New Waves
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Fact Sheet Provides Clues About Water Management Measures Preferred by Regional Planning Participants

Texas is now in the midst of a statewide planning process in which groups of people within each of 16 regions are contemplating how to provide enough water for the next 50 years.

Recently, a team of researchers from Texas A&M University (TAMU), the Texas Agricultural Extension Service (TAEX), and the Texas Water Resources Institute (TWRI) carried out a survey to assess which water management strategies were deemed most desirable and feasible within each of these regions. The project was led by Ronald Kaiser, a researcher focusing on water law and policy, and C. Scott Shafer, a planner (both with the TAMU Recreation, Parks, and Tourism Sciences Department), Bruce Lesikar, an agricultural engineer with TAEX, and TWRI science writer Jan Gerston.

To carry out the project, Kaiser, Lesikar, and Shafer developed a questionnaire which listed 20 wide-ranging water supply and demand management strategies, including the reuse of treated wastewater, the purchase of water rights, construction of new reservoirs, cloud seeding, brush management, rainwater harvesting using cisterns, and many other options. The survey was mailed to all the regional water planning group members, totaling 312 individuals. Of that group, 65% responded. In all but one region, more than 50% of the people taking part in the planning process responded.

The questionnaires were analyzed to determine which strategies were recognized as being desirable and feasible, both Statewide and within individual regions. Obviously, these options might be measures the regions should first consider when planning to meet future needs. Gerston developed the figures which display how all these choices rank for each region and designed the fact sheet.

A striking finding from the results is that, when looking at Statewide results, only two measures were identified as being highly preferred and feasible-- the reuse of treated wastewater and requiring industries to reuse water.

If one views the results from individual regions, it readily becomes apparent that there is a wide disparity in the way different parts of Texas may want to cope with future water needs. For example, while planning group members in Dallas and Fort Worth (Region C)

identified interbasin transfers as a preferred management tool, those surveyed in Northeast Texas (Region D) favored the required use of water-efficient appliances. Participants in the Upper Colorado River area (Region F) overwhelmingly thought brush management was the best idea, followed by cloud seeding and the implementation of water-saving landscape ordinances. In the Houston area (Region H), building new reservoirs was seen as the best path to pursue.

"What this effort really points out," Kaiser says, "is the great diversity throughout Texas in available water resources, climate, water use, and water needs. It also sheds light on how history, politics, and the availability of technical information may be influencing the plans which are developed. We confirmed that water-rich areas are typically much less in favor of exporting waters than are the more arid parts of the state. The other value of this study is that it's one of the first times in which the attitudes of Texans in different regions towards water management have been quantified."

Rice Studies Injecting Hydrogen to Clean Up Polluted Aquifers

Environmentally sound relief may soon be on the way for sites contaminated with chlorinated solvents such as perchloroethene (PCE) and tetrachloroethene (TCE). Joe Hughes of the Rice University Department of Environmental Science and Engineering and Chuck Newell of Groundwater Services, Inc. of Houston have developed a patented method of removing chlorinated solvents used in dry cleaning operations and similar industries from soil and groundwater. The method involves injecting hydrogen gas into soils to stimulate the metabolism of dechlorinating bacteria, which convert the PCE or TCE to harmless ethene gas by removing the chlorine.

Dechlorinating bacteria occur naturally in the ground and metabolize hydrogen given off by the slow fermentation of aromatic hydrocarbons. The bacteria require chlorinated compounds such as PCE and TCE to respire. According to

Hughes, these bacteria "breathe" chlorinated solvents and "eat" hydrogen. These bacteria will suffocate and die without the chlorinated compounds. Apparently, the bacteria evolved within the last 60 years, since PCE and TCE were first produced during World War II.

The rate of dechlorination is not limited by the ability of the bacteria to reduce the chlorinated compounds to ethene, but by the availability of hydrogen. By injecting hydrogen into the ground to "feed" the bacteria, the researchers can greatly speed up the rate of dechlorination, in part because the bacteria reproduce more quickly in a hydrogen-rich environment.

Hughes says this method of dechlorination is environmentally safe and extremely efficient. For each milligram (mg) of hydrogen utilized by the bacteria, 21 mg of PCE are completely converted to ethene. If the bacteria use all the hydrogen, the treatment costs between $0.65 and $1.00 per kilogram of pure chlorinated solvent. If groundwaters contain 1 mg per liter of PCE, for example, it would likely cost only $0.01 per liter to treat them using this method. Laboratory experiments conducted by Hughes, graduate student Cynthia Carr, and post-doctoral research associate Sanjay Garg show that hydrogen injection can speed the dechlorination process up to 80% faster than the natural rate. In the studies, 90% of contaminants were removed after 13 days with use of the hydrogen injection. In a natural setting it may have taken 77 days to remove 90% of the contaminants. The United States Air Force has tested this technology for environmental remediation at Offutt Air Force Base in Nebraska and Cape Canaveral Air Station in Florida, where it has shown to be very effective.

For details, contact Hughes at (713) 348-5903 or hughes@rice.edu.

Impact of the Use of Advanced Irrigation and Biotechnology on Groundwater Conservation

Researchers: Talah Arabiyat, Eduardo Segarra, and David Willis, Agricultural and Applied Economics Department, Texas Tech University, Lubbock, TX.

Background: Four out of 14 million acres of land in the United States irrigated by declining aquifers are located in Texas, mostly in the High Plains region, where groundwater is drawn from the Ogallala Aquifer. At current rates, continued depletion of the Ogallala aquifer for irrigation and other uses may eventually result in loss of this valuable resource. Cotton, grain sorghum, wheat, and corn produced in the Texas High Plains create $2.3 billion in revenue annually, 70% from irrigated agriculture. This project explores if the use of sophisticated irrigation systems such as Low Energy Precision Application (LEPA) and the development of bioengineered crops with high tolerance to water stresses or lower water requirements could preserve the aquifer and benefit the agricultural economy.

Objectives: The broad goal of this study is to determine the impact of new crop production technologies on groundwater use and conservation in the Texas High Plains. The study is intended to determine the economic and groundwater depletion implications associated with the adoption of sophisticated irrigation technologies and anticipated biotechnological advances, as well as to evaluate potential economic effects and trade-offs.

Methods: A dynamic optimization model modified for Hale County was used to determine optimal cropping patterns and to evaluate the impacts of sophisticated irrigation systems and biotechnology on groundwater use. This model is designed to optimize allocation of groundwater over time to maximize net present value of returns

(NPVR) to land as well as to minimize risk. Management strategies are based on the amount of available groundwater per acre. The model simulates the farming of irrigated and dryland cotton, irrigated and dryland grain sorghum, irrigated and dryland wheat, and irrigated corn. Five scenarios were modeled, with four variants (Scenarios A-D) as well a baseline model, and were solved using the generalized algebraic modeling system. Scenario A consisted of biotechnology adoption only, Scenario B consisted of sophisticated irrigation technology adoption only, and Scenario C consisted of joint adoption of biotechnology and sophisticated irrigation systems. Scenario D was a minimization problem to find the least amount of groundwater which would have to be pumped, assuming adoption of sophisticated irrigation technology and bioengineered crops to achieve the NPVR level under scenario B.

Results and Discussion: The baseline simulation indicated an NPVR of $2,188.77 per acre with water use at 26.04 feet per acre over a period of 25 years. Scenarios B and C achieved higher NPVRs and water use reductions of 31%. The results of scenarios A, B, and C, suggest the use of sophisticated irrigation system technology has a much larger impact on water use reduction than the adoption of biotechnology. These three scenarios are not sustainable over time and would continue to decrease aquifer levels. Scenario D was shown to be sustainable over time and would stabilize the aquifer level 17 years after it was implemented, although an increase in the aquifer level was projected in the 25th year. Scenario D achieves a 54% reduction in water use but shows a slightly lower NPVR than Scenario C. These results were calculated for Hale County, and not for the entire region.

Reference: Arabiyat, A., E. Segarra, and D. Willis, "Sophisticated Irrigation Technology and Biotechnology Adoption: Impacts on Ground Water Conservation," *AgBioForum*, Volume 2, Number 2, Spring 1999, pages 132-136.

Note: Segarra can be contacted at (806) 742-2077 or zgseg@ttacs.ttu.edu.

Surveying Environmental Behaviors and Attitudes of Texans

Researcher: O'Neil Provost, Office of Survey Research, College of Communication, the University of Texas at Austin.

Problem: Texas faces a number of potential problems with environmental and water resources management, in large part because of the attitudes and behaviors of Texas residents. More information about how Texans feel about environmental and water issues is needed to gain insights about which environmental and water resources policies may be most effective.

Objectives: To investigate the attitudes of different groups of Texans towards such environmental issues as recycling of aluminum cans, newspapers, and glass, the disposal of lawn trimmings, water conservation, and environmental education.

Methods: This study was commissioned by the Texas Natural Resources Conservation Commission (TNRCC). Telephone surveys were conducted during April 1999. Roughly 713 Texans age 18 or older were surveyed. The questionnaire used in this survey was based on a TNRCC study conducted in 1997. A random sample of 15 people was used in a pre-test to refine the final questionnaire. An electronic questionnaire was created to minimize transcription errors, prevent entry of out-of-range numbers, and allow for automatic execution of skip patterns. Interviewers received 20 hours of telephone interviewing instruction before conducting the survey. Trained supervisors oversaw sample and quality control. A random digit dialing sample provided an equal opportunity for all Texas households with a phone to be surveyed. When the survey was conducted the member of a multi-person household to be surveyed was selected by choosing the adult with the most recent birthday. Statistical analyses were conducted to identify the 95% confidence level.

Results and Discussion: Survey findings show that 25% of Texans do not recycle. Of those who participate, 51% take recyclables to a drop-off center, and 37% participate in curbside recycling. Roughly 60% of Texans who use aluminum cans recycle some or almost all of them, while 48% recycle newspapers and 25% recycle glass. Respondents with more education tended to recycle more newspaper and glass than those with less education. Roughly 55% of the respondents who recycle one or more products recycle with the same frequency as the previous year, while 20% recycled "a little more," and 16% said they recycle "a lot more." Hispanics, and people ages 18 to 34, report they recycled more than the previous year. Roughly 35% of Texans report that their workplace has an organized recycling program, and 87% of those with programs participate. Roughly 60% of respondents leave trimmings on lawns most or all of the time (6% less than last year). The survey yields important information about water issues. For example, 54% favored increases in water rates to fund improvements in water quality. Roughly 60% reported using bottled water or home filters, while 44% of those with children use bottled water. More than 60% say they have personally taken steps to conserve water. Of those with landscapes, 40% said that lawns should be watered once a week during summer months, while 6% said that lawns should be watered daily during that time. Roughly half those surveyed (44%) said they felt the most common cause of surface water pollution was from waste dumped by factories, followed by surface water runoff (19%). Many respondents (84%) said it is very important to educate children about the environment.

Reference: *Survey of Environmental Behaviors and Attitudes of Texans*, Office of Survey Research, College of Communication, University of Texas at Austin, Austin, TX 78712.

Note: O'Neill Provost may be contacted at (512) 471-4980 or provost@mail.utexas.edu.

Water Use and Opportunities for Conservation at Beef Cattle Feedyards in the Texas North Plains

Researchers: David Parker and Louis Perino, West Texas A&M University, Canyon, TX, and Brent Auvermann, Leon New, and John Sweeten, Texas Agricultural Experiment Station, Amarillo, TX.

Background: Feedyards in the Texas North Plains region produce more than 6 million beef cattle per year. Providing drinking water for cattle is the main source of water use at these feedyards, and water conservation measures are beginning to take on more importance as the groundwater supply in the Texas High Plains region dwindles. Many physiological factors (such as temperature and body weight) influence the amount of water cattle consume, and researchers have created equations to model the effects of these conditions. Four kinds of water troughs are commonly used to provide water to the cattle: a standard overflow trough, a temperature-controlled overflow trough, a non-overflow trough, and a ball-type (floating plastic ball) trough.

Objectives: To measure the amount of water used at typical feedyards in the Texas North Plains, to develop relationships between water use with atmospheric conditions, and to identify options for conserving water at feedyards.

Methods: This study was conducted at a feedyard in the Texas North Plains with a one-time feeding capacity of approximately 50,000 head of cattle. This feedyard uses standard overflow water troughs, which are adjusted for continuous overflow during the winter. Total daily water use for the feedyard was determined by daily monitoring of the incoming water supply to the water troughs from November 1995 through October 1997. Overflow was monitored in 72-hour intervals, when floats were adjusted for winter and summer conditions. Weather data were obtained from a National Oceanic and Atmospheric Administration (NOAA) weather station north of the feedyard, and the data were used in a set of equations to predict how total daily feedyard water usage correlates with the meteorological conditions. A quadratic relationship between maximum temperature and water usage was observed, so nonlinear and multi-linear regression were used to determine relationships between water usage and meteorological conditions.

Results and Discussion: Daily water use of the feedyard was calculated by developing five-day moving averages since the large on-site water storage tank holds more than one day's supply of water. The moving averages were calculated and plotted over the two-year study period. This data showed that peak water usage occurred both in the winter and the summer. The increase in summer water use was attributed to higher temperatures and greater water demands by the cattle, while the winter peak was attributed to high trough overflow rates to prevent ice formation. Average water use for the two-year period was 10.5 gallons per head per day.

Reference: Parker, D., L. Perino, B. Auvermann, and J. Sweeten, "Water Use and Conservation at Texas High Plains Beef Cattle Feedyards," *Applied Engineering in Agriculture*, Vol. 16, No. 3 (2000), 77-82.

NOTE: Parker can be contacted at (806) 651-5281, while Sweeten can be contacted at j-sweeten@tamu.edu or 806-359-5401.

Socioeconomic and Biophysical Challenges to Achieving Clean Water Through TMDLs -- Two Texas Examples

Researchers: Keith Keplinger and Ron Jones, Texas Institute for Applied Environmental Research, Tarleton State University, Stephenville, TX.

Problem: Throughout much of Texas, recent initiatives have been implemented to develop total maximum daily loads (TMDLs) for specific stream segments. This process is complicated by many issues, including the fact that few studies of this type have been conducted in Texas previously. In essence, TMDLs now being developed are breaking historical ground because this is the first time these efforts have been initiated. As a result, it is important to assess and evaluate how implementation of TMDL programs has progressed in Texas so far, and to identify success stories and challenges.

Objectives: To discuss Texas' TMDL program, the challenges and issues present in carrying out TMDLs, and to explore long-range approaches which could reconcile economic growth with water quality objectives within this framework.

Background Information: The TMDL program was included in the Clean Water Act of 1972, but has only recently been emphasized as a strategy to maintain or improve water quality. The TMDL program focuses on achieving general ambient water quality standards, while the NPDES (National Pollutant Discharge Elimination System) relies on technology-based effluent standards to clean up point sources. Conducting a TMDL involves determining sources of point and non-point pollutants, and assigning pollutant loads to specific sources. The sum of load assignments can not exceed the TMDL. Two case studies of TMDL programs discussed in this report include an effort for a segment of the Bosque River (which flows from northwest of Stephenville into Lake Waco), and a portion of the Arroyo Colorado (which flows from South Texas into the Laguna Madre). The Bosque River watershed experiences water quality challenges from 43,000 dairy cows and six wastewater plants sited in the watershed. In the Arroyo Colorado watershed, potential sources of contamination include irrigated agriculture, as well as discharges from many wastewater treatment plants and failing individual on-site wastewater systems in border colonias.

Challenges: Several challenges to implementing TMDL programs were identified in this article. The first difficulty involves the adequacy of information used in making decisions. Although extensive data have been collected from a 3-year monitoring project of the Bosque watershed, the precipitation during this time period varied from one extreme to another and little information on "normal" rainfall patterns was collected. Even less monitoring data are available for the Arroyo Colorado TMDL. The social dynamics of TMDL formulation also present a challenge to implementation. Although

stakeholder advisory groups have much decision-making power, the participants have widely varied backgrounds and interests, many of which are directly opposed to one another. Fortunately, conflict resolution approaches and live group settings have had much success in resolving these difficulties. Since the decision process depends so heavily on stakeholder input, an extensive education program about biological and physical processes has been implemented so participants can make better informed decisions. Other challenges include development of effective computer models that incorporate all relevant factors and difficulties in controlling non-point source pollution.

Possible Approaches to Resolve Difficulties: Several solutions were described showing how economic expansion could be accommodated within the TMDL framework. One possible approach would be to implement land use planning to control polluted runoff from landscapes. Land use planning is analogous to municipal zoning in that it restricts land use to certain activities. However, this would require putting increased control in a watershed authority and would likely meet with much resistance because private decisions could be restricted and property values could be diminished. Another approach may be to allow the exchange of defined pollutant credits within a watershed. This strategy is market-driven and would regulate pollutant loads rather than land use. Under this type of program, a new operation that may pollute water supplies would need to buy pollution credits from other polluting entities. There has some success with this approach in air pollution and the EPA has endorsed watershed-based trading. Although this system may decrease pollution in one part of a river, it could increase pollution in another part at the same time. Trading between point and non-point sources can involve much uncertainty, so allowances are often made to reduce non-point pollution more than point source pollution is increased. Efficient use of "green" technology is another way to accommodate economic expansion within the TMDL framework. In this case, environmental technologies can reduce pollutants such as nutrient loads from dairy farms.

Reference: K. Keplinger and R. Jones. "Socio-Economic and Biophysical Challenges to Achieving Clean Water Through TMDLs: Two Texas Examples." *Water Resources Impact*, November 1999.

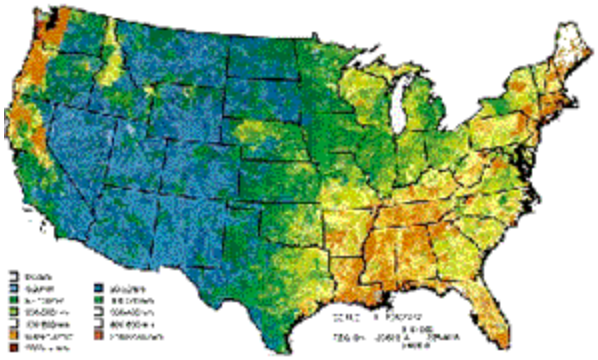
Note: For details, contact Jones at (254) 968-9566 or rjones@tiaer.tarleton.edu, or Keplinger at (254)-968-9572 or keplinger@tiaer.tarleton.edu.

Continental Scale Simulation of the Hydrologic Balance

Researchers: Jeff Arnold, USDA Agricultural Research Service, Temple, TX, Raghavan Srinivasan and Ranjan Muttiah, Texas Agricultural Experiment Station Blackland Research Center, Temple, TX, and Peter Allen, Department of Geology and Hydrology, Baylor University, Waco, TX.

Background: The conterminous United States experiences an average annual precipitation of 30.4 inches, 70% of which evaporates or is transpired. The remaining

30% makes up an average annual runoff of approximately 9 inches. Maps have been prepared at a continental scale to represent annual runoff, precipitation, and evaporation. Existing maps illustrate regional trends fairly well, but they provide little assistance about conditions in small-scale, individual, watersheds. Water balance models attempt to predict the partitioning of water among the various pathways of the hydrologic cycle. This project applied a daily water balance model called the Soil and Water Assessment Tool (SWAT) to the conterminous United States.



Objectives: To develop the most realistic possible physical representation of the water balance in the continental United States, while using data which are readily available for large parts of the country. Also to simulate the impact of climate and land use changes on the water balance.

Methods: The SWAT model represents the local water balance by utilizing such factors as precipitation, soil profiles, and water levels in shallow and deep aquifers. SWAT simulates the components of the water balance using storage models and input parameters. All the necessary databases of soils, land use, and topography were assembled at 1:250,000 scale for the conterminous United States and a GIS interface was used to automate the assembly of the model input files from map layers and the relational databases. The hydrologic balance for each soil association polygon was simulated without calibration for 20 years using dominant soil and land use properties.

Results and Discussion: When the results of the model for a 20-year period were compared with long-term average annual runoff from USGS stream gage records, roughly 45% of the modeled United States came within two inches of measured results, and 18% came within 1 inch of the measured results without calibration. The researchers believe that the model underpredicted runoff in mountainous areas due to the lack of climate stations and consequent lack of data. The results of this project suggest that the hydrologic balance of the United States can be accurately modeled despite the spatial resolution of the databases and the simplicity of the model.

Reference: "Continental Scale Simulation of the Hydrologic Balance," *Journal of the American Water Resources Association*, Vol. 35, No. 5, October 1999, pp. 1037-1051.

Note: Arnold may be contacted at (254) 770-6502 or Arnold@brc.tamus.edu, Srinivasan at srin@brc.tamus.edu or (254) 770-6670, or Allen at Peter_Allen@baylor.edu.

TWDB Awards Five Research Projects

In February 2000, the Texas Water Development Board (TWDB) awarded five research grants, including a project to the University of Texas at Austin (UT).

In one study, Bridget Scanlon of the UT Bureau of Economic Geology (BEG) will lead a study to investigate groundwater recharge in Texas. The work will involve compiling existing data on recharge rates on the basis of physical, chemical, isotopic and modeling techniques for Texas' major aquifers. The researchers will evaluate the range of recharge rates for each aquifer (based on methods used to estimate recharge) and will assess if these techniques are appropriate. They will develop a conceptual model for the recharge processes in each aquifer and determine local and regional limits on recharge. Results will be used to determine which aquifers require additional studies and to recommend methods to quantify recharge in these aquifers.

TWDB awarded a grant to Woodley Weather Consultants to assess weather modification as a water management strategy by analyzing existing data. Woodley will address the capability of cloud seeding to enhance rainfall, estimate statewide cloud seeding opportunities, and investigate the amount of additional rainfall which can be expected from seeding. The work also includes determining the hydrological and agricultural benefits of the added rainfall as well as defining cost-benefit ratios.

R.W. Beck, Inc. was awarded a grant to assess the feasibility of the "Design-Build-Operate" (DBO) model for utility operations. The company will describe and analyze methods used to implement water and wastewater projects, review legal barriers to the use of DBO for water projects, and examine state legislation and local purchasing practices. They will develop a training manual which can be used by TWDB to provide oversight for local DBO projects and will create a workbook for use in site-specific cases.

TWDB awarded a grant to the U.S. Geological Survey (USGS) to evaluate surface and ground water interactions. USGS staff will compile and evaluate streamflow gain and loss studies in Texas, gather data for stream channel widths, and identify important sections within the Carrizo-Wilcox and Gulf Coast aquifers. Areas will be identified where data on gains and losses are lacking.

Turner Collie & Braden, Inc. (TCB) was awarded a grant to evaluate water and wastewater facility needs for economically disadvantaged communities in Texas. TCB will review population, per capita income, and unemployment data for the 210 counties not listed as eligible for the Economically Distressed Areas Program (EDAP). TCB will also develop a statistical model to predict the cost of providing water and wastewater for disadvantaged areas in non-eligible EDAP counties which do not qualify for EDAP.

For details about these projects, contact Dan Beckett of TWDB at dan.beckett@twdb.state.tx.us. Scanlon can be contacted at (512) 471-8241 or bridget.scanlonb@beg.utexas.edu.

UT, UNT to Synthesize and Characterize Compounds to Extract Heavy Metals from Wastewater

The Rio Grande is one of the most polluted rivers in the United States due to many factors, including agricultural runoff, mineral mining, and wastes from the "maquiladora" industries. Pesticides and heavy metals such as arsenic, cobalt, manganese, cadmium, lead, zinc, nickel, selenium, chromium, and mercury are a major concern in the region, since they have been linked to birth defects.

Recently, Jennifer Brodbelt of the Chemistry Department at the University of Texas at Austin and Alan Marchand of the Chemistry Department of the University of North Texas have been awarded a research project to investigate whether a class of compounds known as caged crown ligands may be able to bind to heavy metals and extract them from wastewater. The project was funded by the Texas Higher Education Coordinating Board.

Basically, ligands are molecules which bind metals. Caged crown ligands are molecules with a cyclic "crown" ether and a molecular "cage." Oxygen and nitrogen atoms of the ether bind to the metals, and the molecular cage is used to change the rigidity of the cyclic ether ring. In the future, the molecular cage may be used to anchor the molecules to solid resins for wastewater treatment. In this study, the effectiveness of the new molecules in binding the heavy metals will be assessed by a method called electrospray ionization-mass spectrometry (ESI-MS). This is a versatile method to characterize compounds which can be used to examine proteins and other molecules in solution. ESI-MS will be used in this study to determine if a ligand shows promise for binding heavy metals and if it shows selectivity for specific metals.

Other methods for removing heavy metals from wastewater exist. For example, electrolytic recovery in water involves applying voltage to electrodes to plate out metals, while novel high-capacity ion exchange resins or zeolites bind metals based on ionic interactions. Heavy metals can also be extracted through microorganisms or plants, by fungal adsorption, bioleaching with bacteria, or phytoremediation. However, these methods cannot be tuned to extract specific metals. They also create large amounts of contaminated and non-reusable biomass. Methods developed by Brodbelt and Marchand will allow direct extraction and the ability to extract specific metals. The ultimate goal of this research is to attach novel ligands to solid resin or silica gel supports to facilitate their use in full-scale wastewater remediation efforts. For details, contact Brodbelt at (512) 471-0028 or jbrodbelt@mail.utexas.edu.

UH, Rice, A&M-Kingsville, A&M-International, UT-Brownsville, Team Up to Create Water Management Tools for Border

As the population in the Texas-Mexico border region continues to grow, so does the amount of water which will be needed. To effectively manage water resources in this area, tools are needed which address such issues as water supplies, water quality, water use, and flood and drought management.

Recently, the Texas Higher Education Coordinating Board awarded a grant to a group of universities to develop a multi-purpose water management decision support tool for the border region. The lead investigator in this project is Hanadi Rifai of the Civil and Environmental Engineering Department at the University of Houston (UH). Co-investigators include Philip Bedient of the Environmental Science and Engineering Division of Rice University, Andrew Ernest of the Environmental Engineering Department at Texas A&M University-Kingsville (A&M-Kingsville), Sushma Krishnamurthy of the College of Science and Technology at Texas A&M International University (A&M-International), and William Berg of the Engineering Technology Department of the University of Texas--Brownsville (UT-B).

The goal is to create a Water Resources Management Tool, or WRMT. The WRMT is expected to complement many water management activities, including water planning related to Texas Senate Bill 1, Texas Clean Rivers Program, Water Availability Modeling (WAM) assessments, and the U.S. Environmental Protection Agency Total Maximum Daily Loads (TMDLs) initiative. The project is also expected to help the universities in the Lower Rio Grande valley train professionals in water resources management.

The WRMT will be compatible with Microsoft Windows and can be used in tandem with geographic information systems (GIS). This will allow model users to integrate data on land use distribution, point and non-point pollution, water supply and use, rainfall distribution, and flood zones. WRMT will also provide a way for users to model the availability of water resources, in-stream water quality, return flows, water reuse, and water conservation.

Two prototype applications have already been planned. The WRMT will be utilized to evaluating whether resacas (oxbow lakes near the Rio Grande) can be used as a water supply as well as a stormwater management resource. WRMT will also be used to evaluate water quality in the Rio Grande near Laredo. Previous studies have detected more than 17 priority pollutants at concentrations which may originate from Laredo and Nuevo Laredo which exceed screening levels. Demonstrations associated with this project will use bioluminescent bacteria to determine toxicity levels in the water.

For more details, contact Rifai at (713) 743-4271 or by e-mail at rifai@uh.edu, Bedient at (713) 527-4953 or bedient@rice.edu, Ernest at a-ernest@tamuk.edu or (361) 593-3041, Krishnamurthy at skrishna@tamiu.edu, or (956) 326-2584, or Berg at (956) 574-6652 or wberg@utb1.utb.edu.

A&M Physicist to Develop Use of Electron Beam Technology to Treat Polluted Waters, Industrial Wastewater

Many means exist to purify water of microbiological and chemical contaminants, but treatment processes are often expensive and cannot treat a broad range of pollutants. Recently, Peter McIntyre of the Texas A&M University Physics Department was awarded a grant from the Texas Higher Education Coordinating Board to develop a broad-spectrum water treatment technology which is economically viable and able to treat a variety of contaminants. The technology involves directing electron beams into a flow of water to create large amounts of oxidizing and reducing ions. Detailed studies have shown this process is effective in decomposing a variety of toxic organic compounds and converting them into safe end products.

Recently, McIntyre has worked to create a technology he calls the Electronic Pasteurization System (EPS). EPS is a high-power electron accelerator which can deliver multiple independent beams to treat water flowing over weirs. Because a single accelerator can deliver multiple beams, and treat multiple weirs, one unit can handle 400 million gallons per year.

McIntyre says the use of EPS in water treatment would represent a major breakthrough because it will be able to generate enough power to treat large quantities of water economically. He says the proposed EPS system should be able to treat 400 million gallons per year with a dose of 4 kilograys of energy (4,000 joules of radiation per kilogram of water) , would have a capital cost half that of conventional technology, and is likely to operate more efficiently than methods now used. McIntyre suggests that the cost to treat water in large-volume applications should be only $1 per 1,000 gallons (current techniques cost more than $3 per 1,000 gallons). The EPS would operate independently of such variables as temperature, pH, and turbidity. According to McIntyre, the EPS system will be versatile enough to treat polluted water supplies and to remove contaminants from industrial wastewaters. Studies have shown that EPS is effective in treating halogenated aromatics, methyl tert-butyl ether, benzene, toluene, chloroform, TCE, and paper mill effluent. Results show the process also destroys pathogenic bacteria.

Collaborators on this project include William Cooper of the University of North Carolina at Wilmington, Thomas Clevinger and Randall Curry of the University of Missouri, and Haley & Aldrich Environmental Engineering, Inc. McIntyre will build and operate the accelerator. The team will evaluate how well this system treats pollutants, and if it can be used for remediation. For details, contact McIntyre at (409) 845-7727 or p-mcintyre@physics.tamu.edu.

TPWD Places Synthetic 'Geotubes' in Galveston Bay to Slow Wave Action, Promote Seagrass Growth

To fight significant wetlands losses in the Galveston Bay System, a team of professionals from many agencies are turning to a novel approach. The project leaders are staff members Ted Hollingsworth of the Texas Parks and Wildlife Department (TPWD) , and Will Roach, and Phil Glass of the U.S. Fish and Wildlife Service. They are working to place a comprehensive network of "geotubes" in a pilot restoration project at Galveston Island State Park. The goal is to combat erosion and to foster the growth of seagrasses and emergent tidal marsh vegetation.

Restoration efforts began in the 1990s when the pace of marsh losses greatly increased. Recently, TPWD began a program to install gigantic synthetic tubes called geotubes at strategic points adjacent to the park. In general, two types of geotubes are used in this project. Larger geotubes are 30-feet in diameter and are made of polyester. These larger geotubes are covered with a polypropylene shroud which protects them from the harmful effects of ultraviolet light, which otherwise would deteriorate them. The intent is that these larger geotubes would protect open embayments from the erosive effects of waves. In addition, smaller, polyester, geotubes with diameters of 7- and 15-feet are being deployed to protect earthen marsh terraces from slumping and erosion. Both types of geotubes are anchored by tons of material dredged from the bay. The half-life of both types of geotubes is expected to be roughly 20 years.

In this program, a series of earthen terraces have been placed in an open checkerboard-like pattern and will create 200-foot-long, 10-foot-wide marsh terraces. So far, more than 13,500 linear feet of the large geotubes have been installed, while roughly 10,000 linear feet of the smaller geotubes have been placed. Before the project is finished this spring, project leaders hope to employ an additional 6,000 linear feet.

Since the 1950s, land subsidence (caused by excessive pumping of water, oil, and gas), erosion from wave action, and increased turbidity of bay waters, have led to the loss of 18% of emergent marshes and 72% of seagrass beds throughout the Galveston Bay system. In addition, 900 out of 1,000 acres of tidal salt marsh at Galveston Island State Park have disappeared since 1970. The tidal salt marshes serve as vital breeding grounds for species that sustain the seafood industry, a refuge for waterfowl, and a filter for pollutants.

These restoration efforts have involved collaboration between TPWD, the U.S. Fish and Wildlife Service, the Galveston Bay Estuary Program, the National Marine Fisheries

Service, the U.S. Army Corps of Engineers, the Texas General Land Office, and the Galveston Bay Foundation. Funding is being provided through the Coastal Wetland Planning, Protection, and Restoration Act and the Natural Resources Damage Assessment Trustees.

For details, contact Hollingsworth at (281) 471-3200 or ted.hollingsworth@tpwd.state.tx.us.

UH Research Suggests that Optimizing Computer Use Helps Water Utilities Cut Costs, Become More Sustainable

A University of Houston (UH) researcher recommends that water utilities must make optimum use of information technologies to cope with such pressing challenges as privatization, competition, electricity deregulation, and increasing environmental awareness.

Miriam Heller of the UH Industrial Engineering Department is exploring ways in which information technology can help water utilities improve efficiency. In a recent article published in the Journal of the American Water Works Association, which was co-authored by Eric von Sacken and Richard Gerstberger, Heller suggests that information technology can improve the efficiency of water utilities by enabling the integration of computer systems, environmental data, and human resources.

Information technology used by water utilities has already led to reductions in chemical and energy use, thus lowering operating costs. It has also improved customer service, inventory control, and maintenance. The authors claim that in order to improve efficiency, water utilities should apply such information technologies as the utility communications architecture (UCA), the utility business architecture (UBA), and industrial ecology.

UCA, Heller explains, addresses communication standards among computer systems and is designed to create a platform for true system integration. It provides a way for all computer applications in a water utility plant to communicate with each other and share information. Since all applications can access the same information, costly duplication can be avoided.

UBA is intended to relieve utilities of the need to develop individual business models from scratch by providing a framework for modeling water utility businesses in terms of their organization, processes, and resources. This facilitates effective planning and management, Heller says, and has resulted in significant savings.

Use of the UCA and UBA would allow water utilities to move toward the ultimate goal of industrial ecology, which Heller says aims to allow for sustainable development, preserve biodiversity, and maintain aesthetic richness. Industrial ecology promotes continued economic growth by continuously reducing resource consumption and pollution. For details, contact Heller at (713)743-4193 or heller@uh.edu.

New A&M Press Book Describes "Rivers of Texas"

A new book by the Texas A&M University Press, "The Rivers of Texas," presents a wealth of information about Texas rivers, including descriptions of ecological and landscape conditions, geological formations, historical accounts, economic development, and recreational opportunities along many streams. The book was written by Vern Huser, who was a Texas river guide for more than 40 years.

In the book, Huser identifies four groups of Texas rivers -- those along the border, those in the heart-of-Texas, those along the Gulf Coast, and those with specific regional traits. He provides information about the size, location, and tributaries of each river. The book also describes special sites along each river and combines documented history with colorful legends and personal anecdotes. It provides photographs and descriptions of the wildlife and vegetation along Texas waterways.

For more information or to order, visit the TAMU Press World Wide Web site at http://www.tamu.edu/upress/.

Updated Texas Environmental Almanac Published by UT Press

An updated version of *The Environmental Almanac of Texas* has recently been published by the University of Texas Press. The book was compiled by Mary Sanger and Cyrus Reed of the Texas Center for Policy Studies.

This updated version of the almanac provides crucial and comprehensive information on the state's land, air, water, and energy use, as well as waste generation. It summarizes data gathered from a wide range of state and federal agencies, environmental organizations, and historical and scientific reference sources. The almanac is designed for quick, easy reference by the public, as well as by scientists and government officials and policymakers.

Topics which are addressed in detail in the updated edition include the quantity and quality of the state's environmental resources, present rates of consumption, and future levels of demand.

For details, contact the UT Press at http://www.utexas.edu/utpress.

New NRDC Study Discusses Contaminants in Bottled Water

Bottled water is not necessarily cleaner or safer than most tap water in the United States, and some brands of bottled water may present a health threat to certain vulnerable populations, according to a recent study published by the Natural Resources Defense Council (NRDC).

The study, "Bottled Water: Pure Drink or Pure Hype," surveyed 103 brands of bottled water available nationally or regionally. It shows that 33% of the tested brands exceeded

unenforceable bacterial purity guidelines, or enforceable state standards, in at least one sample. The contaminants found included synthetic organic chemicals, bacteria and arsenic. NRDC undertook the study as part of its formal petition to the U.S. Food and Drug Administration (FDA) to have that agency upgrade its currently weak bottled water regulations and oversight. The study also shows that most water tested was relatively free of contaminants and was of high quality, and therefore generally doesn't pose a health threat to healthy people. The study suggests the presence of bacteria in some water samples might present a health risk to some people with weakened immune systems, including infants, the frail elderly, those with AIDS, and some chemotherapy and transplant patients. Also, certain chemical contaminants found in some waters may pose cancer or other health risks.

More information on NRDC is available through its World Wide Web site, at http://www.nrdc.org.

GERG Studies Suggest Oysters Can Yield Clues of Water Quality Changes in Houston Ship Channel

Research by scientists with the Texas A&M University Geochemical and Environmental Research Group (GERG) suggests that oysters can serve as good indicators of changes in the level of water contaminants. The studies were carried out by Jose Sericano, Terry Wade, and Yaorong Qian.

Recently, the researchers analyzed the concentration of butyltin compounds in Gulf Coast oysters. This experiment involved transplanting oysters from Hanna Reef in Galveston Bay (which is known to be relatively free of contaminants) to a site near the Houston Ship Channel which is known to have native oysters with high levels of tributyltin (TBT). Once Hanna Reef oysters were transplanted in the Ship Channel, levels of tributyltin in their tissues rapidly increased to six times the original amount. Later, the oysters were moved back to the clean Hanna Reef waters to determine if they would excrete the contaminants. The experiment showed that oysters from Hanna Reef were able to depurate the TBT faster than the oysters from the Houston Ship Channel.

Sericano says the fact that it takes a longer time for oysters which live near the Ship Channel to eliminate TBT may indicate that butyltin continues to enter the area, despite the fact that its use in the United States was banned in 1988. Sources of butyltin compounds include sediments, TBT-based paints on vessels larger than 25 meters, and wastes from shipyards. Coastal contamination by TBT has been a source of study since the early 1980s when it was found that TBT caused deformations and reduced growth in oysters. Early estimates predicted that TBT would have a half-life of days to weeks, and thus would be a safe additive. However, recent research has shown that the actual half-

life of TBT in the marine environment of the United States may be more than 3 years, due to the complexity of natural processes in the environment.

For details, contact Sericano at jose@gerg.tamu.edu at (409) 862-2323, or Wade at terry@gerg.tamu.edu or (409) 862-2323.

Texas Tech Investigates Management Strategies to Keep Soils in Playa Lakes Moist More Often

It's fairly well-known that many migratory birds are attracted to lakes and ponds which have water in them. However, a challenge in semiarid areas like the Texas High Plains has always been to manage playa lakes and other surface waters so they are filled with enough water to produce food for migratory birds. Currently, Loren Smith, a researcher in the Texas Tech University Range, Wildlife, and Fisheries Management Department is working with James Anderson of West Virginia University to investigate management techniques which may produce invertebrates and seeds in playa lakes for wildlife.

Birds migrating through the Central Flyway often stop for the winter in the High Plains of Texas and New Mexico and take up a temporary residence in playa wetlands. Playa wetlands are temporarily or seasonally flooded circular depressions in the region. Playa lakes and wetlands are attractive to migratory birds because they foster the growth of native, annual, seed-producing plants as well as invertebrates, both of which are good food supplies for the birds.

In order to encourage increased use of playa wetlands by migratory birds, moist soil management practices have been implemented in these areas to promote the growth of the native annual seed plants such as smartweed. Moist soil management involves applying or removing water at key times to encourage germination, growth, and seed production. This practice directly benefits waterfowl and can be used to help meet wildlife population goals and to improve conditions for hunting.

Recently, Smith and Andersen managed six playas over a two-year period. Six other nearby lakes were left untouched and served as controls. The managed playas were irrigated if they were dry, or drained if they were flooded (this was done to promote aeration). The researchers measured the extent to which waterfowl used the playas twice a week (once during the day and once at night). The playas were marked into transects to inventory invertebrate and plant populations.

Results of the study show that the use of moist-soil management had a positive effect on waterfowl use, since the managed playas harbored four to five times as many ducks and

two more bird species than the unmanaged playas. The researchers found that both seeds and invertebrate population were important in attracting the birds. As a result of this project and previous studies, Smith has developed water management guidelines landowners can use to practice soil moisture management. In general, Smith suggests landowners may only have to add two to three inches of water at critical times to help playas produce food even during dry years. For details, contact Smith at (806) 742-2842 or L.M.Smith@ttu.edu.

TWRI Report Discusses Opportunities for Saving Water in the Lower Rio Grande by Reducing Canal Losses

Improving the efficiency of South Texas irrigation canals could result in a significant water savings, according a new study by the Texas Agricultural Extension Service (TAEX). In addition, the project suggests additional water could be conserved by improving the efficiency of on-farm irrigation use. The report estimates that improving the efficiency of conveying water from the Rio Grande through canals to 90% could save as much as 230,000 acre-feet (AF) annually. In addition, improving the efficiency with which water is used in agricultural fields could conserve an extra 200,000 AF of water per year.

The report, "Characterization of Conveyance Losses in Irrigation Distribution Networks in the Lower Rio Grande Valley of Texas," summarizes a two-year research project led by Guy Fipps, the statewide irrigation specialist for TAEX. Texas A&M University students who participated include Craig Pope, Eric Leigh, Brian Treece, and Azim Nazarov.

The project was funded by the U.S. Bureau of Reclamation Austin office. It was administered by the Texas Water Resources Institute.

"We believe this report provides needed documentation about the actual potential to conserve water by increasing the efficiency of irrigation in the Lower Rio Grande Valley," Fipps says. "It provides a starting point for developing initiatives to address these issues."

Throughout the Lower Rio Grande Valley, there are roughly 917 miles of irrigation mains, which are used to convey water from the Rio Grande to lateral lines which deliver water to individual farmers' fields. Most of these mains are either lined canals (344 miles) or unlined canals (350 miles), and there are also many miles of pipelines and natural channels called resacas. Most agricultural water rights in the Valley are held by water districts. The districts vary widely in size (some manage more than 174,000 acre feet or AF of water rights, while others hold only 625 AF).

Before this project was conducted, no one really had a solid idea about the amount of water being lost through these conveyance systems. It was thought that most districts systems were operating at only 25% efficiency while some larger districts may have efficiencies as low as 40%. The most efficient irrigation districts were typically those which have developed extensive pipeline systems to transmit water. In contrast, the greatest losses occurred within districts which had not rehabilitated their distribution system. Because population and urban water use are expected to increase in the Valley in the future, it's important that all water uses are as effective as possible.

This effort involved actual measurement of seepage losses in lined and unlined canals. The goal was to determine actual conveyance efficiencies in the field and to project the amount of water which could be conserved if efficiencies of all the districts in the region were increased from present levels to 90%. A second objective was to assess the effectiveness of current agricultural water use at the individual farm level and to identify management strategies which could save water.

In the project, Fipps and colleagues gathered data about water rights, water use, and the type, amount, and condition of main and lateral canals, pipelines, and resacas owned and managed by 28 water districts in Hidalgo, Cameron, and Willacy counties.

In the summer of 1998, the team collected field data on seepage losses from five canals and one pipeline in the Valley. Losses were measured using the ponding method, in which the amount of water lost in a specific segment was monitored during a 24-hour period. Efforts were made to quantify specific ways in which water is lost during conveyance, including seepage, leaks, and evaporation. Maps were created using a geographic information system (GIS) to identify areas in which canals were located above permeable soils, thus suggesting where seepage problems may be most likely. Analyses carried out with the use of GIS identified unlined canals in sandy loams and other problem soils which may be likely to lose more water due to seepage.

Results showed that seepage losses from lined canals were very high at some sites, suggesting there may be construction or maintenance problems. The project also shows that four of the six irrigation districts which began programs to make canals more efficient through metering and the use of PVC or gated pipe documented water savings of at least 30%. There are also opportunities to conserve water once it reaches an individual grower's field, Fipps says. Widespread use of meters to monitor the amount of water applied, gated pipe, drip irrigation, proper irrigation management, and adoption of improved irrigation technologies are projected to potentially save 200,000 AF of water annually.

NOTE: The Texas A&M University System has approved hiring of an agricultural engineer who will work in the Lower Rio Grande Valley with water issues. A full copy of this report, including maps, tables, and figures, can be viewed on the World Wide Web at http://dms.tamu.edu/. Fipps can be contacted at g-fipps@tamu.edu or (979) 845-7453.

"MERMAID" Provides Detailed Information About Ports, Maritime Resources

The Texas Transportation Institute's Center for Ports and Waterways, which is located at Texas A&M University-Galveston, has created a new World Wide Web (WWW) site dedicated to providing maritime information. This WWW site is titled MERMAID (the Maritime Economic Resources and Marine and Intermodal Directory), and can be found at http://maritime.tamu.edu.

The creators of this site have listed 1100 relevant sites into such categories as world ports, intermodal facilities, maritime trade, trade data, transportation statistics, and economic resources. In addition, the site provides data on such issues as government agencies, maritime law, and employment opportunities, education, research, publications, and marine engineering and technology. Each category provides not only pertinent links, but also an informative summary of the contents of each link.

The major sections of this site include the "Home Port" (which serves as the main page), "About MERMAID" (which gives a brief history and staff overview), a text-based "Site Map," and "Maritime Information" (which includes links and summaries). Other parts of this site include, "Treasure Search" (a search engine), "On the Horizon," (which links to other pages), "Latest Treasure" (which shows their newest additions), and "Man Overboard" (which aids in navigating through the site).

For details, contact Center Director John Basilotto at basilj@tamug.tamu.edu.

Texas Environmental, Water Resources Issues Discussed at Lone Star Chapter of Sierra Club

The Lone Star Chapter of the Sierra Club has developed an informative World Wide Web (WWW) site that details the group's activities and publications. The Lone Star Chapter of the Sierra Club covers all of Texas except for El Paso, which belongs to the Rio Grande Chapter. The Lone Star Chapter includes regional groups, which cover areas such as Houston, Dallas, Central Texas, Lower Rio Grande Valley, and the Brazos Valley. This site provides Sierra Club members and the general public with much information about the Lone Star Chapter's activities in the form of press releases, newsletter articles, and an e-mail alert list. Recent environmental problems addressed by the Lone Star Chapter include the recovery of the Kemp's Ridley sea turtles along the Texas coast and air pollution caused by "grandfathered" factories which are not signed up for emissions reductions measures.

The Chapter's e-mail alert list is free and provides updates on current state conservation issues. A "Lone Star Library" is also available. It provides special reports such as the Chapter Forestry Policy, and a Texas Poll Report on Global Warming.

The WWW site is at http://www.sierraclub.org/chapters/tx.

TAES WWW Site Provides Information on Water Requirements of Landscape Plants, Trees

A new World Wide Web (WWW) site providing a wealth of information about the native trees of Texas has been created by the Texas Agricultural Experiment Station (TAES). This site may be especially for scientists, as well as the general public, who may wish to implement water-efficient landscapes. A search form on the site lets users select plants and trees with high, medium, or low water requirements, as well as those which do well in bogs. Users can also obtain information on how well given species tolerate heat. Searches can be conducted entering the common or scientific name of landscape plants. Search results produce information about the maintenance requirements of individual species. Obviously, the value of this site is that can assist homeowners and landscape managers in finding species that may be resource efficient in specific settings.

The site is dedicated to horticulturist and native plant enthusiast Benny Simpson, who worked for 40 years at the TAMU Research and Extension Center in Dallas. This WWW site is titled "Benny Simpson's Texas Native Trees" and can be found on the WWW at http://dallas.tamu.edu/native/.