Characterizing Potential Bacteria Loads for the Leona River Watershed Using the Spatially Explicit Load Enrichment Calculation Tool (SELECT)

Prepared for:

Texas State Soil and Water Conservation Board
Project 11-50

Prepared by:

Anne McFarland
Todd Adams

Texas Institute for Applied Environmental Research
Tarleton State University
Stephenville, Texas

TR1305

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Cover photograph is the Leona River above Hoag Dam taken by TIAER on June 7, 2011.

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SECTION 1

Introduction

Problem Statement

The Leona River (Segment 2109) is a tributary of the Frio River within the Nueces River Basin in southwest Texas. Segment 2109, as defined by the Texas Commission on Environmental Quality (TCEQ), stretches 91 miles from the confluence of the Leona River with the Frio River about six miles north of the City of Dilley in Frio County, through the City of Batesville in Zavala County and the City of Uvalde in Uvalde County, to the crossing of the Leona River with U.S. 83 just north of Uvalde, Texas (Figure 1). Assessment of water quality along the Leona River indicates that Segment 2109 meets most criteria, but that the Leona River is impaired with regard to bacteria and the use of primary contact recreation (TCEQ, 2011a; 2011b). Segment 2109 was first included on the 2006 Texas 303(d) List as impaired due to elevated bacteria concentrations (TCEQ, 2007). The 2012 Texas Water Quality Inventory, published in May, 2013, continues to indicate this bacterial impairment (TCEQ, 2013). The impairment of bacteria of the Leona River is categorized as 5b, indicating that a review of the standards as they apply to Segment 2109 will be conducted before a management strategy is selected. Management strategies that may occur include a total maximum daily load (TMDL) and a watershed protection plan or possible revision to the water quality standard for the Leona River Segment 2109. A Recreational Use Attainability Assessment (RUAA) was completed during 2012 for the Leona River and the RUAA report is undergoing review by the TCEQ (see Stroebel and McFarland, 2013).

The purpose of this report is to present an overview of potential bacterial loadings within the Leona River watershed using the Spatially Explicit Load Enrichment Calculation Tool (SELECT). This visual display will aid stakeholders in identifying areas of the watershed where possible sources of bacteria may be a focus for future control efforts.

SELECT

Researchers with the Department of Biological and Agricultural Engineering and the Spatial Science Laboratory at Texas A&M University developed SELECT as a screening tool for evaluating potential bacteria loads resulting from various sources within a watershed (Teague, et al., 2009). This tool is based on the Bacteria Source Load Calculator (BSLC) developed at the Center for TMDL and Watershed Studies at Virginia Tech (Zeckoski, et al., 2005), but builds on the BSLC approach by providing a spatial display of potential loadings. Within a watershed, SELECT calculates and allocates potential bacteria loadings from various sources via an ArcGIS environment at a sub-watershed level. Delineating the watershed into smaller sub-watersheds aids in targeting specific areas that may be “hot spots” for potential bacteria loadings. Potential loads are based on land-use classification with regard to the distribution of nonpoint sources, such as grazing livestock and wildlife, and state and municipal sources for most point sources, such as wastewater treatment facilities (WWTFs).

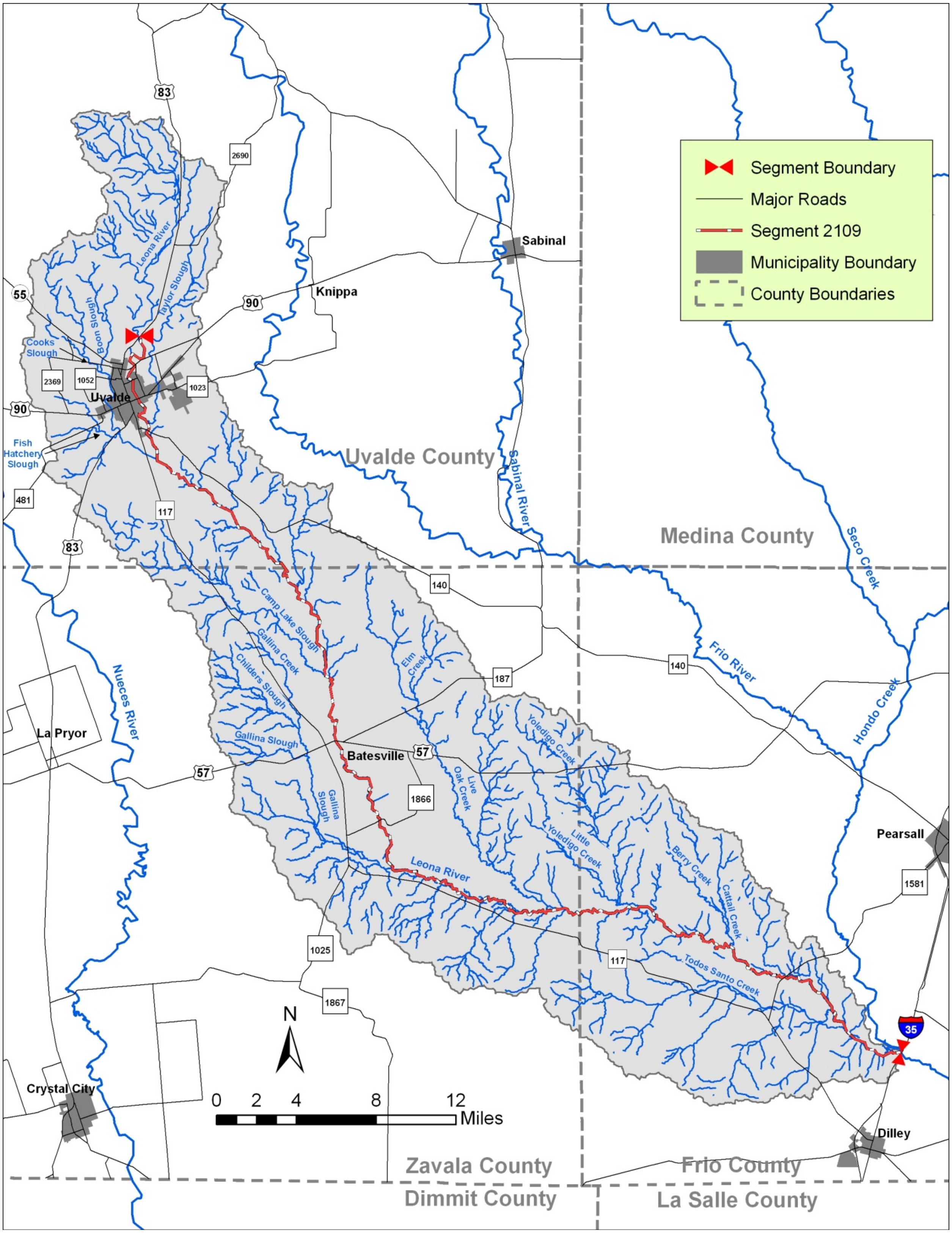

Figure 1 Map of Leona River watershed, Segment 2109.

Of note, the loadings estimated via SELECT for most sources do not take into account any losses associated with treatment or transport across the landscape or in-stream (Teague et al., 2009). These potential loadings present what might be considered a "worst case" scenario assuming all fecal material produced in the watershed by major sources were to make it to the stream system. With natural transport processes, there are some losses of bacteria loadings from the landscape to the stream system, as well as die-off and regrowth that can occur over time. The details associated with the fate and transport processes of bacteria are quite complex (e.g., Benham et al., 2006 and Vidon et al., 2008) and are outside the scope and purpose of SELECT. The purpose of SELECT is only to highlight potential sources and watershed areas where it may be prudent to apply more focused educational efforts on implementing bacteria control practices and not to calculate specific loadings.

Stakeholder interaction on developing source inputs is important for SELECT, because often only county level data are available, which may not adequately reflect watershed-specific conditions. For the Leona River watershed, the SELECT methodology was initially presented to stakeholders on July 28, 2011. In 2012, outreach meetings focused primarily on the recreational use attainability assessment (RUAA) for the watershed, although information regarding sources was also solicited at each meeting. At a meeting held on January 24, 2013, potential source inputs for SELECT were presented to stakeholders. The presentation of SELECT results was made on June 27, 2013 and feedback from that meeting is presented in the summary and discussion portion of this report. Presentations from each of these meetings may be accessed from the project website at http://www.leonariver.org/, a website maintained by the Nueces River Authority (NRA).

Study Area

The Leona River watershed covers about 429,000 acres and includes the cities of Uvalde (estimated population 16,000) and Batesville (estimated population 1,100). The channel of the Leona River is fairly well delineated in its upper portion, although some tributary channels are difficult to define as water often flows underground while crossing limestones associated with the Balcones Fault Zone (BFZ). The BFZ is associated with the Edwards Aquifer and underlies most of the Leona River watershed within Uvalde County (George et al., 2011). These porous or fractured limestones of the BFZ are a conduit for recharge of the Edwards Aquifer, and when groundwater levels are high, springs can feed stream flow. Several groups of springs have been noted along the Leona River in Uvalde County (Brune, 1975), but these springs can be difficult to locate as they often flow beneath the surface of the river or do not flow when extended dry conditions occur due to declining aquifer water levels. While the upper third of the Leona River watershed largely overlays the Edwards Aquifer, the lower two-thirds overlays the Carrizo-Wilcox Aquifer (George, et al., 2011). The Carrizo-Wilcox Aquifer is predominantly composed of sand locally inter-bedded with gravel, silt, clay, and lignite, so percolation of surface water into groundwater is slower than within the region of the Edwards Aquifer (Ashworth and Hopkins, 1995). Along its lower reaches, the Leona River flows through fairly flat terrain and often appears only as shallow depressions in the landscape as it nears its confluence with the Frio River.

The Leona River is part of the Southern Texas Plains Ecoregion (level III; Griffith et al., 2007), which was once covered with grassland and savanna vegetation, is now dominated by thorny brush, such as mesquite (*Prosopis glandulosa*). As part of the Southern Texas Plains, the Leona River watershed falls within the Northern Nueces Alluvial Plains (level IV ecoregion), which differs from much of the Southern Texas Plains by having a higher annual precipitation (generally 22 to 28 inches) and deeper soils. Large parts of the watershed are rangeland with honey mesquite, plateau live oak (*Quercus fusiformis*), guajillo (*Acacia berlandieri*), and blackbrush (*Acacia rigidula*) as dominate woody species.

The Leona River watershed is largely rural with cropland and pastureland as major land uses (Table 1 and Figure 2). Wheat (*Triticum sp.*), sorghum (*Sorghum bicolor*), cotton (*Gossypium sp*.), vegetables, and corn (*Zea mays*) are among the leading crops in all three counties (NASS, 2011). Frio County is distinct from Uvalde and Zavala Counties in that peanut (*Arachis hypogaea*) production is also a major crop. Most cropland areas are irrigated, and with the production of winter vegetables, Frio and Zavala Counties are included in what is commonly referred to as the Winter Garden Region of south Texas (Odintz, 2012). Large amounts of land in all three counties are also used as pasture for hay or grazing of primarily beef cattle, although sheep production is also prominent in Uvalde County. Another notable feature in the upper portion of the watershed is the U.S. Fish and Wildlife Service National Fish Hatchery located in Uvalde, Texas, which raises imperiled fishes, such as the fountain darter (*Etheostoma fonticola*), Comanche Springs pupfish (*Cyprinodon elegans*), and Devils River minnow (*Cryprindodon elegans*).

Table 1 Summary of land use/land cover classifications for the Leona River watershed.

Category	Acres	Percent
Shrubland	206,517	48.1
Woodland	110,848	25.8
Cultivated Crops	41,416	9.7
Pasture Hay	25,699	6
Grassland Herbaceous	17,573	4.1
Developed	13,893	3.2
Near Riparian Forest	12,014	2.8
Barren	654	0.2
Open Water	630	0.1
Total	429,244	

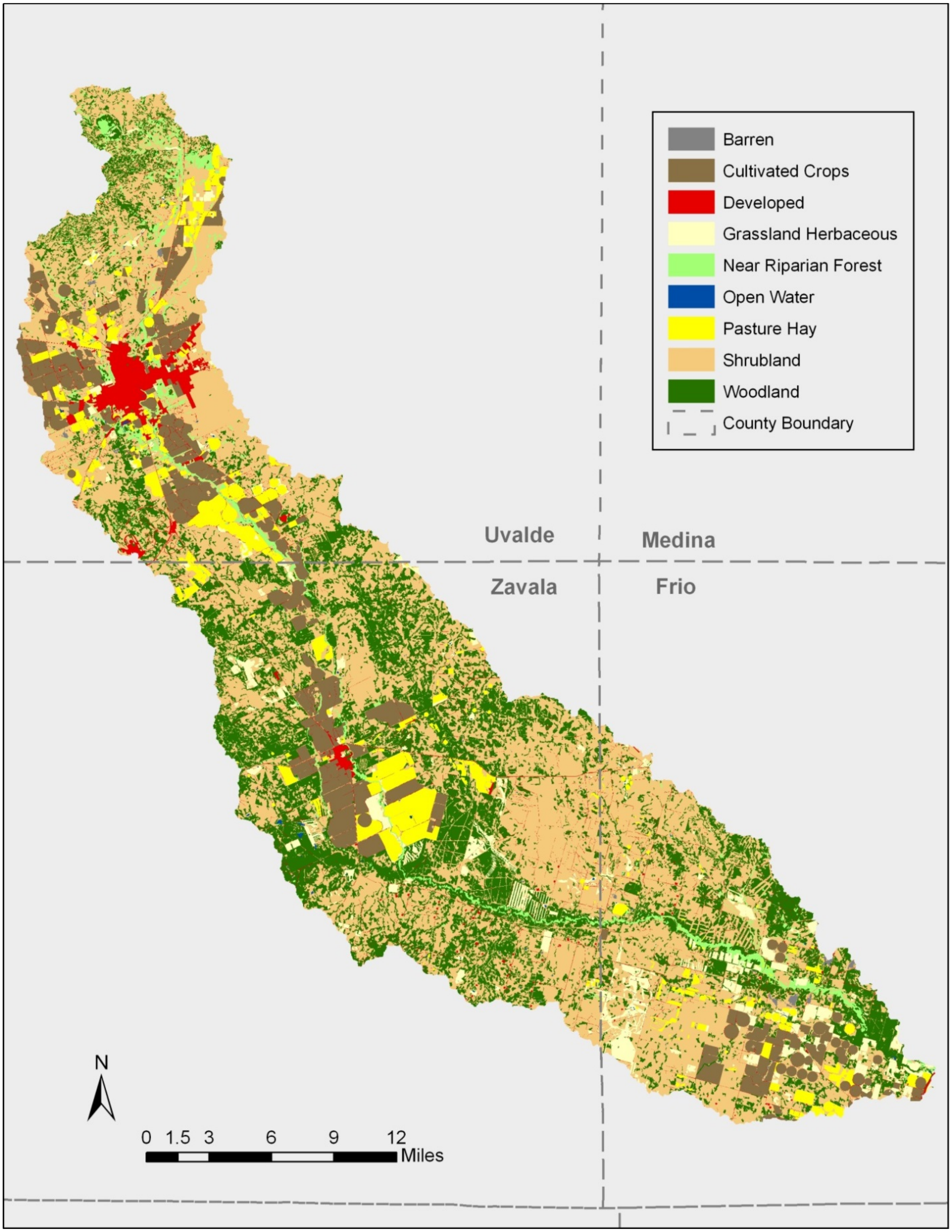

Figure 2 Land use/land cover within the Leona River watershed. Land use/land cover layer developed by the Spatial Science Laboratory at Texas A&M University, College Station, Texas.

SECTION 2

Methods

In producing an overview of potential bacteria loadings for a watershed, SELECT relies on land-use classification data integrated with information regarding the soils, the layout of the stream network, human population and animal densities, as well as the location and discharge of point sources, such as municipal wastewater treatment facilities (WWTFs). Many of the inputs used for SELECT were identified in the geographic information system inventory and bacteria source survey for the project (McFarland and Adams, 2014). Input from local stakeholders is also important in deriving the types and densities of potential pollution sources. For the Leona River watershed, the following major sources were identified for inclusion in SELECT:

- Cattle
- Deer
- Feral Hogs
- Dogs
- Septic Systems
- Sheep/Goats
- Permitted Dischargers
- Concentrated Animal Feeding Operations (CAFOs)

Some other bacteria sources that were identified but not included due to limitations of SELECT or the lack of needed density information include exotics and small wildlife, such as birds, raccoons, opossums and skunks. For small wildlife, the appropriate animal density and fecal production data are not yet available for integration into SELECT. With regard to exotics, the Leona River watershed has many large game ranches with exotics, such as aoudad, axis deer and blackbuck antelope. Density information regarding these exotics was not available, although efforts were made to contact experts working with these ranches. In addition, SELECT lacks the level of resolution to identify specific ranches, but focuses on general land-use categories.

Other categories of livestock not included in the SELECT application included horses and ponies, mules, burros and donkeys, and hogs. Livestock statistics for these livestock categories were available at the county level, but the number of animals was relatively small compared to the livestock categories of cattle, sheep and goats (see McFarland and Adams, 2014).

For most potential sources, such as livestock, an animal density and fecal production rate is related with particular types of land cover to estimate the distribution of animals in the watershed. To aid in targeting areas and potential pollution sources across the landscape, SELECT does not just look at the watershed as a whole, but divides the watershed into multiple smaller sub-watersheds based on elevation changes along tributaries and the main-stem of the river. To delineate subwatersheds, the ArcView Soil and Water Assessment Tool (AVSWAT; Di Luzio et al., 2002; 2004) was employed. A stream threshold of 2,000 acres was used for the delineations resulting in 103 sub-watersheds varying in size from 1,100 to 12,800 acres with an average sub-watershed size of 4,170 acres (Figure 3).

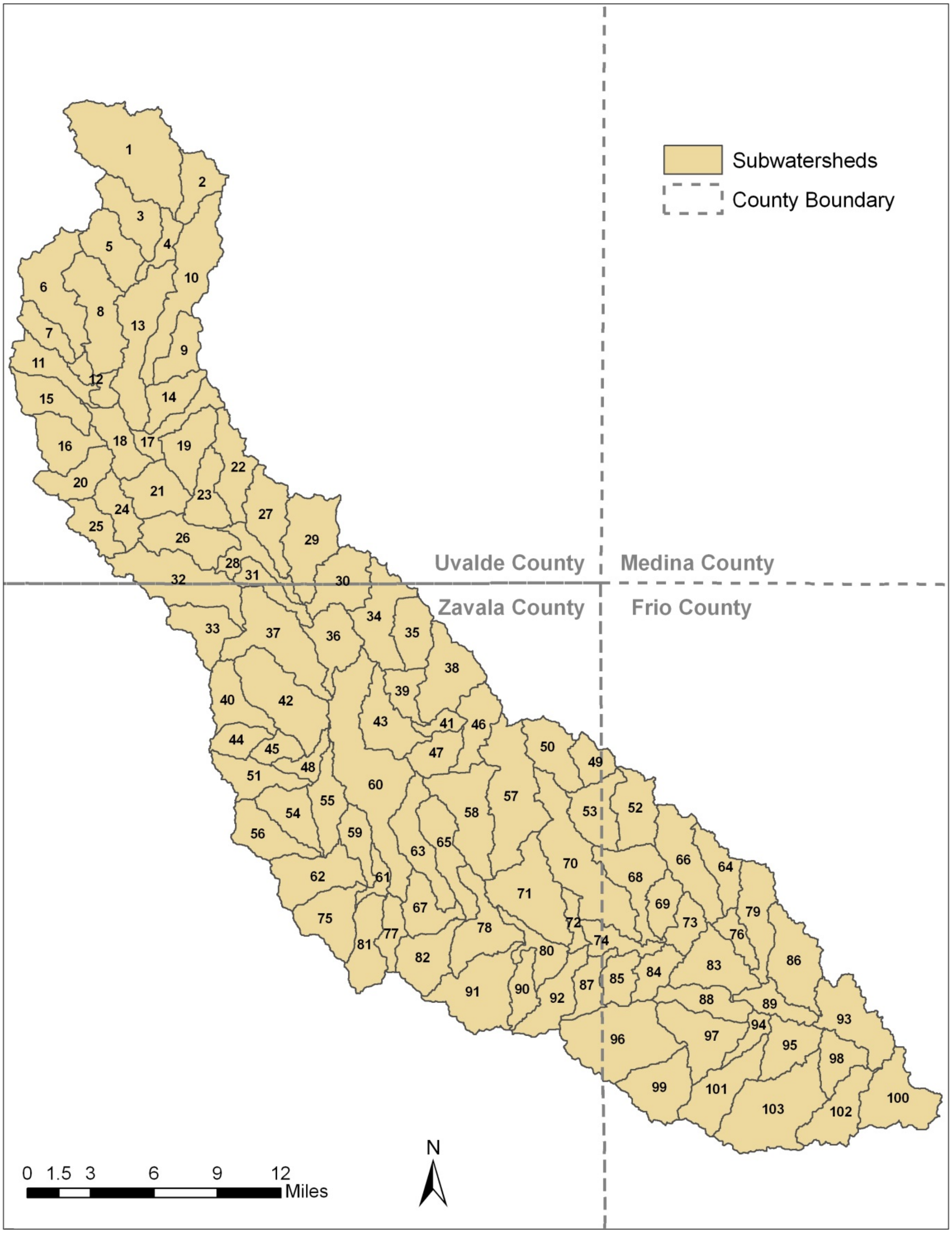

Figure 3 Leona River delineated subwatersheds. Subwatersheds delineated using AVSWAT.

SELECT Methodology

The analysis of potential loadings using SELECT is conducted on a 30-meter-by-30-meter spatial resolution distributing each source over suitable areas within the watershed and aggregating potential loadings at the subwatershed level. For most nonpoint sources, such as livestock or deer, suitable areas are defined by land-use cover with potential bacteria loadings estimated based on the density of the source (for example, number of animals per acre) and the fecal production rate for that source. For point sources, such as WWTFs and CAFOs, potential bacteria loadings are based on the discharge rate and location. Fecal production rates for sources followed previous applications of SELECT (see Teague et al., 2009; Brazos River Authority and Espey Consultants, 2010; and Borel et al., 2013), which were based primarily on information provided in EPA guidance for *E. coli* (USEPA, 2001; Table 2). If only fecal coliform production rates were available, these were converted to *E. coli* production rates by multiplying fecal coliform rate by 0.5 (Doyle and Erikson, 2006).

Table 2 Production rates of *E. coli* by source. Production rates generally based on values for raw waste unless otherwise specified. Production rates are in colony forming units (cfu) per day. Source: USEPA (2001) unless otherwise noted.

Source	Production Rate, *E. coli* (cfu/day) [a]	Load Calculation (cfu/day)
Cattle	10×10^{10} cfu/day * 0.5	Production rate * # cattle
Deer	3.5×10^{8} cfu/day * 0.5	Production rate * # deer
Feral Hogs	1.1×10^{10} cfu/day * 0.5	Production rate * # hogs
Dogs	5×10^{9} cfu/day * 0.5	Production rate * # dogs
Septic Systems	10×10^{6} cfu/100 mL * 0.5	Production rate * potential failure discharge amount
Sheep/Goats	1.2×10^{10} cfu/day * 0.5	Production rate * # sheep & goats
Permitted Dischargers	126 cfu/100 mL [b]	Production rate * permitted discharge amount in milliliters
CAFOs (beef cattle feedlots)	10×10^{10} cfu/day * 0.5	Production rate * # permitted head * 0.2 treatment efficiency [c]

a. Production rate values multiplied by 0.5 are in units of fecal coliform original and converted to *E. coli* using a conversion factor suggested by Doyle and Erikson (2006).
b. For permitted dischargers, the criterion of 126 cfu/100 mL associated with primarily contact recreation was used as the maximum potential production rate for bacteria in potential load calculations.
c. An 80 percent treatment efficiency was assumed for CAFOs, so only 20 percent of the *E. coli* in raw waste was assumed in the calculation of the potential *E. coli* load.

The Spatial Sciences Laboratory at Texas A&M University in College Station, Texas provided the land-use data for the Leona River watershed (SSL, 2013; see Table 1 and Figure 2). This land-use information was developed from aerial photos obtained from the National Agriculture Imagery Program (NAIP) with a one-meter resolution produced in 2010 and 2012 and Texas Orthoimagery Program (TOP) images collected in March 2008. Both NAIP and TOP images were obtained from the Texas Natural Resources Information System (TNRIS; http://www.tnris.org/). Google Earth satellite images collected by GeoEye in March, October, and December of 2012 were used as visual aids in corroborating the land-use classification as well as ground-truthing information provided by TIAER.

Point Source Inputs

Permitted Dischargers

The Leona River watershed has three active permitted dischargers: the City of Uvalde with three outfalls, the Batesville Water Supply Corporation and the U.S. Fish and Wildlife Service National Fish Hatchery (see McFarland and Adams, 2014). Permitted discharge amounts and location of each outfall are indicated in Table 3. Of note, the Batesville WWTF, while permitted to discharge, has never reported an actual discharge in that evaporation from holding ponds is the primary means of effluent removal. Additionally, the National Fish Hatchery discharges only intermittently, not continuously. Thus, the SELECT potential loadings output for these two permitted dischargers represent a "worst case" scenario with regard to discharge rates.

Table 3 Potential loading rates and subwatershed location for permitted dischargers within the Leona River watershed.

Permitted Facility and Discharge Location	Subwatershed Location of Outfall	Permitted Discharge (million gallons per day, MGD)	Potential Daily *E. coli* Loading (cfu/day)[a]
Uvalde WWTF Outfall #1 (wetlands prior to Cooks Slough)	18	0.2604	1.23×10^{10}
Uvalde WWTF Outfall #2 (Leona River in Uvalde City Park and Golf Course)	13	0.6138	2.91×10^{10}
Uvalde WWTF Outfall #3 (directly into Cooks Slough)	18	0.0558	2.64×10^{9}
Batesville Outfall (Gallina Slough)	55	0.184	8.71×10^{9}
National Fish Hatchery Outfall (Fish Hatchery Slough)	16	0.80	3.79×10^{10}

a. Loadings for permitted dischargers were calculated as *E. coli* (cfu/day) = permitted MGD*(126 cfu/100 mL)*(10^6 gallons/MGD)*(3758.2 mL/gallon)

CAFOs

Two permitted CAFOs are located within the Leona River watershed: the Chaparral Cattle Feedlot south of Uvalde (subwatershed #27 in Figure 3) and the Live Oak Feedlot southeast of Batesville (subwatershed #57 in Figure 3). The Chaparral Cattle Feedlot is permitted for 10,000 head and the Live Oak Feedlot for 8,000 head. While CAFOs are in essence permitted for zero discharge, most animal waste produced is land applied near the facility and a certain level of bacteria in rainfall runoff from these fields will occur. As a conservative estimate, a treatment efficiency of 80 percent was assumed for raw waste produced by cattle in each feedlot following guidance provided by Borel et al. (2012) in the application of SELECT. As shown in Table 2, *E. coli* production rates for cattle based on raw waste were multiplied by 0.2 for CAFOs to indicate that only 20 percent of the total raw loading would be input into these two subwatersheds in relation to CAFOs. Loadings for CAFOs were calculated as follows:

E. coli (cfu/day) = permitted head # * production rate * treatment efficiency

Where the production rate is $5x10^{10}$ cfu/day (see Table 2) and 0.2 is the treatment efficiency associated with processing of the waste for a loading of $1x10^{10}$ cfu/day for each permitted head. The daily loading associated with the Chaparral Cattle Feedlot was $10x10^{14}$ cfu/day and the Live Oak Feedlot was $8x10^{13}$ cfu/day.

Nonpoint Source Inputs

Cattle

Cattle numbers were based on United States Department of Agriculture (USDA) National Agricultural Statistics Service surveys for 1997, 2002 and 2007 at the county level. To account for cattle on feedlot, the number of cattle and calves sold “on grain” was subtracted from the total number of cattle and calves noted in each survey (Table 4). In cases where the number sold “on grain” was reported as a “D” indicating that the data could not be disclosed, the total number of permitted cattle within the county was subtracted. The number of cattle and calves sold “on grain” was assumed to represent the cattle in feedlot within each county. Average county numbers, after subtracting the number of cattle associated with feedlots, were then adjusted based on the portion of each county within the watershed to represent the number of cattle within the watershed. Loadings for cattle were calculated as the number of head times the production rate (see Table 2). The *E. coli* loading from grazing cattle was distributed within SELECT on grassland herbaceous and pasture/hay land uses based on the adjusted number of cattle within the watershed for each county. The resulting stocking rate would be about 0.5 cows/acre on these land categories or about 2 acres per cow on average for the watershed.

Table 4 Estimated cattle numbers on grazing land within the Leona River watershed based on county level statistics. County level numbers obtained from USDA National Agricultural Statistics Service (USDA, 2012). Permitted feedlot numbers obtained for each county from a query of the TCEQ permit database.

County	Year	Adjusted Cattle #s[a]	Cattle & Calves Total for County	Sold "on grain" Total for County	Number of CAFO Feedlots in County	Total Permitted Head on Feedlot within County
Uvalde	2007	35,401	52,366	16,965	3	20,000
	2002	44,325	64,325	D[b]		
	1997	47,563	67,064	19,501		
Average		42,430				
Area Weighted for portion in watershed[c]		5,516				
Zavala	2007	58,641	66,641	D	1	8,000
	2002	47,034	55,034	D		
	1997	32,139	40,139	D		
Average		45,938				
Area Weighted for portion in watershed[c]		10,566				
Frio	2007	40,660	51,411	10,751	1	22,500
	2002	33,949	57,554	23,605		
	1997	53,744	72,220	18,476		
Average		42,784				
Area Weighted for portion in watershed[c]		6,418				

a. Adjusted Cattle #s = (Cattle & Calves Total for County) - (Sold "on grain" Total for County)
b. D indicates data cannot be disclosed. The total permitted value on feedlot within the county was used as the number sold "on grain" when a D was reported.
c. 13 percent of Uvalde County, 23 percent of Zavala County and 15 percent of Frio County are within the Leona River watershed.

Sheep/Goats

Similar to cattle, estimated sheep and goat numbers were obtained at the county level from USDA National Agricultural Statistics Service for 1997, 2002, and 2007 (USDA, 2012). These numbers were averaged and then adjusted for the portion of the county within the watershed (Table 5). Stakeholder feedback noted that probably fewer sheep were actually grazed within the area of the watershed within Uvalde County, but it was unclear how much these numbers should be decreased, so values were left as presented in Table 5 as a "worst case" scenario.

Table 5 Estimated sheep and goat numbers on grazing land within the Leona River watershed based on county level statistics. County level numbers obtained from USDA National Agricultural Statistics Service (USDA, 2012).

County	Year	Total Sheep/ Goats	Goats	Sheep
Uvalde	2007	35,855	25,805	10,050
	2002	52,892	30,649	22,243
	1997	97,128	64,287	32,841
Average		61,958		
Area Weighted for portion in watershed[a]		8,055		
Zavala	2007	6,788	6,718	70
	2002	7,214	6,779	435
	1997	2,555	2,302	D
Average		5,519		
Area Weighted for portion in watershed[a]		1,269		
Frio	2007	1,617	1,519	98
	2002	692	594	D
	1997	1,042	944	D
Average		1,117		
Area Weighted for portion in watershed[a]		168		

a. 13 percent of Uvalde County, 23 percent of Zavala County and 15 percent of Frio County are within the Leona River watershed.

Loadings for sheep and goats were calculated as the adjusted number of head times the production rate (see Table 2). Within SELECT, sheep and goat *E. coli* loadings adjusted for the watershed area represented by each county were distributed on the land-use categories of grassland/herbaceous, pasture/hay, shrub land, and woodland within that county.

Feral Hogs

No accurate estimate of the number of feral hogs exists for the Leona River watershed, but they are abundant as an invasive, unmanaged species throughout the watershed according to feedback from stakeholders and signs of feral hog activity observed by TIAER field crews (see McFarland and Adams, 2014). For feral hogs, a density of 30 hogs per square mile or 0.05 hogs/acre was input as typical densities (Taylor, 2003; Hone, 1988; and Tate, 1984).

Feral hogs were assumed to be present on all land-use categories, but open water and developed areas. The density of 0.05 hogs/acre was multiplied by the area available for a total population of 21,462 hogs within the watershed. Feedback from stakeholders indicated some uncertainty in this number as some individuals indicated that it appeared to be too low while others thought it was too high, so some adjustment may be appropriate should better density estimates become available in the future.

Total loadings for feral hogs were calculated as the total number of hog in the watershed times the *E. coli* production rate (see Table 2). Because feral hogs are noted for moving in groups along waterways, and particularly in times of drought and will aggregate near perennial water sources to drink and wallow (Taylor, 2003), SELECT applies the loading of *E coli* associated with feral hogs uniformly across all land uses, but open water and developed areas, within a 100-meter buffer around the stream network.

Deer

For deer, a density of 16.8 deer per 1,000 acres or about 60 acres per animal was applied in SELECT based on survey data obtained from the Texas Parks and Wildlife Department (TPWD) for the South Texas Plains Ecoregion. Within SELECT, deer were distributed across the land uses of woodland, shrubland and near riparian forest.

Dogs

Domestic pets are another unregulated source of E. coli bacteria, particularly from dogs, because storm runoff often carries these wastes into streams (USEPA, 2009). Assuming a rough estimate of 1.6 dogs per household (AVMA, 2012) and about 7,000 households within the Leona River watershed based on 2010 census population data (about 20,000 individuals and 3 individuals per household), there are potentially about 7,000 dogs within the Leona River watershed. Other domestic animals, such as outdoor cats, also will contribute to potential loadings, but the number of cats is difficult to estimate as in many rural areas, domestic cats are often feral. Loadings of *E. coli* from dogs was distributed based on the number of homes in each subwatershed using 2010 Census Block data (USCB, 2010).

Septic Systems

On-site sewage facilities (OSSFs) or septic systems are often used in rural areas that do not have the ability to connect to a central wastewater collection system. Failure of these systems can lead to bacteria loadings to the stream. To account for potential *E. coli* loadings from septic systems, the number of homes within each subwatershed that are not covered by public wastewater services were identified using the Certificates of Convenience and Necessity (CCN) wastewater utility layer obtained from TCEQ. The number of homes in each subwatershed was based on 2010 Census Block data (USCB, 2010). The number of people per home was estimated using the average household size from the 2010 census block per subwatershed (USCB, 2010).

Soils data from the Natural Resources Conservation Service (NRCS) were then obtained from the Soil Survey Geographic (SSURGO) database and used to calculate the potential failure rate of septic systems within a subwatershed based on the dominate limitation class associated with the septic tank absorption field (USDA-NRCS, 2012). The failure rate within SELECT associated with limitation classes for septic drainage fields was as follows (Borel, et al., 2012; USDA-SCS, 1993):

- 15% for severely limited,
- 10% moderately limited,
- 5% for slightly limited, and
- 15% for not rated.

Within SELECT, the *E. coli* loading for each subwatershed is calculated as follows:

E. coli (cfu/day) = (# septic systems) * (average # people/household) * (*E. coli* production rate in cfu/100 mL) * (failure rate) * (individual usage in gallons/person) * (3758.2 mL/gallon)

For the Leona River watershed, SELECT was applied assuming an *E. coli* production rate of $5x10^6$ cfu/100 mL with a daily usage of 60 gallons per person per day.

SECTION 3

Results and Discussion

The spatial analyses performed by SELECT highlights the subwatershed with the highest potential contribution of loadings of *E. coli* to the watershed. The loads of *E. coli* are based primarily on land-use characteristics and the pollution of potential sources (Borel et al., 2012). Within ArcGIS, the SELECT output by subwatersheds is broken into five groups, where applicable, and are in order from highest to lowest (red, orange, yellow, light green, green) with regard to potential loading. Six subwatersheds were identified (either red or orange) as locations with the highest potential loadings (Figure 4). In subwatershed #27 and #57 (see Figure 2 for reference to subwatershed numbers), the CAFOs were clearly the largest potential source. In subwatersheds #60 and #63 in the mid portion of the watershed, cattle dominated as a potential source. In the lower portion of the watershed, subwatersheds #96 and #100 still indicated cattle as the dominant potential source, but potential loadings from feral hogs were also notable.

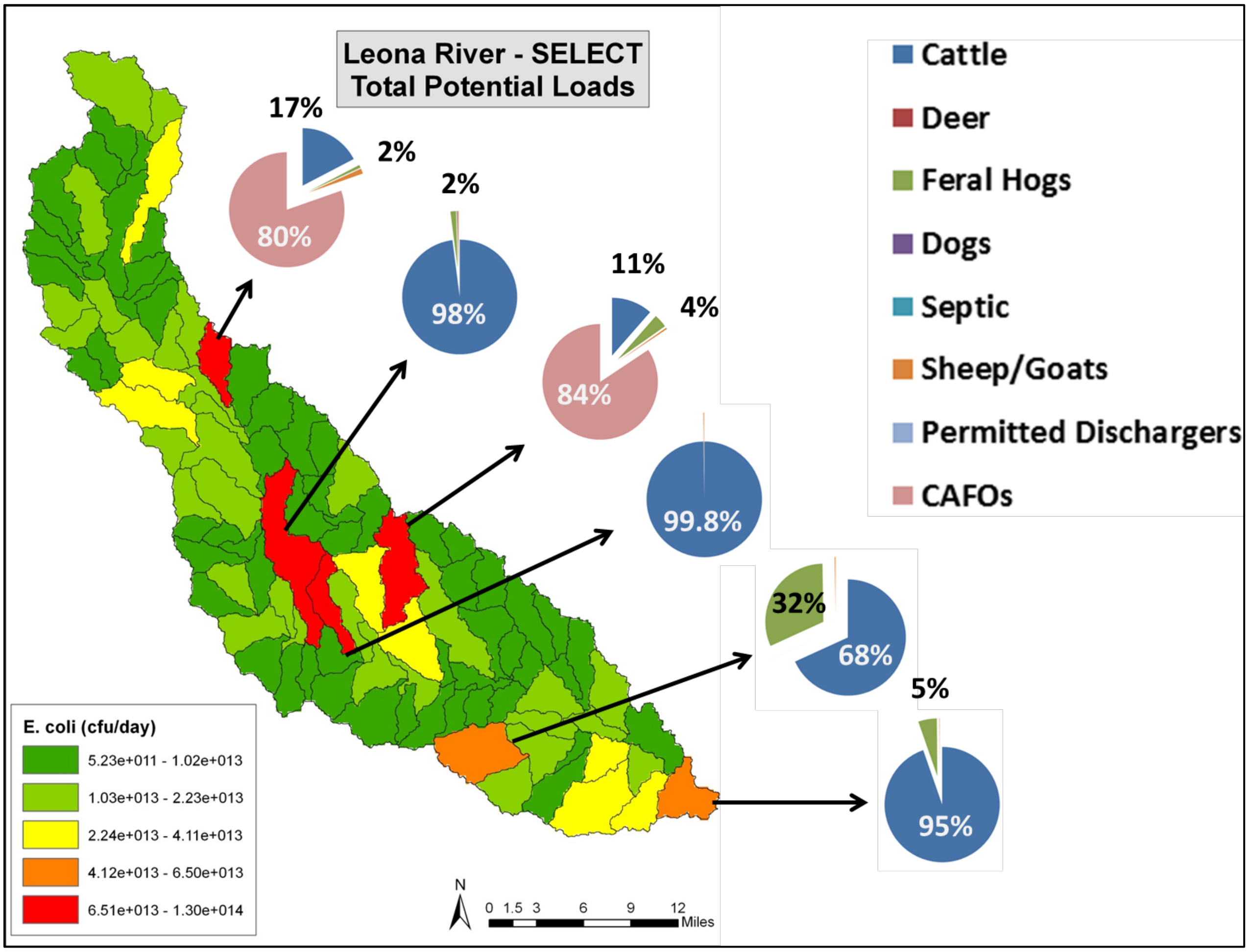

Figure 4 Total potential daily *E. coli* loadings from all considered sources in the Leona River watershed.

In comparing the SELECT results just for grazing cattle with the land use in the Leona River watershed (Figure 5), the subwatersheds dominated by grassland/herbaceous and pasture/hay are clearly highlighted as yellow, orange or red. In these areas, if a reduction in E. coli loadings is desired, educational outreach efforts might be used to promote management practices, such as prescribed grazing, stocking rate management, use of alternative watering sources, and implementation of filter strips (see Redmon et al., 2012).

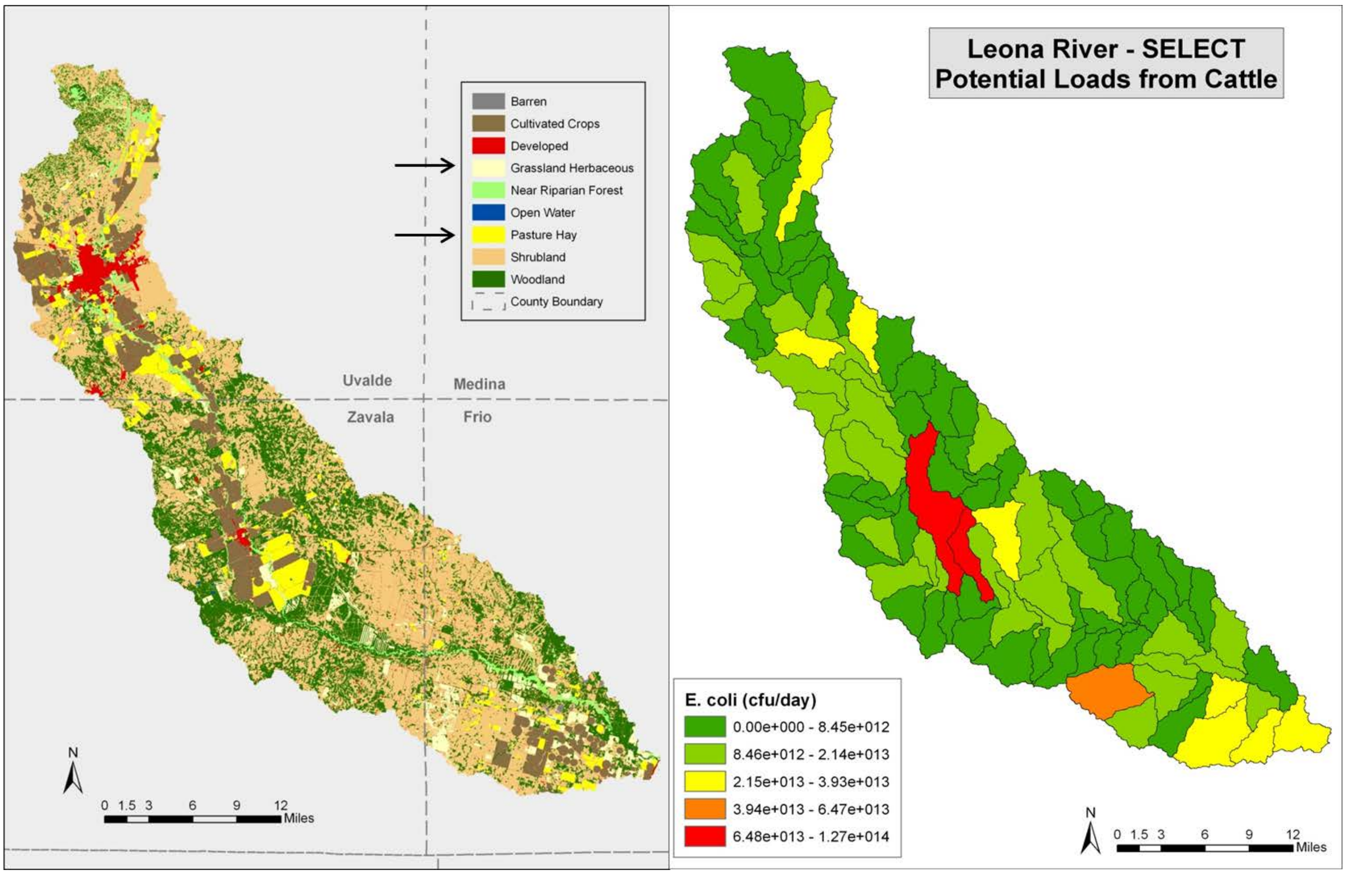

Figure 5 Potential daily *E. coli* loadings from grazing cattle compared to land use within the Leona River watershed. Arrows indicate the land uses that cattle loadings were distributed across within SELECT.

In a similar fashion, the distribution of loadings from sheep and goats and deer were closely related to the location of land uses applied in SELECT for these animal categories (Figures 6 and 7). The sheep and goats indicate most of the potential *E. coli* loading within the upper third of the watershed associated with Uvalde County.

Feedback from stakeholders at the public meeting held on June 4, 2013 indicated that the loadings from sheep and goats were not well represented. Although for the watershed, most sheep and goats are in the upper third within Uvalde County, the number within Uvalde County when taken proportionally overestimates the number within this area of the Leona River watershed. Only a few ranches in the watershed actually graze sheep and goats, so a more refined tool would be needed to better represent this potential loading source. With this feedback noted, the potential loadings from sheep and goats are likely not a source for which focused educational efforts are needed for the Leona River watershed.

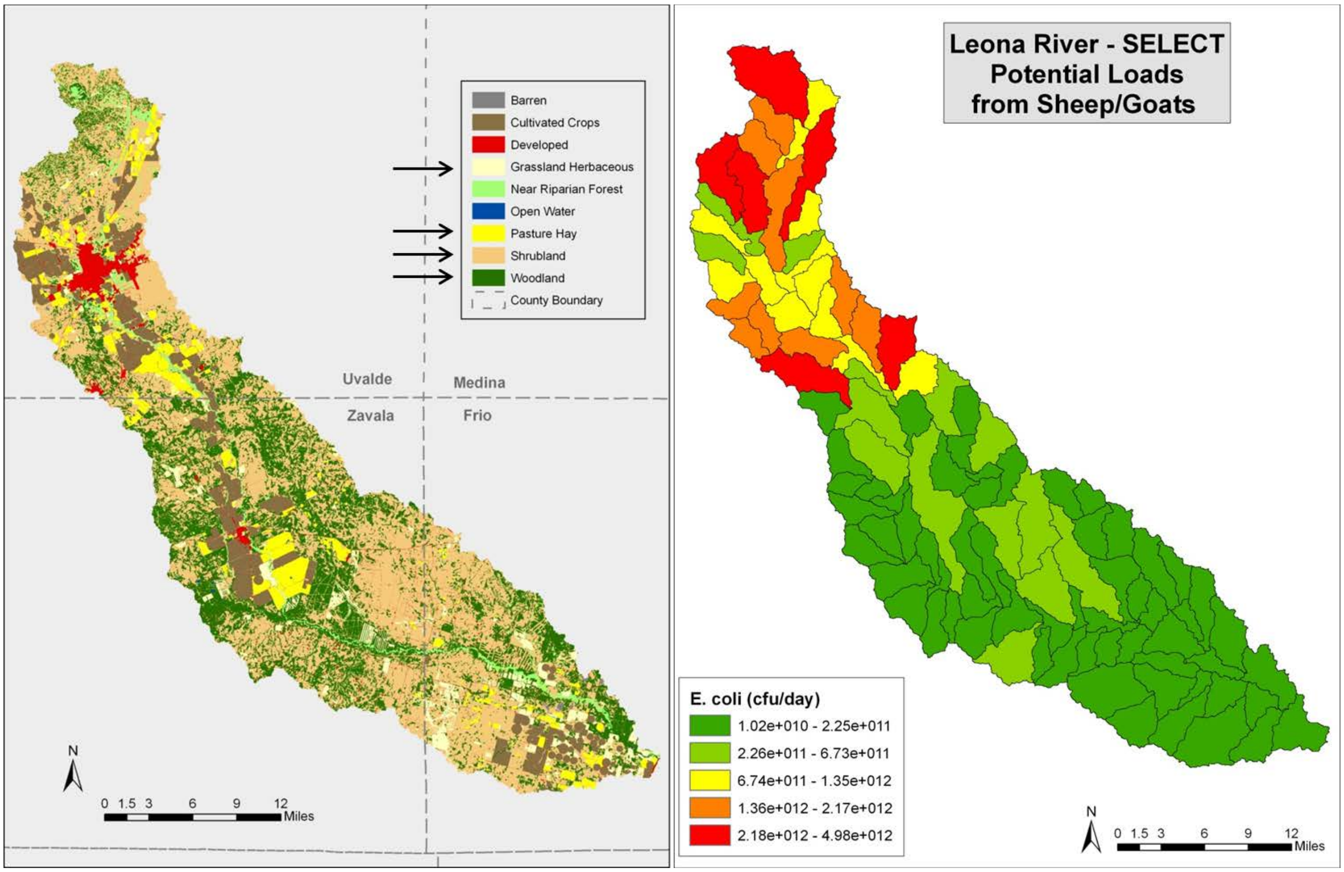

Figure 6 Potential daily *E. coli* loadings from sheep and goats compared to land use within the Leona River watershed. Arrows indicate the land uses that sheep and goat loadings were distributed across within SELECT.

For deer (Figure 7), there was some indication from stakeholders that deer should be distributed over more land uses and possibly at a higher density. A difficulty was noted to that because there are several large ranches with high game fences within the Leona River watershed, and the movement of deer would be restricted within some subwatersheds. Overall, deer were a minor source of *E. coli* loadings representing only a fraction of a percent of the total potential loadings and even if the deer density were doubled (16.8/1,000 acres used in current SELECT application), the potential impact would still be quite limited compared to other sources in the watershed.

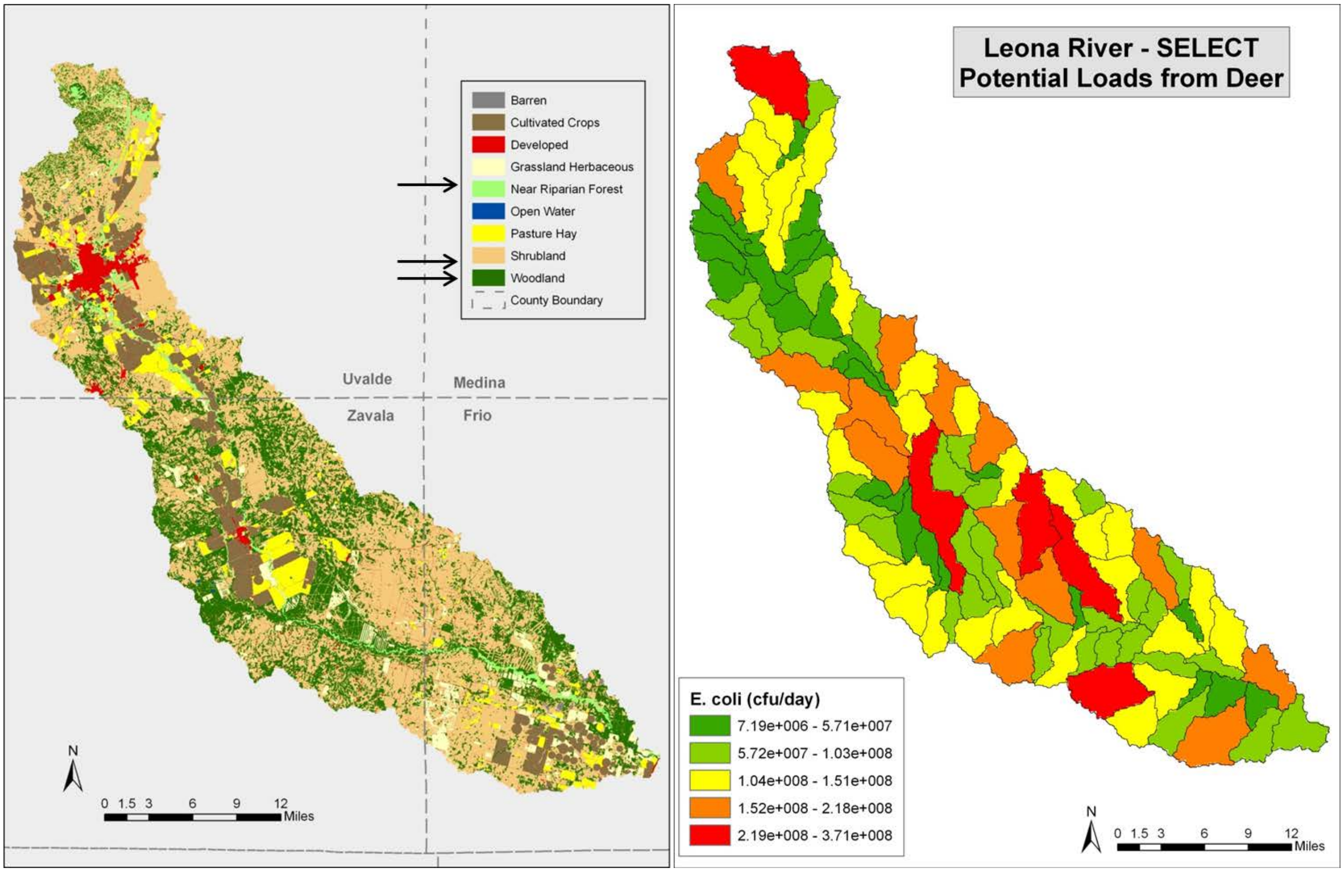

Figure 7 Potential daily *E. coli* loadings from deer compared to land use within the Leona River watershed. Arrows indicate the land uses that deer loadings were distributed across within SELECT.

One of the other major sources was feral hogs (Figure 8). Because SELECT distributed feral hogs in land areas along the stream channels (within a 100 meter buffer), subwatersheds with more creek or stream miles were highlighted with the largest potential loadings. Management practices for controlling feral hogs focus on harvesting methods for removal from the watershed (Peterson et al., 2012).

Other sources with fairly limited potential contributions (< 1 percent) to the watershed are shown in Figure 9. Neither failing septic systems nor permitted dischargers appeared to be large potential contributing sources. Subwatersheds #16 and #18 were highlighted for septic systems and represent a fairly high density housing area known as Uvalde Estates, which is not on the City of Uvalde wastewater collection system. Stakeholders noted that another subdivision is located to the north of Uvalde, but the housing density in this area is much lower than in Uvalde Estates, thus, this area does not show as highlighted in SELECT. The permitted dischargers clearly show up in the subwatersheds where these point sources are located, while the loadings associated with dogs as pets is related to the housing density of the watershed.

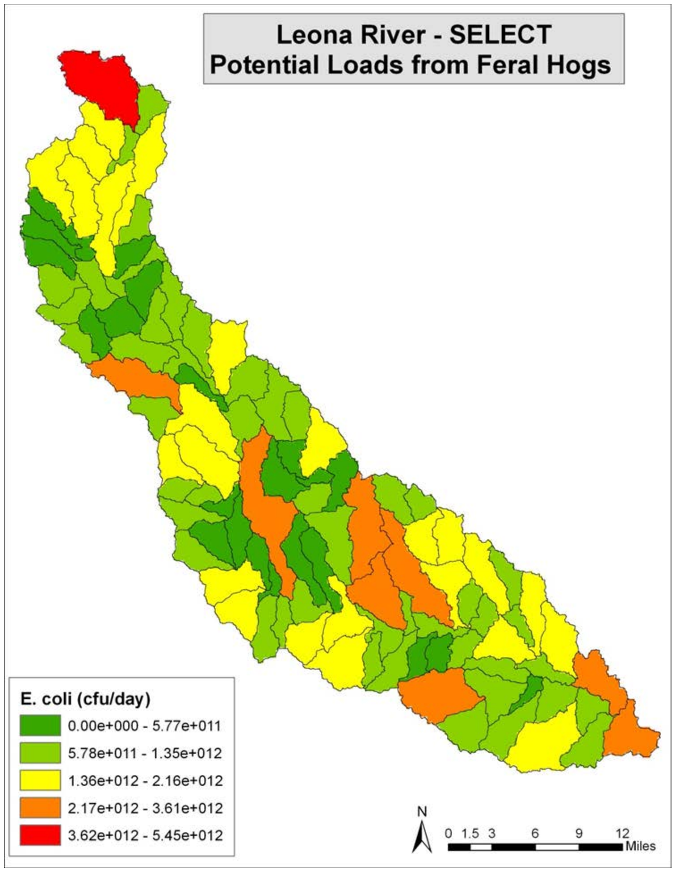

Figure 8 Potential daily *E. coli* loadings from feral hogs within the Leona River watershed.

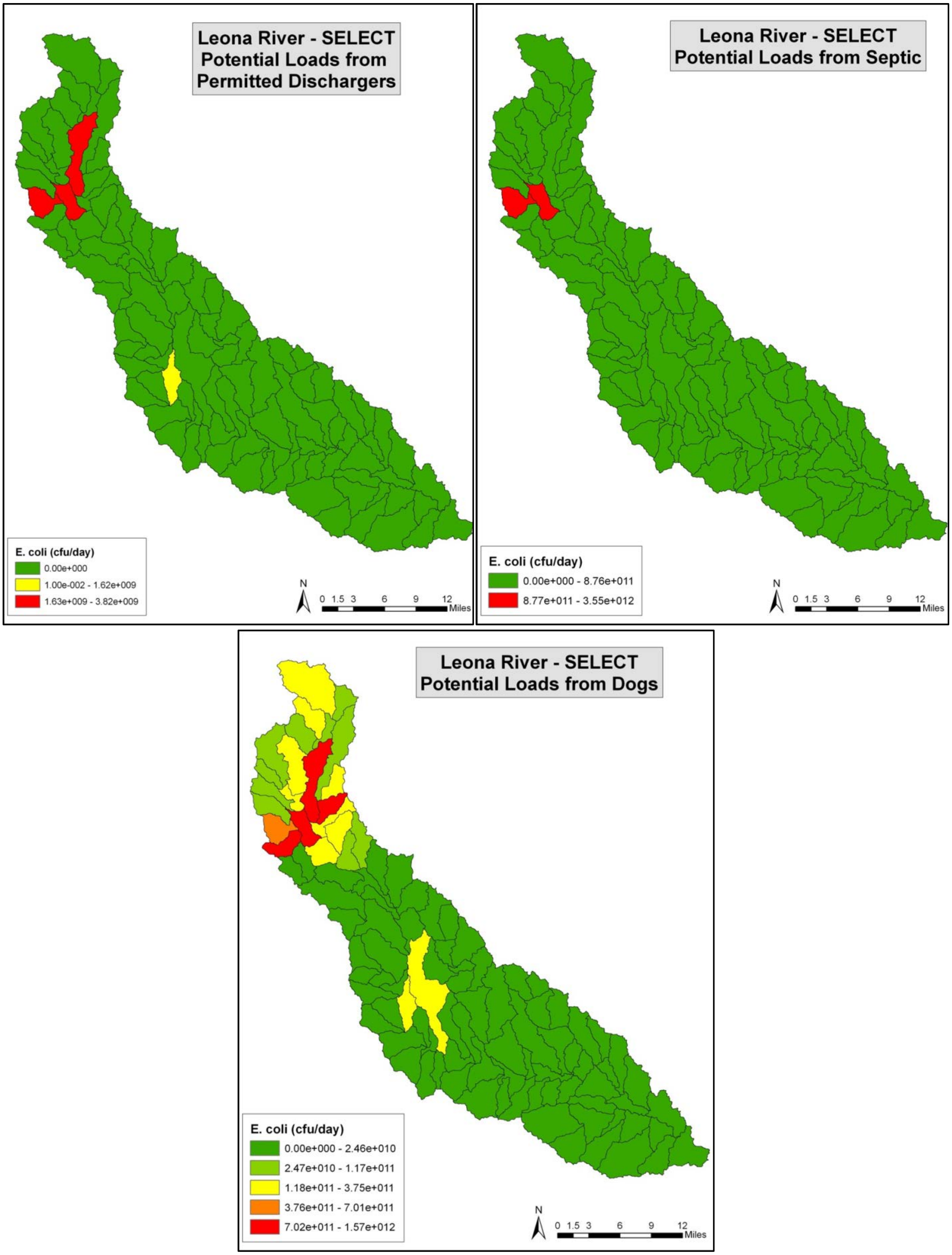

Figure 9 Potential daily *E. coli* loadings from permitted dischargers, septic systems, and dogs within the Leona River watershed.

SECTION 4

Summary

The SELECT methodology enables pictorial presentation of the potential bacterial loadings of major sources within a watershed. The purpose of applying this tool is to engage stakeholders in identifying sources within impaired waterbodies, but also to help them focus educational and outreach efforts that may lead to reductions in *E. coli* loadings. Across the Leona River watershed, grazing cattle appears to be the primary potential contributing source of bacteria followed by feral hogs. For feral hogs, harvesting is the primary mechanism of control, while a number of different management practices may be applied to cattle grazing operations to assist with loading reductions. For subwatersheds that contain a CAFO, the CAFO operation is highlighted as the largest potential source, however based on TCEQ records, the two CAFOs within the Leona River watershed are in compliance with their permits.

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