New Waves
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Texas A&M Researchers Investigate Use of "Dry Year Option" As Water Management Tool for Edwards Aquifer

For many years, Texas policy makers and water managers have agonized about the best way to manage limited water resources in the Edwards Aquifer. The conflict has centered around the dilemma that the area is arid and water-limited, that springflows have to be protected, and that human uses (irrigation and water for urban needs) are substantial and increasing. Recently, researchers at Texas A&M University published a thorough analysis of a policy that may satisfy many of these competing demands. The research focuses on the use of the "dry year option," which would pay farmers not to irrigate in dry years, thus freeing up water for urban and industrial uses and springflows.

The research was conducted by Keith Keplinger, a Ph.D. candidate in Urban and Regional Science, and researchers Bruce McCarl, Manzoor Chowdhury, Lonnie Jones and Ron Lacewell of the Agricultural Economics Department. The work was funded by the Texas Water Development Board. An abstract of the project is included in this issue.

The study involved research into such diverse areas as hydrology, economics, farmer decision making, and public policy. It explored how pumping patterns impact groundwater levels and springflows, how productive farmers could be under drought and dryland conditions, the price that would need to be paid to entice farmers not to irrigate, decisions that farmers would likely make about when to enter a dry year option program, and many other alternatives.

"This is the type of project that we want to be involved in," says McCarl, "because it addresses real concerns and gives us the opportunity to develop answers to real problems. If we can shed some light on Texas' pressing water concerns and offer viable solutions, then I feel we're making a real contribution."

What's the bottom line? A few answers emerge. First, much more water can be generated to enhance flows at Comal and San Marcos Springs by encouraging farmers in the eastern half of the region (Medina and Bexar Counties) to participate in a dry year option program. Second, it's probably more effective for all parties to have farmers sign up to participate in such a program in January than it is to wait until June. The January starting date is more effective at producing additional water because the offer would be made before most cropping decisions are locked in, and the majority of irrigating occurs between January and June. Farmers would benefit from a January starting date because

they could plan for a full season of rainfed agriculture and wouldn't have to change crop management strategies midway through the growing season if a drought occurred.

Finally, and perhaps most importantly, the price that the model suggests would have to be paid to get farmers to participate is much lower than the cost many San Antonio businesses and industries now pay for water. The results of the modeling exercises suggest that the marginal cost of purchasing agricultural water supplies for municipal use is about $32 per acre foot (AF). The cost of purchasing agricultural water, based on a January cutoff date, could be only about $78 per AF. Conversely, some water users in San Antonio now pay more than $1,043 per AF when monthly water bills are converted to the cost in acre-feet.

"The value of the studies is that policy makers now have the information they need to implement a valid management strategy to preserve water for springflows and urban uses at an economical price, while still providing agricultural interests with an incentive to lessen the amount they use for irrigation," McCarl says. Keplinger adds, "This is a plan that can be implemented in the near term that all parties may be able to agree to. The research suggests the cost of implementing a dry year option is very modest, when compared to solutions that require extensive public works. Modeling results indicate the plan would be very effective in producing more water for municipal and industrial use and for augmenting springflows."

It should be noted that agricultural water purchased under this scenario would likely be used by the buyer (cities or industries). To free up water for springflows, water would still have to be purchased (presumably by a state or regional water agency or some other group) and then be allowed to flow to the springs.

For details, contact McCarl at (409) 845-1706 or mccarl@tamu.edu, or Lacewell at (409) 845-2333 or r-lacewell@tamu.edu.

Beaumont Wetland Is Example of Cooperation

Texas A&M University graduate student Robin Witten O'Brien examines samples of benthic organisms she collected at the Beaumont wetland.

A man-made cattail marsh in Beaumont is an excellent example of how universities are cooperating with cities to improve the prospects for water research.

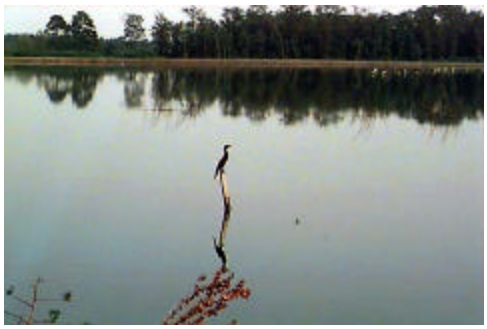
In 1985, the Beaumont Utilities Department decided to develop a series of eight wetlands cells spread out over 700 acres to provide polishing or tertiary treatment for its wastewater. The wetlands cells are located next to Tyrrell Park in south Beaumont. Although improving water quality is the primary goal of

the site, it's also become a magnet for bird watchers, walkers, joggers, and university scientists.

Clarence Cowart and Tommy McDonald manage the site for the city. The city encourages the use of the site for research. His staff cooperates with scientists by providing access, keeping the site safe and secure after hours, and moving equipment around.

So far, the site has been utilized for three studies. Scientist Richard Harrel and graduate student Sylvia Ray of the Lamar University Biology Department are examining water quality and the community structure of macrobenthic organisms. They are trying to determine if water quality and populations of macrobenthic organisms have changed at sites above and below the old, abandoned, effluent outfall where wastewater was discharged before the cattail marsh was constructed as well as above and below the new outfall that was created when the marsh was built. The presence of aquatic insects like larval mayflies, dragonflies, and beetles may indicate that water quality has improved, while high densities of certain worm and midge species may suggest that poor water quality still exists.

Researcher Paul DuBowy and graduate student Robin Witten-O'Brien of the Texas A&M University Wildlife and Fisheries Sciences Department are now monitoring the types and numbers of birds that visit individual wastewater cells. Her focus is to determine the water levels and other parameters that different birds prefer. "Wading birds and dabbling ducks want relatively shallow water while cormorants and diving ducks prefer deeper water. We're not fully aware of the specific conditions each species will visit most often." The research is important if Beaumont wants to promote the site as a facility to attract bird watchers. "Once you have the data we're developing, you could maintain specific water levels to attract the species that bird watchers most want to observe and photograph." DuBowy is also leading efforts to document the populations of dragonflies, aquatic nymphs, diving beetles, and giant waterbugs that live in different cells. The goal is to determine which types of benthic macroinvertebrates tolerate and thrive in waters with different ammonia levels. "The site is also very useful because the conditions that are unique in each cell can be compared to



what is occurring nearby," DuBowy says. In the future, DuBowy hopes to monitor wildlife use of the wetlands, based on vegetation cover and density, water quality and water depth.

In another project, Fred Turner of the Texas Agricultural Experiment Station at Beaumont collected water quality and soil samples from points throughout the system. Turner's goal was to gather data on the amount of phosphorus that had built up in the soils and to determine if soils had accumulated so much phosphorus that they can't absorb any more. Phosphorus in wastewater attaches to soils, and eventually soils may become so loaded that they lose their ability to remove significant amounts of phosphorus. The studies showed that the first two cells have already accumulated substantial amounts of phosphorus. In the future, Turner hopes to investigate strategies to remove phosphorus including bypassing individual cells and allowing them to dry out, excavating the top few inches of soil and applying it elsewhere as a phosphorus fertilizer, tilling the soil to expose more phosphorus, and using soil amendments to absorb more phosphorus.

For more details, contact DuBowy at (409) 845-5765 or p-dubowy@tamu.edu, Turner at (409) 752-2741 or Harrel at (409) 880-8255. Clarence Cowart manages the cattail marsh for the City of Beaumont and can be contacted at (409) 842-0458.

Economic and Hydrologic Implications of A Dry Year Option

Authors: Keith Keplinger, Urban and Regional Planning Department, Texas A&M University, College Station, TX, and Bruce McCarl, Manzoor Chowdhury, Ron Lacewell, and Lonnie Jones, Agricultural Economics Department, Texas A&M University, College Station, TX.

Problem: For many reasons, the Edwards Aquifer cannot produce enough water to satisfy regional needs during dry years. The drought of 1996 lessened springflows substantially and forced some of the regional water management agencies to impose strict water conservation measures. There is also relatively high water use by agricultural producers and urban interests as well as the need to keep water flowing at Comal and San

Marcos Springs to protect sensitive ecosystems and endangered species that live in them. The challenge is to find viable strategies that can be used to efficiently manage water supplies for these competing needs.

Objectives: To develop and utilize computer simulation models that would simulate the hydrologic, agronomic, and economic effects of various dry year option management strategies for use in the Edwards Aquifer.

Methodology: Hydrologic studies were conducted to develop relationships between springflows, ending aquifer elevations, and depths to groundwater as functions of recharge, pumping, and beginning aquifer elevations. An updated monthly version of the Texas Water Development Board GWSIM-IV model was used to output hydrologic variables for different combinations of pumping in the Eastern (Bexar and Medina counties) and Western (Uvalde and Kinney counties) portions of the study area, starting groundwater levels, and recharge. Ordinary least square regression was used to develop relationships between flows at Comal and San Marcos Springs, water levels at index wells, groundwater pumping, and annual recharge. An agricultural sector optimization model was developed to simulate decisions farmers would make about cropping and pumping, based on maximizing profits. The model simulates farmer decisions about what crops should be planted and which irrigation strategies should be used. These decisions were simulated under nine different scenarios of groundwater recharge which were derived from U.S. Geological Survey data from 1934-89. Three dry year option scenarios were simulated, all of which assume that all irrigators throughout the region will be offered a set price per acre for agreeing not to irrigate. The scenarios include: 1) Offering a price in the fall to farmers to not irrigate for a given year beginning in January; 2) Offering a price in the summer to farmers to stop irrigating in June; and 3) Advising farmers in January that they should anticipate a possible dry year offer in June. Scenario 2 could be used if an unexpected drought situation developed after farmers had already planted their crops. Scenario 3 could be implemented if the year was already relatively dry when farmers planted their crops.

Results: The model results suggest that irrigators will withdraw 13,885 acres from furrow-irrigated crop production in the Eastern region when the dry year option price is only $10 per acre. When the price reaches $50 per acre, sprinkler irrigation is taken out of production. When the offer climbs to $90 per acre, all irrigation in the Eastern region will convert to dryland agriculture. In the Western region, as many as 17,618 acres will be taken out of irrigation when prices reach $60 an acre, while all land will be converted to dryland agriculture at prices of $120 per acre. If 13,885 acres in the Eastern region were to stop irrigating, the amount of water used for irrigation would decline by roughly 37,000 acre-feet (AF) and flows at Comal and San Marcos Springs would increase by more than 15,000 AF or as much as 28 cubic feet per second. If 17,618 acres in the Western region were to enter the dry year option, irrigation use would decline by nearly 50,000 AF, but springflows would only increase by 2,789 AF. It is much more efficient to enroll acreage in the Eastern portion of the region to enhance springflows. The results show that water could be withdrawn from irrigation for a cost of only $20-32 per AF while urban water users in the San Antonio area are now paying as much as $1,043 per

AF. This suggests the dry year option makes economic sense for rural and urban interests in the region.

Reference: Keplinger, K., B. McCarl, M. Chowdhury and R. Lacewell, *Economic and Hydrologic Implications of Implementing a Dry-Year Option for the Edwards Aquifer*, Agricultural Economics Department, Texas A&M University, College Station, TX, 1996.

Characterizing Contaminated Sediments in Oso Bay

Authors: S. Hollyfield and Virenda Sharma, Environmental Science Program, Texas A&M University-Corpus Christi (TAMUCC) Corpus Christi, TX.

Problem: The pollution of coastal waters by hydrocarbons and other urban contaminants has become a major research interest as more attention is given to the need to protect bay and estuary ecosystems. The impact of this contamination can be assessed by measuring the concentrations of organic compounds in water, sediment, and biological constituents. Oso Bay, located near Corpus Christi, has experienced many man-made changes including alteration of flows, urbanization, and industrialization. Potential pollution sources include landfills, military bases, municipal and industrial discharges, and the offshore dumping of wastes into coastal waters.

Objectives: 1) To collect sediment samples from Oso Bay and its contributing watershed and to analyze these samples to determine the nature and extent of contamination and the possible origin of these pollutants, and 2) to determine the distribution of various sediments throughout the Bay system by examining and comparing grain sizes.

Methodology: Sediment samples were collected at nine sites located at Oso Creek and Oso Bay in 1994. The upper 5 centimeters (cm) of sediments were removed with a Teflon-coated scoop and placed into a container. Sediment samples to be analyzed for contamination were frozen in the field and transported to the laboratory at TAMUCC for analysis. Sediment samples that were obtained for grain size analysis were not frozen but were stored at ambient temperatures. Sediment subsamples were extracted and were analyzed using gas chromatography and mass spectrometry.

Results: High concentrations of muddy sand suggest that Oso Bay consists of common bay-margin sediments. Coarse sediments generally occur in shallow bay regions, while fine sediments were found in deeper waters. Three major contaminants were detected: tetrachloroethene (TCE), phthalate esters (PAEs), and aliphatic hydrocarbons. TCE, a compound used mainly for degreasing and dry cleaning that is also used in the manufacturing of pesticides, food additives, and drugs, was found at all but two sites in Oso Bay. TCE adsorbs onto clay materials and organic detritus which are sinks for these sorbed contaminants. TCE levels were as high as 1,433 micrograms per kilogram (ug/kg). The locations where TCE was found suggest that this contamination may have originated from area military facilities. PAEs are widely used in the manufacture of plastics and increase the flexibility and workability of polymers. PAEs were found at three sites in the bay and at a site on Oso Creek. They were present in sediments near a waste dumping site and a municipal landfill at levels of as much as 193 ug/kg. This suggests that they may

have originated from the large amount of plastic materials being deposited at local landfills. Aliphatic hydrocarbons are petroleum by-products and were found at all sites at concentrations of more than 2,450 ug/kg. Weathered petroleum oils were found throughout the study region. This suggests that surface runoff may be occurring from military facilities, roads, and parking lots. Additional research should be conducted to develop data on the occurrence of these and other chemicals in water and biological samples that can be compared to these sediment data.

Reference: Hollyfield, S., and V. Sharma, "Organic Contaminants and Characteristics of Sediments from Oso Bay," *Environmental Geology*, Volume 25 (pp. 137-140), 1995.

Drip Irrigation of Corn in the Texas High Plains

Authors: Terry Howell and Arland Schneider, U.S. Department of Agriculture/ Agricultural Research Service (USDA/ ARS), Bushland, TX, and Bobby Stewart, Dryland Agriculture Institute, West Texas A&M University, Canyon, TX.

Problem: Farmers in the Texas High Plains rely on the Ogallala Aquifer and rainfall to provide water for crops. However, groundwater levels are declining in many areas and the depth to groundwater is increasing. Microirrigation (drip irrigation) is a very efficient way to water crops, and it may also potentially increase yields. The efficiency of drip irrigation needs to be compared to other methods, in terms of total water use and its impact on crop production.

Objectives: 1) To evaluate surface and subsurface microirrigation methods for corn production in the Texas High Plains; 2) to compare daily and weekly irrigation intervals required for a wide range of water applications; and 3) to determine the effects of deficit irrigation regimes on crop water use and water use efficiency.

Bobby Stewart of the Dryland Agriculture Insitute of WTAMU checks the moisture of this soil at Bushland, TX. The abstract in this issue describes whether drip irrigation can successfully be used to irrigate corn in a water efficient manner.

Methodology: Corn crops were irrigated either daily or weekly. A randomized block design was utilized with split plots and three replications. Each plot was 30 feet wide and 90 feet long. Plots were laser-leveled and diked on all sides to prevent stormwater runoff. Irrigation amounts varied from full irrigation to medium levels (67%) to low levels (33%). A plot that received only rainfall (no irrigation) was utilized to simulate dryland farming conditions. Separate plots were established for surface and subsurface drip irrigation. Irrigation needs were based on weekly soil measurements using a neutron probe. The microirrigation system that was utilized consisted of Netafim tubing with a 0.64

millimeter (mm) thick wall. Emitters were spaced 1.5 feet apart and the application rate was 0.6 gallons per hour. Subsurface drip irrigation lines were installed with chisels and reels and were connected to a common flush manifold. Irrigation water was treated with diluted phosphoric acid to avoid root plugging. Corn was planted on May 27, 1993. Neutron tubes were installed to a depth of 7 feet on June 15. Irrigation was applied after the crops were tilled and before the seeds were planted to pre-wet the soil and to facilitate planting and germination. The corn was harvested on October 14-15. Grain yield was determined by hand harvesting from center rows in each plot. Water use was determined as the sum of soil water extracted from the 7-foot deep soil profile, rainfall during the growing season, and the amount of water applied by irrigation.

Results: The dryland plot suffered severe water deficits and corn plants were practically dead after tasseling. Both surface and subsurface drip irrigation were effective and efficient irrigation methods, but crop yields were less than expected. Grain yields still exceeded 235 bushels per acre for the highest irrigation rate. Yields and water applications were not significantly different from a nearby study that utilized low energy precision application (LEPA) irrigation. The process of initially establishing the crop is a major problem for drip irrigation. Almost 133 mm of water was needed to make sure corn would germinate and emerge. This is similar to the amount of preplant water that would have to supplied if furrow irrigation systems were utilized. Drip irrigation did improve application efficiency by minimizing application losses. Irrigation frequency did not affect corn yields as long as adequate water was applied. Weekly irrigations were as effective as daily irrigations. The subsurface drip system provided a drier topsoil and permitted rainfall to be stored in the soils, but surface drip irrigation system kept roughly half of topsoils wet.

Reference: Howell, T., A. Schneider, and B. Stewart, "Surface and Subsurface Microirrigation of Corn: U.S. Southern High Plains," in *Microirrigation for a Changing World*, Proceedings of the 5th International Microirrigation Congress, Orlando, FL, 1995.

Relationships Between Dairies and Water Quality

Authors: Anne McFarland and Larry Hauck, Texas Institute for Applied Environmental Research (TIAER), Tarleton State University, Stephenville, TX.

Problem: The Upper North Bosque River watershed in Central Texas comprises roughly 230,000 acres. The watershed contains 94 dairies with a combined herd size of more than 34,000 cows. Other agricultural activities in the region include hay and peanut farming, peach orchards, and beef cattle. Because so many dairies and cows are present, regulators and policy makers are concerned about adverse impacts on water quality in the Upper North Bosque River and Lake Waco and ways to improve dairy operations to minimize water quality concerns. TIAER has implemented a comprehensive strategy to monitor water quality at sites in the watershed.

Objectives: 1) To calculate flow at all automated monitoring sites; 2) to compare chemical and physical water quality between small flood control reservoir sites; 3) to compute flow-weighted stormwater quality levels between stream sites; 4) to compare

water quality at low flows with water quality during storms at major tributaries and main branches, and 5) to evaluate relationships between land use and soils with reservoir and stream water quality constituents.

Methodology: Monitoring sites were established at sites in five agricultural microwatersheds (tributaries to the North Fork and South Fork of the Bosque River, Indian Creek, Spring Creek, and Dry Creek Branch). Two urban sites (Methodist Branch and Industrial Branch) were studied. Major tributary subwatersheds were monitored, including the North and South Forks of the North Bosque River, Alarm Creek, and Green Creek. Three watersheds along the North Bosque River were monitored including stations below the Stephenville wastewater treatment plant, above Green Creek, and at Hico. Monthly grab samples were collected at seven major stream sites and eight reservoir sites. Values were measured in the field for dissolved oxygen, water temperature, specific conductance, pH and Secchi disk depth. Laboratory analyses were conducted for total nitrogen, ammonia, nitrite, nitrate, orthophosphate, total phosphorus, total suspended solids, volatile suspended solids, chemical oxygen demand, total organic carbon, turbidity, 5-day biochemical oxygen demand, fecal coliforms, and chlorophyll-a. Stormwater samples were collected at key sites using ISCO automated samplers. Flow measurements were collected using velocity meters calibrated at TSU Hydrology Department facilities. Land uses in the Upper North Bosque River watershed were determined from Landsat TM images and ground truthing was used to verify those results.

Results: The research suggests that the percent of dairy waste application fields, dairy cow densities, and the percent of woodland and rangeland in agricultural watersheds are strongly correlated to water quality. Water quality data suggest that levels of orthophosphate and total phosphorus often exceed state screening levels in agricultural and urban watersheds. There was a significant correlation between levels of orthophosphate and total phosphorus as the percentage of dairy waste application fields increased in drainage basins above reservoir and stream sites. The data suggest there is a causal relationship between the number of manure application fields and the number of dairy cows to in-stream nutrient levels. In some cases, elevated levels of nutrients were found in streams and reservoirs downstream of dairy operations, but were not present in watersheds where dairies were not sited upstream. The report suggests that policy makers may want to target specific micro- and subwatersheds that provide disproportionate pollution loadings to the river system. In the Upper North Bosque watershed, special attention should be given to address high phosphorus levels.

Reference: McFarland, A., and L. Hauck, *Livestock and the Environment: Scientific Underpinnings for Policy Analysis*, TIAER, Tarleton State University, Stephenville, TX, 1995.

Assessing Tidal Circulation Patterns in Sabine Lake

Authors: Peter Mantz and Ainong Dong, Civil Engineering Department, Lamar University, Beaumont, TX.

Problem: The flow of water into and out of Sabine Lake is dominated by tidal processes in the Gulf of Mexico. Tides from the Gulf are superimposed on freshwater flows of the Sabine and Neches rivers and smaller bayous. Gulf tides may dominate inland water flows several miles upstream of Beaumont and Orange. There are many sites downstream of Sabine Pass and into the Gulf where river flows exert only a minimal influence. Many attempts have been made to understand the relative contributions of Gulf and inland flows to circulation patterns. Since 1993, Lamar University has established eight water level gauges in the Sabine Lake system. This activity is part of the Texas Coastal Offshore Observation Network (TCOON), and includes cooperation between Lamar University, Texas A&M University-Corpus Christi, the National Ocean Service (NOS), the Texas General Land Office, the Texas Water Development Board (TWDB), and the U.S. Army Corps of Engineers. Understanding circulation patterns within the Sabine Lake ecosystem will be beneficial for navigation and recreation as well as dealing with coastal storms and flooding.

Peter Mantz of Lamar University demonstrates a computer model Ric Jensen of TWRI. The model displays data on tidal flows and circulation patterns in Sabine Lake and offshore sites.

Objectives: 1) To synthesize data obtained by TWDB, TCOON, Lamar University and other sources into a geographic computer model of the region, and 2) to simulate trends in tidal flows using complex computer simulation modeling programs.

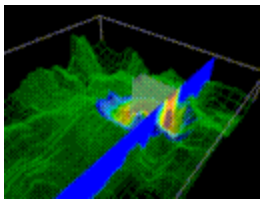
Methodology: Monitoring stations have been established at two upstream sites (Beaumont and Orange), two sites on the inland side of Sabine Lake (Rainbow Bridge and Port Arthur), and two sites on the Gulf side of the lake (Johnson Bayou and Mesquite Point). There are monitoring stations in the lake, at Mesquite and Sabine passes, at High Island, and at an offshore site. The stations measure water levels every second for three minutes in a 6-minute cycle (to provide an average and a standard deviation) and are accurate within one millimeter. Data are transmitted every three hours via the Geostationary Orbital Earth System (GOES) to a NOS database. Lamar accesses this database hourly and a computer program automatically generates charts that graph and spatially display the data. Monthly variations of water levels for May 1996 were examined to analyze "normal" astronomical tides with minimal meteorological interference (excess storms and winds). The NOS method of "tide by tide" analysis was used to summarize these data. A finite element computer program that incorporates hydrodynamic equations of momentum and continuity was utilized to spatially display tidal circulation patterns. Equations were solved for each element and the solution was iterated from boundary conditions (freshwater inflows at Beaumont and Orange and Gulf tides at the offshore site). Theoretical wave speeds were computed and compared to actual recorded data and results of other modeling studies.

Results: The tidal water level studies show that it took 1 hour for water to flow from the Sabine offshore site to Mesquite Point, about 4 hours to Rainbow Bridge, and 5 hours to Orange. Sabine Lake slowed the progress of this tidal wave. Offshore tides lost about half their amplitude at Mesquite Point. Almost 75% of tidal energy was lost in Sabine Pass. Results of the tidal circulation studies show that theoretical gravity wave speeds were closely matched for the Rainbow Bridge to Beaumont and Rainbow Bridge to Orange reaches. Modeled speeds were less than 50% of theoretical wave speeds at Sabine Lake and Mesquite Point and were less than 25% of theoretical wave speeds at Sabine Pass. This is because the modeling accounts for significant energy losses in Sabine Pass due to eddying. Maximum flood currents increased about 2 knots from Sabine Pass to Mesquite Point and then decreased in the lake. After a common water level was reached between the lake and the Sabine Ship Channel, the tide then progressed up the Sabine and Neches rivers.

Reference: Mantz, P., and A. Dong, "Tidal Circulation in Sabine Lake," in *Proceedings of the Sabine Lake Conference: Where Texas and Louisiana Come Together*, September 1996.

Texas A&M Researchers to Develop High Tech Tools to Model Groundwater Flows

Developing computer simulation tools to better understand the flow of groundwater through porous media is the goal of a research project recently awarded to Texas A&M University scientists. The project was funded by the Texas Higher Education Coordinating Board. Lead researchers include David Dobson, Michael Pilant, and Peter Kaup of the Mathematics Department and Mark Everett of the Geology and Geophysics Department.



The goal is to better characterize the geological properties of groundwater formations, including porosity and permeability, using sophisticated computerized methods. Recently, significant progress has been made in numerical modeling of flows in porous media and electromagnetic wave propagation. This project will combine these efforts to develop computer codes to model ground-penetrating radar and controlled source electromagnetic sources in single- and two-phase flow regimes. This may result in more realistic simulations of large two- and three-dimensional problems and may help develop visualization tools that provide users with readily comprehensible results.

A challenge being addressed in this project involves coupling electromagnetic and porous flow models in heterogeneous media to accurately simulate interconnected flow pathways. Research will be conducted to better understand relationships between electrical and fluid pathways and to develop models that will improve the coupling between these processes. The information will be also provide insights into a project Pilant is working on titled "Grand Challenges in Groundwater Contamination."

For details, contact Dobson at (409) 845-1924 or dobson@math.tamu.edu, Pilant at (409) 845-5631 or mpilant@isc.tamu.edu, or Everett at (409) 845-2451. Information on Grand Challenges In Groundwater Contamination can be viewed on the WWW site for the TAMU Institute for Scientific Computation at http://www.isc.tamu.edu/PICS/.

UT to Examine Development of North Mexico Deserts

A large portion of Northern Mexico is now a vast semi-arid desert that is almost devoid of surface water. Now, a research project funded by the Texas Higher Education Coordinating Board is asking, "How did the region get to be that way?"

The research is led by Karl Butzer of the Geography Department at the University of Texas at Austin. Butzer wants to explore two hypotheses. First, was the climate of the region wetter from 1550-1650 than it is today and could that unusually wet period have lured settlers into the region and begun the northward movement of Mexican colonists to Texas and New Mexico? Secondly, has the environment been progressively degraded -- first at a local scale near mining centers, later by regional deforestation and range deterioration, and recently by overambitious irrigation projects that exploit limited water resources and lead to growth in border cities?

The study is different from many analyses of the impact of humans on the environment that rely on data that can be inferred or reconstructed, utilize only fairly recent information, and cross periods where climates are similar. In contrast, this project will incorporate such diverse disciplines as earth science, geography, paleobiology, and the use of historical archives. Ultimately, Butzer believes the concepts developed in this study could be applied to arid regions of the Western U.S. , including Texas, and other situations where man's long-term activities may have impacted the environment.

For details, contact Butzer at (512) 471-5116.

Texas Tech Studies Use of Ultrasound to Degrade Industrial Wastewaters

Industrial wastewaters generated as a by-product of the petrochemical industry in Texas have to be cleaned up or remediated before they can be safely discharged into lakes and streams. A researcher at Texas Tech University is investigating a potentially inexpensive and energy-efficient method to treat these wastewaters.

The research is being conducted by Dominick Casadonte of the Chemistry and Biochemistry Department. The research consists of investigating the use of high-intensity ultrasound devices to destroy hydrocarbon and haloalkyl compounds which are found in industrial wastewaters. Preliminary laboratory experiments conducted by Casadonte suggest that ultrasound can be used to eliminate organic contaminants from aqueous environments, but the optimal strategies for commercial applications need to be developed.

In the project, Casadonte will team up with a commercial company in Bishop, TX, which will supply the industrial wastewater stream. Ultimately, the project could lead to the

development of full scale designs of this technology that could be used in industrial settings.

For details, contact Casadonte at (806) 742-1832 or tkdjc@ttu.edu.

Rice U. Investigates Impact of Severe Storms on Offshore Oil Production Platforms

Improving the understanding of the dynamic response of offshore oil production platforms is the goal of a research project being undertaken by engineers at Rice University. The project was awarded by the Texas Higher Education Coordinating Board.

The project leader is Anestis Veletsos of the Civil Engineering Department. The research will focus on how deep-water platforms respond to hydrodynamic forces such as waves that are induced by severe storms. Special attention will be paid to the effects of fluid-structure interaction, inelastic action, wave directionality and near-surface kinetics.

Results will be interpreted by the use of the response spectrum concept, which has been used to analyze earthquake effects, but which has not yet been utilized in studies of offshore structures. Veletsos hopes that the use of this method will lead to rational, efficient methods to assess the hydrodynamic design requirements of offshore structures.

For details, contact Veletsos at (713) 285-5291.

Texas A&M to Study Use of Algae to Produce Poultry Feed

Health and nutritional professionals now realize that eating fish can significantly improve your health. Fish contain polyunsaturated fatty acids (PUFAs), which may reduce the risk of heart disease and improve maternal and neonatal health. The problem is that few Americans consume enough fish; chicken is a much more popular choice. Now, scientists at Texas A&M University are investigating if a poultry feed could be developed that is rich in PUFAs. The ultimate goal is to produce chickens that are high in PUFAs.

The lead researcher is Mary Van Elswyk of the Poultry Sciences Department. Van Elswyk will test the use of golden marine microalgae as a key component in poultry feeds. The microalgae may have superior lipid stability compared to traditional PUFAs because they are naturally rich in antioxidant carotenoids and vitamins and because lipids are microencapsulated by the algae cell wall.

The study will determine the most efficient concentration and feeding duration of the microalgae to produce PUFA-enhanced poultry meat, will assess the sensory quality and shelf life of these poultry products, and will gauge consumer acceptance of these meats through the use of a statewide survey. Similar research by Van Elswyk has resulted in the development of eggs that are rich in PUFAs that were produced by feeding chickens marine oils. These eggs will soon be on the market.

For details, contact Van Elswyk at (409) 845-7537 or mvanelsw@poultry.tamu.edu.

UH Scientists Explore Use of Geothermal Heat to Protect Aquaculture Operations During Cold Weather

Cold weather along the Texas Gulf Coast poses a potentially lethal threat to many species of fish and shrimp grown in outdoor aquaculture facilities. If problems associated with freezing temperatures could be overcome, year-round aquaculture production could be feasible at many sites along the Texas coast. Researchers at the University of Houston are now investigating if geothermal heat sources can be used to provide thermal refuge areas to help protect aquaculture operations during these cold weather periods.

Lead scientists in the project are Stanley Kleis and Nagaraja Shamsundar of the Mechanical Engineering Department. In this phase of the project, the investigators will demonstrate design strategies that are intended to reduce heat losses while still providing fish with access to water. The designs will utilize commercially available materials and will be tested in ponds ranging from 1 to 7 acres located at Redfish Unlimited in Palacios, TX. Some of the ponds include refuge areas that were installed at the time the ponds were built, while other ponds will be retrofitted. Brackish well water will be floated on the sea water in the refuges to act as a thermal blanket to reduce surface heat losses. The well water will also provide geothermal heat (161deg. F year round) to keep the refuge warm. The investigators will record how temperature and salinity levels change with varying refuge geometries and operating strategies and will monitor groundwater use and weather conditions.

UH graduate students Q. Guo and H. Li install a heat exchange diffuser in a thermal refuge at an aquaculture facility in Palacios, TX.

The project builds upon research Kleis conducted under previous Higher Education Board grants. In 1994-95 he developed prototype designs of a two-curtain refuge system for aquaculture operations and field tested that system at Palacios.

For details, contact Kleis at (713) 743-4536 or kleis@uh.edu.

Austin Uses Innovative, High Tech, Methods to Monitor Hourly Water Flows

Can you ever have too much water information? An innovative program now being carried out by the City of Austin suggests that utilizing high tech methods to monitor hourly flows and water use may be helpful in analyzing peak use trends and setting rates. The program is led by Stephen Rhoades, a finance professional with the Austin Water and Wastewater Utility. The purpose of the program is to capture hourly flow data on the maximum peak use days and to identify peak use hours. Peaking factors can be used to analyze the real cost of water service and to set water rates.

The City of Austin used devices like this one to transmit data on hourly water flows to a central computer. The system provided insights on water use in different neighborhoods that was essential for planning and rate setting.

Beginning in 1992, Austin installed equipment at more than 100 sites to gather hourly flow monitoring data. Representative sample sites were selected so that information on single and multiple family residences, businesses, and industries would be collected. Residential areas in parts of Austin with varying water consumption trends were chosen.

Two types of equipment are used to record hourly flows. For residential samples, transit time ultrasonic flow meters were used. These devices are an inexpensive and practical way to monitor the flow in distribution lines. They do not affect water pressure or reduce flows needed for firefighting and other essential functions. The meters were installed by uncovering a straight section of pipe, putting a vault around it, installing sensors, and mounting the monitoring equipment on a nearby pole. Power was typically supplied by nearby utility lines but solar power was used at some remote sites. Hourly flow data were regularly downloaded using a laptop computer. In the future, the utility hopes to add telephone lines and modems at many sites so that flow rates can be checked instantly. Later, the flow monitoring data were verified against billing records for each site.

For the multi-family, commercial, industrial and wholesale samples, an electronic sensor was placed on each meter that transmits a signal to a computer board mounted on a post. The computer board is connected to a phone line and calls to a host computer in the Finance Department transmits hourly data. At the host computer, a software program is used to generate reports which are loaded directly into databases for statistical analyses.

What do the monitoring results show? The hourly monitoring data provided insights into Austin's hourly water use. Graphs were developed depicting water use trends for single family homes in many neighborhoods. The results show that middle and high income areas show the most distinct trends in hourly water use and clearly reflect hours when automatic sprinklers were operating (4 AM to 8 AM). In single family household areas with fewer automatic sprinklers, daily water use typically peaked from 7 PM to 10 PM. This information was used to help City Council members make informed decisions about how to fairly distribute costs among different customer classes.

Rhoades says that the analyses is also helpful in other areas. Many residential customers said it was easier to understand the concept of peak flows after viewing the hourly data. The information assisted in the design of booster pump stations and the calibration of a computer simulation model of Austin's water distribution system.

Information about this project was featured in the August 1995 issue of the *Journal of the American Water Works Association*. For details, contact Rhoades at (512) 322-3611.

Beaumont is Site of Recent Conferences on Sabine Lake, Big Thicket

Two major conferences dealing with water and environmental issues were held recently in Beaumont.

"The Sabine Lake Conference: Where Texas and Louisiana Come Together" met September 13-14. "The goal of this meeting," said Conference organizer Jim Blackburn of the Houston environmental consulting firm of Blackburn and Carter, "was to examine the coastal water resources of this region without regard to state boundaries. We often ignore the fact that what we are dealing with is a regional, interconnected ecosystem that crosses state lines." The meeting was co-sponsored by the Southeast Study Region of the Trans-Texas Water Program.

Sessions of this conference dealt with geology and sediments, climate and hydrology, coastal marshes, habitat for wetlands species, biological components, human uses, institutional management, and physical management. Panel discussions examined the outlook of the for the future of the region and management goals for the region that have been set by state natural resources agencies.

The conference featured many speakers from Texas universities including George Ward and Robert Morton of the University of Texas at Austin, Peter Mantz of Lamar University, and Dewayne Hollin of the Texas A&M University Sea Grant Program. For more details on this meeting, contact Blackburn and Carter at (713) 524-1012.

"The Big Thicket Science Conference: Biodiversity and Ecology of the West Gulf Coastal Plain Landscape" met October 10- 13. "The focus of the conference is to strengthen local resource management partnerships and focus attention on immediate conservation issues within the region," said Rick Strahan of the Big Thicket National Preserve. "Land managers in this region are faced with many challenges while attempting to conserve biological diversity, maintain environmental quality, provide quality

recreational opportunities, and promote sustainable economic development." This meeting was sponsored by the National Park Service (NPS) Big Thicket National Preserve, The Nature Conservancy of Texas, the U.S. Department of Agriculture's Forest Service, the National Wetlands Research Center, the Trinity River National Wildlife Refuge, Temple Inland, Entergy, and other groups.

Sessions focused on aquatic and wetland communities, water quality, the use of geographic information systems in conservation and ecological restoration, and vegetation management. Some of the speakers from Texas universities included Clark Hubbs of the University of Texas at Austin, Guy Cameron of the University of Houston, James Van Kley of Stephen F. Austin State University, Paul Harcombe of Rice University, N.B. Ford of the University of Texas at Tyler, M.R. Leipnik of Sam Houston State University, S.D. Finley of Texas Tech University, and Kirk Winemiller, Robert Coulson, and Paul DuBowy of Texas A&M University. For more details, contact Strahan at (409) 839- 2689, Ext 224, or rick_strahan@nps.gov.

Tarleton State U. Publishes Reports on Dairies, Water Quality

Two reports have recently been published by the Texas Institute for Applied Environmental Research (TIAER) at Tarleton State University that examine the relationship between the Central Texas dairy industry and water quality and water policy issues.

Livestock and the Environment: Scientific Underpinnings for Policy Analysis was co-authored by Anne McFarland and Larry Hauck of TIAER and was published in 1995. This report documents and describes water quality monitoring efforts by TIAER in the Upper North Bosque watershed and analyzes findings from these efforts. Major sections of the report include descriptions of sampling sites, sampling methods that were used, watershed characteristics, streamflows at automated sampler sites, statistical assessment of water quality by individual monitoring sites, comparison of water quality with land characteristics, and interpretations and implications of water quality findings. *Rethinking Environmental Policy, Institutions, and Compliance Strategies -- 5 Years of Progress*. It was written by TIAER Director Ron Jones. This report summarizes Institute efforts to examine water quality and policy issues associated with the impact of Central Texas dairies on water quality.

For more details, contact TIAER at (817) 968-9567. or visit their WWW site on the Internet at http://tiaer.tarleton.edu:8000.

TCU Press Chronicles Pecos River Settlement, Drought

Two books chronicling how water issues have affected Texas history are available from the Texas Christian University Press.

Crossing Rio Pecos was written by Patrick Dearen. Dearen based the book on a review of archival documents, interviews with long-time area residents, and personal experiences. The book chronicles the legends and true stories of men and women who crossed the Pecos.

The Time It Never Rained is Elmer Kelton's classic novel of the how the drought of the 1950s affected the lives of people living in West Texas. The book traces the story of West Texas rancher Charlie Flagg and his efforts to keep his ranch going through the worst drought in Texas history. Flagg saw how the drought killed his livestock, caused his heart attack, and drove his best friend to commit suicide, but it could not force him from his land.

To order either book, contact the TCU Press at (800) 826-8911.

Rice U. Publishes Proceedings on Environmental Remediation

A conference proceedings that describes issues relating to the remediation of contaminated soils and groundwater systems has been published by the Energy and Environmental Systems Institute (EESI) at Rice University.

The proceedings is titled "Environmental Remediation Technologies: Strategies for Success." It summarizes papers presented at the Second Annual EESI Symposium on Energy and the Environment September 30 - October 1 in at Rice University in Houston. Sections of the report deal with testing and verification programs, technology transfer and commercialization, technology demonstrations now being conducted, and the future of environmental remediation technologies.

Some of the university scientists who published papers in the proceedings that dealt with water-related issues include Gary Pope and Gerald Speitel of the University of Texas at Austin, and Herb Ward, Philip Bedient, Joseph Hughes, and Mason Tomson of Rice University.

A limited number of proceedings from this conference are available by contacting Judy Howell at EESI at (713) 737-5674 or jmhowell@rice.edu.

Sam Houston State U. Utilizes GIS to Measure Changes in East Texas Forested Watersheds

How have East Texas forests changed during the past 50 years and what are the implications for water quality? These are a few of the questions being investigated in a research project at Sam Houston State University (SHSU). The project is coordinated by the SHSU Texas Regional Institute for Environmental Studies (TRIES). Project leaders are Mark Leipnik of the Geography Department, Irene Perry of TRIES, and Poonam Shrestha of the Biological Sciences Department.

The study consists of using geographic information systems (GIS) to spatially analyze how the extent and location of various types of East Texas forest communities have changed from the 1930s to today. Historical data were obtained from a 1935 map developed by the U.S. Forest Service and were digitized into a GIS format. Current land use and land cover conditions were developed using data from the Texas Natural Resources Information System. The project reveals how urban areas are encroaching into previously forested areas.

Perry says the research is an especially valuable method to calculate and compare losses and changes of different vegetation types. In the future, the researchers hope to correlate the vegetation change data with soils, hydrography and elevation. Understanding of factors affecting vegetation change will enable better management of natural resources on a watershed scale. A particular interest is correlating vegetation change and water quality. That's because vegetation maintains soils, prevents erosion, increases groundwater recharge, filters surface water runoff and stabilizes stream banks.

For details, contact Leipnik at (409) 294-3714 or geo_mrl@shsu.edu or Perry at (409) 294-3979 or env_ihp@shsu.edu.

TAMUK Researches Growing Cactus As Drought Option

Can cactus be used for cattle feed? Results from a recent study at Texas A&M University- Kingsville (TAMUK) suggest that cactus may provide a safeguard for South Texas ranchers during droughts.

Peter Felker of TAMUK examines one of the 130 cactus varieties grown on the university farm as a former student looks on.

Recently, TAMUK graduate student Huien Han of China completed a four-year study of the water use efficiency of cactus. The research was supervised by Peter Felker, a scientist at the Caesar Kleberg Wildlife Research Institute at TAMUK who specializes in cactus research. The study shows cactus is more water efficient than many other agricultural crops. This finding could have widespread impact for cattle farmers and fruit and vegetable producers.

The study was conducted at the TAMUK farms using a slow-growing, spineless, cactus variety that was selected for cold hardiness. Twelve 30- by 40- foot plots were planted and the amount of rainfall, evaporation from the soil, and runoff into the soil were measured. A water budget was developed and calculated. At the end of each year, three plots were harvested and weighed to determine annual growth rates. The researchers found it takes roughly 165 pounds of water to produce a pound of dry matter in cactus. In contrast, it takes 250 to 450 pounds of water to produce a pound of dry matter of corn.

"We found that some cactus varieties have a greater conversion efficiency of water to dry matter than many other types of plants," Felker said. "We believe that farmers may want to consider incorporating cactus into our agricultural production systems for fruits, vegetables or cattle feed, given its greater water efficiency." He added that use of cactus as cattle feed may significantly lessen the amount of water required for livestock needs. Some South Texas ranchers now use cactus as a cattle feed source and burn the spines off

of the prickly plant. Felker says the research suggests that cattle need to be fed at least 100 pounds of fresh cactus each day, along with protein and other supplements.

Felker notes that cactus can grow to be about three feet tall in about two years. Cactus of that size would allow farmers to stock one cow on 2 acres of South Texas rangeland instead of current practices that limit one cow to every 10 acres. TAMUK researchers are now making seed stock available for ranchers who are interested in planting spineless varieties of cactus. For details, contact Felker at (512) 593- 3922.

UTSA Archaeologists Unearth 200-Year-Old Dam

Archaeologists with the University of Texas at San Antonio (UTSA) have uncovered what they believe is a 200-year-old Spanish colonial dam inside a city park that once diverted water from Olmos Creek to irrigate farmlands. The dam was discovered in October at Brackenridge Park in San Antonio. It is the third such structure ever found in San Antonio -- previously remains of the Espada and San Juan dams were located.

C. Britt Bousman (center), Waynne Cox, and Edgar Johnson (left) of the Center for Archaeological Research at UTSA discuss excavation techniques on the dam.

The structure, the Upper Labor Dam, was built to supply water for the Upper Labor Acequia, which was the last of seven acequias or ditches that flowed throughout San Antonio. It was constructed on Olmos Creek just below the headwaters of the San Antonio River. In the project, UTSA archaeologists exposed more than 25 feet of the eastern part of the dam and revealed two distinct episodes of construction and repair. The lower portion consisted of roughly hewn limestone block of the Spanish period. The upper portion includes squared stone that was probably added by German immigrants in 1850-60. The excavations show that the structure was designed as a diversion dam, but it did not fully span the stream. Instead, it raised the water level enough to divert water into the acequia for irrigation. Because of its design, the dam provided water to the acequia, but still allowed water to runoff rapidly after heavy rains. The excavations show that the dam's wall was about 4.5 feet thick and ranged from 2 to 7 feet high.

"It's pretty neat," said Waynne Cox, of the UTSA Center for Archaeological Research which led the excavation effort . The city has layer upon layer of history and it's all very interesting."

The acequias were built by Spanish engineers with Native American labor. The Upper Labor Acequia, which was constructed from 1776 to 1778, delivered water to farmlands

owned by the villa of San Fernando de Bexar for drinking water and irrigation. Acequia water flowed along a route that began at the San Antonio River in Brackenridge Park, traveled near St. Mary's Street, moved south of San Pedro Park, crossed the San Pedro Acequia, and returned to San Pedro Creek. In 1875, the acequia was modified to become part of the Alazan Acequia, which irrigated lands west of San Pedro Creek and diverted floodwaters away from downtown. The Upper Labor Acequia was closed in the early 1900s, but a small part of it still functions as part of the San Antonio Zoo.

For details, contact the Center at (210) 458-4378 or visit their WWW site at http://www.csbs.utsa.edu/research/car/.

Texas Tech Examine Relationships Between Macroinvertebrate Levels, Water Quality in Playa Lakes

Researchers at Texas Tech University are examining playa lake ecosystems to determine how factors such as land use, water quality, and water chemistry influence the communities of benthic macroinvertebrates that live in these systems. Leading researchers involved in the project include Dianne Hall, Michael Willig, and Daryl Moorhead of the Texas Tech Biological Sciences Department, Robert Sites of the Entomology Department at the University of Missouri, Tony Mollhagen of the Texas Tech Civil Engineering Department, and Ernest Fish of the Texas Tech Department of Range and Wildlife Management.

Dianne Hall collects samples of benthic macroinvertebrates from this playa lake.

Playa lakes are significant ecological resources on the semi-arid Southern High Plains. They serve as recharge areas for the Ogallala Aquifer and also provide as habitat for millions of migratory birds. The goal of the project was to sample water quality and benthic organisms at playa lakes throughout the Southern High Plains. Specifically, the researchers wanted to find out how different land uses (crop production, rangelands, and Conservation Reserve Program grasslands) influenced playa lake water quality and the numbers and composition of benthic species.

Results of the research suggest that macroinvertebrate richness (the number of macroinvertebrate families collected from a playa) is unrelated to playa area. Significant differences exist in family composition (proportional abundance of macroinvertebrate

families from the playa) and family richness of playas when they are categorized by the dominant land use in individual watersheds. Differences in playas based on resident faunas (those with drought-resistent life stages) were similar to differences among water quality characteristics in playas (turbidity and water depth). Differences in playas based on transient faunas (those with no drought-resistent life stages) were similar to differences among playas in chemical and biological characteristics. Macroinvertebrate communities are more influenced by nearby land uses than by island biogeographic factors.

For details, contact Hall or Willig at (806) 742-2658 or cmdlh@ttacs.ttu.edu.

Rice U. Investigate Ability of Plants to Clean Up TNT

Researchers at Rice University are investigating the ability of many types of plants and roots to degrade TNT and explosives. The studies are led by Joseph Hughes and Rajiv Bhadra of the Environmental Science and Engineering Department and Jacqueline Shanks and John Lauritzen of the Chemical Engineering Department. Phytoremediation, the use of plants to clean up pollutants, is particularly attractive because it offers a "natural" way to restore the environment and because plants may have the ability to transform contaminants into less harmful by-products. Phytoremediation may also be more economical than current methods.

Rajiv Bhadra of Rice University examines plant roots of parrot feather plants that are being tested for their ability to degrade TNT and other explosive wastes. Other plants investigated in these studies include duckweed, hornwort, stonewort, filamentous algae, water hyacinth, waterweed angiosperm, alligator weed, as well as genetically transformed hairy roots.

Plants investigated in these studies include duckweed, parrot feather, hornwort, stonewort, filamentous algae, water hyacinth, waterweed angiosperm, alligator weed, and genetically transformed hairy roots grown in tissue cultures. These species include native, hydroponically grown and axenic plants. Emphasis is being placed on the use of hairy roots to remove pollutants because they can be grown in a sterile culture, are genetically and biochemically stable, have fast growth rates, and can be grown in phytohormone-free media, tissue cultures, and full-scale bioreactors. Results suggest that TNT levels have been reduced significantly by some plants and that tissue cultures such as hairy roots are good model systems for phytoremediation studies. The hairy root

system has been developed as a model to study xenobiotic metabolism in plants. The researchers hope to learn more about the primary interactions between roots and dissolved forms of TNT and related compounds.

For details, contact Hughes at (713) 285-5903 or hughes@rice.edu, Bhadra (713) 527-8101, ext. 2779, or Shanks at (713) 285-5354 or shanks@rice.edu.

Texas A&M to Participate in NIWR Project to Examine Water Management in Droughts

Researchers from the Texas A&M University System have been awarded a grant to participate in a regional study of how water management institutions in Texas, New Mexico and Colorado can adjust operational strategies to cope with droughts. The grant was awarded through the Western Region of the National Institutes for Water Resources. Texas A&M scientists who will participate include Ron Lacewell and John Ellis of the Agricultural Economics Department, Raghavan Srinivasan of the Texas Agricultural Experiment Station's Blackland Research Center at Temple, and Seiichi Miyamoto of the Texas A&M University Agricultural Research and Extension Center in El Paso. Other cooperators include Frank Ward, Tom McGuckin, and J. Philip King of New Mexico State University, and Robert Ward and Marshall Frasier of Colorado State University.

"This grant is significant for many reasons," according to Wayne Jordan of TWRI, who will administer the Texas portion of the effort. "This was the first year that NIWR awarded projects on a regional rather than a state-by-state basis and this will be the only project in Texas this year. This project was ranked highly as one of the most important research topics for the Western U.S. region. It represents the best of the multi-state proposals that the Institutes were encouraged to develop for the new NIWR program."

The basis of the proposal is that the laws and institutions of each state in the region are not prepared for acute and prolonged droughts. No analysis has been performed to evaluate strategies states can follow to manage a drought with minimal economic disturbance. At the same time, population and water demands are increasing, making it more likely that droughts could wreak economically devastating effects.

The project involves a number of analyses that will help policy makers better assess drought risks. Detailed studies will be conducted to develop realistic drought scenarios and to generate a mass balance hydrologic model that accounts for current sources and uses of water in the Rio Grande basin, including the Mexican portion of the watershed. Economic simulations will be performed to identify monetary damages associated with specific drought scenarios and to simulate the magnitude, location, and distribution of drought damages. The project will also help identify and develop strategies that water managers can use to deal with droughts, including currently available and proposed legal and institutional measures. Finally, possible drought management scenarios will be modeled under various hydrologic scenarios to determine the costs and benefits of specific strategies in given situations.

Because of the multidisciplinary nature of the project, Texas A&M researchers will play specific and unique roles. Srinivasan and Miyamoto will help develop the mass balance hydrology model and will formulate credible drought scenarios using past streamflows. Lacewell and Ellis will gather historic data on drought damages in the region and will develop a framework for estimating future losses. Lacewell will also help identify alternate policy responses that show particular promise to minimize the adverse impacts of droughts.

For details, contact Lacewell at (409) 845-2333 or r-lacewell@tamu.edu, Srinivasan at (817) 770-6602 or srin@brcsun0.tamu.edu, or Miyamoto at (915) 859-9111 or s-miyamot@tamu.edu. You can also contact TWRI for more information at (409) 845-1851 or twri@tamu.edu.

Texas A&M to Apply WRAP Model to San Jacinto Basin

A Texas A&M University researcher recently completed a project to apply the Water Rights Analysis Package (WRAP) to the San Jacinto River Basin and to develop guidelines for applying WRAP to other river basins in the state.

The WRAP computer model was previously developed by Ralph Wurbs of the Civil Engineering Department and several graduate research assistants in conjunction with TWRI-sponsored research. The TNRCC is using WRAP to update water availability models developed during the water rights adjudication process of the 1960s through the 1980s. The San Jacinto is the third river basin in Texas recently modeled with WRAP. The water availability studies assess reliabilities in supplying existing rights and unappropriated flows available for new water rights. WRAP simulates management and use of the water resources of a river basin, or multiple-basin region, under a priority-based water allocation system. The generalized model is based on the Texas water rights system, but can be applied elsewhere as well.

The latest version of the WRAP model is documented a new technical report that has been published by TWRI. The report is TR-146 (revised version) and is titled *Water Rights Analysis Package (WRAP), Model Description and Users Manual.* For details about the model, contact Wurbs at (409)845-3079, r-wurbs@tamu.edu, or Anil Yerramreddy at the TNRCC, (512)239-4445. To obtain a copy of the technical report, contact TWRI at (409) 845-1851 or twri@tamu.edu.

TWRI Funds "Wonderful Water" Educational Exhibit

TWRI recently expanded its efforts in public education by helping fund an exhibit that will become part of the recently formed Children's Museum of the Brazos Valley. The exhibit, "Wonderful Water," will allow children to learn about water by adding dams to a stream table, turning valves and placing items in a wall of water. "This exhibit is most popular with younger children," says Dale Whittaker, professor of Agricultural Engineering and founder of the new children's museum.

"It's built low to the ground and it's fun for them because it is very hands-on. Kids like to touch and listen to the water moving," Whittaker said. At Bryan's recent "FestiFall,"

Children examine the Wonderful Water exhibit at Festifall in Bryan. The exhibit allows children to interact with a water wheel [shown here] and many other exciting elements. TWRI funded a portion of the exhibit which is being coordinated by the Children's Museum fo the Brazos Valley.

hundreds of children and adults from the region enjoyed the exhibit. "It is amazing how children react to a "hands-on" type learning experience. There are no grown-ups telling them what to do and not do with the exhibit. The children call all of the shots."

"Wonderful Water" will be a traveling exhibit for about a year, and thousands of Brazos Valley-area children will be able to learn more about water in a "hands-on" setting. Eventually, TWRI hopes the exhibit will continue to be displayed once the Museum establishes a permanent location. For more about the Children's Museum of the Brazos Valley, contact Whittaker at (409) 845-7541 or (409) 779-KIDS or TWRI at (409) 845-1851 or twri@tamu.edu.