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Harpole, Tom
Construction of
geothermal/solar
hybrid greenhouse
on Warm Springs
Creek in Avon,
Montana

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CONSTRUCTION OF GEOTHERMAL/SOLAR
HYBRID GREENHOUSE ON
WARM SPRINGS CREEK
IN AVON, MONTANA

Prepared for
MONTANA DEPARTMENT of NATURAL RESOURCES and CONSERVATION

JUL 7 1993

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CONSTRUCTION OF GEOTHERMAL/SOLAR HYBRID GREENHOUSE ON
WARM SPRINGS CREEK IN AVON, MONTANA

Prepared by

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October, 1982

Prepared for

Montana Department of Natural Resources and Conservation
32 South Ewing, Helena, Montana 59620
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Final Report on Construction of Geothermal/Solar
Hybrid Green House on Warm Springs Creek in Avon, Montana

"How can 85° - 90° water flowing at about 40 g.p.m. be used to grow food year round?", is the question I've asked for a number of years around the state. No one has done this yet to my knowledge even though a few attempts have been made with much warmer water temperatures (140° - 180°) with some success.

The problems inherent in the system are many. Calcium carbonate buildup in the pipes can effectively reduce the flow and thus the heat exchange efficiency within a few years. Attempts at using this lower temperature resource have resulted in less than year round crop production because the buildings weren't built properly. Thermal storage must be considered over simpler air heating pipe grids. The building must be capable of storing heat while having enough glazing to allow sufficient light levels for good growing conditions. The design must allow for passive ventilation that can cool the building in the summer.

Basically, what is called for then is passive solar greenhouse design with geothermal heat transfer and storage capability.

There are a number of very good design books out on passive solar greenhouses and we gleaned what we could for the particular site and needs we have. What we will largely address in this missive are the design and construction of the bottom 12 inches or so of our greenhouse which is where the heat exchange grid is. We will presume to instruct as this is a didactic piece as far as we're concerned and the

building is set back on our hill and it is working. The main point to remember when building something you want to store heat in is don't let it leak. Greenhouses must be built like boats. Every place in a building where air can leak in or out must be sealed. Then you have to protect your wood from rotting with caulk and sealant and visqueen vapor barriers and duct tape. When a greenhouse is built you should be able to leave your hose on in there and the only place for water to get out is where you let it. I will probably wear this theme out in the paper but we can't stress this point enough.

When choosing a site for a geothermal greenhouse proximity to the source is the first obvious determinant. Heat loss and friction loss in the pipe are important but most important is the fact that the buildup of Calcium Carbonate (CaCO_3) in the pipe can be a problem almost immediately depending on the type of pipe used.

Galvanized steel, Black steel or Iron pipe have all been used at the phosphate mine on Rock Creek west of Garrison because of the high pressure requirements in a deep hole. Their springs run at about 140° and have been used for years for everything you need need water in a mine for and Keith Parsons, the mine superintendent told me a 1 1/2" pipe of any type metal will be at least half plugged up from CaCO_3 within a couple years. In the shower my grandfather built on this place, he had to replace the pipes every two years if the water was left running year round. Electrolysis can also eat up your pipes where combinations of metals are used such as aluminum pipe with brass fittings or steel pipe with copper valves. Somehow the minerals in the water react with the metals in the pipe system and cause your pipes to go to hell in a hurry. How I don't know but it's a fact.

If you have to bury a lot of pipe, you don't want to dig it up or abandon it especially if its buried in a building as a heat source so we had to use P.V.C. pipe schedule 40 160 P.S.I. (2 inch diameter) and what we lost in the heat transfer characteristics we gained in useful life of the materials which can be indefinite if you have mechanical accessibility to all of your pipe. This means all the way to the source where the water enters the pipe. An interesting thing to note about CaCo₃ buildup in pipes is that the closer your pipe is to where the water emerges from under ground, the less buildup you get. This is because the oxygen hasn't had a chance to combine with the minerals in the water and make it turn into CaCo₃. This folklore approach to known chemical substances and reactions may not be the most academic pronouncement in this lecture but it's empirical evidence nonetheless. To acquaint yourself with what CaCo₃ is, pour apple cider vinegar or hydrochloric acid on the whitish crusty looking rock around a worm spring. The foaming rock indicates CaCo₃.

In choosing the site for construction of a Solar/Geothermal Hybrid Greenhouse, all the requirements of a solar greenhouse would be observed plus the proximity to the spring itself.

Concrete footings are necessary to build on, and in our building (because of the mechanical accessibility) we had to have clean-out pipes in all of the grid. These pipes had to be accessible from outside our building after the grid was buried. To accomplish this, we drilled 3" holes through the 2" x 12" wooden concrete forms and put 16" pieces of 3" diameter P.V.C. pipe through the footings. When the forms were stripped after pouring the concrete we had a 12" x 12" concrete footing with a 3" diameter access hole running through it every 16 inches down the entire length of

the south wall footing (slides # 5, 6, 7). These access holes will be discussed later when the pipe grid installation is explained. Because we wanted an earth bermed building, we excavated into a south slope to a depth of approximately 6 feet. Next we formed and poured and north west and east walls of the green house and north and east walls of the first floor of the solar chimney. Slides # 10 -15 show the details of the construction. The north wall is 65' long, and 6' high. To properly reinforce the north wall, 3/8" rebar was used every 12" vertically and horizontally. As in the south wall or knee wall footing 6 inch anchor bolts were placed every 3 feet in the top of the concrete to anchor the plates for the knee wall and rebar plates on the north wall (slide 9a). To tie the rebar together between the north wall footing and north wall rebar was placed vertically every 2 feet by about 4 feet tall in the north wall footing. (slide 9b)

Since the north wall would be bermed, we had to waterproof and insulate it. Bantonize was purchased from Bob Olson in Helena, Montana to do this. We bought 105 gallon buckets of trowel grade Bantonize to cover the west, north and east wall (500 square feet). Bantonize is a brand name for bantonite alcohol and glass fibers in a trowel applied muddy solution that is spread on a vertical surface 1/4 inch thick and then 2" styrofoam insulation was pressed onto the applied Bantonize and a 6 mil visqueen vapor barrier was stretched over the whole works to hold it in place until we were filled. Two people applied the bantonize in about 9 hours working together on 4' x 6' sections of wall at a time so the insulation could be stuck to the still moist Bantonize. We think the Bantonize was very nice to work with and it has the best guarantee in the water proofing business. (Slides #16,17)

The solar chimney is located at the east end of the building. Its ground floor serves as an airlock entry and potting shed. The second floor will be the thermal chimney and food drier.

Since the airlock will have minimal solar gain it was kept to minimal size in all dimensions. Again every construction technique we know to seal all joints and make vapor barriers was used. The inside of the ground floor is 8' x 12' x 6'4" in height. It was built like a walk in cooler with R32 walls and ceiling and R12 insulated concrete slab floor. When the door is slammed your ears pop like in an old Volkswagen.

Slides #18 through 23 show the airlock being built. Slide #22 shows details of seam caulking on the front door and the insulation that are representative of the construction of the whole building.

Building materials used in this entire building were chosen from what is available, cost effective and sensible in a very humid environment. Cedar and Redwood have the qualities of being extremely moisture and rot resistant but are prohibitively expensive. Larch was chosen as our framing material both for its strength and moisture resistant qualities.

Thompsons Water Seal was used in three and four-coat applications on all wood in the building. Sike-Flex caulk was used for all seam caulking where photo-resistant caulking was required and Butyl-Flex was used where caulking wouldn't be exposed to the sun.

The solar chimney was the first part of the building with any wooden framing in it and we wanted to establish on that part of the building the patterns of water proofing the wood and sealing any joints or seams in the building where infiltration was possible.

The geothermal pipe grid (slides #24-26) was the subject of quite a bit of discussing and discussion before the final design was decided. The previous discussion on what kind of pipe to use finally led us to agree that P.V.C. pipe was the way to go. Schedule 40 2" diameter P.V.C. pipe has a pressure rating of 160 P.S.I. This would more than cover the 25 P.S.I. we predicted the system would have. However, the schedule 40 P.V.C. is built to handle 76° water. Since we are using 90° water at its source and the water temperature leaving the system is around 74° we looked into using C.P.V.C. (chlorinated poly vinyl chloride). This C.P.V.C. can handle water temperatures of 160° at 180 P.S.I. P.V.C. 2" pipe costs \$.33 per foot. C.P.V.C. 2" pipe costs \$2.92 per foot. We needed 1000 feet of pipe. We think because of the low pressure demanding on the P.V.C. pipe it will work just fine. P.V.C. pipe with 85° water in it wouldn't be used for drinking or cooking as those temperatures are suspected of breaking down minute amounts of the poisons they make. We make these plastic pipes with but the P.V.C. will work fine as a heat transfer system.

The heat transfer system needed to do four things:

- 1) Move enough water to heat 105 cubic yds³ of sand and soil.
- 2) Move the water evenly through the grid.
- 3) Provide mechanical access to all the pipe so it can be manually cleaned
- 4) Drain by gravity so the building can be let to freeze as a pest control measure without breaking any pipe.

We hand excavated the dirt floor within the concrete footings so its highest point was at the north east corner and the lowest edge of the rectangular plane was the south west corner for gravity drainage.

We then laid 2" styrofoam insulation board down and built a big plastic radiator on top of that and covered everything with 20 yds of washed sand. This big plastic radiator, (slides 24-26), is simply an inflow manifold running east to west along the north wall with an out flow manifold running east to west outside the south footing, (slide 24a), connected by north to south flowing pipe on 16" centers. The cleanouts are all located in the connecting "crosses" projecting out of the south footing, (slide # 24a, 25,32).

Before we continued construction, we needed to pressure test the system and there are about 400 glued P.V.C. joints and any leaks would be pretty hard to fix later. We left the screw-on caps on all the cleanouts finger tight and turned the water into the pipes up at the spring. In about 20 minutes the water was flowing out of a six foot stand pipe at about 25 gallons per minute. Once the whole grid was working we poured 3 gallons of beet juice left over from a canning operation into the inflow

pipe at the spring. What we were looking for was pink drips or puddles anywhere. The only place we saw any was coming out of the finger tight cleanout caps and the drips appeared in about seven second intervals starting at the east end and moving west. The pipe grid didn't leak and appeared to move the water evenly. Looking back on the building of the grid I'd say the most important construction techniques were the following:

- 1) Saw all pipe ends as square as possible
- 2) Prime every joint twice before gluing on the male and female joints
- 3) Use plenty of glue and hold onto each joint for 20 seconds after pushing them together

When we laid the styrofoam insulation down we put it right on the ground using no visqueen under it or over it and leaving all seams unsealed. Since the growing beds are built right on top of the heat transfer grid, we wanted plenty of drainage under the growing beds for the irrigation water. The washed sand was used both to help in getting the water from the beds to drain, to make for the best heat transfer mess and because it tamps well and compacts around the pipe grid.

Slide #27 shows the center walk formed and about to be poured. You can't have too much help when it's time to pour concrete. We usually have everything all ready when the truck arrives and on flatwork like walks or slabs, we like to have two people actually pouring and raking around the concrete from the chute and two people to do the rough leveling of the concrete down the length of the walk. We gave the walk a broom finish rather than a slick trowled finish because of the water and mud that can get slick to walk on in a green house. Putting the anchor bolts in the proper places to anchor down the 4" x4" larch bottom plates for the growing beds was another important consideration; (slides 28 and 29).

Slide 29 shows how well the heat transfer system worked for melting the snow away from the south footing. We let the water run all winter and most of the time you could see the entire pipe grid where the snow and frost couldn't maintain low temperatures in the sand.

Spring more or less came and it was time to build the knee wall and growing beds (Slides 32-38).

The growing bed had been designed to do the following:

- 1) Store heat and maintain root zone-temperatures above 52° year around
- 2) Remain moisture and rot resistant for the life of the building
- 3) Be easily accessible to the workers
- 4) Use most square foot available
- 5) Contain south wall venting
- 6) Drain well over and under vents
- 7) Contain about 270,000 pounds of moist soil for the life of the building

Nothing to it when you ask the right people the right questions and use the right materials.

To store the heat we decided to build the beds 33" high which would also mean the workers would be working at a comfortable height. All the wood on the growing beds is larch and it was all given 4 coats of Thompsons Water Seal.

The peninsular design of the growing beds (slides 36, 37, 45, 46, 47) accomplished the goals of easy access for the workers. Nothing is more than a 30" reach in any direction. The design also gives us 70% of the total floor space in food production and the aisles in the south side growing vent beds are also the vents though the kneewell (slides 38,37,34). In slide #34 you can see how the tops of the vents were built.

Standard 2" x 4" framing methods were used to frame the beds except the "studs" were used on 10" centers through out the beds. To keep the beds from bowing or warping out of shape 1/4" galvanized wire cable was used to tie the beds on the north side into triangulation with 4 foot stakes in the ground (slide 48).

On the south side the extra framing in the vents effectively tied the growing bed framing to the kneewell framing which was 2" x 6" construction on 12" centers (slides 37, 51, 52).

The interiors of the growing beds were then covered with 90 lb felt paper and then shingled with aluminum offset sheets obtained from the Helena Independent Record. (Slides 45, 46, 47, 49). Galvanized sheet metal was bent to fit over the top plates of the beds with lead placed under the outside edge to give a drainage to it (slide 19). The sheet metal was purchased already bent which cost an extra 27 bucks for 160 feet of it and was sure worth it. All we did was cut mitered joint at the corners and caulk them with Sike-flex.

Once the beds were finished, we wanted to back fill the greenhouse north wall, bury the pipe up to the spring and haul in our sand and soil mixture. The burying of the pipe was an interesting challenge, [slides 39, 40, 43, 44] and with my 5 cubic yards and Randy Banson's 12 cubic yards we hauled all the sand and soil from nearby in just a day and a half.

We decided that only about 16-18" of actual soil was needed in the tops of the growing beds so we got about 45 yards of silty sand to use in the bottom 14-15". Here we were with about 50 tons of sand to move in our building plus another 45-50 tons of soil, manure, peat and silty sand to mix together and move in the building.

As with all other phases of this project, when in doubt we called Mike Chapman at the DNRC for advice and technical assistance. He suggested using one of these yellow earth-movers and he even offered to come and show us exactly what he meant. We got a yellow earth-mover and Mike arrived on his day-off but within a few minutes declared our earth-mover inadequate, mumbled something about economics of scale and left [slides 33, 54].

Slides 55-58 show the next attempt with a different earth-mover. Within 8 hours we had our beds filled with a soil mixture of 1 part topsoil, 1 part silty, 1 part peat and 1 part manure. After testing this mixture for pH, nitrogen, phosphorus and potash, we mixed in 50 lbs of manure for a better pH balance, 68 lbs of phosphate rock for the proper phosphorus balance, and 26 lbs of wood ash for potash level. I quit spitting Copenhagen in the beds to help prevent Tobacco Mosaic Virus.

Now that the growing beds were built and filled, the top of the building could be finished.

Patio door blanks which are 34" x 76" thermal pane tempered glass units were set into the rabbeted 4" x 4" larch mullions, (slide 59,60,61). The entire south wall, then, is vertical glazing. Vertical glazing is common in solar greenhouses, and is a design that has in its favor certain advantages. It allows for unhindered plant growth vertically, it makes for much easier installation of insulating curtains if necessary, and the percentages of light transmissivity lost are negligible.

One aspect of the building that we felt would be good to demonstrate is that the entire building was done using only hand tools and a Skil saw. No stationary power tools such as table saws or radial arm saws were needed.

The west wall and roof were framed with 2" x 6" larch. Standard 24" on center framing was used and the north roof was sheathed with 1" x 6" larch. Thirty-gauge "4" sheet metal was used to cover the roof. Sheet metal roofs are good for preventing snow loads, can be painted periodically and last a long time. Slide 74 shows the sheet metal north roof. The wind turbines shown in slides 72-75 bring us to the point where we will address the importance of ventilation.

In the passive solar design books they say that 10-15% of the total glazing area should be used as the figure to determine how much venting area is needed. The basic fact to remember when designing venting for a greenhouse is that the bigger the difference in temperature between the cool air coming in and the hot air going out, the better your venting will work. We wanted to bring the air into the

building as low as possible so we put vents in the south wall (knee wall) and ran them under our growing beds and into the aisle in the beds. Slides 50-51 show the vent hole in the knee wall. Next we planned on doors at each end of the greenhouse and a window at each end to help provide cross ventilation. Besides getting enough air moving fast enough you also want the air moving in and around all your plants to keep them healthy. The wind turbines were bought because once they start spinning, the amount of air being vented out of the building increases by 22% when a 6 MPH wind is blowing.

The solar chimney/food dryer which comprises the second floor of the airlock entry at the east end of the building will be the other main component of the ventilation design. The roof of the building is built with 3/12 pitch sloping to the east with four more wind turbines on the top end of the slope. Slide 74 shows the details of the roof with its covering of aluminum offset newspaper sheets. The aluminum sheets will be the under-roof with the 3/4 inch air space and a black 30 gauge sheet metal roof. The airspace between the roof and under roof will be vented right through the base of the wind turbine roof jacks. First thing in the morning the warm air under the black sheet metal roof will rise and cause the wind turbines to start spinning. This will help begin the convection currents that will cool the air in the greenhouse. This part of the building is my design and we won't know how it works until next summer, but we'll have a follow up report next year.

The food dryer wouldn't work at all if humid air from the greenhouse was vented through it. Slide 76 shows the cantilevered roof where the back fed solar hot air collector is being installed by personnel from Daystar Solar Shop in Conrad, Mt. The hot air will be vented through rocks located in the south side of the solar chimney which will be isolated from the humid air from the greenhouse.

In this report I have used the editorial "we" quite often and freely. However, the actual people involved in the building of this dream in its different phases including design should be noted.

Mike Chipman from the DNRC is the one person who has given more technical assistance and support in every phase of this project than anyone. I came into the DNRC a couple years ago knowing nothing about greenhouses, or any of their attendant features let alone how to get heat from my springs.

Mike has given me sources to pursue for answers, connected me with people to go to for advice but mostly has had educated opinions and good knowledge of anything I needed to know to get this building working. I can't say how much help he's been.

On the concrete work, we had help from Bill Smith, Bill Brechis, John Krigger and Herb Winsor. Perry Hofferber and Rob Ellis and Gregg McCurdy and his cousin Tom helped with the forms.

Design and construction of the growing beds is due to the knowledge and skills of Keith Kemble, Den Flenegen and again Mike Chipman. Keith ran the green houses at NCAT in Butte for a couple of years and all I did was tell her what the beds should do and she came up with the raised bed peninsular design. Mike Chipman showed me how to build the vents. Den Flenegen pounded a lot of nails in those beds.

John Krigger could claim he built this building and I'd agree. He has been in on the construction at every major step and I don't think there's anything he can't do with wood.

Jim Masker, another person from N.C.A.T. has helped a lot with all the glazing and Filon overhead. He and Jon Darry and I just plain amazed ourselves one day when we put all the Filon on in 6 hours.

When I think back about all the help I've gotten on this building I feel like all I did was give the project some continuity and a whole bunch of people built this dream.

About the only testing we've done on this building was the day we turned the water into the grid and tested the water temperature coming in and going out and the visual test with the dye to see how well the water flows. Now that the building is closed in the process of building up and storing heat has begun and we'll be monitoring that.

The cost of this building is staying about what we predicted it would be. The grant was for \$13,321.59 and \$2000.00 of that was to build the road and excavate the site. The \$11,321.59 for materials breaks down to about 11 dollars per square foot. Of course, this doesn't include labor or design and that could be a big expense on a building like that, but maybe this paper and slide show will take care of the design problems and I think that anybody that wants a building like this and has a warm springs, will find the other resources to put the project together. As far as cost effectiveness of this building goes, we broke down how much food can be produced in this building on a year round basis. The following pages are excerpted from our Grant Proposal and the crop yields and dollar amounts are all conservative. The bottom line to the analysis after paying for the laborer in the actual food production is that the building could be paid for in 8-10 years. This is a pretty crude analysis but it's hard to figure how much a tomato will be worth

in the November 1990. The building costs are known. Anyone interested in doing this type building for food production and has a source of warm water gets all my encouragement to do it soon.

ECONOMIC ANALYSIS

We have submitted a years growing schematic to show our crop returns. This can be compared to the initial cost that will be required to set up each crop/seasons. The total yearly return comes to between \$5,900.00 and \$6,700.00. A generous estimation of labor hours per week would be 28 hours, at \$3.50 per hour amounting to a yearly salary of approximately \$5,000.00. This labor will be volunteer and/or deferred salaries. Tom Herpole is at present unable to work as a timber feller due to an injury and will be living full time at the greenhouse site. He will be running a mobile dimension sawmill, powered by a Volkswagen engine which will be another source of income for Earth Institute. Other sources of potential income for Earth Institute will be thru a drift horse logging operation. An agreement thru Earth Institute will give Tom a place to live in exchange for managing the geothermal/solar hybrid greenhouse. Other members of the Board of Directors have gladly offered one to two days a week in volunteer labor.

We have researched the potential Market outlets for the sale of produce and these include the following:

- e. D.M. Forbes General Store, Avon, Montana
- b. Avon Cafe, Avon, Montana
- c. Coughlin Store, Helmville, Montana
- d. Trixie's Restaurant, Ovando, Montana
- e. Welch's Truck Stop & Cafe, Garrison, Montana
- f. General Mercantile, Elliston, Montana
- g. Knuckleduster Restaurant, Deer Lodge, Montana

By selling to these local Markets we have eliminated some of the greatest contributors to high produce prices, such as transportation, distribution, processing, packaging, advertising and lack of competition among the major supermarket corporations. All of these operations are highly energy consuming and the majority of profits does not stay within the community or state. For example, profits from Sefewey stores are shipped off to Oakland California.

The commercial market in trying to create non-competitive oligopolies has been the major contributor to the high food prices. The next major contributor is the middlemen, a sector that is also quickly becoming an oligopoly. These firms are in a position to pass along any cost increase that they incur, plus adding on a little extra for themselves. As the cost of the raw product falls, oligopolies are in a position to hold consumer prices high. Consumers in 1974 spent over \$125 billion to take home food. Raw farm commodities - the production of farmers - account for only 40% of that food tab. The other three fifths of the total goes to food processors,

distributors and retailers. Not only did the middle men in 1973 and 1974 pass through to the consumer all of the increased prices of raw commodities but they also added a 6.5% increase to their own bill in 1973 and another increase of 21% in 1974. The cost of processing and packaging is greater than the cost of the food.

Example: A \$.43 head of lettuce pays \$.04 to the farmer and \$.06 to the processor.¹

"Even our present dietary patterns may fall into the dinosaur category. Food in America is very much affected by the price of energy. The most obvious case is seasonal availability of food through hothouse growing and long distance shipping. We like to have our fruit and vegetables all year long. So we get them from Florida and southern California even in the dead of winter. And this requires enormous energy to make sure they don't suffer from frost. In addition, pesticides and fertilizers are derived from oil. As oil prices rise farmers will reduce their use of pesticides and gas-guzzling farm machinery. Fruits and vegetables won't look as beautiful as they do now. Many foods will be less available."²

The higher the costs of energy thru fossil fuels and transportation the better our profit margin will be. Being a non-energy consuming entity our costs can stay level as the markets go up elsewhere.

insert figure of Qualitative Comparison

ESTIMATED COSTS FOR ONE YEAR³

Saed and Plants	\$18.00
Manure and Mulch	25.00
Telephone	6.00
Twine and Containers	6.00
Labor Costs	(Donated as stated previously)
Miscellaneous Costs	<u>30.00</u>
	\$58.00

CALCULATED COST SAVINGS FOR ONE YEAR DUE TO BIOLOGICAL MANAGEMENT AND PASSIVE SYSTEM³

Fertilizer	\$ 70.00
Sprays and Dusts	15.00
Soil Sterilization	144.00
Electricity	30.00
Water	49.00
Operation of Mechanical Equipment	<u>16.50</u>
	\$324.50

INSERT GRAPH OF YEARS SUGGESTED GROWING SCHEDULE

JULY TO NOVEMBER

TOMATOES

Suggested varieties:

Vendor, Jumbo

- Expected yield: 8-12 pounds per plant
- 20 week Harvest
- 3 sq. ft. per plant
- Approximately 72 plants
- Total yield: 576 - 864 pounds
- Price \$.75 per pound
- Total return: \$432.00 - \$648.00

EUROPEAN CUCUMBERS

Suggested varieties:

Tosca, Virgo, Renove

- Expected yield: 10-12 pounds per plant
- 16 weeks Harvest
- 3.5 sq. ft. per plant
- Approximately 60 plants
- Total yield: 600-720 pounds
- Price: \$.75 per pound
- Total return: \$450.00 - \$540.00

BASIL

- Catch Crop
- Expected yield 8-16 oz. per plant
(8 oz. per plant, dried)
- Harvest continual after 12 weeks
- 64 sq. in. per plant
- 78 plants
- Total yield: 468-624 ozs. (dried)
- Price \$.20 per oz.
- Total return: \$93.60 - \$124.80

NOVEMBER 30 - JANUARY 30 AND JANUARY 30 - MARCH 30

LETTUCE

- Expected yield: 12 - 16 oz. per plant

Suggested varieties:

- 8 weeks Harvest

Grend Rapids Forcing,

- 64 sq. in. or apprx. 1/2 sq. ft. per plant

Romaine

- Approximately 370 plants

- Total yield: 277-370 pounds

- Expected price: \$.70 per plant

- Total returns: \$194.00 - \$259.00

SPINACH

- Expected yield: 4 oz. per plant

Suggested variety

- 8 weeks Harvest

Bloomsdale Longstanding

- 36 sq. in or 1/4 sq. ft. per plant

- Approximately 400 plants

- Total yields: 100 bunches

- Expected price \$.45 per bunch

- Total returns: \$45.00

CHARD

- Expected yield: 16 oz. per plant

- 8 weeks Harvest

- 64 sq. in. per plant - approx. 1/2 sq. ft.

- Approximately 30 plants

- Total yield: 30 pounds

- Expected price: \$.25 per pound

- Total return: \$7.50

CARROTS*

- Expected yield: 3-4 oz. per plant
- 12 - 16 weeks Harvest
- 4 sq. in. per plant = 36 sq. foot
- Approximately 3600 plants
- Total yield: 600 bunches
- Expected price: \$.50 per bunch
- Total return: \$300.00

NOVEMBER-MAY

CHIVES

- Expected yield: 6 oz. per plant
- 28 weeks Harvest
- 8 sq. in per plant = 18 sq. feet
- Approximately 900 plants
- Total yield: 5400 oz. or 2700 oz. dry weight
Approximately 16 pounds
- Expected price: \$1.00 per oz.
- Total return: \$2700.00

GARLIC

- Expected yield: 2 oz. per plant
- 28 weeks Harvest
- 4 sq. in. per plant
- Approximately 1800 plants
- Total yield: 3600 oz - 1800 oz. dried weight
- Expected price: \$.30 per oz.
- Total return: \$540.00

* Season extends into Merch

FEBRUARY TO JUNE

Spring Tomatoes and Cucumbers

TOMATOES

- Same information as Fall, BUT:
- Approximately 60 plants
- Total yield: 480-720 pounds
- Expected price: \$.75 lb
- Total return: \$360.00-\$540.00

CUCUMBERS

- Same information as Fall, BUT:
- Approximately 30 plants
- Total yield: 300 - 360 plants
- Expected price: \$.75 lb
- Total return: \$225.00 - \$270.00

APRIL - JULY

SPRING PEPPERS

- Expected yield: 30-50 fruit per plant
- 16 weeks Harvest
- 2.5 sq. ft. per plant
- Approximately 40 plants
- Expected yield: 1200-2000 fruits
- Expected price: \$.20 per fruit
- Total return: \$260.00 - \$400.00

JUNE - AUGUST

BASIL, OREGANO, SAVORY

- Catch Crop
- Expected yield: 8 oz. - 16 oz. per plant
- 12 weeks Harvest
- 64 sq. in. per plant
- Approximately 225 plants
- Total yield: 3600 oz. - 1800 oz. dried
- Expected price: \$.20 per oz. dried
- Total return: \$360.00

Well, the term "final Report" is a misnomer except in terms of the construction process.

We are looking forward to gathering and disseminating information on this project in the future.

I think the most important aspects of the project are the uses of 85 degree water in heating buildings. As an ongoing research project we hope to be gathering data from this building that could be applied to other types of buildings with different warm water sources.

Respectively submitted,

Tom Herpole,
for Earth Institute

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