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Rainwater harvesting: a new water source

by Jan Gerston

An old technology is gaining popularity in a new way. Rainwater harvesting is enjoying a renaissance of sorts in Texas, but it traces its history to biblical times.

Extensive rainwater harvesting apparatus existed 4000 years ago in the Negev Desert. In ancient Rome, residences were built with individual cisterns and paved courtyards to capture rainwater to augment water from the city's aqueducts. And as recently as early in this century, rainwater was the primary water source on many ranches, with stone and steel cisterns still standing today on homesteads upon which wells were long ago drilled.

On small islands with no significant river systems, rainwater is the only source of water. The island of Gibraltar has one of the largest rainwater collection systems in existence.

Now drought-sensitized Texas is waking up to the potential of water literally falling from the sky. In fact, the American Rainwater Catchment Systems Association based in Austin, claims about 50 Texas members, according to vice-president Bill Hoffman. The organization is working on standards for rainwater harvesting systems. (ARCSA). (For information on ARCSA, call Hoffman at (512) 463-7932.

At the National Wildflower Research Center in Austin, a network of aqueducts conveys water from collection surfaces to cisterns. The 6,000-gallon Entry Cistern shown here is connected to a drip irrigation system.

Rainwater offers advantages in water quality for both irrigation and domestic use. Rainwater is naturally soft (unlike well water), contains almost no

dissolved minerals or salts, is free of chemical treatment, and is a relatively reliable source of water for households. Rainwater collected and used on site can supplement or replace other sources of household water.

One of the beauties of rainwater harvesting systems is their flexibility. A system can be as simple as a whiskey barrel placed under a rain gutter downspout for watering a garden or as complex as an engineered, multi-tank, pumped and pressurized construction to supply residential and irrigation needs.

Although configurations vary with each installation, most systems include five basic components: (1) a catchment area, which could be the roof of a house or an open-sided barn sheltering cisterns, (2) gutters and downspouts to channel water from the catchment to storage, (3) cisterns and storage tanks, (4) a conveyance system, either gravity-fed or pumped, (5) water treatment.

Cost of a rainwater harvesting system is comparable that of a drilled well and pump. The primary expense is the storage tank. A good rule of thumb is about $1 per gallon of storage, although the cost of components varies widely. Operating costs can be less than those of a well, since rainwater eliminates the need for water softening treatments.

This 10,700-gallon tank was home-built by Mike McElveen from a stock panel form and sheet metal. Lined with polyethylene film, it stores rainwater for residential use.

The City of Austin, through its Green Builder Program, encourages rainwater harvesting by including it as a factor in its rating system for environmentally friendly houses. The Green Building Guide rates four aspects of a home--energy, building materials, solid waste and water. The program's *Sustainable Building Sourcebook* is a clearinghouse of information on state-of-the-art conservation techniques. For more information, call (512) 499-3545.

Unreliable aquifer creates need: Residential rainwater harvesting

Mike McElveen, an emergency room physician, lives west of Austin over the highly mineralized Glen Rose aquifer. He started with a whiskey barrel under a rain gutter spout as an experiment. After years of gradual augmentation, today rainwater supplies all water

needs for his family of four, irrigation for a vegetable garden and landscape, and make-up water for a swimming pool. At one time, McElveen even raised catfish in a cistern holding overflow water. He is an enthusiastic proponent of residential rainwater catchment. Early on he led countless tours of his ever-expanding residential system, and later developed a slide show and lecture.

"I'm drinking rainwater, but so is everyone else," McElveen said. "The difference is how far the raindrop travels before we drink it." Without chemical treatment, his drinking water is healthier. It is as much as 100 times softer than well water, with lower mineral content and total suspended solids. To illustrate his point quite dramatically in slide lectures, McElveen shows rain falling into a debris-filled ditch draining into Town Lake, and from there to the A.C. Green Water Treatment Plant, which supplies Austin drinking water.

Mike McElveen stands before a fiberglass tank which stores rainwater for garden irrigation at his home near Oak Hill, west of Austin.

McElveen's system consists of a 2,000-square-foot galvanized-steel-roofed pole barn feeding water via screened gutters to two large fiberglass cisterns with a combined capacity of 17,000 gallons for residential use. In one of two overflow tanks, McElveen once experimented with growing catfish. Ever the tinkerer, McElveen is testing a new 10,700-gallon stock-panel form and sheet metal tank with a polyethylene liner. A 0.5-horsepower centrifugal pump pressurizes water for household use. Near the vegetable garden is yet another cistern, this one galvanized steel, to collect runoff from the house roof. Tannin from leaves falling on the house roof render the water unpalatable for drinking, so it is used to irrigate gardens. Total domestic storage capacity is 48,000 gallons.

Although Federal Housing Administration guidelines estimate residential use at 100 gallons per person per day, while designing his system, McElveen measured his family's residential water consumption, with little effort at conservation, at 50 to 60 gallons per person per day. In any event, if rainwater is to provide for all household needs, storage must be sized to compensate for the worst-case scenario of high consumption and drought.

For drinking water treatment, McElveen relies on 5-micron and 1-micron cartridge filters and an ultraviolet (UV) treatment. He runs an Environmental Protection Agency test every 8 months for the same contaminants as municipal utilities test for: heavy metals, volatile organic compounds, pH, and hardness. An anecdote McElveen likes to tell

concerns the refinancing of his house 10 years ago. The well had been disconnected, and despite the fact that rainwater served the needs of the household, his loan request was denied. McElveen reconnected the well and submitted water samples for testing, but the well-water sample failed its water quality test. McElveen then purified the well water, reconnected the well for just the day of inspection, passed the test, and received loan approval. Ironically, the rainwater which had been serving the family exceeded water quality standards all along.

Since that time, rainwater harvesting has become a more acceptable alternative. Banks are more amenable to grant loans for rainwater-dependent residences. Architects, among them Peter Pfeiffer of Austin, integrate rainwater harvesting systems into design for new construction. And insurance companies, who formerly balked at insuring a house relying solely on rainwater harvesting, thereby effectively denying access to home financing, now sometimes offer a slight discount in light of the ready supply of stored water available to fight fires if a fire hose connection is installed at the storage tank.

This month, Hays County, the fastest-growing county in the nation, will consider an ordinance that would allow for smaller lot sizes in new subdivisions using household rainwater instead of groundwater (and central sewer connections instead of septic tanks). "Rainwater harvesting systems are a factor being considered for a waiver in lot size minimum requirement," said Allen Walther, county Director of Environmental Health.

Recognizing the opportunity: University of Texas

There was a problem at the University of Texas at Austin. About 300,000 gallons per month flushed through three cascading ponds supporting aquatic life for an adjacent biology laboratory. Alarmed at the once-through water use, Rusty Osborne of the university's Utility and Energy Management Department, designed a recirculating and filtration process which virtually stemmed that waste. Then he then went one step further. He designed a system to use rainwater as makeup water to compensate for evaporation from the pond.

Rusty Osborne, of the University of Texas, checks 1,000-gallon tank storing make-up water for three recirculating ponds.

Using existing gutters on the roof of the adjacent biology building, runoff from the roof is channeled into a 1,000-gallon tank. A float valve inside the tank maintains the proper water level. Overflow is pumped to a small constructed wetland adjacent to the highest pond, from which it trickles down through soil and rock back to the pond. The tank itself is buried within a bermed garden, hidden from view. When the pond water level drops due to evaporation, a sensor triggers a servo motor, which opens a valve to allow stored rainwater to gravity-feed from the tank to the pond. The first flush of water

from the roof contains dust, debris, and bird droppings. To separate the first flush from the stored water, a 6-inch PVC vertical standpipe, sealed at the top but with a removable bottom plug, is installed. Only after this pipe is filled will rainwater be routed to the tank.

Preferred for irrigation: National Wildflower Research Center

Captured rainwater serves all the irrigation needs of the National Wildflower Research Center in Austin.

The National Wildflower Research Center, founded by Lady Bird Johnson, finds rainwater best for irrigation. The most prominent feature of the center is the 10,000-gallon limestone-and-mortar tower cistern. Roof catchment areas of more than 20,000 square feet feed into three cisterns and two storage tanks with a capacity of 70,000 gallons. A network of aqueducts transports rainwater to storage.

In fact, many city dwellers served by municipal water districts, while finding they cannot justify the capital costs of installing a system adequate for household use, irrigate gardens with collected rainwater. Many rainwater collection systems complement residential graywater recycling efforts, and in fact, interest in rainwater harvesting is a natural outgrowth of graywater irrigation.

Performance with economy: Center for Maximum Potential Building Systems

Rainwater harvesting was a natural fit with the mission of Austin's nonprofit Center for Maximum Potential Building Systems--maximum performance and durability with minimum life-cycle costs, with reliance on local building resources. The rainwater harvesting systems integrated into the demonstration house at the foundation's facility features multi-level collection surfaces which gravity-feed water into three galvanized steel storage tanks totalling 13,700 gallons. As at the Wildflower Research Center, the storage tanks are aesthetically integrated into the overall project design. The house is designed to serve the needs of a family of four. A pump will pressurize the system for domestic use.

Galvanized steel tanks, integrated into the aethetics of this demonstration home, provide 13,700 gallons of rainwater storage at the Center for Maximum Potential Building Systems.

Recently, the Center produced the informative *Texas Guide to Rainwater Harvesting* under the direction of Gail Vittori, in conjunction with Texas Water Development Board. This 60-page primer emphasizing residential and small-scale commercial applications addresses water quality, cost, aesthetics, demand and collection formulas,

and system design. In an appendix are numerous Texas case studies of existing systems using concrete, fiberglass, and steel storage tanks. Some case studies feature composite graywater/rainwater systems.

Organic farming: Avera Armadillo Acres

To construct this 40,000-gallon tank at Avera Armadillo Acres, Sustainable Homesteads first bolted together a frame, then mounted galvanized steel panels to the frame.

Avera Armadillo Acres is an organic vegetable and flower farm near Dripping Springs, 25 miles west of Austin. Water from the underlying Glen Rose aquifer contains high levels of mineral salts, making it unsuitable for long-term irrigation use. In addition to the hardness issue, the aquifer has become less and less reliable due to rapid growth in the area. Several neighboring wells had dried up on occasion. Sustainable Homesteads of Wimberley engineered and is now installing a complex system of roof catchments, galvanized settling tanks and a large concrete cistern, water treatment filters, and a pump and pressurizing system. The system has more than one mile of pipe in an extensive underground collection manifold network, 45,000 gallons of storage, and almost 4,000 square feet of collection area.

The centerpiece of the farm's storage is a site-built 40,000-gallon concrete cistern. The unique cistern, designed by Matt Bachardy and Mark Licklider of Sustainable Homesteads, was constructed by first bolting together a form, to which galvanized panels were mounted. Next, a network of reinforcing steel was installed, and the wall and floors of the cistern were covered monolithically with Shot-crete, a proprietary concrete sprayed over the rebar. The forms were removed, then a center structural column was built. Structural beams were installed for roof support. The

The centerpiece of the rainwater collection system Avera Armadillo Acres in dripping springs is this 40,000-gallon site-built concrete tank. This photo shows reinforcing steel in place before the concrete roof is poured. The rainwater harvesting system at the organic farm was engineered and constructed by Sustainable Homesteads of Wimberley.

roof the cistern is bermed to allow it to function as a collection area. This flexible design allows construction of cisterns ranging from 10,000 to 80,000 gallons.

A proprietary concrete is sprayed monolithically over re-bar to form the inside of the main cistern at Avera Armadillo Acres.

Rainwater from a barn and pole barn constructed over the farm's residence is routed first to buffer tanks, where dust and debris settle out. From there, water is gravity-fed to a sump at the lowest point within the system. A float switch-controlled sump pump lifts water into the main cistern. Water treatment is afforded by UV light, a sand filter, a 20-micron cartridge, and disk filters. Water pressure is controlled by a 2-horsepower centrifugal pump and pressure tank. As currently designed, the system is augmented with an existing well, but eventually, rainwater will supply all irrigation and domestic water for the farm. Sustainable Homesteads can be reached at (512) 832-0737.

A new water source

Strictly speaking, rainwater harvesting is an entirely new water supply, quite apart from existing surface and ground water supplies, rather than a conservation technique. But whether used for irrigation, augmentation, or as an alternative to traditional supplies, rainwater harvesting is a viable option for new and existing construction, and will decrease the population's reliance on dwindling groundwater supplies and reduce demand for surface water.

Subsidence Dist. wins Governor's Award

The Harris-Galveston Coastal Subsidence District won the 1996 Governor's Award for Environmental Excellence in the education category for its *Learning to be Water Wise & Energy Efficient* youth education program.

This innovative program combines a curriculum teaching water efficiency and conservation with the distribution of high-quality plumbing equipment for installation in students' homes. The flexible curriculum developed by the National Energy Foundation conveys the conservation message through 10 hands-on activities, with lessons incorporating math, language, art, science and group dynamics skills Students perform plumbing tests at home, then use the results in classroom activities.

To forge this public-private partnership, Carole Baker, director of public information, and assistant Susan Brown coordinated the recruitment of over 400 public and private sponsors, including municipal utility districts, river authorities, and private corporations such as Texas Instruments, and several civil engineering firms from throughout the Subsidence District's jurisdiction. Sponsors fund the purchase of $28 home plumbing and educational packages distributed to schoolchildren. Sponsorship of more than $2.6 million to date has been generated. For each student sponsored, water suppliers receive a conservation credit from the Subsidence District, which regulates the pumping of groundwater in Harris and Galveston counties.

Since its initiation as a pilot program in 1993, this public-private partnership program has reached almost 95,000 fourth and fifth grade schoolchildren and their families in the Harris-Galveston Coastal Subsidence region of south central Texas. Baker and her staff have presented the program to student assemblies and teachers at more than 150 schools. They have also assisted school districts in over 25 Texas counties in implementing similar programs.

In five years, the program is estimated to conserve 10 billion gallons of water and wastewater.

The fundamental assumption underlying this program is that schoolchildren can effectively influence their families' water and energy use patterns. Installation of the kits' low-flow shower head and sink faucet aerators, coupled with students' new water-wise knowledge, has a positive effect on water conservation at home. The Subsidence District has received positive comments from parents representing almost every school regarding reduction of water use and water bills.

The Harris-Galveston Coastal Subsidence District also was awarded the U.S. Bureau of Reclamation 1995 Water Conservation Award in the Educational Mentor category for *Learning to be Water Wise & Energy Efficient*.

For more information about *Learning to be Water Wise & Energy Efficient*, call the National Energy Foundation, (801) 539-1451. For information about the Subsidence District's program, call Carole Baker or Susan Brown at (713) 486-1105.

Reuse suits small-town golf course

It was a classic case of water, water everywhere, but not a drop for golf course irrigation. Fort Clark Springs, a residential and resort community on the southern edge of the Edwards Plateau held no surface water rights to Las Moras Creek, which meanders through the picturesque community.

Actually a retired cavalry post, Fort Clark Springs is a tiny community of only about 750 households with a small winter population swell. The municipal utility district services 900 water taps.

This one-half-acre, 8-foot-deep pond stores reclaimed water for irrigation of Fort Clark Spring's 18-hole golf course. It is located adjacent to a residential area.

The previous owner of Fort Clark Springs had released its surface water rights when the property was sold. To avoid pumping groundwater from the Edwards Aquifer, this tiny community irrigates its 18-hole golf course with treated wastewater.

Using treated wastewater for golf course irrigation is common in Texas--the city of Odessa supplies treated wastewater to three golf courses, and the Las Colinas development irrigates four golf courses with wastewater from the Trinity River Authority's plant.

Soil at Fort Clark Springs allows percolation so that salt build-up does not create a problem. Grass, Bermuda overseeded with rye, as well as live oaks and huisache, all thrive, said Bob Slate, golf course manager.

Treated wastewater has historically supplied all golf course irrigation needs since its construction in 1982, except during last summer's drought, when groundwater supplement was required.

Tertiary treated wastewater is expected to solve problems of odor control now handled by chlorine injection at the half-acre storage pond. The new plant will have a capacity of 750,000 gallons per day, and will supply golf course irrigation storage ponds via 6-inch-diameter pipeline.

A three-lagoon, 1.3 million-gallon wastewater treatment plant now under construction will replace the existing wastewater treatment plant, which has served the fort since the mid-1940s. Financing is with a 40-year $3.7 million federal grant supplemented by a loan. The loan is being repaid without a bond issue, but rather with a small hike in customer monthly water rates, according to municipal utility district manager Larry Sofaly.

BUREC promotes Western states' reuse

As the federal caretaker of water resources in 17 western states, the U.S. Bureau of Reclamation is incorporating water reclamation and reuse projects into its overall water resources management policies.

Title XVI of the Reclamation Wastewater and Groundwater Studies and Facilities Act of 1992 formally charged Reclamation with promoting water reclamation and reuse, and gave Reclamation authority to participate in five geographic water recycling projects--four in California and one in Arizona.

An amendment in 1996 to Title XVI authorized 16 more projects, including the El Paso Water Reclamation and Reuse Project.

The 1996 amendment also set a $20 million cap on federal contributions and maintains a maximum federal contribution for each project of 25%, with actual contribution tied to the overall national benefit of the project. Demonstration projects which explore new technology, could be eligible of federal cost-sharing of up to 50%, based upon the degree of innovation and risk.

In the 1997 budget, however, Commissioner Eluid L. Martinez adopted a self-imposed cap of a total of$35 million for funding construction projects, a move which demonstrated both Reclamation's fiscal restraint as well as the perception that funding water recycling projects could adversely affect the agency's other on-going projects.

All projects are funded by Congressional authorization, and must first must pass the scrutiny of an appraisal (a preliminary survey of needs and solutions) and a feasibility study (a comprehensive economics and engineering investigation).

In 1996, Reclamation conducted five public workshops of water recycling stakeholders, including one in Austin, with representatives of congressional, federal state, tribal, local government, and private sector entities.

Comments generated by the workshops suggest that Reclamation should coordinate federal, tribal and state interests. Local agencies, assisted by the private sector, should be responsible for design and construction, with Reclamation providing design standards and review. Most attendees favored grant funding and state revolving fund processes, with a competitive funding option for small construction and demonstration projects.

Reclamation should play a role in advancing water recycling technology through research and in educating the public in the role of water recycling in future water supplies, stakeholders said.

In December, Reclamation released a white paper on water recycling with 20 recommendations reflecting a general agency consensus. Since the end of the public comment period in February, a Reclamation team is moving forward to develop

recommendations on feasibility studies and definitions for demonstration projects, according to Shannon Cunniff, supervisor issue manager.

The draft report, *Water Recycling: The Future is Here*, is posted on the Internet at http://www.usbr.gov/water_recyc. For a hard copy, contact Tammy Wentland , U.S. Bureau of Reclamation, at (202) 208-3568.

Estimating a water budget and rainfall harvest

The first step in designing a rainwater harvesting system is to work up a water budget, accounting for the amount of water used by all household devices plus landscape watering. The next step is figuring the potential rainfall harvest. Each square foot of roof area yields 0.6 gallons per inch of rain. Annual rainfall across the state varies from 8 inches in the southwest to 56 inches in the southeast.

Household population to be supported by rainwater harvesting

Collection area (square feet)	1000			2000			2500			3000		
	Conservation scenario			Conservation scenario			Conservation scenario			Conservation scenario		
Rainfall	Min	Mod	Adv	Min	Mod	Adv	Min	Mod	Adv	Min	Mod	Adv
24	0.37	0.47	0.76	0.74	0.93	1.51	0.92	1.17	1.89	1.10	1.40	2.27
28	0.43	0.54	0.88	0.86	1.09	1.77	1.07	1.36	2.21	1.29	1.63	2.65
32	0.49	0.62	1.01	0.98	1.25	2.02	1.23	1.56	2.52	1.47	1.87	3.03
36	0.55	0.70	1.14	1.10	1.40	2.27	1.38	1.75	2.84	1.66	2.10	3.41
40	0.61	0.78	1.26	1.23	1.56	2.52	1.53	1.95	3.16	1.84	2.33	3.79
44	0.67	0.86	1.39	1.35	1.71	2.78	1.69	2.14	3.47	2.02	2.57	4.16
48	0.74	0.93	1.51	1.47	1.87	3.03	1.84	2.33	3.79	2.21	2.80	4.54

Mike Personett of Texas Water Development Board, in a paper published in *The 21st Water for Texas Conference*, worked out average rates of residential water consumption per person in Texas based upon various conservation scenarios.The moderate conservation strategy estimates indoor consumption of 50.4 gallons per person per day and outdoor consumption of 34.1 gallons per person per day, for a total of 84.5 gallons per person per day. Minimum and advanced conservation would reduce totals to 107.2 and 52.1 gallons per person per day, respectively.

For example, a 2,500-square-foot roof receiving 32 inches of rain annually could support 1.23 persons using minimum conservation techniques. The same size house and rainfall for a family using advanced conservation techniques could support 2.52 persons.

Shorter irrigation cycles boost crop yields

PET data indicates advantages of shorter LEPA cycles

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A good thing just got better. Just as automobile manufacturers use aerodynamic body styles to boost the fuel efficiency achieved by lighter, more efficient engines, farmers in the High Plains are finding advantages in combining existing water-conserving equipment with a new method of scheduling crop irrigation.

Since January 1995, a field demonstration program within the High Plains Underground Water Conservation District No. 1 (HPUWCD) meshing the efficiency of low energy precision application (LEPA) irrigation with potential evapotranspiration (PET) data has found the combination boosts crop yields.

According to Ken Carver, HPUWCD's assistant manager, PET data can be used to determine when to irrigate a crop with any irrigation system. "By combining PET data with high-frequency deficit irrigation, a producer has the potential to produce the highest yield possible per inch of water applied," Carver said.

Increase in average cotton yield using LEPA irrigation

Irrigation (%ET)	Lint Yields (lb/ac)		Increased yield due to LEPA	
	LEPA	Spray	lb/ac	%
Dry*	282	282		
20-30	707	546	161	29.5%
50-60	768	604	164	27.1%
75	958	778	180	23.1%
90-100	1010	952	58	6.1%

*Dry land farming using no irrigation shown for comparison.

The demonstration has shown that a 60-hour (2.5-day) revolution of the LEPA center pivot sprinkler system, compared with the usual 5- to 7-day revolution, increases yields. Research performed by Bill Lyle, one of the inventors of LEPA, and others indicates cotton responds better to the shorter cycle.

Lyle, until his recent retirement, was a researcher at the Texas A&M Agricultural Research and Extension Center specializing in irrigation engineering. Since 1976, he has been researching efficient water use by management methods and engineering design. High-frequency irrigation `spoon feeds' crops Field tests indicate that high-frequency scheduling increases yields while conserving water. "When using high-frequency irrigation, farmers are `spoon-feeding' crops, rather than using long cycles that allow the crops to stress, then flood, the root systems. They are providing water as it is needed," said Lubbock County extension agent Mark Brown.

PET is a sort of benchmark--the water requirements of turf growing in a deep soil under well-watered conditions. A coefficient is calculated for each crop based upon the crop's size and stage of growth, as well as type of soil and current climatic conditions. PET is multiplied by the crop coefficient to give the evapotranspiration (ET) rate. (The two

components of evapotranspiration are evaporation, water lost from the adjacent soil, and transpiration, water entering the plant through the root system and consumed or lost to the atmosphere.) The amount of moisture lost to ET is the optimum amount to be replaced through irrigation and/or rainfall. PET data allow farmers to "fine tune" the amount of water applied to a crop, Brown said.

Researchers and farmers in the Texas High Plains find that high-frequency LEPA cycles boost crop yields. LEPA systems demonstrate 95 percent efficiency. Shown here are LEPA drop hoses and furrow dikes, small dams in the furrow which keep water from running off.

"Dr. Lyle's research showed such promise that we decided to offer it to the working farmer," said Scott Libby, HPUWCD irrigation specialist. In a demonstration project recently in the High Plains, six farmers tested high-frequency scheduling with cotton, corn and soybeans. Although impacted by insect and hail damage, cotton averaged 909.1 pounds of lint per acre, compared with an historicaverage of 787.0 pounds per acre using a center pivot with conventional spray irrigation.

"This irrigation scheduling program keeps cotton plants from stressing and keeps the feeder roots alive. Just about the time the plants have used up the available moisture, the pivot makes another round. In addition, by making light water passes, you're less likely to leach nitrogen and other nutrients deeper into the root zone," said Libby. Finding more efficient means of irrigation is important--agriculture accounts for about 9 million acre-feet of water use per year in Texas. In contrast, municipal and industrial water use combined is about 5 million acre-feet annually.

A total of 10 weather stations dispersed over 20 counties gather PET data for the High Plains region. Involved in the weather network are the Texas Agricultural Experiment Station (TAES) in Lubbock, the U.S. Department of Agriculture--Agricultural Research Service, and the Texas Agricultural Extension Service. Subscribers receive data sheets via fax machine early each morning. In addition, local newspapers carry PET data daily.

With high-frequency irrigation and the PET network data, farmers can apply just enough water to make sure the top foot of soil never dries out. "By using PET network data, producers are able to more accurately determine when and when not to irrigate, thus being more efficient with their water, time, energy, and money," said Libby. LEPA shines in deficit irrigation But where LEPA really shines is deficit irrigation. Established

in 1990 in Lamesa, Dawson County, a research validation farm tests emerging technologies to facilitate technology transfer to farmers. The research farm, called Agricultural Complex for Advanced Research and Extension System (AG-CARES), is a partnership between the Lamesa Cotton Growers Association and TAES. As reported in the *Proceedings of the Evapotranspiration and Irrigation Scheduling International Conference*, research results showed that at 25 percent of ET (replacing only 25 percent of the crop's ET coefficient), LEPA increased yields almost 30 percent over spray irrigation.

A producer may choose to conserve water by deliberate deficit irrigation and still end up with acceptable crop yields. Research also shows that irrigation of 75 percent of ET required by the crop would result in only a 5 percent reduction in yield from 100 percent ET irrigation.

Center-pivot irrigation systems typically irrigate a quarter section (160 acres except the 37 acres comprising the corners); each pivot is one-quarter mile long. A few center-pivots are one-half-mile long to irrigate a full section (less the corners), and some of these describe a windshield-wiper pattern to avoid obstructions. LEPA differs from conventional spray irrigation in that the nozzles are located just above the soil, versus 3 to 4 feet above the soil for conventional spray irrigation. Also, LEPA irrigates in alternate furrows which maintains a more stable soil temperature and enables equipment to more readily access fields for cultivation and ground application of pesticides.

Two basic versions of the LEPA system exist, both achieving an impressive 95 percent efficiency. One has bubbler-type nozzles located just above the soil which apply a low-energy stream instead of a spray which significantly reduces losses from evaporation and wind drift. The other uses a trailing "drag sock" which rests in the furrow. About 30 percent of the 9,118 center pivots operating in the HPUWCD's 15-county service area are true LEPA irrigation systems. LEPA accounts for almost all new center pivot systems installed in the district, according Libby.

The High Plains draws most of its water from the Ogallala Aquifer. Ongoing planning for the future of the Ogallala Aquifer leans heavily toward water conservation. According to A. Wayne Wyatt, HPUWCD manager, "Agriculture is the driving force of the Texas High Plains economy. Water is the most limiting factor in agricultural production in the region."