AgriLIFE EXTENSION
Texas A&M System

B-6256
07/12

Lone Star Healthy Streams

Feral hog Manual

Endorsed By:

Texas Wildlife Association
NRCS
Texas and Southwestern Cattle Raisers Association
Texas Pork Producers Association
Texas Parks & Wildlife
GLCI

Lone Star Healthy Streams

Keeping Texas Waters Safe and Clean...

Cover picture courtesy of Jennifer Peterson, Texas AgriLife Extension Service

Lone Star Healthy Streams

Feral Hog Manual

Authors

Jennifer Peterson
Extension Program Specialist
Department of Soil & Crop Sciences
Texas AgriLife Extension Service

James Cathey
Assistant Professor and Extension Wildlife Specialist
Department of Wildlife and Fisheries Sciences
Texas AgriLife Extension Service

Kevin Wagner
Associate Director
Texas Water Resources Institute

Larry Redmon
Professor and State Forage Specialist
Department of Soil & Crop Sciences
Texas AgriLife Extension Service

AgriLIFE EXTENSION
Texas A&M System

Soil Water
TSSWCB

Texas Water Resources Institute
make every drop count

Photo courtesy of the U.S. Fish and Wildlife Service

Table of Contents

Acknowledgements

Funding Sources

The development of this manual has been supported by a federal grant from the U.S. Environmental Protection Agency's Nonpoint Source Management Program under Clean Water Act Section 319 through the Texas State Soil and Water Conservation Board. The authors are grateful to both agencies for this indispensable support.

Review & Development

The authors would like to thank the following groups and individuals for their assistance:

- Diane Bowen and Judy Winn, Texas AgriLife Communications
- Texas Water Resources Institute (TWRI)
- Lone Star Healthy Streams Program Development Committee
- Lone Star Healthy Streams Steering Committee

Steering Committee Members

Texas AgriLife Extension Service

- Todd Bilby
- Jim Cathey
- Galen Chandler
- Craig Coufal
- Monty Dozier
- Marvin Ensor
- Sam Feagley
- Pete Gibbs
- Ellen Jordan
- Saqib Mukhtar
- Joe Paschal
- Dennis Sigler
- Ronald Woolley

Texas State Soil and Water Conservation Board

- Mark Cochran
- Mitch Conine
- TJ Helton
- Aaron Wendt

Texas Water Resources Institute

- Kevin Wagner
- Brian VanDelist

USDA-Agricultral Research Service

- Daren Harmel

Program Development Committee Members

- Grazing Lands Conservation Initiative (GLCI)
- Independent Cattlemen's Association of Texas
- Little Wichita Soil and Water Conservation District
- Texas AgriLife Extension Service
- Texas AgriLife Research
- Texas Cattle Feeders Association
- Texas Commission on Environmental Quality
- Texas Department of Agriculture
- Texas Farm Bureau
- Texas and Southwestern Cattle Raisers Association
- Texas State Soil and Water Conservation Board
- Texas Water Resources Institute
- USDA-Agricultural Research Service (ARS)
- USDA-Natural Resources Conservation Service (NRCS)
- Victoria Soil and Water Conservation District
- Welder Wildlife Foundation
- The 2S Ranch, Caldwell County, TX
- Hall-Childress Soil and Water Conservation Districts

List of Figures

List of Tables

Photo courtesy of Bill Watson, Texas AgriLife Extension Service.

Preface

About 300 Texas water bodies currently do not comply with state water quality standards established for *E.coli* bacteria. Elevated concentrations of *E.coli* bacteria in water are an indicator of fecal contamination and can pose an increased health risk to downstream users.

The Lone Star Healthy Streams program aims to educate Texas livestock producers and land managers on how to best protect Texas waterways from bacterial contributions associated with the production of livestock and feral hogs. To achieve this goal, groups of research scientists, resource conservation agencies, and producers have collaborated to compile this Lone Star Healthy Streams manual which includes best management practices (BMPs) known to reduce *E.coli* contributions to rivers and streams. In addition to reducing bacterial contributions, the BMPs listed in this manual will allow livestock and land owners to further protect Texas waterways from sediment, nutrient, and pesticide runoff.

We hope that landowners and livestock producers find the following information helpful in their pursuit of being the best natural resource stewards they can be. For more information about the Lone Star Healthy Streams program, please visit http://lshs.tamu.edu/.

Chapter 1
Water Quality in Texas

Photo courtesy Billy Higginbotham, Texas AgriLife Extension Service

Water Quality and Feral Hogs in Texas

Water is a finite resource that can be significantly polluted by a variety of sources across the landscape. No one person, industry, or activity is to blame. In recent years, however, feral hogs have become a major threat to water quality in Texas because of their destructive behavior in riparian zones (area of vegetation surrounding streams and other water bodies) and their high reproductive capacity (Fig. 1). As feral hogs congregate around water sources to drink and wallow, their fecal matter is deposited directly in streams, adding bacteria and nutrients to the water bodies.

Hogs were first introduced in Texas more than 300 years ago by Spanish explorers as a source of lard and meat. Over the course of time, many hogs escaped or were released and allowed to roam freely. In Texas today, an estimated 1.9 to 3.4 million feral hogs cause $52 million in damage annually to agricultural lands (damage to crops, facilities, fences) and cost landowners about $7 million each year to control (Burns 2011). Feral hogs can also harbor and transmit diseases to livestock and people. About 79 percent of Texas, or some 134 million acres, is considered feral hog habitat (Fig. 2).

Feral hogs have been shown to contribute bacteria to water bodies (Kaller and Kelso 2003). In one study in Texas, four of seven (57 percent) feral hogs tested contained *E. coli* strains that could infect humans; six of seven (86 percent) contained *E. coli* strains that could infect livestock (Bodenchuk 2008). Fewer hogs mean less risk of their contaminating water with bacteria and other pollutants.

Few studies have been conducted on the effect of feral hog removal on bacteria levels in a water body. One study in Texas found that after 537 hogs were removed from the

Figure 1. A feral hog. © 2011 Photos.com, a division of Getty Images. All rights reserved.

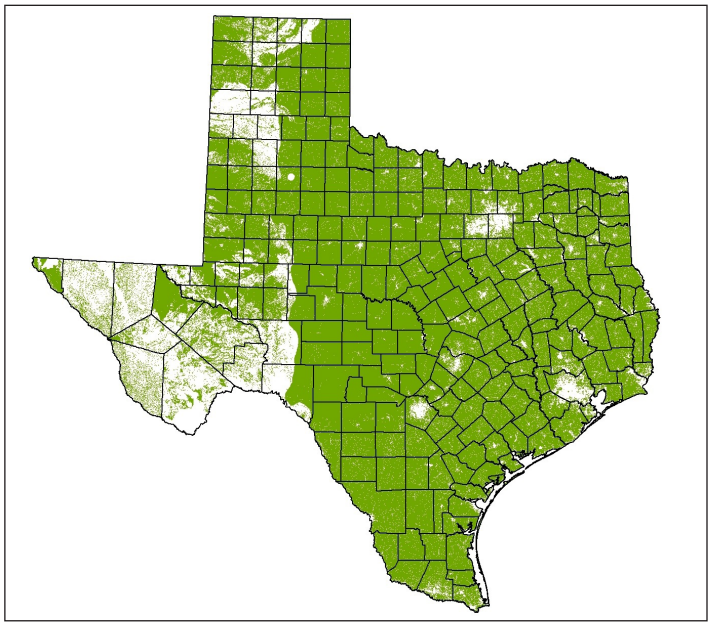

Figure 2. According to a recent study, about 134 million acres, or 79 percent of the state total of 170 million acres, is feral hog habitat (Texas AgriLife Extension Service graphic courtesy of the Texas A&M University Institute for Renewable Natural Resources).

Plum Creek Watershed over a 2 year period, the level of *E. coli* bacteria in Plum Creek dropped 48 percent (Feral Hog Project Accomplishments 2010).

In addition to decreasing the bacterial contamination in water, reducing feral hogs can also:

- Increase plant cover by as much as 80 percent and decrease bare ground by nearly 90 percent (Singer et al. 1984).
- Increase forest litter (Singer et al. 1984)
- Decrease erosion and nutrient losses (Singer et al. 1984)
- Decrease turbidity in streams and rivers
- Increase the health of valuable riparian areas
- Reduce the spread of invasive species (Kotanen 1995, Cushman et al. 2004)
- Improve the health and function of watersheds (Cushman et al. 2004)
- Decrease the potential for disease transmission to humans and livestock (Gingerich 1994)

Feral hogs are unprotected, exotic animals and considered a nuisance species in Texas. Therefore, they can be taken by any legal means or methods at any time of the year. There are no seasons or bag limits, however a hunting license and landowner permission are required to hunt them (Taylor 2003). If a feral hog is causing depredation on a piece of property, the landowner, landowner's agent, or lessee (if given landowner permission) can take a feral hog without a hunting license.

Texas is almost entirely privately owned making landowners the first line of defense in controlling feral hogs. Many management options exist to help reduce the population and damage of feral hogs and also improve water quality.

Figure 3. Clean water is vital to crops and livestock in Texas. Photo by Blair Fannin, Texas AgriLife Extension Service.

Landowners can more easily make wise choices for reducing pollution originating on their operations if they know the benefits of clean water to agricultural operations, the current laws and policies on water quality, the ways that bacteria can enter water, and the range of solutions that are available for them to reduce water quality problems.

Value of Clean Water to Texas Agriculture

Clean water is vital to agricultural producers in Texas. Water is used for irrigating crops (Fig. 3) and raising livestock

and is the reason why the Texas food and fiber system is valued at nearly $100 billion each year. Clean water can also improve animal health, gains, and reproduction, as well as increase recreational opportunities on farms and ranches.

Bacteria can severely reduce or even eliminate some of these valuable water-based activities and associated benefits. The costs of poor water quality include degraded ecosystems, limited agricultural production, reduced recreational opportunities, increased government regulation, increased water treatment costs, and threats to human health.

Water Quality Law and Policy

The foundation for surface water quality protection in the United States is the Federal Water Pollution Control Act, commonly referred to as the Clean Water Act (CWA). Passed in 1972 and amended in 1977, the CWA was enacted to restore and maintain the chemical, physical, and biological characteristics of the nation's waters.

In brief, the Clean Water Act requires that states set standards for surface water quality; it also requires public and private facilities to acquire permits for discharging wastewater. At the federal level, the U.S. Environmental Protection Agency (EPA) is responsible for administering the water quality standards outlined in the Clean Water Act. The EPA delegates water quality management at the state level to the specific state environmental agency.

In Texas, the primary water quality agency is the Texas Commission on Environmental Quality (TCEQ, Fig. 4). The TCEQ is responsible for:

- Establishing water quality standards
- Determining how water quality will be managed
- Issuing permits for point source dischargers
- Reducing all types of nonpoint source pollution, except those from agricultural and silvicultural (forestry) sources

Point source pollution can be traced to a specific location and point of discharge, such as a pipe or ditch; nonpoint source pollution originates from multiple locations and is carried primarily by precipitation runoff.

In 1991, the Texas Legislature delegated some water quality authority to the Texas State Soil and Water Conservation Board

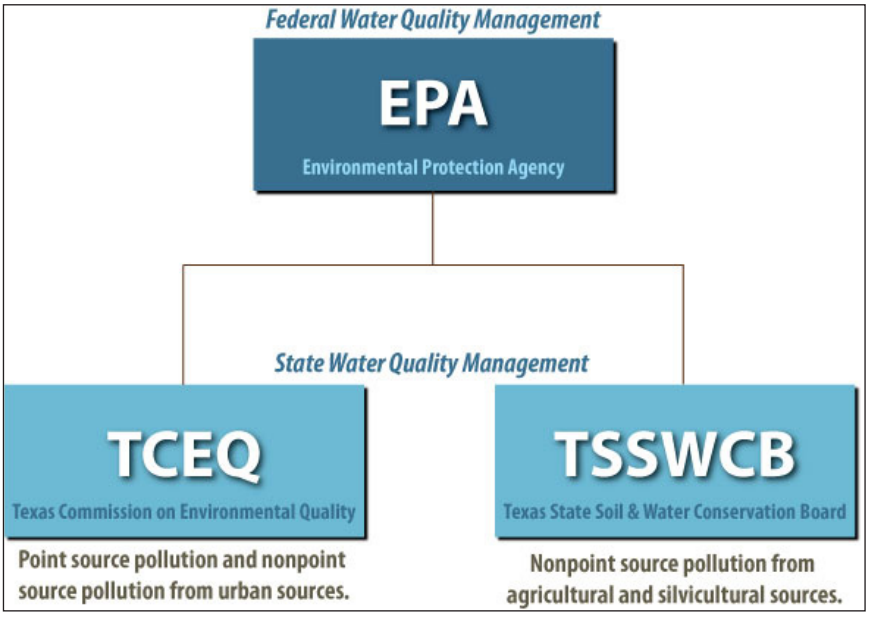

Figure 4. Hierarchy of federal and state agencies involved primarily in water quality management in Texas. Illustration by Jennifer Peterson.

(TSSWCB). The TSSWCB is responsible for administering the state's soil and water conservation law and for managing programs to prevent and reduce nonpoint source pollution from agriculture and forestry.

To comply with Section 303(d) of the Clean Water Act, the TCEQ must report to the EPA on the extent to which each surface water body meets water quality standards. The report must be submitted every 2 years and is known as Texas Integrated Report for Clean Water Act, Sections 305(b) and 303(d). The Integrated Report describes the status of all surface water bodies that were evaluated and monitored in the state over the most recent 7-year period. This report is the basis for the 303(d) List, which identifies all impaired surface bodies of water that do not meet water quality standards.

Water quality standards specify numeric levels of water quality criteria such as bacteria, temperature, dissolved oxygen, and pH that can be measured in a lake, river, or stream without impairing the designated use(s) assigned to that water body. Designated uses include aquatic life, fish consumption, public drinking water supply, and contact and noncontact recreation. Any water body whose water quality criteria measurements fall outside of the levels set by the standards for each designated use is considered impaired and is placed on the 303(d) List.

The Clean Water Act requires that a calculation be made on the pollution reductions needed to restore an impaired water body to its designated use(s). The calculation is called a total maximum daily load (TMDL). A TMDL must be developed for waters on the 303(d) List of impaired waters within 13 years of being listed. If the state does not develop a TMDL within the required time limit, the EPA will.

In Texas, both the TCEQ and the TSSWCB are responsible for developing and submitting TMDLs to the EPA. After a TMDL is complete, an implementation plan (I-Plan) must be developed. This plan includes a detailed description of the regulatory measures, voluntary management measures, and parties responsible for carrying out identified measures needed to restore water quality in accordance with the TMDL. Unlike the TMDL, the implementation plan must be approved by only the TCEQ or TSSWCB, not the EPA.

Regulatory measures are typically applicable only to point source dischargers such as concentrated animal feeding operations (CAFOs) or wastewater discharges. However, some U.S. watersheds have also imposed regulatory measures on nonpoint sources.

According to the 2010 Texas Integrated Report for Clean Water Act Sections 305(b) and 303(d), there were a total of 621 impairments in Texas. Of these impairments, 51% were due to elevated bacteria. As of February 2012, a total of 206 TMDLs have been developed for 134 water segments in Texas.

Some watersheds may have another option that may be more viable for solving complex water issues. Instead of developing a TMDL, they may be able to develop and implement a watershed protection plan (WPP).

A WPP is a voluntary, stakeholder-driven strategy for improving water quality. These plans are developed and managed through partnerships among federal

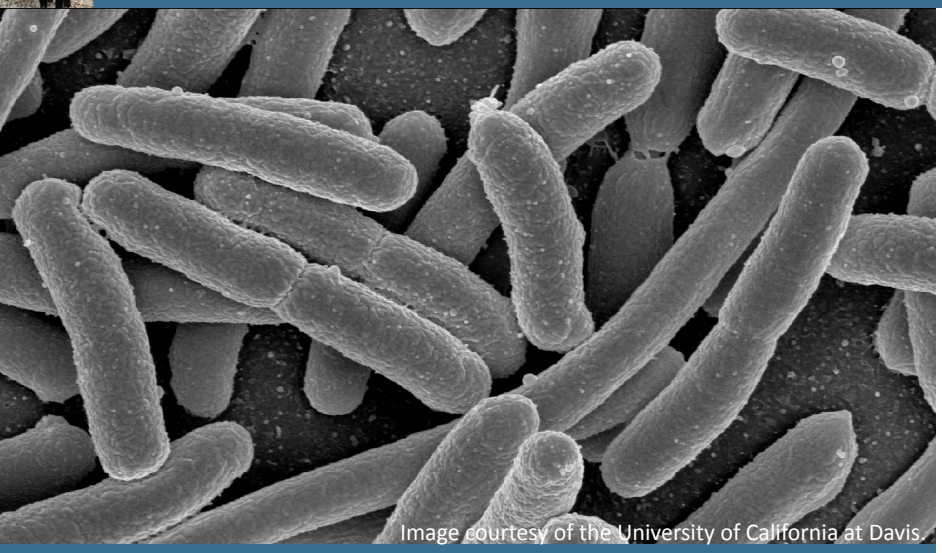

Image courtesy of the University of California at Davis.

Escherichia coli, commonly abbreviated as *E. coli*, is a rod-shaped bacterium found in the lower intestine of warm-blooded organisms. It was first discovered in 1885 by German pediatrician and bacteriologist, Theodor Escherich.

Perhaps the most recognized strain is O157:H7 which can cause serious food poisoning in humans and is often the cause of product recalls. In 2006, more than 200 people became sick and 3 people died after consuming spinach contaminated with *E. coli.*

E. coli are important in water quality because they act as indicator organisms - their presence in water can indicate the potential prescence of other harmful pathogens that are capable of causing disease in humans.

and state agencies and local groups and organizations. They rely heavily on stakeholder involvement at the local level.

To help communities create WPPs, the EPA has produced a guide, *Handbook for Developing Watershed Plans* to Restore and Protect Our Waters. The handbook outlines nine key elements that each WPP should contain:

- Causes and sources of the water quality problem
- Load reductions needed to restore water quality
- Management measures needed to achieve the load reductions
- Technical and financial assistance needed to implement the management measures
- Information and education programs needed
- Implementation schedule
- Implementation milestones
- Criteria to determine success
- Monitoring needed to determine the effectiveness of implementation

The main difference between the two approaches is that TMDLs are required by federal law, and WPPs are voluntary. In general, a WPP gives communities a way to restore water quality, remove the body of water from the 303(d) List, and avoid regulatory action in the watershed. In some cases, however, development of a TMDL is more appropriate and unavoidable, especially if the impairment causes an emergency situation.

Sources of Bacteria in Texas Waterways

Fecal bacteria are microscopic organisms found in the feces of humans and other warm-blooded animals. By themselves, they are usually not harmful, but they are important because they are indicator species and can suggest the presence of pathogenic (disease-causing) organisms.

Pathogenic organisms include bacteria, viruses, or parasites that can cause waterborne illnesses such as typhoid fever, dysentery, and cholera. In addition to the potential health risks, elevated bacteria

levels can also cause unpleasant odors, cloudy water, and increased oxygen demand.

The most common types of fecal bacteria that are measured to indicate the potential presence of harmful pathogens include: total coliform, fecal coliform, fecal streptococci, enterococci, and *Escherichia coli* (*E. coli*). The EPA recommends *E. coli* as the most reliable indicator of contamination for freshwater and enterococci as the most reliable indicator in saltwater.

Bacterial contamination of surface waters is a major problem—it is the leading cause of water quality impairment not only in Texas, but also nationwide.

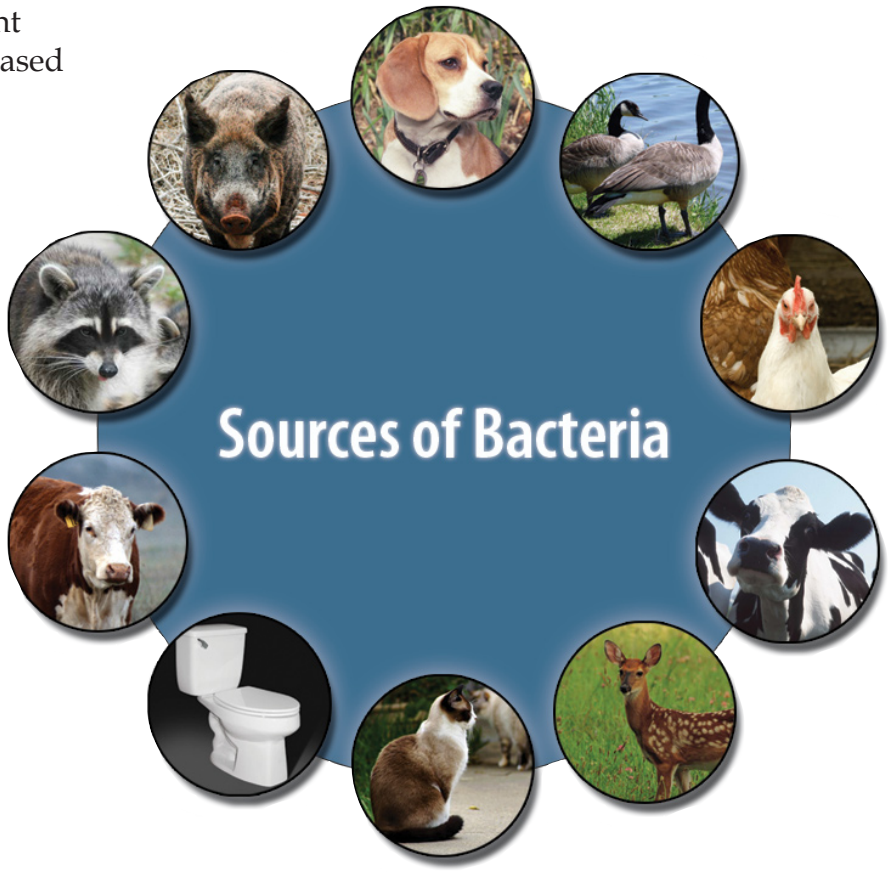

Figure 5. Bacteria in Texas waterways can originate from a variety of sources, including wastewater treatment facilities, wildlife, pets, and livestock. Illustration by Jennifer Peterson.

Bacteria in Texas waterways can come from many sources across the landscape (Fig. 5):

- Wastewater treatment plants, especially from plants that are not up to code or functioning properly
- Leaky septic systems
- Pet waste
- Runoff from neighborhood streets and parking lots
- Wildlife, including deer, rodents, and large flocks of birds resting on public waters
- Feral hogs (Table 1)
- Grazing livestock

One method to pinpoint the sources of fecal bacteria is bacterial source tracking (BST). This expensive process examines the DNA structure of bacteria to determine if it originated from human, livestock, wildlife, pet waste, or avian sources. Although still in its developmental stages, BST can be a useful tool in watershed planning.

The process was used recently to analyze bacteria found in Peach Creek, Copano Bay, and the Leon River in Texas. It found that, on average, cattle accounted for about 19 percent of the bacterial contamination, wildlife accounted for 26 percent, and humans (including via pets and septic

Table 1. Fecal coliform production for major classes of livestock and feral hogs (Wagner and Moench 2009).

Animal	Daily fecal production (lbs/day/AU)	Daily fecal production (g/day/AU)	Fecal coliform density (cfu/g)	Fecal coliform (cfu/AU/day)
Beef Cattle	82	37,195	2.30E+05	8.55E+09
Horses	51	23,133	1.26E+04	2.91E+08
Goats	40	18,144	1.40E+06	2.54E+10
Sheep	40	18,144	1.60E+07	2.90E+11
Hogs	65	29,484	3.30E+06	9.73E+10
Layers	63	28,576	1.30E+06	3.71E+10
Pullets	63	28,576	1.30E+06	3.71E+10
Broilers	82	37,195	1.30E+06	4.84E+10
Turkey	47	21,319	2.90E+05	6.18E+09
Deer	15	6,804	2.20E+06	1.50E+10
Feral Hogs	65	29,484	4.10E+04	1.21E+09

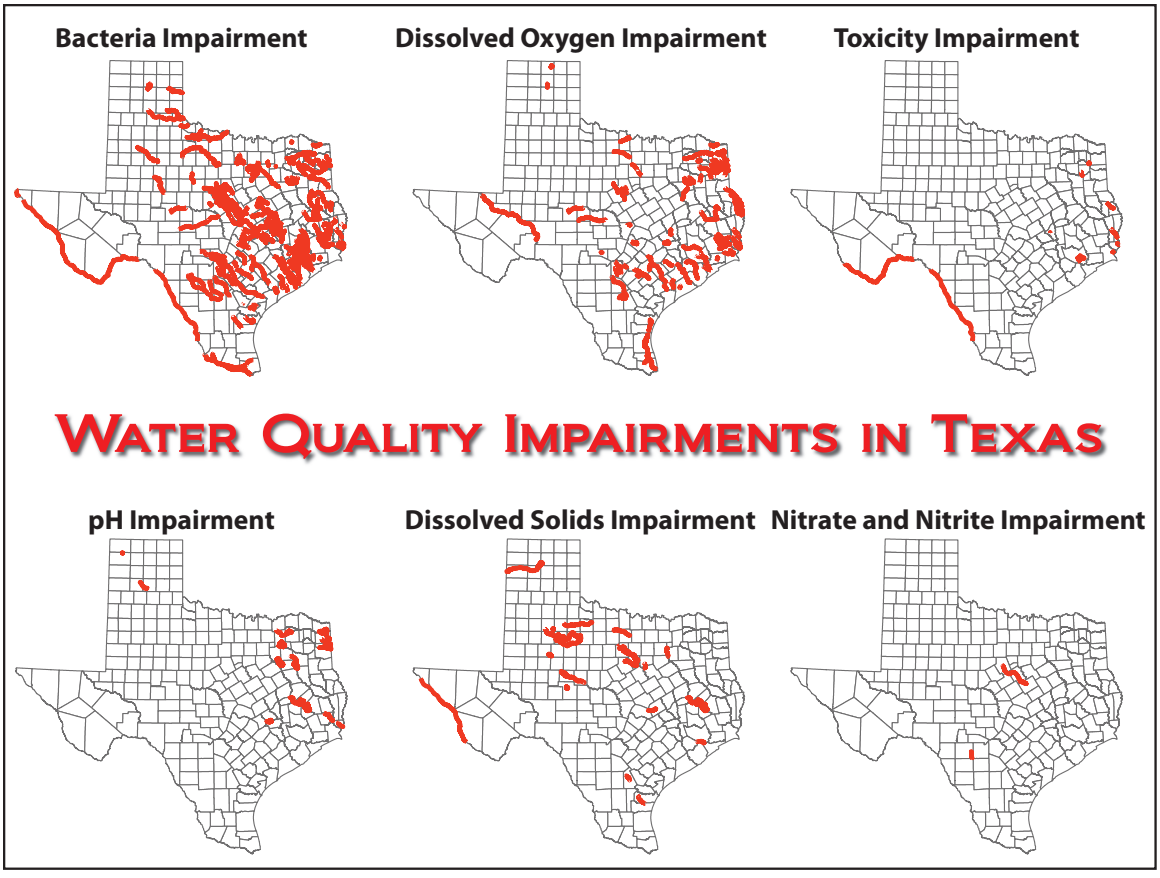

Figure 6. Types and locations of impairments in Texas water bodies. Source: TCEQ, 2008.

systems), 23 percent. In Peach Creek alone, non-avian wildlife (such as deer, raccoon, skunk, armadillo, possum, rabbit, feral hogs, and javelina) accounted for 29 percent of the bacterial contamination. Regardless of the source, excess bacteria levels are involved in more than 50 percent of the water quality impairments in Texas (Fig. 6).

Bacteria Fate and Transport

The behavior of bacteria in water is not well understood because it involves many complex factors in the environment and in the organisms themselves. As a result, it can be a challenge to reduce their levels in waterways.

Several processes affect the fate and transport of fecal bacteria (Table 2).

- **Fate processes** include growth (cell division), death by predation, and die-off.
- **Transport processes** include advection (horizontal transport), dispersion, settling, and re-suspension from the sediment bed.

Both processes are altered by temperature, pH, nutrients, toxins, salinity, and sunlight intensity.

Computer models (Soil and Water Assessment Tool, Hydrological Simulation Program-FORTRAN) can be used to simulate the fate and transport of bacteria at the watershed-scale, however, the predictive strength of these models depends highly on the accuracy of the data entered into the model. A better comprehension of the fate and transport of bacteria is needed to understand the potential impact of the contaminant and to more effectively develop management strategies in a watershed.

Benefits of Voluntary Conservation Practices

In Texas, feral hogs are considered exotic animals and, therefore, do not have protection as do game animals or livestock. As such, the landowner is primarily responsible for managing feral hogs on his or her property.

Voluntary use of effective hog management techniques and conservation practices can help improve water quality. Although improvements in water quality from landowners' efforts can take years to detect, these practices can often result in tangible benefits. The Statewide Feral Hog Abatement Project, funded by the Texas

Table 2. Potential survival of fecal pathogens in water and soil (Olsen 2003).

		Duration of Survival			
Material	**Temperature**	**Cryptosporidium**	***Salmonella***	**Campylobacter**	***E. coli* (O157:H7)**
Water	Frozen	>1 year	>6 months	2-8 weeks	>300 days
	Cold (5°C)	>1 year	>6 months	12 days	>300 days
	Warm (30°C)	10 weeks	>6 months	4 days	84 days
Soil	Frozen	>1 year	>12 weeks	2-8 weeks	>300 days
	Cold (5°C)	8 weeks	12-28 weeks	2 weeks	100 days
	Warm (30°C)	4 weeks	4 weeks	1 week	2 days

Legislature from 2006 to 2010 directly assisted landowners and agricultural producers with abatement of feral hog damage. The study found that the total statewide economic benefit from feral hog control was $4.46 million (Higginbotham et al. 2008). Another project conducted by the Texas AgriLife Extension Service found a $1.48 million reduction in feral hog damage after 3,799 feral hogs were removed over 2 years, saving $389.70 per hog removed (Feral Hog Project Accomplishments 2010).

Although the implementation of conservation practices is still voluntary and can require financial input by landowners, the benefits of having clean water resulting from these practices far outweigh the associated costs. The Lone Star Healthy Streams program aims to provide information to agricultural producers and landowners on practices that can help reduce bacterial contributions. These practices will enable the agricultural sector to do its part to improve water quality.

Chapter 2

Best Management Practices For Feral Hogs

Photo courtesy of the U.S. Fish and Wildlife Service

Like any other wild animal, feral hogs can harm land and water resources. Feral hogs reduce water quality by depositing feces directly into waterways and by rooting along riparian areas. In addition to contributing high levels of *E. coli*, feral hogs can also cause extensive damage to agricultural crops and forages, which can lead to erosion and soil loss. This erosion clouds streams, which alters the water temperature and makes it an unsuitable habitat for aquatic organisms.

To control and manage feral hogs, landowners need to understand how to recognize signs of feral hogs and the potential impacts that feral hogs can have on our watersheds. Landowners also need to know the voluntary best management practices (BMPs) that can help reduce fecal contamination of Texas streams and rivers. Besides ensuring better water quality for you, your neighbors, and Texas, these BMPs will help you maintain better land resources, improve watershed health, and increase property values.

The most effective time to control feral hogs is when they first appear on your land. Once populations become abundant, it is very difficult, if not impossible, to eradicate them. However, you can take a proactive approach by reducing their numbers and preventing their access to critical riparian areas.

Recognizing Feral Hog Sign

The first step in controlling feral hogs is to recognize their sign. Like most animals, feral hogs leave evidence of their passing. The most noticeable sign is the damage caused by their destructive rooting behavior. During a drought, rooting is minimal and other signs are more common, such as hog wallows, rubs (areas of mud rubbed on trees, fallen logs, fence posts, rocks, and utility poles), tracks, trails, droppings, and beds.

Hogs are very mobile and routinely travel from one field that offers cover to another field that provides food. To increase trapping success, look for signs to determine their key travel corridors, which include creeks, sloughs, ponds, and other water sources.

Rooting Damage
As feral hogs feed, they may severely damage native plant and animal communities as well as agricultural crops. Rooting damages lawns, gardens, hay pastures, and native range (Fig. 7). If the hogs disturb the vegetation and soil extensively, they can cause the type, diversity, and abundance of plants in the area to change.

Feral hog diets differ throughout the year, depending on the availability of a wide variety of foods. During drought, they compete with native wildlife for acorns, pecans, and other foods.

Crop Damage
Field crops commonly damaged by feral hogs include rice, sorghum, wheat, corn, soybeans, peanuts, potatoes, watermelon, and cantaloupe. Hogs not only consume planted seed, emerging seedlings, and maturing fruits and grains, but they also trample crops (Fig. 8).

Wallows and Rubs
During warm weather, feral hogs create wallows (Fig. 9) in moist areas near ponds, creeks, and sloughs to access mud, which helps them cool down and ward off biting

insects. In hot weather, hogs often lie in wallows during the day where they deposit waste that is likely to contribute bacteria and pathogens to stream systems.

After wallowing, hogs rub on fixed objects to remove dried mud, hair, and parasites. Look for mud and hair on trees, fallen logs, fence posts, rocks, and utility poles, particularly those near water or wallows. Hogs often rub against utility poles treated with creosote, and many poles within a hog's home range will have visible markings.

Tracks and Trails

Feral hog tracks and trails may yield information on hog numbers, animal size, direction of travel, and local behavior patterns. The hoofed tracks generally register two toes but may also show two dewclaws, which are smaller toes found higher on the leg.

Hogs have blunted or rounded toes, a trait that is apparent in their tracks. Deer tracks are typically heart or spade shaped; feral hog tracks appear more rounded (Fig. 10).

A well-worn feral hog trail indicates frequent use, and a lack of vegetation along the trail may suggest that many hogs use the path. Where trails cross under fences, the hogs often leave hair and mud on the wires as they pass underneath.

Droppings

Examining hog droppings can reveal what the hogs have been eating, which may help you determine the appropriate control methods or trap locations. Feral hogs eat both plant and animal matter, and their diet varies by location and season. For these reasons, feral hog droppings take

Figure 7. Feral hogs can cause damage to rural pastures and urban landscapes alike. Photo by James C. Cathey, Texas AgriLife Extension Service.

Figure 8. Feral hog damage to sorghum caused by both trampling and foraging. Photo by James C. Cathey, Texas AgriLife Extension Service.

Figure 9. Wallows can be found in wet areas during warmer months. Photo by James C. Cathey, Texas AgriLife Extension Service.

many forms, which can make identification difficult.

Hog droppings are often tubular and filled with mast (such as acorns and pecans) and other vegetation. The shape and consistency can resemble those of domestic dogs or horses. A diet of young grasses and shoots results in loose tubes and formless patties.

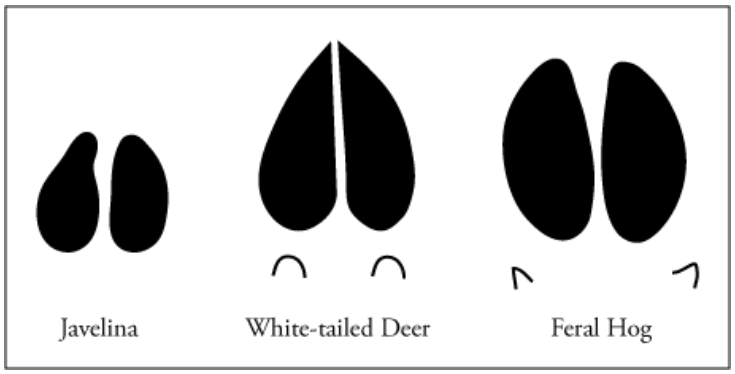

Figure 10. Track comparisons between javelina, white-tailed deer, and feral hog. Source: Taylor, 2003.

Beds

Hogs create shallow beds by overturning the soil to expose the cool dirt in which they rest. During the heat of the day, feral hogs spend a significant amount of time in beds. They typically bed in dense vegetation such as vines, brambles, fallen trees, and other thick or thorny plants. These areas offer security and shade and may be difficult to identify.

To find bedding locations, follow the hog trail into extremely thick vegetation. Hog beds are also often associated with wallowing areas.

Best Management Practices

Feral hog BMPs that help reduce bacterial concentrations include fencing, riparian area management, trapping, snares, hunting, and proper carcass disposal. These practices are not mutually exclusive. Often, a combination of practices will benefit you, your land, and your watershed the most.

Feral Hog Abatement Measures

Fencing. Fencing is one technique for keeping feral hogs out of waterways. If the hogs cannot access a waterway, they cannot deposit their waste directly into it. Of the control methods available for feral hogs, fencing is probably the most expensive and therefore, only applicable on smaller acreages.

Fencing large acreages seldom controls feral hogs permanently because they eventually find their way through most types of fences. Terrain is also a major consideration because canyons, creeks, and ditches can create problem areas in fence that hogs will find and pass through (Stevens 2010).

Fences can be made of chain link, mesh wire, mesh wire combined with electric fence, or multiple-strand electric wire. All have, to some degree, proven successful in keeping feral hogs out of water bodies. Research has found that electric fencing can reduce hog movement by an average of 65 percent compared to non-electric fencing (Reidy et al. 2008). Because no fence design is 100 percent hog-proof, it is most effective to use an integrated management program that combines electric fencing with other damage control methods.

Another study compared eight fence designs and found that net-wire fencing was the only hog-proof fence (Hone and Atkinson 1983). It also found that electric fencing can severely limit the movement of hogs across the landscape.

Research conducted by the Texas AgriLife Extension Service found that six 28-inch or 34-inch tall livestock panels staked with T-posts and arranged in a circle were enough to exclude feral hogs from wildlife feeding stations without limiting deer access.

If fences are built to keep feral hogs out of sensitive riparian areas, the bacterial contamination of water bodies can potentially be greatly reduced. Although studies have not yet been conducted on the direct connection between bacterial reductions, feral hogs, and fencing, research indicates that exclusionary fencing for cattle can reduce bacteria by 30 percent to 94 percent.

In addition to helping minimize bacteria levels in runoff, exclusionary fencing has also been found to provide the following benefits:

- Reduced stream bank destabilization and associated erosion due to trampling and overgrazing of banks
- Increased ability of the riparian vegetation to regrow and act as a full or partial buffer
- Reduced sediment and nutrient yields from streams draining pastures (Owens et al. 1996, Sheffield et al. 1997, Line et al. 2000).
- Reduction of stream turbidity (cloudiness) by 49 percent (Lombardo et al. 2000)
- Increased height and vigor of riparian vegetation (Odion et al. 1988, Kondolf 1993, Knapp and Matthews 1996, Kauffman et al. 1997, Dobkin et al. 1998, Ranganath et al. 2009)
- Reduced annual sediment concentration by more than 50 percent and loss of soil by 40 percent (Owens et al. 1996)
- Reduction of total phosphorus levels by 76 percent and sediment loads by 82 percent as a result of stream bank fencing (Line et al. 2000)

Fence costs vary according to the material used, the length needed, and the terrain where they are installed. According to the Natural Resources Conservation Service (NRCS), permanent electric cross fence costs about $1.80 per foot (on normal soils), four-strand barbed-wire cross fence costs about $2.55 per foot (on normal soils), and four-strand barbed-wire fence costs about $3.11 per foot (on steep or rocky soils).

In the study conducted by the Texas AgriLife Extension Service, T-posts, T-post clips, and 28-inch and 34-inch livestock panels (six panels needed for the design) were $187 and $190, respectively. Fortunately, the NRCS and the Texas State Soil and Water Conservation Board (TSSWCB) offer financial assistance programs to help landowners with exclusionary fencing (financial assistance not available for boundary fencing).

Other incentives provide rental fees for the areas excluded (up to $259 per acre) to further encourage the protection of riparian buffers. For more information on exclusionary fencing and available financial assistance programs, contact the NRCS office at your local U.S. Department of Agriculture (USDA) Service Center (http://offices.sc.egov.usda/gov/locator/app?agency=nrcs).

Riparian Area Management. Riparian area management can be used to protect critical riparian zones that can help reduce bacterial contamination in runoff from land known to provide habitat for feral hogs. Feral hogs prefer riparian areas and can cause great destruction to the vegetation that helps

stabilize slopes and stream banks and filter out pollutants. To adequately protect water quality, feral hogs need to be removed so that riparian areas can be protected and allowed to function properly. If hogs are not removed, this practice will likely increase their population as their habitat will be enhanced.

Maintaining streamside buffers and incorporating the use of filter strips and other vegetative barriers will help lower and even remove bacteria from runoff. A filter strip or streamside buffer is an area of herbaceous vegetation that is established between a body of water and cropland, grazing land, or disturbed land. It is designed to remove sediment, bacteria, organic material, nutrients, and chemicals from overland flow. A filter strip works by slowing runoff, which allows the contaminants to settle out, infiltrate, and be dispersed across the width of the filter strip (Fig. 11).

In addition to improving water quality, filter strips can also improve soil aeration, provide wildlife habitat, provide shade that improves soil moisture content, and recycle nutrients that promote plant growth (Green and Haney 2005).

For adequate protection, filter strips should have specific minimum widths, which vary according to the slope of the land (Table 3).

Table 3. Minimum widths for vegetative filter strips. Standards and Specifications No. 393, USDA-NRCS Field Office Technical Guide, 2004.

Slope	Minimum Width of Buffer Strip
1–3%	25 ft
4–7%	35 ft
8–10%	50 ft

Their effectiveness of filter strips depends on:

- The amount of sediment that reaches the filter strip
- The amount of time that water is retained in the filter strip
- The steepness, length, and slope of the filter strip
- The infiltration rate of the soil
- The type and density of vegetation used in the filter strip
- The uniformity of the water flow through the filter strip
- The correct installation and maintenance of the filter strip (Smith 2000)

Research has found that filter strips can reduce up to 99.995 percent of bacteria in runoff from land where beef and/or dairy cattle are present (Table 4). In addition, filter strips are effective in removing other contaminants, including atrazine, herbicides, nitrate-nitrogen, sediment, soil, and total phosphorus (Fig. 12). They also stabilize the soil, provide shade to help the soil hold moisture, and protect it from the eroding forces of wind, water, and raindrop impact.

The costs of establishing a filter strip vary according to seed, fertilizer, labor, and equipment costs. The NRCS estimates that filter strip installation can cost from $275 to $310 per acre, depending on whether native or nonnative plants are used. However, in many instances, a landowner need only change the stocking rate and/or grazing system to encourage filter strips to develop naturally.

The NRCS offers technical and financial assistance programs to offset up to 50 percent of the cost of implementation. For more information, contact the NRCS at

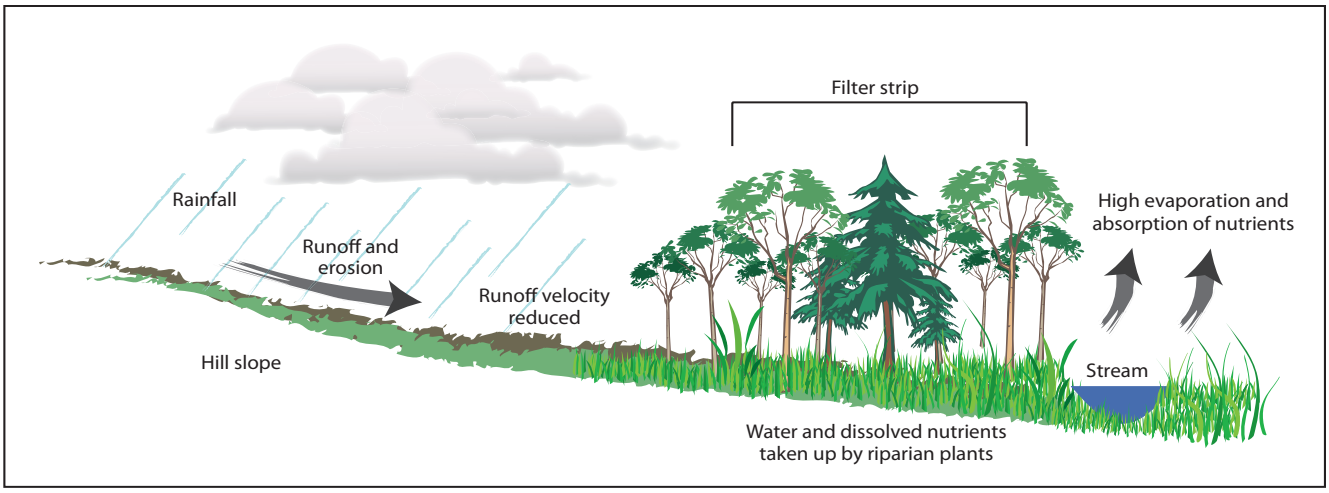

Figure 11. Conceptual model of how vegetative filter strips protect a stream from contaminants and the riparian area from erosion. Illustration by Jennifer Peterson.

http://offices.sc.egov.usda/gov/locator/app?agency=nrcs.

Trapping. Trapping is probably the most commonly used control method for feral hogs. A rigorous trapping program can reduce feral hog populations by 80 percent to 90 percent (Choquenot et al. 1993).

Once trapped, hogs can be cooked and consumed or taken to an approved holding facility that will either harvest the hogs or sell them to an authorized hunting preserve (depending on the gender of the hog).

Of the many types of trap designs, the most common are box and corral-type traps.

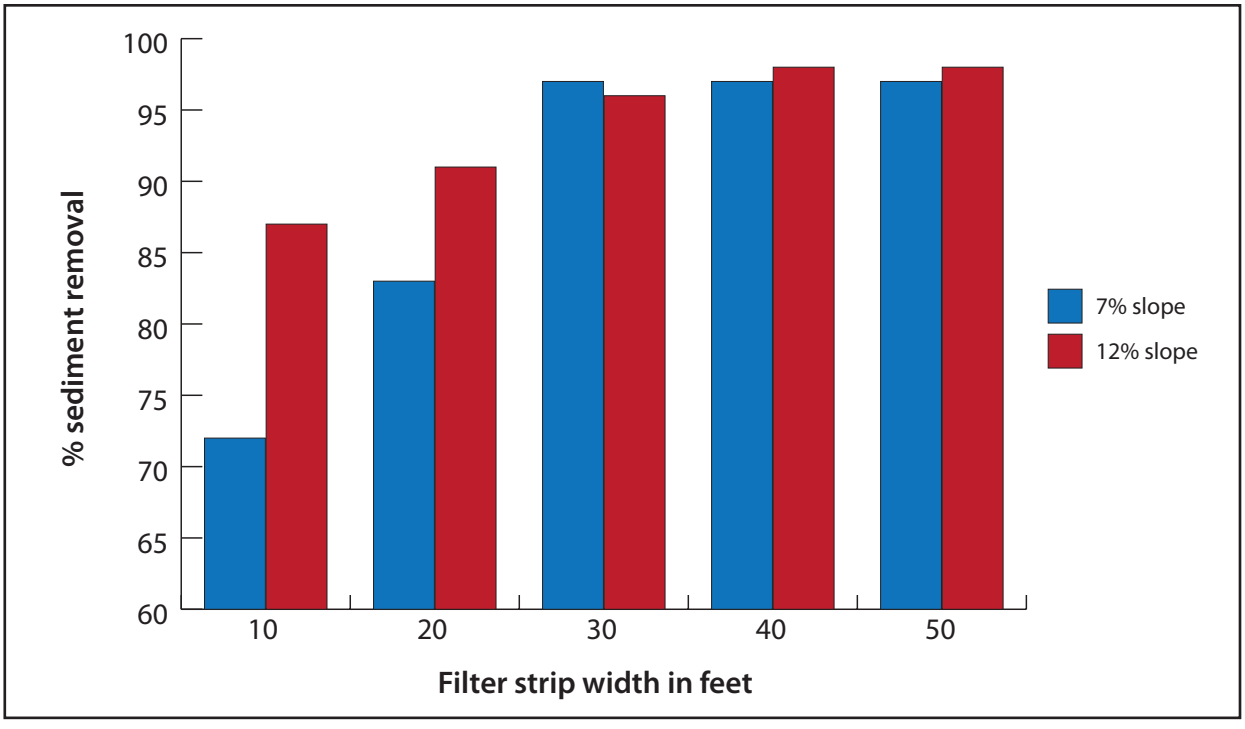

Figure 12. Percent sediment removed by a vegetative filter strip based on the width of the filter strip (Schultz et al. 1992).

Table 4. Effectiveness of filter strips in removing different kinds of bacteria from runoff.

Type of Bacteria	Reduction	Source
E. coli	99.7%	Casteel et al. 2005
	94.8%-99.995%	Tate 2006
	91%	Mankin and Okoren 2003
	57.85%-98.9%	Goel et al. 2004
Total coliform	97%-99.4%	Casteel et al. 2005
	81%	Cook 1998
	69%	Young 1980
	66.89%-92.12%	Goel et al. 2004
Fecal coliform	100%	Lim et al. 1998
	99%	Sullivan 2007, Lewis et al. 2010
	87% and 64%	Fajardo et al. 2001
	83.5%	Mankin and Okoren 2003
	83% and 95%	Larsen et al. 1994
	81%	Stuntebeck and Bannerman 1998
	75% and 91%	Coyne et al. 1998
	69%	Young 1980
	67%	Roodsari et al. 2005
	55.59%-99.78%	Goel et al. 2004
	43% and 72%	Coyne et al. 1995
Fecal streptococci	83.5%	Mankin and Okoren 2003
	76%	Cook 1998
	74% and 68%	Coyne et al. 1998
	70%	Young 1980
Cryptosporidium parvum	99.9%	Atwill et al. 2002
	99.4%	Trask et al. 2004
	99%	Mawdsley et al. 1996
	97%	Miller et al. 2008
	93.5% to 99.4%	Tate et al. 2004
Giardia	26%	Winkworth et al. 2008

Box traps. Box traps can be used to remove a few feral hogs or to trap in a relatively small area. These traps can serve as a first strike in combination with larger traps and other techniques. However, box traps are not effective for removing multiple animals at a time.

Because of their size, box traps offer three main advantages:

- They are relatively easy to move and can be set quickly.
- They can easily fit in the bed of a pickup truck or on a small trailer.

- They are easily handled and moved, so one person can quickly place traps in areas with fresh hog activity.

Box traps also pose disadvantages because of the amount of time, energy, and expense they require and the small number of animals they capture:

- Box traps require pre-baiting, which can be expensive and time consuming.
- Many box traps are needed to significantly reduce hog numbers.
- A box trap may catch only one or two adult pigs; to capture larger groups of pigs, other approaches are needed.
- Box traps can occasionally catch nontarget animals such as deer and calves.

Box traps come in a variety of designs and shapes. Most are built from livestock panels with steel pipe or angle iron frames. Because most traps are built by the users, they differ greatly in size, portability, door configuration, flooring, and roofing. In some areas, ready-to-use box traps and different styles of gates can be bought.

A common design is a 4- by 8-foot, heavy-duty cage (Fig. 13). This trap is typically 3 to 4 feet tall, and a top is recommended to keep the hogs from crowding in the corners and climbing out. If the trap is fully enclosed with a top and a floor, the trapper may be able to transport a live hog without removing it from the trap.

However, all box traps—particularly those without floors—require T-posts to anchor them, adding materials that increase the cost and may deter a hog from entering the trap.

The gate should be designed to prevent the captured hogs from escaping through the trap entrance. Three gate designs are among those most commonly used for box traps:

- Sliding drop (guillotine) gates use a trip wire to trigger the door to fall. One drawback of these traps is that they prevent additional pigs from entering once the trap has been sprung.
- Lifting (top-hinged) gates require that a hog use its nose to root or lift open the door.
- Spring-loaded swing gates use a heavy spring to close the door after the hog pushes its way into the trap.

Swing and lifting gates offer the advantage of allowing more than one hog to be trapped at a time. The first captured hog may serve as a lure to attract additional hogs. However, only one or two adult pigs typically are trapped at a time, because the box trap is small. Sometimes a litter of small pigs may be captured.

Box traps can be an effective tool as part of a broader feral hog management strategy. Consider using them for removing one or two adult animals at a time.

Figure 13. Box traps vary in size and construction. A common design includes a 4- by 8-foot cage built with durable materials. Photo by James C. Cathey, Texas AgriLife Extension Service.

Corral traps. Corral traps can reduce hog numbers numbers quickly. They can capture more than four times as many hogs as can box traps (Williams et al. 2011). Other advantages include:

- They can capture an entire group, or sounder, of feral hogs.
- If a deer is captured, the open trap allows it to escape.
- They can be placed in key areas that hogs will return to in the future.

Corral traps also have a few disadvantages, however:

- The materials can be expensive and the construction time-consuming.
- They are not easily disassembled and moved; they are not portable as a unit.
- Pre-baiting can be expensive and time-consuming.

Most corral traps are made of 20- by 5-foot sheep/goat panels with 4- by 4-inch square mesh and steel T-posts. This type of panel prevents smaller pigs from escaping (Fig. 14).

Many door designs are available for corral traps. The best design for your situation depends on the amount of time available, the number of hogs present, the degree of labor required, and the cost of the materials.

Large sounders are seldom caught in small corral traps, and the hogs that escape or are not captured may become wary of them in the future. Although small traps do catch hogs of all sizes, they are not the most effective method for capturing many hogs. For these situations, a large teardrop-shaped trap is best. This design also serves as a chute for loading the hogs into a trailer.

Corral traps are versatile, and their use can be adjusted according to the situation. Some designs do not require a gate or door (Fig. 15). This trap consists of two panels, each at least 16 by 5 feet with 4- by 4-inch mesh, and eight T-posts. One panel forms the shape of a stretched "C." The other panel forms a tight "C" with the ends touching the stretched "C" panel. T-posts are driven around the outside of the panels for extra support. A T-post should also be placed at each end where the panels touch, wired only at the top of the tight "C" panel. This configuration forms a chute on each side. The trap interior and both chutes are baited. As the hogs try to get the bait inside the trap, they push in the bottom of the tight "C" panel, allowing access to the trap interior. Once inside, hogs find themselves in a circle and cannot push out of the entrance because of the resistance exerted by the outside panel.

This trap type is useful and extremely variable—it can be modified in many ways, including the figure-6 and heart-shaped or

Figure 14. A corral trap constructed with steel panels, t-posts, and a double spring door. Generally, the larger the corral trap, the better it works. Photo by James C. Cathey, Texas AgriLife Extension Service.

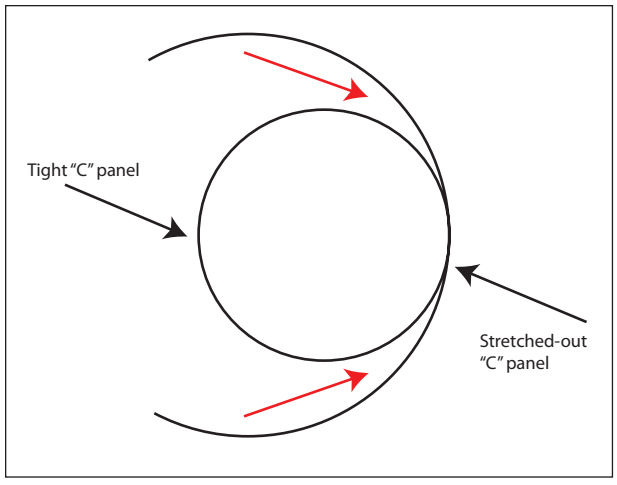

Figure 15. Two panels and a minimum number of T-posts can be used to build a simple yet functional corral trap that does not require a gate. Illustration by James C. Cathey, Texas AgriLife Extension Service.

Wexford traps. "Push-in" designs probably do not catch trap-shy animals very well. Loading pigs into a trailer is more difficult with these designs than with using corral traps that have head gates.

The trap needs to be large enough for hogs to back away as you approach the trap. The trap should not have corners because hogs tend to congregate in them and may escape over the top of the panel. Support the trap every 4 feet by T-posts and leave no gaps along the bottom that would allow the hogs to escape.

Corral traps are extremely effective in reducing feral hog numbers, especially when used in conjunction with other control methods. Although they require more effort to install and maintain, they can capture many hogs at a time. Table 5 summarizes the pros and cons of box and corral traps.

Placing feral hog traps. For traps to be most effective, they must be properly placed on or along hog trails that link resources such as food, cover, and water (Fig. 16).

Aerial photographs can show how these resources are distributed across the landscape, which will help you place the traps strategically. Photos can be obtained through the USDA or with free software such as Google Earth (http://earth.google.com).

Before setting a trap, scout the property for hog sign: trails, scat (dung), wallows, hog damage, and rubs. In areas where

Table 5. Pros and cons of box and corral traps (Hamrock et al. 2011).

Type of Trap	Pros	Cons
Box Trap	• easy to construct • cheaper than commercial steel traps • requires less space for transport and storage • quick setup with wood screws and a cordless drill	• catch size/trapping effort limited • wood panels appear more confining than wire panels • wood requires more long-term maintenance than wire panels • not conducive to one=person transport and setup
Corral Trap	• trap size easily adjusted for larger sounders • open top allows for escape of nontarget species • trap appearance and open top may appear less confiding to pigs	• requires more setup time than cage or box traps • livestock panels may need to be cut in half for transport • tree roots in wooded areas can pose a problem for driving and pulling T-posts

Figure 16. A well-traveled feral hog trail passes under a fence between two properties. This trap is set along a known feral hog trail and is equipped with saloon-type doors on both ends. Photo by James C. Cathey, Texas AgriLife Extension Service.

hogs are abundant, they will create visible paths. Often the easiest form of hog sign to locate and identify is the damage caused by rooting. However, do not place a trap where there is ongoing rooting damage by hogs because the bait will compete with the food source that the hogs are already using, and hogs tend to prefer a familiar food source.

A better approach is to place the traps along trails to and from these areas. Fence lines are good places to start. Hogs often create crawls under fences and leave mud or hair on fence wires when crossing. They may also bend the bottom wires up into a visible arc. If a trail is well established or has significant traffic, it may be heavily eroded.

In some cases, the hogs may just be passing through one property to gain access to a feeding area on another property. If so, determine where the hogs are entering the property and set the trap nearby. Use landscape features to hide the trap as much as possible, or set the trap near a fence line.

Even if no hog trails are evident, ideal trap locations still exist. Feral hogs often travel along creeks and roads and use cover near overgrown fence lines while traveling. These areas funnel feral hog travel and provide excellent places to set corral traps, particularly if they lead to a feeding area.

Other good sites for corral traps are areas frequented by feral hogs throughout the year, such as watering holes, wallowing areas, and utility poles. If possible, place the hog traps upwind from bedding areas used by the animals during the day. This placement will allow the wind to disperse the scent of bait to attract hogs from farther away.

Baiting feral hog traps. No toxicants, fertility agents, or biological control chemicals are legally registered for use against feral hogs in the United States. It is illegal to use toxicants with feral hog baits. Baiting strategies should lure the animals into corral or box traps. Common baits are whole corn, livestock cubes, carrion, sour grain, and commercial hog attractant scents.

If corn is used, nontarget animals such as deer may be captured. Soak the corn in water for 1 week to cause it to sour; the strong odor will deter other animals from feeding on it.

Regardless of bait type, trapping may be less successful if acorns or other readily available natural foods are abundant.

Hog bait recipe. If whole corn does not attract feral hogs, use the following recipe developed by the Georgia Department of Natural Resources:

- 150 pounds of corn
- 8 pounds of sugar

- 1 packet of yeast
- 4 or 5 packets of grape, strawberry, or raspberry flavored gelatin or drink powder

Place the corn in a 40-gallon metal trash can and fill it with water to 3 to 4 inches above the corn. Mix in all the other ingredients. Place the trash can in the sun with the lid secured. Stir it with a shovel or paddle daily for 10 to 14 days. Take care not to spill the product on your clothes. Ladle the bait in and around the trap and replenish it as needed.

Other baits include:

- Corn fermented in beer
- Bread fermented in water
- Dry dog food
- Ripe fruit
- Commercially available baits and scents
- Flour

Pre-baiting. For all feral hog traps, it is critical to pre-bait, which is to place bait in a trap for a period of time before setting the trap. Pre-baiting will attract animals and accustom them to entering the trap.

1. Start by placing bait near the opening and inside the trap (Fig. 17).
2. As the hogs begin to routinely enter the trap, continue pre-baiting inside the trap for a few more days to ensure that the entire sounder is comfortable entering the trap.
3. A game camera is useful for monitoring the number of hogs entering the trap, and it provides information on the best time to set the trap.
4. When the trap is ready to be set, place the bait all the way back to the trigger.

Figure 17. Pre-baiting increases the probability of catching a large number of hogs. Start by placing bait outside and through the gate opening of the trap. Photo by James C. Cathey, Texas AgriLife Extension Service.

Do not scatter it directly along the trip wire, as this may cause the hogs to trigger the gate before all of the animals have entered the trap.

Trapping tips. Some tips include:

- Pre-bait traps to increase your chances of success.
- Build or use large traps; the bigger the better.
- Avoid leaving human scent in and around traps.
- If possible, check the traps from a distance.
- Vary the baits. Hog preferences may change over the course of the year.
- Refresh the baits by spraying them every 2 days with a strawberry gelatin/water mix from a pump sprayer.
- Share gates with your neighbors. Install the gate only after the hogs respond to pre-baiting.
- Trapping feral hogs is a process, not a single event. Be persistent!

*State regulations for trapping feral hogs.*The Texas Animal Health Commission regulates the holding and transportation of feral hogs from the property where they were captured. Female feral hogs—sows and gilts— cannot be transported and released onto another property. They must be held (for up to 7 days) in an escape-proof pen or trailer. They can then be taken directly to a processing facility or sold to an approved holding facility which will then harvest them. Male feral hogs—boars and barrows—can also be held for up to 7 days in an escape-proof pen or trailer and may be taken directly to a processing facility or sold to an authorized holding facility. That facility can take them to harvest them or sell them to an authorized hunting preserve.

Follow the appropriate regulations if you plan to transport captured hogs to a holding facility or a processing plant. For more information on these regulations, see http://www.tahc.state.tx.us/animal_health/swine/swine.html.

Cost of implementation. The costs for box and corral traps vary, depending on the materials used, the size of the trap, and the labor required to build them (Table 6). On average, box and corral traps usually cost between $320 and $460 to build.

The costs in Table 6 include non-recurring costs such as the initial purchase price of all traps and trap materials, salaries explicitly designated for trap removal, and travel costs. Many landowners and managers may not encounter these costs. Should this be the case, the traps would cost $142.12 per pig for box traps and $28.91 per pig for corral traps. Following is a more detailed cost estimate for different types and sizes of corral traps (Pleasant 2007):

- Cost estimate for large teardrop corral trap:
  - 10, 60″ X 20′ utility panels (4″ x 4″ mesh) at $46.50 each: $465.
  - 5 T-posts per panel, plus 5 more to string trip wire (55) 6.5′ T-posts at $3.75 each: $206.25
  - Trap gate: $75.00.
  - Total trap cost: $746.25

- Cost estimate for a small teardrop trap:
  - 7 utility panels (4″ x 4″ mesh) at $46.50 each: $325.50
  - 5 T-posts per panel, plus 4 more to string trip wire (39) 6.5′ T-posts at $3.75 each: $146.25
  - Trap gate: $75.00
  - Total trap cost: $546.75

- Cost for small circle corral trap (used when not trailering hogs):
  - 5 utility panels (4″ x 4″ mesh) at $46.50 each: $232.50
  - 5 T-posts per panel, plus 2 more to string trip wire (27) 6.5′ T-posts at $3.75 each: $101.25
  - Trap gate: $75.00
  - Total trap cost: $408.75

Summary. Box traps and corral traps can be effective management strategies to control feral hog numbers, especially when used in conjunction with other control methods. Though they require some effort to install and maintain, these traps can effectively capture large numbers of hogs and help reduce associated damage in critical riparian areas.

Snares. Snares can be used where you need to capture a few feral hogs inexpensively

Table 6. Approximate per-pig costs associated with wild pig trapping at Fort Benning, 29 February-29 April, 2008 (Williams et al. 2011).

Trap Style	Trap nights[a]	New captures[b]	Trap costs	Half additional costs[c]	Total approximate costs	Cost per pig
Box	252	12	$4,200	$3,855.70	$8,055.70	$671.31
Corral	252	59	$3,300	$3,855.70	$7,155.70	$121.28

[a] 21 nights of trapping x 12 traps of each style. Cost per box trap is $350 ($4,200/12) and cost per corral trap is $275 ($3,300/12).
[b] Unique individuals only; excludes recaptures.
[c] Total non-trap-related costs ($7,711.40; includes labor, travel, and bait expenses)/2; assumes approx. equal labor and travel expenditures for each style of trap, as we placed, constructed, and visited traps arbitrarily each day of preparation and trapping.

and with little maintenance. Snaring has several advantages:

- It is relatively inexpensive and does not require pre-baiting.
- Snares can catch trap-shy hogs effectively.
- They can be used in a variety of situations.
- They can be set quickly and easily and require very little maintenance.

Snares can also have some disadvantages:

- They capture only one hog at a time.
- They have a high risk of capturing nontarget species.
- They are not appropriate where there are no anchor points.
- Large hogs can break snares.

A snare consists of a loop of steel cable attached to a secure object and placed so that the loop catches the animal as it passes through a confined space. Use a 1⁄8-inch galvanized steel cable to prepare a snare for feral hogs (Fig. 18). The snare should have a sliding lock device allowing the loop to close but not open easily. Snares can be constructed for as little as $5/snare.

To minimize the chances of a captured animal breaking the cable, use a heavy swivel on the end of the cable that is attached to an anchored structure such as a fence post, tree, or utility pole.

In most situations, you will need to install a deer stop, which is a device that prevents the snare from closing past a certain point, allowing a captured deer to pull its leg out of the snare. Crimp a single ferrule, small nut, or other similar hardware to the snare cable to ensure that the snare does not close around the leg of a nontarget animal.

To make snares easier to conceal, use one of the following approaches:

- Boil new snares and extension cables in water with detergent and hang them

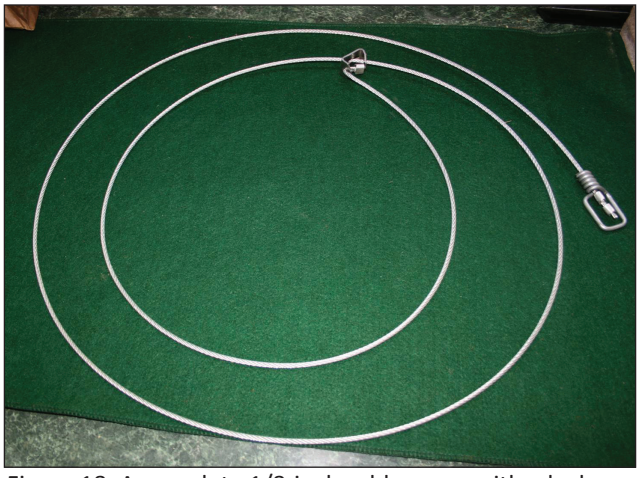

Figure 18. A complete 1/8-inch cable snare with a lock and end swivel for capturing feral hogs. Photo by James C. Cathey, Texas AgriLife Extension Service.

outdoors for a few months until they turn a dull gray.

- Boil the snares in 4 tablespoons of baking soda for 1 hour to age their appearance.
- Dye the snares a dark color by boiling them in brown logwood crystals and dye. Commercial dyes are available from trap supply dealers.

After boiling the snares, keep them free of odors. Store them in a container with cedar boughs, broomweed, or other natural smells. To avoid scent contamination, wear clean gloves when handling and setting snares.

Appropriate sites for snares are like those for traps: Look for animal travel ways (trails) or crossings under fences surrounding pastures or crop fields. Snares for capturing feral hogs are commonly placed under fences where hogs are known to cross. A game camera can also help determine feral hog behavior in the area and identify the optimal sites for snare placement.

To prevent captured hogs from damaging a fence or the landscape, use a cable extension to attach the snare to a large log, uprooted stump, or similar weighted object, which then serves as the drag. Do not tie a snare directly to the fence wire.

The swivel end of a snare is most often tied with a doubled or tripled length of tie wire to a drag or secure anchor point. Suspend the snare's loop from the bottom of the fence with U-shaped wire clips or a single wrap of small gauge copper wire so that the loop pulls free easily when the animal passes through it.

In areas where there is little risk of capturing sheep, goats, calves, deer, or other nontarget animals, snares can be set in trails used by hogs. Snares can also be set directly hog rubs such as utility poles, bridge pilings, or trees near wallowing areas.

An advantage of setting snares on rubs is that you are much less likely to catch nontarget species. Also, you can set multiple snares in known wallowing areas where rubs are common, increasing the potential for capture.

To hang the snare, bend a flexible yet durable piece of wire (such as bailing wire or a clothes hanger) into an inverted S-shape to support the snare (Fig. 19). For extra support, angle the tail end of the wire down into the tree or post. This method also ensures that the support wire does not slip.

When setting the snare, place the lock at either the 11 o'clock or 1 o'clock position to ensure that the snare triggers properly when a hog enters the loop.

Figure 19. Closeup of snare brace hanger. A brace made from a clothing hanger or other heavy wire can be used to set a snare at a rub location or a known feral hog trail. Photo by James C. Cathey, Texas AgriLife Extension Service.

To catch a 30-pound hog, make a loop about 10 to 12 inches and suspend it 7 to 8 inches off the ground. Increase the loop size and height to catch larger hogs; a loop of 20 inches or more may be appropriate. If the snare is not long enough, use cable extensions to attach it to a tree, drag, pole, or steel stakes driven into the ground.

Follow these guidelines to avoid capture nontarget species:

- Avoid setting snares on trails used by livestock and other nontarget animals.
- Do not set snares under fences where deer or dogs are known to pass.
- Keep detailed records on the locations and number of snares so that all can be found.
- Remove the snares when they cannot be checked often.

State regulations. Because snares are likely to capture other animals, it is recommended that you get a hunting license, which is required for snaring animals such as bobcats, raccoons, and opossums.

When snaring feral hogs in Texas, you are not required to have deer stops, but it is a good idea to do so. It is illegal to snare deer. For more details on using snares to control feral hogs, see the hunting laws outlined in the Texas Parks and Wildlife Department (TPWD) Outdoor Annual (http://www.tpwd.state.tx.us/publications/huntwild/hunt/) and contact the TPWD local game warden.

Summary. Snares can be an important part of a feral hog management strategy. Although they can capture only one animal at a time and risk taking nontarget species, they can be an inexpensive, low-maintenance approach applicable to many different situations.

Shooting and Hunting. Shooting and hunting are two common methods used to control feral hog populations. Shooting can be part of a recreational hunt or part of a population control program. In both cases, the shooting program must be carried out consistently and vigorously to have the best chance of reducing populations and associated damage.

Research from dozens of studies conducted on feral hogs has found that hunting can remove between 8 percent and 50 percent of a population, with an average of 24 percent across all studies. To stabilize a population of hogs and prevent any growth, you will need to remove 60 percent to 70 percent of the population every year (Burns 2011). In recent years, hunting feral hogs for sport has gained popularity as a recreational opportunity for hunters, as a source of income for landowners, and as a control option for wildlife managers. Because of the highly prolific nature of feral hogs and the typical selection of adult hogs during sport hunts, this option alone may not be enough to reduce populations significantly (Bieber and Ruf 2005).

Hunting feral hogs uses the same techniques for white-tailed deer. Stand hunting or still hunting can be conducted in baited areas or in areas with abundant fresh hog sign (Mapston 2007). Supplemental feeding sites and deer feeders will attract feral hogs making them easy to shoot. If the hunting pressure is intensive, the hog populations can shift and their feeding habits can change, which can reduce hunter success rate (Barrett and Birmingham 1994).

Hunting with dogs. Trained dogs can be used to locate individual or small groups of hogs. However, studies have shown that dogs can cause pigs to move into nearby areas and simply relocate their damage (Barrett and Birmingham 1994). However, hunting with dogs could be a viable management option if the area vacated by the hogs is of particular concern or needs specific protection (Engeman et al. 2006, Hayes 2007, Gaston 2008).

Poorly trained dogs, inexperienced hunters, hot weather, injuries, and the costs associated with dogs, their training, and their care are all factors that need to be considered. Feral hogs can seriously injure or kill dogs.

Figure 20. Aerial shooting of feral hogs can be an effective management measure. Photo by Eric Gay, Associated Press.

Aerial shooting. Aerial shooting is typically done from a helicopter and has been very effective in areas with low-growing vegetation, gentle topography, and mild climates (Fig. 20, Hone 1983). Permits and licenses are required. Although aerial hunting is costly ($300 or more per hour flown), it is so effective in areas with high feral hog populations that it usually ends up being the most cost-effective option. As the hog populations decline however, it produces diminishing returns and other options such as trapping and snaring should be used (Choquenot et al. 1999). Aerial hunting can be risky because of low-elevation flying, rough terrain, poor weather, and heavy cover.

State regulations. The Texas Parks and Wildlife Department regulates hunting in Texas, and a hunting license is required to take feral hogs. However, this requirement is waived if the landowner, landowner's agent, or lessee (if given landowner permission) takes feral hogs causing damage or depredation on the property. A hunting license permits the use of firearms, snaring and trapping.

Mortality Management

Feral hog carcasses must be disposed of properly for hygienic, environmental, and aesthetic reasons (Gould et al. 2002). Mortality management will provide the following benefits:

- Less pollution of groundwater and surface water.
- Reduced odors from improperly handled carcasses.
- Reduced damage to crops and forages.
- Decreased risk of diseases spreading to animals feeding on the carcass.

If you do not plan to eat, sell, or transport the hog after it has been killed, dispose of it properly. Place the carcass far enough away from a water body to prevent contamination. Because a dead carcass will likely attract other animals to feed, moving the carcass away from a water source will eliminate the direct deposition of bacteria, nutrients, and other contaminants by these animals as well.

Conclusion

Many important responsibilities accompany land ownership and although these activities can take much time and effort, the benefits are far-reaching. Feral hogs in Texas are environmentally harmful. Implementing BMPs that protect the environment will result in a healthy farm or ranch that saves money and is aesthetically pleasing.

Texas is projected to have explosive population growth in the near future. Concurrently, our water supply is projected to decline, making water conservation and protection all the more important. As the population increases, more land will be developed and more large tracts will be divided. These changes will increase the amount of rainfall runoff and decrease the ability of our land to filter runoff effectively.

Although this guide focuses on feral hogs as potential nonpoint sources of pollution, there are many other sources such as wastewater treatment facilities, failing septic systems, and urban runoff. All sectors of society must understand the importance of maintaining and conserving the quality of water in Texas.

Feral hogs will continue to be a challenging problem for farmers, ranchers, landowners, and others across Texas. Populations of this exotic species have continued to rise over the last few decades despite ongoing control programs. The most successful management strategies will employ an integrated approach, using diverse control techniques including fencing, trapping, snaring, and hunting over a sustained period of time.

Landowners will continue to play a critical role in the management and control of feral hogs since the majority of Texas is privately owned. Become knowledgeable about what you can do on your land to help control feral hog damage and to also help improve water quality and watershed health for you and the other citizens of Texas.

Chapter 3

Agencies and Organizations Involved in Feral Hog Management in Texas

Photo courtesy of the U.S. Fish and Wildlife Service

Several agencies and organizations offer technical assistance and some limited funding opportunities to Texas landowners trying to manage feral hogs on their property. Remember: Landowners are the first line of defense in controlling feral hogs.

Although trapping and other control methods can be expensive, landowners can recoup some of these costs by leasing hunting rights on their property or by selling live hogs to an approved processing facility that pays for hogs on a per-pound basis. Although several third-party groups offer hunting and trapping services in Texas, this section focuses on state and federal agencies and organizations that offer technical advice on feral hog management strategies.

Texas Wildlife Services
Texas Wildlife Services is the state-level component of the U.S. Department of Agriculture–Animal and Plant Health Inspection Service (USDA–APHIS) Wildlife Services. Wildlife Services provides federal leadership and expertise to resolve wildlife conflicts and enable people and wildlife to coexist. It presents programs, conducts research, and carries out other activities through its national programs, regional and state offices, and the National Wildlife Research Center and its field stations.

In Texas, Wildlife Services is a cooperative program of USDA–APHIS, the Texas AgriLife Extension Service, and private and public funding partners. Their top research goals are to improve management methods for feral hogs and to monitor the state for disease occurrences related to wildlife. For landowners and managers, Wildlife Services provides technical and direct control assistance related to feral hogs. The agency employs technicians, or country trappers, to help rural and urban landowners trap a variety of wild animals, including feral hogs.

For more information, visit the Texas Wildlife Services website at http://www.aphis.usda.gov/wildlife_damage/state_office/texas_info.shtml.

Texas AgriLife Extension Service
The Texas AgriLife Extension Service (http://agrilifeextension.tamu.edu/) provides community-based education to Texans. Its network of 250 county Extension offices and 900 professional educators makes expertise available to every resident in every Texas county. These specialists and agents serve as technical resources for landowners and agricultural producers dealing with feral hog management.

AgriLife Extension program specialists and county Extension agents regularly organize feral hog workshops across the state and answer landowner questions on site or by phone. AgriLife Extension's website, Coping with Feral Hogs (http://feralhogs.tamu.edu), provides information, maps, and videos on feral hogs. The AgriLife Extension Bookstore (https://agrilifebookstore.org/) provides access to dozens of publications (in English and Spanish) on feral hogs. The Wildlife and Fisheries Sciences Extension Unit maintains a YouTube channel with several videos on feral hog management (http://youtube.com/user/wfscextension).

AgriLife Extension is also involved in several projects related to feral hog management in Texas. In the Plum Creek Watershed, AgriLife Extension is leading a project as part of a watershed protection planning effort. The program

helps landowners in reporting feral hog activity, distributes educational materials to watershed residents, presents educational programs to the public, and conducts site visits for landowners living in the watershed. For more information on this project, visit http://pcwp.tamu.edu.

Texas Parks and Wildlife Department
The Texas Parks and Wildlife Department issues hunting licenses, which are required for people hunting feral hogs. However, the requirement is waived if the landowner, landowner's agent, or lessee (if given landowner permission) takes feral hogs that are damaging property. For regulations on the hunting of feral hogs, consult the department's publication, Outdoor Annual, which is posted on the Web at http://www.tpwd.state.tx.us/publications/huntwild/hunt/.

The agency's biologists also offer technical guidance to landowners on methods to improve the habitat and management of wild animal populations. They work closely with the Texas Department of Agriculture, Wildlife Services, and AgriLife Extension on feral hog abatement projects. For more information on the Texas Parks and Wildlife Department, see http://tpwd.state.tx.us.

Texas Department of Agriculture
The Texas Department of Agriculture helps control feral hogs through its Hog Out County Grants Program. Begun in 2010, the program encourages counties across Texas to make concentrated, coordinated efforts to reduce feral hog populations.

Throughout the year, the department works with Wildlife Services and other groups to carry out various feral hog abatement strategies. It also approves programs to provide continuing education for Texas citizens. For more information on the Texas Department of Agriculture, visit http://texasagriculture.gov.

Texas Animal Health Commission
The Texas Animal Health Commission (TAHC) regulates the movement of feral hogs, holding facilities, and some aspects of hunting preserves to help prevent the transfer of infectious diseases to domestic herds of cattle and swine. Feral swine can be legally moved only from the premises where trapped to either an approved holding facility, a recognized slaughter facility, or an authorized hunting preserve. The Texas Animal Health Commission provides technical guidance on feral hog regulations and participates in various feral hog educational trainings sponsored by Texas AgriLife Extension, Texas Parks and Wildlife Department, and other state agencies. For more information on the Texas Animal Health Commission, visit http://www.tahc.state.tx.us/.

Local Wildlife Management Associations/ Wildlife Co-Ops
Wildlife management associations and wildlife co-ops are formed by landowners to improve wildlife habitats and associated wildlife populations with the assistance of Texas Parks and Wildlife Department field biologists. Over 150 such associations were operating in Texas in 2011. Although typically focused on white-tailed deer management, associations could be formed to coordinate feral hog control and management at the county or regional level (Adams et al. 2005).

If you are interested in joining or forming a wildlife management association, schedule a meeting with your local Texas Parks and Wildlife Department biologist. This free service is provided through the

department's Private Lands and Habitat Program.

Another source of assistance could be the local county tax appraisal district, which may provide land ownership maps and mailing addresses of other landowners who might be interested in joining the wildlife management association.

References

Adams, C. E., B. J. Higginbotham, D. Rollins, R. B. Taylor, R. Skiles, M. Mapston, and S. Turman. 2005. "Regional Perspectives And Opportunities For Feral Hog Management In Texas." *Wildlife Society Bulletin.*

Arora, K., S. K. Mickelson, J. L. Baker, and D. P. Tierney. 1993. "Evaluating Herbicide Removal by Buffer Strips under Natural Rainfall." *American Society of Agricultural Engineers* Meeting Paper No. 93−2593.

Arora, K., S. K. Mickelson, J. L. Baker, D. P. Tierney, and C. J. Peters. 1996. "Herbicide Retention by Vegetative Buffer Strips from Runoff under Natural Rainfall." *Transactions of the American Society of Agricultural Engineers* 39(6):2155−2162.

Atwill, E. R., L. Hou, B. M. Karle, T. Harter, K. W. Tate, and R. A. Dahlgren. 2002. "Transport of Cryptosporidium parvum Oocysts through Vegetated Buffer Strips and Estimated Filtration Efficiency." *Applied and Environmental Microbiology* 68:5517–5527.

Barfield, B. J., R. L. Blevins, A. W. Fogle, C. E. Madison, S. Inamdar, D. I. Carey, and V. P. Evangelou. 1998. "Water Quality Impacts of Natural Filter Strips in Karst Areas." *Transactions of the American Society of Agricultural Engineers* 41(2):371−381.

Barrett, R. H., and G. H. Birmingham. 1994. Wild pigs. Pages D65-D70 in S. Hyngstrom, R. Timm, and G. Larsen, editors. Prevention and control of wildlife damage. Cooperative Extension Service, University of Nebraska, Lincoln, NE.

Bieber, C., and T. Ruf. 2005. Population dynamics in wild boar *Sus scrofa*: ecology, elasticity of growth rate and implications for the management of pulsed resource consumers. Journal of Applied Ecology 42:1203-1213.

Blanco-Canqui, H., C. J. Gantzer, S. H. Anderson, E. E. Alberts, and A. L. Thompson. 2004. "Grass Barrier and Vegetative Filter Strip Effectiveness in Reducing Runoff, Sediment, Nitrogen, and Phosphorus Loss." *Soil Science Society of America Journal* 68:1670–1678.

Blanco-Canqui, H., C. J. Gantzer, and S. H. Anderson. 2006. "Performance of Grass Barriers and Filter Strips under Interrill and Concentrated Flow." *Journal of Environmental Quality* 35:1969–1974.

Bodenchuk, M. J. 2008. Feral hog management: typing performance measures to resources protected. National Conference on Feral Hogs. April 13-15, St. Louis, MO.
Burns, R. 2011. Busting feral hog myths. AgriLife Today, Texas AgriLife Extension Service, College Station, TX.

Casteel, M. J., G. Bartow, S. R. Taylor, and P. Sweetland. 2005. *Removal of Bacterial Indicators of Fecal Contamination in Urban Stormwater Using a Natural Riparian Buffer.* Presented at the 10th International Conference on Urban Drainage, Copenhagen, Denmark.

Choquenot, D. J., R. J. Kilgour, and B.S. Lukins. 1993. An evaluation of feral pig trapping. *Wildlife Research* 20:15-22.

Choquenot, D. J., J. Hone, and G. Saunders. 1999. Using aspects of predator-prey theory to evaluation helicopster shooting for feral pig control. *Wildlife Research* 26:251-261.

Cook, M. N. 1998. Impact of animal waste best management practices on the bacteriological quality of surface water. M.S. Thesis. Blacksburg, Virginia: Virginia Polytechnic Institute and State University, Department of Biological Systems Engineering.

Coyne, M. S., R. A. Gilifillen, R. W. Rhodes, and R. L. Blevins. 1995. "Soil and Fecal Coliform Trapping by Grass Filter during Simulated Rainfall." *Journal of Soil and Water Conservation* 50:405–408.

Coyne, M. S., R. A. Gilifillen, A. Villalba, Z. Zhang, R. Rhodes, L. Dunn, and R. L. Blevins. 1998. "Fecal Bacteria Trapping by Grass Filter Strips during Simulated Rain." *Journal of Soil and Water Conservation* 53:140–145.

Cushman, J. H., T. A. Tierney, and J. M. Hinds. 2004. "Variable effects of feral pig disturbances on native and exotic plants in a California grassland". *Ecological Applications* 14:1746–1756.

Daniels, R. B. and J. W. Gilliam. 1996. "Sediment and Chemical Load Reduction by Grass and Riparian Filters." *Soil Science Society of America Journal* 60(1):246−251.

Dillaha, T. A., R. B. Reneau, S. Mostaghimi, and D. Lee. 1989. "Vegetative Filter Strips for Agricultural Nonpoint Source Pollution Control." *Transactions of the American Society of Agricultural Engineers* 32(2):513−519.

Dobkin, D. S., A. C. Rich, and W. H. Pyle. 1998. Habitat and avifaunal recovery from livestock grazing in a riparian meadow system of the northwestern Great Basin. *Conservation Biology* 12(1):209–221.

Eghball, B., J. E. Gilley, L. A. Kramer, and T. B. Moorman. 2000. "Narrow Grass Hedge Effects on Phosphorus and Nitrogen in Runoff following Manure And Fertilizer Application." *Journal of Soil Water Conservation* 55(2): 172−176.

Engeman, R. M., A. Stevens, J. Allen, J. Dunlap, M. Daniel, D. Teague, and B. Constantin. 2006. Impacts of sport hunting and feral swine control on the conservation of seepage slopes at eglin Air Force Base, Florida (abstract only). Page 15 in 2006 National Conference on Wild Pigs. School of Forestry and Wildlife Sciences, Auburn University, May 21-23, Mobile, AL.

Fajardo, J. J., J. W. Bauder, and S. D. Cash. 2001. "Managing Nitrate and Bacteria in Runoff from Livestock Confinement Areas with Vegetative Filter Strips." *Journal of Soil and Water Conservation* 56(3): 185−191.

Feral Hog Project Accomplishments: March 2008-February 2010. 2010. Texas AgriLife Extension Service, College Station, TX.

Gaston, W. D. 2008. Feral pig (*Sus scrofa*) survival, home range, and habitat use at Lowndes County Wildlife Management Area, Alabama. Thesis, Auburn University, Auburn, AL.

Gilley, J. E., B. Eghball, L. A. Kramer, and T. B. Moorman. 2000. "Narrow Grass Hedge Effects on Runoff and Soil Loss." *Journal of Soil and Water Conservation* 55:190–196.

Gingerich, J. L. 1994. "Florida's Fabulous Mammals". World Publications. Tampa Bay.
Goel, P. K., R. P. Rudra, B. Gharabaghi, S. Das, and N. Gupta. 2004. Pollutants Removal by Vegetative Filter Strips Planted with Different Grasses. *American Society of Agricultural Engineers* Paper No. 042177.

Gould, C., D. Rozeboom, and S. Hawkins. 2002. Best environmental management practices: Mortality management. ID-302. Michigan State University Extension, Lansing, MI.

Green, C. H. and R. Haney. 2005a. Filter strips. SERA-17, Minimizing Phosphorus Losses from Agriculture. http://www.sera17.ext.vt.edu/Documents/BMP_Filter_Strips.pdf.

Hall, J. K., N. L. Hartwig, and L. D. Hoffman. 1983. "Application Mode and Alternate Cropping Effects on Atrazine Losses from a Hillside." *Journal of Environmental Quality* 12(3):336−340.

Hamrick, B., M. Smith, C. Jaworowski, and B. Strickland. 2011. Publication 2659. Mississippi State University Extension Service, Starkville, MS.

Hayes, J. C. and J. E. Hairston. 1983. Modeling the Long-Term Effectiveness of Vegetative Filters as On-Site Sediment Controls. *American Society of Agricultural Engineers* Paper No. 83-2081.

Hayes, R. C. 2007. Feral hogs in central Mississippi: Home range, habitat use and survival. Thesis, Mississippi State University, Starkville, MS.

Helmers, M. J., D. E. Eisenhauer, M. G. Dosskey, T. G. Franti, J. Brothers, and M. C. McCullough. 2005. "Flow Pathways and Sediment Trapping in a Field-Scale Vegetative Filter." *Transactions of the American Society of Agricultural Engineers* 48(3):955−968.

Higginbotham, B., L. Hysmith, G. Clary, and M. Bodenchuk. 2008. Statewide feral hog abatement pilot project, 2006-2007. Texas AgriLife Extension Service, College Station, TX.

Hone, J., and Atkinson, W. 1983. Evaluation of fencing to control feral pig movement. Australian Wildlife Research 10:499-505.
Hone, J. 1993. A short-term evaluation of feral pig eradication at Willandra in Western New South Wales. *Australian Wildlife Research* 10:269:275.

Kaller, M.D., and W. E. Kelso. 2003. Effects of feral swine (Sus scrofa) on water quality in a coastal bottomland stream. *Proceedings of the Southeastern Association of Fish and Wildlife Agencies* 57:291-297.

Kauffman, J. B., R. L. Beschta, N. Otting, and D. Lytjen. 1997. An ecological perspective of riparian and stream restoration in the western United States. *Fisheries* 12(5):12–24.

Knapp, R. A., and K. R. Matthews. 1996. Impacts of livestock grazing on streams and resident golden trout populations in the Golden Trout Wilderness, California. *North American Journal of Fisheries Management* 16:805–820.

Kondolf, G. M. 1993. Lag in stream channel adjustment to livestock exclosure, White Mountains, California. *Restoration Ecology* 1:226–230.

Kotanen, P. M. 1995. "Responses of vegetation to a changing regime of disturbance: effects of feral pigs in a Californian coastal prairie. *Ecography* 18:190-199.

Krutz, L. J., S. A. Senseman, R. M. Zablotowicz, and M. A. Matocha. 2005. "Reducing herbicide Runoff from Agricultural Fields with Vegetative Filter Stripes: A Review." *Weed Science* 53:353−367.

Larsen, R. E., J. R. Miner, J. C. Buckhouse, and J. A. Moore. 1994. "Water Quality Benefits of Having Cattle Manure Deposited away from Streams." *Bioresource Technology* 48:113–118.

Lee, K. H., T. M. Isenhart, R. C. Schultz, and S. K. Mickelson. 2000. "Multispecies Riparian Buffers Trap Sediment and Nutrients during Rainfall Simulations." *Journal of Environmental Quality* 29(4):1200−1205.

Lewis, D. J., E. R. Atwill, M. S. Lennox, M. D. G. Pereira, W. A. Miller, P. A. Conrad, and K. W. Tate. 2010. "Management of Microbial Contamination in Storm Runoff from California Coastal Dairy Pastures." *Journal of Environmental Quality* 39:1782−1789.

Lim, T. T., D. R. Edwards, S. R. Workman, B. T. Larson, and L. Dunn. 1998. "Vegetated Filter Strip Removal of Cattle Manure Constituents in Runoff." *Transactions of the American Society of Agricultural Engineers* 41:1375–1381.

Line, D. E., W. A. Harman, G. D. Jennings, E. J. Thompson, and D. L. Osmond. 2000. Nonpoint-source pollutant load reductions associated with livestock exclusion. *Journal of Environmental Quality* 29:1882-1890.

Lombardo, L. A., G. L. Grabow, D. E. Line, J. Spooner, and D. L. Osmond. 2000. Summary Report: Section 319 National Monitoring Program Projects, National Nonpoint Source Watershed Project Studies, NCSU Water Quality Group, Biological and Agricultural Engineering Department, North Carolina State University, Raleigh, NC.

Magette, W. L., R. B. Brinsfield, R. E. Palmer, and J. D. Wood. 1989. "Nutrient and Sediment Removal by Vegetated Filter Strips." *Transactions of the American Society of Agricultural Engineers* 32(2):663−667.

Mankin, K. R. and C. G. Okoren. 2003. Field Evaluation of Bacteria Removal in a VFS. *American Society of Agricultural Engineers* Paper No. 032150.

Mapston, M. E. 2007. Feral hogs in Texas. B-6149. Texas AgriLife Extension Service, College Station, TX.

Mawdsley, J. L., A. E. Brooks, R. J. Merry, and B. F. Pain. 1996. "Use of a Novel Tilting Table Apparatus to Demonstrate the Horizontal and Vertical Movement of the Protozoan Cryptosporidium parvum in Soil." *Biology and Fertility of Soils* 23:215–220.

Miller, W. A., D. J. Lewis, M. D. G. Pereira, M. Lennox, P. A. Conrad, K. W. Tate, and E. R. Atwill. 2008. "Farm Factors associated with Reducing Cryptosporidium loading in Storm Runoff from Dairies." *Journal of Environmental Quality* 37(5):1875–1882.

Munoz-Carpena, R., J. E. Parsons, and J. W. Gilliam. 1999. "Modeling Hydrology and Sediment Transport in Vegetative Filter Strips." *Journal of Hydrology* 214(1/4):111−129.

NRCS. 2004. "Standards and Specifications No. 393," *USDA-NRCS Field Office Technical Guide*.

Odion, D. C., T. L. Dudley, and C. M. D'Antonio. 1988. Cattle grazing in southeastern Sierran meadows: ecosystem change and prospects for recovery. *In* C.A. Hall and D. Doyle-Jones (eds). Plant Biology of Eastern California – Natural History of the Inyo-White Range symposium. Vol. 2.

Olsen, M. E. 2003. Human and animal pathogens. Microbiology and Infectious Diseases, University of Calgary.

Owens, L. B., W. M. Edwards, and R. W. Van Keuren. 1996. Sediment losses from a pastured watershed before and after stream fencing. *Journal of Soil and Water Conservation* 51(1):90-94.

Parsons, J. E., R. D. Daniels, J. W. Gilliam, and T. A. Dillaha. 1990. Water Quality Impacts of Vegetative Filter Strips and Riparian Areas. *American Society of Agricultural Engineers* Paper No. 90-2501.

Parsons, J. E., J. W. Gilliam, R. Munoz-Carpena, R. B. Daniels, and T. A. Dillaha. 1994. "Nutrient and Sediment Removal by Grass and Riparian Buffers." *Proceedings of the American Society of Agricultural Engineers*, pp. 147−154.

Patty, L., B. Real, and J. J. Gril. 1997. "The Use of Grassed Buffer Strips to Remove Pesticides, Nitrate and Soluble Phosphorus Compounds from Runoff Water." *Pesticide Science* 49(3):243−251.

Pleasant, G. 2007. Feral hogs: whose problem are they? Texas Parks and Wildlife Department, Austin, TX.

Ranganath, S. C., W. C. Hession, and T. M. Wynn. 2009. Livestock exclusion influences on riparian vegetation, channel morphology, and benthic macroinvertebrate assemblages. *Journal of Soil and Water Conservation* 64(1):33-42.

Reidy, M. M., T. A. Campbell, and D. G. Hewitt. 2008. Evaluation of electric fencing to inhibit feral pig movements. *Journal of Wildlife Management* 72(4):1012-1018.

Renard, K. G., G. R. Foster, G. A. Weesies, D. K. McCool, and D. C. Yoder, coordinators. 1997. *Predicting Soil Erosion by Water: A Guide to Conservation Planning with the Revised Universal Soil Loss Equation (RUSLE).* USDA Agriculture Handbook No. 703.

Rohde, W. A., L. E. Asmussen, E. W. Hauser, R. D. Wauchope, and H. D. Allison. 1980. "Trifluralin Movement in Runoff from a Small Agricultural Watershed." *Journal of Environmental Quality* 9:37.

Roodsari, R. M., D. R. Shelton, A. Shirmohammadi, Y. A. Pachepsky, A. M. Sadeghi, and J. Starr. 2005. "Fecal Coliform Transport as Affected by Surface Condition." *Transactions of American Society of Agricultural Engineers* 48:1055–1061.

Schmitt, T. J., M. G. Dosskey, and K. D. Hoagland. 1999. "Filter Strip Performance and Processes for Different Vegetation, Widths, and Contaminants." *Journal of Environmental Quality* 28(5):1479−1489.

Schultz, J., C. A. Robinson, and R. M. Cruse. 1992. "Effectiveness of Vegetative Filter Strips." *1992 Leopold Center Annual Report.*

Sheffield, R. E., S. Mostaghimi, D. H. Vaughan, E. R. Collins Jr., and V. G. Allen. 1997. "Offstream Water Sources for Grazing Cattle as a Stream Bank Stabilization and Water Quality BMP." *Transactions of the American Society of Agricultural Engineers* 40(3):595–605.

Singer, F. J., Swank, W. T., and Clebsch, E. E. C. 1984. Effects of wild pig rooting in a deciduous forest. *Journal of Wildlife Management* 48:464-473.

Smith, K. A., A. J. Brewer, A. Dauven, and D. W. Wilson. 2000. "A Survey of the Production and Use of Animal Manures in England and Wales. I. Pig Manure." *Soil Use and Management* 16:124−132.

Snyder, C. S. 1998. "Vegetative Filter Strips Reduce Runoff Losses and Help Protect Water Quality." *News and Views*. Potash and Phosphate Institute and the Potash and Phosphate Institute of Canada.

Stevens, R. 2010. The feral hog in Oklahoma. NF-WF-10-01. *The Samuel Roberts Noble Foundation*, Ardmore, OK.

Stuntebeck, T. D. and R. T. Bannerman. 1998. *Effectiveness of Barnyard Best Management Practices in Wisconsin*. U.S. Geological Survey Fact Sheet FS-051-98.

Sullivan, T. J., J. A. Moore, D. R. Thomas, E. Mallery, K. U. Snyder, M. Wustenberg, J. Wustenberg, S. D. Mackey, and D. L. Moore. 2007. "Efficacy of Vegetated Buffers in Preventing Transport of Fecal Coliform Bacteria from Pasturelands." *Environmental Management* 40:958−965.

Tate, K. W., D. M. Dudley, N. K. McDougald, and M. R. George. 2004. "Effect of Canopy and Grazing on Soil Bulk Density." *Journal of Range Management* 57:411−417.

Tate, K. W., E. R. Atwill, J. W. Bartolome, and G. Nader. 2006. "Significant *Escherichia coli* Attenuation by Vegetative Buffers on Annual Grasslands." J*ournal of Environmental Quality* 35: 795−805.

Taylor, R. 2003. The Feral Hog in Texas. PWD BK W7000-195. *Texas Parks and Wildlife Department*, Austin, TX.

Tingle, C. H., D. R. Shaw, M. Boyette, and G. P. Murphy. 1998. "Metolachlor and Metribuzin Losses in Runoff as Affected by Width of Vegetative Filter Strips." *Weed Science* 46(4):475−479.

Trask, J. R., P. K. Kalita, M. S. Kuhlenschmidt, R. D. Smith, and T. L. Funk. 2004. Overland and Near-Surface Transport of Cryptosporidium parvum from Vegetated and Nonvegetated Surfaces. *Journal of Environmental Quality* 33:984−993.

U.S. Department of Agriculture, Natural Resources Conservation Service. 2004. "Standards and Specifications No. 393," *USDA-NRCS Field Office Technical Guide.*

Uusi-Kamppa, J., B. Braskerud, H. Jansson, N. Syversen, and R. Uusitalo. 2000. "Buffer Zones and Constructed Wetlands as Filters for Agricultural Phosphorus." *Journal of Environmental Quality* 29(1):151−158.

Wagner, K. and E. Moench. 2009. *Education Program for Improved Water Quality in Copano Bay, Task Two Report.* Texas Water Resources Institute TR-347.

Williams, B. L., R. W. Holtfretter, S. S. Ditchkoff, and J. B. Grand. 2011. Trap style influences wild pig behavior and trapping success. *Journal of Wildlife Management* 75(2):432-436.

Winkworth, C. L., C. D. Matthaei, and C. R. Townsend. 2008. "Recently Planted Vegetation Strips Reduced Giardia Runoff Reaching Waterways." *Journal of Environmental Quality* 37:2256−2263.

Young, R. A., T. Hundtrods, and W. Anderson. 1980. "Effectiveness of Vegetated Buffer Strips in Controlling Pollution from Feedlot Runoff." *Journal of Environmental Quality* 9:483−487.

Additional Resources

1. Approved Feral Swine Holding Facilities (Texas Animal Health Commission): http://www.tahc.state.tx.us/animal_health/feral_swine.html.
2. Coping with Feral Hogs (Texas AgriLife Extension Service): http://feralhogs.tamu.edu.
3. eXtension Feral Hogs Community of Practice: http://www.extension.org/feral_hogs.
4. Feral Hogs in Texas (Texas AgriLife Extension Service Publication B-6149): http://icwdm.org/publications/pdf/feral%20pig/txferalhogs.pdf.
5. Plum Creek Watershed Feral Hog Project (Texas AgriLife Extension Service, Plum Creek Watershed Partnership): http://pcwp.tamu.edu/feral-hogs/.
6. Texas Parks and Wildlife Feral Hogs: http://www.tpwd.state.tx.us/huntwild/wild/nuisance/feral_hogs/.

Funding for this publication came from a Clean Water Act §319(h) nonpoint source grant from the Texas State Soil and Water Conservation Board and the U.S. Environmental Protection Agency.

Produced by the Department of Soil and Crop Sciences and AgriLife Communications, The Texas A&M System.
Extension publications can be found on the Web at http://agrilifebookstore.org
Visit the Texas AgriLife Extension Service at http://AgriLifeExtension.tamu.edu

NEW – 250