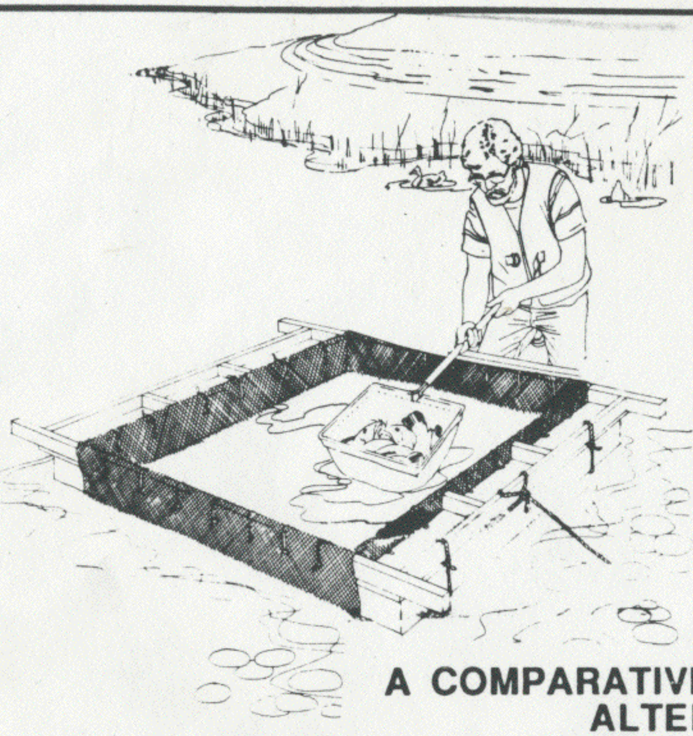

A COMPARATIVE ANALYSIS & RECOMMENDATI
ALTERNATIVE ON- OR NEAR-SITE
WASTEWATER TREATMENT SYSTEMS FO
THE U.S. - MEXICO BORDER REGION

Center for Maximum Potential Building Systems, Inc.
Austin, Texas

January 1993

FORWARD

This report was funded by a contract with The Meadows Foundation of Dallas, Texas. It represents The Meadows Foundation's awareness that appropriate wastewater treatment strategies are intimately linked to the future of our state, its people and environment, especially along the Rio Grande border.

The report is by no means exhaustive, and would benefit from follow-up policy analysis and in-depth research on certain aspects. The prospect of all wastes being treated as resources is inevitable; it is hoped that the report paves the way for more relevant work in this area. Many readers encountering this information for this first time may react, "This is impossible -- people are not ready for these things," or any number of other comments that illustrate a lack of understanding of the degree of change our civilization (especially western civilization) must make in the very near future, and the impressive track record well established in "developing" nations.

These statements also represent a lack of faith in people, in fact the very people that we must have the most faith in, as well as a lack of understanding of our predicament. **Parallel** to the **dilemma** of solving environmental problems related to waste is the problem of a "bail out' mentality. **The latter results in gigantic taxes that are no longer acceptable or affordable**. The report expresses faith in people who live at the edge of poverty, and are captive to false ideals of a future that is out of reach. To this we answer, there is much work to be done. Community leaders to work with, training programs that deal with **relevant** educational principals that could as easily, perhaps more easily (if we tried them) be taught due to their direct effect on people's lives than other principals that are presently being taught. The fact is that virtually none of these things are going on. In our country we **research** them to death, put them on the **shelf** and then do nothing with the contention that the perfect answer is beyond reach, and that if it comes, it will be from the top down.

It is also worth mention that many of the principals highlighted in the report, in whole or in part, emanate directly from the rich history of the cultures living in the border region. Indeed, Mexican heritage is reknowned for examples of sophisticated integrated agricultural systems unrivaled in subsequent eras. An archeological account of this has been included in the appendix.

In many ways, this report pays tribute to this legacy, and expresses a hope that the potentials for change are opportunities to rediscover these valuable traditions. In a sense, we view this report as a proposal to begin to evaluate new approaches to address a crisis which cannot continue. The Center for Maximum Potential Building Systems is dedicated to moving technical opportunities from the paper to the community; it is our intention to find support to demonstrate some of the techniques described here in the near future. As always, comments and constructive feedback is welcome.

Pliny Fisk III
Austin, Texas
January 1993

A COMPARATIVE ANALYSIS & RECOMMENDATIONS for ALTERNATIVE ON- OR NEAR-SITE WASTEWATER TREATMENT SYSTEMS FOR THE U.S. - MEXICO BORDER REGION

1.0 INTRODUCTION

In a curious symmetry, both first and third world nations are confronted by a common challenge: how to manage their nations' human wastes in an environmentally and economically sound manner. The real challenge, however, lies not in identifying the problem, but in constructing solutions which are fundamentally right for both contexts.

Strategies for managing human wastes must consider environmental, economic, and public health impacts in their approach. Increasingly, wastes are being acknowledged as valuable resources, particularly in third world nations which have used this basic concept to further agricultural productivity, enrich soils, and mitigate the soaring infrastructure costs normally associated with development. However, engineering approaches in the "developed" world continue to favor centralized systems which operate on the assumption that wastes are valueless. This clash of approaches is likely to be played out as funds for infrastructure improvements will be a policy priority at the federal level over the next four years. Our perspective in preparing this report is that the transformation of wastes into resources is a fundamental step towards sustainable development, whether in the context of "developed" or "developing" nations. Just as waste is a foreign notion in natural systems, human societies are faced with a challenge to optimize pollution prevention, or face the consequences of natural environments ill-suited to support human populations.

This report addresses a basic issue: how best to handle human wastes that are generated in the form of wastewater at a household scale in a productive way. Our focus is on approaches which optimize wastewater reuse, provide some modicum of economic development incentive, and are applied at the source of waste generation. The recommended systems could be termed "appropriate technologies", implying a sensitive approach to technical solutions, taking into account the users' skills, multiple use options and a range of impacts on a region's natural and human resources. These considerations are the bases for the most dramatic distinction between the alternative and conventional strategies.

Isolating residential wastewater from industrial streams is an implicit recommendation, since this avoids the need to design systems to handle the much more complex and toxic wastewater streams emanating from industrial sources. Indeed, because of the complex nature of industrial wastes and greater scrutiny from regulators, many industrial operations should be required to install on-site treatment facilities of their own to ensure that their specific waste streams undergo proper treatment and even reuse within their own domain of technical options. Many of the approximate 1,440 *maquiladoras* (industrial enterprises given special incentives to locate on the Mexican side of the border) are suspected of polluting the Rio Grande with untreated industrial waste.

Although not specifically addressed in this report, the issue of industrial waste is a particular concern in the border region, with enhanced industrial activity and other ramifications of the North American Free Trade Agreement (NAFTA). Isolating the residential and industrial streams is advantageous since it paves the way for more reuse by addressing the respective streams at their sources, reinforces smaller-scale systems, lowers public costs and minimizes the web of piping, pumping, and processing apparati that make the large, centralized systems unwieldy and inefficient.

1.2 International Perspective

According to a recent article in Worldwatch Magazine, the wastewater problem is referred to as, "... A billion dollar international heist ..... going on with scarcely any notice. ... Millions of tons of valuable fertilizer were intercepted, only to wind up being burned, dumped on the ground, or spilled into water supplies. ... (And as if this weren't enough) the public had to pay for this caper as well as the resulting environmental damage."[1]

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[1] World Watch, March April 1989, "Down the Tubes" pp22-29, Lowe, Marcia D.

In fact, fertilizer produced from human wastes is surprisingly rich. When mixed with water, as is done with current practices, the resulting liquid is nutrient rich as well. Every day, the people inhabiting the world's cities generate between 100 and 150 million tons of nutrient-rich human waste. According to U.S. Environmental Protection Agency (EPA) estimates, the value of sludge (the solid by-product of sewage treatment) generated in the U.S. alone has an equivalent nutrient value of $1 billion per year.

Based on international experience with alternative wastewater treatment methods, where in some parts of the world, wastewater reuse is as integral to development as housing, these approaches are practicable when there are ample labor supplies and adjacency to large tracts of farmland. Given these conditions, there are multiple benefits to be reaped by all parties. For example, South Korea as recently as 1985 required only four municipal waste treatment plants to serve about 12% of the country's urban population, relying instead on its nearly 140 processing plants to transform sewage sludge into fertilizer. As a result, 40% of South Korea's human waste generated in its urban areas is collected and treated for reuse on nearby vegetable greenbelts. And, in Thailand and India, test plots of rice, wheat, cotton, and potatoes using wastewater irrigation consistently boosted yields 25 to 50 percent above those using well water and commercial fertilizers.[2]

Human wastes are also used as fertilizer for fish production. Aquaculture as practiced in cities such as Calcutta has gained acceptance by the U.S. EPA when certain practices are followed.[3] But few cases in the U.S. are reaching the efficiencies of the foreign production levels, where ponds produce 40,000 pounds of fish per day, equivalent to 1/10th of Calcutta's total animal protein consumption.[4]

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2 Ibid pp.27

3 World Bank Technical Paper # 36 "Aquaculture: A Component of Low Cost Sanitation Technology" Peter Edwards 1980, International Bank for Reconstruction and Development, Washington DC

4 World Watch pp. 28

Although these methods are rarely practiced in the U.S., their lack of application is not due to their unfamiliarity. Among the deterrents for wider U.S. acceptance is a cultural bias to deal with human wastes in any way but "out of sight, out of mind." To its credit, however, the U.S. has pioneered the use of hyacinths for wastewater treatment, providing a renewable energy-based process for treating municipal wastewater. And, although other uses have been barely explored, such as energy production in the form of methane from the anaerobic digestion of these plants, other options have been put to limited use such as composting the abundant hyacinth crops and using them as soil amendments.

Mexico, though by no means an outstanding example of well-designed waste treatment systems, has policies and programs in place which illustrate its acknowledgement of the nutrient value of wastewater. For example, based on a survey of wastewater irrigation among selected cities from Austria, Germany, India, Mexico, Peru, Saudi Arabia, Tunisia, and the U.S., Mexico City stands out as having the most acreage under wastewater irrigation with a total of 222,300 irrigated acres.[5] Other examples of alternative waste treatment in Mexico are emerging. In Juarez, for example, a city currently without wastewater treatment, an alternative waste treatment plant is planned, designed to demonstrate treatment by plants[6] And in Tijuana, Roberto Sanchez and colleagues have developed a small packaged waste treatment system for small communities.[7]

1.3 Existing Efforts in the Border Region: Policies & Funding Allocations

In March 1991, the Mexican environmental agency SEDUE, in collaboration with the U.S. EPA and the International Border and Water Commission (IBWC) held an international forum in El Paso, the site of a Microbial Rock Plant Filter system. The conference provided information on the design, construction, operation and

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[5] Ibid pp. 27

[6] Steve Riter Director, Bi-National Water Policy Institute, UNTP, El Paso

[7] Personel conversation with Ms. Mary Kelly, Texas Center for Policy Studies, Austin, Tx.

maintenance of municipal wastewater treatment technology but concentrated little on the alternative treatment example that served as the conference's catalyst. According to our sources, the conference provided no information on operational energy use, labor requirements, economic development potentials of by-products based on requisite equipment and skills, or even by-product utilization strategies. Instead, the conference presented a singularly focused technical fix.

It is important to understand that the economy on the border ranks as one of the poorest in the nation. Twenty five percent of the U.S. border families fall below the federal poverty level and an additional 50% earn less than $12,000 per year.

Recent activities in the more "liberated" parts of Texas from the standpoint of information availbility and willingness to try new directions in waste water treatment are refreshingly focused on environmentally sensitive on-site wastewater treatment. This trend reflects a growing awareness of the need for flexibility in basic design, and the troublesome environmental and economic consequences of conventionally-designed systems . Research funds for experimental systems have been released through the Texas Water Commission (TWC), and a monthly newsletter, available free of charge, published by Texas A&M University with funds provided by TWC, is a source of up-to-date information on alternative waste treatment systems, research activities, and surveys.[9]

With great fanfare and media attention, in 1990 the Texas legislature appropriated bonding authority to improve wastewater treatment conditions along the U.S. - Mexico border, with particular emphasis on the region's *colonias*. Two hundred fifty million dollars was allocated to improve wastewater conditions on the border. Work has already begun and is well under way in the "Laredo/Nuevo Laredo area as well as Tijuana" along the border. Rather than opening up opportunities for more appropriately scaled and designed treatment facilities, bringing with them enhanced environmental quality and economic development potentials, the initial funding was spent on conventional centralized wastewater treatment plants that even in their construction require large contracting firms. These systems are widely

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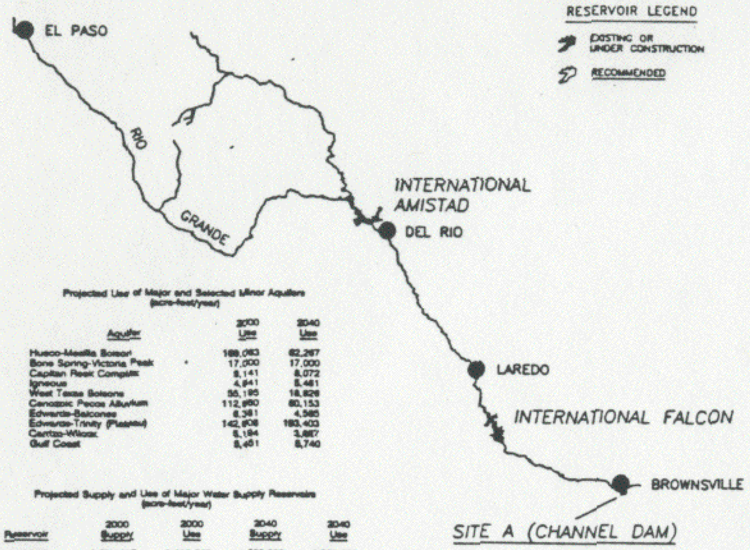
[9] New Waves, The Research Newsletter of the Texas Water Resources Institute, Texas Agricultural Experiment Station, Texas A & M University, College Station, Tx.

RIO GRANDE BASIN



Projected Use of Major and Selected Minor Aquifers
(acre-feet/year)

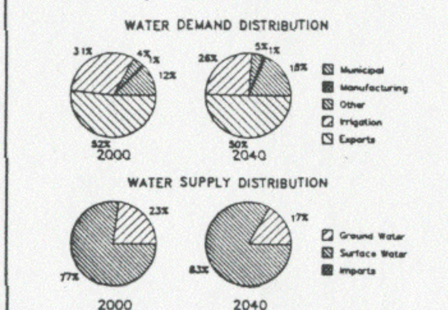
Aquifer	2000 Use	2040 Use
Hueco-Mesilla Bolson	169,063	82,267
Bone Spring-Victoria Peak	17,000	17,000
Capitan Reef Complex	8,141	8,072
Igneous	4,941	5,461
West Texas Bolsons	56,195	18,626
Cenozoic Pecos Alluvium	112,950	80,153
Edwards-Balcones	6,381	4,565
Edwards-Trinity (Plateau)	142,606	193,400
Carrizo-Wilcox	5,194	3,687
Gulf Coast	5,451	5,740

Projected Supply and Use of Major Water Supply Reservoirs
(acre-feet/year)

Reservoir	2000 Supply	2000 Use	2040 Supply	2040 Use
Falcon-Amistad	1,500,000	1,418,080	1,500,000	1,300,000
Rio Grande Project	128,700	128,700	128,700	128,700
Site A Channel Dam	0	0	86,000	84,061

PROJECTED WATER DEMANDS AND SUPPLIES
(acre-feet/year)

ITEM	2000	2040
IN-BASIN DEMAND		
Municipal	277,516	474,030
Manufacturing	15,800	25,607
Steam Electric	16,000	21,000
Mining	54,346	75,343
Irrigation	710,815	673,060
Livestock	21,804	21,804
Total In-Basin Demands	1,096,281	1,290,844
IN-BASIN SUPPLIES		
Ground Water	532,700	388,910
Surface Water	1,725,352	1,750,557
Total In-Basin Supplies	2,258,052	2,139,467
TRANSFERS		
Import Supplies	0	0
Export Demands	1,168,488	1,298,767
ADDITIONAL NEW SUPPLIES	61,100	175,000
AGRICULTURAL SHORTAGE	(27,557)	(171,447)
NET AVAILABILITY	81,940	(103,697)



Source: Texas Water Development Board, Water for Texas (1990)

SOUTH TEXAS AND LOWER GULF CO

CHARACTERISTICS OF THE REGION
THAT AFFECT WATER SUPPLY AND DEMAND

POPULATION :		
	1990	1.456 million
	2000	1.807 million
	2010	2.224 million
	2020	2.758 million
	2030	3.351 million
	2040	3.701 million

MAJOR ECONOMIC SECTORS: Agriculture, Agri-business, Manufacturing, Retail and Wholesale Trade, Services, Mineral Production, Tourism, and International Trade

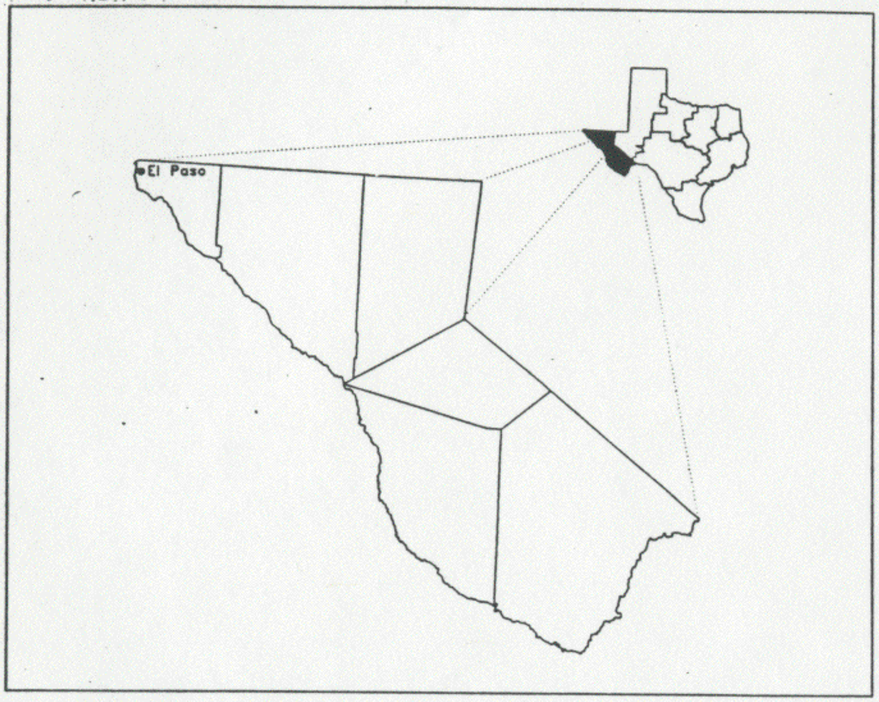
AVERAGE ANNUAL PRECIPITATION: 21 to 40 inches

ANNUAL NET EVAPORATION RATE: 53 inches

PHYSIOGRAPHY: Grassy, brushy flat coastal plains

Source: Texas Water Developmen

UPPER RIO GRANDE AND FAR WEST TEXAS REGION



CHARACTERISTICS OF THE REGION THAT AFFECT WATER SUPPLY AND DEMAND

POPULATION :		
	1990	0.634 million
	2000	0.796 million
	2010	0.977 million
	2020	1.182 million
	2030	1.407 million
	2040	1.528 million

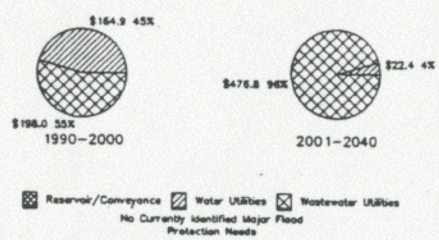
MAJOR ECONOMIC SECTORS: Mineral Production, Manufacturing, Retail and Wholesale Trades, Agriculture, Tourism, and International Trade

AVERAGE ANNUAL PRECIPITATION: 8 to 18 inches

ANNUAL NET EVAPORATION RATE: 66 inches

PHYSIOGRAPHY: Flat to rolling to mountainous, sparsely-vegetated desert with relatively flat, floodplain areas adjacent to the Rio Grande

COST DISTRIBUTION OF IDENTIFIED REGIONAL WATER-RELATED PUBLIC FACILITY NEEDS (mill. $)



Source, Texas Water Development Board, Water for Texas (1990) regarded as being energy intensive, due to their reliance on numerous pump stations needed because of the region's flat terrain, high pressure spray systems and forced aeration.[10] Moreover, these systems offer limited job opportunities for the populations they serve, and lock residents into per person costs of between $500 and $600 per capita start up costs[11]

2.0 Issues Influencing Alternative Waste Treatment Systems for the *Colonias*

The Rio Grande corridor has a current population estimated at two million people; approximately 210,000 of these residents live in *colonias*. Projections indicate that the population will grow between 50% and 230% over the next 10 years. The region is characterized by a year-round growing season, with conventional agricultural practices still the standard, relying on chemical fertilizers, pesticides, and herbicides, pivot irrigation systems, and mono-cropping. Agricultural production could be enormously improved with the introduction of alternative agricultural practices such as agroforestry, shading techniques, windbreaks, soil enhancement through organic fertilizers, and organic pest control techniques.

Several additional issues influence the border region's waste treatment potentials:

1) At a macro scale, water budgets projected by the Texas Water Development Board (TWDB) for the years 2000 and 2040 indicate shortages of agricultural water (even assuming additional new supplies.) According to gross material balance estimates, accessing urban wastewater supplies could substantially alleviate this problem; for the *colonias*, particularly in the lower Rio Grande Valley, waste treatment processes designed for reuse could occur on-site. (See Figure 1)

2) The Texas-Mexico border area is one of the world's most intensively chemically fertilized agricultural regions, and thus a significant contributor to

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10 Vanhuizen, David, "A Decentralized Concept for Waste Water Treatment" Copyright 1983, David Vanhuizen, 21 Cotton Gin Road, Uhland, Texas
11 Ibid

the Rio Grande River's chronic pollution. A coordinated effort of alternative waste treatment facilities and organic agricultural practices--directing the waste treatment facilities' by-products to be used as fertilizer--could start alleviating this condition through example. Even the minor population ratio of *colonias* residents alone could contribute approximately 525 acres of organic farming, based on gross estimates of nutrient value for the existing corridor population. The entire population's contribution of about 5000 acres of organic fertilization methods (just from sewage sludge and some organics using advanced high rate composting methods) could supply 1/10th of the region's overall fertilizer demand using conservation methods and not incorporating organic additives within the composting process.

3) The border region has some of the highest unemployment and poverty levels in the nation. The recommended alternative waste treatment methods are labor intensive and oriented towards small contractors; thus, they could contribute to relieving these chronic conditions both from the aspect of installation as well as upkeep and by-product reuse for micro-enterprise.

4) The region's ecology has suffered from unchecked agricultural and industrial practices, many of which contribute to water pollution and diminished soil quality. The combination of nitrogen rich materials, such as "night soil" (human wastes) with carbonacious wastes derived from yard debris and agricultural residues provides the raw materials for community-based, small scale businesses. Markets for these soil amendments should be coordinated with a transition to sustainable agricultural practices, including the elimination of chemically-based pesticides and herbicides. This transition could be part of a comprehensive effort to restore and sustain the region's ecological balance.

5) Available funds and an enhanced environmental perspective for the border region offer an enormous opportunity to introduce innovative waste treatment practices to further the region's environmental agenda and create new, long term job opportunities.

3.0 SIX WASTE TREATMENT RECOMMENDATIONS

The six recommended waste treatment procedures are specifically chosen to be appropriate for the border region. Though different in technical approach, each method adheres to five common principles:

- Maximize reuse potentials;
- Achieve energy and water use efficiencies;
- Promote sound public health practices by matching technologies to applicable conditions;
- Enhance job opportunities by reinforcing available labor and skills;
- Promote local economic development by advocating small- to medium-scale production systems.

The methods represent choices which are consistent in principle but fulfill requirements of varying contexts. The variables include different cultural/physical community conditions, environmental constraints, and economic indicators. The economic development opportunities range from fertilizer to food gardens and from flower production to micro fish farms. Each requires intensive training by qualified professionals, and on-going technical assistance to ensure that the operations are fulfilling the initial objectives. The orientation towards decentralized, small-scale systems would encourage greater degrees of local control, lower tax burdens, and provide an anchor for sustaining the region's infrastructure requirements.

The six recommended alternative waste treatment methods are:

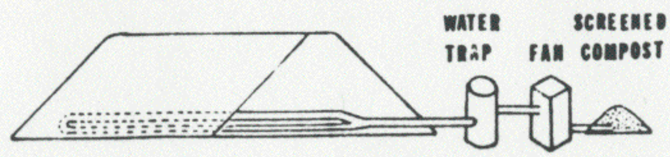
(1) Honey Wagon/BARC Method
(2) Compost Privy/Greywater System
(3) Lagoon/Aquaculture Method
(4) Microbial Rock PlantFlower Production Method
(5) Low Pressure Dosed Trench Irrigation Method
(6) Hyacinth/Methane System

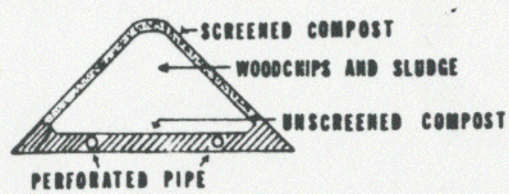
Four of these six methods (systems #1 to #4) are reviewed in detail below.

3.1 System #1: The Honey Wagon/BARC Method

This system is comprised of two main components: (1) tanks that collect sewage sludge for a three to six month period, and are sized for single or multiple homes. A "honey wagon truck" pumps the contents, and delivers it to a community facility. At the processing plant, (2) the sludge is mixed and composted with carbonaceous residues such as chipped tree clippings, sawdust, shredded paper, agricultural waste, and landscape debris. This second phase, referred to as the BARC (Beltsville Aerated Rapid Composting), is illustrated below. The BARC method was developed by the USDA and the U.S. National Park Service while honey wagon pickup methods have a long history of use throughout the world.

AERATION PILE





The two components together represent minimum lifestyle change (i.e. toilet facilities), and operate most effectively at a community level. The World Bank endorses the Honey Wagon BARC Method, while The U.S. National Park Service has successfully used it in the U.S. since 1978. In addition, this system has been tested and approved by the U.S. Department of Agriculture, combining agricultural, landscape, and human wastes to produce a plant fertilizer.[12] The resulting by-product can be enhanced into an organic fertilizer that can serve as a substitute for conventional fertilizers, providing, for example, equivalent minerals, trace elements, and enzymes. The final product can surpass supposed benefits of chemical fertilizers in that it builds the soil by restoring micro flora and fauna. Enhanced soil quality ultimately is the key to preventing plant disease and increasing water retention.

Assuming extra carbonaceous (woody) material is available (household garbage commonly contains one pound of organics per day per person, can also be considered carbonaceous material) a *colonia* of 100 people could sustain an intensive organically fertilized vegetable garden of approximately 6-10,000 square feet. By using "biointensive" methods such as those developed by John Jeavons of Ecology Action in Willits, California, one could produce yields four to five times higher than those of conventional agriculture. Thus, this small "micro-farming" operation could produce enough fresh vegetables to feed the *colonia's* residents, allocating about 100 square feet of garden space per family.[13]

3.11 Energetic & Economic Efficiency

The energy cost of the Honey Wagon/BARC Method is extremely low. In addition to a two to four time per year collection cycle, which, in a *colonia* could be accomplished with a trailer wagon and a portable gasoline suction pump, the only other costs are transportation to a nearby site and the use of a small .33 hp electric fan to aerate the compost pile. Quantities per dry ton of compost come out at approximately 20 kwh of electricity and 20 liters of fuel. The energy costs of the micro-farm operation are 1/100th the energy cost per pound of food produced by conventional farming methods.

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[14] Appropriate Technology for Water Supply and Sanitation - Night -soil Composting, Hellel I. Shuval, Charles Gunnerson, DeAnne S. Julius World Bank December 1981 pp. 29-49

[13] Christian Science Monitor Food Day 1981 (center fold) Laurent Belsie "Intensive Micro-Farming May Help Fill Tables in Third World"

The system's economics are summarized in a spread sheet compiled by The World Bank. A descriptive statement accompanying their spread sheet asserts, "Composting is more economical than incineration, wet oxidation, pyrolysis or other advanced technologies." Since our proposed operation is significantly smaller than that proposed by The World Bank, and because it displaces resources that cost money, we expect that further analysis of this system for the *colonias* would prove it to be economically sound. For example, organic compost is currently marketed at $35 to $100 per cubic yard. The *colonias* system would produce about two tons per year, equivalent to about $800 worth of fertilizer.

Even factoring in the costs of a field inspector, the economics of this method coupled with minimal lifestyle changes hold great promise for its widespread implementation.

3.12 Health Implications

This system's health implications are equally favorable. However, as with any waste handling method, care must be taken relative to worker habits such as washing hands and processing and handling materials. Recognizing the public health implications of handling human wastes, the World Bank suggests that more pathogenic health work be done on this method. However, their studies indicate that the compost produced from this method have reduced fecal and total coliforms to undetectable levels by the tenth day, and that viral bacteria were destroyed by the 13th day. The World Bank's advice concerning the overall method described here is that it should be a suggested method to alleviate major waste problems in India, Korea, Taiwan, Indonesia, Singapore and Nigeria. This is testimony of its replicability in typical third world settings.

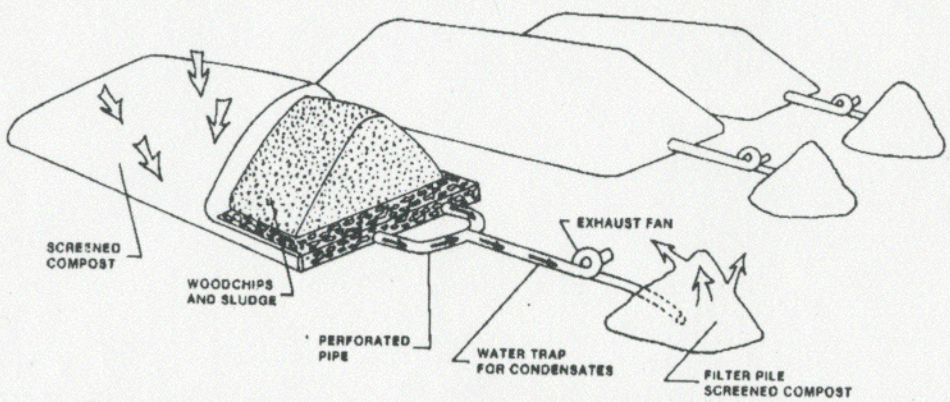
Typical graphs for coliform and viruses are shown to the right.

Public health issues are closely linked with environmental issues. For example, conventional large centralized waste treatment facilities use trickling filters operated with aerobic bacteria. If toxics enter the system from an industrial process (legally or illegally) the entire system could be disrupted for days hindering the proper treatment of the wastewater.

The Honey Wagon/BARC method of treatment has a range of environmental forces at play, some positive, some negative. First, the positive. There are few soil limitations for a sealed tank for septic collection, which can even be installed in bedrock at a cost lower than for a septic field, and in flood prone areas as long as the system is kept full during flood (otherwise it pops out of the ground) and has a sealed lid. Access by the pump truck (honeywagon) is usually not an issue due to the ability to pump, using a hose of sufficient length.

The BARC system requires good drainage (never any flooding), some shade if possible due to over drying in the Texas sun, and some protection from torrential rains by a cover placed over the compost piles. Provision should also be made for any leachate (extra moisture that may seep out of the pile) to be drained away from the pile into a safe location which usually means an impounded area so that surface or ground water is not affected.

COMPOSTING WITH FORCED AERATION



Three-dimensional schematic diagram of the Beltsville Aerated Pile Method for composting sewage sludges.

Once having addressed the initial health issues, the long term health rewards can be great. On the following page is a list comparing typical crops grown organically and chemically relative to their nutritional value.

	% of dry wt.		Milequivalents per 100 grams dry weight				Trace Elements parts per million dry weight				
	Total Ash/ Mineral matter	P	Ca	Mg	K	Na	Bo	Mn	Fe	Cu	Co
LETTUCE											
Organic	24.48	0.43	71	49	176	12	37	169	516	60	.19
Inorganic	7.01	0.22	16	13	54	0.0	6	1	9	3	0.0
TOMATOES											
Organic	14.2	0.35	23	59	148	6.5	36	68	1938	53	.6
Inorganic	6.07	0.16	4.5	4.5	59	0.0	3	1	1	0	0
SPINACH											
Organic	28.56	0.52	96	203	237	69	88	117	1584	32	.2
Inorganic	12.38	0.27	47	47	85	.8	12	1	19	.3	.2

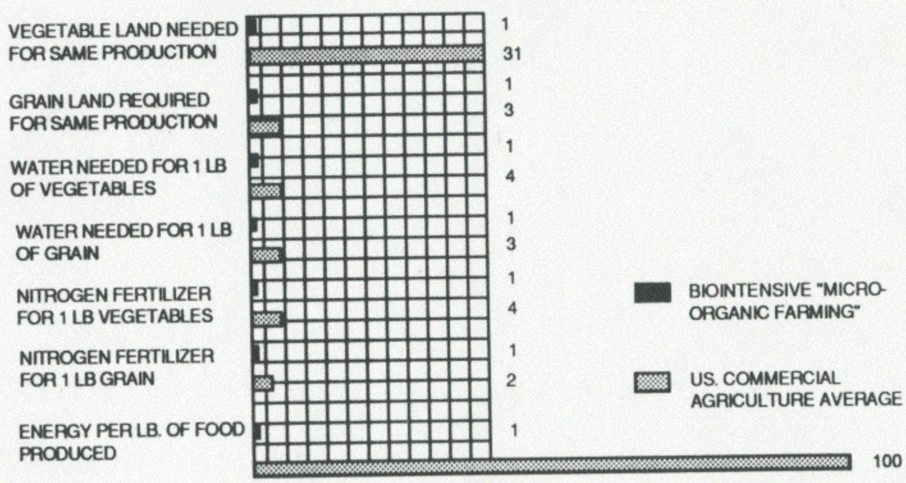
Adapted from "Variations in Mineral Content in Vegetables"
Firman E. Baer Report, Rutgers University

3.13 Economic Development Implications Relative to Skills

One of the principles put forth in this report is to match skills required by technological solutions with those of the community being served. Many residents of the*colonias* are adept at manual construction skills, agricultural and horticultural practices, and household plumbing. Each of these relate to the proposed wastewater treatment system. The holding tank, for example, could be built using ferrocement methods similar to stuccoing, and could be built for a lower cost than a comparable septic tank, since less concrete is used. (A brief manual description for building with ferrocement is in this report's appendix.)

Although most all the operating labor requirements are at a basic skill level, the processing plant would require only about two full time employees per every 100 people. However, the multiplier effects resulting from the gardening are impressive, as is freeing up disposable income as a result of no longer needing to purchase vegetables. Beyond these criteria, quality of life indicators are enhanced. According to an article in The Christian Science Monitor describing similar systems operating in Tula and La Pressita, Mexico, "Beyond an improved diet ...the gardens have given once deprived Tula families a sense of well-being, even of wealth. Seeing the benefits in Tula and La Pressita, Mexican authorities are beginning to expand the biointensive teaching program into several neighboring states, with the goal of introducing the program into all 20 Mexican States." Hopefully this first example of a method of waste treatment can catalyze the same interest in the *colonias* in some parts of the border region.

CONVENTIONAL VERSES
BIO-INTENSIVE AGRICULTURE



"FEEDING THE WORLD"
CHRISTIAN SCIENCE
MONITOR FOOD DAY 1987

3.2 System #2: Compost Privy/Greywater Method

Today, 43% of all groundwater basins in the U.S. are being polluted from septic systems while approximately 68% of the nation's land is unsuitable for use due to soil restrictions, hydrology or bedrock. (A survey of conditions along the Rio Grande shows a similar ratio.) Nationally 49% of problem lakes, 50% of impaired estuaries, and 27% of polluted rivers are a direct result of septic tank pollution.[15]

Compost privies are designed to be installed in the home. Some of the manufactured, higher priced units look much like conventional commodes. Most systems require the addition of carbonaceous materials from the kitchen to maintain proper operations similar to the first method described above. The main limitation of this method lies in the fact that it handles human wastes only, and therefore requires an additional system to handle the home's greywater which comprises the second part of the system. A relatively easy system can be designed to handle the greywater in an equally productive manner. (An article in the appendix describes an Austin, Texas vegetable garden which employs this method.)

Together these sub-systems comprise a home-based waste treatment system similar to the Honeywagon/BARC system, but at a household rather than community scale. With the home being the focal point for system success or failure comes more responsibility for the family to maintain proper operations. These household maintenance requirements, however, are considered to be overshadowed by the system's benefits, as described below.

3.21 Energetic & Economic Efficiency

Today, commercially available compost privies, sized for a family of six, cost about $1000 installed (excluding a socket for electric internal heater and fan inside the unit and the cutting of a hole in the roof for the exhaust vent.) This compares favorably to the lowest cost septic tank and field, which cost from $2,000 to $6,000.

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15 Clivus Multrum Inc, 21 Canal Street, Lawrence, Ma 01840-1801, 1/508/792/1700, May 1991.

However, as stated above, the compost privies are not designed to handle the grey- and black-water generated by the sink, shower and laundry, thus requiring installation of a greywater treatment system. Though the cost of a pre-manufactured greywater system can cost between $775 and $1,500, the systems are simple enough in concept that residents with basic plumbing skills and easy-to-follow directions should be able to build a system themselves. The cost of a do-it-yourself system runs between $100 to $475. (See plans section.)

With proper construction and installation supervision, even the compost privies, which are more complex systems than the greywater systems, can be community manufactured. The plans that have been included in this report have been approved by the State of North Carolina. The cost of constructing such a privy runs in the order of $450 for materials and $500 for labor, bringing the total cost to $950 per unit.

In order to obtain a true economic comparison between the Compost/Greywater system and a conventional waste treatment system, three points should be considered:

(1) the compost privy requires no water, eliminating the largest single source of water use in most homes, and resulting in substantial cost savings

(2) There is a positive economic value to the resources produced in these systems;

(3) There are substantial cost savings through the substituting of greywater for municipal water for garden irrigation.

The quantity of water saved through a waterless toilet is significant. The average commode in the U.S. uses about 40% of a household's total water use. A composting toilet saves about 25-60 gallons per person per day; for a five-person household, this represents an average of 77,563 gallons per year. Using Austin, Texas water rates for comparison purposes, a household's first 2000 gallons per month cost $5.46; each additional 1000 gallons cost $2.26. Therefore, a typical family would use 6,464 gallons per month of fresh (potable) drinking water for toilet flushing, costing $10 per month or $120 per year. (It should be noted that in the

U.S., a centralized sewage treatment plant costs between $500 to $600 per individual served; in the case of the average colonias households, about $2,750 excluding operating costs) front end cost. Our figures indicate on simple rates of return (excluding maintenance costs, electric fan and heater, etc) a $1,000 compost privy would pay for itself in water savings in 8.3 years excluding any maintenance requiring monetary input during this period.

The value of the composted material should be factored into the system's economics. Using a rate of $100 per yard as in System 1 above, the compost privy would produce about 100 pounds of potting soil per year, with a value of about $500. (One can begin to understand why in China there have been many cases reported of people steeling night soil)[16] Combining the water costs saved with the value of compost produced results in a positive revenue stream of $620 per year. This reduces the system's payback from 8.3 years to 1.6 years.

By adding to these savings the water savings resulting from substituting greywater for municipal water for outside uses (e.g. vegetable gardens, flowers, landscape) an additional $180 in annual savings is realized. Assuming the greywater system costs $300 on average, the system's payback would be 1.7 years.

Therefore, assuming average initial costs and no maintenance or utility costs, the compost privy/greywater system cost would have a payback of less than two years, without counting the value of crops (food or flowers).

3.22 Health Implications

Several manufactured compost privies have been approved by the National Sanitation Foundation (NSF) and, therefore, by state health departments throughout the U.S., including by the Texas Department of Health (TDH). Some states have approved owner-builder units, provided they pass pre- and post-operation inspections. The by-product compost resulting from these units has been tested and approved by the NSF based on public health criteria. Composted end

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16 The World Bank, Night-Soil Composting, Ibid

product samples from a number of installations have been tested for fecal coliform disease indicator bacteria as shown below. In all cases the samples have had fewer of these bacteria than the NSF standard of 200 per gram. In contrast, septic tank sludge usually contains about 100,000 bacteria per gram. Thus the process of removing and dispensing of compost is about 10,000 times safer than handling septic tank sludge. Examples of approval letters by health agencies are in the appendix.

Because all waste is contained, the compost unit is not subject to flooding, poor soil conditions, or geological constraints. Therefore, the units are not limited by site-specific environmental conditions. Furthermore, problems associated with rodents, flies, odors and other health related phenomena have been eliminated with appropriate engineering, as verified by the following charts:

Liquid End-Product				Fecal Coliform Test		Nitrogen Analysis	
Site	Clivus Size	Date Installed	Uses per Year	Test Lab and Date	Fecal Coliform Bacteria per 100 Milliliter Sample	Test Lab and Date	Concentration of Total Nitrogen
Wildlife Prairie Park, IL (av., 2 units)	large	1978	14,000	(1) July '79	0	(3) Nov. '82	9.4 grams/liter
Shelly Ridge Camp, PA	medium	1980	6,000	(2) Sept. '81	2	-	
Camp Archbold PA	medium	Mar. 1980	8,000	(3) Sept. '81	0	(3) Aug. '82	2.7 g/l
Hawk Mtn. Park PA (av., 2 units)	medium	1976	20,000	(4) Aug. '82	6	(4) Aug. '82	6 g/l
Kain Park, PA (av. 2 units)	medium	1979	14,000	(4) Aug. '82	43	(4) Aug. '82	5.5 g/l
Blanford Nature Center, MI	small	1981	14,000	-	-	(3) Dec. '82	3.2 g/l
domestic, MI	small	1978	3,000	(6) Mar. '80	3	-	-
domestic, MA	medium	1973	6,000	(5) Dec. '74	0	(5) Dec. '74	7.4 g/l
EPA Standard for Swimming Quality Water					200		
Typical Septic Tank Effluent					430,000		

Vent Gas Data

Gas	Properties	Clivus Multrum	Federal Ambient Air Quality Standard	N.I.O.S.H.* Workroom Safety Limits
carbon dioxide	stimulates plant growth, affects hearing, blood pressure and pulse at .5%	.2% (ambient air is .04%)	none	.5%
water vapor		95% relative humidity		
carbon monoxide	respiratory poison	none detected method limit 8 ppm	9 ppm	50 ppm
sulfur dioxide	irritates mucous membranes at 10 ppm	none detected method limit 1 ppm	.03 ppm	5 ppm
hydrogren sulfide	eye irritant at 10 ppm respiratory irritant at 50 ppm	.5 ppm	none	10 ppm
ammonia	odor at 5 ppm, eye irritant at 25 ppm	3 ppm	none	25 ppm
methyl mercaptan	odor	none detected method limit 2.5 ppm		
methane	explosive above 10,000 ppm	4 ppm (ambient air is 0 to 4 ppm)	none	

3.23 Material By-Product Quality & Use

Because the greywater and blackwater streams are handled by separate systems, each provides for two distinct products well-suited for specific end uses.

The material resulting from a commercially-manufactured compost privy is a nutritionally rich organic fertilizer that can be applied on all non-root crops; crops benefitting from higher pH such as citrus trees, azaleas, rhododendrons, violets, ferns, and many plants needing shade are especially benefitted. With the addition of organic kitchen scraps to the human waste, the quality of the compost is equivalent to commercial grade organic compost perhaps only lacking some of the added trace elements, rock dust, and kelp additives that some of the more sophisticated and expensive organic fertilizers provide.

In contrast to the acidic compost, the effluent from the greywater system is usually alkaline and is best suited for plants that like this environment. These plants therefore complement those that use the compost. Many of these plants tolerate or even thrive on the phosphates present in some detergents which act as supplemental fertilizers, providing the plants aren't over-watered. According to Robert Kourik, author of Grey Water Use in the Landscape, rich loamy soil can absorb up to a quarter gallon of greywater per square foot per week. This means that every 400 square feet soil can absorb 100 gallons of greywater per week. Sandy soils can handle more grey water, clay soils less.

In general, food crops should not be irrigated with greywater because of the possibility of contamination. However, as the article in the appendix entitled "'Gray' System Saves Family Tub Full of Bills" attests,[17] a system is remarkably reliable as long as all piping is just below the top soil surface and is properly sized and distributed. The system described in the article has been successfully operating for ten years, and is well-known by local health inspectors. This method is similar to the Low Pressure Dosing System that has been approved by the Austin-Travis County Health Department for landscape irrigation. (This system is described in greater detail in the appendix.)

3.24 Economic Development Implications Relative to Skills

The skills required for the Compost Privy/Greywater system reinforce skills commonly held by *colonias* residents: carpentry, masonry, plumbing, electrical, and gardening. In many ways, this system reinforces more local skills than those required for System 1.

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[17] Austin American-Statesman, date unknown, article in appendix

3.3 System #3: Vermiculture/Aquaculture Method

The possible diversity of methods known around the world for the successful conversion of waste to a valuable resource is exemplified by this method. The reason most of these methods are relatively unknown and/or unused in the U.S. can be traced to a perceived overabundance of resources (i.e. the relative low oil prices) compared to other nations. With a heightened awareness in the U.S. of non-sustainable resource dependence, and a better understanding of sources of pollution, approaches which have been successfully used by other nations by necessity are now beginning to be looked upon favorably in the U.S. These methods include vermiculture, the processing of organic waste by earth worms, and aquaculture, the growing of fish under controlled means through the use of wastewater as the nutrient producing method for plants or animals upon which these fish forage.

As we have mentioned the approach is not new. Pliny the Elder gives detailed accounts of Roman oyster farming in the early decades of the Christian Era. Laws concerning oyster raising in Japan go back to well before the time of Christ. Artificial ponds have been extensively used in Asia to raise fish fry, netted at sea, until they reach edible size through the use of algae fertilized by sewage. Their harvest is equivalent to 1,300 tons of fish per square mile per year.

These methods are recommended in this report for home-scale operations, and are modelled after successful precedents at this scale in the U.S. Two components serve as complementary units within the system:

(1) A vermiculture composting unit that grows earthworms, and is comprised of two separate worm production sub-units: one for garbage, landscape debris, and paper which is used for fish feeding; the other for metabolizing human waste, which operates as a closed system, with the resulting rich worm castings used as a garden soil amendment.

(2) A greywater treatment system that produces certain leafy plants irrigated from below at their root structure with pre-filtered greywater as in System 2. These leafy plants are then used to feed herbivorous fish.

This system's greywater component is similar to the greywater method described in System #2. However, its operation requires the irrigation of specific plants, such as comfrey, purslane, carrots, and hairy vetch, that provide food for the fish in the aquaculture system. Similarly, the worm castings can provide food for carnivorous fish. Thus, a variety of fish can be supported by this system, ranging from herbivores (tilapia and carp) to carnivores (blue gills and catfish.) As with the previous systems, this approach is well-suited to residents' skills and also fulfills important nutritional needs.

City water, which is suggested for the fish pond water, must be allowed to settle for a 24 hour period to eliminate the chlorine. Though this water adds an additional cost not accrued in the previous, waterless system, it allows for tremendous simplification by avoiding the treating of greywater to be a suitable environment for the fish pond.

3.31 Use of By-Product

The use of wastewater converted to high protein food production is the main objective of System #3. The system's design prevents viruses and pathogens from entering the food chain in a relatively foolproof method. This is achieved by separating the human waste component from the greywater component.

The system can produce impressive quantities of high-protein food, since it sets up a domino effect as the food chain is established. For example, the quantity of feed from the worms feeding on garbage is increased beyond that if the garbage was fed itself through the use of photosynthesis from sun light. By combining elements of photosynthesis and gaseous substances from the atmosphere, the plants gain more weight than what the original substances were in the nutrients of the wastewater. This biological conversion is referred to as a bioregenerative system; in essence, it produces more every time a metabolic conversion is gone through by living mattter.

It is useful to understand the quantities of materials produced at each stage of plant production verses animal production. Worms for example are about 85% water as are fish and other meats, while green plants are 90-95% water. As a rule of thumb, a fish should be fed 3% of its total body weight at each feeding. At 200 fingerlings weighing 2 1/2 pounds total and an assumption of weight at the end of 6 months to be 1/2 pound each, thus yielding 100 pounds total, you would start at .03 x 2.5 = .075 pounds of feed of ration the first day (at 6 days per week) and gradually increase each day till the last day before harvest of .03 x 100 = 3 pounds of feed. Now one has to account for plants verses worms as feed. For animals (worms) these figures would become .425 pounds of worms for the first feeding and 17 pounds of worms at the final feeding. For plants the first feeding would be 1.425 pounds of plants at the first feeding and 57 pounds of plants at the final feeding. To begin to get some idea of the quantities involved here, one should realize that this occurs each day for six days a week. So the final week would require approximately 6 x 55 or 330 pounds of freshly picked plants. This is not a small quantity and obviously would have to be built up to or one would need to go and buy feed. Similarly with worms we are talking about 16.5 lbs x 6 = 99 pounds of fresh worms. Of course one might not want 100 pounds of fish and instead choose to down scale everything and only supply the family on an occasional basis.

A thousand worms weigh 13-14 ounces; worm eggs have a gestation period of about 90 days. A half 55 gallon drum (about 100 mixed sizes per cubic foot) worm container will produce approximately 75-100 worms per day on a constant basis for a total population of about 10,000. The amount of kitchen scraps are enough to feed this quantity of worms on a constant basis. Using our ratios above at a 3% weight per day this is about equivalent to about 1/2 pound of fish per day or about 31/2 pounds per week from the worms alone. If we add to this the quantity of fish produced from the plant greywater system below, we have a fairly reasonable protein diet for a family of almost 3/4 - 2 1/2 pounds per day. This quantity is determined by the conversion of wastewater to plant material and then this plant material to fish.[18]

A conservative estimate for land plants in general is about 10 to 15 pounds per square foot per year assuming a year round growing season which, except for the western end of the Rio Grande, can be considered possible with leafy plants or with plants with simple low cost (caterpillar type) greenhouse structures in the winter

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[18] William McLarney, The Freshwater Aquaculture Book: A Manual for Small-Scale Aquaculture in North America.

time. Assuming the greywater treatment area requires a bed 3 x 50 feet and 18 inches deep similar to the Rock/Plant filter for flower production in this report, that 3 x 50 =150 square feet or approximately 1500 pounds of plant materials per year. This quantity is equivalent to anywhere from 80-800 pounds of herbivorous fish per year.

If one wanted to increase production beyond the inputs provided by a single household, with an interest to establish a small business, simple methods for increasing fish food input are available to adapt to site-specific conditions. Except for the need to keep the young herbivorous fish separate from the young carnivorous fish, accomplished with a low cost net, a single pond should be able to accommodate both species without setting up a competitive environment. The following are food alternatives derived from Bill Mollison's book, Permaculture: A Designer's Manual.

(1) Mealworms, sowbugs, and cockroaches. Scatter food waste or flour, cover with leaves, and "seed" with cockroaches or sowbugs. Add to this pile some leaves and starches from time to time. Millipedes and cockroaches build up in tropical areas, and can be used to feed ducks or fish. Similarly, a "sandwich" mound of boards, paper, leaves, and so on breeds sowbugs and houses earwigs.

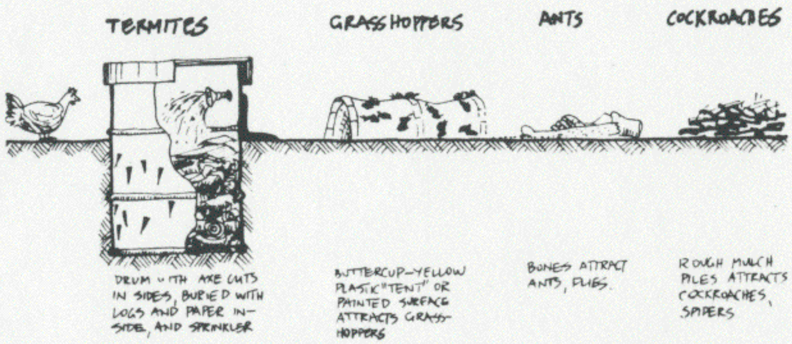
(2) Termites. A perforated 200 liter drum or loose brick pit, covered, can be filled with paper, old wood, cardboard, and straw, and watered. Termites will invade if they are in the area, or sowbugs can be seeded in cool areas. The pit is periodically dug or sieved out for insects.

(3) Zooplankton. Water fleas, cyclops, ostracods, rotifers, and so on can be cultured in small ponds or tanks supplied with lettuce, potato slices, crushed sugar cane, manioc or legume leaves. A shallow bay off the fry ponds can be screened off for thisp urpose, and the plankton will swim out into the fry ponds. Conditions in the enriched area may not suit fish, but produce ample food.

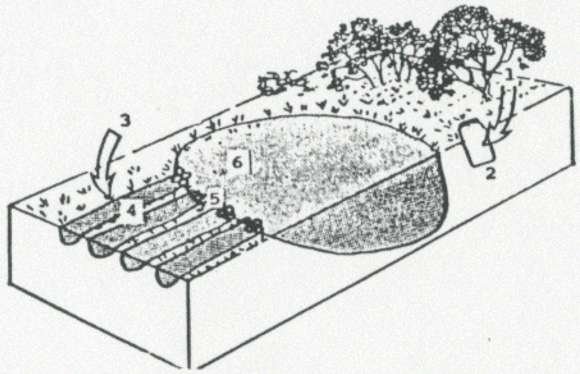
(4) Larval flies. Carrion flies will "blow" waste meats or carcasses suspended over ponds, and near-putrid shallows supplied with kitchen sink

water will breed "gentles" (larvae of *Tubifera tenax* flies) in the muddy base (depth of water 1-2 cm.) It is in the development of such high-protein foods as accessory to fish ponds that we save the greatest continuing cost of fish culture--food. In our site planning such areas are as important as the ponds themselves.

A diagram of these high protein insect methods is included below from Mollison's book:



Below is an illustration of a pond showing the grazing areas needed for the zooplankton area:



3.32 Energetic & Economic Efficiencies

Given the same input in energy and nutrients, we can expect from 4-20 times the yield from water based food systems than from the land. Perhaps the best reference for cultural purposes for the *colonias* is from Lake Tenochititlan in Mexico and Lake Titicaca in Peru. Here farming on raised beds made from the ditches that became channels for fish and water fowl had what is possibly the most productive agricultural system on earth (as much as ten times more efficient than conventional U.S. agriculture.)[19]

Based on cost estimates from two sources, The Kerr Foundation of Poteau, Oklahoma and The New Alchemy Institute in Hatchville, Massachusetts, total input costs range from 45¢ to 66¢ per pound, based on the use of commercially produced and purchased feed.

3.33 Health Implications

From a nutritional standpoint fish is considered a high protein food. According to new studies on health, very little protein is needed to carry on a healthy life style where a high carbohydrate diet is considered optimal. From the standpoint of the aquaculture system being described, a direction being taken to supplement such a diet.

From an environmental issues standpoint no chemicals herbicides petroleum based feeds nor other environmentally degrading elements are used so one may consider that the entire system is quite benign. On the other hand considering that the border environment has become quite toxic (100 different pesticides are used throughout the lower Rio Grande Valley) that the man made environment has become the main problem. As a precautionary step it is suggested that care is taken making sure that flood conditions are not possible on either the growing beds or the fish pond. It is also important to create an artificial subsurface to the pond bottom. Since the pond area is not great (in the order of 10-15 feet in diameter), it is

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[19] William Stevens, "Scientists Revive a Lost Secret of Farming," New York Times, November 22, 1988.

possible to construct the walls from plastic covered wire fencing and line it with 30 mil agricultural greenhouse plastic. This pond should be funnel shaped at the bottom and the drain pipe for stagnant water connected there. This entails some slight shoveling and site work for smoothing.

3.34 Economic Development Implications Relative to Skills

Labor skills for building the Vermiculture/Aquaculture Method are similar to those previously described for other methods. The difference comes with skills needed to operate the system. Here one must be able to do basic arithmetic as shown above, be able to read literature that may contain information on basic measurements for weights and volumes, and be able to use litmus paper for determining alkalinity or acidity (pH). The latter comes in a kit identical to that used by swimming pool owners and is used to determine the acidity of the worm bed in order to keep it alive, and the acidity of the water in the fish tank. To ensure proper training, a demonstration/training site should be built in a *colonia* to transfer skills and provide ongoing technical support.

The cost of building the vermiculture based privy is detailed in this report. (See plans at end of report.). The cost of the worm beds need not be more than buying two plastic 55 gallon drums, slitting them in half the long way, and placing a used sliding glass door panel over each one. Assuming the cost of a good used plastic drum (be careful of what was inside before) is about $40 each and the cost of a used sliding glass door is about $1 per square foot or about $15 ea - four doors is approximately $60. A framed screen with handles for sifting the worms out would run about $18; the total vermiculture system would be about $160.

The cost for the planting bed which is a plastic lined trench in the ground is essentially the cost of the plastic, the plants, plus the irrigation pipe set above pea gravel (with filter fabric between the two). The cost is estimated at about $440 of materials, as follows:

pea gravel at 6 in depth	$50
liner at $1 per square ft	$300

membrane	$15
irrigation piping	$75
	$440

This design is adopted from an article from the Austin American-Statesman and is an operating system at this time. The bed can absorb the worm castings from the privy as well as the greywater. The system therefore incorporates the greywater holding tank, filter, and sump pump detailed for the Compost Privy Greywater system under System #2. The planter bed price is unknown, but is probably exaggerated in the figures shown below.

The fish pond needs a large 2" drain pipe with a 2" valve and a large aerator available from an aquarium store. The drain water with fish wastes from the bottom of the fish pond is distributed onto garden plants for food or landscape. The drain pipe valve and fish water distribution cost about $120, making the total system cost including the filters and dosing pump for the greywater $300, and $320 for the fish tank, or about $1,690 total.

vermiculture privy	$350
worm bed	$160
drain and aerator	$120
wastewater planter bed	$440
greywater dosing pump	$300
fish tank	$320
	$1,690

Maintenance costs would be expected to run about 20% of the total system cost. Operational costs would be assumed at 20 gallons per day of water or 560 gallons a month for a price of about $2.50 per month and an electricity cost of $1.00 per month. Over a ten year period, total costs would be about $5,150.

We mentioned previously that we would be producing an average of about 3/4 to 2 1/2 pounds per day of fish at an approximate market value of $1.00 per pound. If we averaged only 1.5 pounds per day 350 days a year this would be equivalent to $5,250 over a ten year period. So from the standpoint of the homeowner if they would be required to pay for the entire system themselves, there would be a slight payback in a ten year period discounting the money normally spent with the centralized waste treatment plant.

The up front cost of $500 to $600 per person would cost approximately $2,750 for a five person family. If this cost was attributed up front to the family's Vermiculture/Aquaculture system this would completely pay the initial cost of $1690 and supply the family with $710 that could be paid out as needed to develop the system and carry the family's operating costs for 16 months. It would also drop the family's ten year cost of $5,150 to $2,400. Now the family's payback would be 4.4 years using simple payback calculations.

It should be noted that in none of the calculations put forward in this paper has the operational cost of a centralized waste treatment plant been included essentially because we have not been able to find good figures. Undoubtedly it would make our case even better. But the importance might not be so totally in the old fashioned economic terms. The value might be looked at from the standpoint of building security within the community, investing in people instead of technology, and in the overall environmental improvement and economic self sufficiency of the region.

3.4 System #4: The Microbial Rock Plant Filter Approach

In a recent article in New Waves, a newsletter published by Texas A&M's Texas Water Resources Institute, a manual for a home sewage treatment system, called "Low Pressure Dosed Trench Disposal System (LPDT) was referred to as being approved for public implementation.[20] The particular significance of this article was that finally a system was described that could basically be put together by a homeowner with the full support of a county health department. It specifically addresses site specific conditions which make septic fields difficult, and can be built more cheaply than standard septic systems while avoiding many of the environmental problems resulting from improper septic tanks. Because the LPDT system allows the soil to dry out intermittently (thus the name "dosing" system), the soil can become aerated, thus enabling bacteria in the soil and the plants' root zones to metabolize the waste. Essentially, the system enables the soil mantle to prepare the wastewater for use by the plants rooted above.

The Microbial Rock Plant Filter (MRPF) is a close cousin, and, in fact, is a precursor to the LPDT. The National Aeronautics and Space Administration (NASA) has built the MRPF in one form or another over the past 20 years at the Stennis Space Center in Southern Mississippi. As illustrated by the map to the side, there are now many similar systems in the southern U.S. (A complete list is in the appendix.)

Instead of using soil, the system uses a rock media one course at the bottom of the trench, and the other fine (pea gravel) at the top of the trench. Within these media grow certain plants, many of which are flowering varieties which are commonly found in florist shops.

The MRPF system relies on three components: (1) a septic tank; (2) a microbial rock plant filter; (3) a small leach field.

The system works because microbial life on the rock gravel and the plants' roots convert the waste into plant food so that the roots can make use of the beneficial nutrients. The system works in a symbiotic fashion at a number of levels. For

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[20] Texas Water Resource Institute, Texas A&M University, New Waves, 1992.

example, the plants and their roots keep the water below aerated. Since the depth of root structure below the surface can become so dense that it can restrict the flow of the septage it is important to trim the plants in order to restrict the roots' depth.

3.41 Use & Economic Development Potentials

The fact that the system's plants must be continuously harvested to enable the system to work, coupled with the fact that many of the plants used in the system (e.g. arrowhead, calla lily, canna lily, ginger lily, bull rush, elephant ear, cattail) are ornamental flowers enables this method to become the basis for a profitable flower garden. As such, the system is economically sustainable when markets for the cut-flowers are secured.

One look in a city's Yellow Pages provides a good basis to evaluate market potentials. (For example, the Austin phone book has 10 pages of florists.) The value of flowering plants can be considerable especially when one takes into account direct sale possibilities by a family. Lillies, for example, run anywhere from $1.50 to $8.50 each depending on the kind of lilly and the season. At the rate of growth for what is essentially a sophisticated growing technology close to what is called hydroponics and the fact that the family is placing all their wastewater into this flower garden, this system with an average size of between 400 to 500 square feet offers a profitable cottage industry potential, while enhancing a home's landscape.

With a production rate for marsh type plants of approximately 13-16 pounds per square foot per year, based on a 450 square foot plot this system would produce approximately 6,525 pounds of plant material per year. If we estimated the weight of a single, large canna lily to be about 4 ounces, we would be producing 26,100 lilies per year. At a conservative street price of 25¢ each this would be equivalent to $6525 per year; an impressive return on investment for families with average incomes among the lowest in the nation.

The system's cost includes a 1,500 gallon septic tank to serve a five member family, running about $800 to $900 for outside installers, and as low as $200 to $300 for a do-it-yourself ferrocement tank. A sump pump, required for flat sites, would add $200.

The material cost of the rock bed filter is approximately $1,235.[21] This figure includes a wall structure around the bed to keep the treatment system above flood zone. This brings total costs to as much as $2,235 for materials, including an installed septic tank.

Since the cost of a conventional centralized waste treatment plant is about $500 to $600 per person served, the cost to a family of five is about $2,750. Thus, up-front costs of the MRPF system are competitive with conventional waste treatment systems. Moreover, the system provides fairly substantial income for *colonias* residents.

3.42 Public & Environmental Health Implications

The fact that the plant is cut and this cutting is very separated from the presence of wastewater makes this method fit into a sensible health approach towards a small floral business utilizing wastewater as its fertilizer supply.

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[21] David VenHuisen, "Lohman Ranch Waste Water Cost Analysis."

4.0 FUTURE INVESTIGATION

The entire border population has an intimate proximity with significant agriculture areas key to U.S. food production that could benefit from a transition to organic fertilization methods. The extent of this capacity is dependent on where in the corridor urbanization is spatially coincident to agriculture. Both geographic locations and drainage patterns determine the energy cost of pumping. Pumping requirements could be alleviated by acknowledging wastewater as having an economic value, rather than continue to view it as a waste with expensive associated treatment and "disposal" costs. The overall feasibility of this technical transition is largely determined by the expense of isolating domestic wastes from industrial wastes. However, the economics of the methods described above, coupled with the environmental, public health, and financial returns, make these alternative systems worthy of serious consideration.

As serious as the border's wastewater treatment needs are, a companion crisis is emerging in the area of adequate fresh water supplies. A side-by-side water collection program, whereby rainwater was captured in cisterns, would be an impressive complement to the widespread implementation of alternative wastewater treatment systems as described above.

A range of economic, public health and environmental benefits would accrue. No longer would expensive, centralized systems be depended on for basic water or waste treatment needs. Figure 2 illustrates the potential to match a household's water needs with rainwater, based on precipitation, roof size and household water use. Based on this map, the Rio Grande Valley appears to be an ideal candidate for these low-cost, appropriate technology systems.

The economic development potential through the utilization of plentiful manual skills is equally as potent as that for wastewater. In these examples each step of the life cycle of fresh water supply gleaned from runoff is a business similar to the waste water examples discussed in this report .. Starting form the roofing system (the source) to transporting (the gutters) to treatment (biological filtration) to use (water conservation) and finally reuse (solar distillation or productive waste treatment) one can demonstrate considerable job multiplier effect.

APPENDIX

Austin American Statesman July 23, 1984

A dialectic on Texian

It may be that somewhere, at [some] time, one person over[he]ard another person, wheeled [a]round and said, "Say, I'll bet [an]ything you're from Colorado!"

It may be that the words, "Boy, [I] could tell that Arizona accent [an]ywhere," have been [pr]onounced.

Possibly, there are books on [th]e shelves, titled, *How to Talk Or[eg]onian.* Somehow, though, I [do]ubt it.

But they do love to talk about [ho]w Texans talk. This is good. I [lik]e the way we talk and hope we [ke]ep talking like we talk. When I [w]as little, and television was just [co]ming into everyone's home, [th]ey told us that TV would neu[tr]alize regional accents, that [w]ithin a few years, everyone [w]ould talk the same. Even then, [th]at bothered me because the [id]ea of everyone's doing any[th]ing the same sounded pretty [b]oring.

IT DIDN'T HAPPEN. We still [ta]lk like we did and I'm glad. [A]nd non-Texans still talk about [ho]w we talk and I'm gladder. A [fr]iend of mine, a fellow from [P]ittsburgh, once said to me, "I'm [so]rry, but you have a really [st]rong Texas accent." I asked [hi]m why he was sorry. He was [so]rry I asked that and I wasn't a [bi]t sorry about it, either.

There's nothing wrong with [tr]ying to improve the way you do [so]mething. But I've never seen [m]y edge that "can't" holds over "ain't." When I try to say "can't," it comes out "kay-ent," [w]hich is silly, so why fool with it? [I] cain't see a reason.

THERE WAS A story in yester[d]ay's *New York Times Magazine* [ab]out this, by a fellow named [R]obert Reinhold, chief of the [*T*]*imes* Houston bureau. "Like any [go]od foreign correspondent, I [ha]ve been studying the local lan[gu]age. . . and it's not as hard to [le]arn Texian as you might think. . ." says he. He has the right ap[pr]oach. I was favorably disposed [to] Mr. Reinhold's observations [b]ecause he had gone unerringly [to] the ultimate source of knowl[ed]ge regarding all things: East [T]exas State University, long may [it] wave.

He found Fred Tarpley there, [an]d Dr. Tarpley knows about this [st]uff. "Unfortunately," says Tar[pl]ey, "Texans have a great infe[ri]ority complex about their [la]nguage. This is reinforced in [th]e schools by teachers who zero [in] on the dialect, changing 'tin' to [te]n.' (It's tee-in, incidentally.)" [T]arpley says we should realize [t]his is an honorable dialect that [w]e speak for historical reasons; I [fe]el we need to extend the Texas [p]ride to speech."

I WAS PLEASED to see Tar[pl]ey say that and even more [pl]eased that Mr. Reinhold disco[ve]red a Texas accent in Houston. [H]ouston has for so long been peo[pl]ed by refugees from New Jer[se]y and other planets that I [fe]ared the accent had fled to [so]mewhere it would be [ap]preciated.

Staff Photo by David Kennedy

Jim Holmes recycles bath and shower washing water for garden irrigation.

'Gray' system saves family tub full of bills

While the Texas population booms, the state water supply remains constant. In an effort to make the most of this limited resource, many people and cities are seeking ways to recycle — to use water more than once. In stories that will appear from time to time, the *American-Statesman* will examine various methods of recycling.

Water recycling

By MAX WOODFIN
American-Statesman Staff

While many Austin homeowners are griping about not being able to get enough water on their yards, Jim and Wanda Holmes are bragging that they haven't used a sprinkler or hose on their garden or flower beds in three months.

The Holmeses have just about the greenest garden in the Hill Country, but their tomatoes have ripened and their watermelon vines have spread on a water bill that's less than half that of an average family of four.

Instead of using water out of a hydrant, they use gray water — water that has first been used in their shower, tub, or washing machine.

Jim Holmes said they wanted their home in the Long Canyon development west of Austin to fit into the rugged environment and to be energy efficient.

THAT MEANT USE of solar equipment and low water use appliances. The Holmeses decided to go one step further and recycle as much of their water as possible.

The gray water goes into a holding tank separate from their septic tank. The water is then reused as irrigation for two large raised flower and plant beds and for more than 600 square feet of raised garden.

All of the irrigation is under the surface of the garden, but above the natural ground surface. A network of 1½-inch pipes runs through the soil that the Holmeses have built up for the beds.

"The only time I watered the garden (with a hose or sprinklers) was when I first planted," Jim said.

The holding tank for the gray water is divided into three compartments. The first two allow settling of any solids from the water. The third compartment has a pump that starts when the water reaches a predetermined level.

HOLMES SAID HE guesses that every two days the pump pushes 300 to 400 gallons into the pipe system.

The gardens, each roughly 5 feet by 30 feet, include okra, black-eyed peas, several varieties of squash, melons, and tomatoes as well as peach, plum, and fig trees.

The remainder of the yard needs no water other than rainfall. The Holmeses left as many existing plants as possible. Wanda, who is president of the Texas Native Plant Society, has added native plants throughout the 2-acre lot.

Jim said the gray water system added "a little bit" to the cost of the home, but it allowed other savings. Instead of a 1,200 square foot drain field for the septic tank, the Holmeses were only required to have 700 square feet.

THE SYSTEM WAS designed by a professional engineer and meets requirements of the Austin-Travis County Health Department.

Ervin Coonrod, supervisor of septic tank inspections in the health department, said the key to the Holmeses' system is that the irrigation takes place underground.

"I think that technically a surface irrigation with gray water could work," Coonrod said, "but at this point we're not allowing it. The potential for abuse is so great and it's impossible to monitor."

He said that water from a washing machine potentially "has almost as many bacteria and pathogens as water from a toilet." The subsurface system prevents almost all contact with the water.

The Holmeses also get a savings on their monthly water bill. The average water customer in their area uses more than 25,000 gallons monthly during the summer. The Holmeses' June water bill was for 10,700 gallons.

Not all the savings came from not watering flower beds and gardens, however. The Holmeses' two toilets use only one gallon a flush. Toilets in most older homes use five gallons a flush and even standard water-saving toilets use 2.5 gallons a flush.

Science Times

The New York Times TUESDAY, NOVEMBER 22, 1988

Scientists Revive a Lost Secret of

Ancient Peruvian fields yield inexpensive techniques that rival modern technology.

By WILLIAM K. STEVENS

FOR centuries, beginning around 3,000 years ago, there flourished on the high plains of the Peruvian Andes around Lake Titicaca a simple but ingenious form of agriculture that enabled ancient peoples to reap bumper crops in the face of flood, drought and the killing frost of those 12,000-foot altitudes.

Now archeologists have unlocked the secrets of those pre-Colombian fields — and found to their amazement that the techniques can outperform modern agricultural technologies under circumstances found throughout much of the Third World today.

In a striking example of what is known as experimental archeology, the modern scientists have restored an art that died out and was mostly lost even before the coming of the Spanish Conquistadors in the 16th century. All that survived were eroding traces of raised, rectangular platforms of earth alternating with canals in a corduroy pattern across acre after acre of flat expanse. Modern-day Peruvian Indians called the platforms "waru waru" and considered them to be signs left behind by a revered "first race" who ruled the area before the Incas came.

In a dramatic resurrection, modern-day Peruvians using ancient implements have reconstructed the raised-platform fields according to specifications derived from the archeological digs.

The prehistoric technology has proved so productive, so hardy and so inexpensive in its modern application that it is being held out as a possible alternative for wide stretches of the Third World where scarce resources and harsh local conditions have frustrated the advance of the high-tech Green Revolution.

Fields constructed and planted according to what has been termed "raised-field agriculture" require no chemical fertilizer or modern machinery. They cost almost nothing, except human labor. They are farmed with variants of ancient implements rather than expensive tractors and plows. They have outyielded conventional, capital-intensive fields as producers of potatoes, one of the region's main crops both in pre-Colombian days and now. When conventional fields die in a drought or flood, these mostly survive.

"It's fantastic," says Dr. William Denevan, an archeologist at the University of Wisconsin who was one of the first to discover the remains of the prehistoric platforms 20 years ago. "Here's a whole system, abandoned before any Europeans came, now being restored by the local community." Today's Green Revolution, based on heavy use of fertilizer and machinery, has not been able to penetrate everywhere or to all population groups, notes David Bathrick, the director of the United States Agency for International Development's office of agriculture.

Mr. Bathrick headed his agency's agricultural mission in Peru during the early years of the raised-field experiment and has visited the fields. They could, he said, become part of what he called a "second Green Revolution," aimed at less hospitable areas of the Third World, where flood, cold, heat, and drought routinely pose special difficulties, and where modern agricultural technology has not moved beyond the more favorable plains and river basins. They might be

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Peruvian community of Huatta on a northwestern bay of Lake Titicaca, Dr. Erickson sought to use the findings of his excavations to re-create, in real life, not only the fields but the way in which the ancients had organized and cultivated them.

When that had been done and the results were in, he said, "we realized it was such a fantastic system that maybe it could be re-introduced to the region as a replacement for some of the capital-intensive systems" of farming that depend on machinery, fertilizer and lots of money.

Eroded remains of the pre-Colombian raised-field platforms and canals of various sizes cover more than 200,000 acres of the low-lying plains around Lake Titicaca. The raised platforms of earth that were central to the technology generally range from 13 to 33 feet wide, 33 to 330 feet long, and about three feet high. It is on these earthen platforms that crops were planted. Between them are canals of like size and depth. The platforms were constructed of earth, including topsoil, that was removed to make the canals.

By analyzing soil and ancient pollen from the platforms and canals, Dr. Erickson's team learned that the sediment in the prehistoric canals was much richer in plant nutrients than the soil of the plain that surrounded them. The investigators also found pollen grains of potato and quinoa, a high-protein grain that grows in the United States as a weed called lamb's quarters but has been domesticated as a major food crop in South America since ancient times.

Using radio-carbon dating and other techniques, the team found, to its surprise, that the system of raised fields and canals dated to about 1000 B.C., making it not a brief, late phenomenon, as had been previously suspected, but apparently one of the earliest and most stable forms of intensive agriculture. Successive layers indicated that the fields had been re-built several times from about 1000 B.C. to about 1,400 A.D.

Over the centuries since, the platforms were eroded and the canals filled in to such an extent that their original dimensions were hidden. The archeological excavations stripped away that veil, revealing the original canal depth and ridge spacing, and these dimensions were used in the experimental phase of the project. Reconstruction of some of the fields began in 1981. Cultivation has continued since, and Dr. Erickson estimated that up to 200 acres are now being cultivated.

Traditional Andean tools, including a prehistoric plow operated by foot, were used to dig the new canals. Teams of three people were found to be the most efficient work unit. Two used footplows to cut blocks of sod from the old canals between the ridges, while the third tossed the sod blocks onto the field surface. This produced a layer of rich topsoil on the raised platform. Typically, 10 to 50 such groups from the same locality would work a given field.

During the first five years of experimentation, potato yields averaged 10 metric tons per hectare compared with 1 to 4 metric tons on surrounding conventional fields. This was so, Dr. Erickson reported, even though the conventional fields used fertilizers and the experimental fields did not. What the experimenters did use was the green algae that collected in the bottom of the canal, rich in nitrogen, that was shoveled onto the platforms during the dry season. Archeological evidence suggests that the ancients did the same thing.

The added nutrients meant that it was not necessary for the fields to periodically lie fallow.

Water in the canals enabled the experimental crops, including particularly large stands of grain, to survive a severe 1983 drought that caused widespread crop loss elsewhere in the area. The fields' elevation enabled them to survive the worst lake flood in years, in 1986, while crops in other fields all around were inundated. And by retaining solar radiation, the canal water warmed the raised fields and the air above them, limiting the danger of frost.

The larger the complex of raised fields and canals, Dr. Erickson said, "the better for the microclimate effect." In the experiment, communal land-holding groups of Quechua Indians, ranging in size from 30 to 150 families, banded together to create and cultivate the fields. Smaller extended family groups can also do it, said the archeologist.

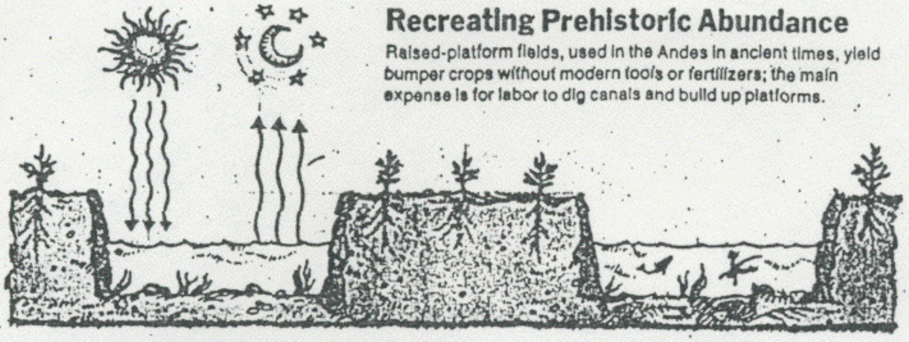
Because of this, and because the method is inexpensive and simple in its very sophistication, raised fields "may be an economical and ecologically sound alternative to agricultural development based on expensive imported technology," Dr. Erickson has written in an article for publication in "Expedition," the University Museum's journal.

Why did the technology die out originally? Does it make sense to put it back into operation without knowing the reason?

Seismic activity, massive floods or droughts, climatic changes: All, Dr. Erickson said, have been advanced as explanations but not proved. Dr. Erickson believes that the field system expanded to support population centers that grew up in pre-Inca antiquity. When power and influence shifted to other areas and empires rose and fell, he suggests, fields were withdrawn from production and abandoned and the art was forgotten.

Recreating Prehistoric Abundance

Raised-platform fields, used in the Andes in ancient times, yield bumper crops without modern tools or fertilizers; the main expense is for labor to dig canals and build up platforms.

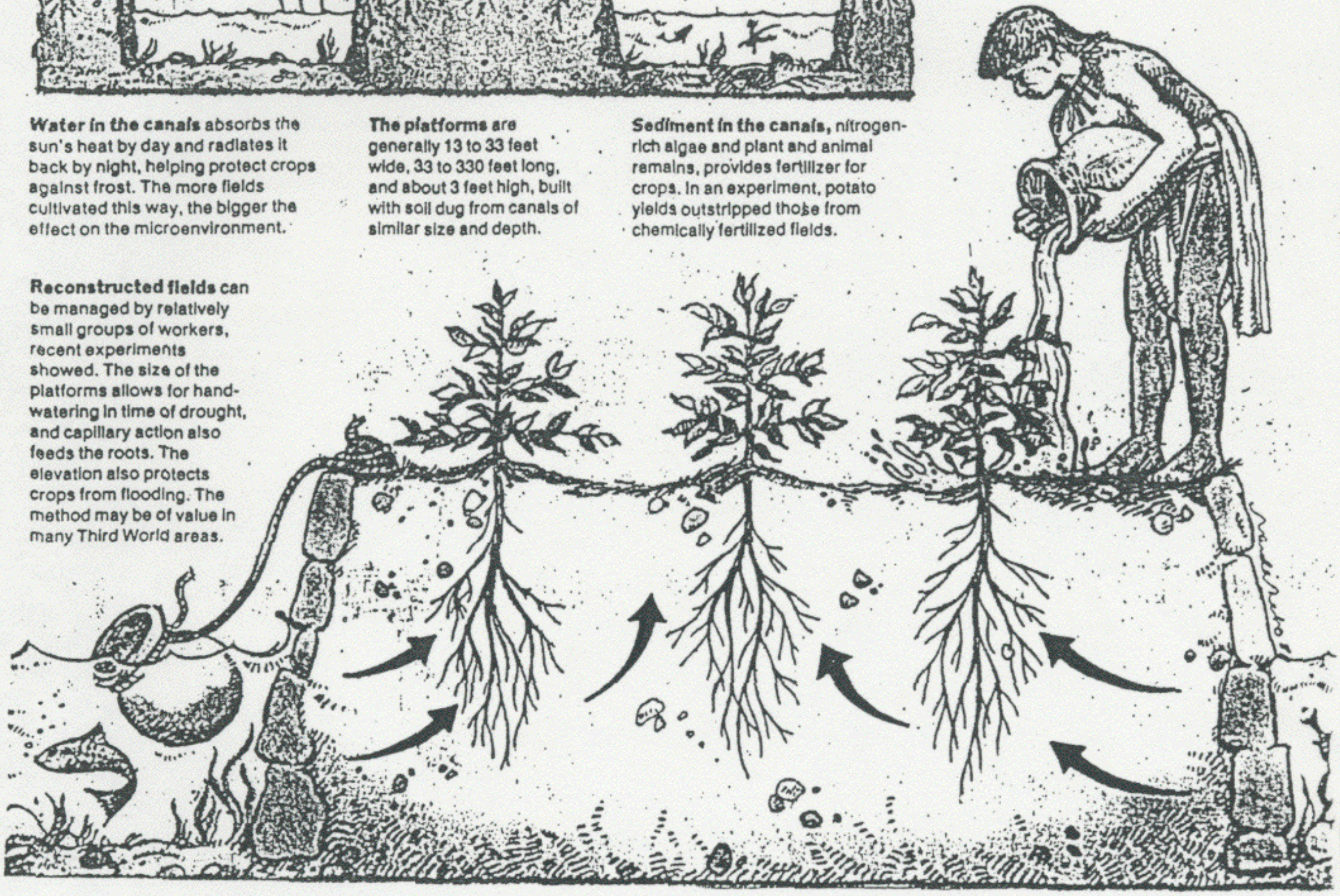


Water in the canals absorbs the sun's heat by day and radiates it back by night, helping protect crops against frost. The more fields cultivated this way, the bigger the effect on the microenvironment.

The platforms are generally 13 to 33 feet wide, 33 to 330 feet long, and about 3 feet high, built with soil dug from canals of similar size and depth.

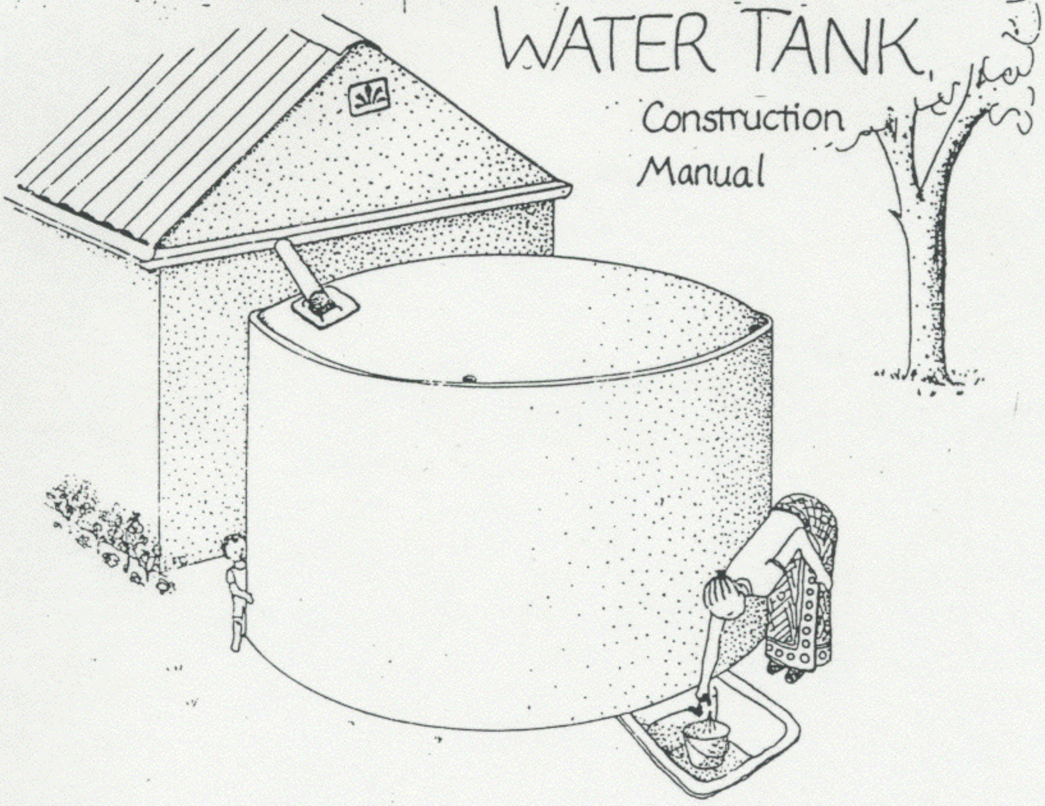
Sediment in the canals, nitrogen-rich algae and plant and animal remains, provides fertilizer for crops. In an experiment, potato yields outstripped those from chemically fertilized fields.

Reconstructed fields can be managed by relatively small groups of workers, recent experiments showed. The size of the platforms allows for hand-watering in time of drought, and capillary action also feeds the roots. The elevation also protects crops from flooding. The method may be of value in many Third World areas.



STANDING FERROCEMENT WATER TANK

Construction Manual



This tank is excellent for storing rainwater collected from roofs with gutters. It can alternatively be set up to store piped water. Because it is a standing tank, it is easy to withdraw the clean water by means of a tap in the floor of the tank.

The tank can be made in many different sizes, up to 50 cubic meters. The size described in detail here holds 20 cubic meters, or 20,000 liters, and has a diameter of just over three and a half meters. Dimensions and materials lists for larger and smaller tanks are found inside.

This construction manual is intended to be used by artisans who are undergoing or have completed a period of training in building the tanks.

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