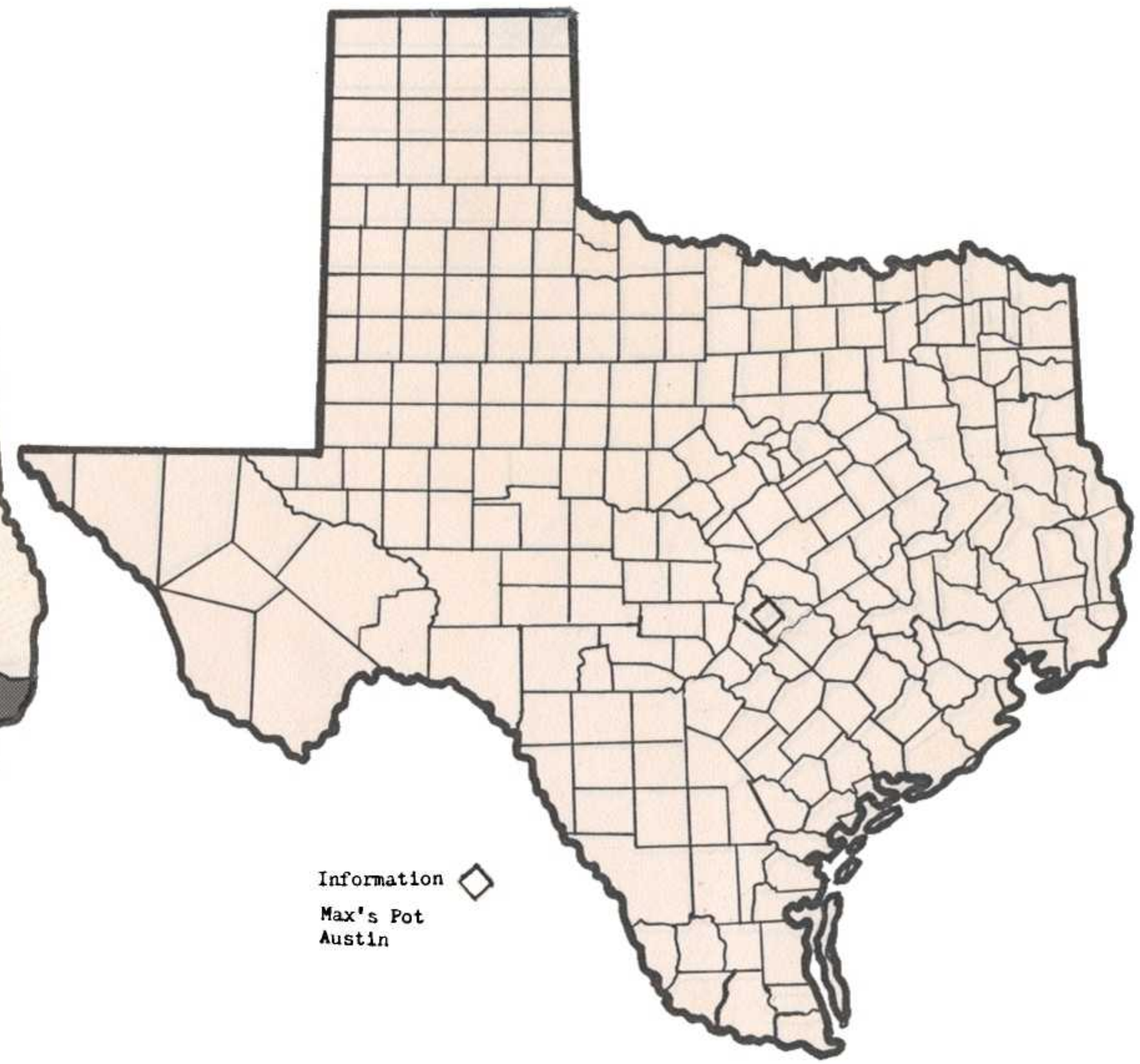
As with other passive system houses, Trombe houses benefit from being well insulated and thermally massive. As in adobe houses, this thermal mass helps maintain a pleasant microenvironment throughout the year, but because the Trombe system is primarily a heating system, the Trombe is best used when heating is more important than cooling.

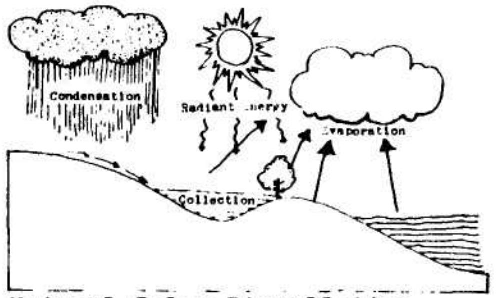
Solar Still

Solar distillation is fundamental to life outside of the oceans. All naturally occurring fresh water on earth, whether surface water, ground water, or ice is a product of a global cycle of evaporation, condensation, and precipitation powered by radiant energy from the sun.

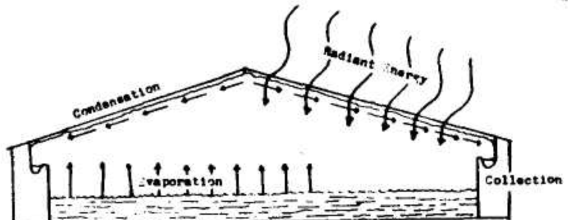
Solar stills were first developed in the late 19th century. However, it was not until recent years that the increasing demand for fresh water has prompted rapid development of solar distillation techniques. Seawater and brackish surface and ground water can be a source of fresh water. All that is necessary is a solar still and abundant sunshine.



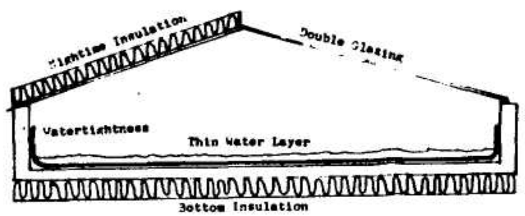




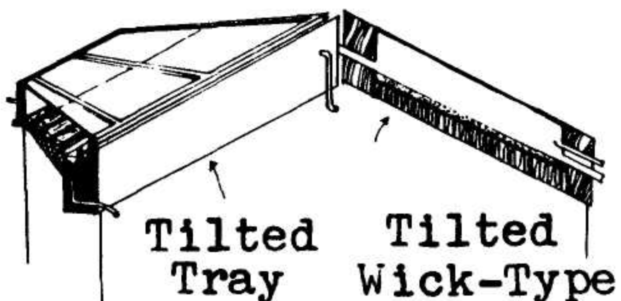
Natural Solar Distillation



Basic Operation of a Solar Still



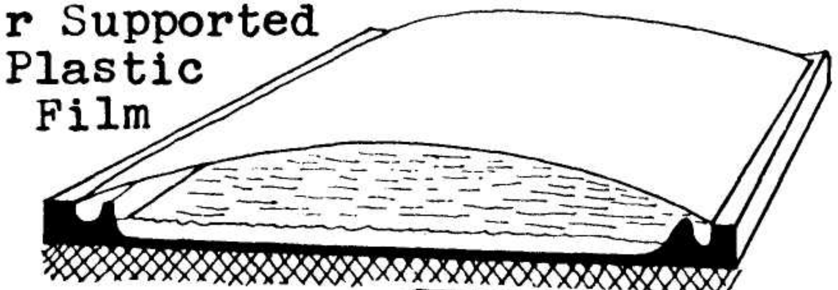
Operating Principles



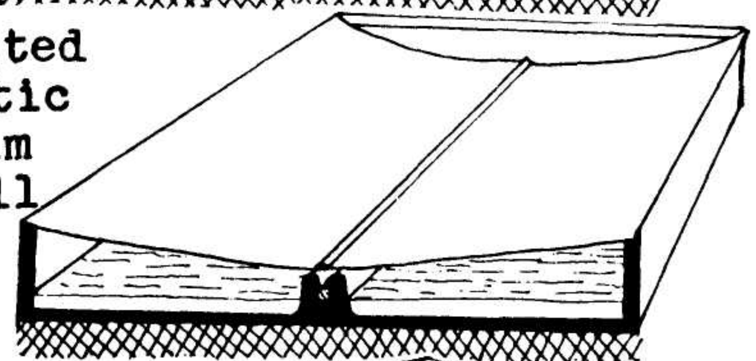
Tilted Tray Still

Tilted Wick-Type Still

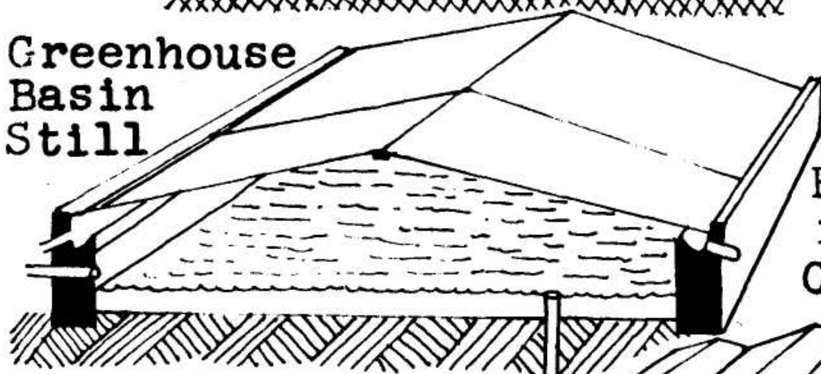
Air Supported Plastic Film



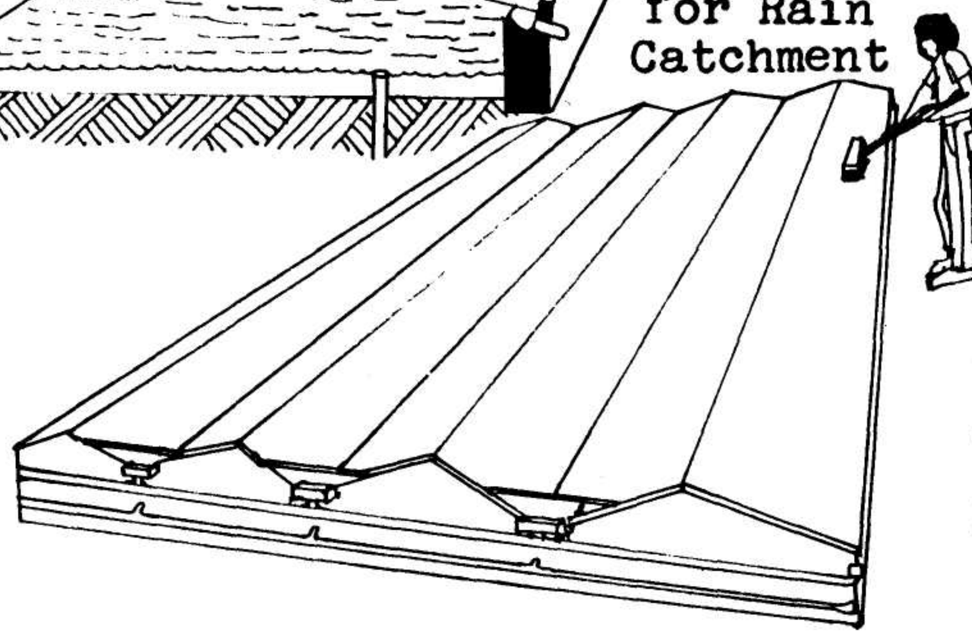
Weighted Plastic Film Still



Greenhouse Basin Still



Basin Still Array Equipped for Rain Catchment



The operation of a solar still is quite simple. Solar radiation passes through a transparent membrane (either glass or plastic) and heats a thin layer of impure water which flows over or in a heat absorbing black surface. Pure water evaporates and condenses on the membrane above, which also prevents the escape of heat energy. The condensed water then flows with gravity into a collection trough and into a storage tank.

The major drawback of solar distillation is the high initial cost of solar stills, and their low output. Twenty five gallons of water per square foot of collector per year is a reasonable estimate of solar still performance in Texas. Yields can be maximized by measures which insure minimal heat loss from the still. Insulation of the bottom of the still, movable night-time insulation, and double glazing are such techniques. A thin layer and slow flow of input water also improves still performance. Finally, the still must be watertight in order to prevent water loss by leakage.

The basin still is the basic still and the type which has been used most widely. It is most economical when used in flat terraces or on flat roofs. The greenhouse type, with glass or plastic in a rigid frame at an angle of ten to fifteen degrees from horizontal is the most popular basin still. It has the advantage of long maintenance free service, but is expensive to build. Recently, plastic films have been experimented with. Large stills can be covered with single or multiple layers of plastic which can either be stretched over a frame, inflated by small fans, or weighted in the center to allow for runoff. These plastics greatly reduce the initial cost of solar stills, but their lifetime is limited by deterioration due to solar radiation. In any type of basin still, costs can be reduced by using the earth or rooftop as the bottom of the still and insulating and waterproofing directly over it. Black plastic or asphalt are good waterproofing materials.

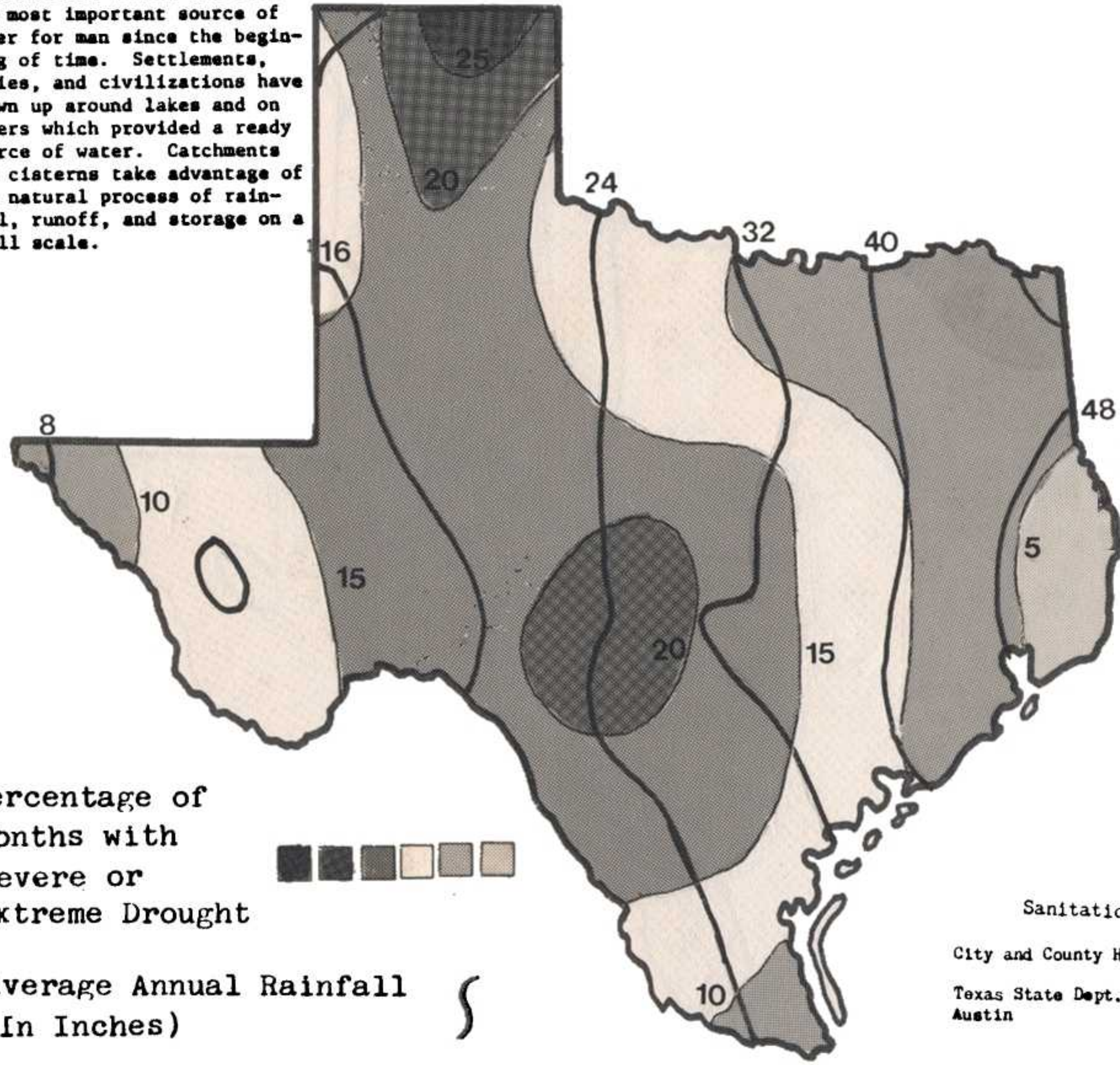
Basin stills can be built in arrays and their glazing used to collect rain water. This can significantly increase the quantity of fresh water produced by a still. In areas where rain is not frequent, the surface of the still must periodically be cleaned to remove efficiency robbing dirt.

In areas of steep terrain, frequent snowfall, or for installation on tilted roofs, basin stills often prove to be economically unfeasible. Two types of stills, the tilted wick still, and the stepped tray still can be used advantageously in these circumstances. In a wick still, impure water trickles through a porous black fabric, which allows a large surface area for evaporation, and causes the brine to flow slowly at a relatively steep angle.

The stepped tray still provides a slow flow and shallow fluid depth by means of a series of terraced trays, down which water flows. These trays can be easily fabricated by forming metal foil over a template. Tilted stills need cleaning less often, and can intercept more radiant energy than horizontal stills. As with basin stills, properly designed tilted stills can be a reliable water supply for individual applications.

Water Catchment and Storage

Rainwater runoff has been the most important source of water for man since the beginning of time. Settlements, cities, and civilizations have grown up around lakes and on rivers which provided a ready source of water. Catchments and cisterns take advantage of the natural process of rainfall, runoff, and storage on a small scale.



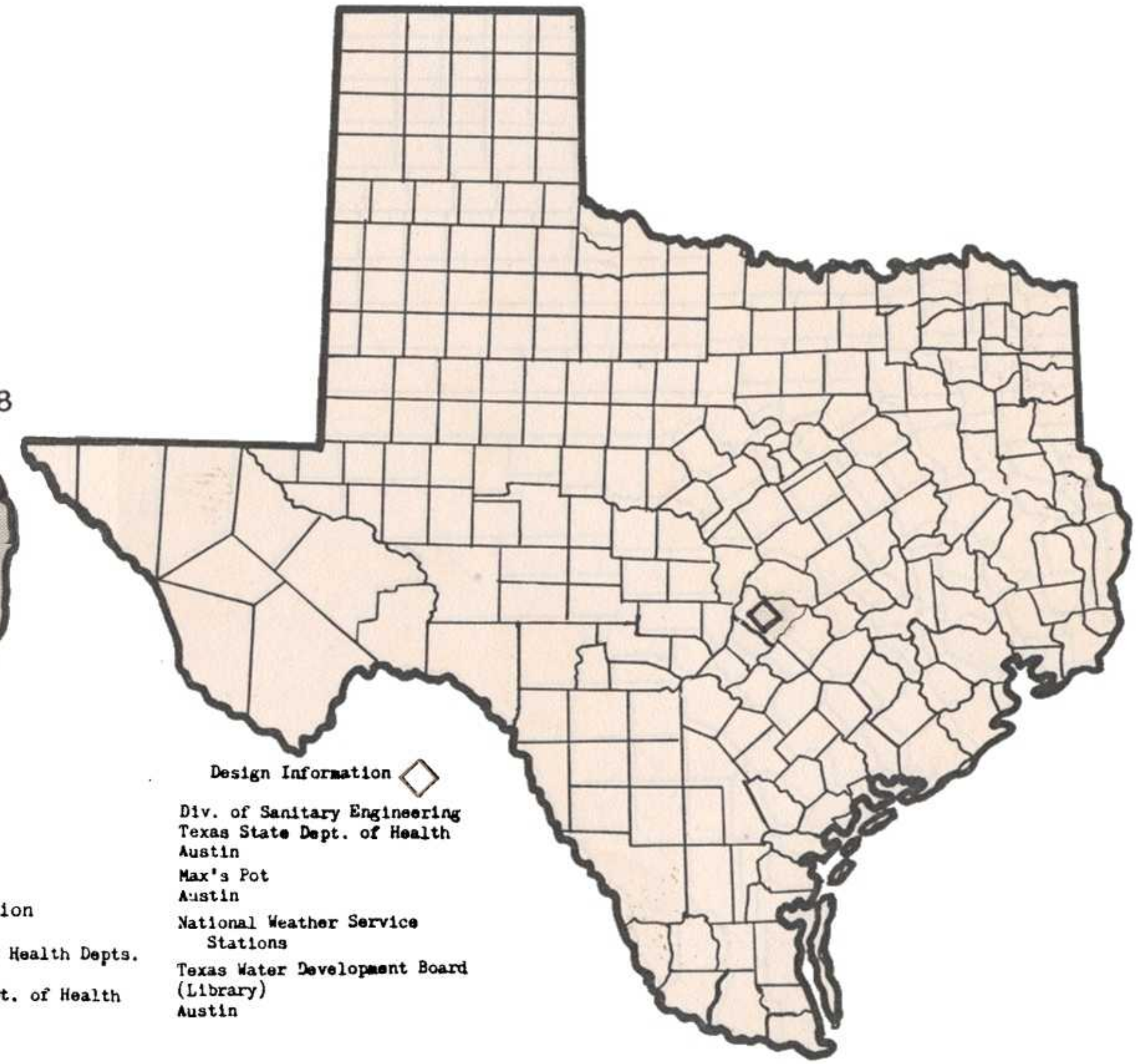
Percentage of Months with Severe or Extreme Drought

(Average Annual Rainfall In Inches)

Sanitation

City and County Health Depts.

Texas State Dept. of Health
Austin



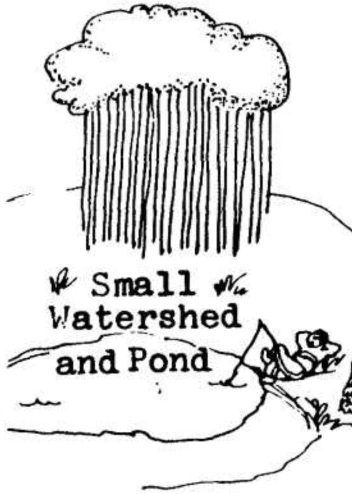
Design Information ◇

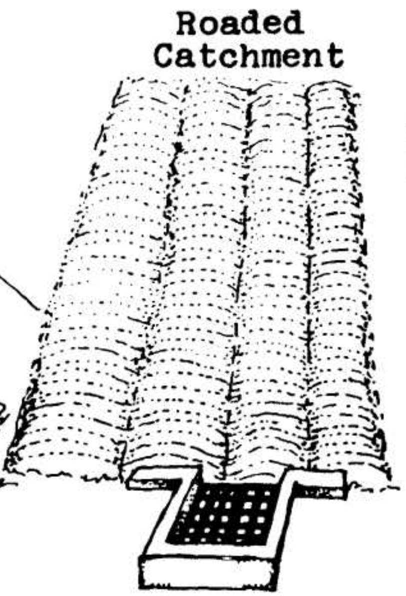
Div. of Sanitary Engineering
Texas State Dept. of Health
Austin

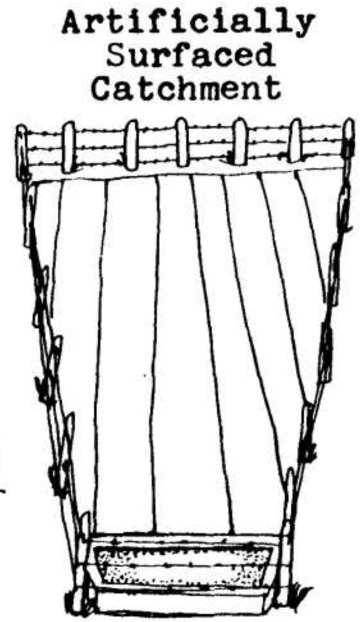
Max's Pot
Austin

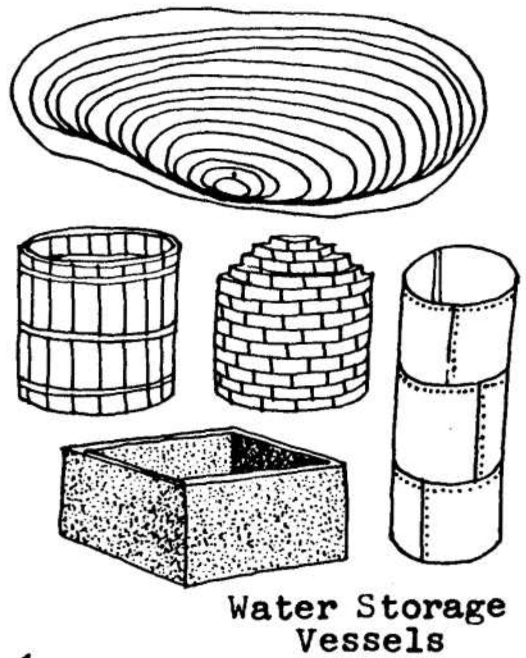
National Weather Service Stations

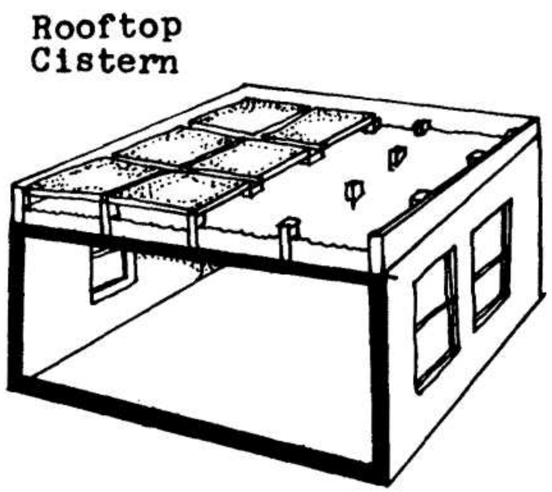
Texas Water Development Board (Library)
Austin

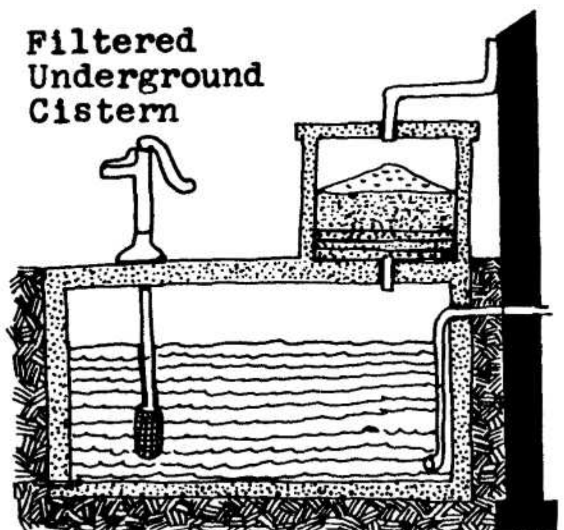


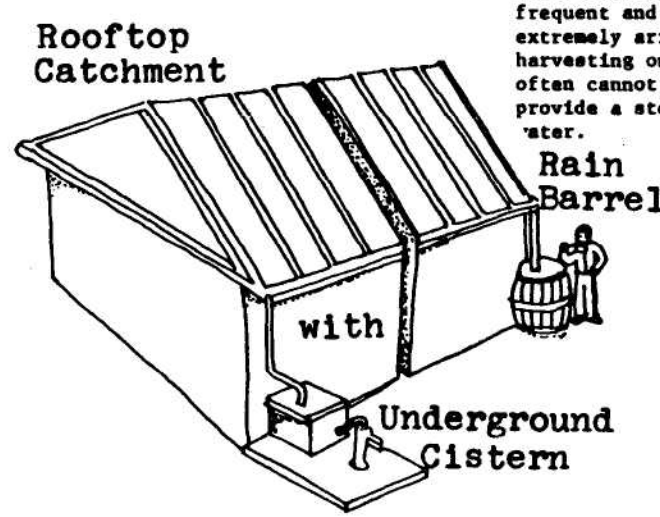












There are two basic types of catchments for small scale application: the rooftop catchment and the surface catchment. In areas of heavy precipitation the rainwater falling on the roof of a building may provide sufficient water. Roof top collectors can either be coupled with a buried cistern or the cistern and catchment can be one and the same. The Zorn house in Seguin has such a rooftop cistern. Rainbarrels, which are still common in some places, are an example of off-roof storage. A more sophisticated cistern wastes the initial roof-cleaning runoff and then passes the cleaner water through a simple sand and gravel filter into an underground cistern. The filtering helps insure pure water and the underground cistern cuts down on water loss.

In areas with infrequent or light rainfall, large catchment areas and large cisterns are necessary to provide sufficient water to carry over between periods of rainfall. In areas where extreme droughts are frequent and prolonged, and in extremely arid regions, water harvesting on a small scale often cannot be relied upon to provide a steady source of water.

The most economical way to obtain a large catchment is to use the land itself as a catchment. Stock ponds, common throughout Texas are examples of simple watershed-pond systems. To increase runoff from an area of land, several techniques have been developed. Grading the surface of the catchment area can increase its water yield. Waterproofing the soil can further improve catchment performance. This can be accomplished in a number of ways. Chemicals can be combined with the soil to make it more impervious, or asphalt or other surfacing materials can be applied. Plastic sheets or corregated metal panels have also proved to be effective. These artifically surfaced catchment areas must be protected against destruction or contamination by animals.

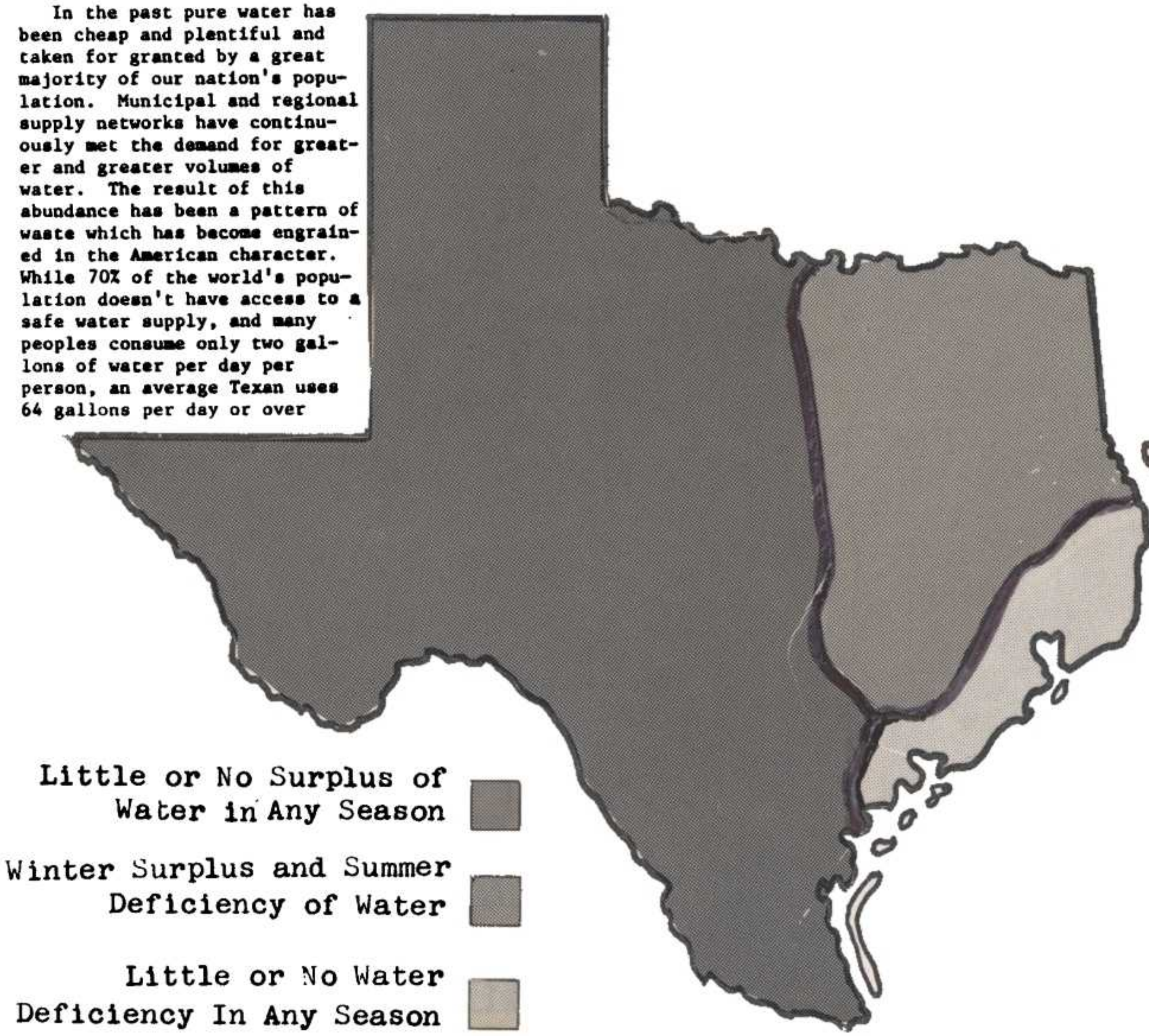
Surface ponds are the simplist water storage vessel, but also allow the greatest water loss, both through evaporation and infiltration and are most likely to be contaminated. Storage in wooden tanks, masonry cisterns, or steel or concrete tanks are more reliable, if more expensive systems of storage.

Runoff should be filtered before being stored and may require filtering or chlorination to insure purity if it is to be used for human consumption. Water quality must be carefully monitored to protect the health of the consumers.

Catchment and cistern sizing is a process with many variables. Hydrology, climate, and water demand are of utmost importance. However, economic tradeoffs with other alternate sources of water supply must be considered also. Local residents and agricultural agents can be valuable sources of information as to the advisability of building a catchment-cistern water supply system.

Water Conserving Bathrooms

In the past pure water has been cheap and plentiful and taken for granted by a great majority of our nation's population. Municipal and regional supply networks have continuously met the demand for greater and greater volumes of water. The result of this abundance has been a pattern of waste which has become engrained in the American character. While 70% of the world's population doesn't have access to a safe water supply, and many peoples consume only two gallons of water per day per person, an average Texan uses 64 gallons per day or over



28000 gallons per year for personal "needs". In an age when unchecked growth is starting to outstrip available water supplies, this sort of profligate waste is clearly untenable. Economically viable individual water supply systems are also unlikely to be able to support such massive water wastage. Thus, steps must be taken to use water more wisely.

Studies have shown that nearly 70% of domestic water usage occurs in the bathroom. Thirty-nine percent is consumed by toilets, and thirty-one percent is used for personal hygiene. After use the water is discarded, flushed into the sewer system and is instantly transformed from a valuable resource into an environmental and economic liability. Clearly, the bathroom must be the prime target of conservation efforts.

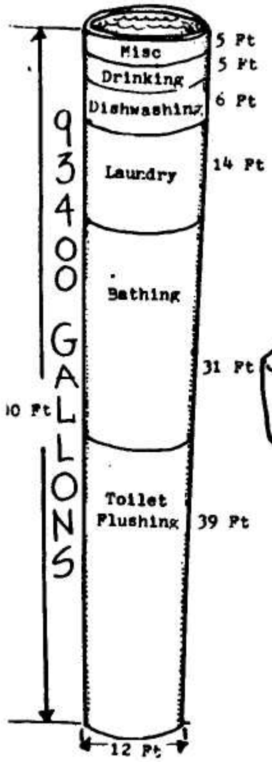
An alteration of Americans' bathroom habits could yield tremendous water savings. Less baths, shorter showers, limited toilet flushing, and closed water taps are a few of the many water conserving techniques. However, our toilets, showers, and sinks are, by their design, wasteful and must be altered.

The simplist and cheapest approach for homes which have normal bathroom fixtures is to retrofit these fixtures to reduce water consumption. Flush water can be reduced by bending the armature on the float ball downward and placing water displacing objects such as bricks or sand filled plastic bottles in the tank. Inexpensive devices are now widely available which require continued pressure on the toilet lever to release flush water. In this way, only the water actually necessary for a particular flushing job is released from the tank. Combined sink-toilets which use water drained from the sink to flush the toilet can be homemade, or ordered from suppliers. Dual flush devices, tank inserts, small tanks and other water saving devices are also readily available. Flow reducing shower heads and faucets sold under a number of commercial names can nearly halve water consumption in showers and sinks. Atomizing shower heads and foot pumps for sinks which dispense only what water is needed for rinsing can even more dramatically reduce water usage.

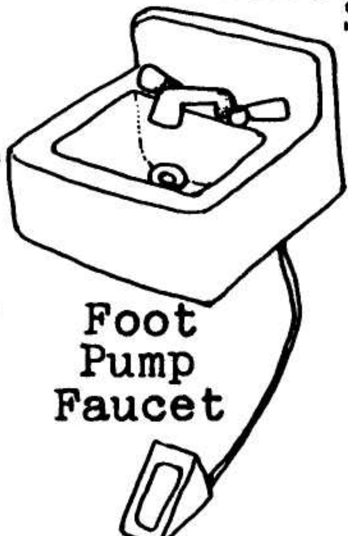
In recent years, a wide variety of alternate toilets have been developed which greatly reduce or eliminate water usage. Mechanical removal toilets collect excreta which is then periodically removed and disposed of. Chemical toilets replace water as a flushing medium with a chemical solution and this solution is recycled for further flushing. Incinerating and freezing toilets are also available, but they merely substitute energy use for water use.

A number of systems have been developed which treat human excretia not as a waste product, but rather as a resource. The ubiquitous pit latrine is by far the cheapest option and can over a period of years produce high quality compost. With a few modern adaptations and some care in siting, pit latrines can be the best alternative for many rural areas. Self composting toilets, first developed in Europe are now available in the U.S. These toilets turn human waste and organic garbage into rich compost by means of aerobic decomposition. These units can be bought prefabricated or may be fabricated by a builder

A number of integrated water production-use-recycling- disposal systems are in various stages of development. These systems deal with the entire problem of water supply, usage and disposal rather than an isolated aspect of it. This sort of wholistic approach is essential to an effective and lasting solution to the water problem.



verage Annual omestic Water Consumption For a Family of Four



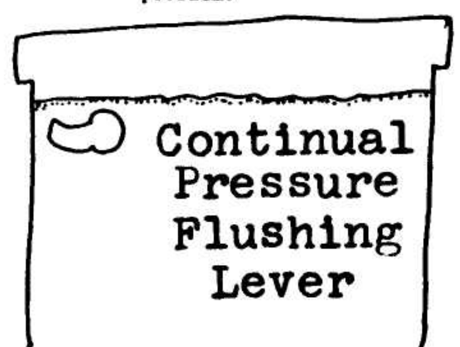
Foot Pump Faucet

Flow Reducing Shower Head

Chemical Toilet

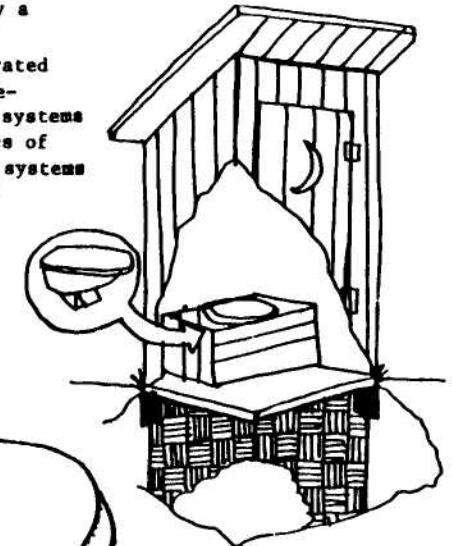
Water Dispacing Bottle Placed in Conventional Toilet Tank

Manual Removal Toilet



Continual Pressure Flushing Lever

Combined Sink and Toilet

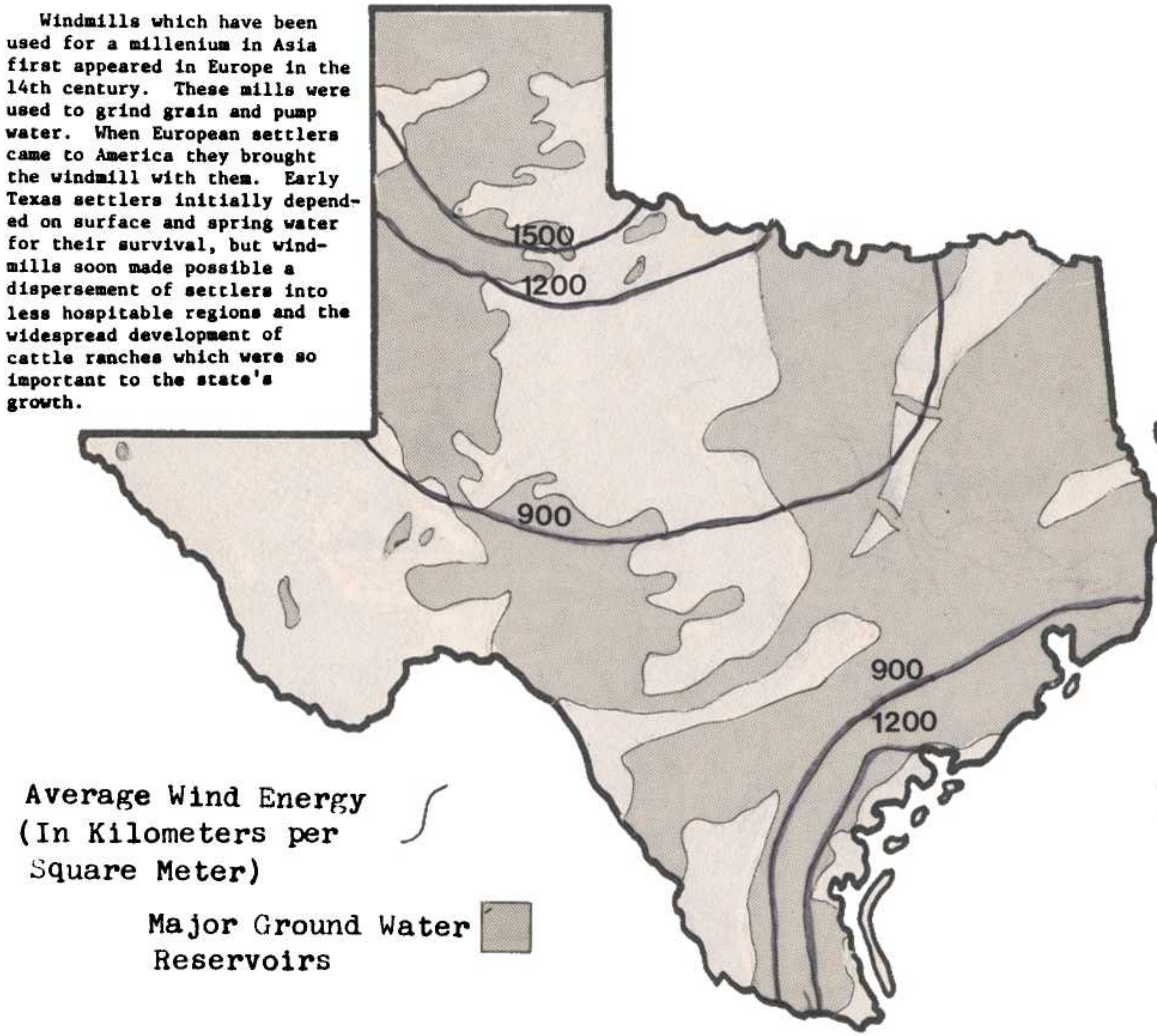


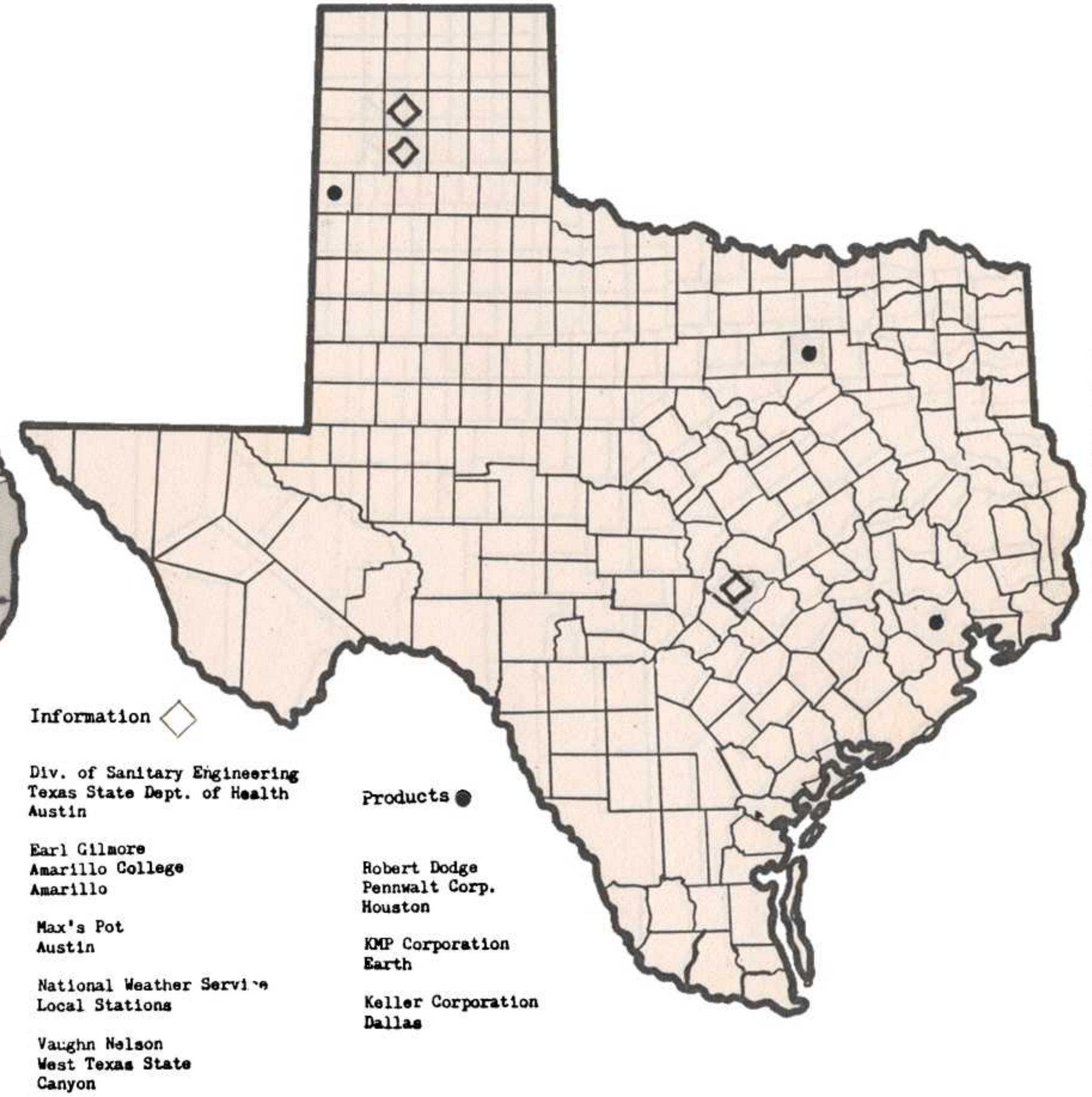
Pit Latrine With Odor Confining Seat

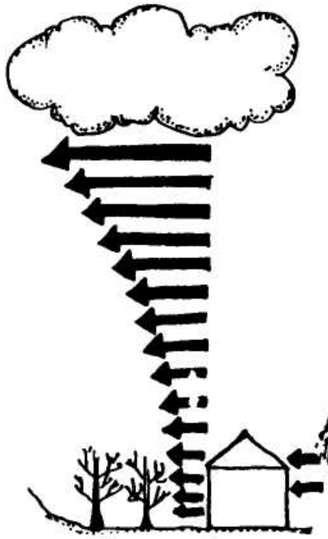
Self Composting Toilet

Water Pumping Windmills

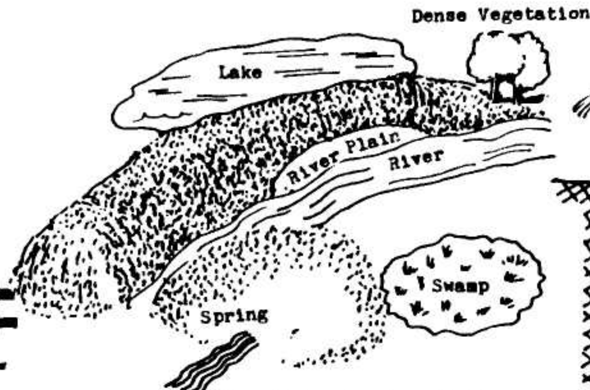
Windmills which have been used for a millenium in Asia first appeared in Europe in the 14th century. These mills were used to grind grain and pump water. When European settlers came to America they brought the windmill with them. Early Texas settlers initially depended on surface and spring water for their survival, but windmills soon made possible a dispersement of settlers into less hospitable regions and the widespread development of cattle ranches which were so important to the state's growth.





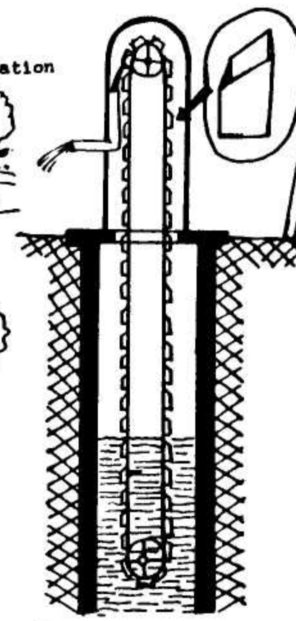


Increasing Wind Velocity with Altitude

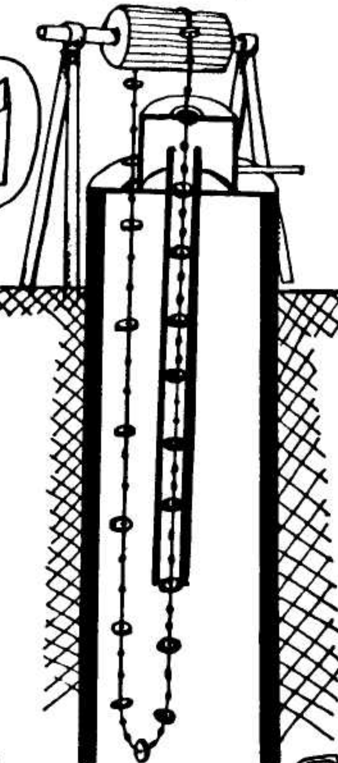


Surface Indications of Ground Water

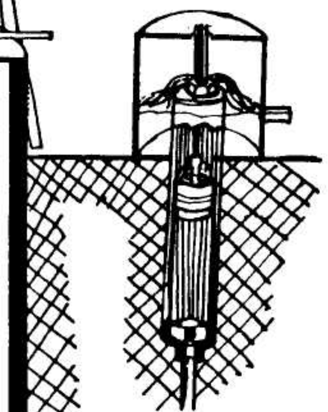
Continuous Bucket-Chain Pump

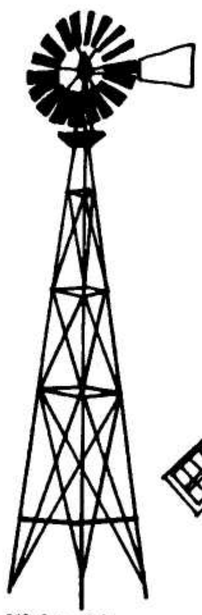


Chain-Pump

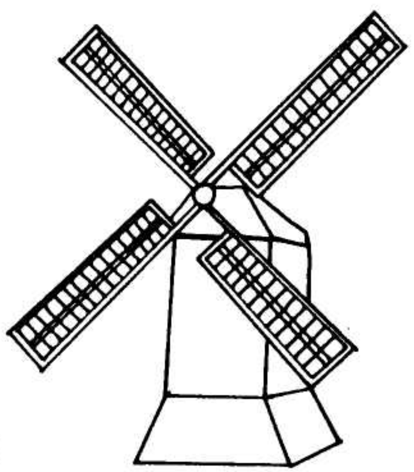


Commercial Reciprocating Pump



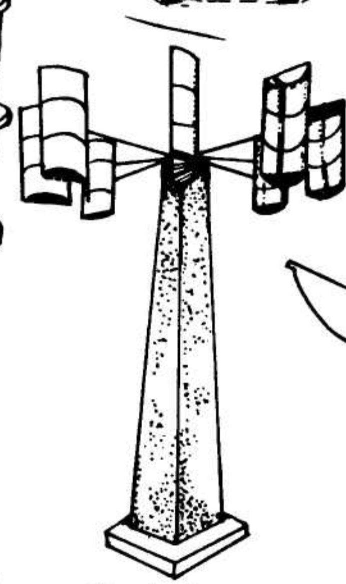


Ubiquitous Multi-vaned Windmill with Steel Tower

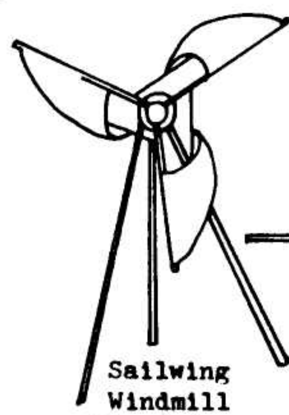


European Windmill

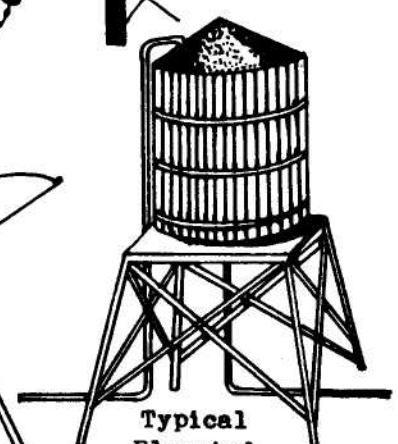
Savonius Windmill with Masonry Tower



Steel Drum Vertical Axis Windmill with Concrete Tower



Sailwing Windmill Mounted on a Tripod



Typical Elevated Water Storage Tank

Before a windmill can be considered, a suitable source of water must be located. Geologic maps of a site may aid this search as may surface indicators of ground water presence. Test pits should be dug and great care exercised in insuring the reliability of the ground water source before an expensive windmill is constructed.

Windmills in Texas today are generally old vintage multi-bladed steel rotors mounted on skeletal steel towers. These windmills have devices which keep the rotors facing into the wind and which turn the mill out of high winds in order to prevent damage to the mill.

Reciprocating piston pumps are combined with bored wells in order to raise water from low to medium depths. Commercial water pumping windmills are available throughout Texas through commercial well drilling and elsewhere. However, effective homemade windmills are well within the technical grasp of most reasonably dexterous individuals.

Homemade windmills are of two sorts. Multi-directional windmills are useful in locations with great variability in the direction of wind. The Savonius windmill can easily be fabricated from bisected steel drums. Likewise, another vertical axis windmill can be made by attaching half drums to a radial spoke arrangement. Single direction windmills are best used in areas with a dominant wind direction such as along the Gulf Coast, or in deep valleys. Otherwise, mechanical arrangements must be devised to continually face the windmill into the wind. The sailwing windmill, an easily fabricated device has triangular cloth sails with wire stays attached to radial spars.

The windmill is only one quarter of a ground water pumping system. The well, pump, and storage tank are the other three components. On a site with a shallow water table, hand dug wells may be economically and technically feasible. In these cases, the continuous bucket-chain pump or chain-pipe pump, both of which can be made rather easily, may be harnessed to a windmill and prove to be a viable means of water raising. Deeper water tables generally require bored wells and commercial pumps. Deep wells can best be drilled by commercial contractors.

A windmill tower is essential to the efficient operation of a windmill. Both wind velocity and wind power near the ground are reduced by surface drag and ground obstructions, and above the surface wind speed increases exponentially with height. Thus an elevated windmill is necessary to take full advantage of available wind power. The tower however, is often more expensive than the windmill itself. Prefabricated steel towers are widely available, but are often prohibitively expensive. If labor is provided by the user, wooden truss towers, earth block masonry towers, and monolithically cast concrete or calcrete towers are attractive alternatives. In any case, the tower must be designed to withstand that lateral force of the wind on the mill and the tower.

A water storage system must be coupled with a wind powered water pumping system. Storage should be provided to provide for prolonged periods of calm. Water tanks may be of any sort, but should be elevated above the point of use to provide sufficient hydraulic head.

When well constructed and maintained, windmills have proven to be a reliable source of water throughout Texas.

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