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Evaluation and Demonstration of BMPs for Cattle on Grazing Lands for the Lone Star Healthy Streams Program

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Texas Water Resources Institute
make every drop count

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Prepared for:
Texas State Soil and Water Conservation Board

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Executive Summary

According to the 2008 Texas Water Quality Inventory and 303(d) List, recreation is impaired in 274 waterbody segments and oyster harvest is impaired in another 21 due to bacteria. One of the primary strategies for reducing bacteria in many of these waterbodies is to provide technical and financial assistance to implement best management practices (BMPs) to reduce bacteria runoff from cattle on grazing lands. In order to inspire behavior change, evaluations and demonstrations of BMP effectiveness are needed to encourage voluntary implementation of BMPs and participation in federal and state technical and financial assistance programs designed to reduce bacterial runoff ultimately improve water quality.

The goal of this project was to reduce bacterial contamination caused by grazing livestock in Texas waterbodies through evaluation and demonstration of BMP effectiveness in reducing bacteria runoff from grazing lands. This BMP effectiveness data then served as the scientific-basis for the *Lone Star Healthy Streams* education program (grazing cattle component). *Lone Star Healthy Streams* programs and other outreach and technology transfer were utilized to increase voluntary implementation of BMPs and participation in federal and state technical and financial assistance programs by providing landowners with feasible options for addressing sources of bacteria through education programs based on the evaluation and demonstration of BMP effectiveness.

From June 2010 to June 2012, edge-of-field runoff was collected using automated ISCO samplers from the Beef Cattle Systems Center, Welder Wildlife Refuge and Riesel demonstration sites and enumerated for *E. coli*, fecal coliforms and *Enterococcus* to evaluate grazing management. Also, from October 2010 through May 2012, the effects of alternative water, alternative shade, and rip-rap on cattle behavior were assessed at the Texas A&M AgriLife Research Center at McGregor utilizing Lotek GPS collars.

Results suggest that stocking rates heavier than 6 ha/AUY (14.8 ac/AUY) increased *E. coli* loading, but only when sites were actively or recently (within the last two weeks) stocked when runoff occurred. The study also showed that reductions in the amount of time that cattle spent within the riparian zone averaged 27% when alternative shade was provided, but reductions varied seasonally. Unlike previous studies, the single alternative water trial conducted did not result in reductions in the amount of time that cattle spent in the riparian zone (likely due to riparian shade). The results of this study underscore the importance of implementing water-quality BMPs on a site specific basis. Finally, findings from the riparian rip-rap trials were inconclusive and as such rip-rap is not recommended as a best management practice at this time. The strong linear correlations of *Enterrococcus* and fecal coliforms with *E. coli* suggest that reductions in *E. coli* observed from implementation of practices evaluated herein would be expected to result in similar reductions for fecal coliforms and *Enterococcus.*

Data collected through the duration of the project was transferred to both landowners and agency personnel. Data was provided for incorporation into the USDA-ARS TBET model, USDA-NRCS standards and specifications, Texas A&M AgriLife Extension Service LSHS BMP manuals and presentations, and various other publications. Further, program information reached almost 1000 web users, over 3000 landowners through county programs and field days, and additional participants at almost 20 public meetings and steering committee meetings.

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List of Acronyms

AUY – Animal Unit Year
BCSC – Beef Cattle Systems Center
BMP – Best Management Practice
CFU – Colony Forming Units
EPA – U.S. Environmental Protection Agency
GPS - global positioning system
LSHS – *Lone Star Healthy Streams* Program
QAPP – Quality Assurance Project Plan
SCSC – Texas A&M Department of Soil and Crop Sciences
TBET - Texas Best management practice Evaluation Tool
TMDL – Total Maximum Daily Load
TSSWCB – Texas State Soil and Water Conservation Board
TWRI – Texas Water Resources Institute
USDA-ARS – United State Department of Agriculture, Agricultural Research Service
USDA-NRCS – USDA Natural Resources Conservation Service
WQMP – Watershed Quality Management Plan

Introduction

Project Background:

According to the 2008 Texas Water Quality Inventory and 303(d) List, recreation is impaired in 274 waterbody segments and oyster harvest is impaired in another 21 due to bacteria. To address the bacteria impaired waterbodies, Texas is developing and implementing total maximum daily loads (TMDLs), TMDL Implementation Plans, and Watershed Protection Plans. One of the primary strategies for reducing bacteria in many of these waterbodies is to provide technical and financial assistance to implement best management practices (BMPs) designed to reduce bacteria runoff from cattle on grazing lands. Because grazing land is the dominant land use in the state, there is a statewide need for BMPs targeted to this land use and livestock category. However, in order inspire behavior change, evaluations and demonstrations of BMP effectiveness are needed to encourage voluntary implementation of BMPs and participation in federal and state technical and financial assistance programs designed to reduce the runoff of bacteria and ultimately lead to improved water quality.

The evaluation of BMPs for cattle on grazing lands was initiated with Grassland Reserve Program funds made available by the TSSWCB through the USDA-NRCS *Environmental Management of Grazing Lands* (TSSWCB Project 06-14), Clean Water Act §319(h) grant funds made available by the TSSWCB through the U.S. Environmental Protection Agency (EPA) *Lone Star Healthy Streams* (TSSWCB Project 06-5), and Conservation Innovation Grant funds provided by USDA-NRCS *Bacteria Runoff BMPs for Intensive Beef Cattle Operations*. The development of a comprehensive education program founded on the evaluation of BMPs in those projects is being supported with CWA §319(h) grant funds made available by the TSSWCB through EPA for *Development of a Synergistic, Comprehensive Statewide Lone Star Healthy Streams Program* (TSSWCB Project 09-06).

Further evaluation of BMPs is needed to verify beneficial impacts and provide the scientific backbone of Texas A&M AgriLife Extension Service educational programs (i.e., *Lone Star Healthy Streams*). Both continued evaluation of new publications/articles/research and field evaluation and demonstration of BMPs ensures the most up-to-date and relevant information is available for Texas ranchers, as well as, decision-makers at the TSSWCB, USDA-NRCS and livestock groups in the state. Only through continued demonstration of BMPs, educational programs, and landowner assistance for implementing effective BMPs will significant progress be made to restore water quality across the state.

Project Goals/Objectives

The project goal was to reduce bacterial contamination in Texas waterbodies caused by grazing livestock through evaluation and demonstration of BMP effectiveness in reducing bacteria runoff from grazing lands. Objectives aimed to reduce nonpoint source pollution affecting surface water quality by:

- Using BMP effectiveness data as the scientific-basis for the *Lone Star Healthy Streams* program.
- Increasing voluntary implementation of BMPs and participation in federal and state technical and financial assistance programs by providing landowners with feasible options for addressing sources of bacteria through education programs based on the evaluation and demonstration of BMP effectiveness.

Measures of success of the project:

- Evaluate the effectiveness of grazing management treatments (no grazing, moderate grazing, and heavy grazing) in reducing bacteria runoff on at least three demonstration sites.
- Evaluate the effectiveness of structural BMPs in modifying cattle movement to change fecal deposition patterns and ultimately reducing bacteria contributions to adjacent waterbodies at the demonstration sites.
- Transfer results from BMP effectiveness studies to landowners, natural resource agencies, and others through the LSHS program and other publications in order to increase BMP adoption rates and participation in federal and state technical and financial assistance programs.
- At least 1 field day will be held at a demonstration site to highlight BMP effectiveness studies.
- Ensure data of known and acceptable quality is collected utilizing established methods.

Methods and Results

Task 1: Project Coordination and Administration

Objective: To effectively administer, coordinate and monitor all work performed under this project including technical and financial supervision and preparation of status reports.

Subtask 1.1: Preparation of quarterly progress reports

TWRI prepared and submitted Quarterly Progress Reports which can be viewed online at http://lshs.tamu.edu/projects/, under “Projects” – “Lone Star Healthy Streams Program.” TWRI submitted 8 Quarterly Progress Reports throughout the project as on the following dates:

- September 15, 2010 TWRI Submitted Quarter 1 Progress Report
- November 15, 2010 TWRI Submitted Quarter 2 Progress Report
- March 14, 2011 TWRI Submitted Quarter 3 Progress Report
- June 14, 2011 TWRI Submitted Quarter 4 Progress Report
- September 15, 2011 TWRI Submitted Quarter 5 Progress Report
- December 15, 2011 TWRI Submitted Quarter 6 Progress Report
- March 15, 2011 TWRI Submitted Quarter 7 Progress Report
- June 15, 2012 TWRI Submitted Quarter 8 Progress Report

Subtask 1.2: Submission of required financial forms every quarter

Invoice #	Date From	Date To	Invoice $$	Balance
R018581	6.1.10	8.31.10	217.64	162,146.36
R018911	9.1.10	11.30.10	26,438.26	135,708.10
R019222	12.1.10	2.28.11	15,088.98	120,619.12
R019543	3.1.11	5.31.11	20,811.34	99,807.78
R019867	6.1.11	8.31.11	21,823.69	77,984.09
R020190	9.1.11	11.30.11	16,747.47	61,236.62

R020495	12.1.11	2.29.12	13,375.86	47,860.76
R020868	3.1.12	5.31.12	12,028.77	35,831.99
R021116	6.1.12	7.31.12	33,074.06	2,757.93
R021182	8.1.12	8.31.12	2,757.93	0

Subtask 1.3: Coordination of meetings as appropriate with project participants to discuss project activities/schedule, lines of responsibility, communication needs, and other requirements

Meetings were held by project partners on the dates below to discuss coordination efforts such as the contract, budget, deliverables, activities, and schedule.

- June 24, 2010
- September 28, 2010
- March 9, 2011
- May 10, 2011
- May 17, 2012
- June 23, 2011
- June 24, 2011
- August 18, 2011
- October 24, 2011

Subtask 1.4: Participation in public communication

TWRI and/or SCSC participated in 15 public meetings to communicate project goals, activities, and accomplishments as listed below:

- TSSWCB Work Session – September 15, 2010
- Ag Council Meeting – October 19, 2010
- Annual Meeting of Texas Soil and Water Conservation District Directors – October 25-27, 2010
- Carters Creek TMDL Natural Resources Workgroup Meeting – November 9, 2010
- TSSWCB Board Meeting – November 10, 2010
- Texas Farm Bureau Annual Convention – December 5-6, 2010
- Copano Bay TMDL Ag Work Group – December 14, 2010
- Carters Creek TMDL Natural Resource Workgroup Meeting – December 15, 2010
- TSSWCB Board Meeting – January 27, 2011
- Independent Cattlemen's Association Annual meeting – June 22, 2011
- Watershed Coordinator Roundtable – July 27, 2011
- Oklahoma Cattlemen's Association Annual meeting – July 29, 2011
- Bacterial Source Tracking- State of the Science Conference – February 28-29, 2012
- 2012 Land Grant & Sea Grant National Water Conference – May 22, 2012
- Southeast & South Central TX Regional Watershed Coordination Steering Committee– June 7, 2012

Subtask 1.5 Development and dissemination of project informational materials

In conjunction with TSSWCB Project 09-06, a LSHS promotional brochure was created (Appendix A).

Subtask 1.6 Hosting of website for information dissemination

Developed in September 2007 by TWRI, the project website, "Improving Water Quality of Grazing Lands" has been continually maintained and hosted. This website displays the efforts associated with this project and other related projects evaluating conservation practices and developing education programs to address bacteria. The website can be found at the following web address:

http://grazinglands-wq.tamu.edu/. Between June 2010 and June 2012, there were 970 unique visitors to the website (fig. 1). Materials on the website include the project work plan, reports, presentations and publications, project personnel, links, and other relevant information.

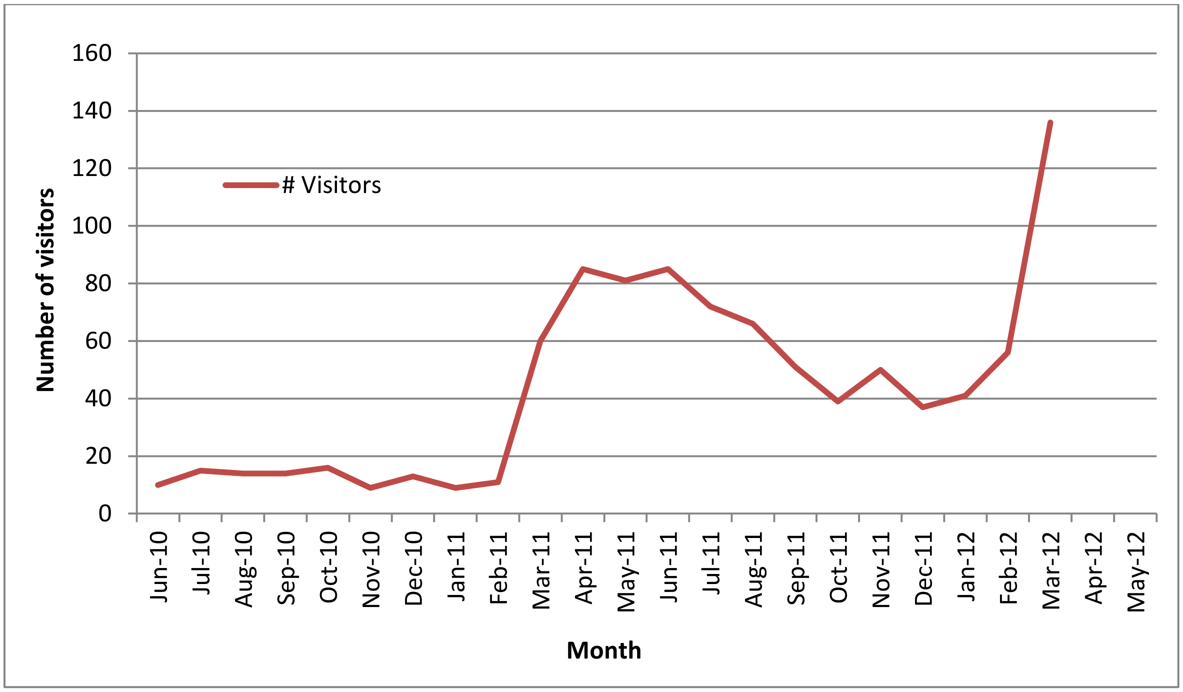

Figure 1. Number of unique visitors to project website from June 2010 through March 2012.

Subtask 1.7 Oversight of the LSHS Project Steering Committee

Four meetings of the LSHS Project Steering Committee took place over the course of the project:

- October 19, 2010 – Ag Council Meeting, Austin, TX
- October 25, 2010 – Annual Meeting of Texas Soil Water Conservation District Directors
- November 29, 2010 – Annual Meeting of Texas Soil Water Conservation District Directors
- October 24, 2011 – Annual Meeting of Texas Soil Water Conservation District Directors

Subtask 1.8 Development of the final project report

TWRI submitted the final report on October 31, 2012.

Task 2: Quality Assurance

Objective: To develop data quality objectives and quality assurance/quality control for activities in Task 3 to ensure data of known and acceptable quality were generated through this project.

Subtask 2.1 Development of Quality Assurance Project Plan (QAPP)

The QAPP was submitted on August 30, 2010 and approved on September 30, 2010.

Subtask 2.2 Revision and upkeep of the QAPP

The first revision of the QAPP was submitted on October 12, 2011 and approved on June 26, 2012.

Task 3: Evaluate and Demonstrate BMPs to Reduce Fecal and Bacterial Loading From Cattle on Grazing Lands

Objective: To evaluate and demonstrate the effectiveness of BMPs in reducing bacteria runoff from grazing lands and verify the water quality impacts on receiving waterbodies

Subtask 3.1 Evaluation of grazing management and stocking rates

From June of 2010 to June of 2012, 58 edge-of-field runoff samples were collected using automated ISCO samplers from the Beef Cattle Systems Center (BB1, BB2, BB3), Welder Wildlife Refuge (WWR1, WWR2, WWR3) and Riesel (SW12, SW17, W10) demonstration sites and enumerated for *E. coli*. Concurrently, fecal coliform and *Enterococcus* concentrations were evaluated in 44 of these runoff samples (from the 3 Beef Cattle Systems Center and 3 Welder Wildlife Refuge sites). Further, *Bacteroides* were measured in select samples to further evaluate and improve this bacterial source tracking method. To broaden the duration and scope of the overall prescribed grazing study, the *E. coli* concentration data was combined with the 127 *E. coli* concentrations results of the Wagner (2011) study. The information presented below summarizes the findings of Clary (2012). For more details regarding the evaluation and findings, see "*Assessing the effectiveness of water quality best management practices for grazing-lands, A Thesis by Calvin Clary*."

Subtask 3.1.1 Evaluation of grazing management impact on E. coli

Similar to the findings of Wagner (2011), days since grazing and stocking rate were not significantly correlated with *E. coli* concentrations in runoff. However, significantly higher *E. coli* concentrations ($p<0.001$) were observed when runoff events occurred while cattle were stocked than when sites were ungrazed or destocked for greater than two weeks (fig. 2 and fig. 3).

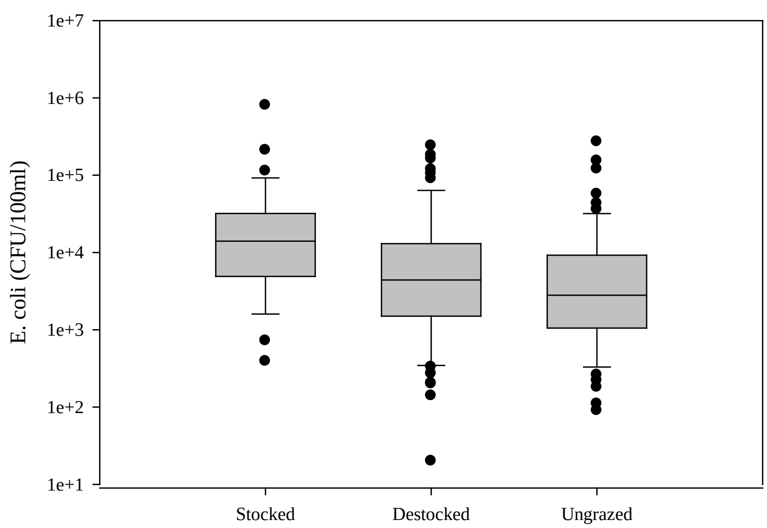

Figure 2. *E. coli* concentrations compared between stocked, destocked, and non-grazed runoff events. Stocked represents all runoff events occurring during a grazing event and within 14 days of sites being destocked. Destocked represents all runoff events occurring after 14 days of being destocked. Ungrazed represents runoff events occurring on control sites with no grazing.

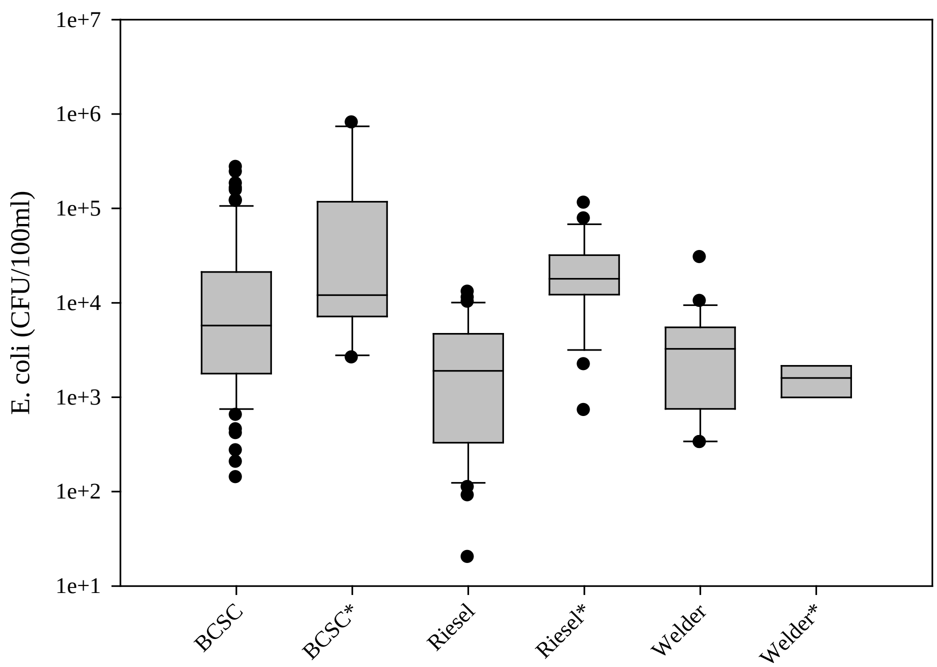

Figure 3. Stocked and destocked *E. coli* concentrations compared by locations. Stocked runoff events are denoted with an '*' symbol. The boundary of the box closest to zero indicates the 25th percentile, the solid line within the box represents the median, the boundary of the box farthest from zero indicates the 75th percentile, the whiskers above and below the box indicate the 10th and 90th percentiles, and the circles indicate data points beyond the 10th and 90th percentiles.

In fact, average *E. coli* concentrations observed while sites were stocked were 57% higher than those observed when grazed sites were destocked for greater than 14 days and 69% higher than those observed at ungrazed sites. Further, there was no significant difference between *E. coli* concentrations observed in runoff from destocked sites and ungrazed sites.

As observed by Wagner (2011), background *E. coli* concentrations were significant with median concentrations ranging from 1E+3 and 1E+4. Moreover, regardless of the stocking rate at the site, if the site had been destocked for greater than 14 days, *E. coli* concentrations were not significantly different (p=0.22) from those observed at ungrazed sites (fig. 4).

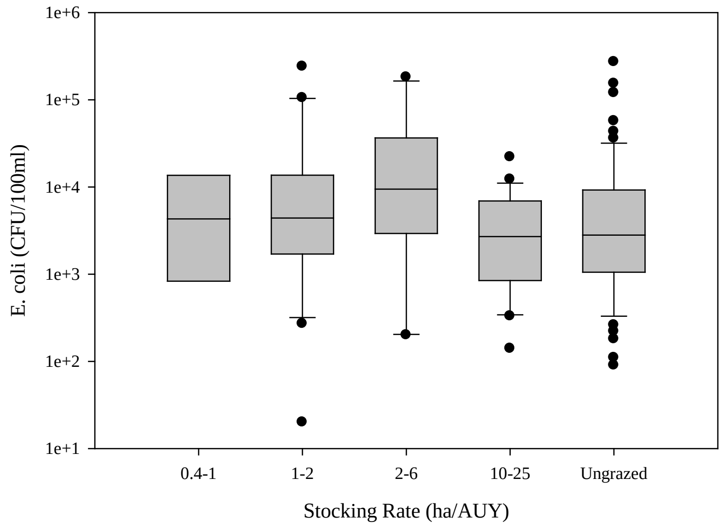

Figure 4. Comparison of *E. coli* concentrations observed at ungrazed sites to those at destocked sites with stocking rates ranging from 0.4 to 25 ha/AUY.

Stocking rate did impact the *E. coli* concentrations in runoff when sites were actively grazed when runoff occurred (fig. 5). When actively grazed when runoff occurred, *E. coli* concentrations in runoff from sites stocked heavier than 6 ha/AUY (14.8 ac/AUY) were significantly higher ($p<0.05$) than *E. coli* concentrations observed at sites stocked at 10 ha/AUY (24.7 ac/AUY) or lighter and ungrazed sites. Similarly, Wagner (2011) reported that *E. coli* concentrations were generally lower for stocking rates lighter than 10 ha/AUY (24.7 ac/AUY). Results suggest that stocking rates heavier than 6 ha/AUY (14.8 ac/AUY) increase *E. coli* loading, but only while actively or recently stocked (i.e. within last 14 days).

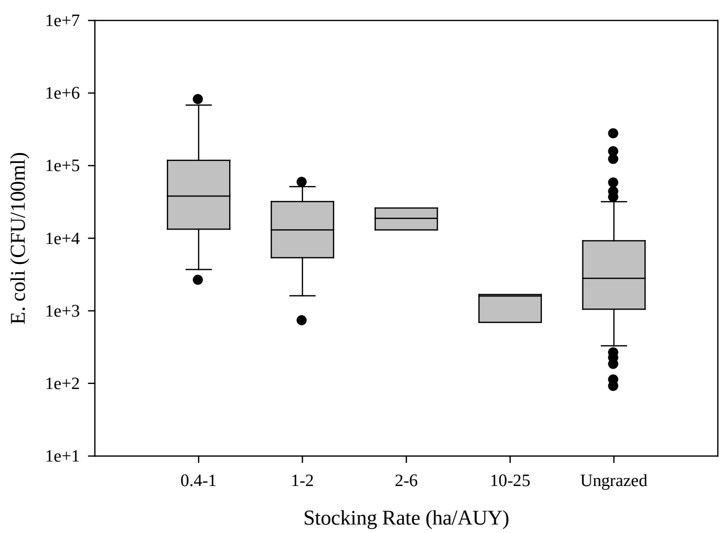

Figure 5. Comparison between stocking rates and *E. coli* concentrations in runoff occurring at grazed sites while sites were stocked or within 14 days of being destocked.

Subtask 3.1.2 Evaluation of grazing management impact on Enterococcus and fecal coliforms

A strong linear correlations was observed between fecal coliforms and *E. coli* concentrations as shown in fig. 6 (r^2=0.81). Similarly, *Enterococcus* and *E. coli* were moderately correlated (r^2=0.48). Because of this correlation, reductions in *E. coli* observed from implementation of practices evaluated herein would be expected to result in similar reductions for fecal coliforms and similarly, *Enterococcus*.

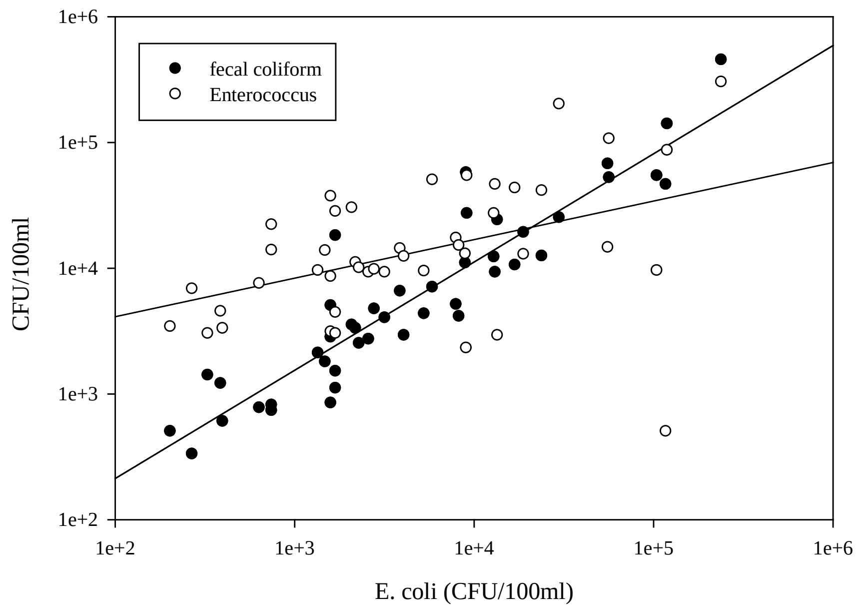

Figure 6. *Enterococcus* and fecal coliform concentrations correlated with *E. coli* concentrations

Subtask 3.1.3 Evaluation of Variability within Sequences Detected by Bacteroides Bacterial Source Tracking Molecular Markers

The over-arching goal of this evaluation was to help reduce misrepresentations of cattle fecal pollution in environmental samples by identifying DNA variances that could affect the AllBac and BoBac assays. Specific objectives were to:

- Determine if base-pair mismatches occur when using the AllBac and BoBac assays on multiple cattle samples.
- Determine if mismatches significantly affect quantitative polymerase chain reaction efficiencies.
- Evaluate if developing gene copy curves from local fecal samples can improve correlations between *E. coli* and AllBac and BoBac molecular markers.

Findings showed that within runoff samples using the BoBac assay, fecal pollution loads were drastically overestimated by using sequences with more mismatches as the standard curve. Even within the GenBank *Bacteroides* sequences, the AllBac assay showed fewer mismatches on fewer occasions than the BoBac assay. This suggested the AllBac assay may be less problematic than the BoBac assay.

As expected, the number of mismatches within the primer/probe regions increased as the phylogenetic distance between *Bacteroides* sequences increased. Genetic diversity, or phylogenetic distance, was observed within samples from all locations. In the same way, genetic similarity was not correlated to a particular geography. This indicated that genetic variability within *Bacteroides* populations occurs within a single location and also between locations. As a result, creating standard curves for individual watersheds may not necessarily improve pollution load estimates. Instead, when creating a standard curve, it is more important to select a *Bacteroides* sequence that has no mismatches along the primer/probe regions, or, at least is representative of the target *Bacteroides* populations at the site. For more details regarding the evaluation and findings, see "*Assessing the effectiveness of water quality best management practices for grazing-lands, A Thesis by Calvin Clary*."

Subtask 3.2 Evaluation of structural BMPs influencing cattle movement

3.2.1 Alternative Shade

Three alternative shade demonstrations (table 1) were used to evaluate the BMP's effectiveness in reducing the amount of time that cattle spent in or near the South Bosque River. Alternative shade was evaluated at the Texas A&M AgriLife Research Center at McGregor, Texas. The study site is a 40.5 ha (100 ac) grazed pasture located at the headwaters of the South Bosque River. Shade is almost exclusively limited to within the riparian zone. Six to eight Lotek ® GPS 3300LR collars (Lotek Wireless Inc., Newmarket, Ontario, Canada) were placed on randomly-selected cows and used to record their locations over multiple 21 to 23 day trials. Each GPS collar was calibrated to take a single locational data-point every 5 minutes. The information presented below summarizes the findings of Clary (2012). For more details regarding the evaluation and findings, see "*Assessing the effectiveness of water quality best management practices for grazing-lands, A Thesis by Calvin Clary*."

Table 1. Start and end dates of alternative shade trials.

Trial	Start	Shade Implemented	End
1	October 7, 2010	October 15, 2010	October 27, 2010
2	May 26, 2011	June 6, 2011	June 18, 2011
4	March 28, 2012	April 7, 2012	April 18, 2012

Significant reductions in the amount of time that cattle spent within the riparian zone were observed when alternative shade was provided. Reductions in the amount of time that cattle spent within 8 m of the river ranged from essentially no change to a 45% reduction (table 2), and averaged 27%. Moreover, as would be expected, the amount of time that cattle spent at the site of the shade pavilion increased following implementation of the shade pavilion. Increases of >257% within 8 m of the shade structure and > 85% within 16 m were observed.

Table 2. Alternative shade GPS data-point totals and percent difference calculations per trial. All data points collected prior to BMP implementation are represented by the acronym 'Pre'. 'Post' represents all data points collected after BMP implementation. '% Diff' represents the percent reduction or increase between 'Pre' and 'Post' periods. Finally, 8 m represents 0-8 m and 16 m represents 8-16 m.

	Total Points		Shade Pavilion						Riparian Zone					
			8m			16m			8m			16m		
	Pre	Post	Pre	Post	% Diff	Pre	Post	% Diff	Pre	Post	% Diff	Pre	Post	% Diff
Trial 1	14,382	22,465	38	212		27	88		468	401		640	602	
%			0.26	0.94	257.2	0.19	0.39	108.7	3.25	1.78	-45.1	4.45	2.68	-39.8
Trial 2	17,135	18,543	5	157		4	31		871	966		1,063	787	
%			0.03	0.85	2,801.6	0.02	0.17	616.2	5.08	5.21	2.5	6.20	4.24	-31.6
Trial 4	15,552	20,736	3	24		13	32		370	300		330	247	
%			0.02	0.12	500.0	0.08	0.15	84.6	2.38	1.45	-39.2	2.12	1.19	-43.9

As table 3 demonstrates, implementation of alternative shade resulted in an average of 10.9 and 22.4 min/d reductions in the amount of time that cattle spent within 8 and 16 m of the river, respectively. Further, cattle increased the amount of time they spent within 8 and 16 m of the shade pavilion by 7.6 and 2 min d^{-1}, respectively. This accounts for almost a third of the time reductions seen in the riparian zone, and provides supporting evidence that the percent reductions seen at the riparian zone are due to the alternative shade structure and not some other cause. The increase in the time cattle spent within 16 m of the pavilion suggested that cattle will graze the area surrounding the shade pavilion more, allowing more grazing to occur on previously underutilized sections of a pasture. It is likely that the other half of the time reductions seen in the riparian zone were distributed across the pasture at further distances from the shade pavilion.

Table 3. Comparison of the amount of time (min d^{-1}) cattle spent within 0-8 and 8-16 m of the shade structure and river pre and post BMP implementation.

	Shade Pavilion				Riparian Zone			
	8m		16m		8m		16m	
	Pre	Post	Pre	Post	Pre	Post	Pre	Post
Trial 1	3.8	13.6	2.7	5.6	46.9	25.7	64.1	38.6
Trial 2	0.4	12.2	0.3	2.4	73.2	75.0	89.3	61.1
Trial 4	0.3	1.7	1.2	2.2	34.3	20.8	30.6	17.2

It is interesting to note that during Trial 2 (May 26-June 6, 2011), cattle spent a greater amount of time within the riparian area than during the other two trials. Likely as a result of hotter weather during this trial in comparison to the other trials, cattle were more dependent upon the riparian shade. This greater dependence on riparian shade during this period resulted in lower percent reductions for Trial 2 than observed during the other trials. Despite this, Trial 2 reductions in the time spent within 16 m of the river were larger than either Trials 1 and 4 (October and April, respectively).

This indicates that although cattle's dependence on riparian shade will be higher in the hotter months, an alternative shade pavilion may still effectively reduce the amount of time that cattle spend within the riparian zone. Other researchers (Larsen et al. 1998 and Byers 2004) have observed that temperature and other atmospheric conditions play a significant role in how cattle use the riparian zone and other watershed features.

Byers (2004) observed that cattle rested within the riparian zone between 1.4% and 4.2% between December and March, while between April and November, cattle spent anywhere from 5.3% to 8.1% of their time within the riparian zone. In this study and prior to BMP implementation, cattle spent close to 7.7% of their time within the riparian zone for the month of October and 4.5% from late March to early April. This falls within the range found by Byers (2004). However, for the month of May, cattle spent 11.2% of their time within 16 m of the riparian zone. The largest percent of riparian usage found by Byers (2004) was 8.1%. The difference is likely due to the presence of abundant non-riparian shade in the Byers (2004) pasture configurations. This suggested that pastures with little non-riparian shade may see increased usage of riparian shade; potentially causing more riparian and water quality degradation. Following BMP implementation at the McGregor pasture, riparian usage was reduced to 9.45% for the month of May. This suggested that non-riparian shade does reduce the amount of time that cattle spend within riparian areas. Although a single shade pavilion can reduce cattle's dependence upon riparian shade, during hotter months, the abundance of riparian shade may draw cattle into riparian zones more frequently and for longer periods. Strategic placement of multiple shade pavilions may optimize pasture utilization and further minimize cattle's dependence on riparian shade. Shade pavilions capable of being disassembled and reassembled or transported may also benefit cattle and other livestock producers using an intensive rotational grazing management method.

3.2.2 Alternative Water

A single alternative water trial was conducted at the Texas A&M AgriLife Research Center at McGregor, Texas (April 26, 2012 – May 18, 2012) to evaluate this BMP's effectiveness in reducing the amount of time that cattle spent in or near the South Bosque River. The study site is a 40.5 ha (100 ac) grazed pasture located at the headwaters of the South Bosque River. Shade in this pasture is almost exclusively limited to within the riparian zone. Six to eight Lotek ® GPS 3300LR collars (Lotek Wireless Inc., Newmarket, Ontario, Canada) were placed on randomly-selected cows and used to record their locations every 5 minutes. The information presented below summarizes the findings of Clary (2012). For more details regarding the evaluation and findings, see "*Assessing the effectiveness of water quality best management practices for grazing-lands, A Thesis by Calvin Clary*."

Unlike previous studies, the single trial (i.e. Trial 5) conducted in conjunction with this study did not result in reductions in the amount of time that cattle spent in the riparian zone. In fact, the amount of time that cattle spend within 8 m of the river actually increased 46% after implementing the alternative water source (table 4). Conversely, the amount of time cattle spent within 16 m of the river decreased 18% following practice implementation. These conflicting results do not provide conclusive evidence of the impacts of implementation of alternative water sources.

Table 4. Time (min d^{-1}) cattle spent within 0-8 m and 8-16 m of the river and water trough pre- and post-implementation of the alternative water source (water trough).

	Riparian Zone				Water Trough			
	8 m		16 m		8 m		16 m	
	Pre	Post	Pre	Post	Pre	Post	Pre	Post
Trial 5	42.7	62.5	61.2	51.8	0.61	25.3	0.98	20.4

However, it is well documented that cattle can be strongly drawn to riparian areas for reasons other than water (Clawson 1993; Godwin and Miner 1996; Miner et al. 1992; Wagner 2011) and is likely the case here. Riparian shade is the most plausible explanation for the increased time cattle spent within 8 m of the river. Nevertheless, the cattle did utilize the trough as evidenced by the increased time they spent in the adjacent area. Between the combined 8 and 16 m trough buffers, on average, there was a 44 min d^{-1} increase following BMP implementation.

The results of this study underscore the importance of implementing water-quality BMPs on a site specific basis, as the alternative water BMP did not reduce the amount of time spent within the riparian zone as effectively. Although it was not tested in this study due to time and drought induced restraints, combining alternative shade and water together would likely have improved effectiveness at reducing the amount of time cattle spend within the riparian zone and improving pasture utilization.

3.2.3 Rip-rap

Rip-rap was evaluated using: (1) preliminary trials consisting of four day-long visual observations and (2) a three riparian rip-rap trials using GPS collars. The preliminary trials served to determine the needed size and dimensions of an effective rip-rap treatment. The most effective rip-rap treatment, as determined by the preliminary trials, was then implemented in a riparian setting at the McGregor study pasture and analyzed with the GPS collars. These trials were conducted in an attempt to quantify changes in cattle behavior due to installation of rip-rap in a riparian setting. The information presented here summarizes the findings of Clary (2012). For more details regarding the evaluation and findings, see "*Assessing the effectiveness of water quality best management practices for grazing-lands, A Thesis by Calvin Clary*."

3.2.3.1 Preliminary rip-rap trial

Preliminary trial observations began before daybreak and lasted until after sunset. Two water troughs were setup approximately 25 m (82 ft) apart from each other in a pasture adjacent to the Beef Cattle Systems Center (BCSC) test plots. Troughs were located away from fences to allow cattle access from all directions. One trough ($T_{rip\text{-}rap}$) was encircled with rip-rap while the other trough ($T_{control}$) remained untreated and served as the control. Rip-rap was placed around $T_{rip\text{-}rap}$ to a distance of 2 m (6 ft) from the perimeter of the trough. The first trial assessed 10 to 20 cm (4 to 8 in) diameter rip-rap. The following three trials assessed 20 to 40 cm (8 to 16 in) diameter rip-rap. To provide an acclimation period, cattle were released into the pasture on the day prior to the observation. Observations were taken from a parked vehicle approximately 40 m (130 ft) from either trough.

The 10 to 20 cm (4 to 8 in) diameter rip-rap had moderate to limited effectiveness at detouring cattle. Cattle watered from both the control and rip-rap encircled troughs; however, more cattle watered from the control trough throughout the preliminary trial. The increased usage of the control trough suggested that cattle did respond to the smaller rip-rap treatment. These results suggest that 10 to 20 cm diameter rip-rap may be more effective at modifying cattle walking trails rather than attempting to exclude them from a water, shade, or forage source altogether.

The larger 20 to 40 cm (8 to 16 in) diameter rip-rap was highly effective as water trough preference was strongly altered by this larger rip-rap. Cattle showed extreme hesitation at crossing the larger rip-rap. Even when there was no available room at the control trough, cattle did not water from the rip-rap encircled trough with the exception of younger calves. Although the majority of the results show that cattle are less likely to cross the rip-rap treatment, this demonstration indicated that cattle are capable of crossing the larger rip-rap if they wish or must.

Although neither rip-rap treatment totally excluded cattle, there was a major difference in the effectiveness due to rip-rap size. By increasing rip-rap size, the treated area became more irregular and uneven, forcing cattle to exert greater effort to cross, thus more effectively deterring them. This suggested that 20 to 40 cm diameter rip-rap may be the most appropriate size for deterring cattle access to sensitive locations such as riparian zones and streams.

3.2.3.2 Riparian rip-rap trials

For the riparian rip-rap trials, frequently used cattle stream crossings were lined with 20 to 40 cm (8 to 16 in) diameter rip-rap in an attempt to deter cattle away from using these crossings along the stream and riparian zone. Previously obtained data points from the alternative shade and water GPS trials served as the pretreatment period and provided control data for the riparian rip-rap trials. Data was analyzed by tracking cattle locations and determining if rip-rap significantly affected their behavior and where they crossed the stream. Findings from the riparian rip-rap trials were inconclusive and the benefits of this practice were not confirmed. Additionally, concerns regarding possible cattle injury stemming from cattle continuing to cross even the larger rip-rap further limit its justification as a recommended best management practice.

Should rip-rap be used, it should be implemented on a case-by-case basis. Additional considerations for rip-rap implementation should include the size and uniformity of rip-rap. Rip-rap with little dirt fill or gravel is best to reduce embedding, settling, and compaction as these things could reduce the effectiveness of the rip-rap. Trees or other obstructions should be considered prior to implementing rip-rap. Obstructions and bank slope may make implementing rip-rap with a front-end loader difficult and hand loading necessary. Because rip-rap is hauled via large tractor-trailer rigs and dump trucks, equipment accessibility and maneuverability should also be considered.

Subtask 3.3 Literature collection

SCSC gathered information from the growing body of literature on 1) bacteria fate and transport, 2) effects of grazing cattle on bacterial levels in waterbodies, and 3) effect of BMPs designed to minimize grazing cattle impacts on riparian areas and bacteria loading.

A compendium of this literature is posted on the Lone Star Healthy Streams project website (http://lshs.tamu.edu/research/). This compendium currently consists of 576 publications. The website allows easy access to both these publications and their abstracts.

Subtask 3.4 Identification of potential cooperators to conduct BMP demonstrations and evaluations

BMP demonstrations were conducted at the BCSC, Welder Wildlife Refuge, Texas A&M AgriLife Research Center at McGregor, and USDA-ARS Riesel Research Center.

Subtask 3.5 Assessment of cattle behavior

The effects of alternative water, alternative shade, and rip-rap on cattle behavior were assessed by SCSC, Texas A&M Department of Ecosystem Science and Management, and TWRI utilizing Lotek GPS collars to determine the amount of time cattle spend in the stream and riparian areas before and after BMP implementation. Five trials were conducted as outlined in table 5. Results of these trials are described in Subtask 3.2.

Table 5. Start and end dates of GPS trials

	Start	BMP Implemented	End
Trial 1	7-Oct-10	15-Oct-10	27-Oct-10
Trial 2	26-May-11	6-Jun-11	18-Jun-11
Trial 3	18-Nov-11	18-Nov-11	9-Dec-11
Trial 4	28-Mar-12	7-Apr-12	18-Apr-12
Trial 5	26-Apr-12	8-May-12	18-May-12

Subtask 3.6 Dissemination of BMP results to the public

SCSC and the project team transferred results from the BMP effectiveness evaluations to landowners, natural resource agencies, and others through LSHS presentations delivered across the state in order to increase BMP adoption rates and participation in federal and state technical and financial assistance programs. Through presentations at the more than 40 events listed below, over 3000 participants were introduced to bacteria issues facing livestock producers, BMPs effective at reducing bacteria runoff, and programs to assist them with implementation. In addition to the LSHS programs, SCSC and the Texas A&M Animal Sciences Department conducted a field day at the McGregor Research Center on September 24, 2010. Among the programs provided at the field day, BMP effectiveness studies and results were discussed to promote adoption of BMPs by ranchers.

LSHS was introduced through presentations at the following (where known, number of participants in parentheses):

- September 17, 2010 – Travis County (NA)
- September 24, 2010 – McGregor Research Center Field Day – McLennan County (NA)
- October 12-15, 2010 – Ranch Management University (NA)
- October 21, 2010 – Burnet County (NA)
- October 26, 2010 – Comanche County (NA)
- October 29, 2010 – Luling Foundation Water Field Day (NA)
- March 9, 2011 - Victoria County TPWD and USDA-NRCS personnel (32)
- March 12, 2011 - Brazos County (96)
- March 28, 2011 - McLennan County (60)
- March 31, 2011 - Caldwell County (31)
- April 7, 2011 - Henderson County (137)
- April 13, 2011 - Brazos County (39)
- April 20, 2011 - Wilson, Karnes, Guadalupe, Bee Counties (45)
- April 29, 2011 - Kaufman County (40)
- May 5, 2011 - Burleson, Lee Counties (45)
- August 11, 2011 - Harris County (79)
- August 18, 2011 - Lampasas County (69)
- August 25, 2011 - Taylor County (78)
- September 1, 2011 – Galveston/Brazoria Counties (67)
- September 6, 2011 – Walker County (62)
- September 24, 2011 – Brazos County (147)
- September 30, 2011 – Austin County (112)
- October 20, 2011 – Johnston County (26)
- October 21, 2011 – Falls County (84)
- October 28, 2011 – Washington County (62)
- November 3, 2011 – Chambers, Liberty, Ft. Bend, Kaufman, Van Zandt counties (92)
- November 12, 2011 – Bexar County (45)
- November 14, 2011 – Coryell County (46)
- November 17, 2011 – Gonzales County (78)
- December 8, 2011 – 19 Texas A&M AgriLife Extension Service District 8 counties (435)
- December 15, 2011 – Edna (78)
- December 16, 2011 – Mabank (112)
- January 24, 2012 – Granbury (68)
- January 27, 2012 – Caldwell (265)
- February 7, 2012 – Waco (201)
- March 23, 2012 - McGregor (64)
- March 29, 2012 - Athens (189)
- March 31, 2012 - Fort Worth (80)
- April 5, 2012 - Lampasas (24)
- April 13, 2012 - College Station (19)
- April 27, 2012 - Schulenburg (58)
- May 24, 2012 - Hamilton, Freestone, Milam, Coryell, McLennan, Eastland, Falls, and Comanche Counties (82)

Subtask 3.7 Evaluation of Watershed Quality Management Plan (WQMP) implementation on livestock operations

A team consisting of USDA-ARS, SCSC, and TWRI continues work to design a process for evaluating whole-farm effects of implementing WQMPs on livestock operations. Once complete, the monitoring and/or modeling regime will be incorporated into a proposal for submission to TSSWCB and others as needed to determine and document the synergistic effectiveness of BMPs prescribed in a WQMP in reducing bacteria loading from grazing cattle.

Subtask 3.8 Assessment of Texas BMP Evaluation Tool for science-based on-farm BMP selection

Data collected through the duration of the project was transferred from TWRI to USDA-ARS for incorporation into TBET.

Subtask 3.9 Provision of information to USDA-NRCS to establish a practice standard for Livestock Shade Structure as a suitable BMP

TWRI and TSSWCB worked very closely with the USDA-NRCS to provide them with the information they needed to establish a practice standard for Livestock Shade Structure as a BMP to effect cattle movement and fecal deposition patterns and impact pollutant loading and water quality. As a result of this, in August 2012, USDA-NRCS established specifications, a design sheet, job sheet, and standard for Livestock Shade Structure (No. 717). These can be accessed on the Texas USDA-NRCS website as follows:

- Livestock Shade Structure (NO) 717 Specification
    - http://efotg.sc.egov.usda.gov/references/public/TX/tg717CSpecstx.pdf
- Livestock Shade Structure (NO) 717 Design Sheet
    - http://efotg.sc.egov.usda.gov/references/public/TX/TX717.pdf
- Livestock Shade Structure (NO) 717 Job Sheet
    - http://efotg.sc.egov.usda.gov/references/public/TX/TX717_LivestockShadeStructure912.pdf
- Livestock Shade Structure (NO) 717 Standard
    - http://efotg.sc.egov.usda.gov/references/public/TX/TX-717_standard_final.pdf

Subtask 3.10 Development of technical reports, refereed journal articles, extension fact sheets, and other publications to demonstrate results of BMP analysis

All generated results were transferred to Jennifer Peterson to be included in the LSHS BMP manuals, website and searchable database in conjunction with TSSWCB Project 09-06. Two journal articles have been submitted to date regarding BMP evaluations as follows:

- Wagner, K. L., L. A. Redmon, T. J. Gentry, and R. D. Harmel. 2012. Assessment of cattle grazing effects on *E. coli* runoff. *Transactions of ASABE.*
- Wagner, K. L., L. A. Redmon, T. J. Gentry, and R. D. Harmel. 2012. Effects of an off-stream watering facility on cattle behavior and instream *E. coli* levels. *Texas Water Journal.*

Conclusion

From the results shown in this study, stocking rates heavier than 6 ha/AUY (14.8 ac/AUY) increased *E. coli* loading, but only when sites were actively or recently (within the last two weeks) stocked when runoff occurred. Significantly higher *E. coli* concentrations ($p<0.001$) were observed when runoff events occurred while cattle were stocked than when sites were ungrazed or destocked for greater than two weeks. Average *E. coli* concentrations observed while sites were stocked were 57% higher than those observed when grazed sites were destocked for greater than 14 days and 69% higher than those observed at ungrazed sites. Further, stocking rate was only found to impact *E. coli* concentrations in runoff when sites were actively grazed when runoff occurred. When actively grazed when runoff occurred, *E. coli* concentrations in runoff from sites stocked heavier than 6 ha/AUY (14.8 ac/AUY) were significantly higher ($p<0.05$) than *E. coli* concentrations observed at sites stocked at 10 ha/AUY (24.7 ac/AUY) or lighter and ungrazed sites. Finally, background *E. coli* concentrations were significant with median concentrations ranging from 1,000 to 10,000 resulting in no significant difference between *E. coli* concentrations observed in runoff from destocked sites and ungrazed sites.

The study also showed that reductions in the amount of time that cattle spent within the riparian zone averaged 27% when alternative shade was provided, but reductions varied seasonally. Although a single shade pavilion can reduce cattle's dependence upon riparian shade, during hotter months, the abundance of riparian shade may continue to draw cattle into riparian zones more frequently and for longer periods. Strategic placement of multiple shade pavilions may optimize pasture utilization and further minimize cattle's dependence on riparian shade. Shade pavilions capable of being disassembled and reassembled or transported may also benefit cattle and other livestock producers using an intensive rotational grazing management method.

Unlike previous studies, the single alternative water trial conducted did not result in reductions in the amount of time that cattle spent in the riparian zone. It is well documented that cattle can be strongly drawn to riparian areas for reasons other than water and this is likely the case here. Riparian shade is the most plausible explanation here. The results of this study underscore the importance of implementing water-quality BMPs on a site specific basis. Future work should evaluate the combined effects of alternative shade and water on reducing the amount of time cattle spend within the riparian zone and improving pasture utilization. The final BMP evaluated, rip-rap, found that 20 to 40 cm diameter rip-rap was the most appropriate size for limiting cattle access to sensitive locations such as riparian zones and streams. However, findings from the riparian rip-rap trials were inconclusive and the benefits of this practice were not confirmed. As a result of this and concerns regarding possible cattle injury stemming from cattle continuing to cross even the larger rip-rap, rip-rap is not recommended as a best management practice.

Finally, strong linear correlations of *Enterrococcus* and fecal coliforms with *E. coli* suggest that reductions in *E. coli* observed from implementation of practices evaluated herein would be expected to result in similar reductions for fecal coliforms and *Enterococcus*.

Data collected through the duration of the project was transferred to both landowners and agency personnel. Data was transferred from TWRI to USDA-ARS for incorporation into TBET. Further, TWRI and TSSWCB worked very closely with the USDA-NRCS to provide them with the information they needed to establish a practice standard for Livestock Shade Structure as a BMP to effect cattle movement and fecal deposition patterns and impact pollutant loading and water quality. All generated results were transferred to Jennifer Peterson to be included in the LSHS BMP manuals, website and searchable database in conjunction with TSSWCB Project 09-06. Materials (i.e. work plan, reports, presentations, publications, project personnel, links, and other relevant information) were also placed on the website which was visited by almost 1000 visitors during the course of the project. Furthermore, two journal articles have been submitted to date regarding BMP evaluations and additional journal articles are planned. In terms of outreach to the public, TWRI and/or SCSC participated in 15 public meetings to communicate project goals, activities, and accomplishments; a LSHS promotional brochure was created; four meetings of the LSHS Project Steering Committee were conducted; and presentations were delivered at more than 40 events to over 3000 participants on bacteria issues facing livestock producers, BMPs effective at reducing bacteria runoff, and programs to assist them with implementation. Finally, SCSC, in conjunction with the Animal Science Department, conducted a field day at the McGregor Research Center.

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Appendix A – Lone Star Healthy Streams Brochure

LONE STAR HEALTHY STREAMS

DID YOU KNOW?

BACTERIA IS THE NUMBER ONE CAUSE OF WATER POLLUTION IN TEXAS AND THAT MORE THAN HALF OF THE WATER BODIES EVALUATED IN THE STATE ARE IMPAIRED BECAUSE OF EXCESS BACTERIA LEVELS?

While some water pollution is often easy to detect, bacteria pollution is not. A water body choked with algae, a muddy river loaded with sediment, or a lake covered with an oily sheen all exhibit clearly noticeable impairments. Bacteria in water, on the other hand, are not at all noticeable to the naked eye.

Lone Star Healthy Streams (LSHS) is a program developed by the Texas AgriLife Extension Service, the Texas State Soil and Water Conservation Board, and the Texas Water Resources Institute.

The program's major goal is the protection of Texas waterways from bacterial contamination originating from beef cattle, dairy cattle, horses, poultry, and feral hogs that may pose a serious health risk to Texas citizens.

LSHS educates Texas farmers, ranchers, and landowners about proper grazing, feral hog management, and riparian area protection to reduce the levels of bacterial contamination in streams and rivers.

BACTERIA IMPAIRMENTS IN TEXAS

RESOURCE MANUALS