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Bacteria Runoff BMPs for Intensive Beef Cattle Operations

Prepared for:

United States Department of Agriculture
Natural Resources Conservation Service

By
Kevin Wagner, Texas Water Resources Institute
Dr. Larry Redmon, Texas AgriLife Extension Service
Dr. Terry Gentry, Texas AgriLife Research

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Texas A&M University System
College Station, Texas 77843-2118

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Texas Water Resources Institute
make every drop count

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Executive Summary

According to the *2008 Water Quality Inventory and 303(d) List*, 291 of the 516 impairments (i.e. 56%) were the result of excessive bacteria. Modeling and bacteria source tracking has identified grazing cattle as a source of this bacterial contamination. To help address this, the Natural Resources Conservation Service (NRCS) funded this project to evaluate the effect of stocking rate on pathogen transport from beef cattle operations and develop guidance for landowners on restoring water quality.

The project included three tasks: (1) Project Coordination and Administration, (2) Assess Bacteria Runoff from Intensively Managed Beef Cattle Operations, and (3) Technical Transfer. Task 1, Project Coordination and Administration, consisted of the Texas Water Resources Institute (TWRI) preparing and submitting eleven quarterly progress reports and the final project report, holding 25 coordination meetings, and submitting 12 invoices.

To evaluate the impact of grazing management on bacterial runoff (Task 2), TWRI and Texas AgriLife Extension Service (AgriLife Extension) installed three 1-hectare watershed sites at the Texas A&M University Beef Cattle Systems Center (BCSC), located near College Station. Sites were bermed and equipped with 90^{o} v-notch weirs, ISCO® samplers with bubble flow meters, and a rain gage. TWRI and AgriLife Extension maintained these watershed sites for two years, conducting over 30 site visits.

A variety of stocking rates were evaluated. Site BB1 was ungrazed. Site BB2 was stocked at typical stocking rates (SR) for the area (i.e., 3-4 acres per animal unit [AU]). Site BB3 was stocked at a rate twice that of site BB2. Over the course of the project, six grazing treatments were conducted at sites BB2 and BB3.

From November 2008 through October 2010, TWRI and AgriLife Extension assessed bacterial concentrations and runoff volume from the watershed sites. *E. coli* concentrations at all sites greatly exceeded Texas Water Quality Standards. Even at the ungrazed site, non-domesticated animals (i.e., feral hogs) and wildlife significantly impacted *E. coli* levels preventing attainment of water quality standards, thus indicating the difficulty in achieving standards during runoff events due to background loadings. Data also indicated moderate stocking does not significantly increase *E. coli* levels above background levels and suggests that 67-85% reductions in *E. coli* levels may be achieved by converting from heavy to moderate stocking rates. It was also found that pastures stocked heavier than 10 acres per AU should be the primary focus of implementation efforts in this and similar environments. Our data indicated (1) stocking at rates heavier than 10 acres per AU (as is much of the improved pastureland in Texas) may increase *E. coli* concentrations in runoff while (2) stocking at rates less than 10 acres per AU (much of the rangeland in Texas) does not yield higher *E. coli* levels than ungrazed pastures. Finally, data show that runoff events occurring while the sites were stocked or within two weeks of them being stocked produced the highest *E. coli* concentrations; thus, it is recommended grazing in creek pastures be deferred during rainy periods. Within two weeks of grazing, *E. coli* levels had fallen substantially and after 30 days, *E. coli* values had declined to background levels.

The findings and recommendations regarding appropriate stocking rates/grazing management to minimize bacterial runoff into surface waters of Texas are being included in a fact sheet, presentation, and other resources that will become part of the *Lone Star Healthy Streams Beef Cattle Resource Manual.*

Throughout this project a series of educational programs conducted through the *Lone Star Healthy Streams* Program transferred information regarding bacterial runoff and conservation practices for reducing it to livestock producers at over 60 programs around the state. Additionally, the website reached 1,038 unique visitors since its inception. These programs have increased awareness of bacterial runoff from beef cattle grazing operations and conservation practices designed to reduce bacterial loading to Texas streams and water ways.

Much work remains to be done. The applicability of water quality standards during runoff events should be evaluated in light of the findings of this study; more data is needed to evaluate the impact of stocked pastures on bacterial runoff; work is needed to assess the impacts of continuous grazing on *E. coli* runoff; and transfer of this information to cattlemen throughout Texas must continue.

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List of Acronyms and Abbreviations

Ac – acre
AgriLife Extension – Texas AgriLife Extension Service
ANOVA – Analysis of Variance
AU – Animal Unit, 1000 pounds live weight
AUD –Animal Unit Day
AUM – Animal Unit Month
AUY – Animal Unit Year
BCSC – Beef Cattle Systems Center
BMP – Best Management Practice
CFU – Colony Forming Units, measure of fecal bacteria present in samples
CIG – Conservation Innovation Grant
Conc. – Concentration
CWA – Clean Water Act
E. coli – Escherichia coli
EMC – Event Mean Concentration
EPA – Environmental Protection Agency
EQIP – Environmental Quality Incentives Program
FY – Fiscal Year
Geo Mean – Geometric Mean
ha – hectare
Hvy – Heavy
Max. – Maximum
Min. – Minimum
mL – milliliter
Mod. – Moderate
mos. – months
NRCS – USDA Natural Resources Conservation Service
PI – Principal Investigator
Q1 – First Quartile (25th percentile)
Q3 – Third Quartile (75th percentile)
RTD – Rapid Transfer Device
SR – Stocking Rate in acres per animal unit
Std. Dev. – Standard Deviation
SWCD – Soil and Water Conservation District
TCEQ – Texas Commission on Environmental Quality
TMDL – Total Maximum Daily Load
TSSWCB – Texas State Soil and Water Conservation Board
TWRI – Texas Water Resources Institute
USDA – United States Department of Agriculture

Introduction

Project Background:

According to the *2008 Water Quality Inventory and 303(d) List*, 291 of the 516 impairments (i.e. 56%) were the result of excessive bacteria. Modeling and bacteria source tracking has identified grazing cattle as a source of this bacterial contamination. Grazing lands represent the dominant land use in the majority of watersheds in Texas; thus implementation of watershed management principles and practices on grazing lands will be critical to the success of water resource restoration and protection efforts in the state for years to come.

Education of landowners and voluntary adoption of conservation practices is needed to reduce bacterial contamination of streams and water bodies as well as reduce the likelihood of increased regulatory oversight of production practices and systems. The USDA-Natural Resources Conservation Service (NRCS), local Soil and Water Conservation Districts (SWCDs), and Texas State Soil and Water Conservation Board (TSSWCB) support producers through technical assistance and cost-share programs that enable the implementation of conservation practices. For such measures to be effective, however, education programs are needed to ensure the practices are accepted, properly implemented and managed, compatible with the overall management system, and result in limited additional economic burden to agricultural producers.

Evaluation of bacteria runoff from a variety of grazing management scenarios is needed to develop science-based Extension education programs and materials and provide producers with necessary information for making management decisions. Much work has already been completed on unmanaged rangeland and pasture through the *Lone Star Healthy Streams* project and *Education Program for Improved Water Quality in Copano Bay* project funded by the TSSWCB and Environmental Protection Agency (EPA) with CWA 319(h) funds, as well as the *Environmental Management of Grazing Lands* project funded by the TSSWCB and USDA-NRCS. This project was coordinated with these projects to expand the scenarios evaluated by assessing managed forages (i.e. improved bermudagrass pastures).

Project Goal/Objectives:

The goal of this project was to reduce bacterial runoff from beef cattle grazing operations by:

- quantifying bacteria runoff from grazing beef cattle operations on improved bermudagrass pastures,
- developing educational materials and programs for stakeholders,
- delivering management guidelines through the *Lone Star Healthy Streams* program, field days and other education programs,
- evaluating changes in producer knowledge regarding stocking rates and bacterial contamination of runoff water from grazing sites, and
- providing bacteria data to the TSSWCB, Texas Commission on Environmental Quality (TCEQ), researchers, and those developing bacterial Total Maximum Daily Loads (TMDLs) to refine models for developing TMDLs in Texas as well as other states to ensure the most accurate loading data for grazing lands are used in the models .

Methods and Results

The project consisted of three tasks: (1) Project Coordination and Administration, (2) Assess Bacteria Runoff from Intensively Managed Beef Cattle Operations, and (3) Technical Transfer.

Task 1: Project Coordination and Administration

The objectives of Task 1 were to coordinate and monitor all work performed under this project, perform accounting functions for project funds, prepare timely and accurate reports, and maintain project files and data. Subtasks completed by Texas Water Resources Institute (TWRI) included (1) preparation of bi-annual progress reports; (2) coordination of meetings as appropriate with project participants to discuss project activities, project schedule, lines of responsibility, communication needs, and other requirements; (3) submitting required financial forms every quarter (SF-272 and SF-269); and (4) working with Texas AgriLife Extension Service to develop the final project report within 90 days of project completion.

Subtask 1.1: Preparation of progress reports

TWRI prepared and submitted Quarterly Progress Reports which can be viewed online at http://grazinglands-wq.tamu.edu/reports as follows:

- January 15, 2008 — TWRI Submitted Quarter 1 Progress Report
- April 15, 2008 — TWRI Submitted Quarter 2 Progress Report
- July 15, 2008 — TWRI Submitted Quarter 3 Progress Report
- October 15, 2008 — TWRI Submitted Quarter 4 Progress Report
- January 15, 2009 — TWRI Submitted Quarter 5 Progress Report
- April 15, 2009 — TWRI Submitted Quarter 6 Progress Report
- July 15, 2009 — TWRI Submitted Quarter 7 Progress Report
- October 15, 2009 — TWRI Submitted Quarter 8 Progress Report
- January 15, 2010 — TWRI Submitted Quarter 9 Progress Report
- April 15, 2010 — TWRI Submitted Quarter 10 Progress Report
- July 15, 2010 — TWRI Submitted Quarter 11 Progress Report

Subtask 1.2: Coordination of meetings as appropriate with project participants to discuss project activities/schedule, lines of responsibility, communication needs, and other requirements.

TWRI presented project activities/results to NRCS and the Lone Star Healthy Streams Steering Committee on November 29, 2007, October 27, 2008, October 19, 2009, and October 25, 2010. On February 13, 2009, TWRI also met with NRCS staff to discuss the need for a no cost extension. Additionally, 20 coordination meetings between the TWRI Project Manager and Texas AgriLife Extension Service Co-PI (see dates below) were held to discuss the project contract, budget, deliverables, activities, and schedule.

- October 4, 2007
- March 28, 2008
- June 19, 2008
- February 13, 2009
- April 8, 2009
- May 1, 2009
- June 12, 2009
- August 27, 2009
- September 11, 2009
- September 28, 2009
- October 2, 2009
- October 19, 2009
- November 12, 2009
- January 21, 2010
- March 16, 2010
- March 26, 2010
- April 19, 2010
- April 29, 2010
- June 10, 2010
- June 22, 2010

Subtask 1.3: Submission of required financial forms every quarter (SF-272 and SF-269).

The *Bacteria Runoff BMPs for Intensive Beef Cattle Operations* contract (#68-7442-7-478) was initiated on August 15, 2007. The following table shows federal expenditures for this project totaling $74,961.72.

Invoice #	Date From	Date To	Invoice $$	Balance
M002179	10.1.07	12.31.07	3,103.40	71,887.60
M002194	1.1.08	3.31.08	3,103.17	68,784.43
R016441	4.1.08	6.30.08	3,103.17	65,681.26
M002220	7.1.08	9.30.08	4,842.24	60,839.02
R016910	10.1.08	12.31.08	1,686.74	59,152.28
R017151	1.1.09	3.31.09	2,637.70	56,514.58
R017369	4.1.09	6.30.09	2,420.02	54,094.56
R017594	7.1.09	9.30.09	4,841.46	49,253.10
R017846	10.1.09	12.31.09	11,520.28	37,732.82
R018093	1.1.10	3.31.10	15,854.68	21,878.14
R018380	4.1.10	6.30.10	10,419.15	11,458.99
R018801	7.1.10	9.30.10	11,429.71	29.28

Subtask 1.4: Development of the final project report within 90 days of project completion.

TWRI submitted the final report to Susan Baggett, Claude Ross, and Kathleen Pinckney of NRCS on December 30, 2010.

Task 2: Assess Bacterial Runoff from Beef Cattle Stocked Bermudagrass Pastures

The objective of Task 2 was to evaluate the impact of grazing management on bacterial runoff from improved bermudagrass pastures stocked with beef cattle. The first subtask was to install three (3) watershed sites at the Texas A&M University Beef Cattle Systems Center (BCSC), located in the Brazos River bottom along FM 50. A variety of stocking rates were evaluated. Site BB1 was ungrazed. Site BB2 was stocked at typical stocking rates (SR) for the area (i.e. 3-4 acres per animal unit). Site BB3 was stocked at a rate twice that of site BB2. Equipment installed included berms and weirs, ISCO® samplers with bubble flow meters, and a rain gage. TWRI and AgriLife Extension maintained the three watershed sites and assessed bacterial concentrations and runoff volume from each of the three (3) sites for a period of two (2) years. TWRI and AgriLife Extension evaluated the water quality data collected throughout the project in order to develop timely and up-to-date information for presentation to producers. The grazing treatments and runoff analysis was performed from November 2008 through October 2010.

Subtask 2.1: Install three (3) watershed sites at the Texas A&M University Farm in Brazos County to evaluate ungrazed, moderately stocked, and heavily stocked improved pastures.

On October 5, 2007, TWRI and AgriLife Extension selected a site at the Beef Cattle Systems Center for construction of three 1-hectare (2.5 acres) watersheds to evaluate grazing management (Fig. 1).

Figure 1. Sites BB1, BB2, and BB3 at Beef Cattle Systems Center.

On October 23-26, 2007, berms were constructed around each 1-ha watershed site and slope was modified so that each site would drain to the watershed outlet. Immediately following berm construction, all sites were sprigged with Tifton 85 (Fig. 2).

Figure 2. Berm construction (left) and sprigging Tifton 85 (right) in October 2007.

All three watershed sites are under a ½-mile center pivot irrigation system (Fig. 3) affording the opportunity to irrigate. However, due to the expense of irrigating, it was only used on a limited basis, primarily for establishing the Tifton 85 on the watershed sites and elsewhere in the pasture under the pivot.

Figure 3. Irrigating sites after planting (left) and Tifton 85 plug following planting (right).

Soils within the study area are comprised of Belk clay, a heavier-textured alluvial soil (Hydrologic Soil Group D) found along the Brazos River. Measured slope averages 0.2% (Fig. 4).

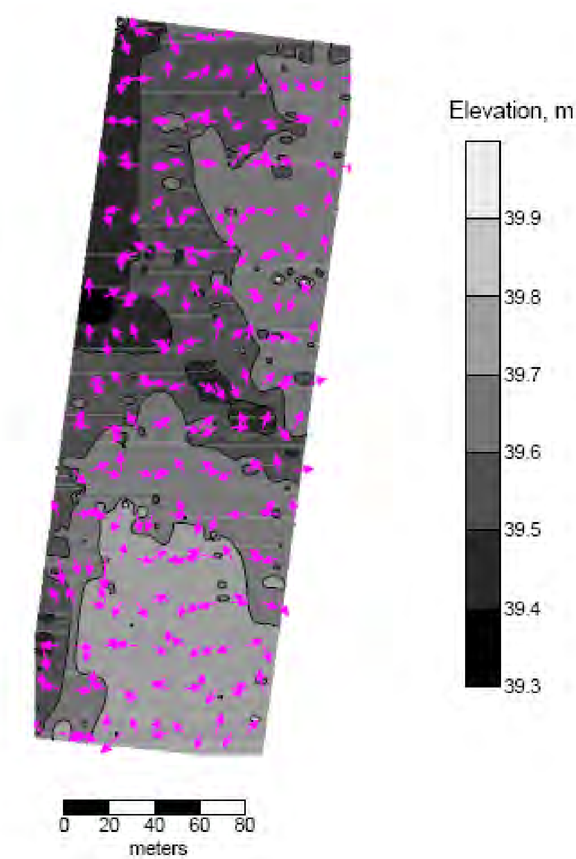


Figure 4. Elevation map of Brazos Bottom watersheds (arrows indicate predicted water flow).

Installation of 90° v-notch weirs at all three watershed sites was completed on August 29, 2008; and installation of electric fence around each watershed site was completed on September 9 (Fig. 5).

Figure 5. Electric fence and weirs installed (September 15, 2008).

Monitoring equipment installation was essentially complete by the end of October 2008 so that monitoring effectively commenced on November 1, 2008 (Fig. 6).

Figure 6. Fully equipped sites BB2 (right) and BB3 (left) on January 12, 2009 during first grazing of sites

Subtask 2.2: Maintain the three watershed sites and assess bacteria concentrations, runoff volume, and precipitation from each of the three (3) sites for a period of two (2) years.

Maintenance on the three watershed sites was conducted at least monthly as follows:

- January 23, 2009
- February 11, 2009
- March 11, 2009
- April 9, 2009
- May 14, 2009
- May 28, 2009
- June 2, 2009
- June 5, 2009
- June 17, 2009
- July 22, 2009
- August 13, 2009
- August 28, 2009
- September 30, 2009
- October 27, 2009
- November 13, 2009
- November 16, 2009
- November 19, 2009
- December 2, 2009
- January 30, 2010
- February 5, 2010
- March 21, 2010
- April 22, 2010
- May 5, 2010
- June 2, 2010
- June 21, 2010
- July 6, 2010
- July 9, 2010
- July 12, 2010
- August 3, 2010
- August 23, 2010
- September 17, 2010

Maintenance included:

- Checking bubbler rate to ensure the tube was not pinched or clogged
- Changing the desiccant
- Ensuring the sampler tube was not clogged or holding water
- Calibrating the Bubbler water level with the actual water level
- Checking the battery
- Downloading rainfall and flow data using an ISCO® 581 Rapid Transfer Device (RTD)
- Cleaning the strainer
- Measuring grass height (Fig. 7)

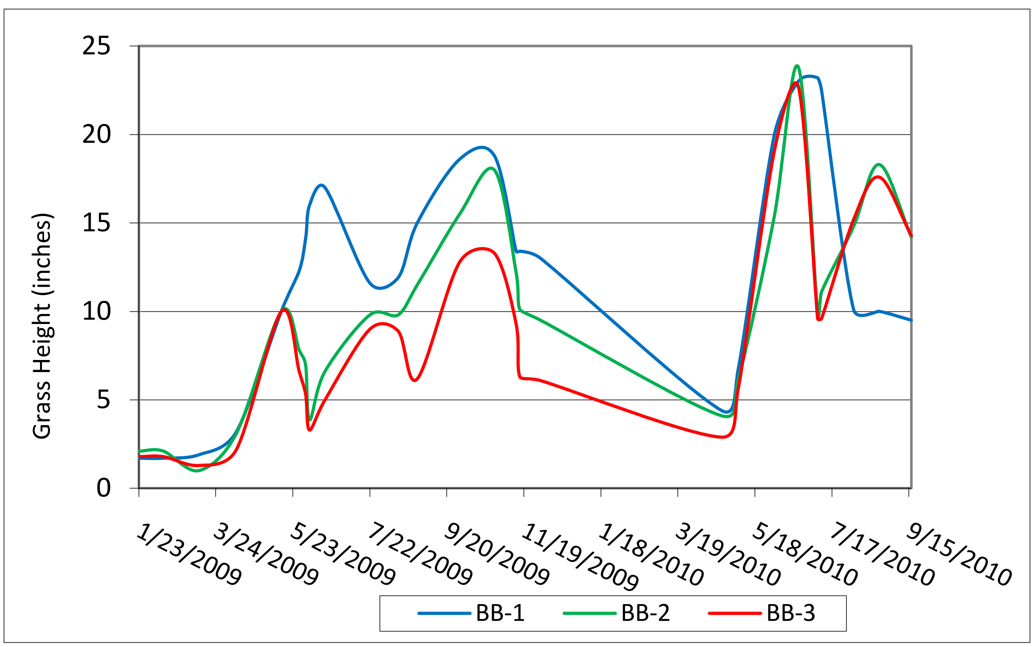


Figure 7. Grass Height Measurements (in inches) at Beef Cattle Systems Center.

The stocked sites (BB2 and BB3) were not stocked continuously. Instead, over the course of the project, six grazing treatments (Fig. 8) were conducted at sites BB2 and BB3. Additionally, electric fences went down on February 1-8, 2010; however minimal grazing occurred on the sites during this time. Site BB1 remained essentially ungrazed with the exception of when the electric fence went down briefly on March 11, 2009, November 13, 2009 and February 1, 2010.

Figure 8. Grazing of site BB3 on November 13, 2009.

These grazing treatments allowed the evaluation of a variety of stocking rates over the 2-year monitoring period (Table 1). Over the two-year study, stocking rates at site BB2 ranged from 3.8 acres per animal unit year (AUY) to 56.3 acres per AUY while stocking rates at site BB3 ranged from 1.8 to 28.2 acres per AUY.

Table 1. Beef Cattle Systems Center Grazing Treatments.

Site	Start	End	AU	AUD	12 mos. SR (ac/AUY)
BB2	1/12/09	1/16/09	4	16	56.3
BB2	5/22/09	6/5/09	6	79	9.5
BB2	8/7/09	8/8/09	6	6	8.9
BB2	8/12/09	8/19/09	6	46	6.1
BB2	11/12/09	11/17/09	18	90	3.8
BB2	2/1/10	2/8/10	2	17	3.8
BB2	6/21/10	7/2/10	18	194	4.3
BB3	1/12/09	1/16/09	8	32	28.2
BB3	5/22/09	6/5/09	12	175	4.4
BB3	8/7/09	8/8/09	13	13	4.1
BB3	8/12/09	8/19/09	13	92	2.9
BB3	11/12/09	11/17/09	36	180	1.8
BB3	2/1/10	2/8/10	2	17	1.9
BB3	6/21/10	7/2/10	31	346	2.5

Subtask 2.3: Evaluate water quality data collected throughout the project in order to develop timely and up-to-date information for presentation to producers.

E. coli concentrations were measured (using EPA Method 1603) in 63 water samples (Appendix A) collected from the three sites during the study including nine grab samples and 54 flow-weighted composite edge of field samples. Because flow-weighted samples were collected using ISCO® 6712 full-size portable samplers with single bottle configuration into sterile polyethylene 4-gallon round bottles, calculation of event mean concentrations (EMCs) for *E. coli* for each runoff event was possible. Flow from each watershed site was measured with ISCO® 730 Module bubble flow meters, which, in combination with the EMCs, allowed calculation of *E. coli* loading for each runoff event.

The data was validated before it was analyzed. Eighteen *E. coli* measurements were omitted from the final analysis as a result of the following:

- No measurable flow/runoff occurred when grab samples were collected on 3/25/09 (at BB2 and BB3), 10/22/09 (at BB3) and 10/26/09 (at all sites); thus, the *E. coli* concentrations measured in these six samples had no downstream impact and were excluded from the final data analysis.
- Large runoff events on 10/13/09, 10/26/09, 1/29/10, and 6/9/10 resulted in water from the drainage ditch adjacent to the three watershed sites backing up into sites BB1 and BB3, impacting flow measurement and invalidating 12 *E. coli* measurements. As a result, data collected on these dates were omitted from the final data analysis.

The validated *E. coli*, flow, and loading data used for analysis are included in Appendix B. Graphical and tabular summaries of *E. coli* levels are shown in Fig. 9 and Table 2.

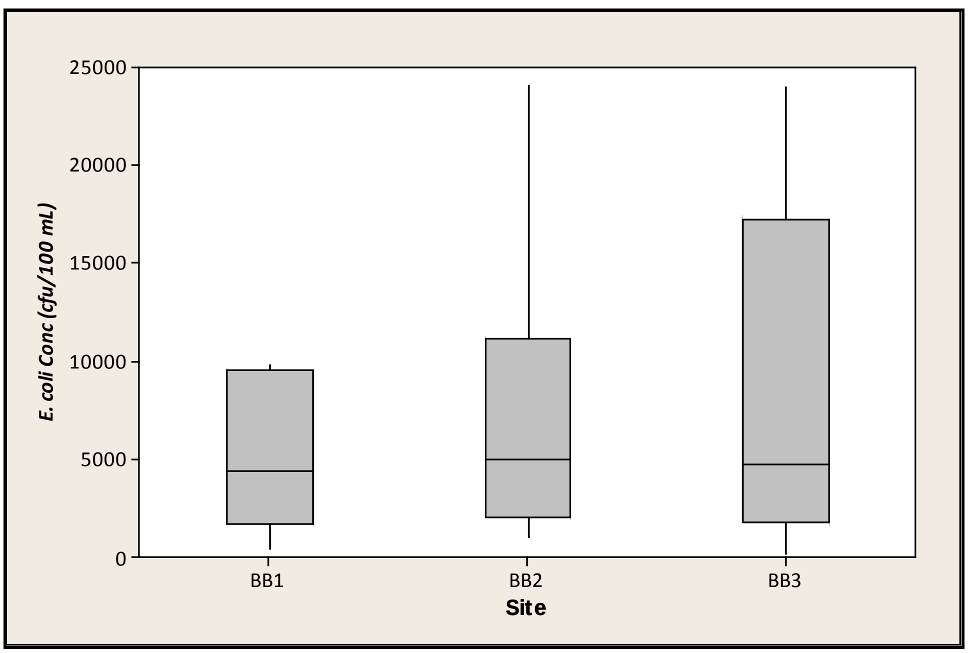


Figure 9. Box plot of validated *E. coli* measurements at sites BB1, BB2, and BB3. The upper and lower whiskers extend to the maximum data points within 1.5 box heights from the top and bottom of the box. The box represents the middle 50% of the data. The middle line is the median. Outlier observations beyond the upper and lower whiskers are not displayed.

Table 2. Summary statistics for validated *E. coli* concentrations (cfu/100 mL).

Statistic	BB1 (Ungrazed)	BB2 (Mod. SR)	BB3 (Hvy SR)
Mean	10,943	10,090	66,669
Std. Dev.	16,669	15,120	190,787
Min	410	980	140
Q1	1,650	2,044	1,775
Median	4,400	5,007	4,700
Q3	9,550	11,150	17,250
Max	57,000	58,000	800,000
Geo Mean	4,594	5,007	6,202
Site Mean	7,003	7,102	21,638

Comparison of Edge-Of-Field E. coli Concentrations to Texas Water Quality Standards

As data in both Table 2 and Appendix A indicate, only one sample during the entire study met the single sample maximum for *E. coli* in water (394 cfu/100 mL) required by the Texas Water Quality Standards. In fact, the median *E. coli* values observed at all sites exceeded this single sample maximum by an order of magnitude. Similarly, the *E. coli* geometric means in runoff observed at all sites exceeded the geometric mean required by the Texas Water Quality Standards (126 cfu/100 mL) by over an order of magnitude as well. Although these standards only apply to water bodies, such as streams and reservoirs, and not to edge-of-field runoff as described here, it does provide an indication of the potential difficulties in achieving water quality standards during runoff events, even in ungrazed areas.

Comparison of E. coli Concentrations among Sites

The best indication of *E. coli* concentration in runoff at a site is the site mean concentration (i.e. flow-weighted concentration for all events). As Table 2 indicates, there is little difference between the ungrazed (BB1) and moderately stocked (BB2) site mean concentrations; however, site mean concentrations at BB1 and BB2 were 67% lower than those at the heavier stocked BB3. Similarly, the mean *E. coli* concentrations at BB1 and BB2 were essentially the same; however, BB1 and BB2 *E. coli* levels were 85% lower than the mean at BB3. Evaluation of the data using One-way ANOVA indicated mean values observed, however, were not different between sites ($p=0.328$). Additionally, median values are not different per the Kruskal-Wallis Test ($p=0.977$). Although not statistically substantiated, the site mean concentrations and mean concentrations suggest that (1) moderate stocking does not significantly increase *E. coli* levels above background and (2) 67-85% reductions in *E. coli* levels may be achieved by converting from heavy to moderate stocking rates.

Comparison of Stocking Rate (SR) and E. coli Concentration

Because the stocking rates varied substantially at each of the grazed sites throughout the project (Table 1), a better method for assessing the data is to evaluate the relation of stocking rate to *E. coli* EMC for each event (Fig. 10). The 12-month SR was selected for this comparison since *E. coli* can survive in soil for up to 12 months (University of Wisconsin 2007 a & b). This evaluation permits observation of a general increasing trend in *E. coli* concentrations with increasing stocking rate.

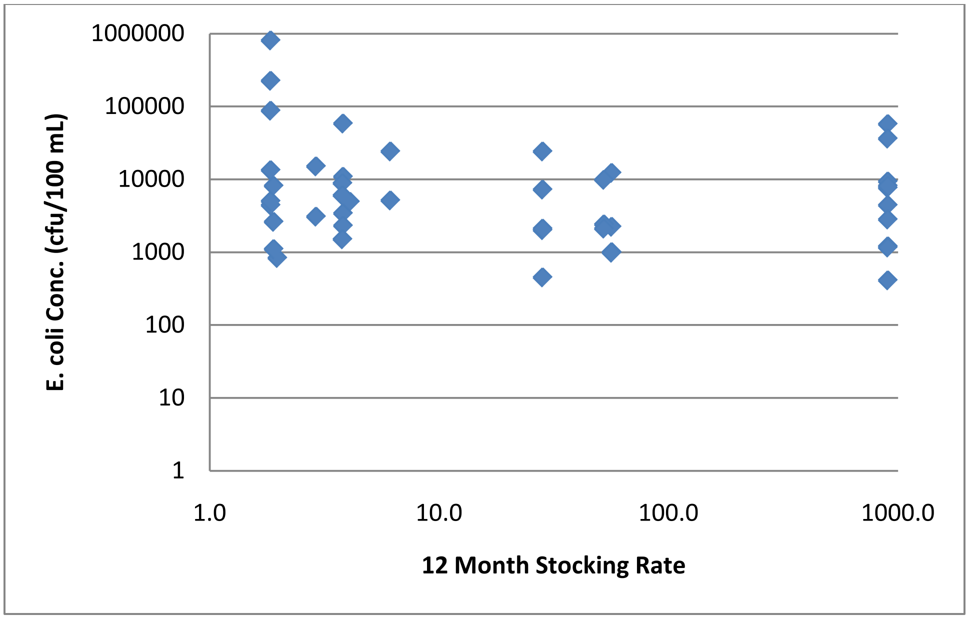


Figure 10. Comparison of 12 month stocking rate to *E. coli* concentrations in runoff at BCSC.

Data in Fig. 10 were further divided into groups of three and five for analysis (Table 3 and Table 4). Both mean and median *E. coli* levels associated with the ungrazed SR (set at 901.6 for analysis; equates to 1 AUD of grazing annually on 1-ha) are noticeably higher than would be expected. This is primarily due to two events in October 2009 where *E. coli* levels in the ungrazed pasture (site BB1) exceeded all other measurements at site BB1 by an order of magnitude. A potential source of these elevated *E. coli* levels is feral hogs, which are common along the Brazos River bottom. This is a good example of how non-domesticated animals and wildlife can significantly impact *E. coli* levels, even at ungrazed sites. This does, however, complicate the evaluation of the impacts of grazing domestic livestock.

Table 3. Mean and median *E. coli* concentrations (cfu/100 mL) observed in runoff from pastures that are ungrazed, stocked at 10-100 acres/AU, and stocked at <10 acres/AU.

SR	Mean *E. coli* Conc.	Median *E. coli* Conc.
Ungrazed	12,797	6,000
10-100 ac/AU	5,538	2,162
<10 ac/AU	58,591	5,557

Table 4. Mean and median *E. coli* concentrations (cfu/100 mL) observed in runoff from pastures that are ungrazed and stocked at 50-100 acres/AU, 10-50 acres/AU, 2.5-10 acres/AU, and <2.5 acres/AU.

SR	Mean *E. coli* Conc.	Median *E. coli* Conc.
Ungrazed	12,797	6,000
50-100 ac/AU	4,386	2,225
10-50 ac/AU	7,150	2,100
2.5-10 ac/AU	11,910	5,557
<2.5 ac/AU	114,608	6,550

Partly as a result of the previously mentioned elevated levels of *E. coli* observed during October 2009 at the ungrazed site BB1, the statistical analysis of median *E. coli* concentrations from the 3-way split using the Mann-Whitney Test indicated runoff from the grazed pastures was not significantly different from that of the ungrazed pasture. Median *E. coli* concentrations in runoff from <10 acres/AU, however, were significantly greater than median *E. coli* concentrations in runoff from pastures with stocking rates of 10-100 acres/AU (Table 5).

Table 5. p-values for Mann-Whitney Test of differences in median *E. coli* concentrations between observed stocking rates.

SR	Ungrazed	10-100 ac/AU	<10 ac/AU
Ungrazed	1.00	0.41	0.45
10-100 ac/AU	0.41	1.00	0.05
<10 ac/AU	0.45	0.05	1.00

Further statistical analysis of mean *E. coli* concentrations from the 3-way split using One-way ANOVA indicated no difference between any of the stocking rates (Appendix C). Similarly, statistical analysis of mean and median concentrations from the 5-way split did not yield any difference between treatments (Appendix C).

In an attempt to better evaluate the impacts of stocking rate on *E. coli* levels, the two unexpectedly high values observed at the ungrazed site BB1 in October 2009 were removed from the dataset and the dataset was re-analyzed. Eliminating these two unexplained outliers reduced the ungrazed mean and median *E. coli* concentrations to 4,371 cfu/100 mL and 3,600 cfu/100 mL, respectively. This did not, however, result in additional differences being observed between mean or median concentrations (Appendix D and Table 6). As Table 6 indicates, only median *E. coli* concentrations at SR 10-100 and <10 acres/AU were different. This re-analysis did reveal *E. coli* levels in runoff from unstocked and stocked at 10-100 acres/AU were essentially the same (p=0.97), while the difference between *E. coli* levels in unstocked and stocked at <10 acres/AU approached statistical significance (p=0.13).

Table 6. p-values for Mann-Whitney Test of differences in median *E. coli* concentrations between observed stocking rates when unexplained outliers removed from ungrazed dataset.

SR	Ungrazed	10-100 ac/AU	<10 ac/AU
Ungrazed	1.00	0.97	0.13
10-100 ac/AU	0.97	1.00	0.05
<10 ac/AU	0.13	0.05	1.00

This assessment suggests (1) stocking at rates heavier than 10 acres per AU may increase *E. coli* concentrations in runoff and should be the primary focus of implementation efforts, (2) stocking at rates less than 10 acres per AU may not yield higher *E. coli* levels than ungrazed pastures (much of the pastureland in Texas would fall into this category), and (3) *E. coli* contributions from non-domestic animals can result in significant *E. coli* concentrations, greatly exceeding water quality standards.

Impact of Cattle Presence during Rainfall Event

Runoff events occurring while the sites were stocked or within two weeks of them being stocked produced the highest *E. coli* concentrations. In fact, the four highest *E. coli* observations of the study occurred within this period. Two runoff events occurred at site BB2 (November 21 and December 1, 2009) and four runoff events occurred at site BB3 (November 16, 21, 29, and December 1, 2009) during or within two weeks of them being stocked during November 12-17, 2009 (Appendix B). Runoff *E. coli* levels at the moderately stocked BB2 were six times higher during this period (referred to as "Stocked" on Table 7) than the levels observed during the rest of the study (referred to as "Destocked" on Table 7). Results were even more dramatic at the heavier grazed site BB3 where average *E. coli* levels (mean and geometric mean) were approximately 50 times higher and the site mean concentration was 12 times greater than levels observed during the remainder of the study. These increased levels are significant as indicated by ANOVA p-values of 0.007 for site BB2 and 0.006 at site BB3.

By two weeks of the grazing termination, concentrations had fallen substantially and after 30 days, *E. coli* values had declined to background levels. Based on these findings, we recommended grazing in creek pastures be deferred during rainy periods and that upland sites be used. More data is needed to confirm this finding. Additionally, work is needed to assess the impacts of continuous grazing.

Table 7. Comparison of *E. coli* levels observed when runoff occurred during or within 2 weeks of grazing (Stocked) and *E. coli* levels observed more than 2 weeks after grazing (Destocked).

Statistic	BB1 (Destocked)	BB2 (Stocked)	BB2 (Destocked)	BB3 (Stocked)	BB3 (Destocked)
Mean	10,943	34,400	6,039	281,013	5,428
Geometric Mean	4,594	25,028	3,829	119,965	2,660
Site Mean	7,003	21,652	4,606	84,972	7,079
n	13	2	12	4	14

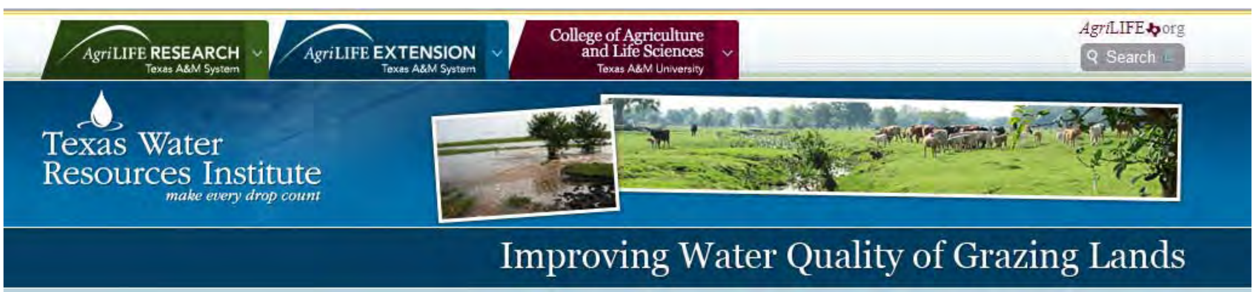
Task 3: Technical Transfer

The objective of Task 3 was to develop and deliver educational materials regarding bacterial runoff and conservation practices for reducing it to agricultural producers. Results from Task 2 formed the basis of the educational materials. The primary delivery mechanism was the *Lone Star Healthy Streams* program.

Subtask 3.1: Develop And Deliver Educational Materials Regarding Bacteria Runoff And Conservation Practices For Reducing It To Agricultural Producers.

Improving Water Quality of Grazing Lands Website

In September 2007, TWRI developed the website titled "Improving Water Quality of Grazing Lands." This website displays the efforts associated with this project and other related projects evaluating conservation practices and developing education programs to address bacteria. It can be found at the following web address: http://grazinglands-wq.tamu.edu/.



Between September 2007 and September 2010, there were 1,038 unique visitors to the website (Fig. 11). As materials for the project were developed, they were added to the website. Materials found on the website include project work plan, reports, presentations and publications, project personnel, links, and other relevant information.

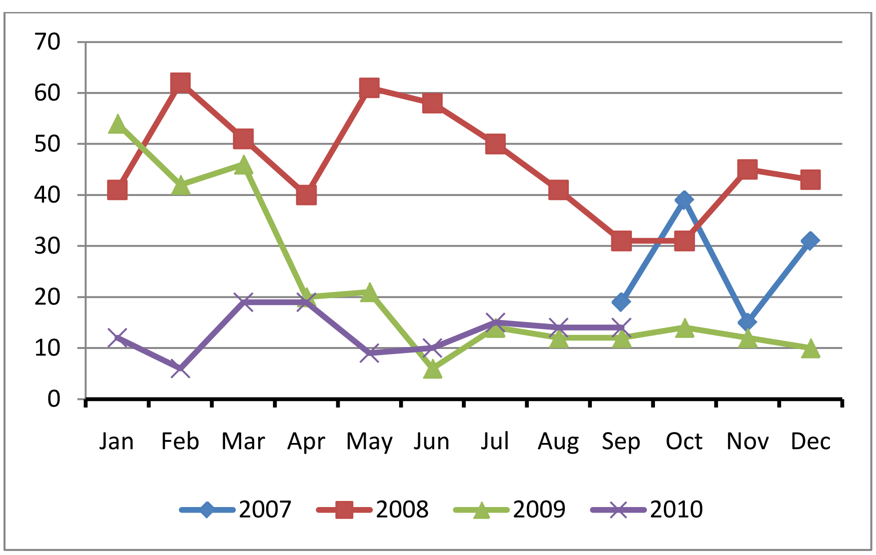


Figure 11. Number of unique visitors to *Improving Water Quality of Grazing Lands* website

Prescribed Grazing Fact Sheet

A fact sheet was drafted summarizing project findings and their implications to producers (Appendix E). This fact sheet will be included in the *Lone Star Healthy Streams Beef Cattle Resource Manual* expected to be completed in spring 2011. Findings from grazing work at Riesel and the Welder Wildlife Refuge will be included alongside the findings from this study. This fact sheet will be an important component of the *Lone Star Healthy Streams* educational program.

State-Wide Educational Program Delivery

Producer participation took place as a result of county educational programs and field days held throughout the state. Through the statewide *Lone Star Healthy Streams* educational effort, information gathered through this demonstration and evaluation was provided to livestock producers statewide. Educational materials regarding bacterial runoff and conservation practices for reducing it were delivered to agricultural producers at over 60 programs around the state as follows:

- November 29, 2007 – Lone Star Healthy Streams Steering Committee, Temple
- December 2, 2007 – Copano Bay TMDL Meeting, Refugio
- January 16, 2008 – Texas Ag Industries Association Annual Membership Conference, Arlington
- January 29, 2008 – Farm Bureau Ag Leadership Conference, College Station
- February 3-5, 2008 – Annual Meeting of the Southern Branch of the American Society of Agronomy, Dallas
- February 6, 2008 – Texas Farm Bureau AgLead Class VIII, College Station
- Feb 15, 2008 – Harris County Master Urban Rancher Series, Houston
- March 15, 2008 – Texas and Southwestern Cattle Raisers Association, Natural Resource Committee, Corpus Christi
- April –June 2008
    - Victoria County educational program
    - Bosque County educational program
    - McClennan County educational program
    - Hamilton County educational program
    - Coryell County educational program
    - Henderson County educational program
    - San Augustine County educational program
    - Wharton County educational program
- July-September 2008
    - Austin County educational program
    - Brazoria County educational program
    - Falls County educational program
    - Travis County educational program
    - Bastrop County educational program
    - McLennan County educational program
    - Hunt County educational program
    - Jackson County educational program

- September 17, 2008 – My Piece of Texas Grazing Workshop, Hunt (Appendix F)
- October 1, 2008 - My Piece of Texas Grazing Workshop, Beeville (Appendix F)
- October 8, 2008 –American Society of Agronomy Meeting, Houston
- October-December 2008
    - Brazos County educational program
    - Robertson County educational program
    - Gonzales County educational program
    - McLennan County educational program
- January 9, 2009 –Central Texas Cow-Calf Clinic, Milano
- January 21, 2009 –Howard Payne University Seminar, Brownwood
- January-March 2009
    - Walker County educational program
    - Williamson County educational program
    - Travis County educational program
    - Rusk County educational program
- April 21, 2009 - Lee County educational program
- April 24, 2009 – Polk County educational program
- April 24, 2009 – Tyler County educational program
- April 24, 2009 – Houston County educational program
- April 30, 2009 – Bastrop County educational program
- May 21, 2009 – Luling Foundation Field Day
- May 29, 2009 – Brazos County educational program
- January 11, 2010 – Texas Pasture and Forage Work Group
- January 11, 2010 – Texas Beef Workers
- January 21, 2010 – Jackson County educational program
- January 26, 2010 – Bell County educational program
- January 27, 2010 – National Cattlemen's Beef Association annual meeting, San Antonio
- January 29, 2010 – Burleson County educational program
- February 9, 2010 – Blackland Income Growth educational program
- February 18, 2010 – Williamson County educational program
- March 30, 2010 – AgriLife Pasture & Livestock Management Program for Novices
- April 13, 2010– Victoria County educational program
- April 30, 2010 – Fayette County educational program
- May 19, 2010 – Texas Beef Workers, San Angelo
- June 7, 2010 – Liberty County educational program
- June 7, 2010 – Limestone County educational program
- July 9, 2010 – Austin County educational program
- July 15, 2010 – Mid-Tex Chapter, Independent Cattlemen's Association, Lockhart
- September 17, 2010 – Travis County educational program
- September 24, 2010 – McGregor Research Center Field Day, McGregor

Education Program Evaluation:

The education program was evaluated with beef cattle producers by the use of a retrospective post evaluation survey instrument that analyzes a) mean scores of pre- versus post-presentation results using a Likert scale, and b) percent change of knowledge prior to and following an educational program where the project results are presented. The survey was administered at the Luling Foundation Water Field Day on October 29, 2010. Survey results (Appendix G) indicated that 97% of participants were mostly or completely satisfied with the educational program; 100% would recommend the program to others; and most importantly, 82% were likely to adopt one or more of the BMPs presented during the program to improve water quality. Further, the survey indicated that as a result of the education program, the average knowledge gained was 52%. The survey indicated specific increases in the understanding of:

- the Clean Water Act of 60.6%
- the 303(d) List of 54.54%
- TMDLs of 54.54%
- *E. coli* causing illnesses of 39.39%
- *E. coli* as an indicator of 51.51%
- water quality is determined by *E. coli* of 51.51%
- riparian areas of 51.51%
- BMPs to protect riparian areas of 57.57%
- cost-share programs of 48.48%

Conclusion

Evaluation and demonstration of the effect of grazing management on bacteria runoff at the BCSC has produced some interesting results. First, *E. coli* concentrations in runoff observed at all sites (even the ungrazed) greatly exceeded Texas Water Quality Standards. Although these standards only apply to water bodies, such as streams and reservoirs, and not to edge-of-field runoff as described here, it does provide an indication of the potential difficulties in achieving water quality standards during runoff events, even in ungrazed areas.

Second, feral livestock and wildlife can significantly impact *E. coli* levels, even at ungrazed sites. Both mean and median *E. coli* levels associated with the ungrazed SR were noticeably higher than would be expected due primarily to two events in October 2009 where *E. coli* levels in the ungrazed pasture (site BB1) greatly exceeded all other measurements at the site. It is speculated that feral hogs, which are common along the Brazos River bottom, were the source of these elevated *E. coli* levels.

Third, site mean concentrations and mean concentrations suggest that moderate stocking does not significantly increase *E. coli* levels above background levels. Further, site mean concentrations and mean concentrations suggest that 67-85% reductions in *E. coli* levels may be achieved by converting from heavy to moderate stocking rates.

Fourth, pastures stocked heavier than 10 acres per AU should be the primary focus of implementation efforts. Data indicate that stocking at rates heavier than 10 acres per AU may increase *E. coli* concentrations in runoff while stocking at rates less than 10 acres per animal unit do not yield higher *E. coli* levels than ungrazed pastures. Much of the pastureland in Texas would fall into the category of being stocked at greater than 10 acres per AU.

Finally, runoff events occurring while the sites were stocked or within two weeks of them being stocked produced the highest *E. coli* concentrations. By two weeks of the end of grazing, concentrations had fallen substantially and after 30 days, *E. coli* values had declined to background levels. Based on these findings, it is recommended that grazing be deferred on creek pastures during rainy periods to reduce bacterial loading to water bodies. More data, however, is needed to confirm this finding. Additionally, work is needed to assess the impacts of continuous grazing.

To increase the awareness of the bacteria issue and BMPs for addressing them, AgriLife Extension and TWRI developed a fact sheet, provided posters and presentations, and developed a website to help disseminate information to local, state, and national audiences. The website alone has reached 1,038 unique visitors since its inception.

Much work remains to be done. Water quality standards should be evaluated in light of the findings of this study, additional evaluation of BMPs is needed, and transfer of this information to cattlemen throughout Texas must continue.

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Appendix A

E. coli levels (cfu/100 mL) measured at sites BB1, BB2, and BB3.

Sample Date	*BB1 (Ungrazed)*	*BB2 (Mod. SR)*	*BB3 (Hvy SR)*	*Collection Method*
3/13/09			140	Grab
3/25/09	1,200	1,500	6,600	Grab
3/26/09		1,000	7,200	ISCO®
3/27/09			2,000	Grab
4/17/09	1,155	980	450	ISCO®
4/18/09	4,400	2,225	2,100	ISCO®
4/28/09	7,600	12,200	24,000	ISCO®
10/4/09	57,000	5,114	3,065	ISCO®
10/9/09	36,000	24,043	15,000	ISCO®
10/13/09	42,851	23,826	5,591	ISCO®
10/22/09			172,500	Grab
10/26/09	153,000	162,000	90,000	Grab
10/26/09	261,000	181,000	45,000	ISCO®
11/16/09			800,000	ISCO®
11/21/09	9,300	58,000	223,750	ISCO®
11/29/09			87,000	ISCO®
12/1/09	8,100	10,800	13,300	ISCO®
12/22/09	2,800	3,400	4,400	ISCO®
12/30/09		2,300	5,000	ISCO®
1/16/10	410	4,900	830	ISCO®
1/29/10	5,400	9,500	4,400	ISCO®
2/4/10	2,400	8,800	2,699	ISCO®
2/8/10	9,800	6,000	8,100	ISCO®
2/11/10	2,100	1,500	1,100	ISCO®
6/9/10	8,900	8,200	9,250	ISCO®

Appendix B

Validated *E. coli* levels (cfu/100 mL), runoff quantity (cubic feet), and loading (cfu) at BB1, BB2, and BB3.

	BB1 – Ungrazed			BB2 - Moderate SR			BB3 - Heavy SR		
Date	**Conc. (cfu/100 ml)**	**Runoff (cf)**	**Load (cfu)**	**Conc. (cfu/100 ml)**	**Runoff (cf)**	**Load (cfu)**	**Conc. (cfu/100 ml)**	**Runoff (cf)**	**Load (cfu)**
3/13/09							140	205	8.14E+06
3/25/09	1,200	210	7.15E+07						
3/26/09				1,000	3,261	9.24E+08	7,200	1,703	3.47E+09
3/27/09							2,000	62	3.52E+07
4/17/09	1,155	1,342	4.39E+08	980	14,881	4.13E+09	450	9,913	1.26E+09
4/18/09	4,400	1,755	2.19E+09	2,225	10,505	6.62E+09	2,100	5,572	3.31E+09
4/28/09	7,600	597	1.28E+09	12,200	5,173	1.79E+10	24,000	7,710	5.24E+10
10/4/09	57,000	200	3.23E+09	5,114	781	1.13E+09	3,065	4,173	3.62E+09
10/9/09	36,000	472	4.82E+09	24,043	3,085	2.10E+10	15,000	7,134	3.03E+10
11/16/09							800,000[1]	257	5.82E+10
11/21/09	9,300	267	7.03E+08	58,000[2]	2,153	3.54E+10	223,750[2]	3,474	2.20E+11
11/29/09							87,000[2]	323	7.95E+09
12/1/09	8,100	3,477	7.98E+09	10,800[2]	7,210	2.20E+10	13,300[2]	9,300	3.50E+10
12/22/09	2,800	86	6.82E+07	3,400	1,093	1.05E+09	4,400	2,585	3.22E+09
12/30/09				2,300	287	1.87E+08	5,000	1,113	1.58E+09
1/16/10	410	249	2.89E+07	4,900	1,888	2.62E+09	830	1,893	4.45E+08
2/4/10	2,400	319	2.17E+08	8,800	1,893	4.72E+09	2,600	2,378	1.75E+09
2/8/10	9,800	1,992	5.53E+09	6,000	4,653	7.91E+09	8,100	5,448	1.25E+10
2/11/10	2,100	3,456	2.06E+09	1,500	7,059	3.00E+09	1,100	8,204	2.56E+09

1 – Runoff event occurred while pasture stocked

2 – Runoff event occurred within 2 weeks of pasture being stocked

Appendix C

p-values for One-Way ANOVA and Mann-Whitney Test of Differences in Mean and Median *E. coli* Concentrations Observed in Runoff from Stocked and Ungrazed Pastures

p-values for Mann-Whitney Test of differences in median *E. coli* concentrations observed in runoff from pastures that are ungrazed, stocked at 10-100 acres/AU, and stocked at <10 acres/AU

SR (ac/AU)	Ungrazed	10-100	<10
Ungrazed	1.00	0.41	0.45
10-100	0.41	1.00	0.05
<10	0.45	0.05	1.00

p-values for One-way ANOVA of mean *E. coli* concentrations observed in runoff from pastures that are ungrazed, stocked at 10-100 acres/AU, and stocked at <10 acres/AU

SR (ac/AU)	Ungrazed	10-100	<10
Ungrazed	1.00	0.23	0.41
10-100	0.23	1.00	0.30
<10	0.41	0.30	1.00

p-values for Mann-Whitney Test of differences in median *E. coli* concentrations (cfu/100 mL) observed in runoff from pastures that are ungrazed and stocked at 50-100 acres/AU, 10-50 acres/AU, 2.5-10 acres/AU, and <2.5 acres/AU

SR (ac/AU)	Ungrazed	50-100	10-50	2.5-10	<2.5
Ungrazed	1.00	0.46	0.58	0.53	0.52
50-100	0.46	1.00	0.94	0.08	0.16
10-50	0.58	0.94	1.00	0.27	0.30
2.5-10	0.53	0.08	0.27	1.00	0.87
<2.5	0.52	0.16	0.30	0.87	1.00

p-values for One-way ANOVA of mean *E. coli* concentrations observed in runoff from pastures that are ungrazed and stocked at 50-100 acres/AU, 10-50 acres/AU, 2.5-10 acres/AU, and <2.5 acres/AU

SR (ac/AU)	Ungrazed	50-100	10-50	2.5-10	<2.5
Ungrazed	1.00	0.27	0.54	0.91	0.22
50-100	0.27	1.00	0.52	0.24	0.27
10-50	0.54	0.52	1.00	0.55	0.37
2.5-10	0.91	0.24	0.55	1.00	0.17
<2.5	0.22	0.27	0.37	0.17	1.00

Appendix D

p-values for One-Way ANOVA and Mann-Whitney Test of Differences in Mean and Median *E. Coli* Concentrations Observed in Runoff from Stocked and Ungrazed Pastures (EXCLUDING BB1 OUTLIERS)

p-values for Mann-Whitney Test of differences in median *E. coli* concentrations observed in runoff from pastures that are ungrazed, stocked at 10-100 acres/AU, and stocked at <10 acres/AU when unexplained outliers removed from ungrazed dataset

SR (ac/AU)	Ungrazed	10-100	<10
Ungrazed	1.00	0.97	0.13
10-100	0.97	1.00	0.05
<10	0.13	0.05	1.00

p-values for One-way ANOVA of differences in mean *E. coli* concentrations observed in runoff from pastures that are ungrazed, stocked at 10-100 acres/AU, and stocked at <10 acres/AU when unexplained outliers removed from ungrazed dataset

SR (ac/AU)	Ungrazed	10-100	<10
Ungrazed	1.00	0.67	0.39
10-100	0.67	1.00	0.30
<10	0.39	0.30	1.00

p-values for Mann-Whitney Test of differences in median *E. coli* concentrations (cfu/100 mL) observed in runoff from pastures that are ungrazed and stocked at 50-100 acres/AU, 10-50 acres/AU, 2.5-10 acres/AU, and <2.5 acres/AU when unexplained outliers removed from ungrazed dataset

SR (ac/AU)	Ungrazed	50-100	10-50	2.5-10	<2.5
Ungrazed	1.00	0.95	1.00	0.13	0.27
50-100	0.95	1.00	0.52	0.24	0.27
10-50	1.00	0.52	1.00	0.55	0.37
2.5-10	0.13	0.24	0.55	1.00	0.17
<2.5	0.27	0.27	0.37	0.17	1.00

p-values for One-way ANOVA of differences in mean *E. coli* concentrations observed in runoff from pastures that are ungrazed and stocked at 50-100 acres/AU, 10-50 acres/AU, 2.5-10 acres/AU, and <2.5 acres/AU when unexplained outliers removed from ungrazed dataset

SR (ac/AU)	Ungrazed	50-100	10-50	2.5-10	<2.5
Ungrazed	1.00	0.99	0.47	0.21	0.24
50-100	0.99	1.00	0.52	0.24	0.27
10-50	0.47	0.52	1.00	0.55	0.37
2.5-10	0.21	0.24	0.55	1.00	0.17
<2.5	0.24	0.27	0.37	0.17	1.00

Appendix E

PRESCRIBED GRAZING

NRCS CODE 528

---DRAFT---

Description:
The controlled harvest of vegetation with grazing or browsing animals, managed with the intent to achieve a specified objective. This practice employs utilization of grazing management principles that define stocking rate; rest periods; and intensity, frequency, duration, and season of grazing to promote ecologically and economically stable plant communities that meet both the land manager's objectives and resource needs. Moderate stocking has been shown to not significantly increase *E. coli* levels above background levels and provide additional benefits to producers. This, in combination with deferred grazing on creek pastures during rainy periods and use of other practices can significantly reduce bacterial runoff (Wagner, 2010).

Benefits to Producer:

- Greater distribution of grazing and utilization of forage.
- Reduces supplemental feed costs.
- Reduces manure deposition and associated bacterial contamination of surface waters.
- Reduces streambank destabilization and associated erosion due to trampling and overgrazing of banks.
- Improved health and vigor of desired plants to maintain a stable plant community.
- Provides and maintains food, cover, and shelter for wildlife.
- Maintains and improves surface and/or subsurface water quantity and quality.
- Reduces accelerated soil erosion and maintains or improves soil condition.
- Improves or maintains animal health and productivity by providing better quantity and quality of forage for grazing.
- Allows for regeneration of riparian zone vegetation to act as a full or partial buffer.

Bacterial Removal Efficiency:

- Prescribed grazing resulted in the following bacterial reductions:
  - *E. coli:*
    - 200% (from 1250 cfu/100mL to 425 cfu/100mL) when intensity of grazing was changed from heavy (1.9 AUM/ha) to moderate (0.8 AUM/ha) over a 7-month period (Tate et al., 2004).
    - 72% reduction (from 177.6 cfu/100 mL to 103.5 cfu/100 mL) with use of prescribed grazing on 152 acres and when combined with other practices including contour farming, grassed waterways, nutrient management, and pest management (EPA, 2010).
    - 67-85% reductions in *E. coli* levels may be achieved by converting from heavy to moderate stocking rates (Wagner, 2010).
  - Fecal coliform:
    - 90% reduction (from 30.2 cfu/100mL to 2.9 cfu/100mL) when intensity of grazing was changed from heavy to no grazing (Tiedemann et al., 1987).

        - 96% reduction (from 92 cfu/100mL to 4.0 cfu/100mL) when intensity of grazing was changed from heavy to no grazing (Tiedemann et al., 1988).
- Prescribed grazing is typically used in conjunction with other practices such as fencing and alternate watering facilities. These practices have been shown to reduce concentrations of bacteria.

Other Benefits:

- The use of prescribed grazing resulted in the following benefits:
    - Increased potential for improved ranch profits by 50% (Richards and George, 1996).
    - Reduced suspended sediment by 8% and nitrogen loads by 34% when combined with other practices (Portneuf SWCD, 2008).
    - Runoff from a heavily stocked pasture (1.35 AUM/acre) was 1.4 times greater than from a moderately stocked pasture (2.42 AUM/acre), and 9 times greater than from a lightly stocked pasture (3.25 AUM/acre) (Kauffman and Krueger, 1984).
    - Increased fish production by 184% where livestock use was light (Bowers et al., 1979).
    - Reduced soil compaction under light to moderate grazing intensities (Tate et al., 2004).
    - Increased infiltration, runoff attenuation, and soil moisture retention when appropriate rest periods are utilized (Ratliff et al., 1972).
    - Enhanced herbaceous plant diversity (Marty, 2005).
    - Control of noxious weeds (DiTomaso, 2000; Frost and Launchbaugh, 2003).

Estimated Installation Costs:

- $3.10/acre to $8.37/acre depending on duration of grazing deferment
- If used in conjunction with fencing and alternate watering facilities, implementation costs will be higher.
- Cost information obtained from the Texas NRCS Electronic Field Office Technical Guide for Zone 4; costs may vary for other zones.

Practice Life Span:

- 1 year (renewed annually)

Available Cost-Share Programs:

- EQIP (up to 75% cost-share).

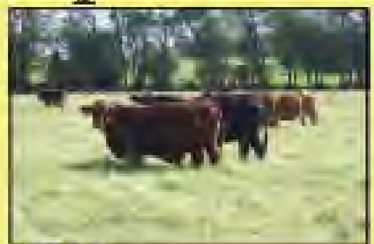
For More Information:

- Contact your local SWCD; to find your contact, visit http://www.tsswcb.state.tx.us/swcds.

Appendix F

My Piece of Texas Grazing Workshops

Lunch will be served
Morning session will be classroom presentations. Afternoon session will be field examples.



Presented by
Texas Grazing Lands Conservation Initiative (GLCI)
USDA-Natural Resources Conservation Service (NRCS) & Texas AgriLife Extension Service

For more info on the workshops and times, call the offices listed below.
Some locations do have limited seating, call now to reserve your spot!

Town	Date	Location	Point of Contact
Clarendon (Donley Co.)	9-3-08 Registration Deadline: Aug. 29.	Clarendon College	Donley Co. SWCD (806) 874-3561 ext. 3 AgriLife Extension Service (806) 874-2141
Cresson (Parker/Hood Co.)	9-10-08 Registration Deadline: Sept. 5	Bear Creek Ranch 2701 Bear Creek Road, Aledo	Parker Co. SWCD (817) 594-4672, ext. 3 AgriLife Extension Service (817) 598-6168
Hunt (Kerr Co.)	9-17-08 Deadline: Sept. 12	Kerr Wildlife Management Area 2625 FM 1340, Hunt	AgriLife Extension Service (830) 257-6568
Crockett (Houston Co.)	9-24-08 Deadline: Sept. 19	Houston County Livestock Commission, Hwy 21, W. of Crockett	AgriLife Extension Service (936) 544-3255, ext. 265
Beeville (Bee Co.)	10-1-08 Deadline: Sept. 26	Bee County Expo Center 214 South FM 351, Beeville	AgriLife Extension Service (361) 362-3280

A $25 registration fee will include lunch and a newly published handbook titled, "Managing My Piece of Texas." The how-to guide was developed to assist landowners in managing grazing lands across Texas. Landowners will learn to estimate forage production, grazeable acres, and setting proper stocking rates, among other grazing management principles.

AgriLIFE EXTENSION

Texas Section
Society for
Range Management

NRCS
Helping People Help the Land
An Equal Opportunity Provider and Employer

NRCSTX0808

Appendix G

BEFORE PROGRAM	**AFTER PROGRAM**	**KNOWLEDGE GAIN** (%completely + %good)
Understanding of Clean Water Act 3.03% Completely 18.18% Good 42.42% Fairly 33.33% Poorly 3.03% Didn't answer	Understanding of Clean Water Act 24.24% Completely 57.58% Good 18.18% Fairly 0.00% Poorly 0.00% Didn't answer	Understanding of Clean Water Act 60.6%
Understanding of 303(d) List 9.09% Completely 12.12% Good 24.24% Fairly 48.48% Poorly 6.06% Didn't answer	Understanding of 303(d) List 33.33% Completely 42.42% Good 21.21% Fairly 3.03% Poorly 0.00% Didn't answer	Understanding of 303(d) List 54.54%
Understanding of TMDL s 9.09% Completely 12.12% Good 15.15% Fairly 54.55% Poorly 9.09% Didn't answer	Understanding of TMDL s 33.33% Completely 42.42% Good 18.18% Fairly 0.00% Poorly 6.06% Didn't answer	Understanding of TMDL s 54.54%
Understanding of *E. coli* causing illnesses 18.18% Completely 33.33% Good 21.21% Fairly 21.21% Poorly 6.06% Didn't answer	Understanding of *E. coli* causing illnesses 39.39% Completely 51.52% Good 6.06% Fairly 0.00% Poorly 3.03% Didn't answer	Understanding of *E. coli* causing illnesses 39.39%
Understanding that *E. coli* is an indicator organism 6.06% Completely 33.33% Good 33.33% Fairly 18.18% Poorly 9.09% Didn't answer	Understanding that *E. coli* is an indicator organism 36.36% Completely 54.55% Good 3.03% Fairly 0.00% Poorly 6.06% Didn't answer	Understanding that *E. coli* is an indicator 51.51%

BEFORE	AFTER	DIFFERENCE
Understand water quality is determined by *E. coli* 12.12% Completely 21.21% Good 36.36% Fairly 24.24% Poorly 6.06% Didn't answer	Understand water quality is determined by *E. coli* 39.39% Completely 45.45% Good 12.12% Fairly 0.00% Poorly 3.03% Didn't answer	Understand WQ is determined by *E. coli* 51.51%
Understanding of riparian areas 15.15% Completely 27.27% Good 27.27% Fairly 24.24% Poorly 6.06% Didn't answer	Understanding of riparian areas 42.42% Completely 51.52% Good 6.06% Fairly 0.00% Poorly 0.00% Didn't answer	Understanding of riparian areas 51.51%
Understand BMPs can protect riparian areas 9.09% Completely 15.15% Good 39.39% Fairly 21.21% Poorly 15.15% Didn't answer	Understand BMPs can protect riparian areas 30.30% Completely 51.52% Good 9.09% Fairly 0.00% Poorly 9.09% Didn't answer	Understand BMPs protect riparian areas 57.57%
Understand cost-share programs 3.03% Completely 24.24% Good 30.30% Fairly 33.33% Poorly 9.09% Didn't answer	Understand cost-share programs 33.33% Completely 42.42% Good 18.18% Fairly 0.00% Poorly 6.06% Didn't answer	Understand cost-share programs 48.48%
AVERAGE KNOWLEDGE GAIN FOR ALL QUESTIONS:		***52.18%***

Overall, how satisfied are you with this educational program activity?

48.48% Completely
48.48% Mostly
0.00% Somewhat
0.00% Slightly
0.00% Not at all
3.03% Didn't answer

What did you like most about this educational program activity?

- Everything
- Learned a lot and I can use these practices at home
- Variety of topics covered
- The range management
- That there were many different, yet related, subjects
- It applied to current issues facing the farmer/rancher
- All
- Speakers
- Field trips
- *E. Coli* information
- Tours and speaker
- Water law
- Rainwater harvesting, solar water well
- Onsite, in field presentations
- Clean water act
- Texas water laws
- Laws
- Hay ride tour
- Texas water laws
- Field trip visit to rain harvest sites
- 39.39% did not answer question

What did you like least about this educational program activity?

- Fertilizer info
- Cold and dusty out in the field
- Some info was only to commercial agricultural producers
- Too fast
- Got started too late
- Soil nutrient (not a cattle producer)
- Sleepy after lunch
- None, all good
- Fertilizations
- Hard seats
- 69.70% did not answer question

Would you recommend this particular educational program activity to others?

100% Yes
0.00% No

How likely are you to adopt one or more of the BMPs presented in today's program designed to improve water quality?

81.82% Likely
18.18% Not likely