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The Benefits of Small Watershed Dams

Federal, State Agencies Team Up to Prevent Flooding and Sediment Runoff and to Protect Lives and Property

In almost any part of Texas, drive into a rural area and look for a large pond. When you find one, it's likely to be a small dam funded, built, and managed through a unique coalition of federal, state, and local agencies.

Throughout the years, dating back to the 1950s, the Natural Resources Conservation Service (NRCS) has worked with the Texas State Soil and Water Conservation Board (TSSWCB) and many local sponsors across Texas to build and maintain small watershed dams. These dams are designed to store between 100 and 5,000 acre-feet (AF) of water, and typically are meant to hold about 2,500 AF. Roughly 10,400 dams have built as part of 1,600 of watershed projects throughout the United States.

The projects provide many benefits including flood control and bettering water quality by trapping sediments and contaminants. Other purposes of these small watershed dams include water supplies for municipal or agricultural uses, fish and wildlife habitat, or simply a place to go boating or fishing.

In general, the people who work with these projects or have one in their area are positive and enthusiastic about them. At the same time, however, there are serious questions that have to be addressed.

First, most of these projects were constructed during the 1950s and 1960s when the Federal government picked up most of the cost. Since then, with decreased Federal funding and increased construction costs, fewer projects have been built. It's becoming more expensive to develop and construct new structures because land prices are higher (especially in urbanizing areas) and it's more difficult, and costly, to comply with tight environmental criteria. To critics, new projects may be unneeded if no one wants to pay for them.

The Navarro Soil and Water Conservation District has sponsored the construction of many small dams and grade stabilization structures, including this one near Mill Creek.

Photo Courtesy of Navarro Soil and Water Conservation District

Second, many of the small watershed dams are reaching the end of their designed life (often referred to as the useful life) and aging can be associated with many potential problems. Most of these facilities built in the 1950s were intended to store about 50 years of sediment (those built afterwards were designed to store 100 years of silt). In theory, many of the reservoirs created by these dams should be filled with silt by now or soon will be. This could curtail the ability of these dams to trap additional sediments, thus reducing the water quality benefits these dams were intended to provide. Significant amounts of silt could limit the ability of these dams to store floodwaters. Another concern is that routine structural repairs may be needed as these dams reach the end of their designed life (typically repairing inlet and outlet structures). In some cases, major repairs such as reinforcing the banks of dams, may be needed following heavy floods. Unfortunately, there are no federal funds to assist in rehabilitating small watershed dams, although a bill is now pending in Congress which would, if passed, provide this funding.

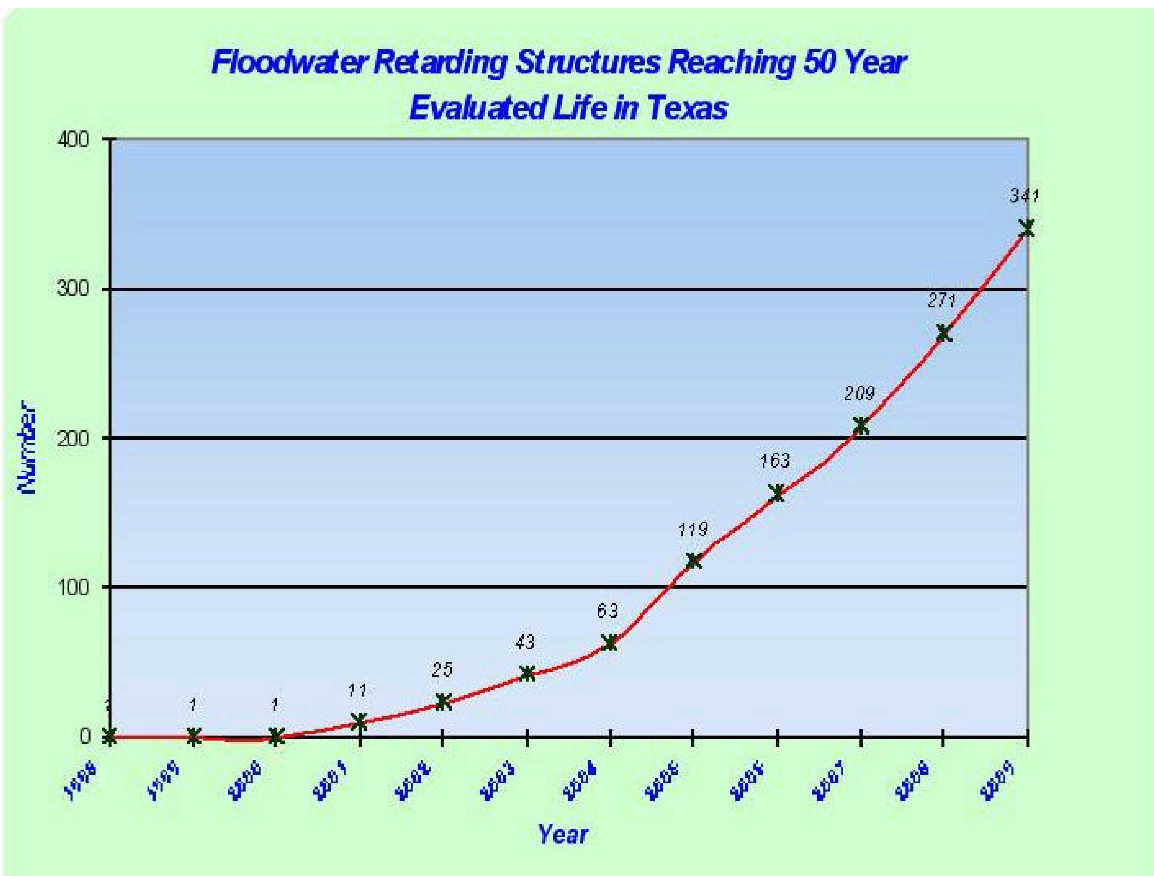
Third, many of these projects were originally sited in agricultural watersheds and were designed to accommodate the amount of flows which could be expected from farming conditions. As rural watersheds become urbanized, the nature and type of flows changes radically. Often, runoff problems worsen as agricultural areas are paved over with streets and parking lots. The situation is especially problematic since it's difficult, if not impossible, to modify these dams after conditions change.

Planning, Developing, and Managing Small Dams

The small watershed dam program operated by the NRCS consists of three components. In 1944, Congress passed the Flood Control Act (Public Law, or PL 78-534). In 1953, the Pilot Watershed Program was authorized and the Watershed Protection and Flood Prevention Act was enacted (PL 83-566). Most small dams in Texas (62%) were built through the PL-534 process, followed by the PL-566 program (33%) and the Pilot activities (3%). A few small dams (2%) were constructed with the assistance and cooperation of local Resource Conservation and Development units.

The process of developing small watershed projects involves cooperation among many federal, state, and local agencies. The TSSWCB prioritizes projects submitted by local sponsors (typically soil and water conservation districts or water districts). If Board staff recommend that a project is needed and feasible, they can request that the Texas office of the NRCS begin planning and design work. Most of these projects also involve employing best management practices (BMPs), such as "no till" farming or the use of terraces, which can be implemented by landowners to prevent sediment and nutrient runoff. These dams serve the purpose of protecting prime farmland from flooding, thus keeping the most fertile areas with the best topsoil in agricultural production. Throughout Texas, 144 watershed projects and more than 2,100 small dams have been authorized by the NRCS. To date, the cost has been shared by the federal government ($630 million from the USDA) and local sponsors ($870 million). Texas NRCS officials estimate that these small dams have resulted in "capitalized benefits" of as much as $2.5 billion, based largely on projected losses that may have occurred if the structures were not built. An additional 35 projects and 285 small dams have been approved and are awaiting construction, when funds are available. These will cost $155 million.

The pace of approving and constructing these projects has slowed considerably in recent years. Some of the small dams which have recently been developed include two locations near San Antonio (an urbanized site on Salado Creek and a rural area on Ecleto Creek), Chocktaw Creek near Sherman, and Elm Creek near Temple.



Aging Small Dams and Dam Safety

According to the NRCS, as many as half of the small watershed dams are at least 30 years old. In the next 10 years, the agency estimates that more than 1,300 small dams throughout the United States will reach the end of their design life, thus limiting the ability to lessen flooding and trap sediments. In Texas alone, the NRCS suggests that 25 small dams will reach the end of their design life by 2002, with that number escalating to 341 dams by 2010. Roughly half of Texas' small watershed dams (49%) are 30 to 39 years old, while 16% are more than 40 years old. Many dams may require major or minor structural repairs as a consequence of growing older.

Just how much help do Texas' small watershed dams need? In 1999, the Texas Office of NRCS estimated that roughly 125 small dams need to repaired now because of problems associated with excessive sediment buildup, structural deterioration, or unstable slopes. The cost of modifying these small dams is estimated to be $28.6 million.

In Texas, the Texas Natural Resource Conservation Commission (TNRCC) oversees dam safety issues. The main functions of this program include evaluating existing dams and performing on-site inspections of spillways and other structures, reviewing and approving plans for new dams and modifications to existing facilities, assisting in the development of emergency action plans, and maintaining an inventory of Texas dams. The Dam Safety Office also ranks the hazard classification of individual dams -- low hazard structures are those in which no loss of life or minimal economic loss would result if a dam failed, significant hazard dams are those in which loss of life would be possible but not expected and economic losses would be appreciable, and high hazard structures are those in which a loss of life is expected and economic losses would be excessive.

In 1998, a multi-agency task force published a thorough report on dam safety issues in Texas. According to this study, there are roughly 5,200 small dams in Texas (which are less than 40 feet tall); about 1,918 intermediate dams (which range in height from 41 to less than 100 feet); and 123 large dams (which are more than 100 feet high). As many as 1,560 dams (including many smaller structures) were identified as being "at risk." The classification of a dam as small, intermediate, or large also depends on the amount of water these structures can store. Unfortunately, the report notes that current funding levels only allow resources to survey less than about 2% of the dams in Texas each year.

Roughly (27%) of the dams in Texas are small watershed structures built by the NRCS. The task force report suggests that many of these dams, especially those designed for rural watersheds but are now in suburban and urban locations, need to be upgraded so they can provide adequate flood protection.

Another problem is that Texas had no specific dam safety rules before 1986, and roughly 96% of Texas dams were built prior to this date. Of the dams built since 1986, roughly 300 structures (about 4%) of those sites which have received formal plan approval have generally not presented a dam safety problem.

The task force recommended that all dams in Texas be classified as representing either a low or high hazard, that a "cafeteria plan" consisting of many options be developed that could provide flexibility in dealing with at-risk dams, and that staff resources be increased so that more structures could be assessed on-site more often. These recommendations have not been implemented because of limited staff resources.

Local Success Stories

The small watershed dam program has developed sites throughout Texas to deal with site-specific problems. Although few formal evaluations of the effectiveness of these dams have been conducted, you can get a good idea of the value of these efforts by talking to local program managers who work with them every day.

A comprehensive effort to ascertain the extent of potential sediment problems into major reservoirs is now being conducted by the Brazos River Authority (BRA). Phil Price, who works in the BRA's Water Resources Division, said the agency contracted with the Texas Water Development Board to perform volumetric surveys of its lakes. Based on survey results, BRA selected Lake Limestone, Lake Aquilla, and Lake Granger for analysis, and contracted with the Water Resources Assessment Team (WRAT), based at the Blackland Research Center (BRC) in Temple, to assess flow and sediment loadings to these lakes, and to quantify the effect of best management practices on sediment loads. The results of the volumetric surveys were used to calibrate the Soil Water Assessment Tool (SWAT) computer simulation model.

Results of this study suggest that installing more small dams in watersheds feeding into Lake Aquilla can reduce sediment loads by roughly 6%, while employing land-based best management practices, such as terraces, could cut sediment loads by 24%. Results for Lake Granger were similar to those for Lake Aquilla. Additional watershed dams could reduce sediment loads by 7%, while the use of BMPs on croplands could lessen silt runoff by 16%, the modeling results suggest. BRA is now targeting areas upstream of these major reservoirs where it may be effective to apply such conservation practices as terraces and vegetative buffer strips.

Evaluating the effectiveness of current small dams and projecting the benefits that may be brought about by building additional structures is the focus of recent investigations by the Tarrant Regional Water Authority (TRWA). According to Woody Frossard, who leads this program, the question that needed to be answered was whether additional small dams in the Big Sandy and Salt Creek watersheds could lessen sediment runoff into adjacent streams and rivers and Lake Bridgeport and Eagle Mountain Lake. Frossard says TRWA first formed the West Fork of the Trinity River Study Group in an effort to work with leaders and landowners in Wise County and involve them in the process. "We wanted to reach out and involve residents in the upper part of the watershed and help them understand the potential benefits of these small dams and decide if they should be built," he said. Afterwards, TRWA and the study group worked with Steve Bednarz of the NRCS Texas Office and Raghavan Srinivasan of BRC, who utilized the SWAT computer model to simulate sediment runoff problems with and without 60 to 90 small dams in place upstream of Lake Bridgeport and Eagle Mountain Lake. Outputs were linked into and displayed on a geographic information system. Results suggest that existing small dams have trapped more than 10 million tons of sediments. As a result, as much as 8,000 AF reservoir storage capacity has been preserved and high water quality in these lakes has been maintained. "Because of these dams, we have more space to store water, not silt, in our major water supply lakes," Frossard says. "These small dams are helping us extend and preserve our water supply."

Fernando Garza and Allan Colwick of the NRCS, Jim Blair of SARA, and Jaime Villena of the TNRCC (shown here from left to right) look at erosion damage resulting from the 1998 floods at a small dam on Salado Creek.

Photo Courtesy of the Texas Office/ NRCS

In northeast Texas, the Navarro Soil and Water Conservation District sponsored the construction of roughly 105 small watershed dams from 1958 to 1972. In addition, the District helped pass a county tax that provides funds to routinely maintain these structures. In many cases, their work is a team effort with the TRWA. According to Bobby Wilson, who directs the District, these projects are effective and trapping sediments, thus improving water quality. "I know these dams are effective in collecting sediments and holding them long enough so the sediments can settle out," he says. "Water quality downstream would be worse if these small watershed dams were not in place." Now, the District is working to lessen erosion problems in a segment of Mill Creek, which runs off into the Richland-Chambers Reservoir. Sediment runoff in this area began to be a problem in the 1940s, when farmers cut through a slough to increase the amount of agricultural acreage. In the 1960s, Mill Creek was identified as one of the tributaries which produced the greatest amount of sediment runoff in Texas. The solution is to install small watershed dams and "gabions" (rock placed in wire baskets) to trap sediments, and to implement a suite of BMPs, including grass filter strips and related measures.

Jim Blair manages the small dam program of the San Antonio River Authority (SARA), which developed, operates, and maintains roughly 40 of these structures in Bexar and Karnes counties. According to Blair, many of these dams were originally designed to trap sediments resulting from the row-cropping of cotton. Even though much of the row-cropping has been replaced by pastures (which should lessen sediment runoff), Blair contends these structures still serve a valuable purpose. "It's obvious to me that these small dams are improving water quality because they retain floodwaters," he said. "The dams prevent rural and urban areas from flood damage."

Other examples of the value and performance of small watershed dams have been described in fact sheets prepared by the NRCS Texas Office. For example, 17 dams have been built in the Salt Creek watershed in Wise and Parker counties upstream of Fort Worth. Besides traditional flood control and sediment trapping purposes, these efforts have created 270 acres of wetlands and enhanced 20,000 acres of upland wildlife habitat. Estimated annual benefits from this work average $692,000. Meanwhile, 43 small dams have been constructed in the Tehuacana Creek watershed in Hill and McLennan counties in Central Texas to lessen gully erosion and to protect valuable prime farmlands. According to the Texas NRCS, annual benefits from this project, including improved water quality, average $1.2 million.

Many Watersheds Are Urbanizing

According to officials from the NRCS, there are many areas in Texas where small watershed dams originally designed to serve rural areas now have to cope with heavily urbanized conditions. In general, regions with small dams which have become urbanized are concentrated near San Antonio, Austin, and Dallas-Fort Worth. At least 160 small dams in Texas need to be upgraded so they can provide adequate flood prevention, because downstream watersheds have become urbanized, according to the Texas NRCS Office. The cost to prepare small dams to cope with urbanized watersheds is anticipated to be at least $55.6 million.

A small watershed dam near Corsicana illustrates what is happening throughout much of Texas, according to Bobby Wilson of the Navarro Soil and Water Conservation District. In the 1950s, a small dam was built on a creek on the edge of town in an agricultural watershed. Now, the watershed protected by this structure includes 250 homes.

The difficulty, according to Larry Goertz of the NRCS, is that dams intended to prevent flooding from rural regions were not designed to deal with higher flows associated with paved urban areas. As a result, it's possible that small watershed dams that functioned well in rural areas may not provide the optimal level of flood protection needed in suburban and urban sites. The ideal solution, Goertz says, would be to go into these watersheds and assess whether flood hazards have increased as a result of urbanization. If they had, the height of the dam could be increased or the structure could be modified to provide added protection.

Due to the lack of federal financing and the potentially high cost of these efforts, this has only been done in a few cases in Texas. Near Lake Lavon, a private developer upgraded a small watershed dam to safeguard new home sites.

A critical policy issue centers on which parties may potentially be responsible should flood damages occur in watersheds where small dams have not been upgraded to deal with urbanization. Although situations like this have not yet occurred in Texas, the question is being raised in many forums. Local sponsors are very concerned about increased flood damages and liability issues in urbanizing areas.

The 1998 Floods

A primary purpose of many small watershed dams is to control flooding within small rural watersheds or to lessen the magnitude of downstream damage. According to a recent report prepared by staff members of the Texas office of the NRCS, taking a careful look at the massive floods of October 1998 can provide critical insights into the extent to which these dams lessened flood damage in many watersheds.

From October 17-19, 1998, a band of severe thunderstorms swept through San Antonio, New Braunfels, and the Austin area, dumping significant amounts of rainfall throughout an area covering roughly 20,000 square miles in Bexar, Hays, Comal, Guadalupe, and Caldwell counties. The storms dropped the most rainfall on the area since recordkeeping began in 1885, and some areas received as much as 31 inches of rain from these storms. At its worst, 2 to 3 inches of rain fell per hour. As a consequence of these storms, roughly $1 billion of flood-related damage occurred, 31 people died, more than 10,000 people were displaced, and thousands of animals drowned.

Ironically, the catastrophic floods provided an opportunity for state leaders of the Texas Office of the NRCS to assess how well small dams functioned during the floods and whether they actually saved lives and property. Long before these storms occurred, local sponsors had cooperated with the NRCS to install small dams in many watersheds, including Salado Creek, Calaveras Creek, Martinez Creek, York Creek, Plum Creek, the Comal River, and the Upper San Marcos River.

Baylor University student Luis Nieda-Ramos and researcher John Dunbar conducted a sediment survey of this small lake near Eddy.

Photo by Ric Jensen/ TWRI

Analysis conducted by the NRCS utilized a hydrologic computer software program, "TR-20 Watershed Hydrology," to determine the extent to which the small dams reduced flood damages. Results suggest that the combined effect of the small watershed dams in the area reduced peak flood flows by at least 50%, while many individual structures were even more effective, cutting flood flows from these watersheds by 75%. For example, the dams in the Salado watershed stored more than 30,000 AF of stormwater during the flood. If these small dams had not been built, flood flows could have been as much as 9.5 feet higher than they were with the dams in place. Without the watershed dams, significant flooding of urban areas near the Interstate 410 Freeway would have also taken place, the report says.

"Our analysis show that these small dams provided significant protection from flood damage to many downstream areas," said Larry Goertz of the Texas NRCS office, one of

the lead authors of the report. "We estimate that flood protection benefits resulting from this storm event exceed $55 million."
By and large, the small watershed dams emerged from the floods with little damage, although structures at three sites (the Comal River, Plum Creek, and York Creek) suffered spillway damage which will need repairs totaling roughly $2.5 million.

According to Jim Blair of the San Antonio River Authority, which sponsored many watershed projects in the affected area, "the dams were instrumental in saving lives and property during the 1998 floods."

University Research

Scientists at Texas universities have studied issues related to small dams, including methods to measure the amount of sediment running off into small and large reservoirs, ways to monitor changes in the volume of water reservoirs can store, and the effect of these facilities on improving water quality.
Studying the changes which have occurred in a small watershed reservoir south of Waco is the emphasis of an ongoing research project by researchers and graduate students at the Baylor University Geology Department. The work is being conducted by researchers John Dunbar and Peter Allen and graduate student Luis Nieda-Ramos at the Cow Bayou Reservoir near Eddy. According to Dunbar, this reservoir rapidly filled with sediments shortly after it was built in the 1950s. By 1995, roughly two-thirds of the lake had filled with sediments. At that time, it was rehabilitated by the NRCS and much of the silt was removed. Since then, the rate of sedimentation has decreased markedly. The research team is investigating the extent to which changes in land use may be correlated to sedimentation and how silt is distributed throughout the lake.

To survey the lake, the researchers first had to create a way to adapt the methods used for large reservoirs to this small lake. Because Cow Bayou is relatively hard to access, the researchers had to carry the survey boat and related gear into the water. As a result, they created a more portable survey method which involves bolting two smaller "john boats" together as well as more compact instrumentation. Once the survey began in the spring of 1999, Dunbar and colleagues identified the bathymetry of the lake by using a differential global positioning system (GPS) which was used from the boat as well as on land. Although it was relatively easy to get the boat in deeper waters, it was difficult to survey more shallow sites. In these areas, they relied on signs of water-logged areas, including marks on trees and the presence of water-tolerant vegetation. Other technological advances used to measure the amount of sediment buildup in this effort include a precision fathometer and four sub-bottom profiling frequencies. Another complication was that the research team occasionally encountered pockets of methane gas in the lakebed, which interfered with soundwaves used to gauge the depth of the reservoir. In 1995, this method was also used to survey the volume of sediment which had built up in Lake Waco.

Results from both the Cow Bayou and Lake Waco studies show that this method can be much more accurate than currently used techniques. The system measures sedimentation directly in one survey (current methods often require at least two measurements so results can be compared) and provides graphs that display how silts have accumulated.

"We feel this system may be a major advancement in techniques for surveying small reservoirs and we hope to apply this method to similar sites in rural and urban areas in Texas," Dunbar said. "At the same time, we think that the lessons learned in this work may lead to improvements in surveying larger lakes, since we were able to differentiate between older and recent sediments which were deposited in the lake."

At the University of Texas at Austin, Jim Gibeaut and colleagues at the Bureau of Economic Geology have developed and field tested methods which may be more accurate in describing the extent to which reservoirs have filed with sediment. Gibeaut has developed a method which incorporates the use of GPS, an electronic motion sensor, a digital-gyro compass, a digital-analog echo sounder, a probe which measures conductivity, temperature, and water depth as well as specialized computer hardware and software into a system that may provide more accurate data than methods now being used, especially in rough and turbulent waters. The system may be especially useful in surveying small lakes, like the ones created by watershed dams, because it can be employed by boats as small as 18-feet in length. Gibeaut calls this method HARBSS (a high-accuracy, high resolution, bathymetric surveying system). In 1995, the researchers tested this system in a trial survey of a shallow creek, which is part of Lake Travis in Austin. Gibeaut says that results suggest that the use of this method may improve the accuracy of reservoir measurement, because it better defines and profiles the bottom surface of lakes. Repeat surveys are expected to show that this system accurately measures changes in sediment build-up over the short-term, Gibeaut says. The system has also been tested in bay waters along the Texas coast.

Robert Ramirez (front) and Gary Franklin of TIAER take a phytoplankton sample from a small lake in Central Texas in 1992.

Photo Courtesy of Don Gosdin/ TIAER

Since 1991, scientists with the Texas Institute for Applied Environmental Research (TIAER) at Tarleton State University in Stephenville have been studying interactions between agricultural land use and water quality within reservoirs created by these small dams. For example, a 1997 TIAER report by Larry Hauck and Anne McFarland describes studies to correlate such land uses as range, woods, forage fields, sites where dairy manure was applied, and the concentration of dairy cows to water quality in small watershed dams. In general, the research shows that there are strong relationships between watersheds where large amounts of dairy manure is applied to the land and high nutrient levels in small reservoirs.

"A benefit of this project," Hauck says, "is that it proved that small watershed dams are excellent sites to monitor and evaluate water quality, since they retain much of the rainfall runoff and provide sites where samples can be collected."

UT BEG researchers Roberto Gutierrez (on shore) and Robert Sanchez and Jim Gibeaut (left to right, in boat) survey Lake Travis using high tech methods.

Photo Courtesy of Jim Gibeaut, UT BEG

Currently, TIAER is monitoring phytoplankton levels at six lakes and identifying the diversity of algae which live in waters behind these dams. Richard Kiesling is leading ongoing studies to measure the levels of nitrogen and phosphorus loadings that may accumulate behind small dams as a result of the application of dairy manure, and whether there is a link between these nutrients and algae levels. "We have found that there are correlations between areas with a high concentration of dairy manure application and nutrient loadings in watersheds where these small dams are located," Kiesling said. "In some cases, these reservoirs receive so much phosphorus loading that they become nitrogen-limited and very eutrophic. At these sites, undesirable, bluegreen algae are widespread."

Throughout much of the 1990s, researchers at the BRC have cooperated to study issues related to sediment processes and problems in rivers and lakes. Raghavan Srinivasan of TAES and Jeff Arnold of the USDA Agricultural Research Service published a 1993 assessment of sediment and organic nutrient loadings in major rivers of the United States which stem from non-point sources. The work, which was part of a project titled "Hydrologic Unit Modeling of the United States," correlated land use to sedimentation and water quality. More recently, Srinivasan has worked with Steve Bednarz of USDA/ NRCS to assess the extent to which small dams may lessen sediment loads for the TRWA.

Summary

For many years, and still today, the small watershed dam program of the USDA NRCS has provided a valuable service in preventing floods, trapping sediments, and increasing water supplies. At the same time, it needs to be noted that there are many challenges facing these dams that must be addressed, including construction of new facilities, rehabilitating existing dams where needed, and identifying sites where these structures may need be modified to cope with changing conditions. Certainly, it seems to be in the best interests of Texas to keep these dams as viable as possible and to determine how this valuable program can be strengthened to meet today's needs.

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