New Waves
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New TAMU Press Book Showcases Whitewater Kayaking

Steve Daniel, a researcher in the Texas A&M University Philosophy Department, recently wrote a book about kayaking opportunities in Texas rivers and streams titled Texas Whitewater.

The book provides an introduction to whitewater recreation issues and provides in-depth discussions of individual river systems. Illustrations and maps detail individual rivers, and appendices discuss sources of water level information, stream flow data locations, and legal issues associated with recreational access to rivers.

Daniel says he wrote the book to increase the awareness of whitewater resources in Texas and to identify sites which the public may want to access for whitewater recreation.

According to Daniel, his favorite rivers are those that are technical, where there are many waterfalls and the streams are constricted. His favorite river is Crabapple Creek, near Fredericksburg. "Of course," he adds, "that all depends on whether there is water in the river. Most of these rivers are dry most of the year." Other favorite rivers for paddlers are those with "big water," where streams are wide and pour-overs and waves can be found. These include the Pedernales (west of Johnson City) and Cherokee Creek, which is near Lampasas and flows into the Colorado River.

Daniel suggests that rivers appropriate for beginning paddlers include the San Marcos River near Martindale and Barton Creek in Austin. The Guadalupe River, between Canyon Lake and New Braunfels, is good for those who are just beyond beginning paddlers. In addition, Daniel says kayakers may want to choose a river that is dependable and has water in it most of the year. He says the Guadalupe River and the San Marcos River are the most dependable rivers in Texas.

Daniel says that winter and early spring are good times for paddlers to "run" the rivers in Texas, except in drought years. He adds that the months of Texas' typical hurricane season may also be a good time of year to go kayaking, since many Texas rivers depend on rainfall for their flows.

There has been confusion in the past over the rights of paddlers to access waters for recreational use. Daniel explains there are many points paddlers should keep in mind when choosing a river for recreation. First, a river or stream is legally navigable if the creek bed at the gradient boundary points (midway between the creek bed and the top of the bank) is at least 30' wide on average. Secondly, kayakers should access a river or stream from a public point (such as a bridge) and avoid getting on private property. Third, because there may be a fence across a river, it does not mean that the river is not navigable (the fence may have been put there by the landowner to keep livestock from straying). Most of those fences give way, which allow kayakers to paddle underneath them. Fourth, keep in mind that landowners may be sensitive to trespassing and protective of their property. Fifth, because a river is a public resource, it is owned by citizens, and paddlers are not trespassing if they are in the water. He cautions kayakers to "back off" and not confront landowners, if they become upset about trespassing.

Daniel says that eight water recreation clubs exist in Texas, with several thousand members. He says that kayaking is becoming more popular each year. "People are interested in adventure, exercising, and being healthy," he says. "They have more free time and more disposable income." He adds that the media and advertisers are publicizing water recreation more now than they did in past years.

Kayaking has become a love of Daniel's life. "I go kayaking because I can view scenery and other things and go places which, otherwise, I would never see," he says. "The solitude of being out in nature brings a sense of serenity to me. The ultimate reason why I kayak is the excitement, the thrill of running a rapid successfully."

For more details about Daniel's interest in kayaking and whitewater issues, visit his WWW site at http://www-phil.tamu.edu/Philosophy/Faculty/Steve/ or e-mail him at sdaniel@unix.tamu.edu. The book can be ordered from the TAMU Press by visiting their WWW site at http://www.tamu.edu/upress/books/ or by calling (409) 845-1436.

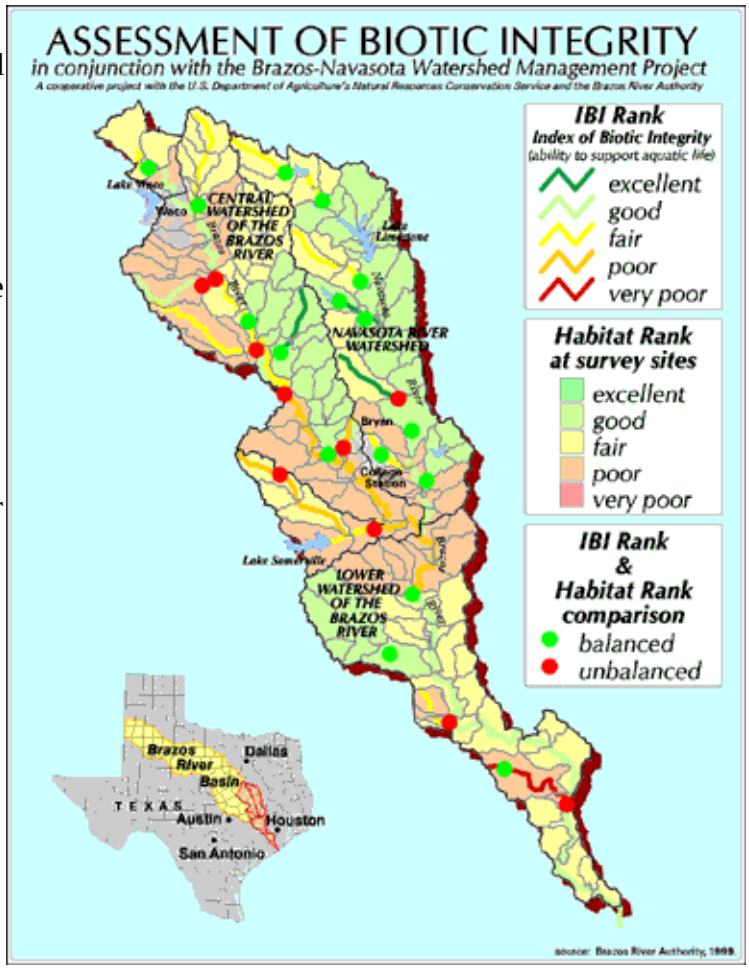
Texas A&M Scientists Use IBI to Study Ecology of Brazos, Navasota Rivers

A survey of ecological integrity of rivers and streams within the central Brazos and Navasota River watersheds was recently conducted by Kirk Winemiller and Frances Gelwick of the Texas A&M University Wildlife and Fisheries Sciences Department. Their work centered on assessing the ecological integrity of these rivers through extensive measurements of habitat conditions, surveys of flora and fauna, and the use of fishes as biotic indicators.

The need for the study arose because of concerns about increased nutrient loadings throughout the watershed. "Large-scale chicken farming is rather new to this area, and

many groups were concerned that it might cause water quality problems," says Winemiller. The Brazos River Authority contacted Winemiller and Gelwick to see if they could establish baseline information on the ecological health of the rivers and streams of the watershed which could be useful in future monitoring studies. Winemiller says this is the first comprehensive attempt to document the condition of streams in this region. Previously, only scattered information was available on ecological conditions and organisms within rivers and streams in the watershed. Results from the recent study will be used as a reference for future changes.

In this study, Winemiller and Gelwick first developed an Index of Biotic Integrity (IBI) for fishes of the region. This represents the first time the IBI has been used in this region of Texas. Winemiller and Gelwick adapted elements of the original IBI (which was first used in the Midwest in the 1980s) to conform to the characteristics of fishes in this region. The IBI relies on information about the environmental needs of fishes to provide the basis for a large-scale picture of ecological health in watersheds. Says Winemiller, "More ecological information is available for fishes than other taxonomic groups, such as aquatic insects. Fishes live longer than most invertebrates, and are better long-term indicators of the health of rivers and streams. They are higher in the food chain and integrate more processes over the entire river system."



Part of this project involved identifying indicator fish species with specific water quality needs. Some fish species can only live in clean waters while others can tolerate relatively polluted streams. In some cases, they chose indicator species specifically for Texas conditions. Winemiller and Gelwick then converted the IBI to a habitat grading scale. Big Creek, a channelized stream near Pleak, rated "very poor" since only a few species were found there, and those that were found could survive in a degraded habitat. On the other end of the scale, Walnut Creek near Calvert rated "excellent" and many species that cannot tolerate poor water quality were found there. As a whole, the watershed ranged from "good" to "fair" condition, except for a section of the

Brazos River from Hearne to Hempstead and the western floodplain region (both were rated "poor").

Currently, row-crop agriculture and cattle grazing are the dominant land uses in the region, but these activities may reduce water quality and ecological integrity in the watershed. Winemiller says the study suggests that row cropping in the central Brazos River floodplain may be impacting aquatic life, if pesticides and other agricultural chemicals run off from fields into rivers and streams. Soil erosion and runoff from plowed fields may cause increased sedimentation in rivers and streams. The researchers found less indication that cattle grazing is currently degrading stream ecosystems in the region.

Congress recently approved funding through the EPA for continued monitoring within the watershed. For more information, contact Winemiller at (409) 862-4020 or kow1956@zeus.tamu.edu or contact Gelwick at 862-4172 or fig0697@acs.tamu.edu.

Impact of Arsenic Contamination of Waters on Tadpoles, Frogs, and Turtles

Researchers: Donald Clark and Deborah Cowman, Biological Resources Division, U.S. Geological Survey, College Station, TX, and Roxie Cantu, Texas Parks and Wildlife Department, Austin, TX.

Problem: Arsenic is a toxic chemical which has been produced at many industrial locations in TX. Some research has been conducted to examine the effect of arsenic contamination on various media (water and soil) and human health. Relatively little has been done to learn how arsenic impacts aquatic species, which are often directly exposed to this pollutant. Because of the life history of these species and the extent to which arsenic may contaminate the areas in which they live, frogs and aquatic turtles may be ideal organisms to study to ascertain the impact of this type of pollution on the environment.

Background Information: A site in Bryan, TX, was the focus of this study. It consists of a series of waters, including (in order) Finfeather Lake, Lateral Pond, Kazmeier Pond, an unnamed connecting stream, and Municipal Lake. Finfeather Lake is sited closest to a manufacturing plant which began producing calcium arsenate in 1940. In 1944, the plant started making an arsenic-based cotton defoliant. As early as 1969, the Texas Water Quality Board found unsafe levels of arsenic at Finfeather Lake. Regulatory actions continued in the 1970s and 1980s. In 1976, the plant was ordered to remove arsenic-contaminated sediment from Finfeather Lake and Municipal Lake. The lakes were drained and sediments removed, and they were refilled in 1983. In 1993, the plant ceased production.

Objectives: 1) To describe the levels of arsenic and other toxic elements in tadpoles from this ecosystem; 2) To evaluate the current levels of arsenic and other toxic elements in these waters; 3) To interpret how water pollution may affect the survival of amphibians at

this site, and 4) To gauge whether contaminated tadpoles could be toxic to wildlife species which eat them.

Methods: In May 1994, tadpoles were collected from Lateral Pond and Municipal Lake using hand-held dip nets. A dead leopard frog and a dead bullfrog were found at Lateral Pond. Later that summer, dead tadpoles were found along the shoreline of Municipal Lake. Tadpoles could not be found in Finfeather Lake. Tadpoles were taken to the laboratory and individually weighed and identified by species. Samples were analyzed for arsenic, chromium, mercury, selenium, and zinc. Whole tadpoles were individually placed in liquid nitrogen until they became brittle and then ground with a mortar and pestle until homogenized. Samples were analyzed using instrumental neutron activation analysis at the University of Texas at Austin. For comparison purposes, tadpole samples were also taken from a Range and Forestry Area pond at Texas A&M University which served as a reference site.

Results and Discussion: Tadpoles collected from Lateral Pond were identified as cricket frogs, those from Municipal Lake were green frogs, and samples from the range pond included green and leopard frogs. Chemical analyses of the tadpoles from the polluted sites showed elevated levels of arsenic, chromium, and zinc. Green frog tadpoles from Municipal Lake contained significantly more arsenic than green frog tadpoles from the range pond. Cricket frog tadpoles contained significantly more of all three pollutants than the reference samples from the range pond, and significantly more arsenic and zinc than green frog tadpoles from Municipal Lake. Tadpoles typically concentrated zinc to a much greater extent than arsenic or chromium. The research suggests that the age and developmental stage of the tadpoles at the time they died may have influenced the amount and type of pollutants they contain. Concentrations of arsenic, chromium, and zinc were higher in sediments of Finfeather Lake (where tadpoles could not be found) than in Municipal Lake. Concentrations of these pollutants in tadpoles appear to exceed the levels known to be toxic in foods consumed by birds, turtles, and other predators. Sampling from 1994 to 1996 revealed no turtles or snakes in Finfeather Lake and an absence of snakes in Municipal Lake. This suggests that snakes may be more sensitive to contaminants than frogs and turtles, or that they may be able to tolerate higher pollutant levels.

Reference: Clark, D.R., Jr., R. Cantu, D.F. Cowman, and D.J. Maxson, "Uptake of Arsenic and Metals by Tadpoles at a Historically Contaminated Texas Site," *Ecotoxicology*, Vol. 7 (61-67) 1998.

Note: Clark is housed in the Texas A&M University Wildlife and Fisheries Sciences Department and can be contacted at donald_clark@usgs.gov or (409) 845-5784.

Ability of Models to Simulate Phosphorous Removal from Constructed Wetlands

Researchers: Mary Paasch and Ann Kenimer, Agricultural Engineering Department, Texas A&M University, College Station, TX.

Problem: Phosphorus is a nutrient of concern in many watersheds because of fears that it may lead to eutrophication. Wetlands (both constructed and man-made) have been proposed as a reliable method of reducing phosphorus levels. Various computer simulation models which have been used to evaluate how well wetlands remove phosphorus have yielded markedly different results. Careful comparisons of simulation models which assess the performance of wetlands need to be undertaken.

Objectives: 1) To compare the ability of three commonly used models to accurately predict the phosphorus concentrations within wetlands; 2) To characterize the applicability and limitations of wetland phosphorus models; 3) To validate available phosphorus models for other wetland sites, and 4) To compare the robustness of various wetland phosphorus models.

Method: This study compared the performance of three simulation models: 1) a mass balance model with first order aeral uptake; 2) a Vollenweider-based wetland model, and 3) a detailed ecosystem model. The mass balance and Vollenweider models were assessed using at least two years of actual wetlands data, while the ecosystem model was evaluated using one year of data. Inputs to the models were provided from field data collected at the Boney Marsh Experimental Area in FL from 1978-86; the Jackson Bayou Experimental Wetlands in OR during 1989-92; and the Des Plaines River Wetland Demonstration Project in IL from 1989-91. Some of the characteristics of these models which were evaluated include the ability to predict outflow concentrations, trends in outflow levels, and annual total phosphorus retention.

Results and Discussion: As it relates to outlet concentrations of phosphorus, the mass balance model provided the most accurate predictions, the Vollenweider model had greater difficulty in accurately reflecting average outlet concentrations, and the ecosystem model performed poorly. In terms of predicting phosphorus retention, the Vollenweider model provided the most accurate predictions, the mass balance model yielded acceptable estimates, and the ecosystem model produced widely mixed results. Although the ecosystem model was unable to accurately predict average outlet levels of phosphorus, it did perform best at estimating phosphorus trends at outlets. Paasch suggests that future research may need to be directed at refining algorithms used to develop input parameters and to predict phosphorus concentrations.

Reference: Paasch, M., *Phosphorus Water Quality Model Evaluation and Comparison for Natural and Constructed Wetlands*, Master of Science Thesis, Texas A&M University, 1998.

Note: Paasch's research was funded in part by TWRI. Kenimer can be contacted at (409) 845-3677 or a-kenimer@tamu.edu.

Developing an Automated Method to Assess Historical Pollution Risks from "Brownfields"

Researchers: Melissa Cordell, Geography and Planning Department, Southwest Texas State University, San Marcos, TX.

Background: "Brownfields" are properties which were previously utilized as industrial or commercial properties and are likely to be contaminated. It is estimated that as many as 450,000 brownfields may exist in the United States. In many cases, federal and state agencies are encouraging the use of these sites as areas to revitalize communities. Environmental professionals need a method which generates quantifiable results to prioritize the extent to which these sites may contain hazardous materials or pollute the environment before deciding if these properties should be redeveloped.

Objectives: To determine if historical maps and records can be incorporated into a geographic information system (GIS) format to prioritize potential pollution risks from Brownfield sites.

Methods: Sanborn fire insurance maps for Austin TX from 1885, 1900, 1921, and 1935 were utilized as primary data sources. These maps provide detailed information identifying industrial buildings and sites for their potential to create or resist fires. In addition, a database was created with a description of these facilities, the number of pits, ponds and lagoons they contain, possible contaminants which are generated or stored at the sites, Toxic Hazard Rating Code rankings, and standard industrial classification codes. The likelihood and severity of pollution was assessed by determining which materials were on-site, land uses (whether sites contained abandoned or currently used industrial facilities), the characteristics of the surrounding environment (specifically, soils, geologic conditions and the distance to surface and ground waters), and the concentration of industries in the area. Data were input to a GIS using ARC/VIEW software.

Results and Discussion: Data suggest that, in 1885, industries which were widespread in the downtown Austin area included tin shops, wagon building enterprises, and blacksmithing operations. These could have introduced antioxidants, heavy metals, lubricants, acetates, and other pollutants into the environment. By 1900, some of the new industries which had moved into the area included photography studios, print shops, and laundries, which may have introduced new types of pollutants. The industrial activity had shifted east during this time. Analysis of 1921 conditions reveals that businesses related to coal, oil and gas, and railroads began to appear downtown. By 1935, industrial development began to shift south of Town Lake and east along the railroad. By this time, many of the activities which may result in contamination now consisted of service stations and automobile repair shops. In general, this research shows that GIS can be used

to rank sites according to the amount and types of pollutants these sites may contain, as well as to assess what contamination problems they may pose if they are redeveloped**.**

Reference: Cordell, M., "Identifying and Mapping Historical Industrial Hazards for Brownfields Redevelopment," *Proceedings of the 1998 Annual Conference of the Geographic Information Systems/ Land Information Systems Society*, 1998.

Note: Cordell now works for the U.S. Geological Survey in Austin and can be contacted at Mcordell@usgs.gov.

Results of Stream Water Quality Sampling Throughout the Bosque River Watershed

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

Background: The Bosque River watershed, which is located in North Central Texas, has been a focus of concerns about water quality, especially since large numbers of dairies moved into the area beginning in the 1980s. According to the 1996 State of Texas Water Quality Inventory, nonpoint source loadings were described as the most serious threats that may lead to elevated levels of nutrients and fecal coliform bacteria for the North Bosque River. The Inventory reported that elevated levels of nitrogen, as well as nonpoint pollutants from agricultural operations, are concerns for the Middle and South Bosque River Segment. In addition, the Inventory suggests that advanced wastewater treatment for McGregor and Stephenville may be required to meet stream standards. Water quality is a major concern in this region because the watershed flows into Lake Waco, a drinking water supply, and because of the widespread interest in contact recreation throughout the region.

Objectives: 1) To sample hydrologic and water quality conditions at sites throughout the Bosque River Watershed, with an emphasis on gathering data during baseflow and storm events, and 2) To analyze these data to assess the status of stream quality at various points within the watershed and ascertain the likely sources of water quality concerns in the region.

Methods: The focus of this study examines hydrologic and water quality monitoring data collected by TIAER and the Brazos River Authority between October 1995 and March 1997 within the Bosque River Watershed. Routine grab samples were gathered weekly or bi-weekly from 29 stream sites as well as eight municipal wastewater treatment plants within the watershed. Stormwater samples were collected at 26 stream sites using automatic sampling equipment. Water quality parameters routinely analyzed for baseflow and storm samples included ammonia-nitrogen, nitrite-nitrogen, nitrate-nitrogen, total Kjeldahl nitrogen, total phosphorus, orthophosphate-phosphorus, chemical oxygen demand, and total suspended solids. During baseflow, pH, chlorophyll-a, specific conductance, dissolved oxygen, fecal coliform, and water temperature were sampled. At sites along the main stem of the North Bosque River, fecal coliform samples were

collected during storm events. Sites were grouped into four categories for analysis representing small microwatersheds, sites on major tributaries to the North Bosque River, locations on the main stem of the North Bosque River, and sites on rivers and major tributaries to Lake Waco. Water quality data were compared to numeric criteria and screening levels established by the Texas Natural Resource Conservation Commission (TNRCC). Automated stormwater samplers were utilized to gather real-time variations in stream levels and combined with site-specific, stage-discharge relationships to measure flow. Flows were integrated with water quality data to estimate nutrient loadings of phosphorus and nitrogen at sampling sites. A multiple regression method based on land uses in drainage areas above sampling sites was used to estimate nutrient export coefficients for the major land uses in the watershed.

Results and Discussion: At three types of sites (microwatersheds, major tributaries to the North Bosque River and main stem sites along the North Bosque River), high levels of phosphorus and organic nitrogen were associated with areas where dairy waste was being applied. High levels of inorganic nitrogen were linked to row crop areas. At all sites, the lowest nutrient levels were associated with woods and rangelands. Along the main stem of the North Bosque River, water quality concentrations were generally lower at downstream sites than upstream sites. When water quality was compared to TNRCC screening criteria, stormwater samples were more likely to exceed screening values than samples taken during baseflow conditions. Fecal coliform levels often exceeded TNRCC criteria for contact recreation at sites in the upper portion of the North Bosque River watershed. For sites along the main stem of the North Bosque River, significantly higher concentrations of fecal coliform were associated with storm events than baseflow conditions. In general, little difference was found in the water quality concentrations for three of the major tributaries (Hog Creek, Middle Bosque and North Bosque Rivers) feeding into Lake Waco. The greatest nutrient loadings were associated with the North Bosque River, which comprises over 70% of the drainage area flowing into Lake Waco. Preliminary estimates of land use and nutrient export coefficients indicate dairy waste applications fields are the largest contributor of phosphorus loadings to the Bosque River watershed. Row crop agriculture was indicated as the largest contributor of nitrogen loadings.

Reference: McFarland, A., and L. Hauck, *Stream Water Quality in the Bosque River Watershed*, TIAER, June 1998.

NOTE: This report can be downloaded from the World Wide Web at http://tiaer.tarleton.edu.

Determining Populations of Freshwater Mussels in East Texas Rivers

Researchers: Dana Feaster and Jack McCullough, Biology Department, Stephen F. Austin State University, Nacogdoches, TX.

Problem: Among the 52 species of freshwater mussels which have been reported in Texas, 17 are listed as threatened, endangered, or of special concern. In East Texas, it is believed that the Neches and Angelina River watersheds may support some of the most abundant and diverse mussel populations in Texas. This includes areas of the Davey Crockett National Forest (DCNF) and the Angelina National Forest (ANF). However, little field survey work has been conducted to verify numbers of mussels in the majority of streams in this region.

Objectives: 1) To determine the numbers and types of freshwater mussels in East Texas streams, and 2) To assess which factors may lead to the abundance or scarcity of these species.

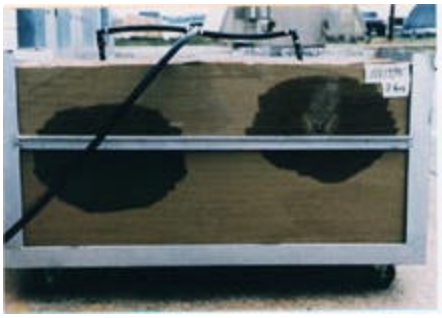
Methods: In this study, 15 previously unclassified streams which are tributaries of the Neches and Angelina Rivers were sampled. Sites monitored in the DCNF include Alabama Creek, Austin Branch, Camp Creek, Cochino Bayou, Hackberry Creek, Hagar Creek, Hickory Creek, Lynch Creek, Piney Creek, and Sandy Creek. In the ANF, sites which were studied include Big Creek, Graham Creek, Harvey Creek, Sandy Creek, and Turkey Creek. The researchers waded into these creeks and collected mussel samples by hand. Samples of representative mussel species were placed in plastic containers, cleaned, dried, and sprayed with an acrylic sealant to prevent the epidermis from flaking. Specimens were identified to the species level. When more than one mussel was found, individuals were counted, identified, and immediately returned to the substrate.

Results and Discussion: Roughly 191 individuals representing nine unionid species and numerous *Corbicula fluminea* were collected from streams in both forests. Of the streams which were sampled, 10 contained living mussels while five did not. In those streams which did not house live mussels, it is thought that the substrate or hydrology may not have been suitable to support these species. Stream segments which contained the greatest number of mussel species include Piney Creek (6), Cochino Bayou (5), and Big and Sandy Creeks (5 each). The findings are revealing, the researchers suggest, because Piney Creek (which contained the most species) has been identified as the least impacted stream in the South Central Plains and received a very high score when analyzed by the Index of Biotic Integrity. On the other hand, no mussels were found at Hackberry Creek, which has fragile sandy soils and often deposits sand in streambeds, smothering live mussels and creating an unstable habitat for future mussel populations. Because mussels are parasitic (when released by a female, young mussels attach to a "host" fish), findings of healthy mussel populations may also suggest there are good conditions for fish resources in nearby waters.

Reference: Feaster, D., "Lotic Freshwater Mussels (Family Unionidae) of the Angelina and Davey Crockett National Forests of East Texas," *Texas Journal of Science*, May 1998.

TAMU, Israeli, Scientists Examine if "V-Shaped" Trenches Help Drip Systems Apply Water Evenly

Researchers at Texas A&M University (TAMU) and the Volcani Center of Israel recently completed a two year study to determine if incorporating a V-shaped polyethylene trough immediately beneath subsurface irrigation lines improves the performance of these systems.



The project was conducted by Kirk Brown and Jim Thomas of the TAMU Soil and Crop Sciences Department and Shmulik Freidman and Avraham Meiri of the Volcani Center. It was funded through the Texas Department of Agriculture's Texas-Israeli Exchange Program.

In the project, the researchers installed a 2.5" wide, 2.5" tall polyethylene trough under soil where turfgrasses were being grown. A drip irrigation line was placed in the bottom of the "V." According to Thomas, the question the researchers wanted to answer was whether the trough would capture waters which could then be used by the grasses. Without the trough, waters could drain into lower soil profiles below the root zone where they would be unavailable for crop use. Experiments were carried out in Texas and in Israel.

Results of the research suggest that the use of the V-shaped trough improved the extent to which water was applied uniformly throughout the field. "We observed that, when the trough was used, we didn't see as many wet or dry spots," Thomas says. The research may have practical applications. Because the trough helps apply water more evenly, it may allow system designers to space drip irrigation field lines more widely, thus reducing the number of lines which are needed. Depending on the soil and the crop being irrigated, Thomas suggests that the space between drip lines could be doubled if the trough were used, thus reducing installation costs. Thomas suggests the V-shaped trough could be used along with drip irrigation to water landscapes, orchards, and vineyards.

For details, contact Brown at (409) 845-5251 or Thomas at (409) 845-5252 or jc-thomas@tamu.edu.

UT, UTPA, Utilize Remote Sensing from Multiple Sites to Assess Marsh Habitats in the Rio Grande Delta

Marshes in the Rio Grande Delta provide essential habitat for a variety of waterfowl as well as threatened and endangered species. Currently, there is a lack of information about the composition and structure of marshes in the Rio Grande Delta. Such information is needed because many marshes are being cleared and replaced by agricultural crops, cities, and flood control structures.

In response to these needs, Frank Judd and Robert Lonard of the University of Texas-Pan American (UTPA) and Melba Crawford of the University of Texas at Austin (UT) are now working to develop a system which will utilize remote sensing to improve the understanding of marsh communities in the Rio Grande Delta. The study is funded by the Texas Higher Education Coordinating Board.

"It is a challenge to map the existing marshes because the Rio Grande Valley is so flat. The difference in elevation from place to place might be only a few centimeters," explains Judd. Because the habitats of the Rio Grande are complex, the researchers plan to develop the capability to remotely sense data from a system of multiple sensors and determine if the technique is viable for use in this environment. The remotely sensed imagery will provide the information needed to map the marshes of the Rio Grande Delta, according to the different vegetation characteristics. Information obtained will be validated by comparing it to data obtained from conventional techniques.

Governmental agencies have begun efforts to acquire lands that may be set aside for environmental purposes as part of the Lower Rio Grande Corridor. The researchers want to develop data about whether maintaining and reestablishing marshes may be a cost-effective means of abating water pollution in the Rio Grande, thus potentially improving the water quality of the Laguna Madre. The study will also explore if the absence of freshwater overflows from the Rio Grande is changing the composition and structure of marshes.

For details, contact Judd at (956) 316-7001 or fjudd@panam.edu or Lonard at rlonard@panam.edu or (956) 381-3656.

A&M-Galveston Tests Whether Iodine Isotope Can Detect Presence of "Nuclear Age" Pollutants

A researcher at Texas A&M University Galveston is now testing the applicability of using a specific iodine isotope to identify pollutants which may have been released into the environment after the "nuclear age" of World War II. The studies are carried out by Peter Santschi of the A&M-Galveston Marine Science Department and are funded by the Texas Higher Education Coordinating Board.

The idea behind the research is that a specific form of iodine (I-129) may be ideal for environmental studies. The presence of I-129 often results from human activities (such as

bomb testing and nuclear fuel processing), although it may also result from the spontaneous fission of Uranium-238 in rocks. Discovering I-129 in the environment can signal the presence of pollutants generated since the 1950s, when nuclear weapons were tested in large numbers.

Santschi and colleagues have conducted tests to learn if I-129 is found in the Gulf of Mexico and the North Atlantic Ocean. He also tested for I-129 in rivers in Texas, the United States, and Europe. Results suggest that high levels of I-129 can be found in many Texas rivers which exhibit high evaporation rates and significant human water use. These rivers also exhibit low ratios of I-129 to I-127. Based on these results, Santschi believes this material may have originated from weapons tests and work at nuclear processing plants.

Santschi is also carrying out studies to seek I-129 in shallow coastal sediments. He feels that I-129 may react with organic matter to form chemical bonds. It may then migrate with organic matter into marine sediments. I-129 levels are being compared to the levels of other radionuclides in sediments to learn more about whether these isotopes are mobile in coastal sediments. For details, contact Santschi at (409) 740-4476 or santschi@tamug.tamu.edu.

UT Geologist Assesses Likely Impact of Pumping, Transfers, on Carrizo - Wilcox Aquifer

A hydrogeologist at The University of Texas (UT) at Austin recently conducted a modeling study for the Texas Water Development Board (TWDB) to assess the potential hydrological effect of increased demand for groundwater resources in Central Texas.

The research resulted from a proposal from the San Antonio Water System to purchase up to 90,000 acre-feet of water annually from Alcoa Inc., which produces water from the Carrizo-Wilcox aquifer in Lee and Milam Counties as part of its lignite mining operations. The study was needed to determine how water supplies in the aquifer would be affected by groundwater pumping for the Alcoa operations and other anticipated needs.

The research was carried out by Alan Dutton of the UT Bureau of Economic Geology (BEG). In this effort, Dutton developed a model specifically for the study region (the area between the Brazos and Colorado Rivers where the aquifer is present). He used the model to simulate six scenarios representing different degrees of development. The report predicts the extent of water-level declines in the aquifer and concludes there will be sufficient groundwater to meet demands through the year 2050 under all scenarios.

A draft report describing this study was published by TWDB. It can be viewed on the World Wide Web at http://www.twdb.state.tx.us. For details, contact Dutton at (512) 471-1534 or duttona@begv.beg.utexas.edu.

UTEP Study Examines What Customers Will Do to Earn Water Conservation Rewards

What lengths will people go to save water if a sufficient financial reward is offered? That's the focus of an ongoing investigation by researchers at the University of Texas - El Paso (UTEP). The project is led by Tony Tarquin of the UTEP Civil Engineering Department and Robert Moss, an environmental engineering graduate student. Other participants include Bert Cortez and David Allen of the U.S. Bureau of Reclamation (USBR) and Anai Padilla of El Paso Water Utilities. USBR and UTEP funded the effort.

According to Tarquin, the program arose from a desire to find out how much it would cost to reduce per capita water use and stretch water supplies in this parched region. The project began in 1998. Initially, the researchers sought volunteers who could choose to cut water use by 35% and earn $250 as well as those who would save 20% and make $100. After publicizing the effort, the first 100 respondents were enrolled in the program. Comparisons of before and after water use suggest the program achieved a 15% water savings among those who took part. When the total amount of the awards was divided by the amount of water saved, the cost of the water which was conserved was roughly $1 per 1,000 gallons less than the cost for the utility to provide that water.

This year, the study team wanted to follow a more methodological approach. Participants with a wide range of water using behaviors from as little as 50 gallons per capita per day (gcd) to more than hundreds per person daily are being selected randomly. Rewards for saving water are now based on a sliding scale, in which participants only earn money if they save more than 15%. Savings of 16 to 30% will provide water saving households with $50, while people can make $150 if they cut water use by 31 to 45%. The greatest incentive, $250, is reserved for those who save more than 46%. The research team will regularly monitor water use on-site. EPWU is providing data from individual water bills on historic water use.

"The goal of this year's effort is to develop scientifically collected, broad-based, data that can give a water utility a realistic idea of the costs and payoffs they could expect if this program were implemented," Tarquin said. "We are finding that people will be very creative at saving water if they know there's a payoff in the end," he said. Many participants saved water by converting lawns to desert xeriscapes. Others captured bleed-off, condensated water which ran off swamp coolers, or stored cold water which was running while they waited for hot water heaters to warm up.

Tarquin hopes that this project may help EPWU and other utilities when they consider which pricing strategies could be incorporated into rate-setting efforts. For details, contact Tarquin at (915) 747-6915 or atarquin@utep.edu.

Texas A&M INA Excavates Civil War Blockade Runner

For roughly a year, scientists at the Texas A&M University (TAMU) Institute of Nautical Archaeology (INA) have been excavating the *Denbigh*, a blockade-runner which fought in the American Civil War.

Barto Arnold is the Director of Texas operations for INA. He notes that historical and background studies were begun by INA in late 1997. Shortly afterwards, INA researchers discovered the location of the *Denbigh* wreck (in shallow waters of Galveston Bay) by using an 1880 U.S. Army Corps of Engineers map. In 1998, Arnold and other INA researchers began exploring the site of the *Denbigh* wreck. In April, INA staff conducted a side-scan sonar survey of the wreck site to determine how much of the wreck extends above the sand. In May, the first major fieldwork was undertaken and INA staff began measuring and drawing paddlewheels which protruded out of the sand. In June, INA workers performed a sub-bottom profiling sonar of the wreck site, which provided evidence of the buried shipwreck. In July, the project staff began mapping the site to prepare for excavation.

This is the first research that has been done on the *Denbigh* wreck. Arnold says that by studying shipwrecks like this, INA gets to perform research, helps TAMU students gain experience, and makes information available to the public. Although the excavation has just begun, Arnold says the INA team has already studied the construction of the paddlewheel and the broiler, and artifacts have been sent to museums. Future plans involve more excavation, determining how much of the ship is intact, and inventorying the cargo, machinery, and the crew living areas.

Arnold can be reached at (409) 845-5296 or jarnold@acs.tamu.edu.

TAMU Real Estate Center Article Provides Overview of Water Marketing in Texas

An article which was recently published by the Texas A&M University Real Estate Center provides an excellent overview of legal issues associated with water marketing in Texas. The article, "Before the Well Runs Dry," was written by Charles Gilliland, a research economist at the Center, and was published in the Center's *Tierra Grande* newsletter. The article discusses the evolution of Texas water law, existing and emerging water markets, and legal issues which may help shape the extent to which water markets may exist in Texas in the future. It also presents a summary of how Senate Bill 1 may influence water transfers.

The article is available on the Center's World Wide Web site at http://recenter.tamu.edu. Gilliland can be contacted at (409) 845-2037 or ceg0506@unix.tamu.edu.

Managing Water Supply Reliability Discussed in TAMU Report

A technical report which discusses techniques that cities and other water providers may want to employ to increase the reliability of water supplies has recently been published by two economists at Texas A&M University (TAMU). The study, "Valuing and Managing Water Supply Reliability," was written by Ronald Griffin and James Mjelde of the TAMU Agricultural Economics Department and was published in December 1997. Work to develop the report was funded by the Texas Water Development Board.

The central theme of the report is that it may not always be optimal to develop "perfect" water supply reliability (which would mean there would be no chance of shortfalls). Instead, the authors suggest that utilities and other water suppliers work with customers to determine the extent to which they want reliability built into their water system. For example, the costs to develop a water system may be lessened if the amount of reliability which is desired is reduced. The report presents policy options that water managers can use when determining the right level of reliability (including both water supply and demand measures). It illustrates how the principles of reliability can be incorporated into "real world" scenarios using the "Logit" model.

For details about this research, contact Griffin at (409) 845-2334 or ron-griffin@tamu.edu or Mjelde at (409) 845-1492 or j-mjelde@tamu.edu.

TIAER Reports Focus on Water Quality

The Texas Institute for Applied Environmental Research (TIAER) at Tarleton State University recently published a series of reports describing water quality issues in the Upper North Bosque River Watershed. These include the following: *Biological Data Analysis Report Volumes 1 & 2 - Upper North Bosque River Watershed, Agricultural Nonpoint Source Studies (September 1992-November 1995)* by Tina Hendon, Forrest Mitchell and Anne McFarland; *Determining Nutrient Contribution by Land Use for the Upper North Bosque River Watershed* by Anne McFarland and Larry Hauck; and *Relationship of Fecal Coliform Bacteria with Water Quality and Land Uses in the Upper North Bosque River Watershed* by Amy Truman, Anne McFarland and Larry Hauck.

For more information about these reports, contact TIAER at (254) 968-9567 or visit them on the World Wide Web at

http://tiaer.tarleton.edu.

PVAMU Researcher Works to Improve Processes Utilized to Identify Wetlands

To really learn about the properties of wetlands and how they change throughout the year, Richard Griffin of the Agriculture Department at Prairie View A&M University recommends a hands-on approach. Many times each year, Griffin, William Anthony, Jesse Trevino, and students crawl over a fence or drive through the dirt and mud into a pastoral wetland only a few miles east of campus. By observing the changes that take place throughout the entire wetlands not just the soils this team gains valuable insights into how wetlands function. They hope to develop improved guidelines that regulators and delineators can use to differentiate which sites are wetlands.

Griffin explains that observations made of changes in plant species, land use by cattle and other animals, and subtle changes in soils provide clues about the extent to which a ponded wetland swells when it rains and shrinks as the area dries out. The plants closest to the ponded wetland tend to be reedy and able to tolerate a substantial amount of water, while other species delineated the boundary between the wetland and more typical upland conditions. By examining soils, Griffin pointed out colors and patterns which note the presence of plant roots as well as small pieces of rock which had been washed from the Brazos River. "The more we visit this site, we better know what to look for to determine wetland features," he explained. "If you know what characteristics you are seeking, this site will tell you a lot about the wetlands which are here."

Griffin serves on a national committee which is setting national standards to identify wetlands. The committee includes representatives of the U.S. Department of Agriculture Natural Resource Conservation Service, the Agricultural Research Service, and the U.S. Army Corps of Engineers.

An innovation being explored by Griffin's research team include looking for subtle variations in color (wetlands soils often tend to be red or pink because they contain ferrous iron) which may indicate that rust or oxidized iron is occurring in the outer layer. Griffin is also studying whether the presence of hard, thin, white zones of calcium carbonate, may also signal the presence of iron.

In a related study, Griffin regularly observes a suite of wetlands soils which are kept in Mason jars filled with water. These soils are being observed to see what kinds of fungi develop or if the water becomes cloudy or oily. The goal is to look for features which may indicate if ferrous iron is present in these soils, thus suggesting that they are hydric or wetland soils.

"Throughout the years, wetland soils may not have been as precisely defined as they need to be," Griffin says. "There is a substantial amount of differences in opinion about which specific sites are really wetlands and which ones are not. Under the existing rules, consultants and scientists can often manipulate the current guidelines to obtain the answer they want for example, if they set out to show a site is not a wetland they can often do so."

For details, contact Griffin at Richard_Griffin@pvamu.edu or (409) 857-4012.

Effects of Disturbed Sediments on Rio Grande Water Quality Are Theme of A&M International Research

The Rio Grande is essential to the survival of Laredo and the surrounding region. For example, the city depends on the river as its only source of drinking water. As a result, the quality of the water in the Rio Grande is a prime concern. A scientist at Texas A&M International University is now taking a close look at the extent to which the river contains polluted sediments and what they may imply for human health and the environment.

Over the past two years, Sushma Krishnamurthy of the A&M-International Natural Sciences Department has been gathering samples from Rio Grande sediments and testing them to identify whether they contain heavy metals and other toxic pollutants. She is also carrying out experiments to determine the extent to which contaminants in the sediments become more mobile when they are disturbed by storms, extreme flows, and even such simple acts as recreation and people wading into the river.

What has Krishnamurthy learned so far? One of the most revealing findings is that levels of two heavy metals (copper and lead) increased significantly after waters were disturbed. On the other hand, concentrations of aluminum, chromium, selenium and antimony dropped after sediments had been disturbed. As a result of this study, Krishnamurthy suggests it may be important to consider the impact of disturbed sediments on a wide range of issues including aquatic life and the cost of treating drinking water. It may also be important, she says, to assess the variety of nonpoint sources which run off into the river and ways to minimize the amount of pollutants that are generated by these land uses.

For details, contact Krishnamurthy at (956) 326-2584 or skrishna@tamiu.edu.

SWT Researcher Studies How Geographical Factors Influenced Evolution of Texas' Water Laws

What can you find when you look at the evolution of Texas' water pollution laws from a geographical perspective? Craig Colten, a researcher in the Geography Department at Southwest Texas State University (SWT) recently took this approach. Colten combed through the Texas State Archives, court records, legislative efforts, and industry

databases about water quality and industrial pollution trends that impacted the petrochemical industry on the Texas Coast.

Colten noted a number of broad trends. For example, some of Texas' early environmental regulations (developed in the 1930s) were designed to manage oilfield brines. Later, the Texas Fish, Game and Oyster Commission (the predecessor to the Texas Parks and Wildlife Department) instituted programs to limit the extent to which oilfield pollutants may contaminate streams, especially during droughts. In the 1950s, Colten notes, the State filed suit to prevent pollution, based in large part on concerns that public waters were being threatened.

What lessons can be learned from this project? A broad theme is that big companies set the agenda, Colten contends. For example, DuPont worked with the state to monitor water quality in San Antonio Bay in the 1950s and similar trends took place in other estuaries. He also found that industries sited near the coast or in areas with sufficient rainfall lessened pollution problems by diluting wastes, not treating them.

"This project reinforces the idea that Texas has a legacy of a state which accommodates industries and help them set the pollution control agenda," Colten says. He suggests that Texas efforts to keep petrochemical wastes out of streams may have led, in turn, to land disposal and, perhaps, the presence of Superfund sites throughout the State.

For details, contact Colten at (512) 245-7976 or cc20@swt.edu.

UNT Researcher Examines Role Rhetoric Plays in International Environmental Crises

When an environmental crisis occurs, do people throughout the world view themselves first as people living in a particular country (Danes or Germans, for example) or as part of a global environmental community (members of the Sierra Club)? These are some of the environmental rhetoric issues currently being explored by Michael Bruner and Raymie McKerrow of the Communications Studies Department at the University of North Texas (UNT).

An area Bruner is delving into centers around the issue of social identity theory. The basic idea is that the defining characteristics of a social category (such as nationality or belonging to an ecological group) may form part of one's "self concept." This may influence how individuals perceive situations and act when those scenarios occur. Because everyone fits into several social categories at the same time, the trick is being able to determine which aspects of social categories most strongly influence people to act in specific cases.

Recently, Bruner assessed an incident in which the Shell Oil Company proposed that the Brent Spar oil rig be dropped into the North Sea. This idea caused a furor among many Europeans, who feared the pollution this action might cause. The case is interesting for many reasons, Bruner contends, because it represents a face-off between a multinational

corporation and an international environmental organization (Greenpeace). People from many European nations became involved and carried out such actions as a boycott of Shell gasoline stations, other protests, and even death threats. The important lessons to be learned from this case, Bruner says, are that individuals from many nations joined together to support the environment (even though this case had strong nationalistic undertones) and that environmental groups won the war of public opinion, even though many scientists disagreed with their point of view.

For more details on Bruner's research, contact him at bruner@unt.edu or (817) 565-2588.

A&M-Commerce Biologist Explores Whether Sunlight Makes PAH Pollutants More Toxic to Shellfish

Nearly all humans have heard warnings that too much sunlight may be hazardous to our health. A biologist at Texas A&M University-Commerce is now investigating whether the same message might apply to shellfish which live in aquatic ecosystems in Texas and other regions with warm climates.

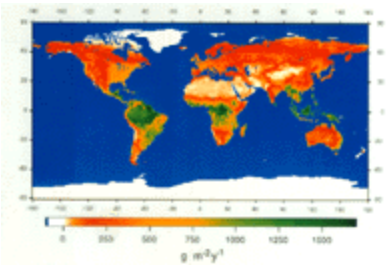
John Weinstein is a researcher with the A&M-Commerce Biology and Earth Sciences Department. He is exploring the extent to which a particular class of pollutants called polycyclic aromatic hydrocarbons or PAHs (which are associated with automobile exhaust emissions and the use of petroleum-based products) may become more toxic when exposed to natural sunlight. Many researchers believe that PAHs which receive a lot of sunlight become as much as an order of magnitude more toxic for extremely brief time periods. Exposure to these "phototoxins" can be lethal for a variety of fish and shellfish.

In this project, Weinstein is collecting a mussel species called the paper pondshell from an East Texas cattle pond. In a lab on the A&M-Commerce campus, he exposes both juvenile and adult shellfish to waters which exhibit PAH phototoxicity. Weinstein is particularly interested in how young shellfish are affected since they haven't yet formed a hard shell and are thus vulnerable to the effects of this type of pollution. "I think this issue could be especially pertinent to Texas, since there are so many days with significant amounts of sunlight," he says. "Still, this issue has largely not been studied in Texas yet, so a lot of research needs to be done."

For details, contact Weinstein at (903) 886-5369 or john_weinstein@tamu-commerce.edu.

TAMU Research Team Works to Improve Accuracy of Climate Change Simulation Model

As part of a national effort to improve the accuracy of predictions about climate change and global warming, a team of Texas A&M University (TAMU) hydrologists is working to refine techniques that simulate how moisture is recycled in the environment.



The project is being carried out by Ranjan Muttiah of the Texas Agricultural Experiment Station Blackland Research Center in Temple, Ralph Wurbs of the Civil Engineering Department, and Jean Bowman of the Geography Department. The research, which is part of a national assessment of the effects of climate change, is sponsored by the South Central Regional Office of the National Institute for Global Environmental Change (NIGEC). NIGEC is a program of the U.S. Department of Energy. Funds for the project are being administered by the Texas Water Resources Institute (TWRI).

The fundamental problem, Bowman says, is that general circulation models or GCMs (a class of simulation models commonly used to assess climate change) are typically not accurate at simulating precipitation amounts and trends. It is therefore difficult to use GCMs to generate accurate scenarios of future warmer climates. In this study, Bowman is testing methods which may better incorporate concepts of how moisture is recycled throughout the environment. These methods could provide insights into some of the GCM precipitation errors. Muttiah is incorporating these regional predictions into simulations carried out with another model, the Surface Water Assessment Tool (SWAT), to determine how changes in rainfall may affect flows into rivers and lakes throughout Texas watersheds. Wurbs is inputting this data into the Water Rights Analysis Package (WRAP) to assess the potential impact of global change on the amount of water available for cities, industries, agriculture and other uses.

The hope is that this information may be useful in better estimating rainfall trends, which can then be used to produce regional predictions of how the climate will change by global warming scenarios. "If we can better simulate precipitation," Bowman says, "we may eventually take a small step towards developing more reasonable estimates of changed climates. A lot of work is going on to assess and predict global change throughout the world, and we hope we can help improve the process by which these estimates are made."

For details, contact Bowman at (409) 862-6544 or jeanann@csrp.tamu.edu, Wurbs at (409) 845-3079 or r-wurbs@tamu.edu, or Muttiah at (254) 770-6602 or muttiah@brc.tamus.edu.

TWRI Water Conservation Programming Recognized for Excellence in Education

An innovative public education program which informs Texas water suppliers and users about the latest news in water conservation, reuse, and recycling recently captured two honors.

In April, Texas Water Resources Institute (TWRI) Science Writer Jan Gerston, who edits the *Texas Water Savers* newsletter, received the award for the Indirect Water Conservation Program for a Non-Utility. The award is given by the Conservation and Reuse Division of the Texas Section of the American Water Works Association (TAWWA). That same month, she garnered the Watermark Award, which is given jointly by the Public Information Committees of TAWWA and the Water Environment Association of Texas.

Texas Water Savers features the latest information about water conservation opportunities in urban, municipal, industrial, and agricultural settings. The majority of stories in the newsletter deal specifically with Texas, including case studies, research highlights, and publications. By showcasing what's going in within Texas, the newsletter allows water users in the state to learn from what their colleagues are doing and then apply these water-saving ideas to their own situations.

"I like to think of *Texas Water Savers* as a tool that can help water managers build on the success of others to become more water efficient," Gerston says. "We present an idea or example of a water conservation success story which others can emulate, thus increasing water savings throughout the State."

The awards are significant, says TWRI Director Wayne Jordan, in that they are voted on by professional staff members of state agencies, cities, water districts, and major water suppliers and users.

"In this case, the people who determined this program should be recognized are the same ones who are using the information. Obviously, they place a great value on the products generated through this effort." Another evidence of the success of *Texas Water Savers*, Jordan says, is that it is supported by more than 22 sponsors, including governmental agencies and water management districts, cities, and consultants and affiliated industries.

TWRI initially developed *Texas Water Savers* in 1994 to communicate water conservation information to major water providers and users as well as the general public. With the passage of Senate Bill 1 (SB 1) a major piece of water planning and management legislation in 1997, the mission of *Texas Water Savers* was expanded to help water resources agencies develop plans to save water. SB 1 requires all major water rights holders (including irrigators) to develop water conservation plans and submit them to the Texas Natural Resource Conservation Commission by September 1, 1999.

In addition to developing the newsletter, Gerston and Texas A&M University student Eric Hinesley created the Texas Water Education World Wide Web (WWW) site which focuses on these issues. The address is http://tx-water-ed.tamu.edu. Gerston also distributes e-mail messages through an Internet list server which provides timely news about water conservation efforts.

Texas Water Savers is a joint effort between TWRI and the Texas Agricultural Extension Service (TAEX). Subscriptions are available free upon request by contacting TWRI at (409) 845-1851 or twri@tamu.edu. Gerston can be contacted at (409) 845-1852 or jan@twri.tamu.edu. The coordinator for TAEX water conservation programming is Bruce Lesikar, who can be contacted at (409) 845-7453 or b-lesikar@tamu.edu.

"SPLASH! into the Edwards Aquifer" Describes Educational Resources About Barton Springs

The Austin City Connection World Wide Web (WWW) site has developed a section describing an educational exhibit titled "SPLASH! into the Edwards Aquifer." The exhibit is housed in the Beverly Sheffield Education Center at Barton Springs in Zilker Park.

"SPLASH" is a highly visible educational exhibit about the Edwards Aquifer and especially about the Barton Springs segment. This exhibit opened in October 1998 and is designed to reach as many as a million visitors annually. Success is evident as the exhibit hosted some 17,000 visitors between March and April. Especially noteworthy is the fact that the exhibit is also a repository for the endangered Barton Springs salamander.

One of the best features of this WWW site is that it illustrates and describes many interactive and hands-on exhibits of SPLASH!. The WWW site also provides scientific information about water quality issues, including discussions of such topics as water chemistry, microbial ecology, and erosion. In addition, a Barton Springs/Edwards Aquifer bibliography contains an extensive list of web sites (which are divided into subjects) as well as sources of printed information which are relevant to aquifer issues.

To find out more, access the site at http://www.ci.austin.tx.us/nature-science/splash.htm.

Wetlands Site Registry Lists Areas Available for Restoration

The Texas Parks and Wildlife Department has developed a World Wide Web (WWW) site which contains a database that lists public and private lands which may be available to create, restore or enhance wetlands.

The WWW site, "The Wetlands Project Site Registry," is intended to bring together individuals or groups who need or want to restore wetlands. The site allows users to search for wetlands within river basins or counties. Search results provide a detailed description of individual sites, including details on the size of each wetland, types of habitats which are present, current land uses, and goals which have been proposed for this location (for example, a landowner might want to improve wildlife habitat).

Additional resources at this site include a handbook titled *The Wetlands Assistance Guide for Landowners* as well as TPWD newsletters about wetlands. This site also allows individuals to add their wetlands to the database and provides a way to contact the manager for this project.

The WWW site address is http://realvid.tpwd.state.tx.us:8080/wetland/. For more information, contact Heather Bond of TPWD at heather.bond@tpwd.state.tx.us.