New Waves
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TAMU "Watershed Working Group" Brings Scientists Together from Many Disciplines

Texas A&M University (TAMU) researchers from many disciplines are now getting together to discuss common problems that may impact watersheds, thanks to an initiative recently launched by the Texas Water Resources Institute (TWRI) and the TAMU Agricultural Program.

The effort is titled the "Watershed Working Group." The group began meeting regularly so that scientists from many disciplines could meet and identify multidisciplinary projects as a result of strategic initiatives developed through the TAMU Agricultural Program. TWRI helped organize the group and provides administrative support for it.

"So many varied issues impact watersheds that a multidisciplinary approach works best," says TWRI Director Wayne Jordan. "This is especially true with many of the problems we are facing today which may involve components dealing with water quality, water law, engineering, and ecosystem issues."

Marty Matlock and Frank Acker of the Academy of Natural Sciences gather periphyton samples from the Guadalupe River near Victoria.

The watershed working group began meeting in January. So far, roughly 15 scientists from such diverse disciplines as agricultural and civil engineering, recreation, parks and tourism sciences, wildlife and fisheries sciences, political science, and soil and crop sciences have participated in each meeting.

Marty Matlock of the TAMU Agricultural Engineering Department has played a key role in organizing the meetings, spurring discussion, and following up with potential collaborators. Matlock says a major topic that has emerged from the meetings is the emphasis that state and federal regulatory agencies will be placing on the concept of total maximum daily loads (TMDLs). Basically, TMDLs are a strategy water quality managers

use to establish scientifically based maximum allowable loadings of target pollutants to a water body in a watershed. Water bodies with historical problems with specific types of pollutants (high oxygen demands, nutrients, sediments, or toxic chemicals) are priorities for TMDLs. This could include reducing the loadings of oxygen-consuming pollutants to aquatic reaches of rivers and lakes. After the maximum load is established, water managers then assess point and nonpoint sources and identify management strategies to meet that goal.

The first project funded through the group will focus on TMDLs. It was funded by the Texas Agricultural Experiment Station. Lead scientists in this study include Matlock, Bill Neill of the Wildlife and Fisheries Sciences Department, John Ellis of the Agricultural Economics Department, and Keith Keplinger of the Public Policy Research Institute. Collaborators include many state and federal agencies. The goal of this study is to examine issues that are associated with uncertainty in the nutrient trading process. This includes wide fluctuations in nonpoint source pollutants, the effectiveness of best management practices (which can vary widely from site to site), potential regulatory actions that the Texas Natural Resource Conservation Commission may take if water quality is not improved, and the difficulty of placing an economic value on limiting pollution. In the project, the researchers hope to determine the amount of key pollutants water bodies can assimilate before the ecology is degraded, and to identify and quantify pollutant sources from many activities in Texas watersheds. Another focus of the study is to identify and organize agreements for parties that generate large amounts of pollution and may want to enter into nutrient trading systems. The study will also monitor the effectiveness of existing pollutant trading mechanisms using a combination of contaminant transport models and chemical and biological monitoring.

Other issues being discussed by the working group include environmental policy, watershed management, and protecting water quality. For details about participating in the working group, contact TWRI at (409) 845-1851 or twri@tamu.edu. To contact Matlock, call (409) 862-7476 or e-mail him at mmatlock@agen.tamu.edu.

TWRI Examines Factors That Influence Future Rice Irrigation

Two projects recently funded by the Texas Water Resources Institute (TWRI) are examining different aspects of a critical problem -- "What is the future of rice irrigation and how may it impact the environment?"

TWRI Director Wayne Jordan says this issue is timely and essential for many reasons. "Many experts associated with rice irrigation feel the industry is at a crossroads now. Acreage is down from historically high levels, in part because prices are low. At the same time, competition for water is increasing and this may limit the amount of water available for rice production in the future. As a result, we have to consider potential scenarios that may impact the rice industry as well as associated ecosystems. These projects are among the first activities to implement recommendations from the recent Texas A&M University Agricultural Program Rice Summit, which was organized by Texas agricultural leaders."

The first project will be led by Robert Coulson, a landscape ecologist in the Texas A&M University (TAMU) Entomology Department, who will map key rice irrigation areas in Matagorda, Wharton, and Colorado counties near the mouth of the Colorado River. Other participants include Douglas Wunneburger of the TAMU Mapping Sciences Laboratory and graduate students Maria Guzman and Yancy Craft of the Geography Department.

"The focus of this project," says Jordan, "is to inventory the ecosystems that have evolved in the region because of the development of rice irrigation, and to develop a framework where we can assess ecosystem changes that may occur if irrigated rice acreage declines or increases."

In the study, the team will develop a geographic information system (GIS) using ARC/Info software. The end product, scheduled to be produced later this year, will be a spatial database that can be queried to predict and map various levels of rice acreage and the environmental effects associated with those changes.

The second project will be conducted by researcher Ronald Kaiser, who specializes in water law issues, and graduate student Michelle Foss of the TAMU Recreation, Parks and Tourism Sciences Department. The goal is to determine the amount of water rights now available for rice production, to look at the restrictions on those rights, and to determine what has happened to rights that used to support irrigated production on roughly twice the current acreage. The project will consist of a search of the state's water rights files, an analysis of Texas legal and regulatory statutes, and interviews with experts and policy makers.

Jordan notes that the rice industry may also provide environmental benefits the public generally doesn't know about. "Shallow ponds created by flooded rice fields are essentially constructed wetlands that provide many of the water quality and wildlife habitat benefits of natural wetlands," Jordan says. "These constructed wetlands have mitigated the loss of natural wetlands along the Texas coast." This region now supports as many as 3 million overwintering geese, at least 70 species of wading birds, and many other waterfowl and wildlife species that use wet habitats.

"We have to be concerned about what may happen to the environment if irrigated rice acreage declines significantly," Jordan says. "This study will be important because rice irrigation is dependent on large quantities of water, but most rice farmers don't own their own water rights. We need to develop data on how vulnerable rice irrigators may be if water rights now held by irrigation districts and companies are lost. We want to answer questions as to whether water rights will still be available for rice irrigation in the future."

For details, contact TWRI at (409) 845-1851 or twri@tamu.edu, Coulson at (409) 845-9725 or coulson@tam2000.tamu.edu, or Kaiser at (409) 845-5303 or rkaiser@rpts.tamu.edu.

Do Firms Profit from Unethical Environmental Behavior?

Researchers: Michele Daley and Douglas Schuler, Jesse Jones Graduate School of Administration, Rice University, Houston, TX.

Problem: Despite changes in social attitudes, legislation, and advances in technology regarding the environment, industrial pollution remains a major problem throughout the United States. Many federal and state statutes control pollution and can impose penalties if requirements are not met. Little is known about how the imposition of penalties for polluting activities affects the economic performance and public perception of major firms. This information could be extremely useful in assessing the impact of federal and state regulations on punishing polluters and in determining if corporations are faced with forceful enough incentives to avoid polluting.

Objectives: To conduct an exploratory examination of informational disclosures made by and about firms that are penalized by the government for polluting, and to determine if there is any relationship between polluting activities and the public perception of and economic performance of these firms.

Background Information: Disclosures about the environmental performance of firms was examined in the context of the U.S. Environmental Protection Agency (EPA) Office of Enforcement and Compliance Assurance, which administers the monitoring, compliance, and sanctioning of industrial polluters. EPA issues an annual report that lists actions brought and resolved against firms for violating pollution statutes, such as the Clean Water Act (CWA) and the Clean Air Act (CAA). Disclosures made by corporations in annual reports, 10-K forms, and articles in the business press were examined. The federal Securities and Exchange Commission requires that firms report certain environmental liabilities in 10-K forms. There is less of a requirement to disclose environmental wrongdoing in annual reports. Corporate reputation indices that include an environmental component were examined. Disclosures of firms that violated environmental regulations were examined to determine if these corporations acknowledged the existence of the violations. EPA provides notification of violations of the CWA and CAA and can impose penalties or bring about civil or criminal actions. The measure of environmental performance used in this paper is the lack of compliance with mandatory environmental regulations. Violation of the CWA and CAA were considered to be evidence of poor environmental performance.

Methodology: A sample of firms that violated the CAA and CWA in 1994 was obtained from EPA. A total of 89 named defendants were identified in 69 CWA enforcement cases, while there were 101 named defendants and 63 CAA incidents. These cases involved 71 corporate defendants for CAA cases and 49 corporations in CWA cases (the others were local environmental management agencies and individuals). Then, only 49 firms that were involved in 57 cases were identified for which annual reports and 10-K forms were available. 10-K forms were gathered for 42 of the 49 firms and, of these only 19 corporations provided specific information about the cost of complying with environmental laws (including violations) and only 11 firms discussed specific environmental rule-breaking. Annual reports were obtained for 37 of 49 firms and

environmental issues were discussed in 26 of them. Information about environmental violations was less specific than that in the 10-K forms. Articles in the business press (*the Wall Street Journal*, *Forbes*, *Fortune* and other related publications) were examined to identify corporate environmental issues and violations. Searches were conducted using media databases and entering the name of individual corporations and the key words "EPA" or "pollution." These articles were read and classified by two reviewers as being positive, neutral, or negative to the companies involved. Roughly 60% of the articles had a negative tone while 30% were neutral. Finally, the *Fortune* list of "Most Admired Corporations" (which evaluates firms on "responsibility to the community and/or environment" as well as quality of management and product quality) was compared to the firms who were identified as incurring environmental violations.

Results: By and large, none of the heavily penalized firms were rated highly in the Fortune survey. The three firms receiving the highest penalties for CWA and CAA violations (Southern Pacific Transport, GATX, and LTV) were rated 387, 307, and 363, respectively in 1994. DuPont was ranked 29th but received $3.7 million in CWA and CAA penalties during this period. The highest ranked firms with CWA and CAA penalties were Boeing and AT&T (ranked 13 and 19, respectively), which suffered relatively small penalties. The authors suggest two tentative conclusions can be drawn. First, the *Fortune* ratings seem to have little to do with environmental penalties imposed on corporations. Second, firms subject to significant CAA or CWA penalties do not seem to be rated very high in the *Fortune* survey. This research is preliminary, but suggests that more studies need to be done in comparing the links between economic and social performance, social disclosure, and stock prices associated with EPA violations. The economic trade-offs of incurring penalties under other environmental rules also needs to be studied.

Reference: Daley, M., and D. Schuler, "Do Firms Benefit from Unethical Behavior? An Examination of Disclosures Related to Violation of Environmental Statutes," in *Proceedings of the International Conference on Sustainable Development*, Published by the Energy and Environmental Systems Institute (EESI), Rice University, 1997.

NOTE: The Proceedings can be purchased from EESI at (713) 527-4685. Daley can be contacted at (713) 285-5391 or brisbane@rice.edu, while Schuler can be contacted at (713) 285-5472 or schuler@rice.edu.

Development of the Texas Water Priorities Act of 1931

Researcher: Laura Wimberley, History Department, Texas A&M University (TAMU), College Station, TX.

Problem: A key element of the Texas Water Code is the Water Priorities Act of 1931, commonly known as "the Wagstaff Act." The act prioritizes different uses of water and gives the highest priority to municipal use and irrigation. The act also includes an exemption that allows cities to take control of water put to non-municipal or non-domestic uses without paying previous users, although it should be noted that no city has attempted to use this provision. Examining the development of this act and understanding

the circumstances under which it was passed may provide critical insights into how the act has been interpreted and implemented and how it now affects Texas water use policies.

Objective: To analyze the conditions under which the Texas Water Priorities Act of 1931 was passed, and to examine the role key legislators and policy makers played in its development.

Methodology: A number of contemporary historical sources from the period in which the act was under development (roughly 1920 - 1940) and after it was enacted were examined including newspaper accounts, reports from the Texas Legislature, publications by special interest groups, and personal correspondence.

Background Information: Most of the credit for the passage of this act is given to Robert Wagstaff (a member of the Texas House of Representatives from Abilene). The author feels that more credit should be given to Walter Woodward, a state senator from Coleman. Texas began utilizing an appropriation system for arid regions of the state in 1895 (after a severe drought) and expanded this to the whole state in 1913. The issue of establishing priorities for various water uses came to the forefront in the 1920s, after utilities attempted hydroelectric development. Based in part on the success of the Tennessee Valley Authority's river development efforts, Texas tried to establish rules for developing its rivers for flood control, industrial and municipal supplies, irrigation, and hydroelectric power. As a result, interest began to build among power companies and several out-of-state dam developers to harness the energy of the Colorado and other rivers for hydroelectric power. In 1927, the Brown County Water Improvement District No. 1 applied for a permit to build a dam and reservoir on the Colorado River to provide water for irrigation and municipal supplies for Brownwood. Although many downriver permit holders objected, the West Texas Chamber of Commerce announced its support for the project and stated that it opposed all state policies that would deny West Texas the use of water for domestic, municipal and irrigation uses in favor of hydroelectric power. Woodward proposed bills to establish a priority system for water appropriations soon after beginning his Senate term in 1927 and again in 1929. The 1929 bill was opposed by Alvin Wirtz (a strong proponent of Colorado River hydropower projects) and by the Farmers Educational and Cooperative Union of Texas, which promoted widespread electricity for rural farmers. In 1931, Woodward introduced a water priorities bill in the Senate while Wagstaff championed the bill in the Texas House. The inclusion of the exemption clause (which gave cities the legal authority to acquire water rights previously utilized for irrigation, mining, navigation, recreation and electric power) may have been due to the fact that upriver cities were concerned that too much water had already been appropriated downstream for hydroelectricity and were worried about additional future developments. Despite the passage of the Water Priorities Act of 1931, many upriver advocates still felt insecure. When the Legislature pursued the development of the Lower Colorado River Authority (LCRA) in 1934, Woodward sought reassurance that the LCRA's water rights would remain subservient to those of cities and towns in the watershed. These assurances were passed as the Dean Amendment in 1934, after much work by Woodward. The conflicts between hydropower development and municipal

interests surfaced again in 1948 when the West Texas Chamber of Commerce urged members to claim hydroelectric appropriations that had not yet been used. The goal was to help long-term development by ensuring that waters were preserved for future growth, not hydroelectricity.

Discussion: Woodward seems to been have the major proponent of the establishment of Texas water priorities, even though he is not generally recognized for his efforts. Research shows that he created the water priorities bill and first presented it in the Texas Legislature in the 1920s, when this concept was not popular. Woodward was a key participant in the creation of the LCRA and the passage of the Dean Act, which protects upstream interests. The truly important fact is that the efforts of Woodward and Wagstaff in passing the Water Priorities Act of 1931 are profound and have significantly influenced the development and use of Texas waters until today and will continue to do so in the future.

Reference: Wimberley, L., "Woodward or Wagstaff? West Texas Authorship of the Water Priorities Act of 1931," in *West Texas Historical Association (WTHA) Year Book*, Vol. 72, 1996.

NOTE: Wimberley received the Percy Jones Award for this article. The article is given for the best paper in the WTHA Year Book. Wimberley is a Ph.D. candidate in the TAMU History Department and can be contacted at (409) 845-7151 or lwimberley@tamu.edu.

Use of Two South Texas Oxbow Lakes by Aquatic Birds

Researchers: Diane Teter, Science and Mathematics Department, South Texas Community College, McAllen, TX, and David McNeely, Biology Department, University of Texas at Brownsville, Brownsville, TX.

Problem: Many studies have investigated the relationship between birds and the habitats in which they are found. Such factors as the height of foliage and vegetational structure have been linked to increased diversity of avian species, while the prevalence of man-made structures has been associated with decreases in diversity. These relationships can vary significantly on a site-by-site basis, and few studies of this type have been performed in South Texas.

Objectives: To determine if human influences are a key factor that affects the use of urban oxbow lakes (known locally as resacas) by aquatic birds in South Texas.

Background Information: Fort Brown Resaca and Lozano Banco, two oxbow lakes near the UT Brownsville campus, were the site of this study. The resacas are similar in many ways: they are roughly 650 feet apart, they are roughly the same size (0.4 square miles), and both are within 0.6 miles of the Rio Grande. There are some major differences, however. Fort Brown Resaca is horseshoe shaped and is located in a highly developed urban area and is surrounded by homes, hotels, and offices. Lawns are regularly trimmed and cultivated plants have been introduced. Most of the lake's edge

consists of man-made vertical retaining walls although there is occasional weedy shoreline vegetation. The water level is kept near-constant (minimum depth is roughly 2.6 feet) and is maintained by water pumped from the Rio Grande. The bottom is deep silt. Lozano Banco is a hook-shaped lake located in a former agricultural area. The shoreline is heavily vegetated with native and introduced vegetation, including trees and shrubs. A stand of giant reed grass occupies some of the lake margin. The banks of the lake are very steep next to artificial levees, but slope naturally around most of the lake. Lozano Banco receives most of its water from runoff, and its level fluctuates. The lake is shallow (the maximum depth is roughly 3.3 feet) and the lake bottom slopes gently and is composed of deep silts.

Methodology: Bird censuses of both resacas were conducted weekly. They consisted of 15-minute walking surveys conducted at mid-day from March 1992 to February 1993, and 15-minute observations at dawn taken from August 1992 to January 1993. Observations were made with binoculars from a vantage point that afforded a view of the lake surface and perimeter. Estimates of numbers of birds and number of species were based on visual observations. Diversity was estimated using Shannon's formula.

Results and Discussion: During the study, 22 species of aquatic birds were observed. Only five of these species (the double-crested cormorant, the neotropic cormorant, the great egret, the snowy egret, and the black-bellied whistling duck) were observed at both resacas. The laughing gull was the only species observed only at the Fort Brown Resaca. Differences were observed to be greatest during autumn and early winter months, due to the presence of large numbers of migrating birds. Lozano Banco was also visited by large numbers of cattle egrets and several species of herons, while Fort Brown Resaca was not. Results of this project suggest that high levels of human traffic and the absence of a well-vegetated shoreline at Fort Brown Resaca may be primary reasons that aquatic birds visited Lozano Banco in greater numbers.

Reference: Teter, D., and D. McNeely, "Abundance and Diversity of Aquatic Birds on Two South Texas Oxbow Lakes," *Texas Journal of Science*, February 1995, pp. 62-68.

Impact of On-Site Wastewater Systems on Barton Creek

Researchers: Michael Barrett and Randall Charbeneau, Center for Research in Water Resources (CRWR), University of Texas at Austin (UT), Austin, TX.

Problem: Rapid urban development is occurring in the Barton Creek watershed, which recharges such environmentally sensitive areas as Barton Springs and the Barton Springs portion of the Edwards Aquifer. Many homes built in the watershed utilize septic tanks and drainfields and on-site wastewater treatment and disposal systems. There are concerns that the use of on-site systems may increase nitrate concentrations in the aquifer.

Objectives: To assess the impact of increased numbers of on-site systems in this watershed, using a nitrogen balance for the aquifer.

Methodology: The current level of nitrogen in the aquifer was determined by analyzing the water quality discharged from Barton Springs, wells, and baseflow to Barton Creek. Data collected from 1983-93 were utilized to determine average levels of nitrogen in the springs, which was assumed to represent average levels in the aquifer. The mean concentration for total nitrogen was 1.6 parts per million (ppm). A mass balance equation was utilized to determine how changes in nitrogen loadings could impact groundwater quality. Nitrogen inputs include septic tank effluent, stream recharge, infiltration from rainfall, runoff, leaking sewer pipes, and leaching from fertilized crops and landscapes. Outputs consist of springflows, well pumpage, and discharges to Barton Creek as baseflow. 1990 information from the U.S. Census Bureau was used to estimate that there are roughly 5,900 on-site systems over the recharge zone. Septic tank effluents were assumed to have high levels of nitrogen (40 ppm), but very little nitrate (less than 1 ppm). Based on previous studies, it was assumed that nitrogen in effluents from on-site systems consist of 75% ammonia and 25% organic nitrogen. Outputs of nitrogen from on-site systems include runoff, sedimentation, plant uptake, crop yields, leachate, and denitrification. A computer simulation model, GLEAMS (Groundwater Loading Effects of Agricultural Management Systems), was used to estimate the input of nitrogen to the aquifer from on-site systems. In the GLEAMS model, outflows from septic tanks were modeled as injected fertilizer so the researchers could specify the nitrogen level. National Weather Service (NWS) data from the Austin airport were used for rainfall, while solar radiation and mean temperatures were obtained from a NWS site in San Antonio. Runoff was calculated based on curve numbers developed by the U.S. Department of Agriculture Natural Resource Conservation Service. Total nitrogen levels in rainfall averaged 1.5 ppm. Actual rainfall volumes were increased by 0.2 inches per day to account for water associated with septic tank influent, because GLEAMS does not account for extra water added by fertilizers. This amount was based on the assumption that wastewater flows from septic systems serving a four-person household are roughly 176 gallons per day, and that the size of the average drainfield was 500 square feet. Simulations predicted that an average nitrate level of 12 ppm would be leached to the aquifer during the 20-year study period. This is roughly the same level that has been reported in regional monitoring studies. The study suggests that only 15% of the nitrogen introduced into drainfields is leached to the aquifer. Other major losses include plant uptake (36%), denitrification (6%), and nitrogen retained in vegetation and soils (43%). The total nitrogen load from individual septic systems was estimated to be 3.5 pounds annually. The total mass of nitrogen introduced into the aquifer by septic systems is 10.1 tons annually, based on a total water volume of 200 million gallons. A sensitivity analysis was performed to assess which variables were critical in contributing nitrogen to the aquifer. They suggest that the most sensitive parameter is the total nitrogen concentration of effluent applied to the drainfield.

Results and Discussion: The study shows that the smallest nitrogen load to the aquifer is derived from on-site wastewater systems (10%), while diffuse recharge contributed 50% and creek recharge 37%. The total amount of nitrogen entering the aquifer is roughly 116 tons annually. The average level of nitrogen from all known sources is about 1.5 ppm, which is roughly the same as average levels at Barton Springs. The researchers examined if increases in the number of on-site systems may increase nitrogen concentrations.

Average nitrogen levels were computed for different numbers of on-site systems using loading estimates from 1979-93. The impact of increasing the number of septic tanks was estimated by calculating the increased nitrogen level in the aquifer that would result from additional systems. Average levels in the aquifer were calculated by dividing the estimated total annual nitrogen load by the estimated volume of recharge. A mathematical equation was developed that uses data on the number of septic systems, masses of nitrogen in creeks and diffuse recharge, the annual amount of nitrogen per septic system, and average recharge from creeks and diffuse sources to predict the average total nitrogen in recharge waters. Results suggest that only relatively small changes in nitrogen loadings will result if as many as 5,000 new on-site wastewater systems are utilized in the region. Another implication of the research is that use of substantially greater numbers of on-site systems will not likely create significant water quality problems or health risks.

Reference: Barrett, M., and R. Charbeneau, *Current and Potential Impacts of Septic Systems on a Karst Aquifer*, UT CRWR, 1996.

NOTE: Barrett can be contacted for more information at the UT CRWR at (512) 471-0935 or mbarrett@mail.utexas.edu.

Occurrence of Hypoxia in Corpus Christi Bay

Researcher: Paul Montagna, University of Texas at Austin Marine Science Institute at Port Aransas (UTMSI), Port Aransas, TX.

Problem: Long-term studies by UTMSI in Corpus Christi Bay show that hypoxic (low oxygen conditions below 2 mg per liter) events were noted each summer since 1988 in bottom waters in portions of the bay. The hypoxia occurs only in the summer when temperatures and salinities are high, and the water column is stratified. Several processes are thought to be related to the onset of hypoxia, including water column stratification and organic matter decomposition. The most likely explanation for hypoxia in Corpus Christi Bay is water column stratification. This is surprising because the estuary is well mixed, shallow and windy, and has a low tidal range.

Objective: To sample Corpus Christi Bay to determine the spatial and temporal extent of hypoxic conditions as well as the biological implications of these events.

Methodology: The Coastal Bend Bays Foundation (CBBF) funded research to sample the hypoxic area in Corpus Christi Bay. The area south of Shamrock Island was sampled every three weeks between 3 May and 26 August 1994. Between June and July 1994, hypoxia was found in this area and was linked to with water column stratification . The hypoxic area extended south from Shamrock Island for about 2 miles. In July 1996, sampling was performed to study the spatial extent and biological effects of the hypoxia. Hydrographic sampling over a broad area was performed by the Marine Environmental Science class, and biological sampling was performed by UT graduate student Christine Ritter. Ritter sampled 10 stations, five within the hypoxic area and 5 outside the hypoxic area.

Results and Discussion: In 1996, the areal extent of the hypoxic zone was relatively small. The area with hypoxia roughly formed a triangle with three points between the Oso Bay inlet to Corpus Christi Bay, Shamrock Island, and southeast of Corpus Christi Bay. There was a gradient of increasing salinity from Oso Bay to the Ship Channel and Port Aransas. The distribution of saline bottom waters indicates that the source of the hypersaline water was Oso Bay, where water from the Laguna Madre is used for cooling the Central Power and Light power plant and is sent to a cooling pond that discharges into Oso Bay. There was twice as much oxygen in the control regions (non-hypoxic) than in the hypoxic areas. This had a large effect on productivity in those sediments, as indicated by a biomass standing stock that was 14 times greater in sediments with normal oxygen levels. There was a corresponding 500% decrease in density and species number in the hypoxic sediments. The cause of the hypoxia is water column stratification. There was a large difference in surface and bottom water salinity. Temperature was constant throughout the water column at both stations, so the differences in the water masses was driven by the influx of salty water of the same temperature as the Bay water. The dividing line where the salinity changed rapidly was at 6 feet below the surface at both stations. The salinity was similar in the surface water of both stations, and constant throughout the water column at the non-hypoxic station. In the lower half of the water column, the salinity decreased by about 2 parts per thousand (ppt) in the normal station, but increased by about 5 ppt at the hypoxic station. Oxygen levels decreased continuously at the non-hypoxic station from 5.6 mg per liter (mg/l) to 3.6 mg/l. At the hypoxic station, oxygen was constant at 5.3 mg/l above the dividing line, but decreased to 1.9 mg/l below the dividing line. The differences in the structure of the water mass indicate that a layer of hypersaline bottom water is causing the stratification, and that the oxygen is being depleted from the bottom water mass which is not mixing with the surface. It is interesting that the conventional wisdom that suggests open bays are well-mixed because of high winds and shallow depths is simply not always true. The hypoxic events appear to be limited to a short duration during summers and to a small part of Corpus Christi Bay. The events appear to be due to altered circulation patterns in the bay.

Reference: Montagna, P., "Hypoxia in Corpus Christi Bay," in *Bay Foundation News*, Published by the Coastal Bend Bays Foundation, December 1996.

NOTE: Montagna can be contacted at paul@utmsi.zo.utexas.edu or (512) 749-6779.

LCRA Studies Effectiveness of Dragonflies to Assess Water Quality in Stormwater Ponds

A recent study by staff members of the Lower Colorado River Authority (LCRA) sheds further light on the use of dragonfly naiads as potential indicators of nonpoint source pollutants in stormwater wetlands.

In lotic systems (running waters), macroinvertebrates have been widely used as reliable indicators of water quality. Most species of stoneflies live in high quality waters while some species of midges can be found in a wide range of conditions. Biological indicators for lentic systems such as ponds, lakes and other still or slow-moving waters are lacking and still under development. Water managers recognize the need to develop cost-

John Trevino (left) and Jeff Garrett of LCRA gather dragonfly samples near Austin.

effective tools (biological indicators) to gage the health of lentic systems. In 1992 the Texas Water Development Board awarded a grant to the LCRA to construct and monitor a wetland pond to treat stormwater runoff from a bridge over Lake Austin. One objective of that grant was to identify potential macroinvertebrates that could tell water managers more about the effects of runoff pollutants on lentic systems.

The macroinvertebrate component of the study was conducted by John Trevino of the LCRA. The wet pond was built in Travis County on the Mansfield Tract. In the project, local emergent and submerged vegetation were introduced into the pond to create and enhance habitats. Macroinvertebrate surveys of vegetation in the pond were conducted between November 1994 and July 1996.

The final grant report was completed in May 1997. Trevino says the results indicate that some genera of dragonfly naiads were absent or found in low numbers in the impacted pond. When compared to reference ponds, the same genera were present and numerous. These genera include three families of "skimmers" (*Tramea* sp., *Celithemis* sp. and *Dythemis* sp.). The implication of the research, Trevino says, is that water managers may be able to use the presence or absence of some dragonfly naiads as a screening tool to assess the amount of pollution at a given lentic site.

For details, contact Trevino at (800) 776-5272 or john.trevino@lcra.org.

UNT Uses GIS to Assess if Landfills Are Sited Near Streams

Researchers at the University of North Texas (UNT) Geography Department are utilizing high-tech tools to assess whether contaminants from landfills may pose a risk to area streams and rivers. The studies are being conducted by Paul Hudak and William Langley of the UNT Geography Department.

The goal of the project was to identify the location of landfills in the Upper Trinity River watershed, near Dallas and Fort Worth, and to determine if these sites were too close to rivers and streams or upstream of water supply reservoirs. In the project, the researchers first constructed stream and lake boundaries from U.S. Geological Survey digital line graph files. Data on permitted and unauthorized landfill sites was obtained from the Texas Natural Resource Conservation Commission. A geographic information system (GIS) was created using ARC/Info software. The GIS was queried so that the researchers could specify stream segments that were within key distances of landfills.

The researchers found there were 165 landfills in the study area and 33 miles of stream segments are within 328 feet of at least one landfill. Many landfills are sited near major tributaries of the Trinity River drainage area. More than 15 miles of stream segments that may be affected by landfills are sited upstream of water supply reservoirs. Hudak says the research is critical because it is a tool policy makers can use to assess pollution threats from landfills that may adversely affect drinking water sources.

For details, contact Hudak at (817) 565-4312 or hudak@unt.edu.

Border Aerial Photo Project Nearly Complete, Says GLO, USGS

The U.S. Geological Survey (USGS) is near completion on a border aerial photography project that is a key element in the Transboundary Resource Inventory Program (TRIP). TRIP is a binational consortium that includes federal, state and local agencies and border universities who are developing of a comprehensive resource inventory along the 2,000-mile border between Mexico and the U.S. The project facilitates the North American Free Trade Agreement's commitment to protect environmental resources. The Texas General Land Office (GLO) is a major TRIP sponsor.

USGS officials say that the project, which covers a 100-mile swath along the U.S. side of the border, is virtually complete. The USGS's Mexican counterpart, Instituto Nacional de Estadistica Geografia e Informatica, is making significant headway on similar photographic work.

Historically, there has been no collaboration between the two nations to assess border resources. Inventories generated by the two nations are often inconsistent and incompatible. This makes it difficult to map shared resources such as watersheds, rivers and groundwater systems. Once the data is in digital form, scholars and government officials will be better able to research and develop soil and water conservation projects for the Rio Grande basin, to protect coastal resources, and to combat air pollution.

For details, contact Jeff Long of the GLO Public Affairs Office at (512) 463-5339 or jlong@glo.state.tx.us or visit the TRIP WWW site at http://www.glo.state.tx.us/infosys/gis/trip/. You can contact Marshall Jennings of the USGS at mejennin@maildtxast.cr.usgs.gov.

UTEP Project Helps Colonias Residents Treat Drinking Water

The University of Texas at El Paso (UTEP) is working to teach residents along the U.S. - Mexico border how to properly treat their drinking water. The project is led by Amy Liebman with the UTEP Center for Environmental Research Management (CERM).

The work is part of a long-term effort to reduce gastrointestinal illness and improve the quality of drinking water. In 1994, CERM began implementing a drinking water and hygiene education program called "Agua Para Beber" for low-income communities along the border. The program combines outreach education with the distribution of low-cost water receptacles and uses volunteers to implement health education efforts. In 1995,

CERM began transferring the program to community organizations, providing them with training, materials, and technical assistance.

Volunteers with this program conducted workshops and in-home demonstrations and made follow-up visits to participating households. They monitored the chlorine levels in drinking water and distributed educational materials about water disinfection.

So far, CERM and local project participants have trained roughly 175 volunteers and have reached more than 2,200 families. The volunteers teach colonia residents the importance of boiling water or adding chlorine bleach for disinfection as well as safe water storage methods (for example, the use of polyethylene liners that can be placed inside of 55-gallon drums now used to store drinking water).

The results of the pilot project are significant, Liebman says. When volunteers first visited colonia residents only roughly 46% of households said they attempted to disinfect drinking water. After five visits and personalized training sessions, roughly 90% of participants said they disinfect their drinking water. Roughly 80% of the household drinking water samples that were tested contained suitable amounts of chlorine for disinfection.

The project is conducted in cooperation with the Southwest Center for Environmental Research and Policy (SCERP), which provided seed money and continuation funding. For details, contact Liebman at CERM at (915) 747-5893 or aliebman@utep.edu. You can also visit the CERM WWW site at http://www.cerm.utep.edu or the SCERP WWW site at http://www.civil.utah.edu/scerp/docs/apb.html.

TAMU Researcher Contributes to Irrigation Book

A Texas A&M University researcher recently contributed to a new book that examines the future of irrigation. Ron Lacewell of the TAMU Agricultural Economics Department was part of a National Research Council committee which developed the book, titled *A New Era for Irrigation*. The book describes such issues as competition for water, continued urbanization, the growing international marketplace, and the shifting roles of federal and state governments in regulating water use.

Individual chapters describe the future of irrigation, the culture of irrigation, irrigation today, forces of change and responses, the irrigation industry: patterns of change and response, and future directions. It states that irrigated agriculture must evolve to compete in a new era and must adopt more efficient technologies and management strategies, develop more flexible institutional arrangements, and work cooperatively with other water users to allocate limited water resources equitably. Water costs and the demand for water are rising and these trends are likely to continue.

The report can be purchased from the National Academy Press (NAP) by calling (800) 624-6242. The book is available on the NAP WWW site at http://www.nap.edu. Lacewell can be contacted at (409) 845-2334 or r-lacewell@tamu.edu.

USFWS Report Analyzes Changes in Texas Coastal Wetlands

A 32-page illustrated report on the status and trends of Texas coastal wetlands from the mid-1950s through the early 1990s is available from the U.S. Fish and Wildlife Service (USFWS) National Wetlands Inventory Southwestern Region.

The report analyzes data from aerial photographs of the area taken between 1955 and 1992 to determine changes in wetlands, deepwater habitats, and uplands acreage. According the report, the amount of acreage for many types of wetlands declined significantly during the study period. For example, saltwater wetlands declined by 9%, freshwater wetlands dropped by 4%, and 10% of forested wetlands were lost or converted to other wetland types. On the other hand, scrub-shrub wetlands increased by 58%, although this was typically at the expense of emergent and forested wetlands. Freshwater ponds increased by 137% during the study period as many farm ponds and stock tanks were developed.

To order the book, call the USFWS regional office at (505) 248-6668. An executive summary of the report is on the World Wide Web at http://www.nwi.fws.gov/texas.html.

GLO Publishes Coastal Wetlands Handbook for Governments

The Texas General Land Office (GLO) recently published a coastal wetlands handbook that will be especially useful for local governments. The book, titled *Texas Coastal Wetlands: A Handbook for Local Governments*, was funded by the U.S. Environmental Protection Agency. It was developed by an advisory committee comprised of coastal citizens, public officials, and business leaders from the region.

The handbook is a practical "how to" guide for coastal officials interested in voluntary initiatives to conserve, restore, or create coastal wetlands. It addresses the role of local governments in coastal wetlands management and identifies a variety of tools that municipalities, counties, conservation and reclamation districts, ports and navigation districts, river authorities, and regional councils of governments can use to keep wetland systems intact.

To request a copy of the handbook, contact Claire Randle at (800) 85-BEACH or e-mail claire.randle@glo.state.tx.us.

UTSA Researchers Write Book on Drinking Water Economics

Economists at the University of Texas at San Antonio (UTSA) have written a book that focuses on the economics of water use. The book, *Economics by Design: Principles and Issues*, was written by Robert Collinge and Ronald Ayers of the UTSA Economics and Finance Division. A part of the book that may be especially interesting to water managers is titled, "Drinking Water - Stirring Together Markets and Government." It discusses the

inefficiency of increasing block rates used by many municipal water suppliers, the influence of government on water pricing, the use of average and marginal cost pricing to establish drinking water rates, why increasing block rates may look fair to policy makers but really aren't, and the development and use of market-based alternatives. For details, contact Collinge at (210) 458-5312 or rcolling@pclan.utsa.edu. To order the book, contact Prentice Hall at (800) 643-5506.

AWWARF Reports Include Information on Texas Projects

The American Water Works Research Foundation (AWWARF) has recently published many reports that contain information about water research in Texas.

Use of Constructed Wetlands for Protection of Water Quality in Water Supply Reservoirs (Report 90696) describes a project conducted by Woody Frossard and Darrel Andrews of the Tarrant County Regional Water Authority, and consultants Loretta Mokry, Alan Plummer, and John Mancini. The emphasis of the study was to determine whether constructed wetlands could be used to improve the quality of Trinity River water before it flows into the Richland Chambers and Cedar Creek Reservoirs. The reservoirs serve as raw water sources for the Dallas - Fort Worth area. This report comes with computer software that can be used to evaluate the efficiency of such constructed wetlands.

Other recent AWWARF reports contain contributions by Texas co-authors. *Aquifer Storage Recovery of Treated Drinking Water* (Report 90689) includes data from the Upper Guadalupe River Authority in Kerrville. Dallas Water Utilities participated in research for a report titled, *Managing the Revenue and Cash Flow Effects of Conservation* (Report 90686). The City of Houston Water Department took part in a study titled *Impacts of Demand Reduction on Water Utilities* (Report 90690). Jeannie Wiggington of the City of Austin Water and Wastewater Utility participated in *Public Involvement Strategies: A Manager's Handbook* (Report 90694).

To purchase these or other AWWARF reports, call the AWWA Bookstore at (800) 926-7337 or visit their WWW site at http://www.awwa.org. AWWARF subscribers can order the reports for free by contacting Phalita Hampton at (303) 347-6121 or phampton@awwarf.com. More details on the Research Foundation is available on their WWW site at http://www.awwarf.com.

TAMU Scientists Use Modern Chemistry To Date Pecos River Rock Paintings

By analyzing and dating rock paintings, two Texas A&M University (TAMU) chemists hope to develop better ways to preserve history while offering a glimpse into what life was like for ancient Native Americans. Marian Hyman, Marvin Rowe and graduate students in the TAMU Chemistry Department are using radiocarbon dating, scanning electron microscopy with energy dispersive x-ray analysis, x-ray diffraction and DNA analysis to study rock paintings in the lower Pecos River region of Southwest Texas.

"This area has the largest concentration of rock paintings in North America, and archaeologists believe the region has been home to Native American cultures for 11,000

years," Hyman said. "By determining the approximate age of rock paintings, they can help anthropologists assign the artworks to specific cultures. The oldest genre in the region has been dated from 2,700 to 4,200 years ago."

Marvin Rowe (left) and Marian Hyman take samples from this cave near the Pecos River.

"Dating rock paintings and collecting samples present special challenges," Rowe said. Radiocarbon dating requires the presence of residual dead animal or plant material that had been added originally to the paint to measure the rate of carbon decay. "Collecting samples also presents unique problems," Hyman said. "Many of the paintings are located on the sides of cliffs, in rock overhangs or along river banks and are difficult to reach. Once they collect samples and purify the organic components in the lab, the scientists are often left with a sample weighing only 0.1 milligrams (about the weight of a grain of salt) to use for radiocarbon dating."

They also face a lack of rock painting standards with which to compare their results, Rowe said. "We don't have any paintings where we know exactly when they were painted," he said. "We have to rely on archaeological inference to determine how old they are for comparison with our experimental dates." By studying the chemicals in the paints, the rocks they are painted on and the chemical deposits covering rock paintings, Rowe and Hyman hope to devise better ways to protect and preserve them.

For details, contact Rowe at (409) 845-1929 or rowe@chemvx.tamu.edu or Hyman at (409) 845-4084 or hyman@chemvx.tamu.edu.

TSU Researcher Investigates Use of Wood Charcoal Filters to Filter Water, Wastewater Supplies

A researcher at Texas Southern University (TSU) is conducting preliminary investigations into the ability of raw hardwood charcoal to filter water and wastewater. Ultimately, he wants to determine if this could be a practical method to recharge groundwater supplies.

The research is being conducted by Ray Agbanobi of the TSU School of Technology. Initially, Agbanobi wants to determine if wood charcoal can be a cost-effective substitute for expensive materials such as activated carbon and anthracite that are now used to treat wastewater effluents. He feels that enough wood could be obtained from homes and businesses that routinely burn wood products.

In this project, Agbanobi developed experimental filters that utilized clean sand and hardwood charcoal. Raw water with high levels of bacteria and turbidity were collected from a Houston Bayou and were allowed to settle. Afterwards, they were passed through the filters by gravity and the polished effluents were analyzed for turbidity, bacteria counts, and total suspended solids.

Results of the research suggest that the wood charcoal performed better than the clean sand filter in many areas, including endurance and contaminant removal. In the future, Agbanobi hopes to treat effluents from a Houston wastewater treatment plant and to develop an engineering design for a pilot-scale recharge well.

For details, contact Agbanobi at (713) 313-7681.

TAMIU Biologist Uses DNA Analyses to Study Seagrasses

A biologist at Texas A&M International University (TAMIU) is investigating if DNA testing can be used to identify the impact of pollution on seagrasses that grow in South Texas estuaries. The research is led by Jerilyn Jewett-Smith of the Biology Department.

In the study, Jewett-Smith has been gathering samples of a seagrass called clover-grass or star-grass (*Halophila engelmanii*) which is commonly found in subtidal and saline areas in the Laguna Madre and other South Texas estuaries. The samples are being collected from shallow sites in Red Fish Bay, Corpus Christi Bay, and the upper Laguna Madre. After being cleaned, the grasses are ground and the DNA is extracted. Polymerase chain reaction techniques are used to generate bands that can be examined to show if the grasses are genetically similar or diverse.

Preliminary results of the research show that star-grasses from Red Fish Bay had a high degree of genetic similarity, which suggests that most of the grasses originated locally. On the other hand, the analysis suggests that the genetic traits of star-grasses from Corpus Christi Bay may be less similar. Jewett-Smith suggests this may be due to the fact that a long-lasting brown tide which is reducing the amount of light that penetrates underwater and helps the seagrasses grow. As a result, environmental stresses are being created which may restrict the number of star-grass and clover-grass varieties that can survive in the region.

For details, contact Jewett-Smith at (210) 326-2586 or jjewett@tamiu.edu.

TAES Scientists Use Drip Irrigation to Grow Sugarcane

Scientists in the Lower Rio Grande are investigating whether water-efficient methods can be used to grow high quality sugarcane. The studies are led by Robert Wiedenfeld of the Texas Agricultural Experiment Station at Weslaco.

Wiedenfeld says that as much as 40,000 acres of sugarcane are grown annually in the Lower Valley, and most growers apply a large amount of water through flooding. Three years ago, Wiedenfeld began working with agricultural producers to see if there was any

interest in using water-saving drip irrigation to grow the crop. Since then, three growers in the region are managing 600 acres of sugarcane with drip irrigation.

The overall goal of this project is to compare the use of drip and flood irrigation for sugarcane production in the Lower Rio Grande Valley. In the project, researchers want to determine how to schedule the amount of water crops need using tensiometers, potential evapotranspiration (PET), pan evaporation, and other climatic data. Direct measurements are taken using the tensiometer and an automatic drip irrigation system takes the data from the tensiometer and uses it to automatically apply water when needed.

Bobby Wiedenfeld of TAES shows how drip irrigation is used to grow sugarcane in Weslaco.

"The key is to apply enough water to keep the sugarcane crop from being stressed," Wiedenfeld says. "Flood irrigation isn't real practical because it requires so much water, and you typically can't apply water more often than once every 10 days. More frequent irrigations that use less water and less time do better."

Results are encouraging, Wiedenfeld says. Sugarcane yields were 45 tons per acre with drip irrigation, compared to 40 tons per acre with flood irrigation. The drip irrigation used 30% less water. Wiedenfeld is working with scientists at the United States Department of Agriculture Research Service in Weslaco to study how water quality affects sugarcane production. These studies suggest that high levels of potassium can substantially reduce the amount of sugar that is produced.

For details, contact Wiedenfeld at (210) 968-5585 or b-wiedenfeld@tamu.edu.

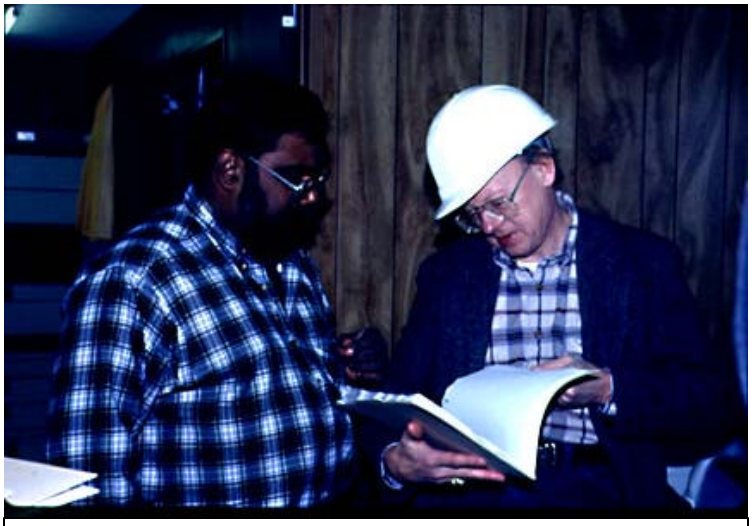
Coastal Oil-Spill Cleanup Facility Will Aid TAMUS Research

A new Coastal Oil Spill Simulation System (COSS) facility in Corpus Christi will enable environmental researchers to undertake many new coastal oil spill research projects and will create opportunities for graduate engineering students in four Texas A&M University (TAMU) System universities.

The facility is located at the Central Power and Light Company Davis Power Plant. The COSS site is funded by the Marine Spill Response Corporation and the Texas General Land Office (GLO), which will own the facility when it is completed. Recently, Andrew

Ernest of the TAMUK Environmental Engineering Department was awarded a grant from the GLO to staff and support operation and maintenance of the COSS facility.

The project will involve scientists and students from TAMU - Kingsville (TAMUK), Texas A&M University - Corpus Christi (TAMUCC), and Prairie View A&M University. In addition, the Texas Engineering Experiment Station is coordinating many aspects of the project. Other key participants in this effort include Roy Lehman and Jim Bonner of TAMUCC.



Andy Ernest (left) of TAMU - Kingsville studies plans for a new coastal oil spill simulation facility in Corpus Christi.

The overall goal of the project is to investigate oil spill cleanup techniques in coastal environments. Ships make roughly 5,000 trips into and out of Texas ports annually and roughly 58% of these ships carry oil or oil products. "The coast of Texas experiences a great amount of oil tanker traffic that travels through many environmentally sensitive wetlands," Ernest said. "Many oil spills occur annually, ranging from a few barrels of oil being spilled to tankers being run aground. When large oil spills occur, the environmental damage can be enormous. Not only is the area ruined by the tarry, black residue, the effects on wildlife and aquatic species can be devastating."

The facility recently became operational. At the site, researchers will be able to simulate lagoon, marsh, lake and freshwater environments in wave tanks, which can be utilized to study the effects of oil spills on many environments. Seawater from the Laguna Madre can be pumped into nine wave tanks. Computer-controlled wave makers can be made to swing back and forth to create waves of adjustable heights. Lengths and tidal influences can also be simulated.

The facility includes a wastewater treatment pad that will prevent oil and other materials used in studies from reaching the Laguna Madre. Water removed from the wave tanks will go into an oil and water separator and will then flow through two large activated carbon filters to remove pollutants. Ultraviolet sterilizers will kill bacteria before the water is returned to the Laguna Madre. Separated oil will be stored for later reuse.

Two experiments are scheduled for this year. The first study will investigate oil and fine particle interactions. A beach environment will be created and tides and waves will be generated. Oil will be applied to the beach, and researchers will study the effect of tidal

energy on the rate that oil is removed from the system and interactions between the oil and beach particles. The second study will examine the effectiveness of chemicals and biological molecules called dispersants that act like detergents to disperse oil into the water.

For more information, details, contact Ernest at (512) 593-3041 or a-ernest@tamuk.edu, or Lehman at (512) 994-5819 or rlehman@falcon.tamucc.edu. Bonner can be contacted at the TAMUCC Blucher Institute for Surveying and Science at (512) 994-2646.

TWRI Fellowship Recipient Publishes Dissertation on Role of Rainfall in Agricultural Decision Making

A recently published doctoral dissertation by a Texas Water Resources Institute (TWRI) Fellowship recipient examines how households in developing nations integrate rainfall and climate information when deciding how to manage agricultural crops.

The dissertation is titled "Non-Controllable and Non-Commercial Resources in Agricultural Production Models." It was written by Janice Stroud, who graduated with a Ph.D. in Agricultural Economics in December 1996. The co-chairs of her committee were Richard Shumway and Atanu Saha.

The focus of the dissertation dealt with how poor agricultural households in the semi-arid tropics make decisions about crop management. For example, the research investigated how these households consider the likelihood of drought and rainfall when choosing how to best manage their crops. The study also examined how strategies could be developed that link crop production and harvesting to protect endangered species. It focused on the relationship between natural resources that are harvested (crops and forests) and those that are not harvested (national and state parks and wildlife refuges). It then examined how these relationships may increase the vulnerability of endangered species to become extinct.

The results of the study show that rainfall and weather conditions account for a considerable portion of the risk that agricultural households take when growing crops in these regions. The research suggests that an effective way to introduce new techniques into developing countries may be to ensure agricultural producers that they will be able to produce a minimum level of food to subsist on, even if crops fail. The research also stresses that climate change may exert a serious effect on dryland agriculture and endangered species in third-world, developing, countries if it produces even only slight modifications in weather patterns.

The TWRI Ph.D. Fellowship Program provides supplemental funds for outstanding graduate students to come to Texas A&M University to work on doctoral degrees in water-related fields. For more details about this program, contact TWRI at (409) 845-1851 or twri@tamu.edu. For more information on Stroud's project, contact Shumway at (409) 845-7379 or rshumway@tamu.edu.

UNT Creates WWW Site for Clam Studies

Researchers at the Institute for Applied Sciences at the University of North Texas have developed a World Wide Web site with real-time information on clams that are used to monitor water quality in North Texas waters. The site was developed by Joel Allen and Tom Waller of the UNT Biology Department and Institute of Applied Sciences. It was based on research funded in part by TWRI.

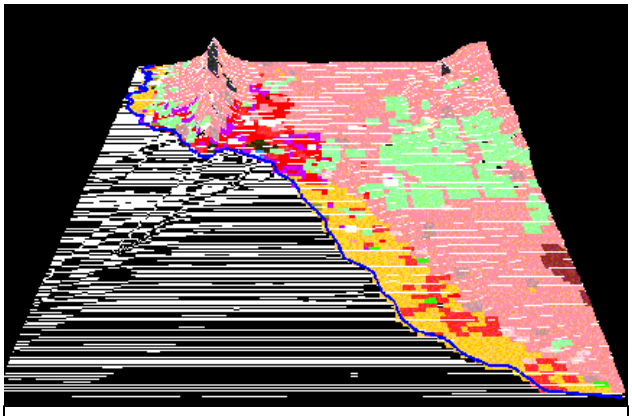
In general, the web site describes UNT efforts to measure the extent to which the shells of clams are opened or closed. Waller believes the clams open and close their shells, in part, due to the presence of water contaminants. In other words, poor water quality is one reason clams may close their shells.

The Web site describes the project and includes real-time data from four sites, each of which are instrumented with 15 clams. Data describe the number of clams that have opened their shells, the extent to which they are open, and how long they are open. Data for the project is being gathered both in the field and at the UNT Aquatic Toxicology Laboratory. The real-time data displayed on the web page are from the laboratory.

The Web Site address is http://www.cascss.unt.edu/~jallen/clampage.html. You can contact Waller for more information at (817) 565-2982 or waller@gab.unt.edu.

TAMU WWW Site Contains Environmental Maps

Many innovative projects that create computer-generated maps about Texas water and environmental issues are available at the WWW site of the Texas A&M University Mapping Sciences Laboratory.



The map displays the slopes, watersheds, and other physical features of the El Paso area as well as land uses.

The site contains extensive information on the Borderlands Geographic Information System (GIS) Database, which will eventually cover 32 Texas counties and will extend 62 miles inland from the Rio Grande. Information that is now on-line includes computer-generated maps of the hydrology of El Paso County, and views of land uses in the region that are draped over digital elevation models. Lab staff are now working with Raymond Sims and Rick Hammer of the Cooperative Fish and Wildlife Research Unit to develop a home page for the Texas Gap Analysis Project, which will eventually include information on vegetation, key biological indicator species, and many other environmental topics.

The address for the mapping lab's WWW site is http://www-msl.tamu.edu. The lab is led by Robert Maggio of the TAMU Forest Sciences Department. You can contact him for more information at (409) 845-5069 or maggio@rsgis4.tamu.edu.

EIH WWW Site Describes UHCL Environmental Programs

Detailed information on a variety of environmental research and education projects is available from the WWW site of the Environmental Institute of Houston (EIH). The institute is a component of the University of Houston -- Clear Lake.

The strength of this site is that it contains thorough summaries and graphics of many projects conducted by EIH researchers from 1995 to 1997. Topics of many of these projects center on the broad areas of pollution prevention, climate and ecosystem change, environmental management and monitoring, and environmental education. The site also describes EIH publications, presentations, grants, and principal investigators.

Projects described on the WWW site include the use of remote sensing techniques to estimate pollutant loading into Galveston Bay, assessing the number of violations of domestic wastewater plants in the Houston region, investigating the relationships between changes in wetlands resources and populations of marsh rice rats, and the use of coral reef skeletons to reconstruct climates.

The WWW site was developed by EIH director Jim Lester. The address for the site is http://server.enl.uh.edu/eih/. You can contact him at (281) 283-3950 or lester@cl4.cl.uh.edu.

Information About Texas Legislature is Now On-Line

Information about the Texas Legislature is now on the WWW. Types of information on this site include information on individual bills, committee schedules and membership, events at the Capitol, Texas statutes, and the Texas Constitution.

A useful feature of this WWW site is that it allows individuals to search bills by text or keyword. You can also seek legislative actions about a bill and view the full text and history of a bill. Many water related bills are included. A recent search of bills on this site found the full text of 85 bills relating to such diverse topics as water resources development and management, irrigation, water rights, natural disasters (including water contamination outbreaks, floods and droughts), on-site wastewater issues and many others.

For more information, visit the site at http://www.capitol.state.tx.us.