Dry Comal Creek and Comal River Watershed Protection Plan

Developed by the Dry Comal Creek and Comal River Watershed Partnership

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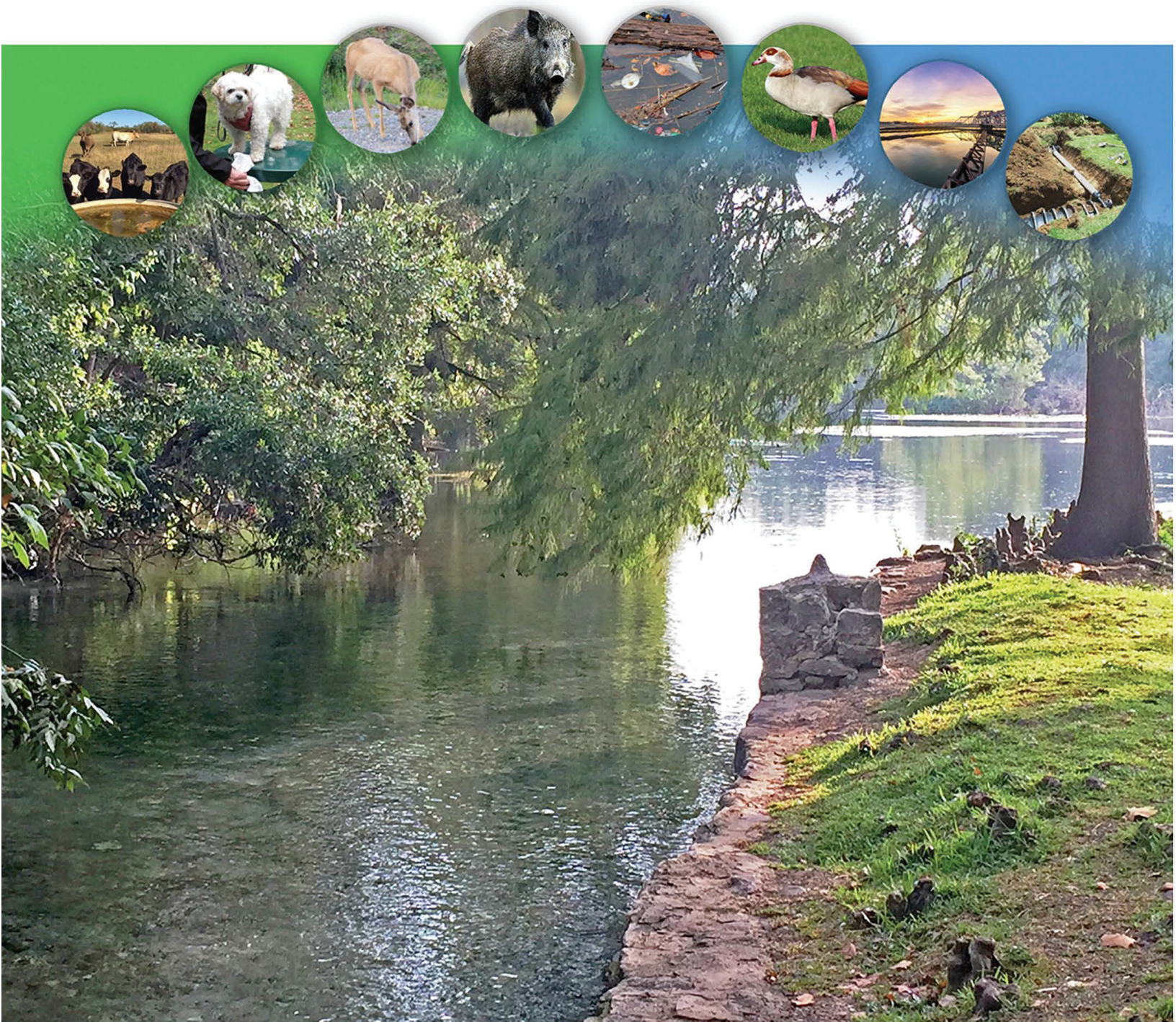

Dry Comal Creek and Comal River Watershed Protection Plan

Prepared for the Dry Comal Creek (1811A) and Comal River (1811) Watershed Partnership by:

Greg Malatek and Mark Enders - City of New Braunfels

Mike Urrutia, Lee Gudgell, and Cinde Thomas-Jimenez - Guadalupe-Blanco River Authority

Nathan Pence, Alicia Reinmund-Martinez, and Jim Boenig - Edwards Aquifer Authority

Ashley Evans, PE, Fred Blumberg, and Debbie Magin - Arcadis U.S., Inc.

Bree Carrico, PE - Alexa Engineering

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This Dry Comal Creek (1811A) and Comal River (1811) Watershed Protection Plan (WPP) is the result of collaboration and cooperation between many different groups and individuals. First, the Watershed Partnership, a collaboration between the City of New Braunfels (City), the Guadalupe-Blanco River Authority (GBRA), the Edwards Aquifer Authority (EAA), the Stakeholder Group, and the Technical Advisory Group (TAG), expresses its thanks to members of the WPP Stakeholder Group and WPP Work Groups for their investment of time and energy to participate and provide valuable input throughout the process. The stakeholders' insight, support, and information on activities and potential sources of pollution in the watershed have been instrumental. The Dry Comal Creek and Comal River Watershed Partnership (the "Watershed Partnership") also thanks the individuals and organizations that provided technical information and support, expertise and/or advice throughout the project including the following:

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Statement of Purpose

The Dry Comal Creek and Comal River are essential natural resources in Comal and Guadalupe Counties, supporting economic development and recreation in the City, as well as agricultural operations and wildlife throughout the area. In 2010, the Dry Comal Creek was listed by the State of Texas as having impaired water quality for *Escherichia coli (E. coli)* bacteria. Specifically, the geometric mean (geomean) *E. coli* concentration within the Dry Comal Creek exceeded 126 colony forming units per 100 milliliters (CFU/100 mL), which is the Texas statewide criterion for surface water categorized for primary contact recreation. The City and GBRA responded by conducting additional *E. coli* sampling at supplementary sites along the Dry Comal Creek and Comal River to aid in identification of potential sources of impairment. The City also sponsored a study ("Dry Comal Creek Outfall Reconnaissance Inventory" dated 2011) to assess watershed conditions and improvement options. Review of *E. coli* data suggested that *E. coli* concentrations in the Comal River were also increasing. Thus, the City started the process of applying for grants from the USEPA to secure funding for development of a WPP for the Dry Comal Creek and Comal River watersheds (the "Watershed"). The City secured two separate grants to allow development of a WPP in two phases:

- **Phase 1: Watershed Characterization** – Quantification of bacteria loads in the Dry Comal Creek and Comal River and identification of sources of bacteria pollution within the Watershed.
- **Phase 2: Development of a WPP** – Development of best management practices (BMPs) to reduce bacteria loads in the waterbodies, and identification and development of Outreach and Education activities required for successful, Watershed-wide implementation of the WPP.

A primary goal of the Phase 1 and 2 processes was to create a means for stakeholders to develop an understanding of the Watershed and to actively improve the quality and health of water resources through adoption of voluntary management practices. Stakeholders are a critical part of the WPP process. Stakeholders include any individual or group that may be directly or indirectly affected by activities implemented to protect water quality. Stakeholders can include citizens, businesses, municipalities, county governments, river authorities, soil and water conservation districts, agricultural committees, nonprofit organizations, and state and federal agencies.

The purpose of this WPP is to document the results of Phase 1 and Phase 2 of the WPP project and present an implementable WPP to reduce bacteria levels in the Dry Comal Creek and Comal River. The goals of Phase 1 of the WPP project were to: 1) establish a Stakeholder Group and a procedure to drive public participation and input into the WPP process; and 2) concentrate on the impaired Dry Comal Creek, while including a holistic watershed approach to evaluate increasing bacteria levels in the Comal River. The primary goals of Phase 2 of the WPP project were to: 1) facilitate a stakeholder-driven process to select implementable BMPs to reduce bacteria levels in the Dry Comal Creek and Comal River; 2) facilitate a stakeholder

process to plan outreach and education activities related to the WPP and BMPs that are important for the WPP's success; and 3) develop an EPA-accepted WPP for the Watershed.

The WPP also supports implementation efforts and enables financial and technical assistance to facilitate improvements in the Watershed. This WPP is structured to address the nine necessary elements of a WPP as determined by the USEPA (refer to Appendix A). This WPP is intended to be a living document, adjusted from time to time to include new data and adapted as conditions in the Watershed change over time. It will evolve as needs and circumstances dictate, and will be guided by the City with stakeholder involvement as they undertake active stewardship of the Watershed.

Contents

▶ ACKNOWLEDGEMENTS I

▶ STATEMENT OF PURPOSE II

EXECUTIVE SUMMARY ES-1

Watershed Partnership and Stakeholder Engagement ES-2
Implementation Plan for Improving Water Quality ES-6

1. WATERSHED MANAGEMENT 1

1.1 Watersheds and Water Quality 1
1.2 Benefits of a Watershed Approach 2
1.3 Dry Comal Creek and Comal River Watershed Protection Plan Purpose and Funding 2
1.4 *E. coli* Overview 4

2. OVERVIEW OF THE WATERSHED 6

2.1 Watershed Boundaries 6
2.2 Geography 7
2.2.1 Dry Comal Creek 7
2.2.2 Comal River 8
2.3 Physical and Natural Features 10
2.3.1 Ecoregions 10
2.3.2 Soils 11
2.3.3 Fish and Invertebrate Communities 12
2.4 Climate 12
2.5 History 12
2.6 Watershed Development 13
2.7 Permitted Discharges and Land Application Sites 14
2.8 Water Quality 16
2.8.1 Clean Rivers Program 19
2.8.2 City-GBRA Water Quality Monitoring Program 20
2.8.3 Edwards Aquifer Habitat Conservation Program 30
2.8.4 Bacteria Source Tracking 32
2.9 Supplemental Monitoring 32
2.10 Water Quality Activities in the Watershed 32
2.10.1 City of New Braunfels Municipal Separate Storm Sewer System Program 33
2.10.2 Edwards Aquifer Habitat Conservation Plan Projects 33
2.10.3 Other Water Quality Projects 34

3. COMAL WATERSHED STAKEHOLDER PROCESS 35

3.1 Formation of the WPP Stakeholder Group 35
3.2 WPP Stakeholder Process 36

4. WATERSHED CHARACTERIZATION 39

4.1 Methodology for Estimating Pollutant Loads 39
4.1.1 Flow Duration Curves 39
4.1.2 Load Duration Curves 41
4.2 Results of Pollutant Load Analysis for the Dry Comal Creek and Comal River 42
4.2.1 Flow Duration Curves 46
4.2.2 Load Duration Curves 48
4.2.3 Estimated Required Load Reductions 51
4.3 Sources of Bacteria Pollution in the Dry Comal Creek and Comal River 52
4.4 Methodology for SELECT Tool 55
4.4.1 Land Covers 55
4.4.2 Subwatersheds 56
4.4.3 Bacteria Pollution Sources in the Watershed 57
4.5 SELECT Results for the Dry Comal Creek and Comal River Watershed 58
4.5.1 Livestock 58
4.5.2 Feral Hogs 60
4.5.3 Deer 61
4.5.4 Urban Avian Wildlife 63
4.5.5 On-Site Sewage Facilities 64
4.5.6 Pets 66
4.5.7 Sanitary Sewer Collection Systems and Wastewater Discharges 67
4.5.8 Urban and Stormwater Runoff 67
4.6 Data Gaps 67

5. BEST MANAGEMENT PRACTICES 68

5.1 BMP Terminology 68
5.2 BMP Implementation Roles 69
5.3 BMP Development Process 71
5.3.1 Methodology for Estimating Potential *E. coli* Load Reductions 71
5.3.2 Development of BMP and Outreach and Education Activity Cost Estimates 74
5.4 Overabundant Urban and Non-Native Wildlife BMPs 75
5.4.1 Overabundant Urban Deer BMPs 75
5.4.2 Non-Native Avian Wildlife BMPs 79
5.4.3 Feral Hog BMPs 82
5.5 Livestock BMPs 85
5.6 Stormwater and Infrastructure BMPs 88
5.6.1 OSSF BMPs 88
5.6.2 Urban Runoff and Stormwater BMPs 90
5.6.3 Pet Waste BMPs 93
5.6.4 Wastewater BMPs 96
5.7 Estimated WPP Potential Effectiveness at Reducing *E. coli* Loading 98

6. OUTREACH AND EDUCATION PLAN 102

6.1 Completed and Ongoing Outreach and Education Activities 102
6.2 Core Message 113
6.3 Outreach and Education Roles 114

6.4 Planned Outreach and Education Activities 116

7. IMPLEMENTATION SCHEDULE, ESTIMATED LOAD REDUCTIONS AND ESTIMATED COSTS 124

7.1 Implementation Schedule 124
7.2 Estimated Costs for WPP Implementation 128

8. MEASURES OF SUCCESS 133

8.1 Measurable Implementation Milestones 134
8.2 Monitoring and Water Quality Criteria 134
8.2.1 Water Quality Monitoring Program 135
8.2.2 *E. coli* Targets 135
8.3 Population Dynamics 136
8.4 Adaptive Implementation 137

9. TECHNICAL AND FINANCIAL RESOURCES 139

9.1 Technical Assistance 139
9.2 Sources of Funding 142

List of Tables

Table 1: Median Annual Load Reduction Targets ES-5
Table 2: WPP Implementation Schedule ES-8
Table 3: Water Quality Monitoring Sources and Parameters 16
Table 4: *E. coli* Concentrations in Stormwater Samples Collected September 26, 2016 24
Table 5: EAHCP 2016 Water Quality Data Provided to Watershed Partnership 31
Table 6: Summary of WPP Stakeholder Group Meetings in Phase 1 of the Project 36
Table 7: Summary of WPP Stakeholder and Work Group Meetings in Phase 2 of the Project 38
Table 8: *E. coli* and Streamflow Data Used in CRP Site LDCs 45
Table 9: Median Annual and Daily Load Reduction Targets 52
Table 10: Median Percentage of *E. coli* Measured in BST Analysis 53
Table 11: Potential Pollutant Sources in the Watershed 58
Table 12: BMP Terminology 68
Table 13: BMPs to Address Overabundant Urban Deer 78
Table 14: BMPs to Address Non-Native Avian Wildlife 81
Table 15: BMPs to Address Feral Hogs 84
Table 16: BMPs to Address Livestock 87
Table 17: BMPS to Address OSSFS 90
Table 18: BMPS to Address Urban Runoff and Stormwater 92
Table 19: BMPS to Address Pet Waste 95
Table 20: BMPS to Address Wastewater 97
Table 21: Estimated Potential *E. coli* Load Reduction by Source 98
Table 22: News Releases Completed To-Date 107
Table 23: Youth Activities Completed To-Date 110

Table 24: Community Activity Completed To-Date 112
Table 25: Promotional Materials....116
Table 26: Source Targeted Outreach and Education Activities....123
Table 27: WPP Implementation Schedule 126
Table 28: WPP Cost Summary Table....129
Table 29: Projected *E. coli* Benchmarks....136
Table 30: Summary of Planned Technical Assistance for WPP Implementation by Source of Pollution....139
Table 31: Summary of Potential Funding Sources 143

List of Figures

Figure 1: TCEQ CRP Monitoring Locations and USGS Flow Gage Locations ES-3
Figure 2: Load Duration Curves Calculated for the Three TCEQ CRP Monitoring Locations in the Watershed....ES-4
Figure 3: Average of BST Results from 2013 and 2016 Sampling for the Dry Comal Creek and Comal River ES-6
Figure 4: Summary of WPP Activities....ES-7
Figure 5: Potential E. coli Reduction Estimated Based Upon Selected BMPs ES-9
Figure 6: Estimated Cost of BMP Implementation Per Year ES-10
Figure 7: Dry Comal Creek and Comal River Watershed (Comprising Three HUC 12 Watersheds).... 7
Figure 8: Dry Comal Creek at Seguin St. (Looking Upstream) 8
Figure 9: Comal Springs at Landa Park (Spring Run #1).... 9
Figure 10: Comal River at Hinman Island.... 9
Figure 11: Ecoregions of Texas [Image Courtesy of TPWD] 11
Figure 12: Fountain Darter (Left) and Comal Springs Riffle Beetle (Right) [Eckhardt, 2017].....12
Figure 13: City of New Braunfels Population Change from 2010 to 2016 14
Figure 14: Permitted Wastewater Discharges in the Watershed....15
Figure 15: Edwards Aquifer Habitat Conservation Plan (EAHCP) and EAA Water Quality Sampling Locations on the Comal River....18
Figure 16: Dry Comal Creek E. coli Monitoring Locations and E. coli Geomeans from January 2011 through May 2017....22
Figure 17: Comal River E. coli Monitoring Locations and E. coli Geomeans from January 2011 through May 2017....23
Figure 18: 12- Month and 24-Month Geomeans of Monthly E. coli Concentrations for Dry Comal Creek....24
Figure 19: Photos of the Dry Comal Creek Between the Walnut Ave. and Seguin St. Sampling Locations....25
Figure 20: Dry Comal Creek E. coli Monitoring Stations and Stormwater Outfalls 26
Figure 21: 12-Month and 24-Month Geomeans of Monthly E. coli Concentrations for the Comal River 27
Figure 22: Comal River E. coli Monitoring Stations and Stormwater Outfalls....28

Figure 23: Monthly Geomean E. coli Concentrations Measured in the Dry Comal Creek and Comal River (January 2011 – May 2017) Excluding Data from Stormwater Samples 29
Figure 24: E. coli Concentrations Versus Flow in the Comal River at Hinman Island 29
Figure 25: *E. coli* Concentrations Versus Flow in the Dry Comal Creek at Seguin St. 30
Figure 26: Stakeholder Work Groups 37
Figure 27: Example Flow Duration Curve 40
Figure 28: Example Load Duration Curve 42
Figure 29: Map of CRP and *E. coli* Sampling Locations and USGS Flow Gages 43
Figure 30: Flow Duration Curves Developed For Three CRP Sites 47
Figure 31: LDC for CRP Site 12570: Dry Comal Creek at Seguin St. 48
Figure 32: LDC for CRP Site 15082: Comal River Near Landa Lake, New Braunfels, Texas 49
Figure 33: LDC for CRP Site 12653 - Comal River at Hinman Island 50
Figure 34: Comparison of LDCS for the Three CRP Sampling Locations in the Watershed 51
Figure 35: Comparison of BST Results for Samples Collected in September and October of 2013 and 2016 Using a 3-way Split 54
Figure 36: Comparison of BST Results for Samples Collected in September and October 2013 and 2016 Using a 7-way Split 54
Figure 37: Land Cover Map for the Watershed 56
Figure 38: Map of Subwatersheds 57
Figure 39: Average Daily Potential *E. coli* Load Estimated from Cattle 59
Figure 40: Average Daily Potential *E. coli* Load Estimated from other Livestock (Goats and Sheep) 60
Figure 41: Average Daily Potential *E. coli* Load Estimated from Feral Hogs 61
Figure 42: Land Cover Interpretation of Deer Densities Applied to Select Tool for the Watershed 62
Figure 43: Average Daily Potential *E. coli* Load Estimated from Deer 63
Figure 44: Average Daily Potential *E. coli* Load Estimated from Avian Wildlife 64
Figure 45: Average Daily Potential *E. coli* Load Estimated from OSSFs 65
Figure 46: Average Daily Potential *E. coli* Load Estimated from Dogs 66
Figure 47: BMP Development Process 71
Figure 48: Potential *E. coli* Reduction Estimated Based Upon Selected BMPs 99
Figure 49: Potential *E. coli* Reduction Estimated for Selected BMPs 100
Figure 50: Potential *E. coli* Reduction Estimated for Selected BMPS for the Comal River (Left) and Dry Comal Creek (Right) 101
Figure 51: Stakeholder Work Groups 102
Figure 52: Outreach and Education Work Group Process 103
Figure 53: WPP Website 104
Figure 54: WPP Infographic Page 1 105
Figure 55: WPP Infographic Page 2 106
Figure 56: Fischer Park 108
Figure 57: Headwaters at the Comal 109
Figure 58: City of New Braunfels Watershed Management Logo 114

Figure 59: Implementation of Outreach and Education Activities will be a Collaborative Process 114
Figure 60: Do Not Feed Sign (Klingener, 2016).....121
Figure 61: Summary of BMPs and Outreach and Education Activities Selected for the Dry Comal Creek and Comal River WPP 125
Figure 62: Implementation and Maintenance Phase Definitions 126
Figure 63: Estimated Cost of BMP Implementation Per Year 130
Figure 64: Estimated Costs per *E. coli* Source in Years 2-4 (left) and Years 1-10 (right).....132
Figure 65: Adaptive Implementation Strategy.....133
Figure 66: WPP Implementation Milestone Status and Response.....134
Figure 67: Funding Source Prioritization 142

Appendices

Appendix A. Reference Table for EPA's Nine Elements for WPPs
Appendix B. Analysis of General Water Quality in the Comal River from the Edwards Aquifer Habitat Conservation Plan Monitoring Program
Appendix C. Maps of Locations of *E. coli* Sources Observed by Stakeholders
Appendix D. Low Priority BMPs Not Included in WPP
Appendix E. Low Priority O&E Activities Not Included in WPP
Appendix F. Estimated Probable Cost Calculations for BMP Implementation
Appendix G. Estimated *E. coli* Load Reduction Calculations
Appendix H. Citations

Acronyms

AACE	Association for the Advancement of Cost Engineering
BMPs	Best Management Practices
BST	Bacteria source tracking
cfs	Cubic feet per second
CFU/100 mL	Colony forming units per 100 milliliters
City	City of New Braunfels
CRP	Clean Rivers Program
EAA	Edwards Aquifer Authority
ETJ	Extraterritorial jurisdiction
EAHCP	Edwards Aquifer Habitat Conservation Plan
FDC	Flow duration curve
GBRA	Guadalupe-Blanco River Authority
Geomeans	Geometric means

IH-35	Interstate Highway 35
LDC	Load duration curve
MGD	Million gallons per day
mL	Milliliters
MOS	Margin of Safety
MPN	Most Probable Number
MRLC	Multi-Resolution Land Characteristics
MS4	Municipal Separate Storm Sewer System
NASS	National Agricultural Statistics Service
NBU	New Braunfels Utilities
NED	National Elevation Dataset
NLCD	National Land Cover Database
NPS	Nonpoint source
NRCS	Natural Resources Conservation Service
NWIS	National Water Information System
OSSFs	On-Site Sewage Facilities
QAPP	Quality Assurance Project Plan
RMU	Resource Management Unit
SELECT	Spatially Explicit Load Enrichment Calculation Tool
SSO	Sanitary sewer overflow
SWQMIS	Surface Water Quality Monitoring Information System
SWCD	Soil and Water Conservation District
TAES	Texas Agriculture Extension Service
TAG	Technical Advisory Group
TAMU	Texas A&M University
TCEQ	Texas Commission on Environmental Quality
TDA	Texas Department of Agriculture
TMDL	Total Maximum Daily Load
TPDES	Texas Pollutant Discharge Elimination System
TPWD	Texas Parks and Wildlife Department
TSSWCB	Texas State Soil and Water Conservation Board
TWDMS	Texas Wildlife Damage Management Service
TWRI	Texas Water Resources Institute
TWS	Texas Wildlife Services
USDA	United States Department of Agriculture
USEPA	United States Environmental Protection Agency
USFWS	Unites States Fish & Wildlife Service
USGS	United States Geological Survey

WAC	Watershed Advisory Committee
WPP	Watershed Protection Plan
WQMP	Water Quality Management Plan
WWQWG	Watershed Water Quality Work Group

Executive Summary

The Dry Comal Creek, surface water quality segment 1811A, was listed on the 2010 Texas Commission on Environmental Quality (TCEQ) 303(d) list for impairment to its designated contact recreational use due to elevated *Escherichia coli (E. coli)* concentrations. *E. coli* are bacteria commonly found in the lower intestines of warm-blooded animals. As a result of the listing, the City of New Braunfels, Texas (the "City") and the Guadalupe-Blanco River Authority (GBRA) began monthly *E. coli* monitoring at 12 locations along the Dry Comal Creek, as well as the Comal River, surface water quality segment 1811, (including the three TCEQ Clean Rivers Program (CRP) sampling locations). These *E. coli* data indicated that concentrations were generally increasing over time.

In 2014, the City partnered with GBRA and applied for, and was awarded, Clean Water Act Section 319(h) grant funds to develop a Watershed Protection Plan (WPP) for the Dry Comal Creek and Comal River watersheds (the "Watershed"). WPPs are stakeholder-driven watershed-based plans designed to prevent and manage nonpoint source (NPS) pollution. Public participation and involvement are important in the development and implementation of a WPP, because the success of the plan depends primarily on good stewardship by landowners, businesses, municipalities, elected officials, and residents who live and work within the watershed area. The WPP planning process was funded by two separate 319(h) grants and implemented in two phases:

- **Phase 1 – Watershed Characterization:**
  - Evaluated *E. coli* loading in the Dry Comal Creek and Comal River;
  - Estimated *E. coli* load reductions required to meet water quality goals; and
  - Estimated *E. coli* loading from pollutant sources in the watershed (e.g., livestock, feral hogs, humans, deer, and avian wildlife)

- **Phase 2 – Watershed Protection Plan:**
  - Expanded the assessment of *E. coli* loading from pollutant sources in the Watershed to include two additional subwatersheds that comprise the upper reaches of the Dry Comal Creek;
  - Selected and prioritized best management practices (BMPs) to reduce bacteria levels in the Dry Comal Creek and the Comal River;
  - Developed an Outreach and Education Plan to guide activities necessary to successfully implement the selected BMPs and effectively communicate with both residents and visitors in the Watershed;

- Established measures of success that will serve as criteria for evaluating the effects of the BMP implementation process;
- Estimated the costs for implementation and expected load reductions based upon established goals for each BMP; and
- Projected an implementation schedule and required technical and financial assistance required to meet the WPP goals.

Watershed Partnership and Stakeholder Engagement

Upon initiation of WPP development, a Stakeholder Group was established to provide information on activities and potential sources of pollution in the Watershed, give feedback on the results of technical analyses in terms of the relevance to actual Watershed conditions, recommend BMPs to reduce *E. coli* loads, and guide the public outreach and education process that is important to the success of the WPP. The WPP Stakeholder Group is comprised of approximately 25 interest groups, with one to three representatives per group. The interests represented by the WPP Stakeholder Group included local businesses (tourism, industries, etc.), New Braunfels Utilities (NBU), developers, neighborhood associations, agricultural interests, wildlife/conservation groups, and individual citizens. Affected City departments, such as Public Works, Public Communication, and Parks and Recreation, were also included. Additionally, a Technical Advisory Group (TAG) was established as a subset of the stakeholders, and primarily included agencies which had specific technical expertise, such as the Texas Parks and Wildlife Department (TPWD). The Stakeholder Group met regularly throughout the WPP development process. The primary goals of this group were as follows:

1. Identify sources of bacteria pollution in the Watershed;
2. Select BMPs to implement in the Watershed to reduce *E. coli* loading to the waterbodies;
3. Develop outreach and education activities to support BMP implementation; and
4. Act as WPP ambassadors to communicate the WPP efforts to the community and garner support.

Collectively, the Stakeholder Group, TAG, the City, GBRA, and EAA form the Dry Comal Creek and Comal River Watershed Partnership (“Watershed Partnership”). The Watershed Partnership collaborated to complete both the Watershed characterization and develop this WPP. The Watershed Partnership will continue to collaborate throughout the implementation of this WPP.

Watershed Characterization

The Watershed was characterized using the following information:

- Historical water quality and flow data;
- Load duration curves (LDCs) calculated from historical data to quantify bacteria loads in the waterbodies;
- Bacteria Source Tracking (BST) analyses indicating the sources of the *E. coli* (i.e., warm-blooded animals);
- Results of the Spatially Explicit Load Enrichment Tool (SELECT), which was developed by researchers at Texas A&M University (TAMU) in 2006, to estimate locations of sources within a watershed; and
- Stakeholder knowledge of sources of pollution in the Watershed.

E. coli loads were calculated for the three TCEQ CRP monitoring locations in the Watershed (two on the Comal River and one on the Dry Comal Creek) using nearby United States Geological Survey (USGS) gaged flow data. The locations of the TCEQ CRP sampling locations and USGS gages are illustrated in Figure 1.

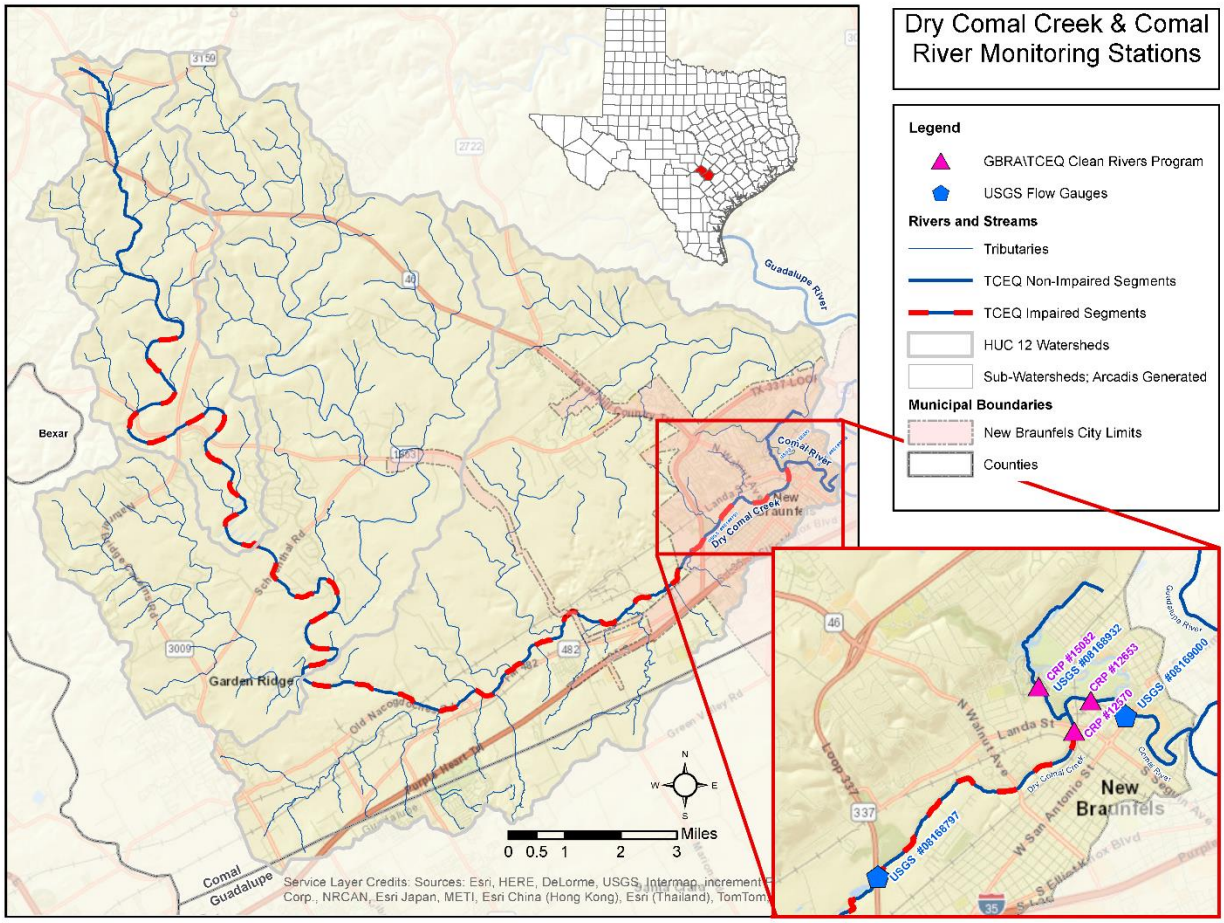

Figure 1: TCEQ CRP Monitoring Locations and USGS Flow Gage Locations

The LDCs developed for the three CRP locations using historical *E. coli* data compared to the *E. coli* loading goals for the water segments are shown in Figure 2[1]. The *E. coli* loading goals were calculated using the TCEQ water quality standard for primary contact recreation of 126 colony forming units per 100 milliliters of water (CFU/100 mL). A 10 percent margin of safety (MOS) was applied, resulting in an overall goal of 113 CFU/100 mL.

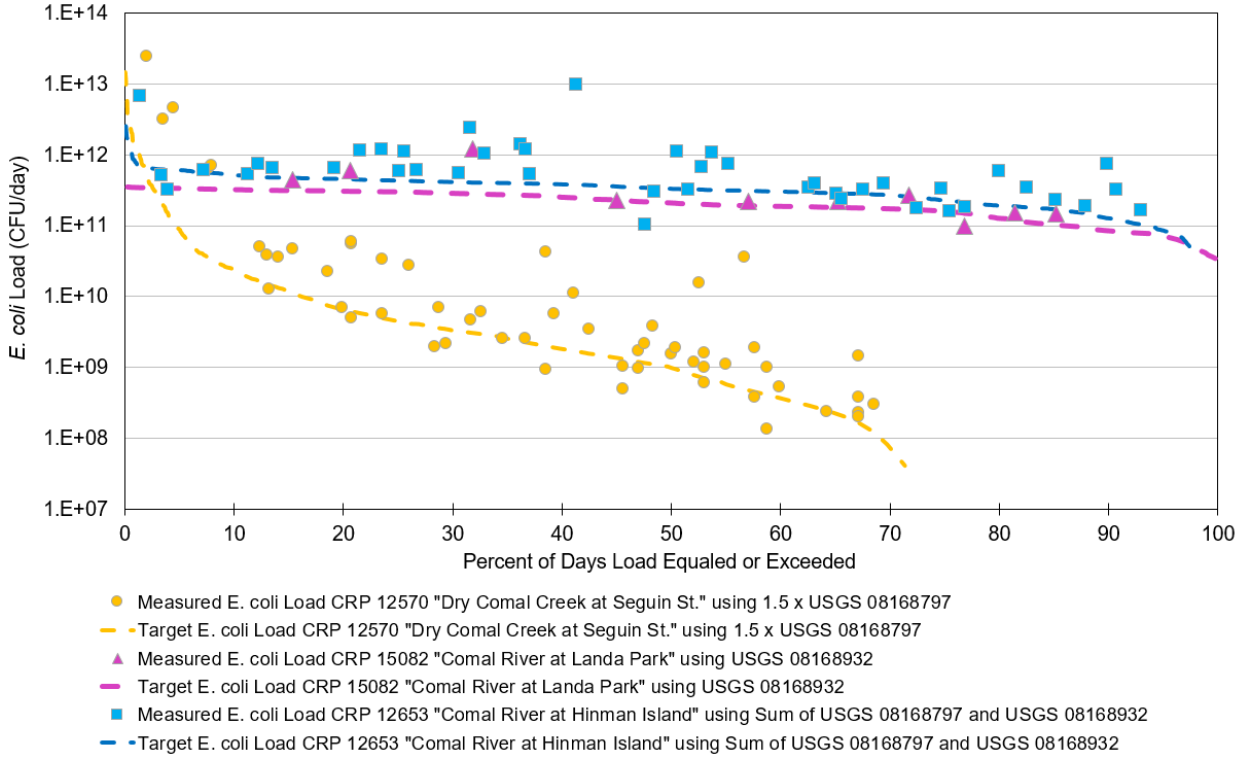

Figure 2: Load Duration Curves Calculated for the Three TCEQ CRP Monitoring Locations in the Watershed

The *E. coli* load reductions required in the Dry Comal Creek and Comal River to achieve the water quality goals for the medium flow classes (shown in Section 4.2.2) are 34 percent and 50 percent, respectively (Table 1). Target reductions for *E. coli* loads are based on the median

[1] All bacteria data collected in this study are reported in terms of colony forming units which are more widely understood and are used in the recreational standard. However, all data were collected using the Colilert method. MPN, or most probable number, is the unit used to report the concentration of *E. coli* bacteria determined using the Colilert method. The Colilert method analyzes water samples by a series of dilutions and observing positive or negative reactions. CFU are the units used to report the bacterial concentration determined by filtration and culturing of viable bacterial cells. The MPN method is a statistical estimate of the bacterial concentration and is an accepted reporting method especially in the analyses of samples whose expected concentration range is unknown and most likely broad. Although MPN methods are estimates, inherent problems with culturing methods that are based on the viability and growth of bacterial cells, make MPN the most accepted method for the analysis of stream samples for comparison to the recreational stream standard.

reductions needed to meet the target for the medium flow class, which is the range of flows for which the effective implementation of management measures is considered feasible. Goals for each BMP selected in Phase 2 (as part of the WPP-development process) were established, in part, by the estimated potential *E. coli* load reduction in relation to these target load reductions.

Table 1: Median Annual Load Reduction Targets

Site	Median *E. coli* load Reduction Needed to Meet Target (For Medium Flows)	
	%	Load (CFU/year)
Dry Comal Creek @ CRP 12570 (Seguin St.; Formerly Knights of Columbus	34	3.92×10^{11}
Comal River @ CRP 12653 (Hinman Island; Formerly Clemons Dam)	50	1.28×10^{14}

Locations of potential *E. coli* pollution sources in the Watershed, and their respective *E. coli* loading rates were estimated using SELECT (see Sections 4.4 and 4.5). SELECT uses land cover information to distribute potential *E. coli* loading sources and rates throughout a watershed. The potential sources were derived from stakeholder input, agricultural statistics, and municipal datasets, which were then multiplied by a theoretical *E. coli* loading rate to estimate the total amount of daily *E. coli* production for each potential source. However, the number of bacteria actually reaching the streams depends on several environmental factors including proximity to the creek, bacteria die-off, geomorphology, connectivity of stream network, temperature, and other factors. Thus, the results from SELECT were most useful for understanding the location of sources in the Watershed when selecting and prioritizing BMPs.

The pollutant sources evaluated in SELECT included cattle, other livestock (e.g., sheep and goats), on-site sewage facilities (OSSFs), deer, feral hogs, and dogs throughout the Watershed, and non-native avian wildlife in the City's Landa Park. Other potential sources of pollution in the Watershed, which were not analyzed using SELECT, include wastewater overflows, stormwater, leaking sanitary sewer lines, and other mammals. Additionally, the Stakeholder Group provided local knowledge of potential locations of *E. coli* pollution sources in the Watershed, which were considered during evaluation of BMPs (Appendix C).

The Watershed Partnership also conducted BST analyses (the average of three sampling events each year are illustrated in Figure 3) on water samples collected from the Dry Comal Creek and Comal River in 2013 and 2016. The average BST results for the Dry Comal Creek indicated approximately 59 percent of the *E. coli* bacteria were from wildlife, and 26 percent of the bacteria were from livestock sources. Average BST results for the Comal River showed that approximately 64 percent of the *E. coli* bacteria were from wildlife and 23 percent were from livestock. Comparing data from 2013 and 2016 (data shown in Section 4.3), the percentage of *E. coli* in both the Dry Comal Creek and Comal River from wildlife increased.

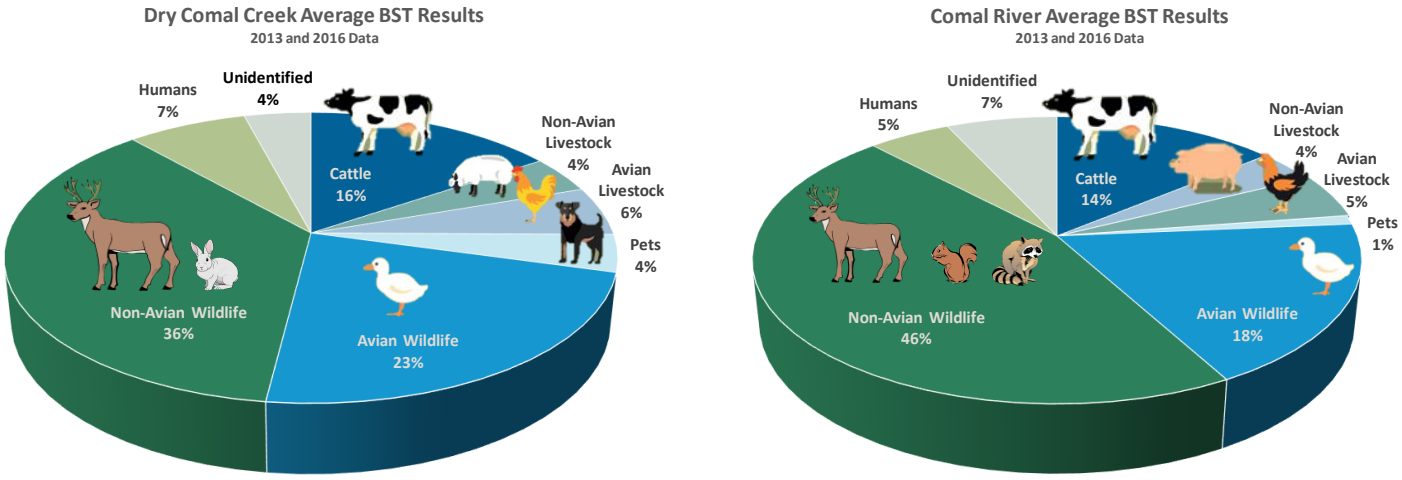

Figure 3: Average of BST Results from 2013 and 2016 Sampling for the Dry Comal Creek and Comal River

Implementation Plan for Improving Water Quality

Watershed characterization data indicate wildlife and livestock are the two largest sources of *E. coli* pollution in the Dry Comal Creek and Comal River. Thus, the overall approach for implementation of BMPs to reduce *E. coli* pollution is to focus on outreach and education activities targeting these sources initially, followed by implementation of more-costly active management and/or control measures. Figure 4 provides an overview of the outreach and education activities and BMPs selected to implement in this WPP.

The Watershed Partnership developed a projected implementation schedule (Table 2) based upon the prioritization, cost, and effectiveness of the selected BMPs, the overall implementation approach, and identified implementation milestones. Based on stakeholder input, the implementation approach and schedule are arranged to target the most important pollutant sources first, whenever possible. A mid-course checkpoint is set for the end of the third year to review progress towards BMP and water quality goals and to adjust the implementation schedule and activities, as necessary, to meet the WPP goals.

All BMPs will have started by Year 5, and the majority will continue through the 10-year implementation period. Over the 10-year implementation period, most activities will transition from an intense initial implementation phase to a longer-term maintenance phase. The Watershed Partnership also defined a list of potential technical and financial resources necessary to support implementation of the selected BMPs, and outreach and education activities.

Figure 4: Summary of WPP Activities

Table 2: WPP Implementation Schedule

Category	BMP or Outreach and Education Activity	Years 1	2	3	4	5	6	7	8	9	10
KEY:	◆ Purchase of new equipment, development of new materials, etc.	Implementation					Maintenance Phase				
Outreach and Education	Social Media Campaign		◆		◆		◆				
	News Campaign		◆		◆		◆				
	Youth Activities	◆					◆				
	Local Event Outreach										
	Wildlife Management Workshops										
	Do-Not-Feed Wildlife Ordinance and Campaign within City Limits		◆				◆				
Overabundant Urban Deer	Do-Not-Feed Wildlife Ordinance and Campaign within City Limits		◆				◆				
	Deer Population Assessment										
	Voluntary Do-Not-Feed Wildlife Campaign in Rural Neighborhoods		◆				◆				
	Wildlife Management Workshops										
	Active Management of Deer with Council Approval		◆								
Non-Native Avian Wildlife	Do-Not-Feed Wildlife Ordinance and Campaign within City Limits		◆				◆				
	Non-Native Duck and Goose Population Assessment										
	Discourage Non-Native Ducks and Geese from Congregating in the Park		◆								
	Rapid Removal of Dead Animals										
	Wildlife Management Workshops										
	Trap Non-Native Ducks and Geese										
	Oil Coat Non-Native Duck Eggs										
Feral Hog	Feral Hog Workshops										
	Bounty Program		◆								
	Trapping Intensity Assessment										
	Feral Hog Website				◆						
Livestock	Water Quality Management Plans (WQMPs)										
	Livestock Outreach and Education										
OSSF	OSSF Education and Assistance Programs										
	Mandatory OSSF Inspection and Maintenance Program										
Stormwater	Non-Structural Stormwater BMPs Outside of the City's MS4 Jurisdiction		◆		◆						
	Stormwater Outreach and Education			◆			◆				
	Engineering Analysis of Opportunities for Structural Stormwater BMPs				◆						
Pet Waste	Pet Owner Outreach and Education										
	Pet Waste Stations		◆								
	Pet Code Enforcement				◆		◆				
	Tailored Pet Solutions		◆				◆				
Wastewater	Wastewater Discharge Water Quality Assessment										

Based upon the BMP goals and implementation milestones, and assuming a 10-year implementation period, the estimated potential *E. coli* load reduction was calculated for each BMP. The estimated total potential reduction of *E. coli* for the WPP BMPs exceeds the targeted potential reduction for the Comal River, the Dry Comal Creek and the entire Watershed, as shown in Figure 5. Thus, implementation of the selected BMPs is anticipated to reduce the *E. coli* loading in the Watershed to the WPP target.

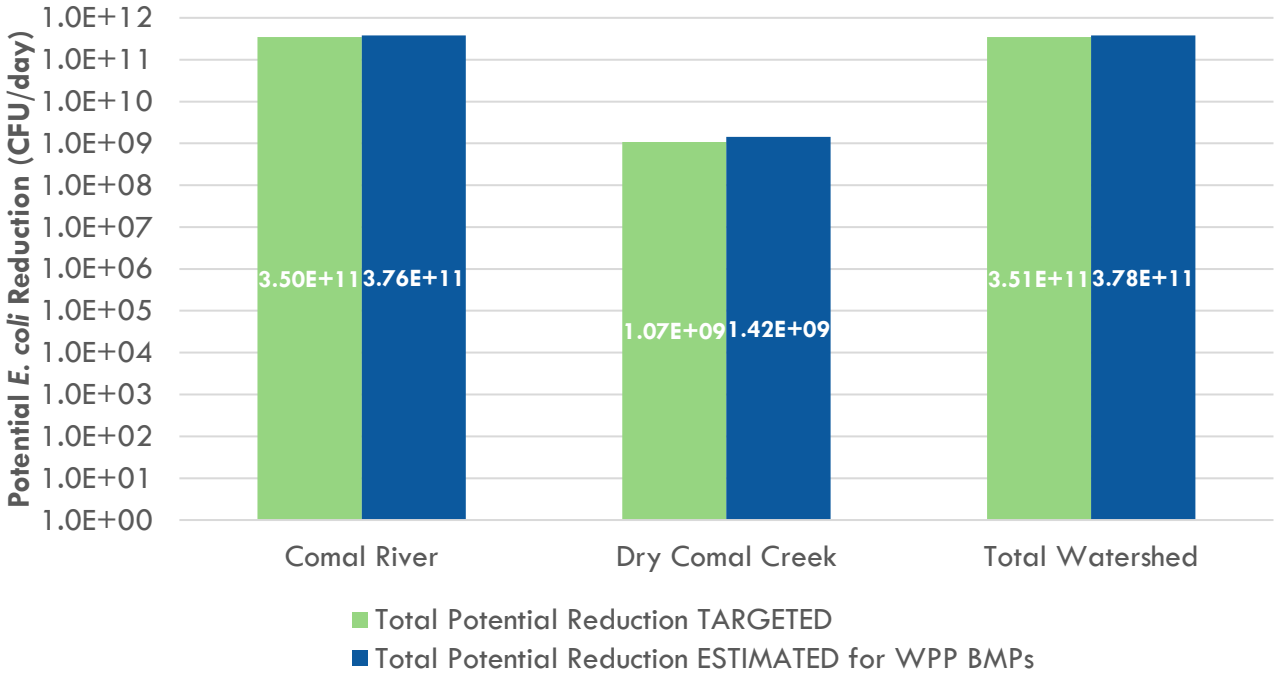

Figure 5: Potential *E. coli* Reduction Estimated Based Upon Selected BMPs

Opinions of probable cost ("cost estimates") were developed for each BMP, and outreach and education activity. The costs do not consider the source of funding (i.e., in-kind versus a grant), but rather account for the total cost of implementation to the agency primarily responsible for implementing each BMP. Figure 6 is a visual representation of the estimated annual costs for BMP implementation. The estimated total cost for implementation of all BMPs and outreach and education activities for the WPP over the 10-year implementation period is approximately $6.8M with a 30 percent contingency or approximately $4.8M without a contingency factor. The total annual cost for any given year is estimated to range from $108,500 to $1,090,000 (assuming implementation follows the projected schedule). Year 1 has the lowest implementation cost per year, due to the initial focus on lower-cost outreach and education activities, while Year 6 has the highest costs per year.

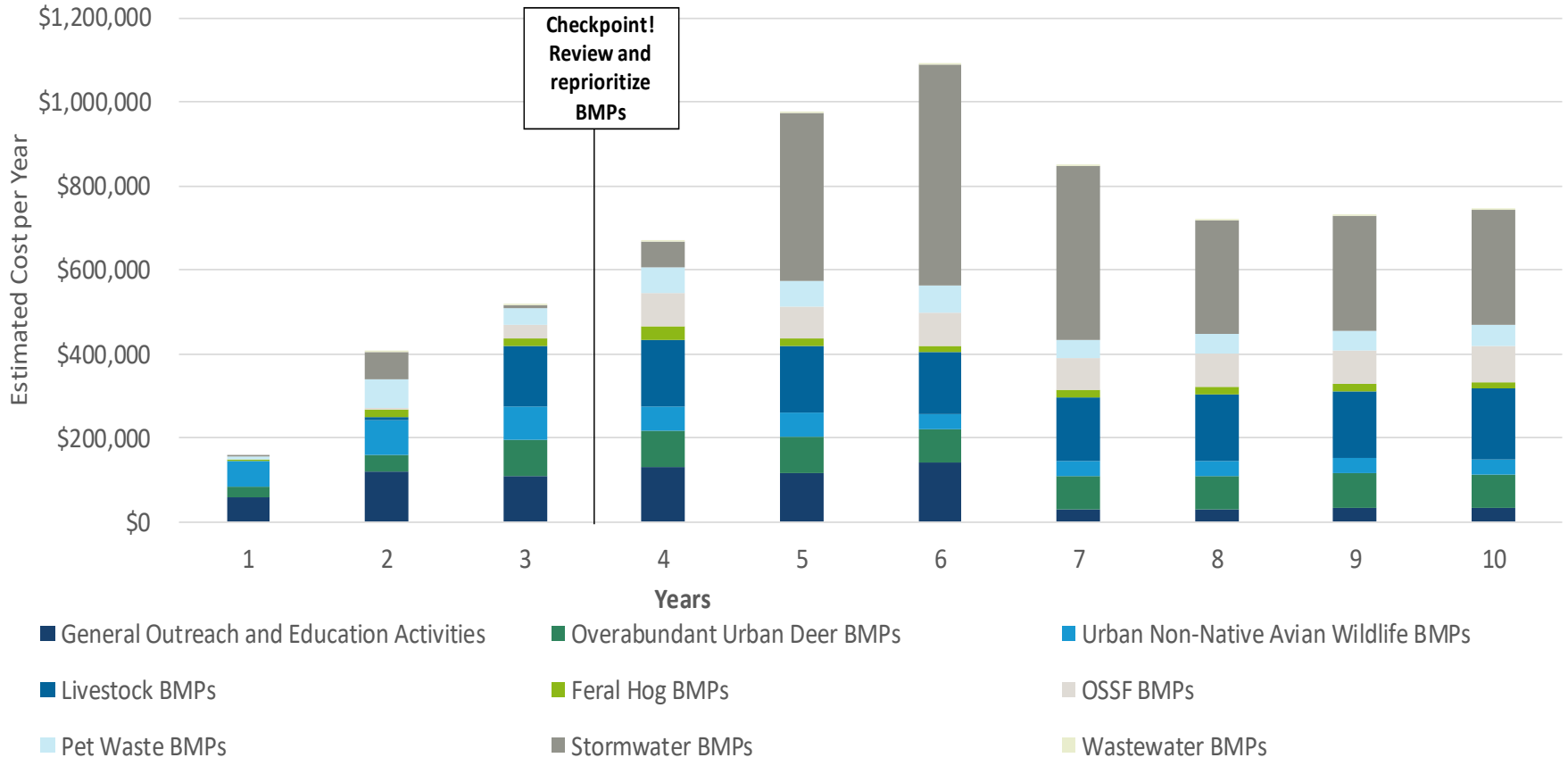

Figure 6: Estimated Cost of BMP Implementation Per Year

BMPs and activities addressing overabundant urban and non-native wildlife constitute approximately 50 percent of the total estimated costs during the first four years of implementation, illustrating the Watershed Partnership's focus on reducing *E. coli* from overabundant urban and non-native wildlife. Many of the efforts focused on managing the overabundant urban deer population and non-native wildlife are relatively inexpensive (e.g., outreach and education campaigns), but are anticipated to be very effective. More expensive stormwater BMPs will be delayed until Year 5, to maintain focus on the wildlife BMPs during the initial years after BMP implementation. Stormwater BMPs are a key component of how the watershed operates. Although the BST results indicate that a majority of the *E. coli* originated from deer and non-native avian populations, most of this *E. coli* is carried into the Dry Comal Creek and the Comal River by stormwater during rainfall events. It is anticipated that implementing BMPs for stormwater will significantly reduce the number of bacteria entering the water system—bacteria from urban deer and non-native avian wildlife, as well as pets, humans, and livestock. Furthermore, although stormwater BMPs are costliest over the 10-year implementation period due to required engineering and construction, implementation of stormwater BMPs will not limit the Watershed Partnership's investment in wildlife BMPs.

The actual load of bacteria reaching the stream depends on several environmental factors including proximity to the creek, bacteria die-off, geomorphology, riparian conditions, connectivity of stream network, temperature, and other factors. Therefore, it is difficult to predict the *E. coli* reduction that will be observed in the waterbodies based on established implementation. Thus, the Watershed Partnership will follow an adaptive implementation approach to continually assess progress and adapt the WPP as needed. Measures of success will include milestones established for each BMP or activity, review of water quality data (especially changes in *E. coli* concentrations), and review of Watershed data (e.g., changes to land use, reduction in car accidents due to less deer).

1. Watershed Management

A watershed is an area of land that includes a particular body of water (e.g., river, lake, creek or stream) and all of the rivers, creeks, and streams that drain into it. Watersheds include not only waterbodies, but also all of the adjacent lands that contribute, or "shed", water to a waterbody during and following rain events. The relationship between the quality and quantity of water affects the function and health of a watershed. Watersheds may be extremely large, covering thousands of acres, but may also be divided into smaller subwatersheds for the purposes of study and management.

1.1 Watersheds and Water Quality

To effectively address water quality issues in a waterbody, it is imperative to examine all of the natural processes and human activities occurring in the watershed that may either directly or indirectly influence the quality of water. Stormwater runoff that ultimately reaches a waterbody begins when rainfall contacts the ground surface. Depending on the characteristics of the watershed, the runoff from a storm event flows across agricultural, urban, residential, industrial, and/ or undeveloped areas. As stormwater runoff flows toward a waterbody, it has the potential to collect pollutants distributed on the ground surface and deposit them in the water. In addition, wastewater effluent from varying sources may contain pollutants that are released directly into a waterbody. To identify pollutant sources and water quality best management practices (BMPs), contaminants are classified based on their origin as either "point" source or "nonpoint" source pollution, as described below:

- **Point source pollution** – is discharged from a discrete location, such as a stormwater outfall pipe or a wastewater treatment plant discharge. Sources of this type of pollution can be traced back to a single point of origin. Point source pollution is typically discharged directly into a waterbody and often contributes flow and potential contaminants throughout varying flow and weather conditions. In Texas, entities discharging point sources are typically required to obtain a permit through the Texas Pollutant Discharge Elimination System (TPDES) or the Municipal Separate Storm Sewer System (MS4). These effluent discharge permits often include specific pollutant limits that are intended to minimize impacts to the water quality of the receiving waterbody.

- **Nonpoint source pollution (NPS)** – comes from pollutants that are dispersed throughout the land surface of a watershed, and therefore, do not have a single point of origin. Pollutants dispersed and distributed across the land are typically picked up by stormwater or urban runoff and carried to adjacent waterbodies.

As runoff flows over the land surface, it has the potential to pick up natural and/or human-related pollutants and deposit them in the nearest creek, river, or lake. Ultimately, the types and amounts of pollutants dispersed across the landscape of a watershed will have a direct impact on the water quality of the receiving waterbody. The quality of water of a given waterbody must be protected for the assigned designated use, such as irrigation, drinking, contact recreation (e.g., swimming), or fishing. The current Texas Surface Water Quality Standards include four contact recreation categories with different water quality standards: primary contact recreation 1 (PCR1); primary contact recreation 2 (PCR2); secondary contact recreation 1 (SCR1); secondary contact recreation 2 (SCR2); and noncontact recreation (NCR), listed in order from more stringent to less stringent.

1.2 Benefits of a Watershed Approach

Both federal and state water resource management agencies have embraced the watershed approach for managing surface water quality. This approach involves holistic examination of sources and causes of water quality impairments throughout an entire watershed area. Watershed Protection Plans (WPPs) may then be developed based on watershed boundaries, rather than political borders. A WPP is a stakeholder-driven strategy for preventing and managing nonpoint source pollution. Public participation and involvement are important in the development and implementation of a WPP, because the success of the WPP depends on sustained involvement from the stakeholders and good stewardship by landowners, businesses, municipalities, elected officials, and residents who live and work within the Watershed. The watershed approach encourages participation from a variety of stakeholders who have an interest in protecting water quality.

1.3 Dry Comal Creek and Comal River Watershed Protection Plan Purpose and Funding

The Dry Comal Creek, surface water quality segment 1811A, was listed on the 2010 Texas Commission on Environmental Quality (TCEQ) 303(d) list for impairment to its designated contact recreational use, due to elevated *Escherichia coli (E. coli)* concentrations. Additionally, bacteria levels in the Comal River have been rising, as evidenced by the increasing *E. coli* geometric mean[2] provided in the bi-annual Texas Integrated Reports of Surface Water Quality.

[2] A geometric mean or geomean is defined as the n^{th} root of the product of n numbers. geomeans generally dampen the effect of a single data point on the calculated mean compared to an arithmetic mean.

E. coli, discussed further in Section 1.4, are bacteria commonly found in the lower intestines of warm-blooded animals. As a result of the listing, the City of New Braunfels, Texas (the "City") and the Guadalupe-Blanco River Authority (GBRA) began monthly *E. coli* monitoring at 12 locations along the Dry Comal Creek, as well as the Comal River (including the three TCEQ Clean Rivers Program [CRP] sampling locations).

These *E. coli* data indicated that concentrations were generally increasing over time; therefore, in 2013, the City collected samples from the Dry Comal Creek and Comal River, and had them analyzed using bacteria source tracking (BST) to provide information on the sources of the bacteria in the water. The BST results indicated approximately 50 percent of the *E. coli* bacteria in the water were from wildlife, and 30 percent of the bacteria were from livestock sources (see Section 4.3 for BST results). BST analyses were repeated in 2016 and showed that the percent of the *E. coli* from wildlife in the Dry Comal Creek and Comal River increased up to 70 percent. Wildlife, livestock, pets and humans, are potential sources of bacterial pollution that is distributed across the land in a watershed and enters waterbodies via runoff.

This WPP defines BMPs and programs that can be voluntarily implemented by individuals, organizations and stakeholders within the Dry Comal Creek and Comal River Watershed ("Watershed") to restore and protect water quality. Stakeholder involvement is critical in the selection, design, and implementation of water quality management measures and/or BMPs. Collectively, the Stakeholder Group, Technical Advisory Group, the City, GBRA, and Edwards Aquifer Authority (EAA) form the Dry Comal Creek and Comal River Watershed Partnership ("Watershed Partnership"). The Watershed Partnership collaborated to complete both the Watershed characterization and develop this WPP. Additionally, the Watershed Partnership will continue to collaborate throughout the implementation of this WPP.

Grants are made available through a federal program authorized under Section 319(h) of the Clean Water Act (also called "319 funds") for development of WPPs. The City applied, and was approved for, two separate grants supporting development of this WPP as follows:

- **Phase 1 – Watershed Characterization:** The City partnered with GBRA to apply for TCEQ Fiscal Year 2014 (FY2014) §319(h) grant funding (contract number 582-15-53180) for watershed characterization (Phase 1 of the WPP Project). Phase 1:
    - Evaluated *E. coli* loading in the Dry Comal Creek and the Comal River;
    - Estimated *E. coli* load reductions required to meet water quality goals; and
    - Estimated *E. coli* loading from pollutant sources in the watershed (e.g., cattle, feral hogs, humans, deer, and avian wildlife)
- **Phase 2 – Watershed Protection Plan:** The City partnered with GBRA and the EAA to apply for TCEQ FY2015 §319(h) grant funding (contract number 582-16-60283) for development of this WPP (Phase 2 of the WPP Project). Phase 2:
    - Expanded the assessment of *E. coli* loading from pollutant sources in the watershed (e.g., cattle, feral hogs, humans, deer, and avian wildlife) to include

two additional subwatersheds that comprise the upper reaches of the Dry Comal Creek;

- Selected and prioritized BMPs to reduce bacterial levels in the Dry Comal Creek and Comal River;
- Developed an Outreach and Education Plan to guide activities necessary to successfully implement the selected BMPs and effectively communicate with both residents and visitors in the Watershed;
- Established measures of success that will serve as criteria for evaluating the effects of the BMP implementation process;
- Estimated the costs for implementation and expected load reductions based upon established goals for each BMP; and
- Projected an implementation schedule and required technical and financial assistance required to meet the WPP goals.

All WPPs funded with 319 funds are required to meet U.S. Environmental Protection Agency's (USEPA) nine elements for watershed-based plans. These nine elements form the foundation for the development of a successful WPP. By utilizing the nine key elements as guidance, WPPs can be developed by local entities and stakeholders with the intent of protecting and restoring water quality within a given waterbody through a voluntary, non-regulatory approach. Appendix A summarizes the nine elements to be included in a WPP and the corresponding sections of this WPP that address each required element. The stakeholder process is further described in Section 3.

1.4 *E. coli* Overview

E. coli is a subgroup of fecal coliform bacteria that is commonly found in the intestines of warm-blooded mammals. *E. coli* encompasses a wide group of bacteria, including many different strains, not all of which are necessarily pathogenic; however, while not all strains of *E. coli* are harmful, their presence in water indicates the potential presence of fecal contamination and other pathogens. Because it is easier and more cost-effective to test for *E. coli*, rather than all disease-causing organisms, biologists use it as a marker to judge if water is microbiologically safe (Swistock, 2017).

E. coli primarily enters the Comal River and Dry Comal Creek through NPS pollution. In addition to direct deposition, animal waste may also be carried by stormwater and urban runoff to the river. Sources of *E. coli* in the Comal River and Dry Comal Creek can be categorized as "livestock" (e.g., chickens, goats, cattle), "urban" (e.g. pets, onsite septic facilities), or "wildlife" (e.g., urban deer, avian, hogs). Each source's *E. coli* loading rate was calculated through measuring the source's fecal loading rate and converting the amount of fecal bacteria to *E. coli* using a rate of 0.63 *E. coli* per fecal coliform. Of these three categories, livestock has the highest *E. coli* loading rate per animal unit. Cattle contribute 1.03×10^{10} CFU per day of *E. coli*. Deer, the largest contributor of *E. coli* to the Watershed, have a lower loading rate of 9.16×10^{07}

CFU per day. For more information on characterization of *E. coli* sources in the Dry Comal Creek and Comal River, refer to Section 4.

Although the intestines of warm-blooded mammals are a more ideal host, *E. coli* can survive and grow in water as well. In an open environment like freshwater, *E. coli* growth and survival is most limited by availability of nutrients, such as nitrogen and phosphorus, and by die-off from sunlight radiation. Recent studies have also demonstrated that *E. coli* is, in fact, able to reproduce in sterile freshwater, given there is a low carbon concentration in the water (Van Elsas *et al.*, 2011).

In general, the presence of *E. coli* increases after heavy rain events. After heavy rain events, higher levels of turbidity and lower levels of conductivity and temperature also occur. The details of how these factors affect one another are unclear, but there is evidence indicating *E. coli* grows more quickly at warm stable temperatures (Swistock, 2017) and that *E. coli* may attach to particulate matter (i.e., turbidity) in water. For more information on how water quality relates to *E. coli* concentrations in the Comal River and the Dry Comal Creek, refer to Appendix B.

The TCEQ classifies the Comal River as “primary contact recreation 1” (PCR1), meaning that the recreation activities occurring at this site lead to a high risk of water ingestion. While the TCEQ has not officially classified the Dry Comal Creek as PCR1, it recognizes that it is used for contact recreation. According to §307.3.49 of the Texas Water Quality Standards, examples of contact recreation include, but are not limited to, wading by children, swimming, surfing, kayaking, tubing, and rafting. For freshwater classified as PCR1, the geomean criterion for *E. coli* is 126 CFU/100 mL, and the single sample criterion is 399 CFU/100 mL. A CFU is a measure of how many individual colonies of bacteria are present.

2. Overview of the Watershed

The Watershed was initially defined by researching the Watershed boundaries, geography features, climate, and history. Permitted discharges in the Watershed were also reviewed, and available water quality data were analyzed at various locations in the Dry Comal Creek and Comal River. Additionally, the reasons for pursuing a WPP and ongoing activities were documented. Collectively, the information summarized in this section, ensured that all the stakeholders had a clear understanding of the Watershed and the current water quality challenges.

2.1 Watershed Boundaries

Watershed boundaries are determined solely upon science-based hydrologic principles, not favoring any administrative or political boundaries. The Watershed Boundary Dataset (WBD) defines the areal extent of surface water drainage to a point, accounting for all land and surface areas. Watershed boundaries, or "hydrologic units" define a drainage boundary framework and are assigned a "Hydrologic Unit Code (HUC)." The hydrologic unit hierarchy is indicated by the number of digits in the HUC, with HUC 12 being a 12-digit code for local watersheds that capture tributary systems.

Three HUC 12-level watersheds make up the Watershed as shown in Figure 7. Note that the officially-designated name for the southeastern HUC 12 watershed (HUC 12 code: 121002020106) is the "Dry Comal River – Guadalupe River", which includes the Comal River. The segments of the Dry Comal Creek in the northwestern two HUC 12 watersheds (i.e., the "Headwaters West Fork Dry Comal Creek" – [HUC 12 code: 121002020104] and the "West Fork Dry Comal Creek" [HUC 12 code: 121002020105]) are generally intermittent or dry, with flow increasing during storm events.

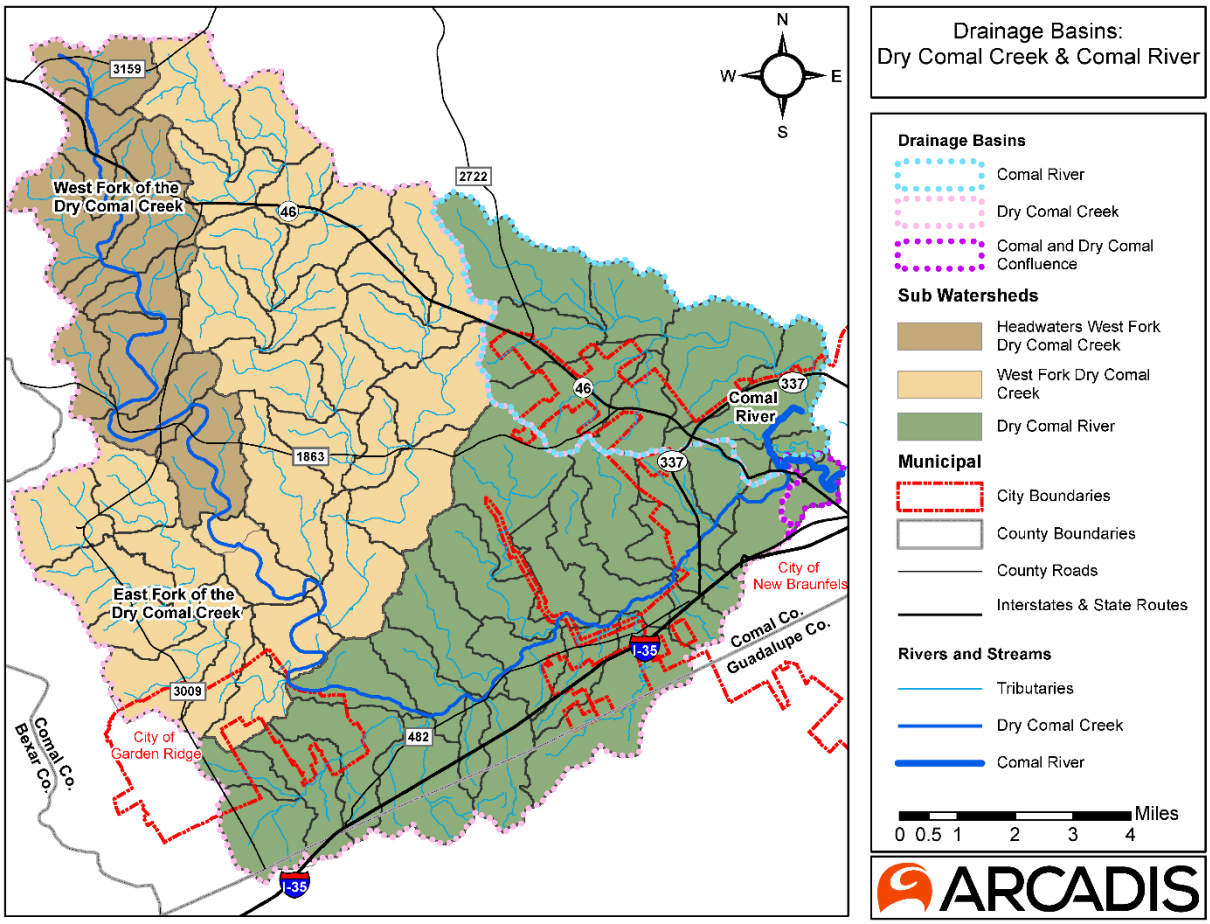

Figure 7: Dry Comal Creek and Comal River Watershed (Comprising Three HUC 12 Watersheds)

Figure 7 also highlights the areas within the Watershed draining to the Dry Comal Creek and Comal River. The 71,120-acre Dry Comal Creek drainage basin is much larger than the 11,487-acre Comal River drainage basin. There are an additional 553 acres which drain to the Comal River downstream of the confluence with the Dry Comal Creek. Thus, these three areas cover a total of 83,160 acres.

2.2 Geography

This WPP covers the watersheds for both the Dry Comal Creek and Comal River. The Watershed spans from southeast of Canyon Lake near Hwy 46, to the City of Garden Ridge and the City. The geography of the Dry Comal Creek and Comal River are further described below.

2.2.1 Dry Comal Creek

The main channel of the Dry Comal Creek (Segment 1811A) is located entirely within Comal County; however, a portion of its watershed, or drainage area, extends into Guadalupe County. Dry Comal Creek is an approximately 34-mile long tributary of the Comal River, which lies within

the larger Guadalupe River Basin. The Dry Comal Creek begins approximately five miles southeast of Canyon Lake in northern Comal County, just north of Hwy 46, and continues in a sinuous path toward the south. Just east of the City of Garden Ridge, the Dry Comal Creek turns abruptly to the northeast and continues parallel to Interstate Highway 35 (IH-35) in a northeast direction toward the City. The Dry Comal Creek joins the Comal River near Seguin St. within the City's corporate limits. A recent photo of the Dry Comal Creek at Seguin St. is provided in Figure 8.

The Dry Comal Creek watershed encompasses more than 100 square miles. As its name implies, much of the Dry Comal Creek remains dry other than during, and immediately following, large rain events. This is due in part because the upper portions of the creek lie within the Edwards Aquifer Recharge Zone. The Recharge Zone has highly faulted and fractured Edwards limestone outcrops at the land surface, allowing significant volumes of water to flow into the Aquifer during rain events. In fact, about 75 percent to 80 percent of Edwards Aquifer recharge occurs where streams and rivers cross the permeable formation and water goes underground. In the downstream reaches of the Dry Comal Creek, small springs and seeps provide flow to the creek during average weather conditions.

Figure 8: Dry Comal Creek at Seguin St. (Looking Upstream)

2.2.2 Comal River

The Comal River (Segment 1811) originates as groundwater from the Edwards Aquifer, and percolates through numerous spring openings located along the Balcones Escarpment in and near Landa Park (see one of these springs in Figure 9), which is located within the City limits. The Comal Springs are the largest springs in Texas (Eckhardt, 2017).

Figure 9: Comal Springs at Landa Park (Spring Run #1)

The Comal River is the shortest navigable river in Texas and is located entirely within the City. The Comal River flows approximately two and one-half miles from its source at Comal Springs prior to joining the Guadalupe River.

Figure 10 shows a small portion of the Comal River at Hinman Island. The Comal River provides a significant portion of the baseflow to the Guadalupe River, especially during times of drought. The Comal River typically exhibits constant flow with an average discharge of approximately 300 cubic feet per second (cfs). In recorded history, the only time the Comal Springs have ever gone dry was for a period of about six months during the 1950's drought-of-record.

Figure 10: Comal River at Hinman Island

2.3 Physical and Natural Features

The ecoregions and soil in the Watershed allow for habitation of a variety of land and water animals, including some endangered species. A description of the ecoregions, soils and fish and invertebrate communities is provided below.

2.3.1 Ecoregions

The upper reaches of the Dry Comal Creek are located within the Edwards Plateau ecoregion. This ecoregion is a rugged, semi-arid region, which includes a large portion of the Texas Hill Country. Upland areas within the Edwards Plateau are dominated by grasslands, ash juniper/ oak woodlands, and mesquite trees; riparian areas include bald cypress, pecan, sycamore, and hackberry trees.

The downstream portions of the Dry Comal Creek flow through the transition zone between the Edwards Plateau and the Blackland Prairie ecoregion. The Blackland Prairie ecoregion comprises deep, fertile soils that support tall-growing grass species. The Comal River is also located in the transition zone between the Edwards Plateau and the Blackland Prairie ecoregion. A map illustrating the ecoregions of Texas is provided in Figure 11**.**

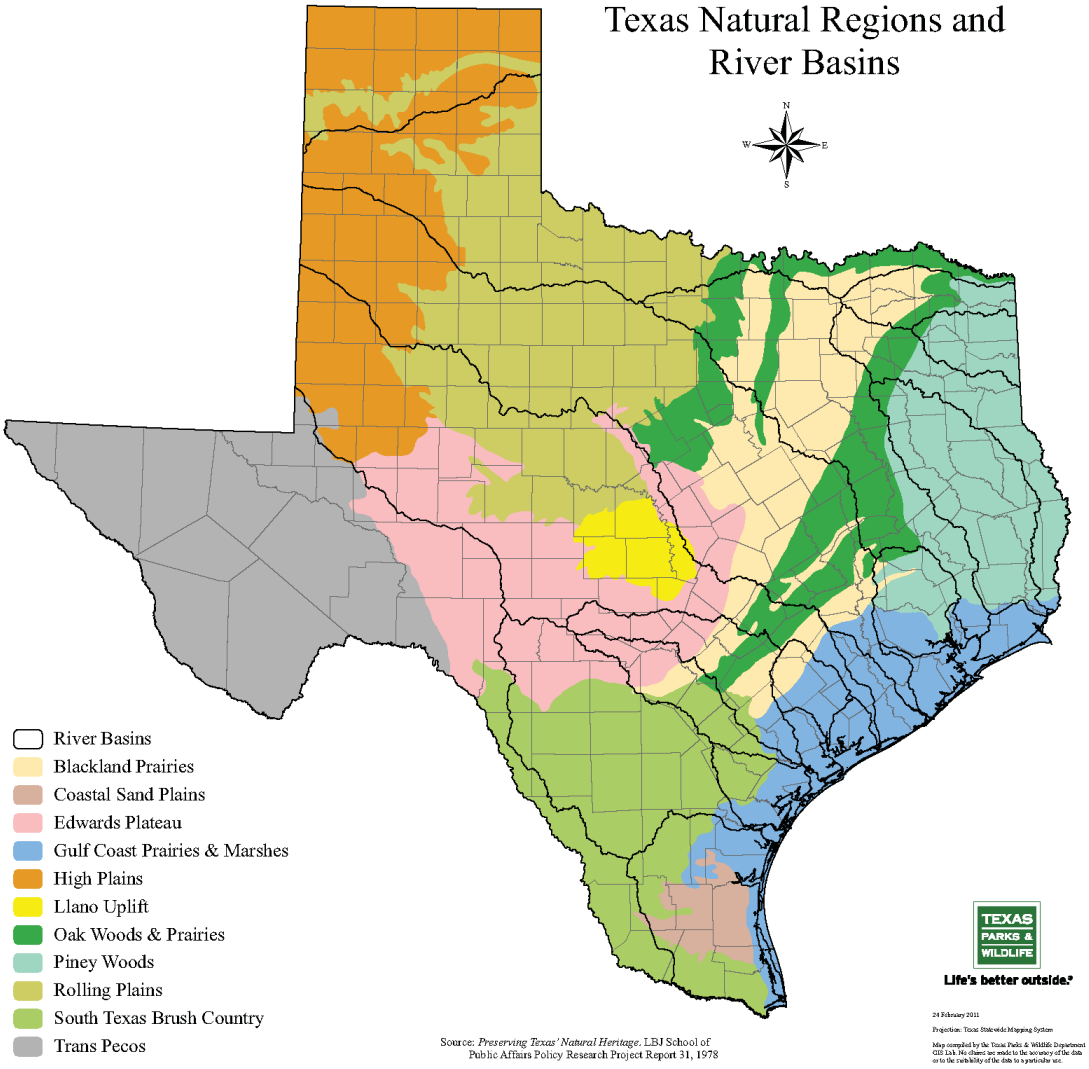

Figure 11: Ecoregions of Texas [Image Courtesy of TPWD]

A large portion of the Watershed is located within the Balcones Fault Zone, a system of northeast trending faults that runs roughly parallel to Interstate Hwy 35. The Balcones Escarpment, a very distinct topographic feature, is often considered the dividing line between the Edwards Plateau and the Blackland Prairie ecoregions. Native animal species within the Watershed include white-tailed deer, raccoon, squirrel, fox, skunk, and a diversity of other small mammals and birds. Non-native feral hogs also inhabit portions of the Watershed.

2.3.2 Soils

Soils in the upper portions of the Watershed typically consist of shallow, clay soils produced by the weathering of limestone rock. The shallow, clay soils of the Edwards Plateau region generally transition to deeper clay soils in the downstream portions of the Watershed.

2.3.3 Fish and Invertebrate Communities

The U.S. Fish & Wildlife Service (USFWS) has designated eight species that live in the Edwards Aquifer, the Comal Springs, and the San Marcos Springs as either threatened or endangered. The Comal River system is home to several of these federally listed species including the Fountain Darter (*Etheostoma fonticola*), Comal Springs Riffle Beetle (*Heterelmis comalensis*) (Figure 12), Comal Springs Dryopid Beetle (*Stygoparnus comalensis*), and the Peck's Cave Amphipod (*Stygobromus pecki*). Fish species found in both the Dry Comal Creek and Comal River include largemouth bass and multiple sunfish species. Several non-native, invasive fish species, including tilapia and suckermouth catfish, are also found in the Comal River.

Figure 12: Fountain Darter (Left) and Comal Springs Riffle Beetle (Right) [Eckhardt, 2017]

2.4 Climate

The Watershed is located in a subhumid, subtropical climate zone typified by long, hot summers and short, mild winters. Average annual rainfall for the New Braunfels area is approximately 34 inches. However, the region can experience severe droughts, such as those of the mid-1950s, 2011 and 2014, when less than 15 inches of rainfall was received over twelve-month periods. Conversely, the region can experience extreme flooding, due to the location of Central Texas within a convergence zone of high and low-pressure air masses and the onset of tropical storms and hurricanes. Flooding is exacerbated by the steep slopes and thin soils present in the Edwards Plateau and along the Balcones Escarpment that limit infiltration of rainfall and promote rapid runoff. The Balcones Escarpment, through abrupt changes in land elevations over short distances, is prone to intense rainfall amounts through orographic uplift. Peak rainfall is typically received in the spring and fall months, but flooding can occur at any time throughout the year.

2.5 History

Early settlers of the area included Tonkawa and other Native American tribes that inhabited the area long before the settlement of the area by Europeans. These Native American tribes, as well as European settlers, were attracted to the area by the Comal Springs and the overall abundance of fresh water. Spanish explorers visited the area beginning in the 1600's and

reportedly discovered large Native American tribes inhabiting the area in the vicinity of Comal Springs in 1691. French and Spanish expeditions, including those of the Marqués de Aguayo and Louis Juchereau de St. Denis, commonly passed through this area via the El Camino Real de Tejas, or Royal Road of Texas, which was a major historic route through the area and is now a National Historic Trail. In 1825, a Mexican land grant gave title of the area around the springs to Juan M. Veramendi. During the eighteenth century, the Comal Springs and Guadalupe River (which had been called Las Fontanas [the “fountains”] and the Little Guadalupe, respectively) took the names Comal, Spanish for "the round, flat earthenware griddle used to make tortillas," and Guadalupe.

In 1836, the Republic of Texas was formed after years of battles with the Mexican government, which had laid claim to the territory. To pay off war debt and weaken political ties with Mexico, the new nation of Texas offered public land to Americans and Europeans. This offer, in conjunction with political strife in their homeland, enticed a group of German noblemen to form an immigration company named the Adelsverein. German immigrants began to arrive in Indianola, Texas in December 1844 and make their way to central Texas.

On March 13, 1845, Prince Carl of Solms-Braunfels, Germany, entered into an agreement with Maria Antonio Garza and her husband Rafael E. Garza for 1,265 acres of the Veramendi land grant for a sum of $1,111. The German immigrants settled in the area of present-day New Braunfels. The Germans quickly built grist mills and cotton gins along the Comal River. A millrace, located parallel to present-day Landa Park Drive, was dug to divert water to power one of the mills. Joseph Landa purchased the land surrounding the upstream portions of the Comal River (i.e., Landa Lake) in 1860 and dedicated the land as a park (i.e. Landa Park) in 1898.

The Comal Settlement was one of the first settlements outside of New Braunfels and was located along the Dry Comal Creek. The Comal Settlement was founded by several German families and grew to include schools, a cotton gin, a store, church and cemetery. At that time, the Dry Comal Creek offered a source of fresh water for the Comal Settlement and for those traveling south along the Camino Real trail toward markets located near San Antonio.

2.6 Watershed Development

Today the City is among the “Top Fastest Growing Large Cities in the U.S.,” according to the United States (U.S.) Census Bureau. The City ranked second based on a 6.6 percent increase in population from July 1, 2014 to July 1, 2015, and ranked ninth based on a 4.7 percent increase from July 1, 2015 to July 1, 2016. From a population of only 36,494 people in 2000 to an estimated 73,959 people in 2016 (U.S. Census Bureau, 2016), the City is growing at an estimated average of over 2,000 people each year. Figure 13 shows the estimated increase in population from 2010 to 2016 along with the yearly percent increase and percent change (based off the 2010 population estimate). The population has increased by more than 25 percent since 2010 and saw the highest percent change from 2014 to 2015.

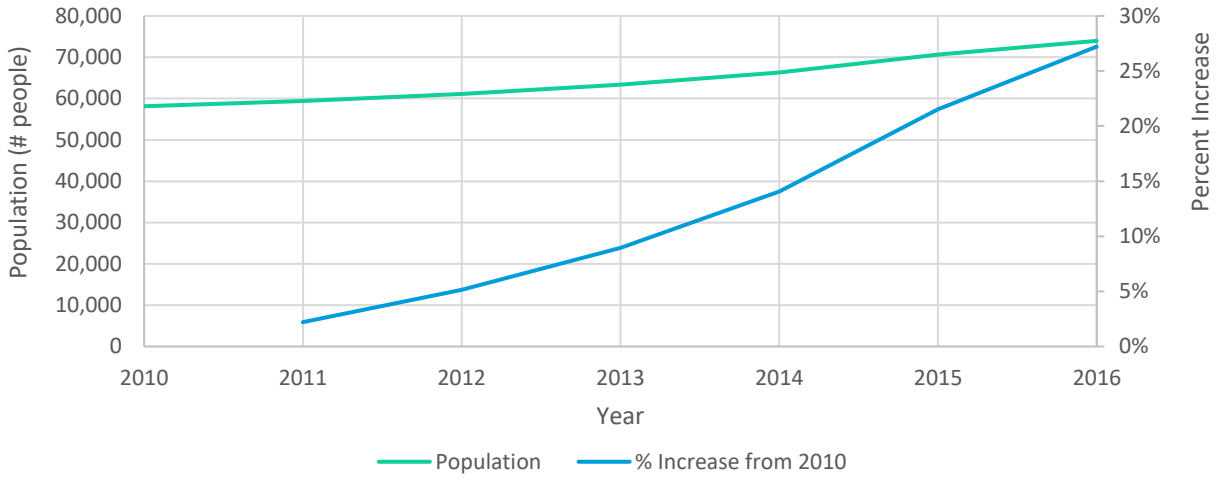

Figure 13: City of New Braunfels Population Change from 2010 to 2016

With the addition of so many people to the City each year, development has increased throughout the Watershed. The latest Subdivision Development Map for Comal County shows approximately 49 new (or active since 2000) subdivision developments existing as of June 2008, representing a total of 19,539 new lots (Comal County Engineer's Office, 2008). Based upon local stakeholder knowledge, this trend of increasing development, especially in rural areas, has continued to increase.

2.7 Permitted Discharges and Land Application Sites

Based on TCEQ data, there are currently two permitted wastewater discharges (TPDES permits WQ2179000, and WQ15314001) in the Watershed (Figure 14). The first permittee is Cemex Construction Materials South, LLC (TPDES permit WQ2179000). Permit WQ2179000 authorizes discharge from the Balcones Cement Plant, which manufactures Portland and masonry cement. Discharges are made to a settling pond through a controlled weir and into a 24-inch concrete pipe, and subsequently to the Dry Comal Creek. When discharge occurs, monitoring is required in the form of grab samples collected from outfall number 001, where outflow from the stormwater settling pond flows to the Dry Comal Creek. Monitoring must be conducted daily and must be reported to the TCEQ monthly for parameters including flow, oil and grease, chemical oxygen demand, total dissolved solids, total suspended solids, turbidity, and pH. Stormwater discharges are monitored according to provisions outlined in the facility's Stormwater Pollution Prevention Plan, which is a requirement of the facility's TPDES permit.

The second permittee is the Randolph Todd Company, LLC (TPDES permit WQ15314001. The Randolph Todd Company is a land development company located in Austin, TX. The permit authorizes the discharge of treated wastewater and stormwater from the Meyer Ranch Wastewater Treatment Facility. The existing treatment plant is currently being expanded from 0.27 million gallons per day (MGD) to 0.39 MGD, and the permit includes interim discharge requirements for the two different facilities. Self-monitoring is required for parameters including flow, carbonaceous biochemical oxygen demand (5-day), total suspended solids, ammonia

nitrogen, total phosphorus, total nitrogen, and *E. coli*. A grab sample of all parameters other than flow and *E. coli* must be collected once per week. Flow must be recorded continuously, and a grab sample for *E. coli* must be collected once every five weeks. Randolph Todd Company, LLC is also authorized to land apply or landfill approved sewage sludge.

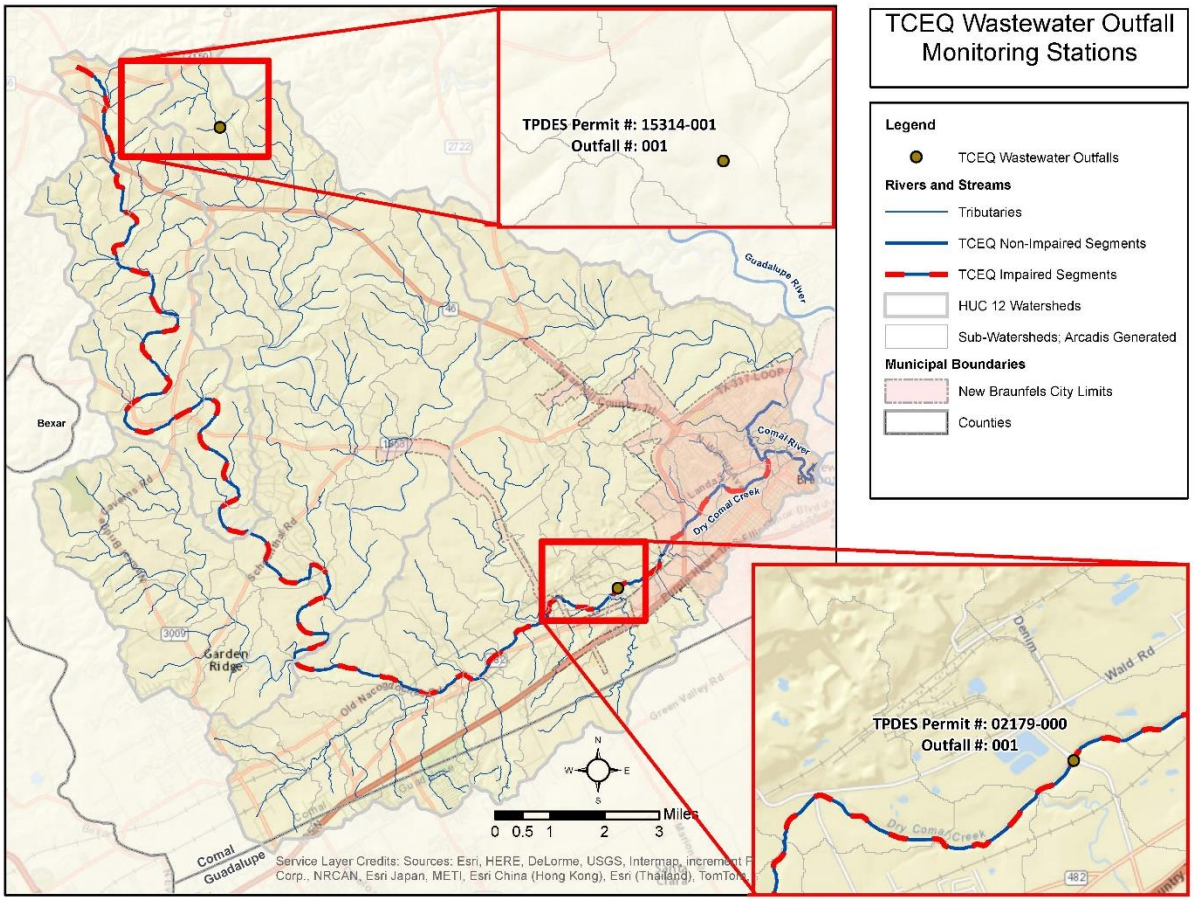

Figure 14: Permitted Wastewater Discharges in the Watershed

There is also a permit for SJWTX, Inc. (TPDES permit WQ15320001), a water service provider located in New Braunfels, TX. The permit authorizes the treatment of private domestic wastewater from the facility, Vintage Oaks at the Vineyard, a 40-acre subdivision. The facility is owned by a property development company, SouthStar at Vintage Oaks, LLC, which is based in Austin, TX. While the permit does not authorize discharge, it does authorize wastewater storage in a synthetically lined pond on-site. The permit also requires annual grab samples at two different soil monitoring points on-site. SJWTX, Inc. is required to self-report the soil's pH level, conductivity, nitrate, phosphorous, potassium, calcium, magnesium, sulfur, and sodium to the TCEQ.

In addition, the Northcliffe Wastewater Treatment Facility (Permit No. WQ11751001), owned and operated by GBRA, is permitted to dispose of treated domestic wastewater effluent at a daily average flow rate not to exceed 0.30 MGD via surface irrigation at the Northcliffe Country Club golf course in the City of Schertz. Self-monitoring is required for parameters including

flow, biochemical oxygen demand (5-day), total suspended solids, pH, and chlorine residual. A grab sample of all parameters other than flow and chlorine residual must be collected once per month. Flow must be recorded instantaneously at least five times per week, and a grab sample for chlorine residual must be collected five times per week.

2.8 Water Quality

The Watershed Partnership tracks water quality over time in the Dry Comal Creek and Comal River. Analysis of water quality provides a quantitative assessment of water quality trends and of changing conditions within a watershed. EAA, GBRA and the City monitor for the parameters, at the frequencies, and at the locations shown in Table 3[3]. The monitoring locations for EAA's monitoring programs are shown in Figure 15. The locations for GBRA and GBRA-City monitoring are shown later (Figure 16 and Figure 17) with data from those sites. Analysis of historical water quality data collected through these monitoring programs is discussed in the following sections.

Table 3: Water Quality Monitoring Sources and Parameters

WPP Partner	Monitoring Site	Parameters	Frequency
EAA[1]	Comal Spring 3 Comal Spring 7 Comal River at Landa Lake Comal River at Hinman Island	Dissolved oxygen (DO), pH, Conductivity, Temperature and Turbidity	Continuous water quality recorders (i.e., every 15 minutes)
GBRA Clean Rivers Program (CRP)	Comal River at Landa Park Area 16 - Station ID 15082; Added 05/05/14 (29.70950277, -98.13372500)	Water Quality[2], Flow, Bacteria	Monthly
	Comal River at Hinman Island (Formerly Clemons Dam) - Station ID 12653 (29.707925, -98.12551944)	Water Quality[2], Flow, Bacteria	Monthly
	Dry Comal Creek at Seguin St. (Formerly Knights of Columbus) - Station ID 12570 (29.703933, -98.12898611)	Water Quality[2], Flow, Bacteria,	Monthly
		Metals, Biological[3]	Annually

[3] Any applicable surface water quality data collected in future monitoring efforts that is not already part of one of the above programs will be submitted to TCEQ for use in biennial assessments of water quality for Clean Water Act purposes (i.e., 303(d) List).

Table 3: Water Quality Monitoring Sources and Parameters (Continued)

WPP Partner	Monitoring Site	Parameters	Frequency
Additional Monitoring by the City and GBRA	Comal River at Pecan Island (29.7160277, -98.133622)	*E. coli*	Monthly
	Comal River at Landa Haus (29.71050833, -98.13459722)	*E. coli*	Monthly
	Comal River at River Run Condominiums; Added 07/06/13 (29.70795833, -98.12783055)	*E. coli*	Monthly
	Comal River at Mill Pond (29.7057388, -98.130988)	*E. coli*	Monthly
	Dry Comal Creek at Walnut Ave. (29.69785, -98.13671944)	*E. coli*	Monthly
	Dry Comal Creek at Loop 337 (29.689022, -98.15413611)	*E. coli*	Monthly
	Dry Comal Creek at Altgelt Lane (29.6805611, -98.1619055)	*E. coli*	Monthly
	Dry Comal Creek at Solmes Road (,29.672177, -98.17560277)	*E. coli*	Monthly
	Dry Comal Creek at Krueger Canyon (29.6698055, -98.1939388)	*E. coli*	Monthly

1 – There are additional stations monitored by EAA that were not analyzed in this WPP.

2 – Temperature, conductivity, dissolved oxygen, pH, nitrate/nitrite-nitrogen, ammonia-nitrogen, total kjeldahl nitrogen, total phosphorus, total suspended solids, turbidity, sulfate, chloride, Chlorophyll-a, total hardness, and *E. coli*.

3 – Aquatic Commun-Habitat, Routine Benthics, and Routine Nekton

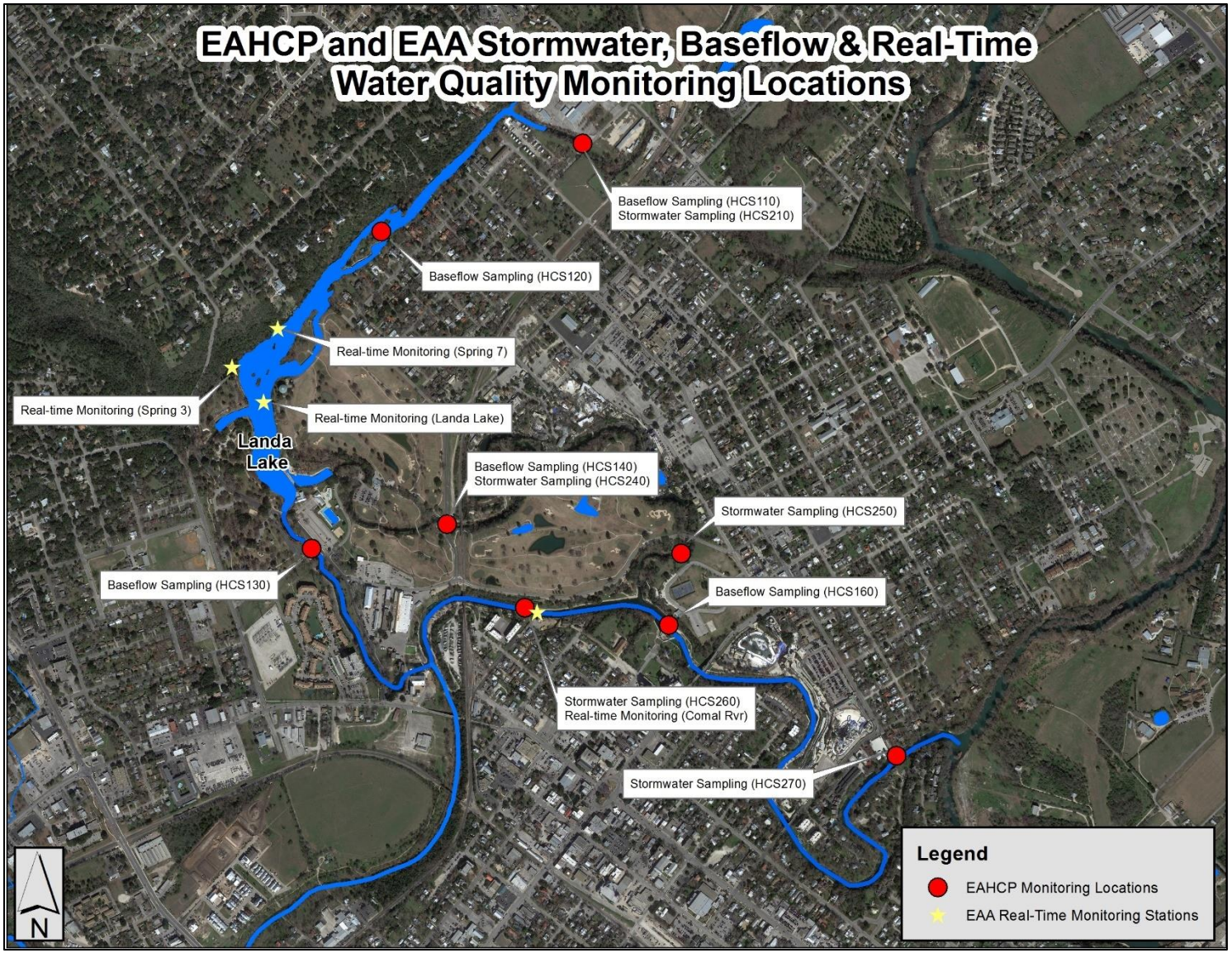

Figure 15: Edwards Aquifer Habitat Conservation Plan (EAHCP) and EAA Water Quality Sampling Locations on the Comal River

2.8.1 Clean Rivers Program

The Dry Comal Creek and Comal River have been monitored monthly since October of 1996 by GBRA as a part of the Texas CRP. The CRP was established by the Texas legislature in 1991 to holistically monitor and manage water quality issues throughout the state at the watershed level. The CRP is administered as a partnership between TCEQ and regional water authorities. A CRP Dry Comal Creek monitoring station (station 12570) is located upstream of the Landa St. bridge near the Wurstfest grounds. Two CRP water quality stations are also currently being monitored by GBRA on the Comal River. The original Comal River monitoring station (station 12653) is located within Hinman Island Park and has been monitored since November of 1994. In June of 2014, GBRA began monitoring a second CRP station (station 15082) on the new channel of the Comal River in Landa Park, upstream of the Dry Comal Creek confluence.

The Dry Comal Creek, segment 1811A, was listed in category 5b for the first time on the 2010 Texas Integrated Report of Surface Water Quality (303 (d) list) (303(d) list) for impairment to its designated contact recreational use, due to elevated *E. coli* concentrations. All waterbodies in the state of Texas are evaluated for their ability to support a contact recreation designated use. The TCEQ evaluates whether a designated use is being met by calculating the geometric mean (geomean) of the *E. coli* concentrations collected on a stream segment over the previous seven years. In order for a stream to meet the designated use, meet a primary contact recreation use, the assessed geomean must fall below 126 CFU/100 mL of water. The 2010 303(d) list reported a geomean of *E. coli* concentrations of 173.90 CFU/100 mL[4] in the lower 25 miles of the Dry Comal Creek. In the 2012 303(d) list, the waterbody was reevaluated by the TCEQ and moved to category 5c because the assessed geomean of *E. coli* concentrations was 291.03 CFU/100 mL. The move from category 5b to category 5c indicated a determination by the TCEQ that the current water quality standards were appropriate, and more water quality information needed to be gathered before an appropriate strategy could be implemented to address the impairment. In the 2014 Texas Integrated Report of Surface Water Quality, the assessed geomean of *E. coli* concentrations in the Dry Comal Creek was 301.89 CFU/100 mL

[4] All bacteria data collected in this study are reported in terms of CFU which are more widely understood and are used in the recreational standard. However, all data was collected using the Colilert method. MPN, or most probable number, is the unit used to report the concentration of *E. coli* bacteria determined using the Colilert method. The Colilert method analyzes water samples by a series of dilutions and observing positive or negative reactions. CFU are the units used to report the bacterial concentration determined by filtration and culturing of viable bacterial cells. The MPN method is a statistical estimate of the bacterial concentration and is an accepted reporting method especially in the analyses of samples whose expected concentration range is unknown and most likely broad. Although MPN methods are estimates, inherent problems with culturing methods that are based on the viability and growth of bacterial cells, make MPN the most accepted method for the analysis of stream samples for comparison to the recreational stream standard.

of water. The Comal River does not currently have any assessed impairments for its designated uses, although *E. coli* concentrations have been rising.

The 2014 Texas Integrated Report ("Report") does not include any impairments or concerns for nutrients. The Report included Nutrient Screening levels data from 2005 through 2012 for nitrate, ammonia, total phosphorous and chlorophyll-a in the Dry Comal Creek, however, those levels were indicated to be of no concern. There were also no nutrient impairments for the Comal River. The 2018 CRP Basin Summary Report for the Guadalupe Basin also includes screening criteria and an assessment of nitrate, ammonia, total phosphorus and chlorophyll-a data from 2002-2016. This report was reviewed, and no concerns were noted for nutrients.

Future TCEQ Integrated Reports and CRP Basins Summary Reports will be monitored and reviewed as part of the WPP implementation process. Any reported changes in impairment or concerns for nutrients will be incorporated into future revisions of the WPP as necessary. Implementation of BMPs addressing bacteria from stormwater runoff would also be expected to reduce nutrient loadings.

2.8.2 City-GBRA Water Quality Monitoring Program

In response to the Dry Comal Creek being placed on the 303(d) list in 2010, and to increasing *E. coli* concentrations in the Comal River at Hinman Island Park (discussed further below), the City funded *E. coli* monitoring, in addition to the CRP monitoring, to aid in the identification of bacteria load trends and bacteria "hotspots". This additional City-GRBA monitoring began in January 2011, and is conducted by GBRA along both stream segments upstream of the respective CRP monitoring sites. Samples are collected at each of the additional monitoring locations on a monthly basis on the same day routine samples for the CRP program are collected. Monitoring at these additional locations has continued.

Along the Dry Comal Creek, five additional *E. coli* monitoring sites were established in January 2011, upstream of CRP Station 12570 (Seguin St.). Figure 16 illustrates the locations of the additional *E. coli* monitoring stations on the Dry Comal Creek, as well as the geomean of the monthly *E. coli* concentrations from January 2011 through May 2017. The City-GBRA sampling sites are located at Walnut Ave., Loop 337, Altgelt Lane, Solms Road and Krueger Canyon Road.

Within the two Comal River segments (upstream and downstream of the confluence with the Dry Comal Creek), three additional *E. coli* monitoring stations were established in January 2011 upstream of the CRP site at Hinman Island Park, with the uppermost monitoring location in Landa Lake near the headwaters of the Comal River. These sites are located along the Comal River at "Mill Pond" (immediately upstream of the old Lower Colorado River Authority hydroelectric dam and of the confluence with the Dry Comal Creek), at the crossing of Landa Park Drive near the Landa Haus, and at Pecan Island in Landa Lake. An additional monitoring location was added in July 2013 in the vicinity of the River Run Condos located immediately across and upstream from the Hinman Island Park CRP site. Figure 17 illustrates the location

of the additional *E. coli* monitoring stations along the Comal River, as well as the geomean of the monthly *E. coli* concentrations from January 2011 through May 2017.

The geomeans shown in both Figure 16 and Figure 17 exclude data for samples collected on September 26, 2016. The City and GBRA elected to collect a set of samples following a storm event to better understand the impact of stormwater on the creek and river. Prior to this sampling event, the area had experienced 2.38 inches of rainfall, and the flow in the Dry Comal Creek had increased to 2,100 cfs (i.e., about 6 times higher than typical in the creek). As illustrated by the *E. coli* concentrations summarized in Table 4, the storm event caused a significant increase (i.e., 28 to over 300 times the geomean) in *E. coli* concentrations in the waterbodies.

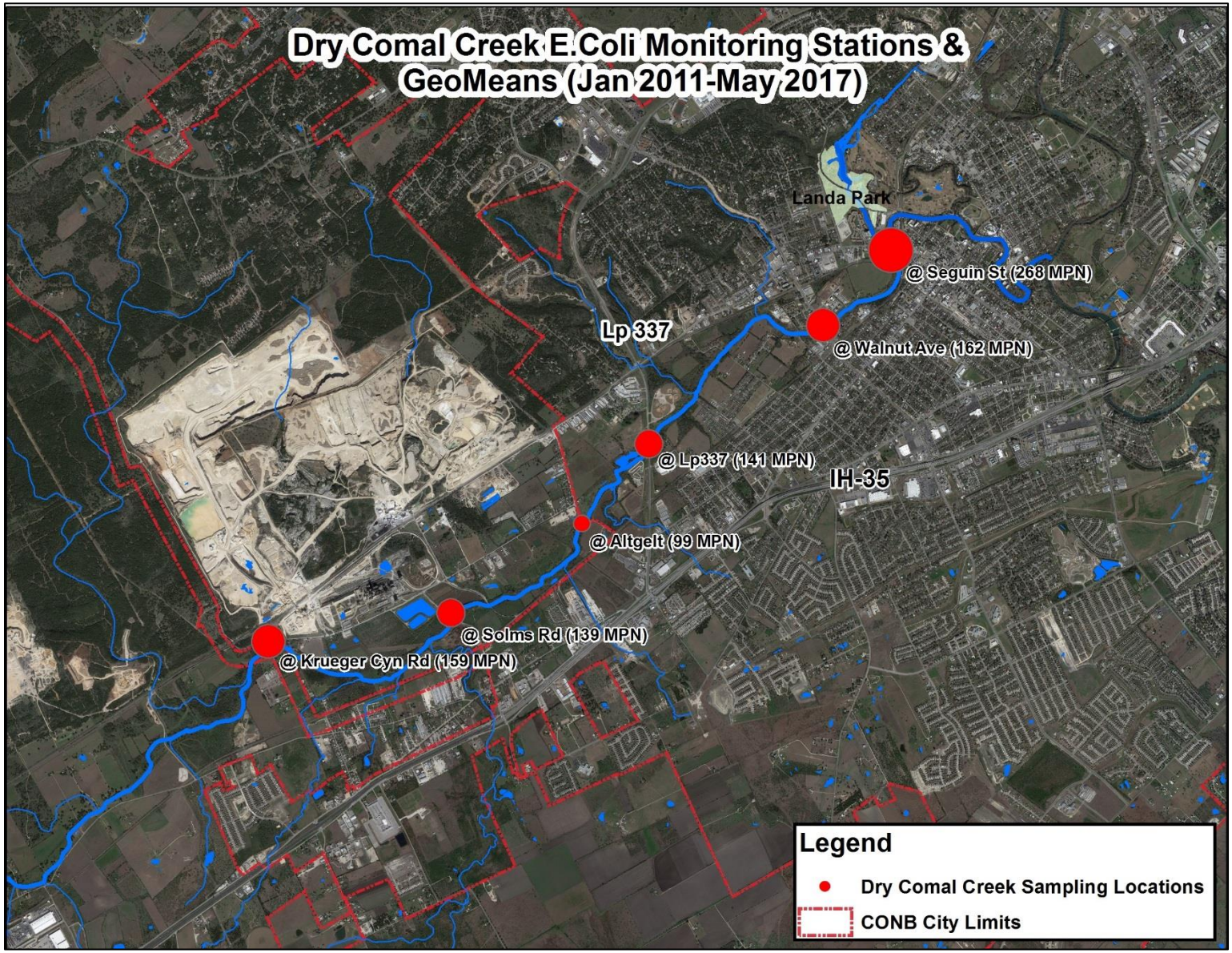

Figure 16: Dry Comal Creek *E. coli* Monitoring Locations and *E. coli* Geomeans from January 2011 through May 2017

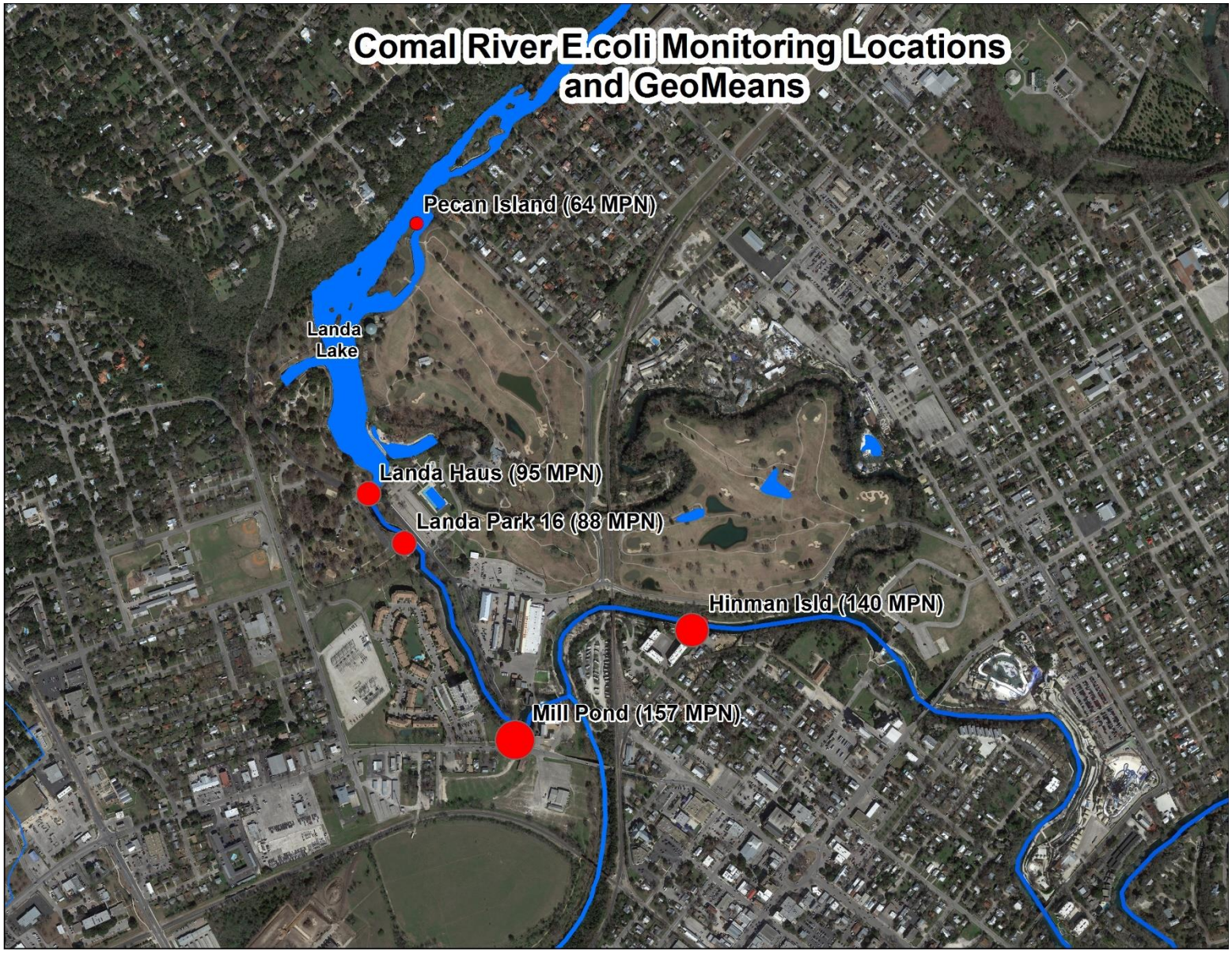

Figure 17: Comal River *E. coli* Monitoring Locations and *E. coli* Geomeans from January 2011 through May 2017

Table 4: *E. coli* Concentrations in Stormwater Samples Collected September 26, 2016

Location	*E. coli* Concentration (CFU/100 mL)
Comal River at Landa Park Area 16 - Station ID 15082	2,700
Comal River at Hinman Island (Formerly Clemons Dam) - Station ID 12653	48,000
Dry Comal Creek at Seguin St. (Formerly Knights of Columbus) - Station ID 12570	40,000

Data collected between 2011 and 2017 at the Dry Comal Creek sampling locations indicate a progressive increase in *E. coli* concentrations from upstream to downstream between Altgelt Lane and CRP Station 12570 near Seguin St. based on the 12- and 24-month running geomean concentrations (illustrated in Figure 18). Flow rates measured at the Seguin St. sampling location are also plotted in Figure 18. The flow rates range from several cfs to over 4,000 cfs.

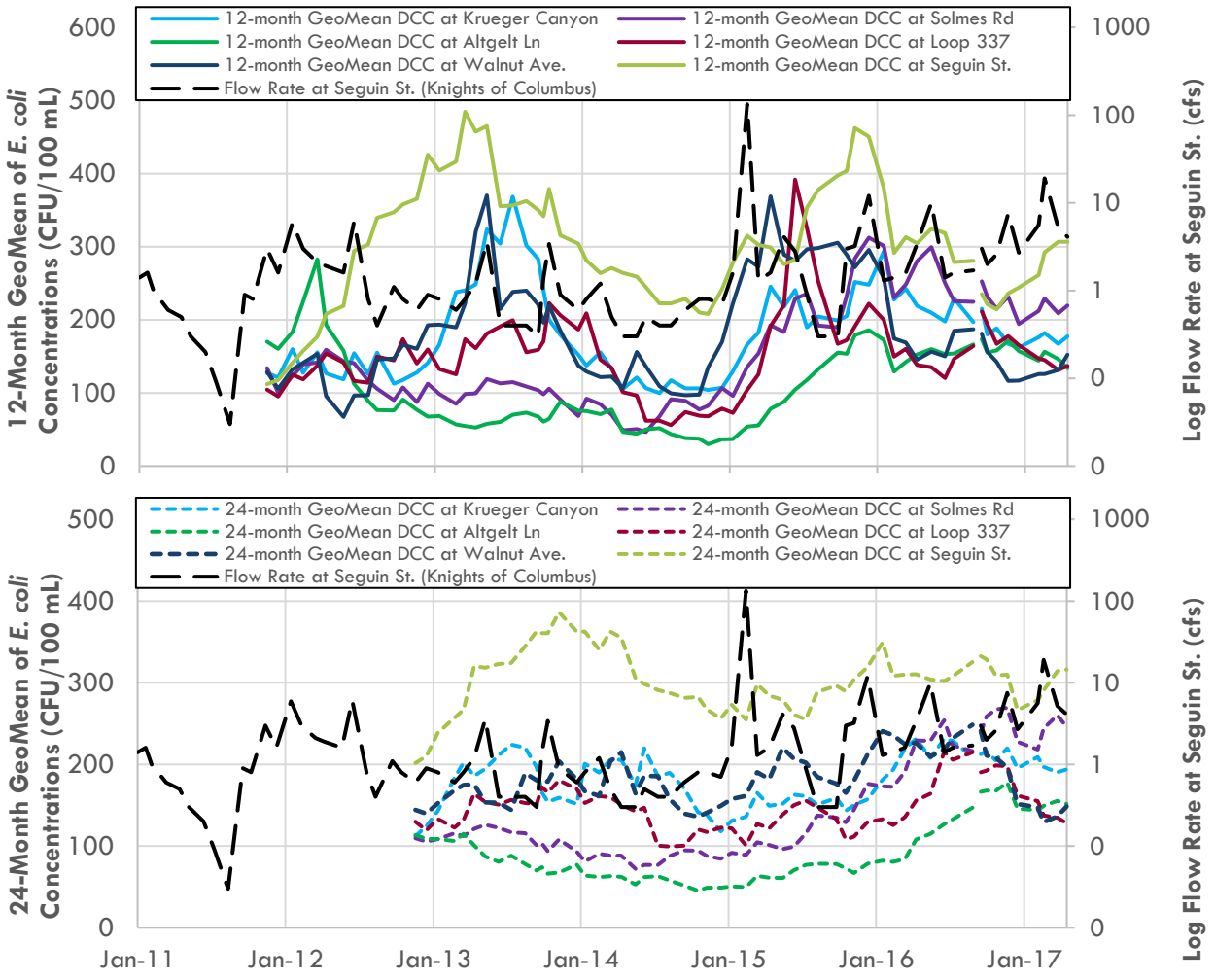

Figure 18: 12- Month and 24-Month Geomeans of Monthly *E. coli* Concentrations for Dry Comal Creek

The City and the City's consultants did a stream survey in May of 2017 along the Dry Comal Creek between the Walnut Ave. and Seguin St. sampling locations. No point sources of pollution were identified; however, different species of wildlife, including deer and birds, were identified. As shown in Figure 19, the creek is highly vegetated in this area and has been protected from development, making it an ideal habitat for wildlife. There are also walking trails where residents are known to walk dogs.

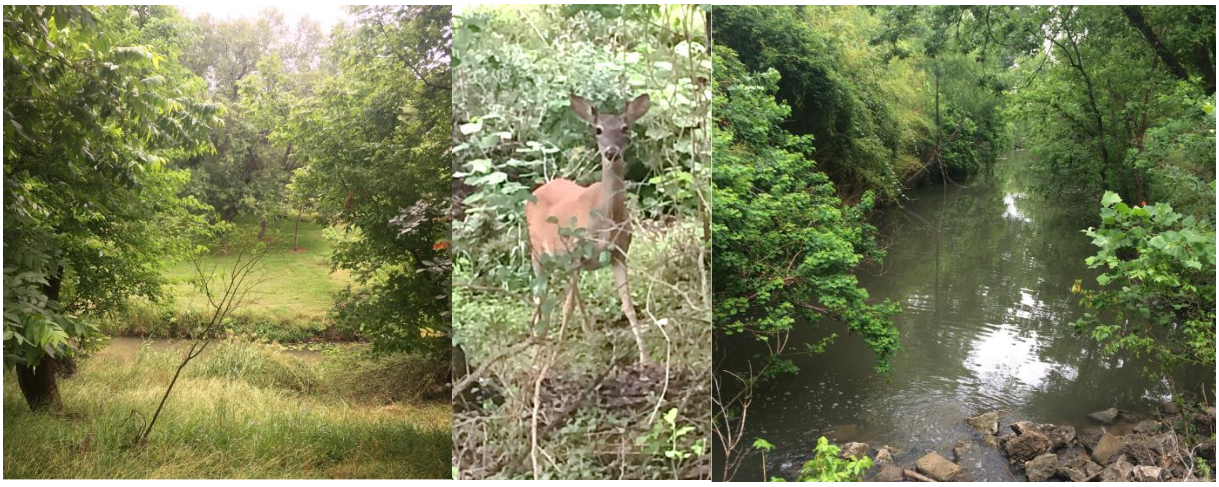

Figure 19: Photos of the Dry Comal Creek Between the Walnut Ave. and Seguin St. Sampling Locations

In addition to being a highly vegetated area, the sampling location at Seguin St. (CRP Station ID 12570) is located downstream of and in the vicinity of eleven stormwater outfalls, as shown in Figure 20. The effect of stormwater on *E. coli* concentrations was illustrated in Table 4. Seguin St., an area which had previously contained, on average, less than 500 CFU/100 mL, was found to have an *E. coli* concentration of 40,000 CFU/100 mL after a heavy rainfall event. The dramatic elevation in *E. coli* concentration following the rainfall event indicates that a significant amount of the bacteria in the Dry Comal Creek may be carried to the creek by stormwater and urban runoff.

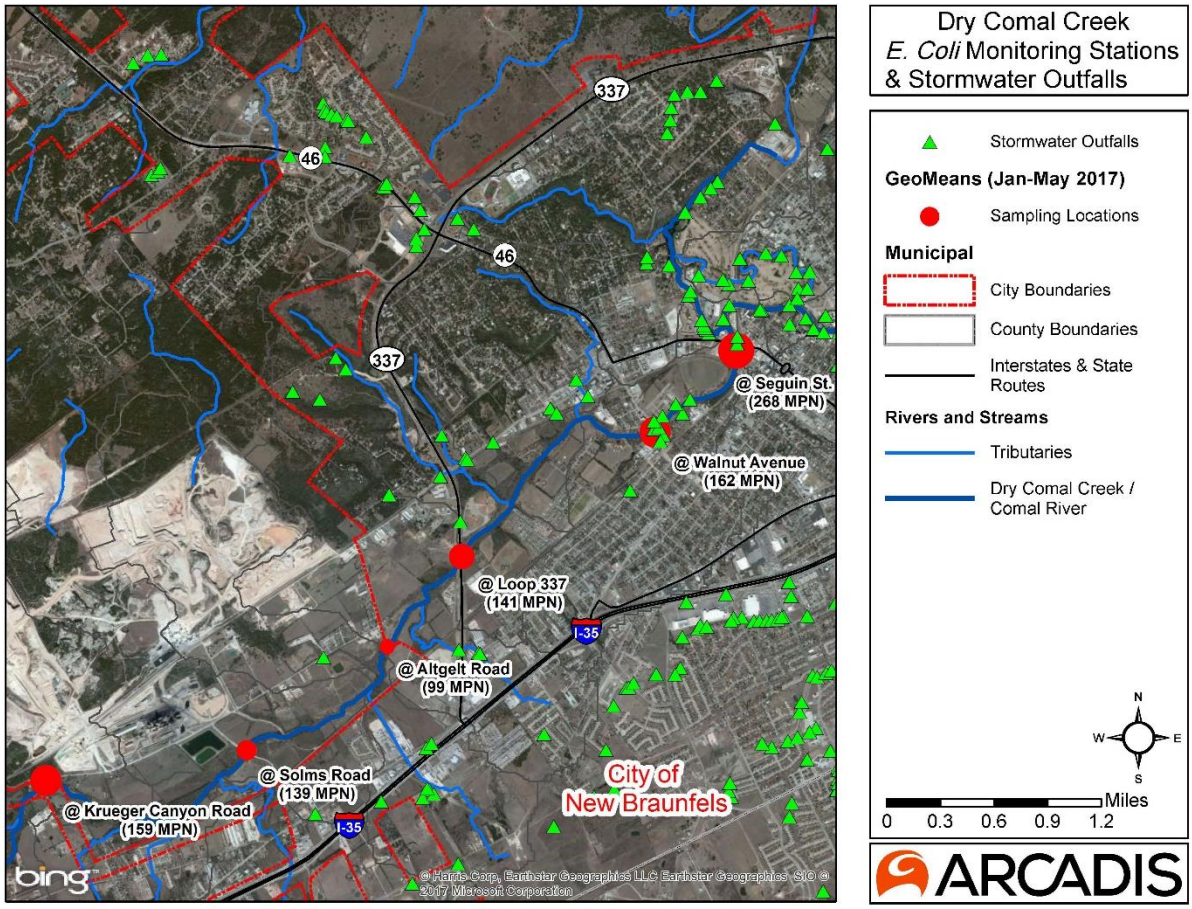

Figure 20: Dry Comal Creek *E. coli* Monitoring Stations and Stormwater Outfalls

City-GBRA 12-month and 24-month running geomeans of the *E. coli* data collected from the Comal River are illustrated in Figure 21**.** Generally, the *E. coli* geomean values calculated for the Comal River are lower than the Dry Comal Creek. The decreasing *E. coli* geomean values at all Comal River sampling locations since spring 2015 generally correspond to increased stream flow, as also illustrated in Figure 21**.** This is likely due to increased flow from the Comal Springs into the Comal River during this period. The data also suggest an increase in the *E. coli* concentration geomeans between the Comal River sampling locations**.**

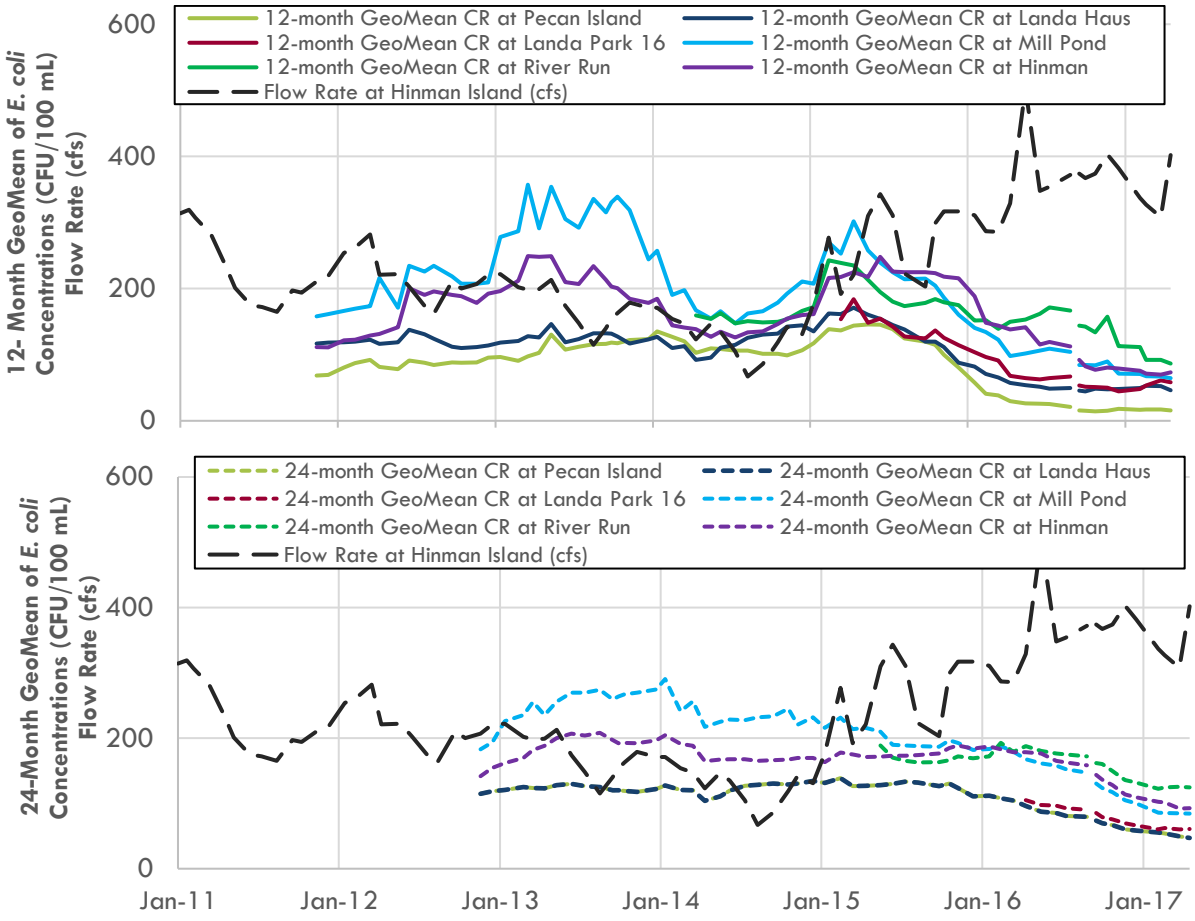

Figure 21: 12-Month and 24-Month Geomeans of Monthly *E. coli* Concentrations for the Comal River

As the Comal River moves downstream from Pecan Island, the *E. coli* concentration gradually increases, as seen in Figure 21. The elevated level of *E. coli* at Mill Pond correlates with an increased number of stormwater outfalls between the Landa Park and Mill Pond sampling locations. Although stormwater samples at Mill Pond were not analyzed, Hinman Island (CRP Station ID 12653) experienced an influx of bacteria after the previously mentioned rainfall event, shown in Table 4. Thus, it is likely that a significant amount of the bacteria in the Comal River may also be carried to the river by stormwater and urban runoff.

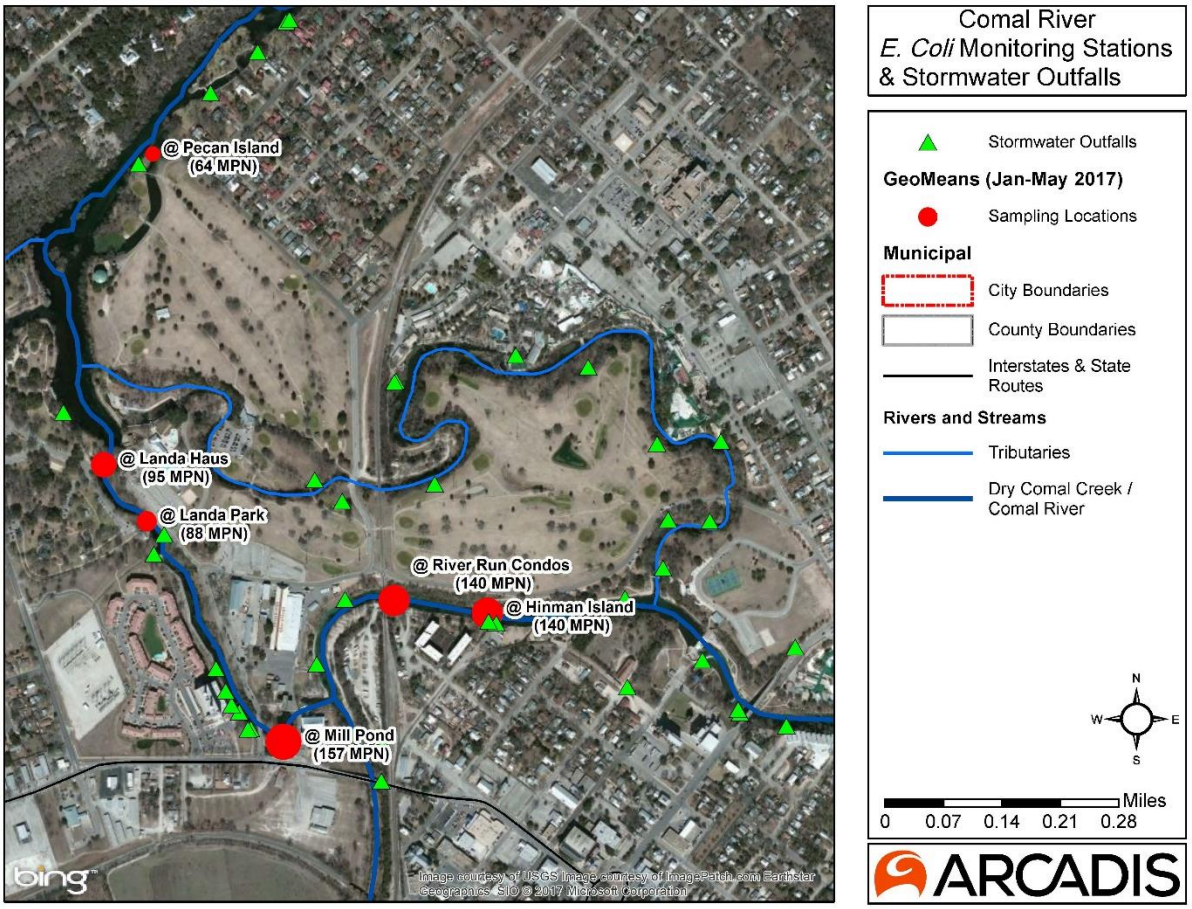

Figure 22: Comal River *E. coli* Monitoring Stations and Stormwater Outfalls

Monthly GeoMean *E. coli* data collected between January 2011 and May 2017 were calculated and plotted in Figure 23 to assess seasonal trends in bacteria concentrations. Note that the September 26, 2016 data shown in Table 4 are not included. However, there were data points with notable (i.e., 1-inch or greater) precipitation within seven days prior to sample collection; these data points could skew the results. Based upon this data set, the Dry Comal Creek has higher monthly geomean bacteria concentrations than the Comal River, with the highest monthly geomean occurring being March, June, November, and December. On average, the highest monthly geomean *E. coli* concentrations in the Comal River occur in July and November.

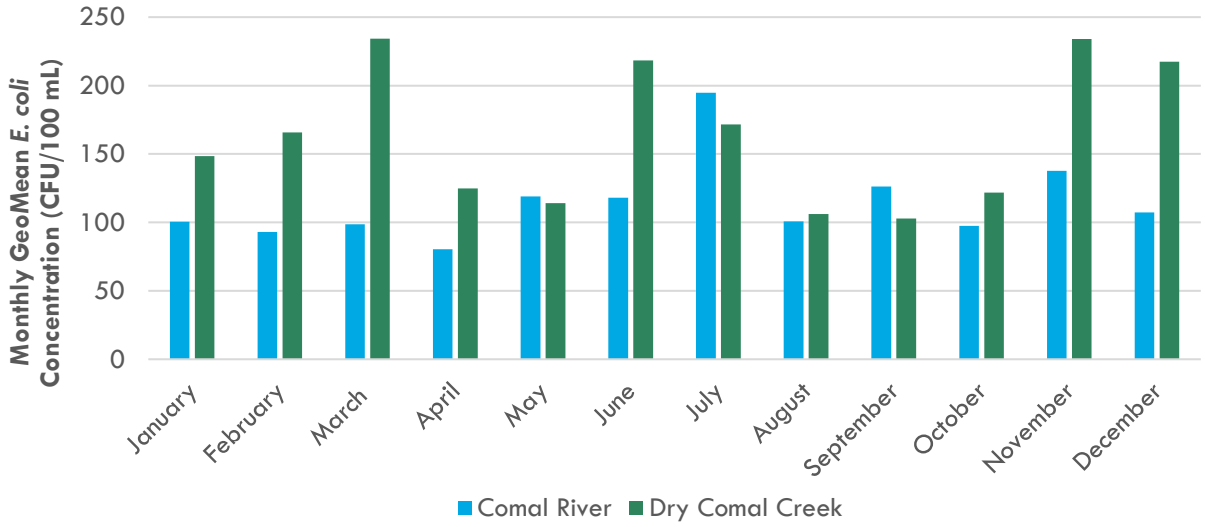

Figure 23: Monthly Geomean *E. coli* Concentrations Measured in the Dry Comal Creek and Comal River (January 2011 – May 2017) Excluding Data from Stormwater Samples

Lastly, analysis was conducted to evaluate whether a relationship between flow and *E. coli* was observed. The Comal River monitoring station located at Hinman Island illustrated that there is a very weak correlation between flow and *E. coli* as shown in Figure 24. After flow in the Comal River exceeds approximately 250 cfs, *E. coli* concentrations are more consistently below the statewide criterion for contact recreation of 126 CFU/100 mL, which may be attributed to dilution from the spring water. As stated above, the long-term average flow rate from the Comal Springs is approximately 300 cfs.

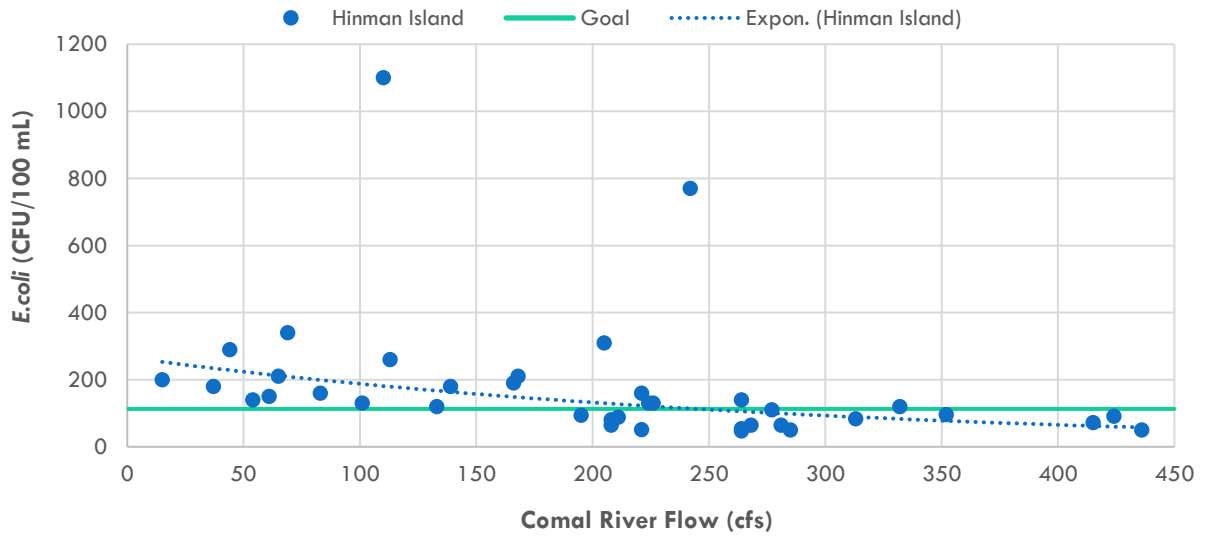

Figure 24: *E. coli* Concentrations Versus Flow in the Comal River at Hinman Island

Conversely, the Seguin St. monitoring location located on the Dry Comal Creek indicated that there is no observed relationship between flow and *E. coli* as can be observed in Figure 25.

The concentration of *E. coli* is consistently above the statewide criterion for contact recreation of 126 CFU/100 mL over all flow rates analyzed. In fact, the limited *E. coli* concentrations below the statewide criterion for contact recreation of 126 CFU/100 mL occurred when flows were below 5 cfs. Although higher loading rates are observed during storm events, when flows are higher, *E. coli* concentrations are high year-round as long as flow is present in the stream.

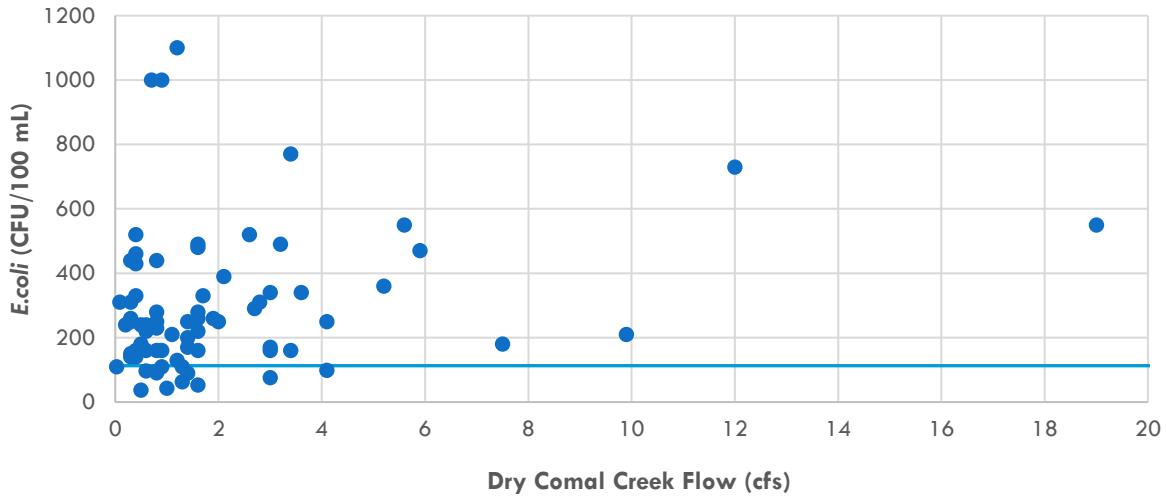

Figure 25: *E. coli* Concentrations Versus Flow in the Dry Comal Creek at Seguin St.

2.8.3 Edwards Aquifer Habitat Conservation Program

The Edwards Aquifer Habitat Conservation Program[5] (EAHCP) includes a water quality monitoring program. The program was developed in accordance with the directives of the EAHCP to identify and assess potential impairments to water quality within the Comal River and headwaters of the San Marcos River systems. The program includes surface water (base flow) sampling, sediment sampling, real-time instrument water quality monitoring, stormwater sampling and passive diffusion sampling.

The Comal Springs complex has five sample locations along the main channel of the Comal River from the upstream end of Landa Lake (where Blieders Creek empties into the headwaters of Landa Lake) to the south end of the Comal River, upstream of the confluence with the Guadalupe River. During this study, surface water (base flow) and stormwater samples were collected twice annually from each spring complex. Sediment samples were collected once

[5] Reference Edwards Aquifer Habitat Conservation Plan Expanded Water Quality Monitoring Report dated January 2017

annually from each spring complex. Passive diffusion samplers were deployed in each spring complex for two-week periods, six times per year.

The EAHCP provided the Watershed Partnership with general water quality data collected in 2016 and 2017. The water quality parameters included DO, pH, specific conductance (SC), temperature, and turbidity. A summary of the EAHCP data provided is shown in Table 5**.** In addition to general water quality parameters, the EAHCP also analyzed volatile organic compounds, pesticides, herbicides, metals, phosphorus, total organic carbon, dissolved organic carbon, total kjeldahl nitrogen, fecal *coliform* and fecal *streptococcus* bacteria (surface and stormwater samples), and caffeine.

Table 5: EAHCP 2016 Water Quality Data Provided to Watershed Partnership

Sample Location (Type of Monitoring)	Parameters	Timeframe	# of Data Points
Comal Spring 3 (Real-time)	DO, pH, SC, Temp, Turbidity	6/5/2016-12/31/2016	18,936 - 19,968
Comal Spring 3 (Grab samples)	DO, pH, SC, Temp, Turbidity	6/14/2016-12/21/2016	18
Comal Spring 7 (Real-time)	DO, pH, SC, Temp, Turbidity	6/5/2016-12/31/2016	18,732 – 19,042
Comal Spring 7 (Grab samples)	DO, pH, SC, Temp, Turbidity	6/14/2016-12/21/2016	18
Comal River (Real-time)	DO, pH, SC, Temp, Turbidity	6/5/2016-12/31/2016	19,240 - 20,152
Comal River (Grab samples)	DO, pH, SC, Temp, Turbidity	6/14/2016-12/21/2016	16
Landa Lake (Real-time)	DO, pH, SC, Temp, Turbidity	1/10/2017 – 5/12/2017	11,723 - 11923

Analysis of the general water quality data is provided in Appendix B. Generally, the data show a correlation between precipitation, a decrease in specific conductance and temperature, and an increase in turbidity.

2.8.3.1 Stormwater Sampling for Bacteria

Bacteria in stormwater samples collected as part of the EAHCP program provide an indication of the level of bacteria in watershed runoff to the Comal River. Two stormwater sampling events occurred in 2016 on April 12th to 13th and September 26th to 27th. Recorded rainfall for the April event was 1.00 to 1.49 inches and recorded rainfall for the September event was 3.00 to 3.99 inches. Stormwater samples generally had high concentrations of *E. coli*. The geomean for all stormwater samples collected within the Comal River system during April 2016 was approximately 3,999 CFU/100 mL; bacteria counts from stormwater samples in April 2016 ranged from 1,200 CFU/100 mL to 16,000 CFU/100 mL. The geomean collected from all stormwater samples within the Comal River system during September 2016 was approximately 6,029 CFU/100 mL; bacteria counts from stormwater samples in September 2016 ranged from

1,100 CFU/100 mL to 240,000 CFU/100 mL. Comparing to the data collected as part of this study (Table 4), the geomeans of stormwater samples approximately match the concentrations in the samples collected at Landa Lake in September of 2016, but are much lower than the stormwater samples collected downstream in the Comal River and in the Dry Comal Creek.

2.8.4 Bacteria Source Tracking

The City and GBRA also partnered to investigate potential sources of bacteria loading to the Dry Comal Creek and Comal River. In fall 2013, and again in fall 2016, the City commissioned GBRA and Texas A&M AgriLife Research to collect samples and perform bacteria source tracking analysis on the Dry Comal Creek and Comal River. The analysis of the isolated *E. coli* "fingerprints" collected on the Dry Comal Creek and Comal River were compared against the Texas *E. coli* BST library. At the time of sampling, the Texas *E. coli* Bacteria Source Tracking Library (version 6-13) included 1,524 isolates from 1,358 different fecal samples from over 50 animal subclasses which were collected from 13 watersheds across Texas. TAMU continues to expand the library and as of August 2016 it contained 1,765 isolates from 1,554 different fecal samples. Results from the BST analysis, described in detail in Section 4.3, indicate the source of *E. coli* in both waterbodies is primarily attributed to native and non-native wildlife.

2.9 Supplemental Monitoring

The Watershed Partners conducted supplemental monitoring (i.e., data collected in addition to the CRP *E. coli* and United States Geologic Survey (USGS) streamflow data collected and used to calculate pollutant loads and target pollutant load reductions). The City-GBRA data (Section 2.8.2) and EAHCP (Section 2.8.3) data provided additional information on base flow water quality, as well as stormwater water quality. These data sets provided sufficient data to characterize the Watershed, establish load reductions, and, if programs are continued at the current rate of sampling, will provide information in the future on the effectiveness of implementation of the WPP.

A limited number of samples were also collected and analyzed in 2013 using BST techniques (as described in Section 2.8.4). Through the WPP Stakeholder Group meetings, and other meetings the City conducted with the public in 2014 and 2015, there was significant interest in conducting additional BST sampling in the Watershed. Thus, the City conducted another round of BST analysis in 2016 to estimate relative contributions of bacteria pollution sources in 2016 compared to 2013. The cost of the 2013 and 2016 BST analysis in the Watershed was covered by the City, and the 2016 costs were used as match toward the FY2015 319(h) grant that funded this WPP. BST results are further described in Section 4.3.

2.10 Water Quality Activities in the Watershed

There are many activities taking place within the Watershed to better understand, protect, and improve water quality. Major initiatives include the City's new Stormwater Management Plan (SWMP) and the EAHCP, described below. Additional information on ongoing and planned activities in the Watershed is summarized in the Outreach and Education Plan in Section 6.

2.10.1 City of New Braunfels Municipal Separate Storm Sewer System Program

The City applied for and received Phase II Municipal Separate Storm Sewer System (MS4) permit coverage from the TCEQ in late 2014. As a result, the City has developed a SWMP that includes the following stormwater management measures:

- Public education and outreach,
- Public involvement or participation,
- Detection and elimination of illicit discharges,
- Controls for stormwater runoff from construction sites,
- Post-construction stormwater management in areas of new development and redevelopment, and
- Pollution prevention and "good housekeeping" measures for municipal operations.

The City is currently initiating practices consistent with the SWMP and new TCEQ Phase II MS4 permit, including routine street sweeping, development of an illicit discharge detection program, public outreach and education, construction stormwater management inspections, and implementation of housekeeping measures at municipal facilities. The City will continue to develop and expand this existing MS4 program, which will be supplemented by new or additional BMPs recommended in this WPP[6].

2.10.2 Edwards Aquifer Habitat Conservation Plan Projects

The EAHCP is a regional effort to protect endangered and threatened species that live in the Comal and San Marcos River systems. The City is a partner on the EAHCP and is responsible for implementing habitat protection measures that benefit the species in the Comal River system. Specific EAHCP projects that are ongoing in the City include riparian restoration, aquatic plant restoration, and water quality improvement projects. A water quality planning document was prepared on behalf of the City in 2017 that identifies stormwater controls that can be implemented to minimize NPS pollutant loading. The stormwater controls are intended to be implemented throughout the term of the EAHCP program (i.e., through 2027).

Additionally, the EAHCP includes a water quality monitoring program (implemented in 2013) to detect water quality impairments that may negatively impact listed species. If certain constituents of concern are detected at levels indicating the potential for adverse effects, BMPs will be identified to eliminate those constituents. The data collected as part of this program are

[6] The City is fully aware and appreciates that §319 funding cannot be used to implement MS4 regulatory activities. The information developed through the City's MS4 program will be considered, but not duplicated, in the §319 projects related to this WPP. Section 319 funding will not be used for MS4 regulatory activities; the WPP activities will go above and beyond the MS4 program (which focuses just on stormwater discharges) by implementing the holistic, across-the-board activities identified in the WPP. This WPP establishes BMPs based on the Watershed characteristics, including addressing NPS items of concern not necessarily associated with stormwater. Further, this WPP focuses on the entire Watershed, which extends well outside the limits of the City.

valuable to understand water quality in the Watershed and provide information on constituents other than bacteria that may be a concern. These data are collected and evaluated as part of this WPP (refer to the water quality discussion in Section 2.8.3 and Appendix B).

2.10.3 Other Water Quality Projects

Additional projects the City has completed or is in the process of completing include:

- The City has initiated studies and projects (e.g., Panther Canyon Low Impact Development and Landa Park and Golf Course Improvements) to improve water quality in the Watershed. For example, the new golf course was designed and constructed to divert runoff away from the river.
- The City is also undertaking several low impact development (LID) projects.
- NBU is leading the funding and development of a new environmental facility near the headwaters of the Comal River. The “Headwaters at the Comal” will establish a relationship between the community and the environment by demonstrating the regeneration and protection of water and ecological resources (refer to Section 6.18 for more information).
- NBU maintains an aggressive sanitary sewer overflow (SSO) program for inspecting, cleaning and repairing its wastewater collection system.
- The City has taken proactive measures to begin outreach and education in the community (refer to Section 6 for more information).
- The City established a dog park with pet waste stations and has also installed pet waste stations in certain areas of the City.

3. Comal Watershed Stakeholder Process

Prior to starting development of the WPP, the City was already facilitating two stakeholder groups. Those groups met periodically to discuss the status of water quality of the Dry Comal Creek and the Comal River, as well as activities within the Watershed. These two groups included:

- **Watershed Advisory Committee (WAC) –** A Council-appointed committee that serves in an advisory capacity to the City on matters relating to watershed management. Membership requirements are one engineer, one developer, one landscape planner, one architect or arborist, one business representative, one representative of biological or environmental interests, one citizen at-large, one agricultural or landowner within the Watershed, and two representatives from different homeowners' associations. The WAC was formed in February 2011 with members serving three-year terms. The WAC is still active, and is a separate committee from the Stakeholder Group formed for this WPP.
- **Watershed Water Quality Work Group (WWQWG) –** This volunteer group was formed in October 2013 in response to increasing bacteria levels in the Comal River and the listing of Dry Comal Creek as an impaired river segment on the 303(d) list in 2010. Members include EAA, GBRA, the City, New Braunfels Chamber of Commerce, New Braunfels Utilities (NBU), and local businesses. The WWQWG is no longer active, as it was transformed and expanded into the Stakeholder Group formed for this WPP.

3.1 Formation of the WPP Stakeholder Group

The WPP Stakeholder Group for this WPP was formed by first gathering members of the WWQWG to discuss the goals and objectives of the WPP Project and to identify additional stakeholders to supplement the WWQWG. The goal was to form a group of diverse interests and backgrounds to provide input and guidance for the development and implementation of the WPP, such as potential sources of bacteria in the Watershed and public outreach activities. The WPP Stakeholder Group was eventually comprised of approximately 25 interest groups, with one to three representatives per group.

The interests represented by the WPP Stakeholder Group include local businesses (tourism and river recreation, Chamber of Commerce, etc.), NBU, developers, neighborhood associations, agricultural interests, wildlife/conservation groups, and citizens with an interest in the Watershed. Affected City departments, such as Public Works, Public Communication, and Parks and Recreation, are also included.

A Technical Advisory Group (TAG) was also established. Technical advisors, which are stakeholders or project participants with specific technical expertise, also participated in the WPP and provided technical information to support the analyses of water quality and bacteria sources, selection of BMPs, and the development of the WPP. The TAG includes representatives from GBRA, EAA, City of New Braunfels Watershed Management, Texas Parks and Wildlife Department (TPWD), Comal County, Texas State Soil and Water Conservation Board (TSSWCB), Texas A&M AgriLife Extension Service ("Texas A&M AgriLife"), and the United States Department of Agriculture (USDA).

Collectively, the Stakeholder Group, TAG, the City, GBRA, and EAA form the Dry Comal Creek and Comal River Watershed Partnership ("Watershed Partnership"). The Watershed Partnership collaborated to complete both the Watershed characterization and develop this WPP. Additionally, the Watershed Partnership will continue to collaborate throughout the implementation of this WPP.

3.2 WPP Stakeholder Process

The WPP Stakeholder Group met three times during the 12-month Phase 1 portion of the Project. A summary of the meeting dates and discussions of each meeting is provided in Table 6. The general goals of these three stakeholder meetings were as follows:

- To establish a WPP Stakeholder Group that can function throughout both phases of the WPP Project;
- To provide the Stakeholder Group with data and results of analyses related to water quality in the Watershed and the sources of bacteria;
- To begin brainstorming how to share the results of the WPP with the public; and
- To collect input from stakeholders on activities and sources of pollution in the Watershed.

Table 6: Summary of WPP Stakeholder Group Meetings in Phase 1 of the Project

Meeting Date	Key Goals and Discussion Items
November 9, 2015	• Met with the WWQWG • Reviewed the City's activities in the Watershed over the previous several years that were aimed at understanding and improving water quality • Discussed goals and phases of the WPP • Identified new interests/members to invite to participate in the WPP Stakeholder Group (in addition to WWQWG members)
February 17, 2016	• Introduced the expanded WPP Stakeholder Group (i.e., WWQWG plus recently added members to expand representation) • Reviewed the WPP goals and status • Reviewed historical *E. coli* and BST data for the Watershed • Discussed results of LDCs developed for the Watershed, which identify bacteria loading in the Dry Comal Creek and Comal River (see Section 4.1)

Table 6: Summary of WPP Stakeholder Group Meetings in Phase 1 of the Project (Continued)

Meeting Date	Key Goals and Discussion Items
May 5, 2016	• Presented and discussed results of analyses to identify bacteria pollution sources within the Watershed • Discussed the transition from Phase 1 to Phase 2 of the WPP development • Discussed regulatory framework for the WPP (i.e., Texas Surface Water Quality Standards)

Through the Phase 1 activities, the Watershed Partnership and Stakeholder Group identified several beneficial changes to the stakeholder process, which were implemented at the beginning of the second phase. Changes, focused on increasing participation and involvement, included:

- A professional facilitator was hired by the City to assist with meeting organization and facilitation, and to optimize stakeholder input;
- Stakeholders agreed to be divided into four Work Groups (Figure 26) that met separately to focus on specific aspects of the WPP;
- Stakeholder and Work Group meetings were made more accessible to the public by additional advertising and advance notice;
- Meeting materials for stakeholders and the public were posted in advance of the meetings; and
- A questions/comments section was added to the end of each meeting.

Figure 26: Stakeholder Work Groups

Each Work Group met separately from the stakeholder meetings to focus on selection and development of source-specific BMPs, or outreach and education activities in the case of the Outreach and Education Work Group. A summary of the Stakeholder Group and Work Group meetings conducted in Phase 2, along with key goals and discussion topics for each meeting is provided in Table 7. Although not noted in the table, a public comment period was provided at the end of each meeting. In addition, the City hosted a half-day Watershed Stewardship seminar on February 7, 2017. The seminar was presented by the Texas A&M AgriLife Extension Service, and members of the Stakeholder Group attended.

Table 7: Summary of WPP Stakeholder and Work Group Meetings in Phase 2 of the Project

Meeting Date	Key Goals and Discussion Items
October 24, 2016 Stakeholder Meeting	• Updated group on completion of the Phase 1 Report and kick-off Phase 2 of the WPP • Introduced Adisa Communications as the meeting facilitator for Phase 2 • Provided an update on the 2016 BST sampling • Introduced the stakeholder Work Group concept, asked stakeholders to confirm number and type of Work Groups and to sign up for at least one Work Group • Reviewed the Phase 2 schedule and milestones
December 5, 2016 Work Group Meeting #1	• Reviewed the contents of a WPP and required EPA nine elements to be included • Provided examples of BMPs • Introduced the Work Group members based upon sign-ups from previous meeting • Presented the Work Group meeting schedule • Presented data and information available to Work Group members to aid in BMP and outreach and education activity selection
January 27 and 31, 2017 Work Group Meetings (met separately / independently)	• Reviewed information on pollution sources, *E. coli* concentrations, and BST data • Drafted and prioritized a list of BMPs and outreach and education activities
March 7, 2017 Stakeholder Meeting	• Presentation by Texas A&M AgriLife Extension (Ward Ling) on NPS pollution control strategies implemented in the Geronimo and Alligator Creek WPP • Reviewed the lists of BMPs and outreach and education activities developed by Work Groups • Reviewed results of the 2016 BST analyses • Discussed and approved the draft list of BMPs and outreach and education activities
April 5, 2017 Outreach and Education Work Group Meeting	• Finalized the details of the recommended outreach and education activities • Prepared a “Core Message” for the WPP (refer to Section 6.2)
June 22, 2017	• Reviewed and approved the draft Dry Comal Creek and Comal River WPP*

* Stakeholders were provided a week after the meeting to submit additional comments and questions. Responses to all comments were provided to stakeholders electronically with the final draft of the WPP, which incorporated the Stakeholder Group’s comments.

4. Watershed Characterization

The Watershed was characterized to establish *E. coli* load reduction targets, potential *E. coli* pollution sources, and likely locations of the pollution sources. Flow duration curves (FDCs) and LDCs for the Dry Comal Creek and Comal River were developed to understand *E. coli* bacteria loading in the two waterbodies under the range of historic flows measured. Next, the 2013 BST data were reviewed to identify the bacteria sources contributing the largest fractions of *E. coli* in the Watershed. Lastly, land use and land cover were identified and mapped across the Watershed, and subwatersheds were delineated. The approximate locations of bacteria sources were estimated based upon the land types and data on animal concentrations in the Watershed.

4.1 Methodology for Estimating Pollutant Loads

Pollutant loads are the amount of a pollutant passing a cross-section of a river or stream in a specific amount of time, expressed as mass per interval of time. Because the pollutant of concern in this Watershed is bacteria, the *E. coli* loading in the Dry Comal Creek and Comal River was evaluated using LDC analyses. LDCs are a methodology to determine pollutant loadings under varying flow conditions. The LDC approach has been used in the development of many Total Maximum Daily Loads (TMDLs) and WPPs as a screening tool to evaluate temporal trends and pollutant loading in streams (EPA, 2007a; Cleland, 2003).

LDCs are developed using historic streamflow and measured water quality data for a particular pollutant of concern. The data are then graphed to represent pollutant loads associated with varying streamflow conditions. The first step in generating an LDC is to develop an FDC. An FDC is typically developed prior to developing an LDC, because the streamflow values and their frequencies of occurrence, as displayed in an FDC, are used to calculate the load of a particular pollutant over time, given measured concentrations of the pollutant.

4.1.1 Flow Duration Curves

An FDC shows measured streamflow rates (expressed as volume per time [e.g., cfs]) versus the frequencies of occurrence. An FDC, for instance, may be developed for a particular site using historical mean daily streamflow measured at the site over time. These daily streamflow time series data are compiled and ranked in order from the highest to lowest (i.e., the highest streamflow value has a rank of 1). The rank of each value is then used to calculate an associated frequency of occurrence based upon the range of values in the data set.

The frequency of occurrence is expressed as an exceedance probability or percent chance a particular streamflow value will be exceeded. The exceedance probability is calculated using the following formula, where P is the percent chance of exceedance, M is the rank of a streamflow value, and N is the total number of streamflow values (or count of values) in the data set.

$$P = 100 [M/(N + 1)]$$

A graph can then be plotted to show each streamflow value versus the associated frequency of its occurrence. An example of an FDC (not specific to the Dry Comal Creek or Comal River) is shown in Figure 27. Interpretation of the example FDC in Figure 27 indicates that, as expected, high streamflows (expressed as mean daily discharge in cfs) are exceeded less frequently than lower streamflows. More specifically, for the example given below, high streamflows (≳ 700 cfs) occurred in less than 10 percent of the flow measurements collected over the period, while lower streamflows (≲ 500 cfs) occurred in more than 75 percent of the measurements.

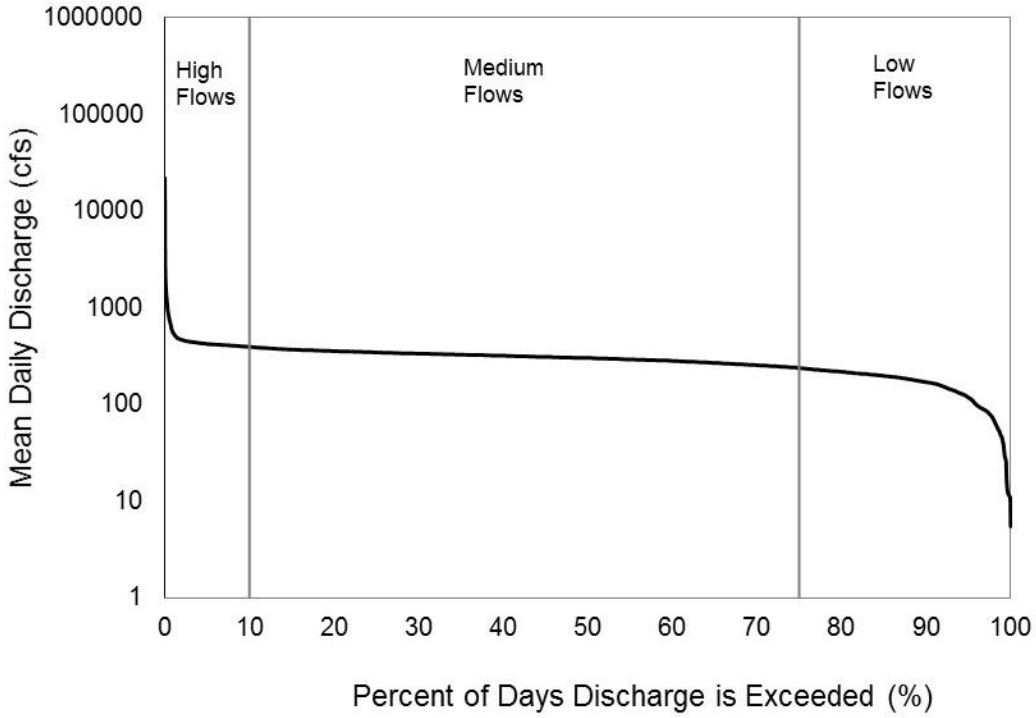

Figure 27: Example Flow Duration Curve

As depicted by the vertical lines at the 10 percent and 75 percent exceedances on the x-axis in Figure 27, FDCs may be divided into high, medium and low flow classes. In this example, the 10 percent exceedance probability represents the threshold above which higher streamflows occur less than 10 percent of the time. These are the highest streamflows in the data set, which occur less often. Similarly, for this example, the 75 percent exceedance probability represents the threshold below which lower flows are exceeded more than 75 percent of the time. These are the lowest streamflows in the data set, which occur more often. The streamflows that occur

more than 10 percent of the time but less than 75 percent of the time, represent the medium flow class, meaning these flows are moderate in magnitude and occurrence frequency for the dataset. However, the cutoff percentage for each flow class may vary from one watershed dataset to the next. The cutoffs are generally placed at the locations where the slope of the line changes. In other words, the medium flow class should generally represent the portion of the curve that has a constant slope.

4.1.2 Load Duration Curves

Like FDCs, LDCs are a type of duration curve. An LDC graph shows the maximum pollutant load (amount per unit time; e.g., for bacteria, cfu/day) a stream can assimilate across the range of flow conditions (low flow to high flow) without exceeding the water quality standard. The foundation of an LDC is an FDC, which, as described in Section 4.1.1, shows the percentage of time a particular streamflow rate is equaled or exceeded.

Using the flow frequency probabilities calculated for the FDC, an LDC can be developed to estimate the corresponding relationship between the load of the water quality parameter (i.e., the pollutant load) and streamflow. To generate the LDC, concentration data measured for the water quality parameter are multiplied by streamflow rates and a series of conversions to produce a mass of the water quality parameter or pollutant load at each flow exceedance probability. *E. coli* loads, specifically, can be calculated using measured *E. coli* concentrations at a particular sampling site using the following formula, where A is equal to the measured concentration in CFU/100 mL and B is equal to streamflow in cfs.

Measured *E. coli* Load (CFU/day) = *[**A** (CFU/100 mL)] x [(28,317 mL/1 ft^3)] x [**B** (ft^3/second)] x [(86,400 seconds/1 day)]*

Using this approach, LDCs can be developed for measured and target pollutant concentrations to determine loads for each. The target load for this WPP was determined by applying a margin of safety (MOS) to the water quality standard for a given pollutant. A 10 percent MOS was applied to the *E. coli* criterion of 126 CFU/100 mL for contact recreation. As shown in the formula below, the target load is thus 10 percent less than the water quality standard. An MOS may be applied to the water quality standard to produce a target load that accounts for uncertainties, such as those that are inherent in streamflow and pollutant concentration measurements, as well as calculated exceedance probabilities.

Target *E. coli* Concentration (CFU/mL) = *[(126 CFU/100 mL) - (0.1 x 126 CFU/mL)]* = ***113 CFU/mL***

Once measured and target loads have been computed, these can be plotted on the same graph where the x-axis represents the frequency of occurrence and the y-axis represents the load, as shown in the example presented in Figure 28. A “line of best fit” can then be plotted through the measured load data points using a regression analysis to estimate the measured load at all exceedance probabilities (i.e., even when no measured data exist).

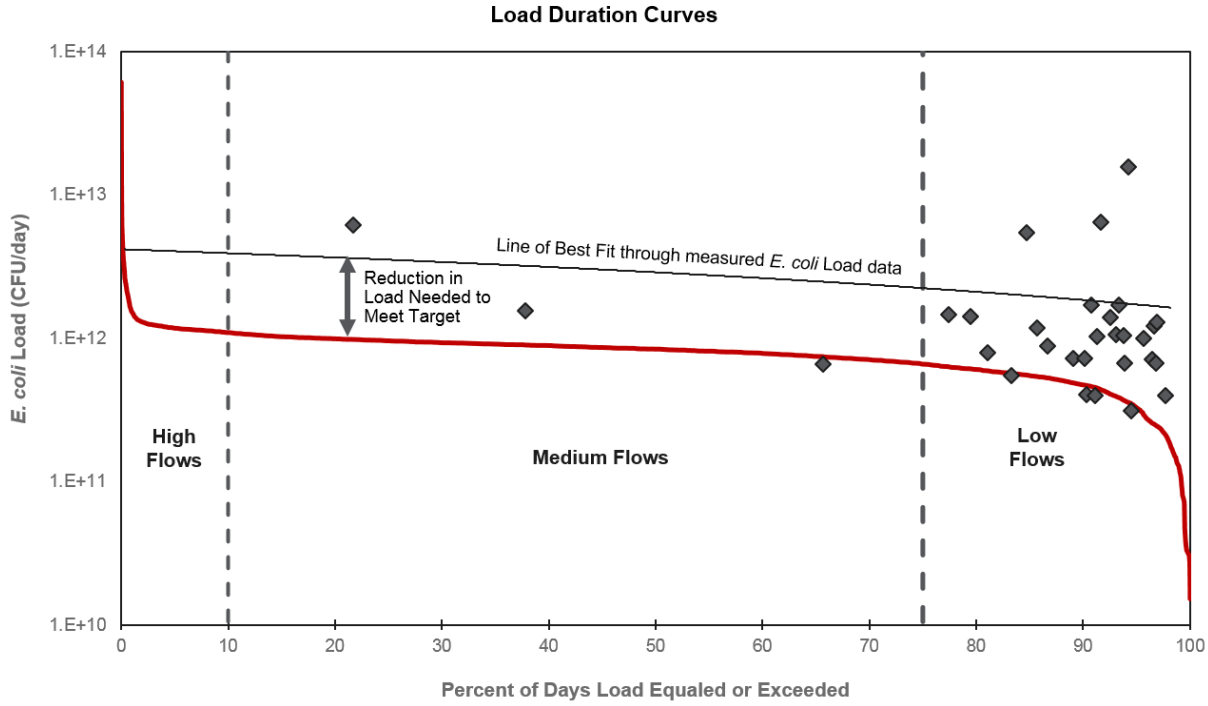

Figure 28: Example Load Duration Curve

In the example LDC presented in Figure 28**,** the red line represents the maximum acceptable stream load for *E. coli,* the black line represents the line of best fit through the measured *E. coli* load, and the diamonds are the water quality data collected under all flow conditions. The difference between the line of best fit for the measured load and target load can then be averaged for each flow class (high, medium and low flows) to determine the required reduction in pollutant loading at different flow classes.

4.2 Results of Pollutant Load Analysis for the Dry Comal Creek and Comal River

Historical streamflow and *E. coli* concentration data were used to develop LDCs for the three TCEQ CRP sampling sites in the Watershed. Streamflow data in the form of measured mean daily discharge were obtained from the USGS National Water Information System (NWIS) database for three existing stream gages in the Watershed. The locations of the CRP sample sites and USGS gages are illustrated in Figure 29**.**

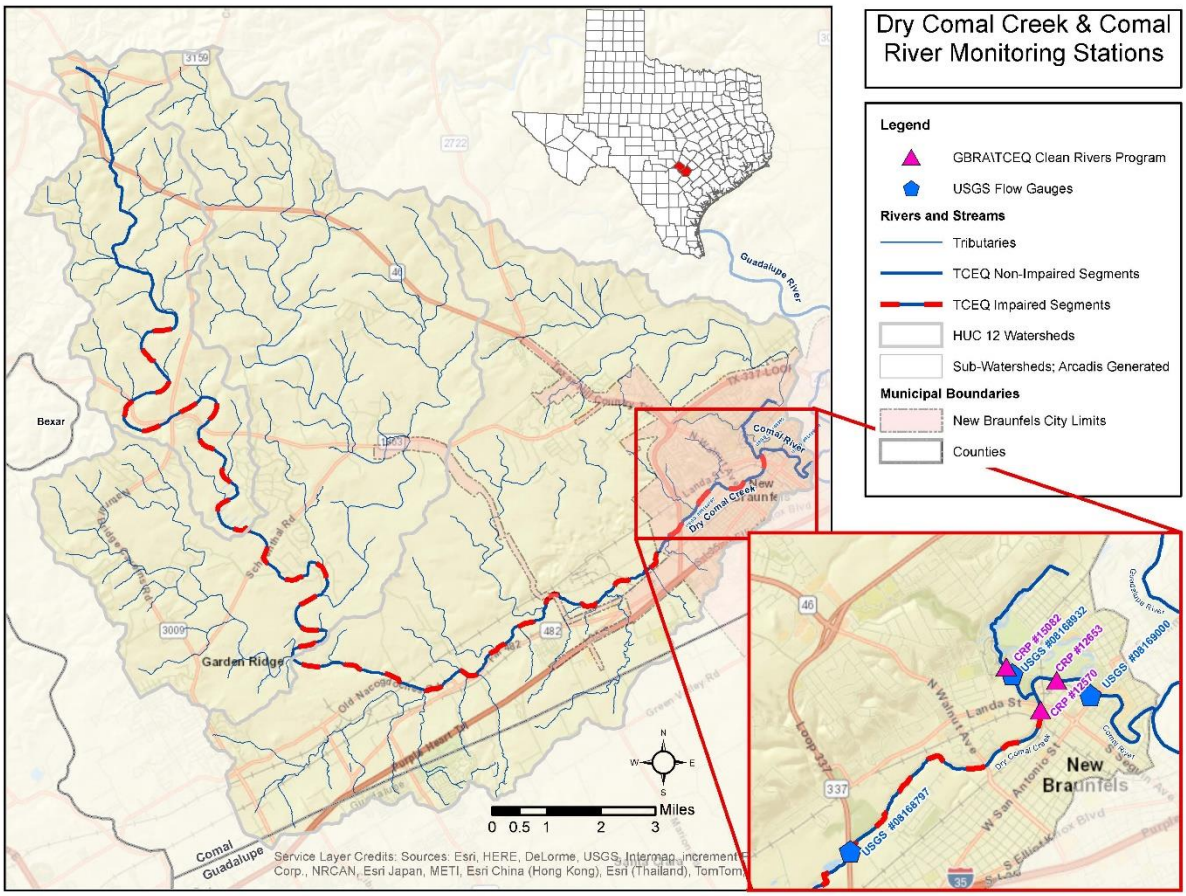

Figure 29: Map of CRP and *E. coli* Sampling Locations and USGS Flow Gages

Bacteria loads were determined using the LDC approach for each of the three CRP water quality sampling sites within the Watershed. Historical *E. coli* concentration data were used, in addition to measured mean daily streamflow at USGS gages near the CRP sites as described below, to develop FDCs and LDCs for the Watershed.

- CRP 12570 (Dry Comal Creek at Seguin St.) – The closest USGS gage to this site is USGS gage 08168797 (Dry Comal Creek at Loop 337). There are several tributaries between this USGS gage and the CRP site; therefore, the Loop 337 flow data were expected to underestimate the flows at the Seguin St. sampling location. To assess this theory, historical grab sample flow data measured at the CRP 12570 site were compared to USGS gage data at the Dry Comal Creek at Loop 337. On average, the flow values measured at Seguin St. were 50 percent higher than the flow rates measured at the Dry Comal Creek at Loop 337. Therefore, for this analysis, the FDC was developed using 1.5 times the flow rates measured at USGS gage 08168797.
- CRP 15082 (Comal River at Landa Park) – Used USGS gage 08168932 (Comal River near Landa Lake) data as reported.

- CRP 12653 (Comal River at Hinman Island) – Because the closest USGS gage to this site is downstream of the CRP sample location and downstream of the confluence of the old river channel and the Comal River (i.e., USGS gage overestimates the flow at this location), two upstream gages were used. The sum of the flow data from USGS gages 08168932 (Comal River upstream of confluence with the Dry Comal Creek) and 08168797 (Dry Comal Creek) were used to estimate the historic flow rates at CRP 12653 and develop the FDC and LDC.

The *E. coli* data period of record used in the LDC analyses is seven years (84 months of monthly data) from February 2009 through January 2016. This period of *E. coli* data was selected for this WPP because it corresponds to the period of record likely to be used by TCEQ, in part, to determine compliance with the *E. coli* water quality standard for results published in the pending Texas Integrated Report of Surface Water Quality (2016). All CRP data can be accessed via TCEQ's CRP Data Tool located on the TCEQ website.

The target period of record for streamflow data is the maximum amount of daily streamflow data available for the USGS gage sites. The maximum amount of streamflow data was selected to improve confidence in estimated exceedance probabilities associated with each streamflow data set. The periods of record used in development of the Dry Comal Creek and Comal River LDCs and FDCs presented herein are summarized below in Table 8.

Table 8: *E. coli* and Streamflow Data Used in CRP Site LDCs

Location	Data Type	Source	Site No.	Site Name	Period of Record Available as of May 2016		Period of Record Used in LDC Analysis	
					Start Date	End Date	Start Date	End Date
Dry Comal Creek	*E. coli*	CRP	12570	Dry Comal Creek at Seguin St.	1996-10-14	2016-01-04	2009-02-02	2015-09-01
	Flow	USGS	08168797	Dry Comal Creek at Loop 337 near New Braunfels, TX	2006-03-03	2015-09-22	2006-03-03	2015-09-22
Upper Comal River	*E. coli*	CRP	15082	Comal River at Landa Park	2014-05-05	2016-01-04	2014-05-05	2015-03-09
	Flow	USGS	08168932	Comal River (nc) near Landa Lake, New Braunfels, TX	2011-10-01	2015-03-31	2011-10-01	2015-03-31
Lower Comal River	*E. coli*	CRP	12653	Comal River at Hinman Island	1996-10-14	2016-01-04	2011-10-12	2015-03-09
	Flow	USGS	Sum of USGS gages 08168797 and 08168932	Comal River at CRP site 12653	2011-10-01	2015-03-31	2011-10-12	2015-03-31

4.2.1 Flow Duration Curves

The FDCs developed for the CRP locations, based on the approach described above, are illustrated in Figure 30. The FDCs for the three CRP sites illustrate the following, based on the dataset:

1. The Comal River upstream and downstream of the confluence with Dry Comal Creek (blue and pink lines in Figure 30, respectively) flows at approximately 300 cfs more than 95 percent of the time. The relatively-consistent 300 cfs flow rate is due to the springflow from Comal Springs that provides most of the flow to the river. To some extent, flow through small channel dams located within the river system may also impact measured flow rates.
2. The historical flow rates measured in the Dry Comal Creek are typically one to two orders of magnitude lower than the flow rates measured in the Comal River more than 95 percent of the time.
3. The flow rates measured in the Dry Comal Creek are less than 0.1 cfs approximately 35 percent of the time. Flow rates in the Dry Comal Creek are primarily dependent upon precipitation in the Watershed.

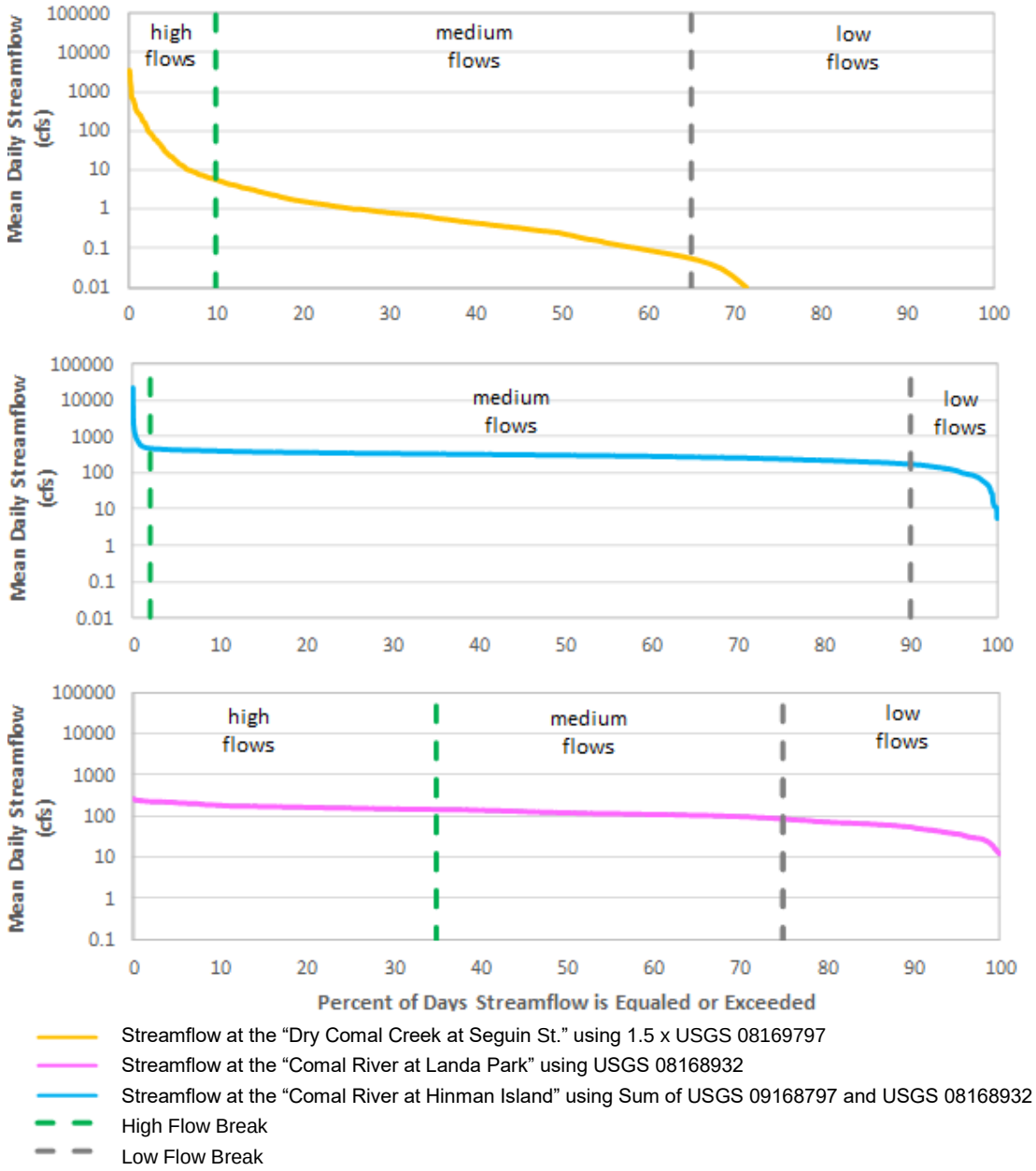

Figure 30: Flow Duration Curves Developed for Three CRP Sites

4.2.2 Load Duration Curves

LDCs were developed for the three CRP sites and the measured data sets listed in Table 8 to evaluate *E. coli* bacteria loads and to determine load reductions required to meet water quality goals or the target load (Figure 31 through Figure 33). In each of the LDC figures, the red line represents the *E. coli* target load (based on an *E. coli* concentration of 113 CFU/100 mL [refer to Section 4.1.2]) and the black line represents the line of best fit through the measured *E. coli* loads.

The percent reduction required to reduce the loads from the line of best fit to the target load was calculated for each flow class (high, medium and low) and the median reduction required for each flow class is displayed on the charts. In other words, as shown in Figure 31, at high flows, bacteria loading needs to be reduced by 93 percent (median) in the Dry Comal Creek to meet the target *E. coli* concentration of 113 CFU/100 mL. At medium flows, bacteria loading needs to be reduced by 34 percent.

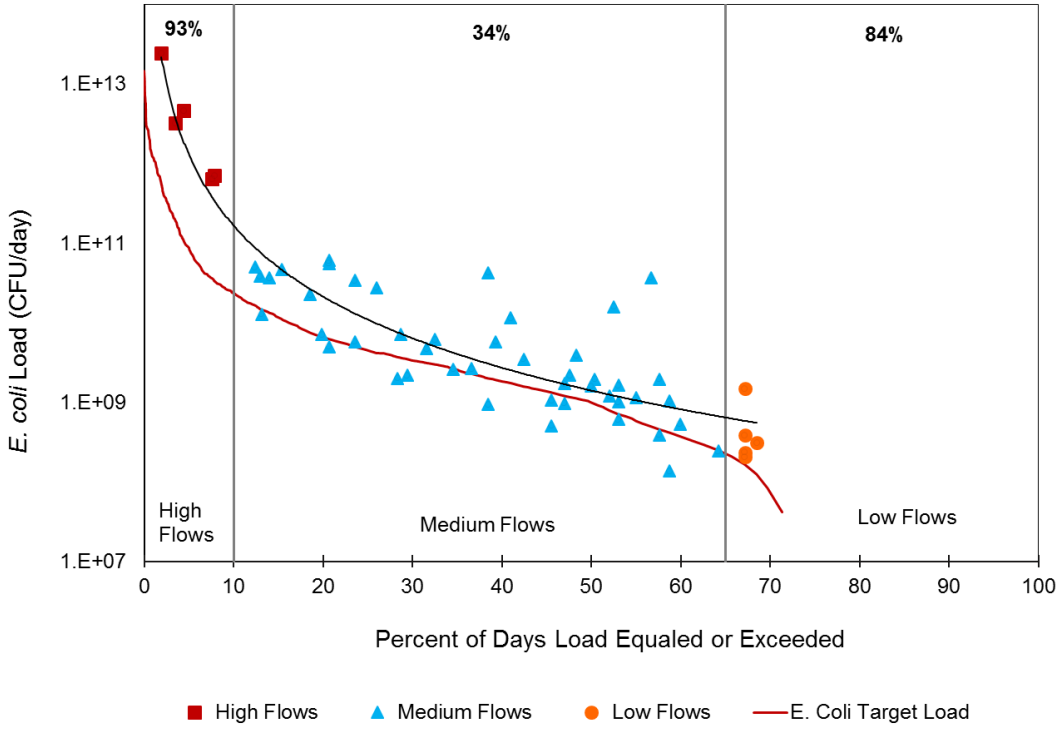

Figure 31: LDC for CRP Site 12570: Dry Comal Creek at Seguin St.

Target load reductions calculated for CRP Site 15082 (Comal River at Landa Park), are 55 percent at high flows, 45 percent at medium flows, and 0 percent at low flows. As shown in Figure 32, because this site was recently added to the CRP, the *E. coli* data set is limited.

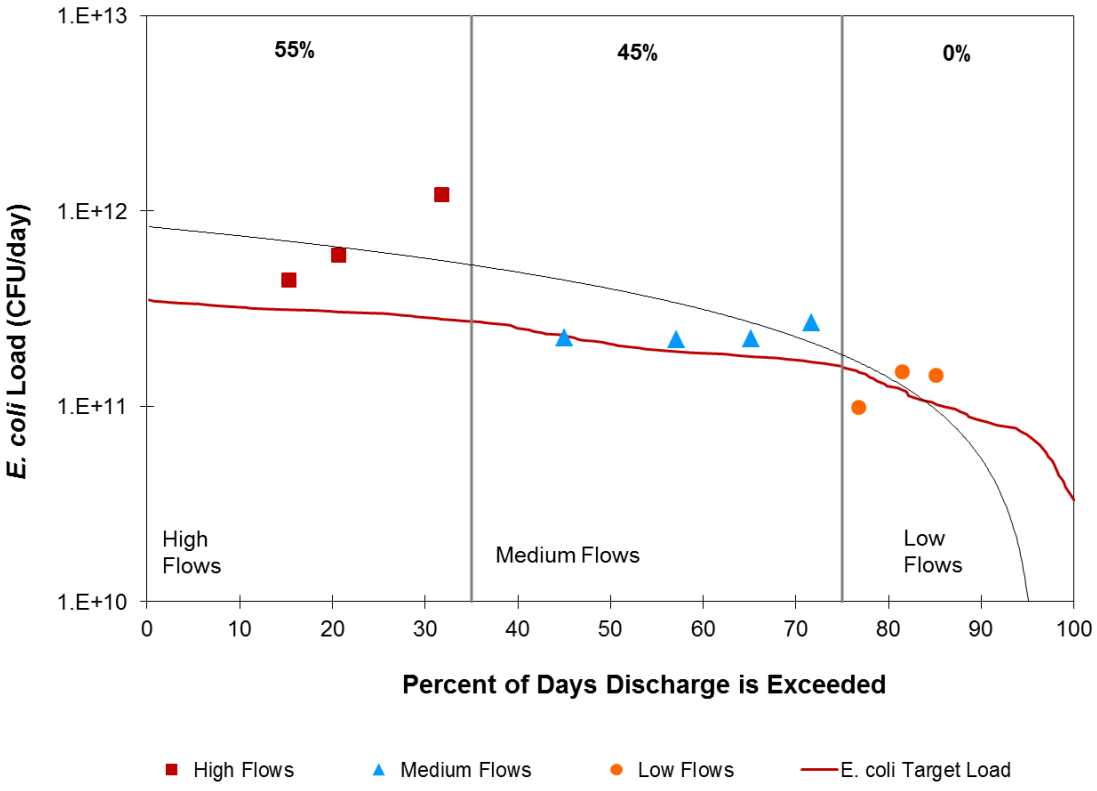

Figure 32: LDC for CRP Site 15082: Comal River Near Landa Lake, New Braunfels, Texas

The target load reductions at CRP Site 12653 (Comal River at Hinman Island) shown in Figure 33, at high and medium flows are 75 percent and 50 percent, respectively. The target load reduction at low flows is 66 percent to meet the water quality goal of 113 CFU/100 mL.

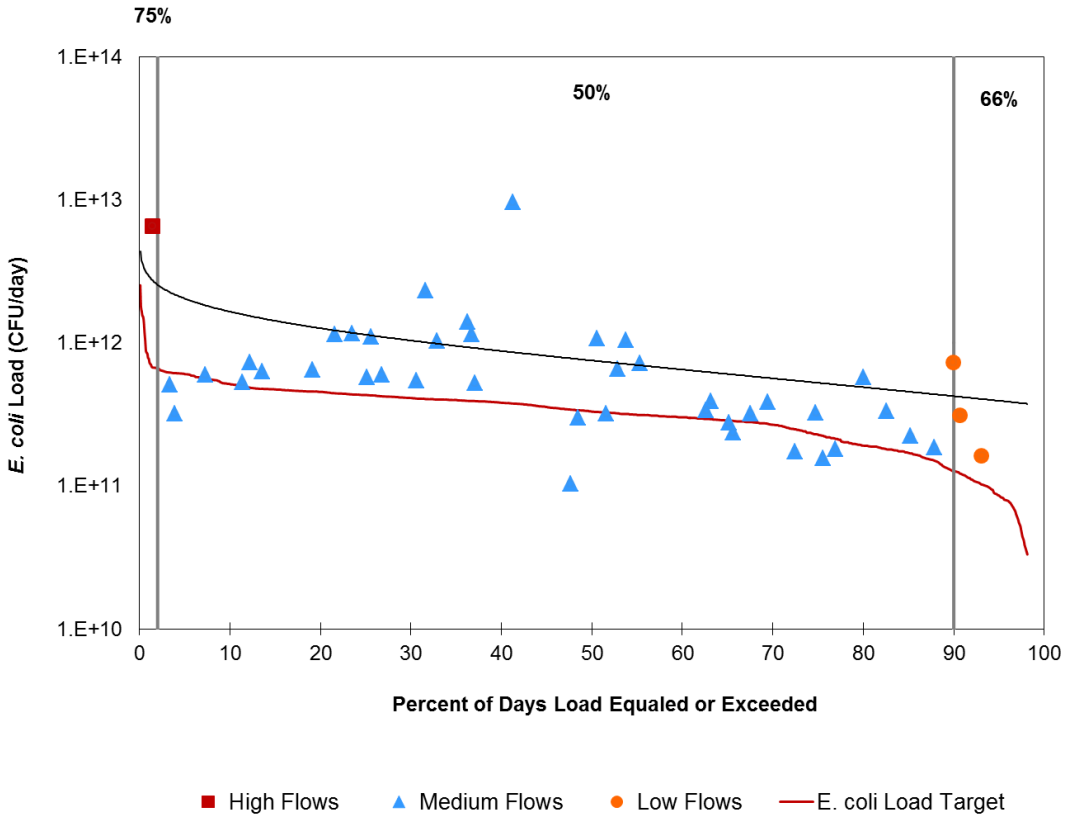

Figure 33: LDC for CRP Site 12653 - Comal River at Hinman Island

While the concentrations of *E. coli* in the Dry Comal Creek are relatively high, the streamflows are relatively low compared to the Comal River, as shown in the summary of all three LDCs in Figure 34. While the Dry Comal Creek provides *E. coli* loads to the Comal River, the *E. coli* loads in the Comal River upstream of the confluence with the Dry Comal Creek are orders of magnitude higher than those estimated in the Dry Comal Creek. This indicates the sources of bacteria in the Comal River are not limited to those coming from the Dry Comal Creek. However, a reduction in *E. coli* loads in the Dry Comal Creek will have a positive impact on *E. coli* loads in the Comal River downstream of the confluence.

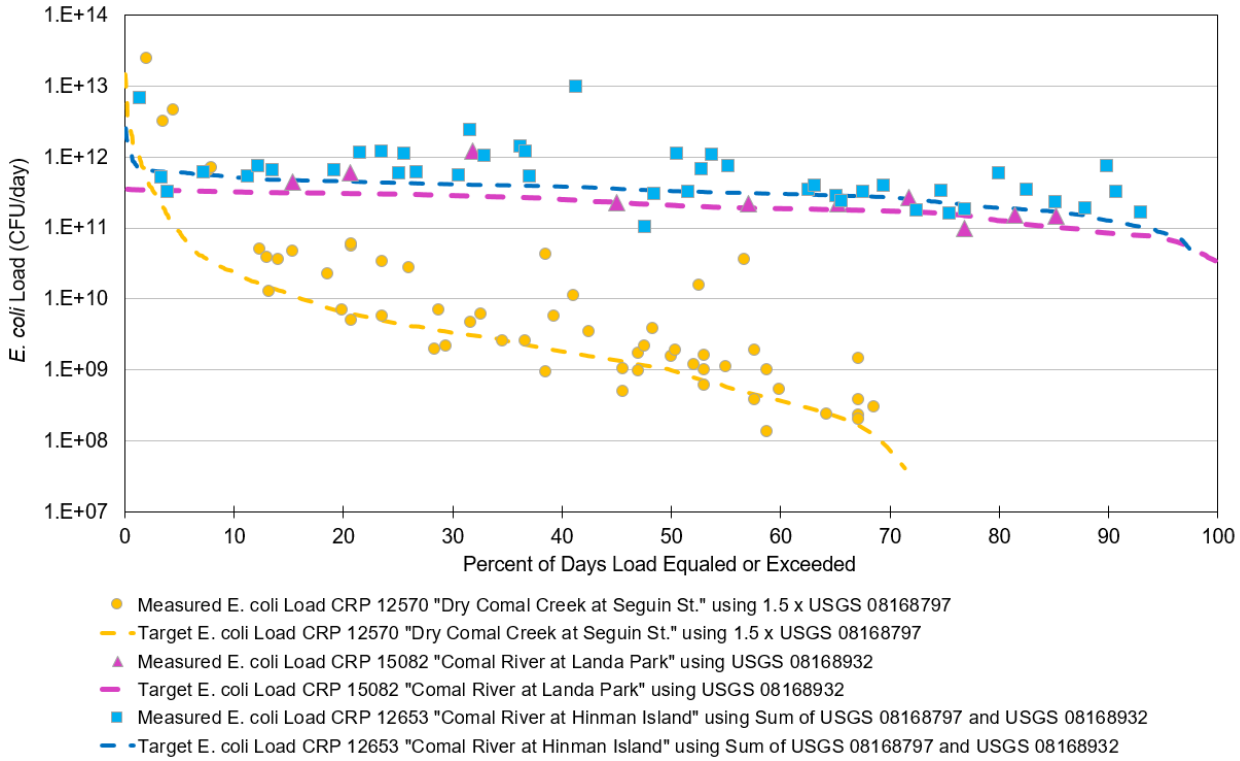

Figure 34: Comparison of LDCS for the Three CRP Sampling Locations in the Watershed

4.2.3 Estimated Required Load Reductions

A target *E. coli* concentration of 113 CFU/100 mL was selected as the goal for water quality in the Watershed (refer to Section 4.1.2 for details). For Watershed planning purposes, average annual *E. coli* load reduction targets were computed for two of the CRP sites (Site 12570 – Dry Comal Creek at Seguin St. and Site 12653 – Comal River at Hinman Island). These two sites will be used as target reduction locations because they are representative of current Watershed conditions. The CRP site on the Dry Comal Creek was selected because the segment is listed as impaired according to the 2014 303(d) List. The Comal River CRP site downstream of the confluence of Dry Comal Creek with the Comal River was also selected for determining target load reductions because this site represents the largest proportion of the Watershed's drainage area (compared to the other CRP sites) and because this CRP site best represents the area of the Comal River that is heavily used for primary contact recreation during the warm months of

the year. CRP Site 15082 (Landa Park) was not used due to limited available data (see Table 8).

The final load reductions determined for CRP site 12570 and site 12653 for the medium flow classes are 34 percent and 50 percent, respectively (Table 9). Target reductions for *E. coli* loads are based on the median reductions needed to meet the target for the medium flow class, which is the range of flows for which the effective implementation of management measures is considered feasible. Goals for BMPs selected for implementation as part of this WPP were established, in part, based upon the associated potential *E. coli* load reduction estimated in relation to these target load reductions.

Table 9: Median Annual and Daily Load Reduction Targets

Site	Median *E. coli* load Reduction Needed to Meet Target (For Medium Flows)		
	%	Annual Load (CFU/year)	Daily Load (CFU/day)
Dry Comal Creek at CRP 12570 (Seguin St., formerly Knights of Columbus)	34	3.92×10^{11}	1.07×10^{9}
Comal River at CRP 12653 (Hinman Island, formerly Clemons Dam)	50	1.28×10^{14}	3.50×10^{11}

4.3 Sources of Bacteria Pollution in the Dry Comal Creek and Comal River

As previously discussed, *E. coli* bacteria are associated with the fecal material of warm-blooded animals; therefore, BST sampling was conducted to estimate bacteria loading from various sources of warm-blooded animals in the Watershed. BST methods are described in Section 2.8.4. In 2013 and 2016, the City conducted BST sampling to provide preliminary information on the sources of bacteria in the Watershed.[7] Both sampling events took place in September and/or October. In 2013, three BST sampling events were conducted by the City at two locations (Dry Comal Creek at Seguin St. and Comal River at Hinman Island). Three additional sampling events were conducted at these two locations in 2016, and in 2016, one new sampling location was added (i.e., Comal River at Landa Park). Table 10 summarizes the median percent of *E. coli* measured in BST analysis, which was used to assess the load reduction required per source (see Section 5.3.1 for details)

[7] The 2013 BST sampling was not funded under the FY2014 319(h) project grant, but the 2016 BST sampling was counted as match for the City in the FY2015 319(h) grant.

Table 10: Median Percentage of *E. coli* Measured in BST Analysis

E. coli Source[1]	Comal River (%)	Dry Comal Creek (%)
On-site Sewer Facilities	1.3%	2.5%
Pets	4.0%	4.0%
Deer	34.0%	25.9%
Urban Non-Native Avian Wildlife	17.0%	21.5%
Livestock	16.0%	25.0%
Feral Hogs	14.6%	11.1%
Wastewater	1.3%	2.5%
Unidentified	11.9%	7.4%
Total	**100%**	**100%**

1 – The portion of bacteria contributed by humans is likely due to OSSFs, wastewater, and other sources (e.g., dumping, transient populations, etc.). It is unclear what percentage of human *E. coli* comes from each of these sources. Thus, it was assumed the human contribution of *E. coli* is 33 percent from OSSFs, 33 percent from wastewater, and 34 percent from other sources. Non-avian wildlife was assumed to be 70 percent deer and 30 percent feral hogs, based upon stakeholder knowledge and SELECT.

The 2013 and 2016 BST results are compared in Figure 35 and Figure 36. Figure 35 illustrates the data for a 3-way split, which differentiates between *E. coli* bacteria from humans, wildlife, and livestock and pets. The BST results indicate that 45 to 60 percent of the bacteria in the 2013 samples were from wildlife, compared to 65 to 70 percent from wildlife in 2016. The second largest bacteria source was livestock and domestic animals. In the 2013 samples, 20 to 40 percent of bacteria were from livestock and domestic animals compared to 15 to 25 percent in 2016. The relative decrease in bacteria from livestock correlate with USDA Census data suggesting that the rapid development of the Watershed is resulting in a steady decrease in livestock operations. Figure 36 illustrates the BST results using a 7-way split, which differentiates bacteria sources into the following seven categories:

1. Human
2. Pets
3. Cattle
4. Avian livestock
5. Non-avian livestock, excluding cattle (e.g., goats, sheep)
6. Avian wildlife
7. Non-avian wildlife

These results show that out of the 40 to 70 percent of bacteria from wildlife, over half were from non-avian wildlife (e.g., feral hogs and deer) and the remainder were from avian wildlife, such as ducks and geese. These data also indicate 10 to 20 percent of the bacteria were from cattle, with the remainder from avian livestock, non-avian livestock, pets, and humans. Additionally, 5 to 15 percent of the bacteria collected in the samples are shown as “unidentified,” meaning the *E. coli* isolates identified in the samples did not match any of the samples in the TAMU isolate library.

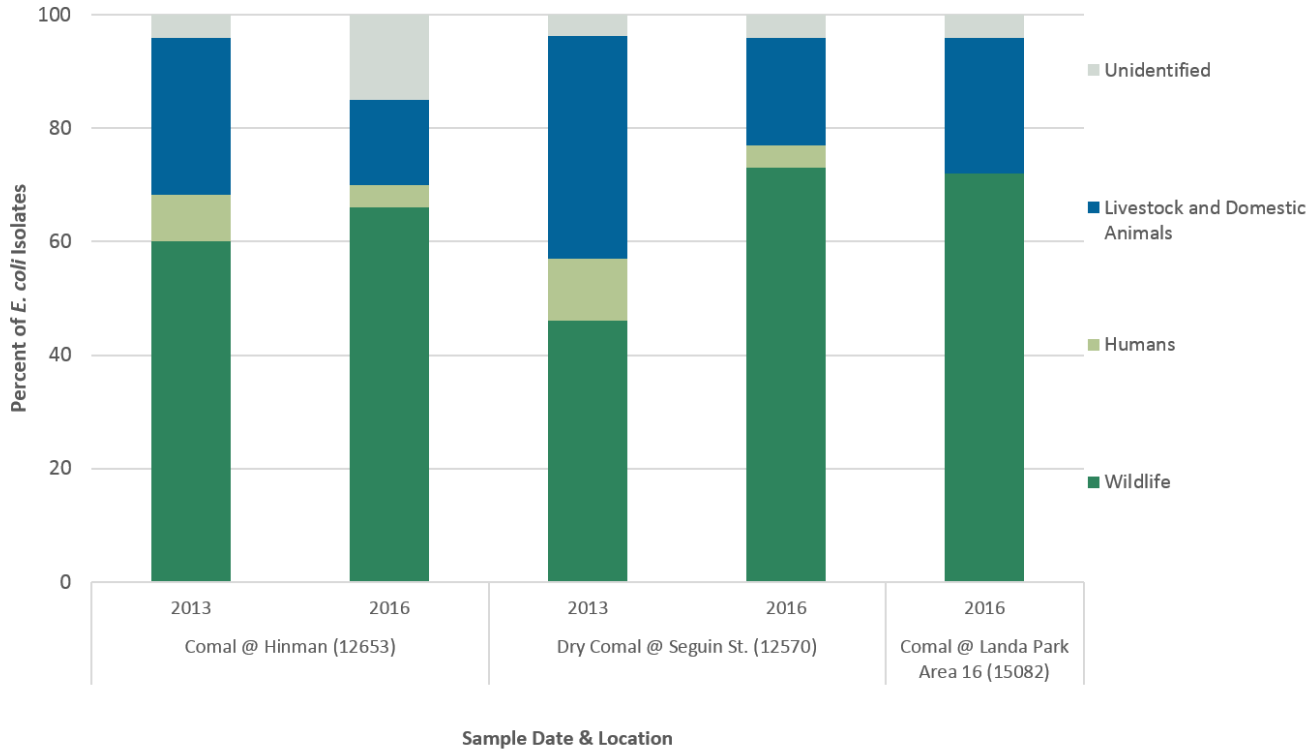

Figure 35: Comparison of BST Results for Samples Collected in September and October of 2013 and 2016 Using a 3-way Split

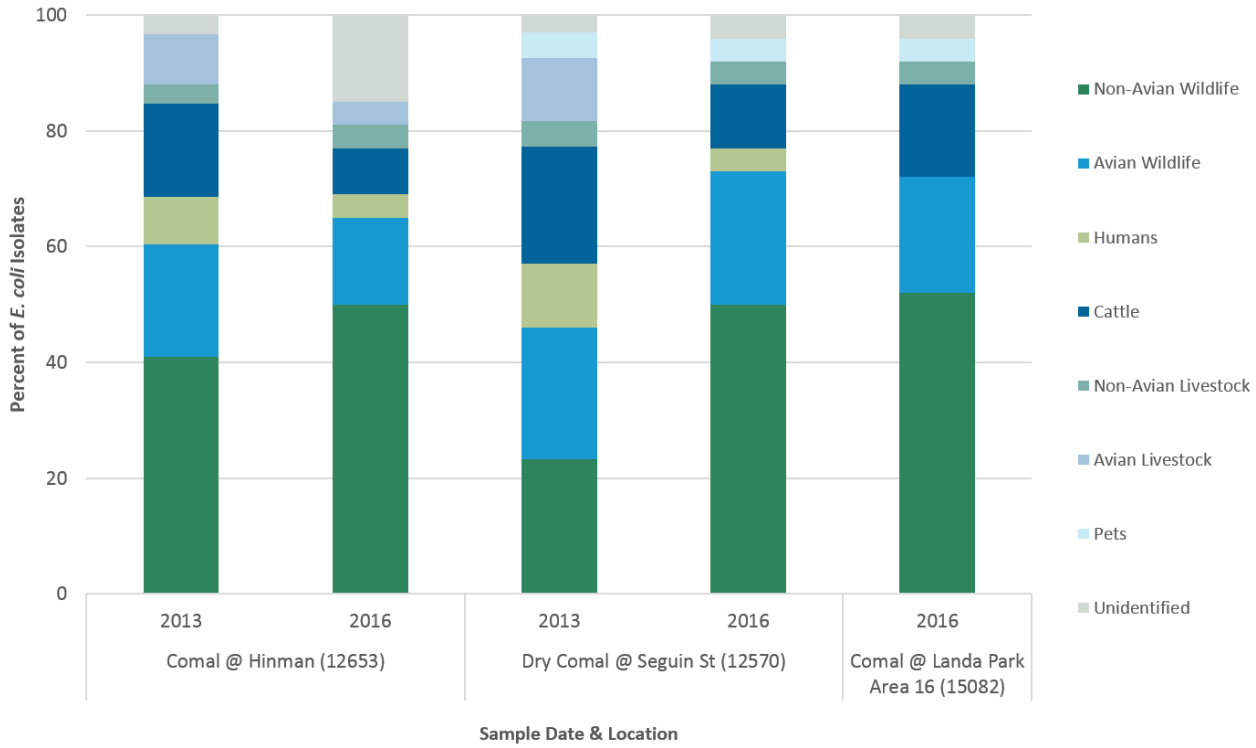

Figure 36: Comparison of BST Results for Samples Collected in September and October 2013 and 2016 Using a 7-way Split

4.4 Methodology for SELECT Tool

To estimate the most likely locations of bacteria sources in the Watershed, a tool called the Spatially Explicit Load Enrichment Calculation Tool (SELECT) was employed. SELECT was developed by researchers at TAMU in 2006 and uses land cover information to distribute potential *E. coli* loading sources and rates throughout subwatersheds. The number of potential sources in a watershed is generally derived from stakeholder input, agricultural statistics, and municipal datasets (e.g., number of households). The potential number of sources are then multiplied by an *E. coli* loading rate to estimate the total amount of daily *E. coli* produced by the population of each source in a watershed (Teague, Karthikeyan, & Babbar-Sebens, 2009). However, it is important to note that SELECT does not indicate the potential loading of *E. coli* that reaches a waterbody, but rather just the potential loading deposited by each source at some location in a given watershed.

4.4.1 Land Covers

Land cover information is a dataset displaying the physical material covering the earth derived from aerial imagery (e.g. forest, herbaceous, developed). The land cover dataset used for this WPP was the National Land Cover Database (NLCD) developed by the Multi-Resolution Land Characteristics Consortium (MRLC) (Homer et al., 2015). This dataset was updated and quality controlled using Google Earth's latest imagery for the Watershed to obtain an accurate depiction of real-world conditions (Google Earth, 2016). Land cover information for the Watershed was reviewed and refined to current land covers by converting the polygons that have changed from the old land cover to the updated land cover (Google Earth, 2016). Further edits were made to the land use land cover (LULC) dataset for livestock and wildlife sources, and the methodology for these are detailed in the following respective WPP sections. The land cover map developed for the Watershed is provided in Figure 37 below.

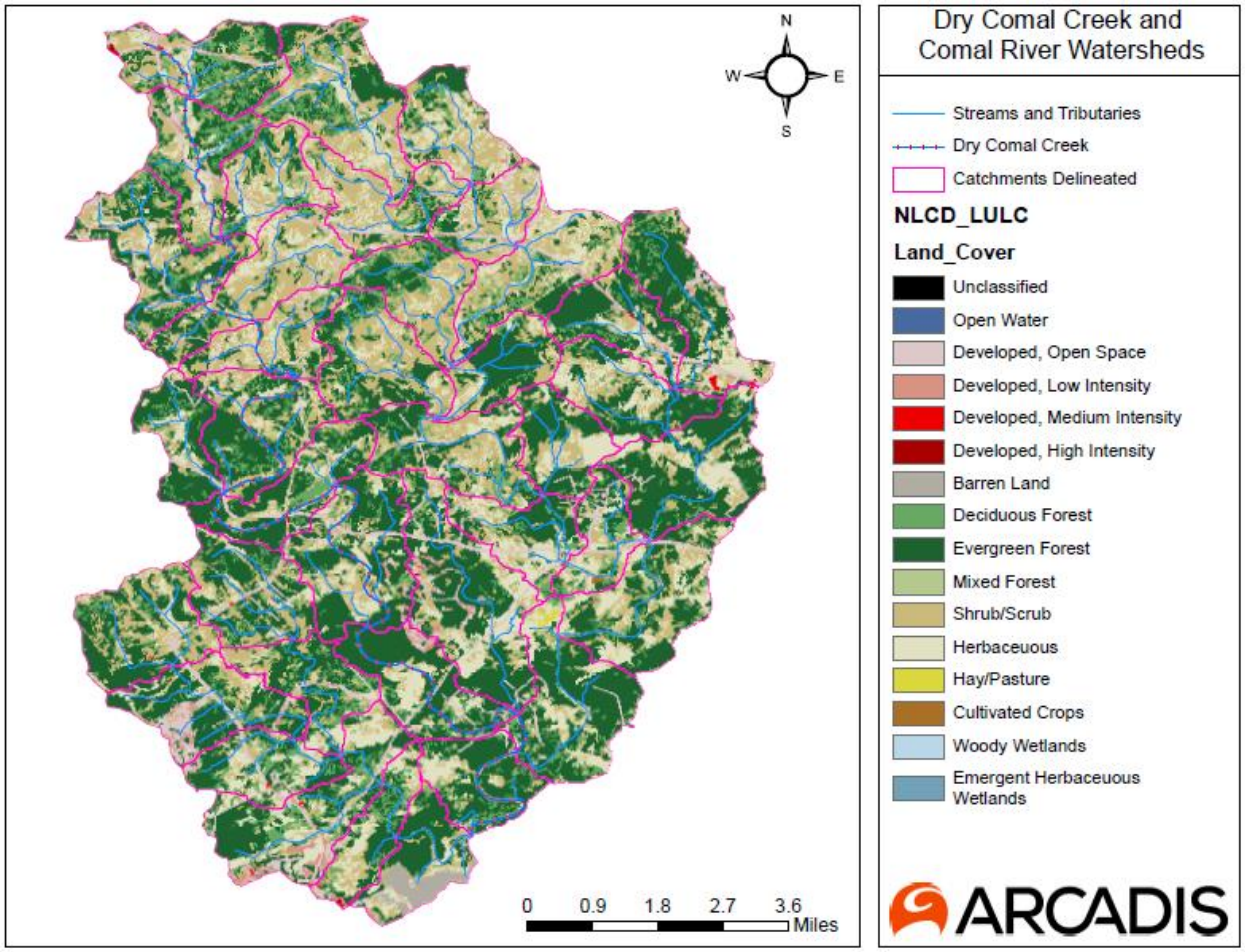

Figure 37: Land Cover Map for the Watershed

4.4.2 Subwatersheds

A watershed is an area of land that includes a particular body of water (e.g. river, lake, creek or stream) and all of the rivers, creeks, and streams that flow into it. Watersheds generally contain many subwatersheds for the subsidiary creeks and streams that flow into the main waterbody. For this Watershed, subwatersheds were delineated using the USGS's National Elevation Dataset (NED) (U.S. Geological Survey, The National Map, 2016) using ArcHydro software (ESRI Water Resources Team, 2015). ArcHydro uses the elevation dataset to delineate drainage patterns and basins, which can then be exported and saved as subwatersheds. These subwatersheds were quality-controlled with two-foot contour topography provided by the City. Consolidation of subwatersheds was performed on those that had similar land covers, while other subwatersheds were broken up further near the sampling locations and downtown areas to ensure subtle differences in potential pollutant loads were accounted for in these highly-scrutinized areas. A map of the subwatersheds is provided in Figure 38**.** Note that the official name for the southeastern HUC 12 watershed is the "Dry Comal River-Guadalupe River", even though the area ultimately drains to the Comal River.

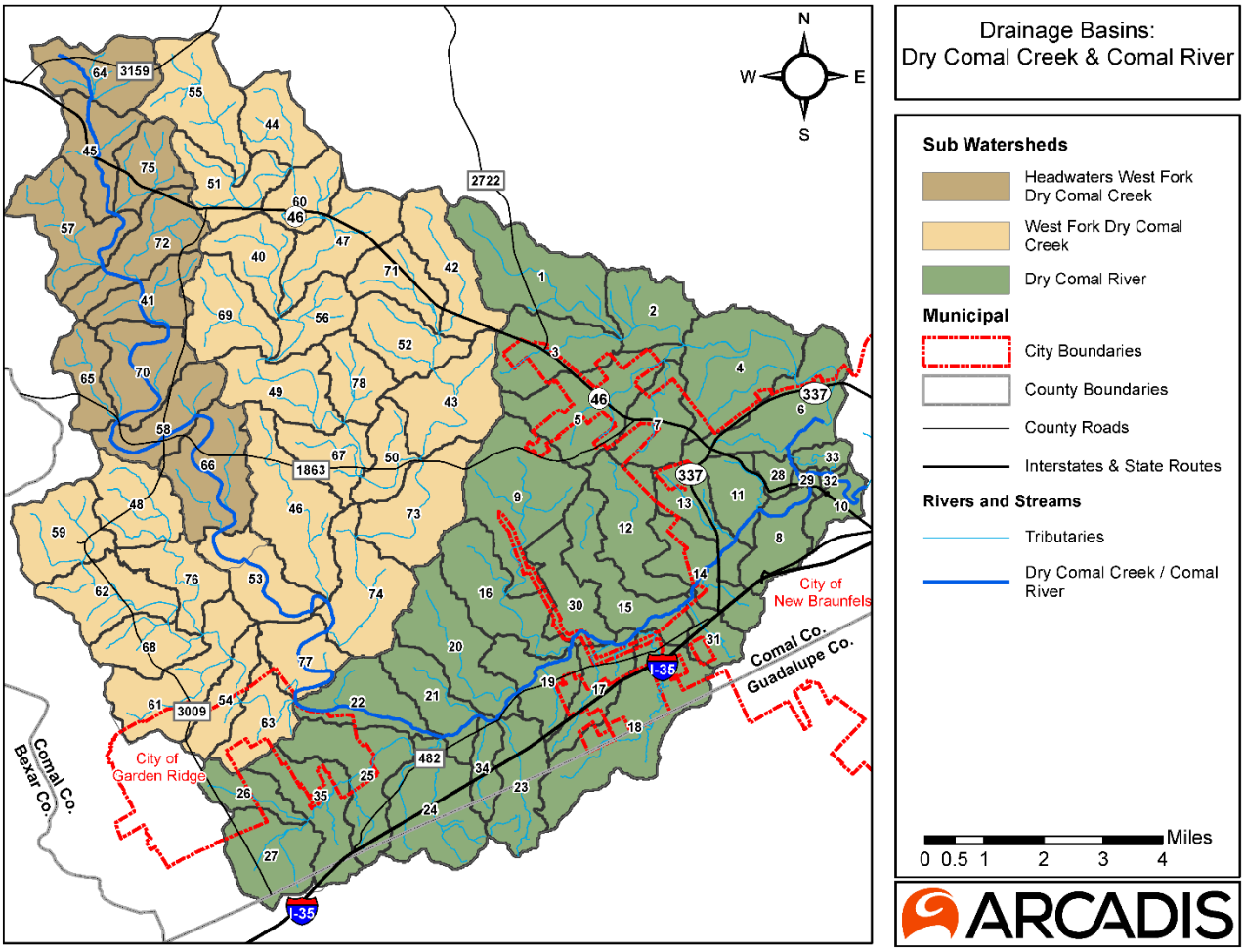

Figure 38: Map of Subwatersheds

4.4.3 Bacteria Pollution Sources in the Watershed

After evaluating the BST results, as well as data available on the populations and densities of pollutant sources in the Watershed (e.g., census data on livestock in Comal County), the list of sources was narrowed to those summarized in Table 11 with the goal of focusing on the sources contributing higher pollutant loads in the Watershed. Table 11 also presents the *E. coli* loading rate estimated for each pollutant source (i.e., per cow or per goat) based on a literature review of mammal *E. coli* production rates per day and failure rates of on-site sewage facilities (OSSFs) (Reed, Stowe & Yanke, LLC, 2001).

Table 11: Potential Pollutant Sources in the Watershed

Source Category	Potential Source	*E. coli* Loading Rate per Source/Animal* (CFU/day)
Livestock	Cattle	1.03×10^{10}
	Goats & Sheep	2.55×10^{9}
Urban	Dogs	3.15×10^{9}
	OSSFs	1.93×10^{3}
Wildlife	Avian	3.00×10^{9}
	Deer	9.16×10^{7}
	Feral Hogs	2.35×10^{9}

*Calculated by converting the fecal loading rates from EPA, 2001 to *E. coli* using a conversion rate of 0.63 *E. coli* per *fecal coliform.*

4.5 SELECT Results for the Dry Comal Creek and Comal River Watershed

The results of the SELECT analyses by pollutant source are provided in the sections below. On each map illustrating SELECT results, the red subwatersheds are those with the highest potential pollutant loading for that source, and the green subwatersheds are the lowest. However, it is very important to understand that, while the colors on all the maps display the same relative ranking, the scale (in CFU/day) on each map can be different (i.e., the areas with a "green" *E. coli* loading on one map may not have the same loading range as the "green" area on another map for a different pollutant source). The goal of utilizing SELECT is to know, for each specific source of bacteria pollution, the location of the highest potential loads in the Watershed (identified by red subwatersheds), so BMPs could be focused and prioritized on those areas.

4.5.1 Livestock

Livestock stocking rates were obtained from the National Agricultural Statistic Service (NASS). There were two forms of data utilized from this dataset: yearly survey data and more extensive census data taken every five years (NASS, 2016). Every January, the NASS performs a survey collecting data at the county level for the total of each livestock inventory and the components of that total (e.g. breeding animals, market inventory, and sexually immature animals). Every five years, a more rigorous Predator and Non-Predator Loss Survey is conducted nationally and incorporated as part of the January survey, deemed census information (NASS, 2014).

Since not all livestock numbers obtained from the NASS are uniformly distributed throughout the county, land covers from the NLCD were used to distribute the livestock to suitable habitats (Homer et al., 2015). The livestock were distributed on deciduous, evergreen and mixed forest, shrub/scrub, herbaceous and hay/pasture land cover types. Also, since the NASS data are

prepared and delivered at the county level, it was necessary to find the proportion of suitable habitats in the Watershed compared to both Comal and Guadalupe Counties to establish the number of livestock in the Watershed. These calculations resulted in an estimated 2,748 cattle and 2,501 goats and sheep, in the Watershed. Although NASS data shows chickens, horses and swine also in the Watershed, the population sizes and/or relative bacteria contributions per animal are small compared to the contributions from cattle, goats and sheep. Thus, for the purposes of estimating loading and performing SELECT analysis, calculations focused on cattle, goats and sheep. BMPs selected targeting cattle, goats and sheep will also include chickens, horses and swine. The SELECT results for *E. coli* loads estimated for cattle, and for other livestock combined (goats and sheep) are illustrated in Figure 39 and Figure 40, respectively, in units of CFU/day.

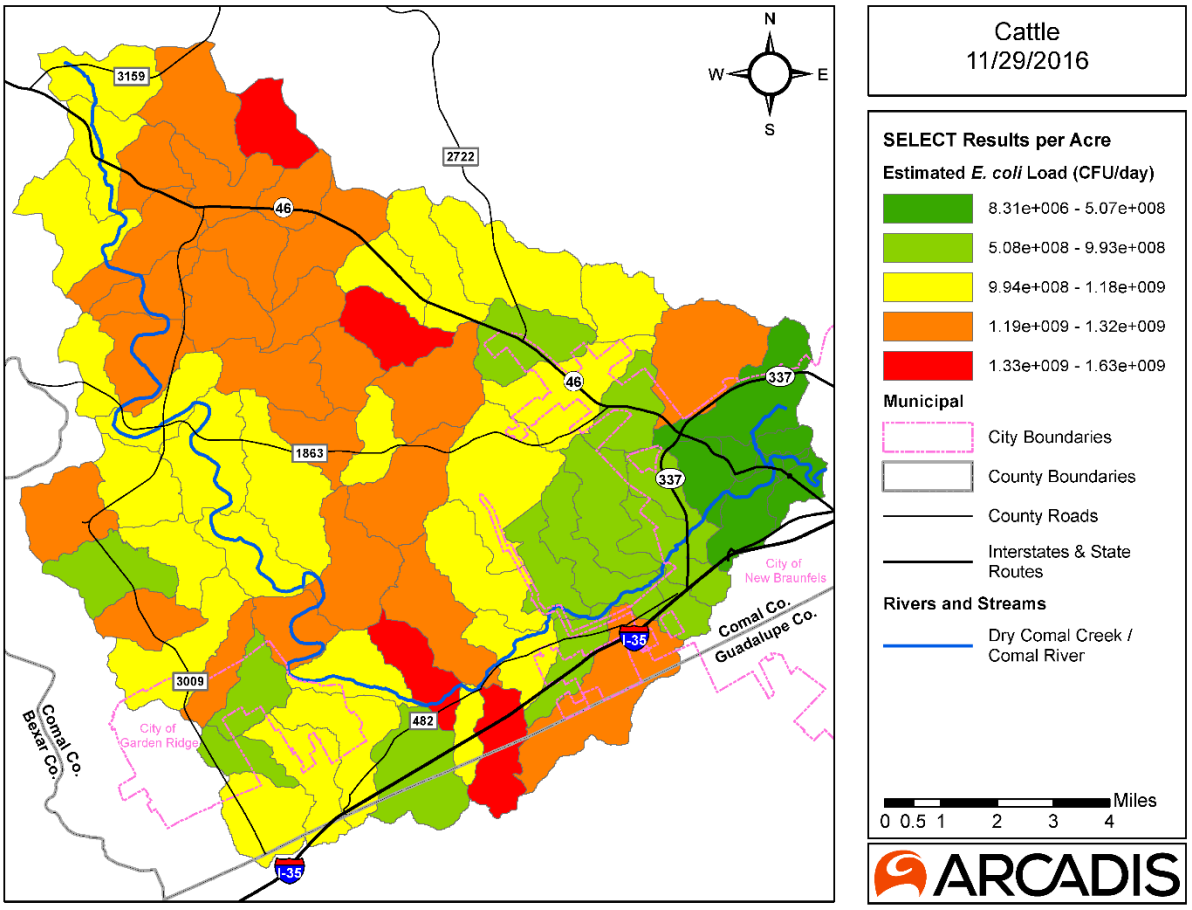

Figure 39: Average Daily Potential *E. coli* Load Estimated from Cattle

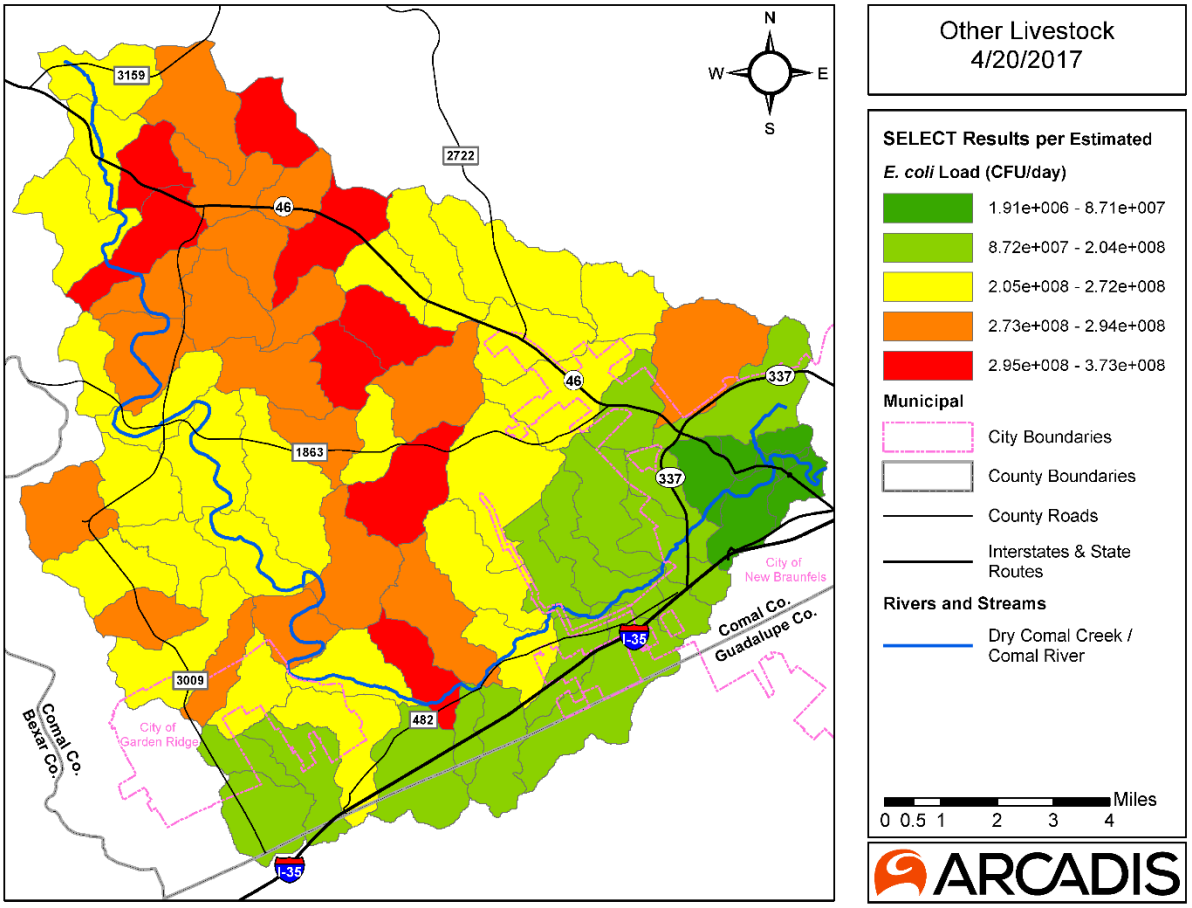

Figure 40: Average Daily Potential *E. coli* Load Estimated from other Livestock (Goats and Sheep)

4.5.2 Feral Hogs

Using stakeholder feedback provided by the Texas A&M AgriLife Extension and stakeholders that manage rangeland in the Watershed, two habitat-based population density ranges were developed for feral hogs. The County Extension Agent indicated feral hogs are more prolific in the southwest portion of the watershed due to the deep soils characteristic of the Blackland Prairies. Feral hogs are also able to travel up stream beds into the lower portion of the Edwards Plateau for shade and relief from predators during the daytime (Luepke, 2016). This suitable habitat is similar to the habitat described in the Geronimo and Alligator Creek WPP (Geronimo and Alligator Creeks Watershed Partnership, 2012), which assigned a feral hog density of 0.039 hogs per acre, which is the value applied in this WPP to the Blackland Prairie portions of the Watershed. Stakeholder input was also used to estimate the feral hog population density in portions of the Watershed with a less suitable habitat for the hogs. A stakeholder who manages rangeland indicated approximately five to ten hogs are present on the property he manages covering approximately 2,000 acres, resulting in a density of 0.00375 hogs per acre. This lower

feral hog density aligns with expected values in this portion of the Watershed and was applied accordingly. *E. coli* loads estimated by SELECT for feral hogs are illustrated in Figure 41**.**

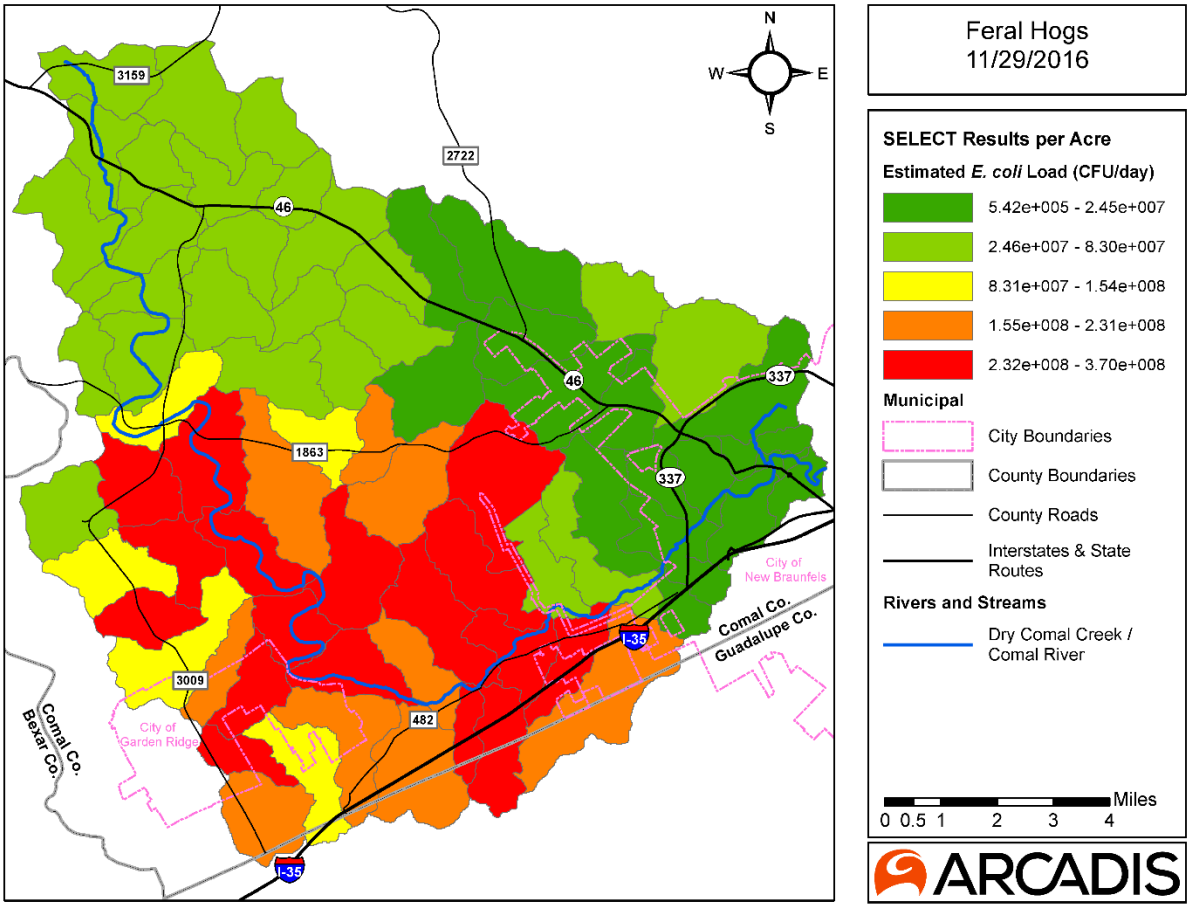

Figure 41: Average Daily Potential *E. coli* Load Estimated from Feral Hogs

4.5.3 Deer

TPWD Wildlife Biologist Elizabeth Bates was consulted to provide information on deer densities in the Watershed (Bates, 2016). While the TPWD performs surveys at the Resource Management Unit (RMU) scale, which is an area much larger than Comal County, the Wildlife Biologist suggested a higher deer density for the Watershed than the RMU's value. For more rural areas of Comal County, an estimate of one deer per every three acres was applied. In 2017, an estimate of one deer per six acres for rural areas of Comal County was provided by Ms. Bates. This updated estimate suggests that the densities used in this WPP are conservative.

The City has a relatively dense population of urban deer around Landa Park and through the neighborhoods around Landa Park. The density suggested by TPWD was one deer per two to three acres for the urban areas within Comal County. The City conducted three separate surveys of deer in the neighborhoods and around Landa Park that resulted in an estimated one

deer per every two acres that was applied in SELECT analysis. This "neighborhood or urban deer" population estimate was applied to the "Urban Deer" range illustrated in Figure 42. The corresponding estimated potential daily *E. coli* load from deer in the Watershed is illustrated in Figure 43. As the goal of utilizing SELECT was to estimate the locations of the highest potential loads in the Watershed, stakeholder knowledge of increased population density in urban areas, illustrated in Figure 43, was more critical to selecting BMPs than the precise loading from deer in each subwatershed.

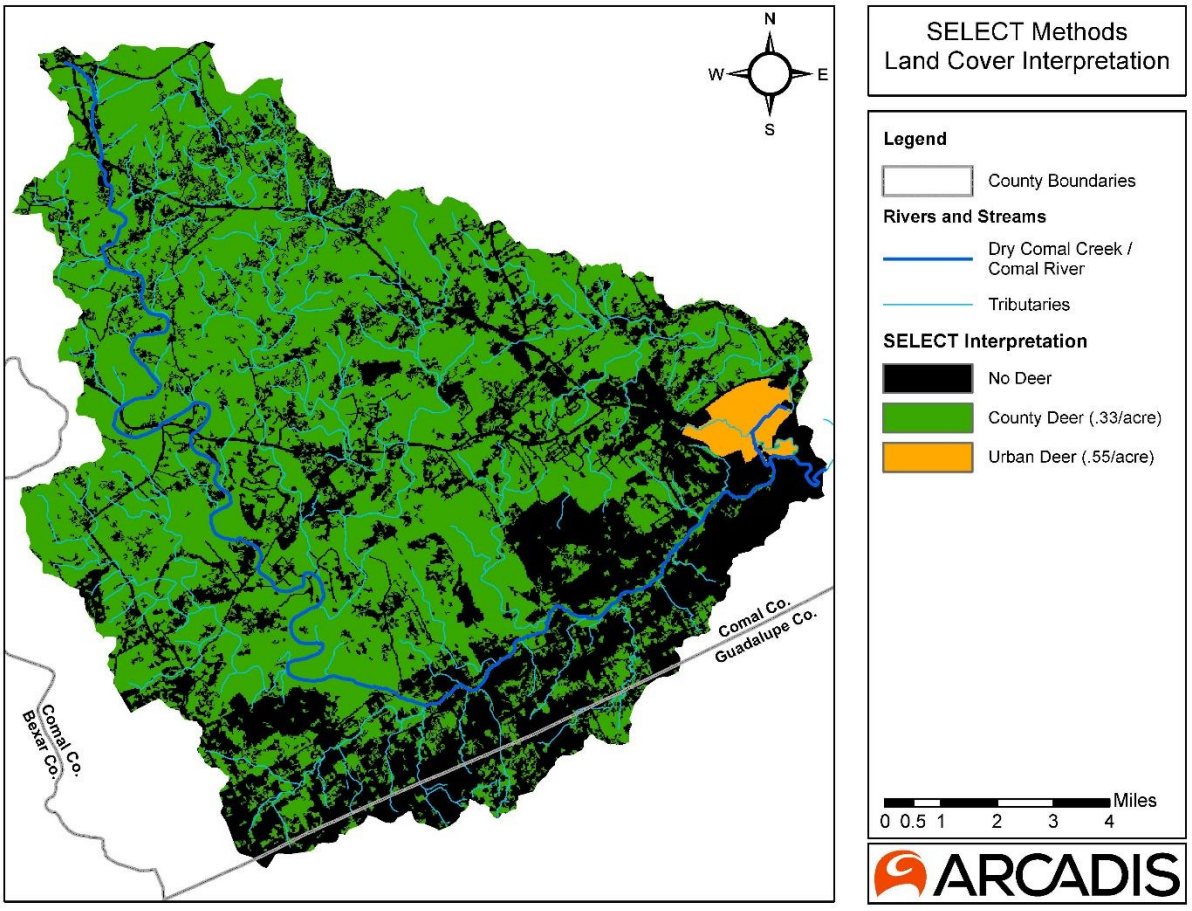

Figure 42: Land Cover Interpretation of Deer Densities Applied to Select Tool for the Watershed

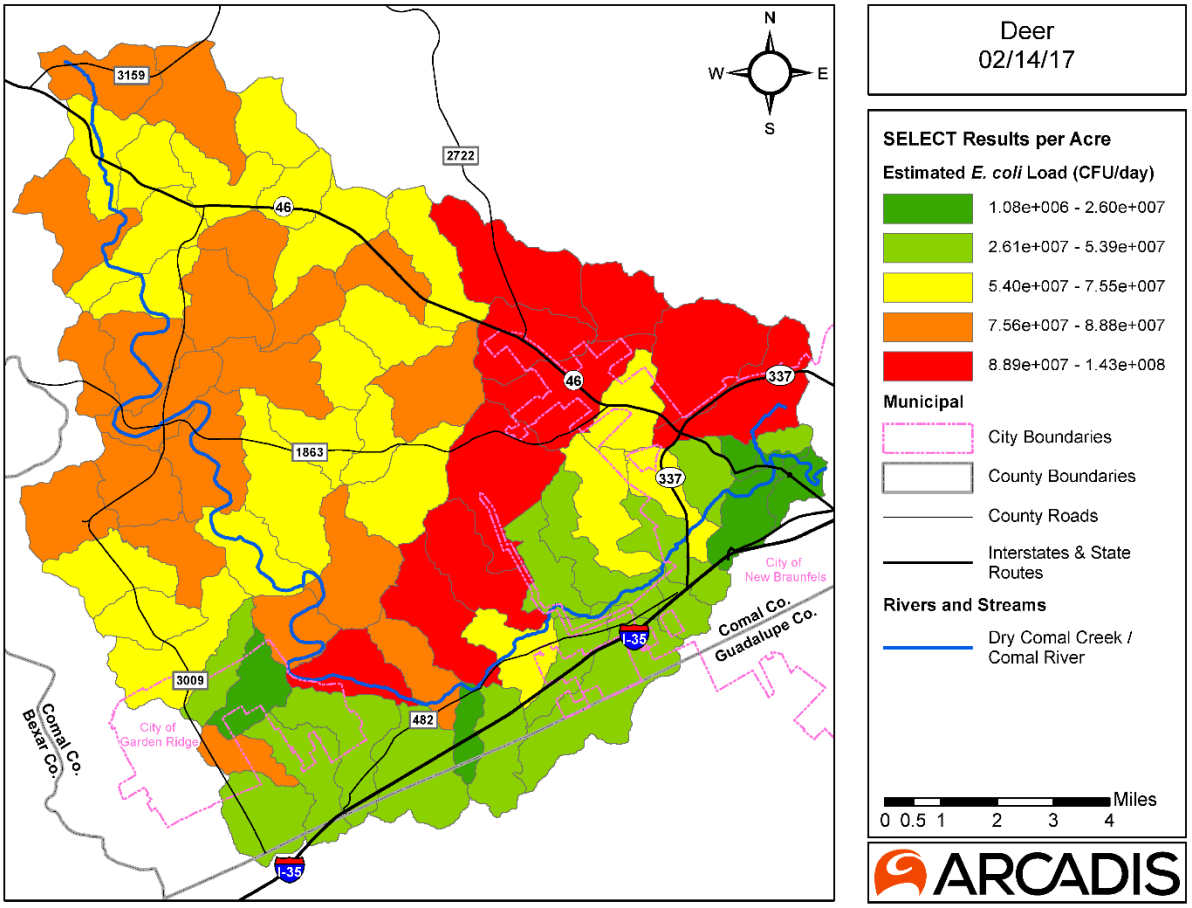

Figure 43: Average Daily Potential *E. coli* Load Estimated from Deer

4.5.4 Urban Avian Wildlife

The avian populations within and surrounding Landa Park are of high concern to stakeholders and the City. There is known to be an increased population of non-native ducks and geese due to recreational feeding by citizens and tourists in the park. To account for this potential source, surveys by environmental scientists were conducted on three separate dates. The results from the surveys were averaged and divided by the total number of acres covered in the survey area, to estimate an avian population density per acre. The urban avian population's range was created by combining the survey areas surrounding Landa Lake. The density was then distributed to this range resulting in an estimated avian population of 288[8] birds around Landa Park. As there are no reliable data on avian populations in the remainder of the Watershed, no non-native avian population densities applied to areas outside the area surrounding Landa Park.

[8] Note that focus of any BMPs will be on control of non-native avian populations only. However, surveys included both native and non-native avian wildlife.

This is consistent with a SELECT methodology, which focuses on managing the highest loads of a given source. Based upon local stakeholder knowledge, the highest concentration of non—native wildlife is known to be around Landa Park, as illustrated in Figure 44.

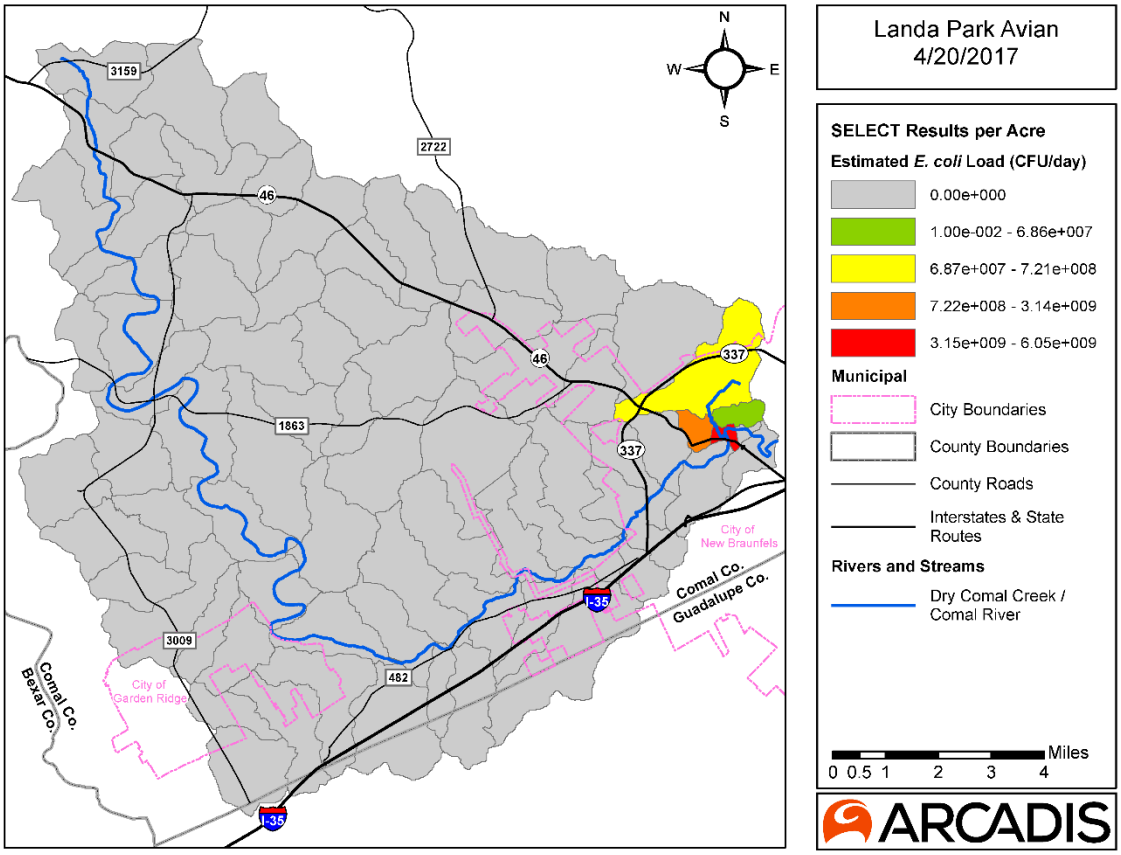

Figure 44: Average Daily Potential *E. coli* Load Estimated from Avian Wildlife

4.5.5 On-Site Sewage Facilities

Rural residents of Comal and Guadalupe Counties rely on OSSFs, or septic systems, for disposal of household wastewater. These are typically outside the city limits and are installed when new homes or businesses are constructed. Comal County has regulations related to the design and construction of OSSFs. However, the maintenance and inspection of these facilities is the responsibility of the owner, with the exception of required professional maintenance for the first two years of operation of aerobic systems. Homeowners may not always be as effective as trained professionals at maintaining and inspecting OSSFs, which can lead to failure of these systems, particularly as they age. Failing OSSFs are generally considered to include systems with leaks and systems that are undersized or improperly maintained, resulting in untreated wastewater overflows.

Locations of OSSFs within the Watershed were provided in GIS format by the Comal County Engineers Office (Comal County Engineer's Office, 2016) and the City (City of New Braunfels, 2016). Guadalupe County's Department of Environmental Health provided addresses for OSSFs within its portion of the Watershed. The addresses were then converted to GIS format. All OSSF data were combined into one GIS dataset, with a total of 2800 OSSFs located within the Watershed.

Much research has been performed to determine the approximate failure rate for OSSFs (Morrison, Munster, Karthikeyan, & Jacob, 2013; Napier, Rahn, & Kramer, 2015; Water Quality Planning Division, Office of Water, 2012). The report that was deemed most applicable to this Watershed distributed a survey to different OSSF representatives for regions throughout Texas. Based on survey responses and other research, the Watershed is estimated to have a 12 percent failure rate for OSSFs within a given year (Reed, Stowe & Yanke, LLC, 2001). The 12 percent failure rate was multiplied by an average daily load for a failing OSSF to estimate the *E. coli* load in the Watershed. The estimated potential *E. coli* load for OSSFs in the Watershed is illustrated in Figure 45, where areas of higher loading are in subwatersheds known to have relatively more OSSFs than other subwatersheds.

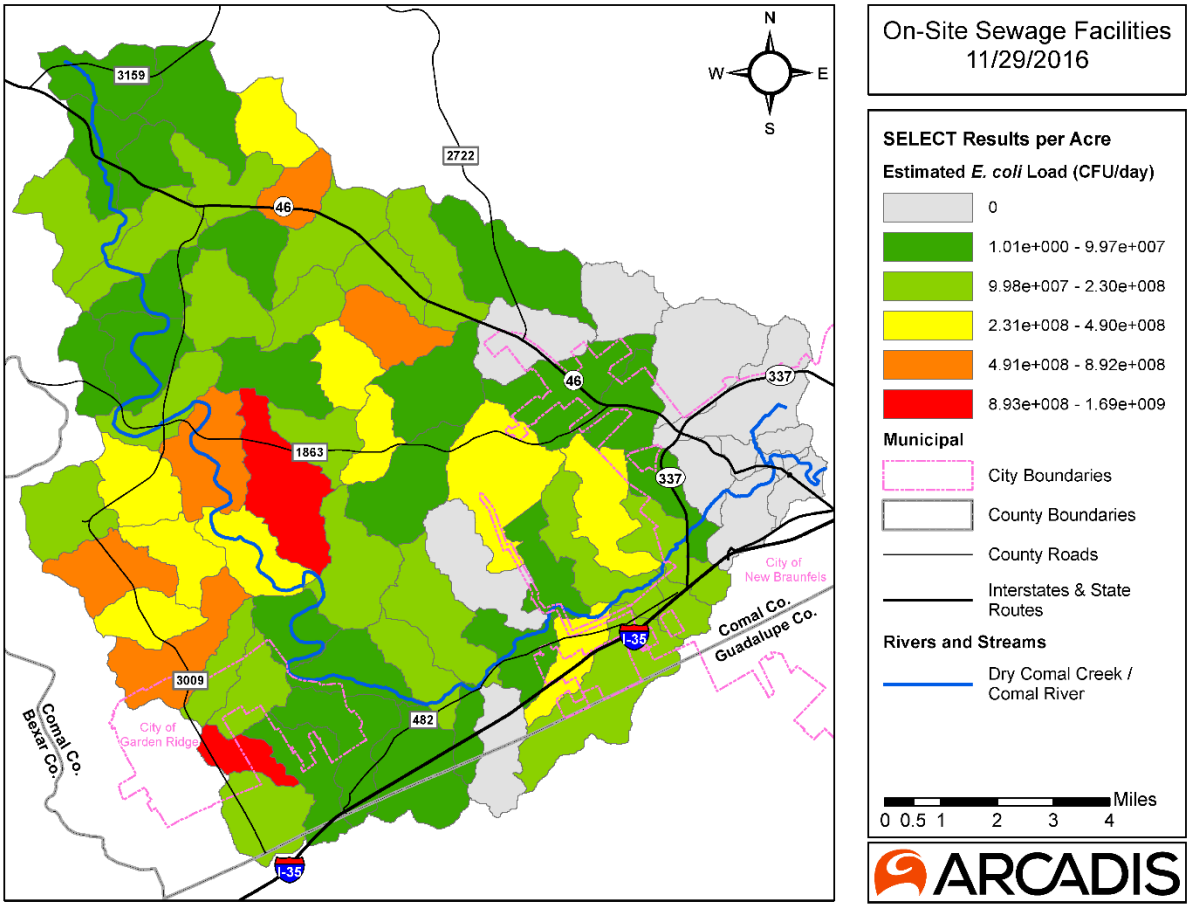

Figure 45: Average Daily Potential *E. coli* Load Estimated from OSSFs

4.5.6 Pets

Pet waste can have a substantial impact on the quality of stormwater runoff from areas with high pet populations. SELECT analysis was focused on pet waste generated by dogs as a potential source, as there were limited to no data on feral cat populations that could be utilized. However, BMPs for feral cats will also be considered based upon stakeholder knowledge of the Watershed and the presence of feral cats.

The number of dogs in the Watershed was calculated by multiplying the total number of estimated households in the Watershed by a density of 0.8 dogs per household. This density value is the density of dogs per household for the State of Texas, and was obtained from the American Veterinary Medical Association's U.S. Pet Ownership and Demographics Source Book (American Veterinary Medical Association, 2007). To estimate the number of households in the Watershed, the Comal County and Guadalupe County Tax Assessor's Parcel Database was queried to find single family residential and multifamily housing parcels. The resulting *E. coli* loads estimated for dogs in the Watershed are provided in Figure 46.

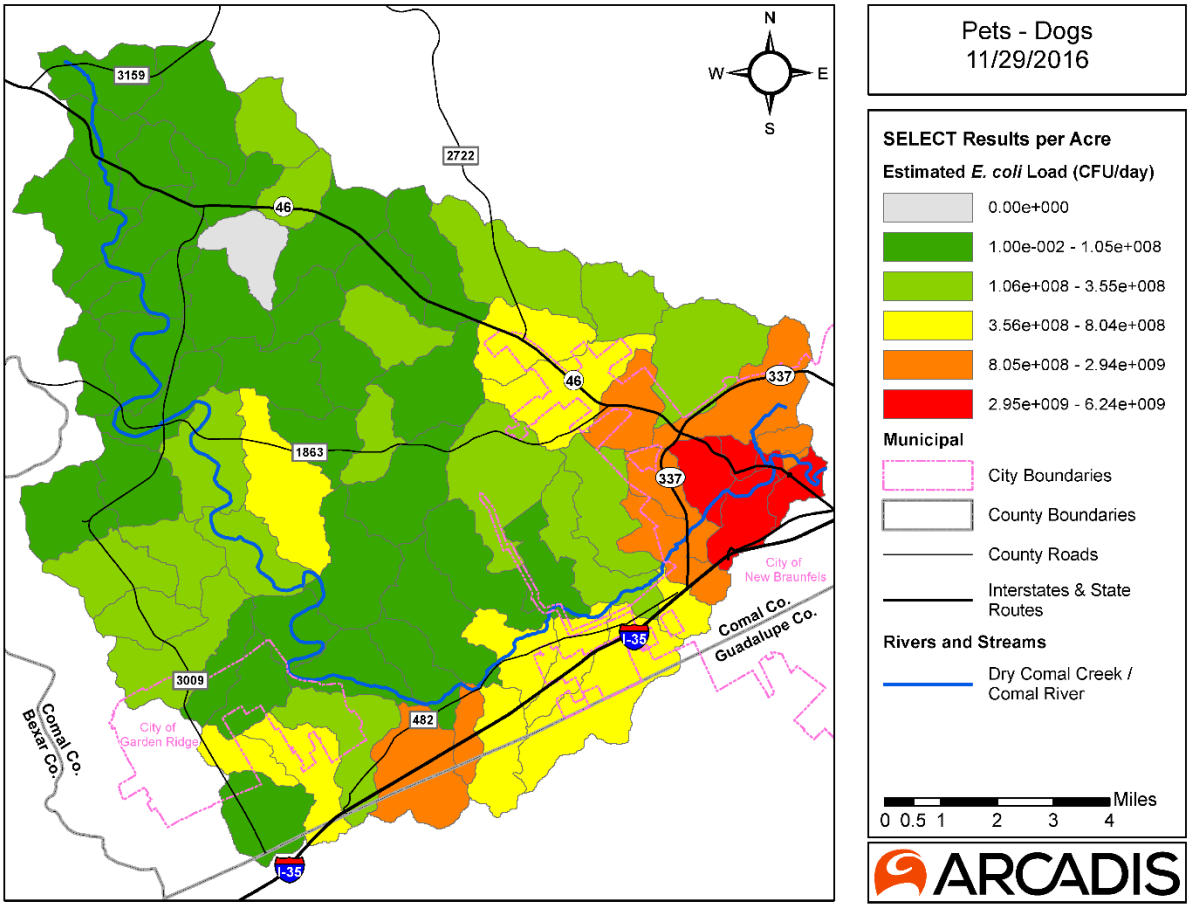

Figure 46: Average Daily Potential *E. coli* Load Estimated from Dogs

4.5.7 Sanitary Sewer Collection Systems and Wastewater Discharges

There are currently two permitted wastewater discharges, a sanitary sewer collection system, an on-site waste disposal pond, and a permitted land application site in the Watershed. The two discharges, as well as the land application site, are described in Section 2.7. A sanitary sewer system collects wastewater from residents and businesses in the City and delivers it to wastewater treatment plants operated and maintained by NBU. NBU is extending its collection system as growth occurs. Although leaks and overflows in sanitary sewer pipes or manholes can be a source of *E. coli* pollution, NBU has an aggressive SSO program for inspecting, cleaning, and repairing its wastewater collection system. As confirmed by the BST sampling, human waste is not currently a major source of bacteria in the Watershed. However, the integrity of collection systems and discharges within the Watershed will continue to be monitored to minimize the potential for pollution. Thus, no SELECT analysis was performed for sanitary sewer collection systems or wastewater discharges. However, a map of current wastewater discharges is provided in Figure 14.

4.5.8 Urban and Stormwater Runoff

After substantial research, coordination with the TCEQ, and discussions with the City of Austin's lead *E. coli* expert (Roger Glick, PhD), it was decided not to include urban runoff in the SELECT analysis performed for this Watershed for the following reasons:

- The data typically used in Central Texas for assigning values for urban runoff are based on water quality samples taken at different developed and undeveloped sites and does not take into account specific bacteria sources to support BMP development; therefore, the potential pollution from urban runoff does not include enough detail to inform BMP placement and design.
- Many bacteria sources that would be estimated indirectly by analyzing urban runoff (i.e. OSSFs, dogs, and urban wildlife) are already accounted for in the Watershed and would be double counted in urban runoff estimates (PBS&J, 2000; City of Austin, 1990; City of Austin, 1997; City of Austin, 2009; Glick, 2016).

4.6 Data Gaps

Data available for analysis are described in Sections 2.8, 2.9, 4.3 and 4.5. Data not shown in these sections were not analyzed for this project. Gaps identified include, but are not limited to, those summarized below. The Watershed Partnership and its professional consultants are confident that these data gaps do not impact or change the recommended BMPs.

- Additional water quality data (e.g., *E. coli* data before 2011 or at locations not currently monitored);
- Additional isolates for *E. coli* Bacteria Source Tracking which would minimize the percentage of *E. coli* shown as "unidentified" in Table 10;
- The exact locations of animals in the Watershed, which were approximated using statistics, such as County stocking rates and average pets per household, and land cover datasets; and
- Data on avian wildlife outside of Landa Park.

5. Best Management Practices

Following a thorough evaluation of water quality data and information on sources of *E. coli* pollution in the Watershed, the Stakeholder Group identified best management practices (BMPs). BMPs are structural, vegetative and/or operational practice(s) that treat, prevent or reduce bacteria loading to the Dry Comal Creek and Comal River, are effective and practicable, and can be easily communicated to stakeholders and the public. Although BMPs primarily address bacteria concentrations in the Watershed, most steps taken to reduce bacteria loads will also result in reductions from other types of pollution (e.g., nutrients). BMPs, targeting reduction and control of the major sources of bacteria loading, were established under three categories: Overabundant Urban and Non-Native Wildlife; Livestock; and Stormwater and Infrastructure.

5.1 BMP Terminology

There are multiple terms used in this WPP to describe BMPs. These terms are listed and defined in Table 12 below.

Table 12: BMP Terminology

Term	Definition
Goals	Targeted impact of the BMP on water quality and the *E. coli* source (e.g., reduction in animal population)
Implementation Milestones	Measurable milestones established to track progress of BMP implementation toward achieving BMP goal(s)
Description	High-level description of how selected BMPs will address the specific source of bacteria
Location	Areas within the Watershed where each BMP will be implemented
Implementation Period	Defined as 10-year period over which BMPs will be implemented; cost estimates and estimates of BMP effectiveness were calculated over the implementation period
Implementation Timeline	Timeline for BMP implementation activities over the 10-year implementation period

Table 12: BMP Terminology (Continued)

Term	Definition
Responsible Party	Key party responsible for executing the BMP
Estimated Cost	The estimated capital and operations and maintenance costs associated with the BMP over the 10-year implementation period
Estimated Potential *E. coli* Load Reduction	The potential *E. coli* load reduction in Dry Comal Creek and the Comal River due to implementation of a BMP in units of CFU/day
Technical Resources	Organizations, municipalities, human resources, etc. that are key to successful implementation of a BMP
Financial Resources	Potential sources of funding for the estimated BMP costs over the 10-year implementation period
Priority Subwatershed	Subwatersheds (see Figure 39) corresponding with the highest potential loading (based upon SELECT analysis in Section 4.5) and/or the areas prioritized by the Stakeholder Group based on their knowledge and experiences (see Appendix C for summary maps).

5.2 BMP Implementation Roles

The BMPs developed by the Watershed Partnership integrates science with local input and stakeholder knowledge. Engagement of stakeholders and the broader community (Section 6.1) has been and will continue to be an integral component in the success of this WPP. To ensure BMPs are implemented effectively and efficiently, two key roles within the Watershed Partnership, **the Watershed Coordinator and WPP Consultant**, have been identified and are described below.

▶ Watershed Coordinator

The City's Watershed Coordinator will continue to fill a critical role at the heart of the WPP implementation by facilitating between the Watershed Partnership, stakeholders, and the community. Key responsibilities of the Watershed Coordinator may include, but not be limited to the following tasks:

- Organize and host periodic public meetings, and regular stakeholder and Watershed Partnership meetings to gather and incorporate local input and encourage citizen participation;
- Update the WPP website to track the implementation process, promote watershed awareness and stewardship, and provide information on engagement opportunities;
- Serve as a single point of contact for the WPP and implementation activities;

- Maintain working partnerships with the WPP stakeholders, and local city and county governments;
- Provide updates to and engage local city and county governments to support implementation of the WPP;
- Coordinate and conduct local outreach and education activities, as defined in Section 1.1;
- Draft and publish regular updates on the WPP implementation and community engagement opportunities through news and social media outlets; and
- Assure that any required reports are submitted to TCEQ, other agencies, and funding entities.

▶ WPP Consultant

Monitoring, adapting, and expanding (if needed) the ongoing and proposed implementation strategies is essential to the success of this WPP and the future water quality in the Watershed. Thus, the Watershed Partnership has identified the need for an experienced engineering firm (the "WPP Consultant") to serve as an extension of the City staff and to provide continuity as the WPP is implemented. The WPP Consultant will provide technical consulting and support to the Watershed Coordinator and the City by tracking WPP progress and maintaining consistency so that important activities are completed in a timely manner. Key responsibilities of the WPP Consultant may include, but not be limited to the following tasks:

- Identify and assist the City and others in securing funding for implementation activities;
- Evaluate water quality and/or bacteria data collected in the Watershed and produce reports summarizing the data in an easily-understood manner;
- Track and document WPP progress toward established goals and measures of success;
- Summarize and document WPP outcomes;
- Coordinate and organize efforts to implement portions of the WPP, including meetings or calls with focused groups of stakeholders;
- Recommend adaptive management during the WPP implementation process, as needed, based upon review of progress and/or stakeholder feedback (see Section 8.4 on Adaptive Implementation);
- Engage additional technical resources (e.g., TAG members), as needed, to bring technical and financial resources to the WPP implementation program;
- Develop content and graphics for publications (e.g., news, social media, factsheets, website);
- Facilitate regular stakeholder meetings and communication, including developing and presenting updates on implementation activities;
- Review and provide quality assurance on reports or documents provided to the City by others; and
- Provide the City with periodic reports on new technologies (e.g., testing and analysis methods) that might improve the implementation process or make it more efficient.

5.3 BMP Development Process

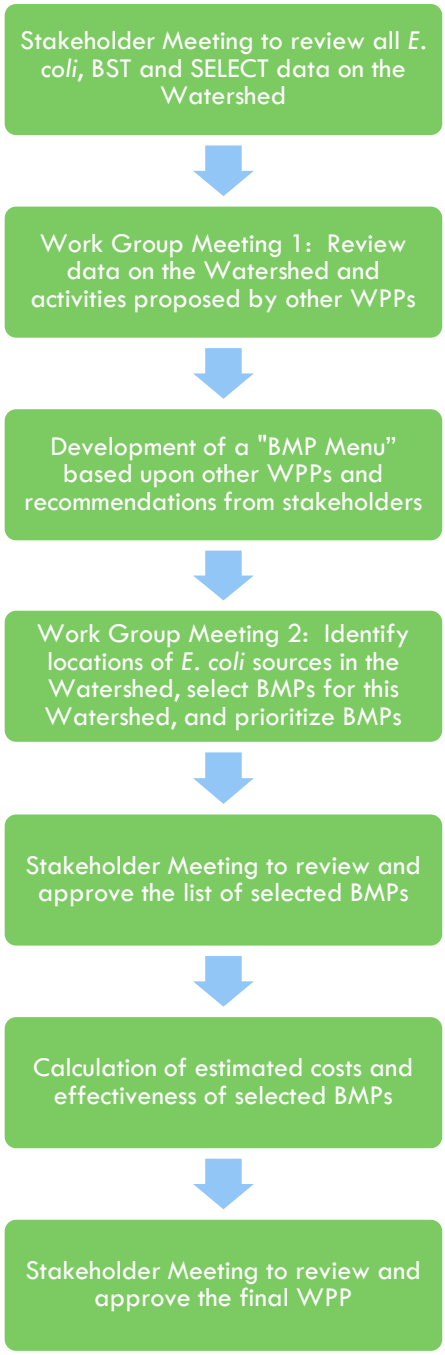

Figure 47: BMP Development Process

BMPs were selected by the Stakeholder Group based upon characterization of the Watershed and sources of bacteria pollution, information on strategies implemented in other regional WPPs, and recommendations from the TAG. The BMPs developed in this WPP were established incrementally with the input and revision from the Stakeholder Group during multiple meetings summarized in Figure 47. Some meetings included all members of the Stakeholder Group and addressed all three BMP categories, while smaller Work Group meetings focused specifically on one of the three categories of bacteria pollution (i.e., overabundant urban and non-native wildlife; livestock; and stormwater and infrastructure).

The Stakeholder Group studied all the available data on *E. coli* and *E. coli* sources in the Watershed (refer to Section 4), and was also provided a menu of potential BMPs to consider. After reviewing the available data on the Watershed, each Work Group identified the locations of *E. coli* sources in the Watershed based upon SELECT results (Section 4.5) and local stakeholder knowledge (refer to Appendix C for maps). The Work Groups then selected and prioritized BMPs based upon the location of each source in the Watershed and the percentage of the *E. coli* in the waterbodies attributed to each source. After BMPs were selected and prioritized, an estimated cost and effectiveness of each BMP was calculated, as described in 5.3.1 and 5.3.2. The Stakeholder Group met again to review the draft WPP and final BMPs, including the estimated costs and effectiveness, to ensure the goals of the WPP were met.

5.3.1 Methodology for Estimating Potential *E. coli* Load Reductions

Potential *E. coli* load reductions were calculated for each BMP. Load reductions were based upon the goal (i.e., implementation milestones as further described in Sections 7 and 8) established for each strategy. In some cases, goals were adjusted until the targeted load reduction was achieved. For example, if a load reduction target was not achieved based upon the initial goal, then the goal (e.g., the number of Water Quality Management Plans (WQMPs) to be implemented) was increased to increase the estimated load reduction. TAG and Stakeholder Group members reviewed goals to ensure they were practical and achievable in the Watershed,

and also reviewed assumptions to ensure they matched Stakeholder knowledge and experiences. The process for estimating load reductions is summarized below:

1. The median (i.e., at medium flow rates for the Comal River or Dry Comal Creek) *E. coli* load and the necessary load reduction for the two waterbodies were calculated, using the load duration curves (i.e., CRP data), to meet the WPP target *E. coli* load of 113 CFU/day (refer to Section 4.1.2 for the detailed discussion of load duration curves).
2. The average percentage of *E. coli* in the Dry Comal Creek and Comal River from each pollutant source was calculated using the BST results, which indicate the portion of the *E. coli* load from each source (refer to Section 4.3 for the detailed discussion of BST results). As BST results did not further divide the *E. coli* percentage from non-avian wildlife, a 30/70 split was assumed between feral hogs and deer. The portion of bacteria contributed by humans is likely due to OSSFs, wastewater, and other sources (e.g., dumping, transient populations, etc.). It is unclear what percentage of human *E. coli* comes from each of these sources. Thus, it was assumed the human contribution of *E. coli* is 33 percent from OSSFs, 33 percent from wastewater, and 34 percent from other sources.
3. The total *E. coli* load for each waterbody was multiplied by the estimated percent of loading attributed to each source upstream to calculate the *E. coli* loading per source per waterbody. Refer to Appendix G: Estimated *E. coli* Load Reduction Calculations.
4. Source population estimates and theoretical loads per source, based upon literature research, were used to calculate the theoretical load produced by the total population of each source[9]. Note that this is the same approach used for the SELECT tool described in Section 4.4 (refer to Table 11 and Section 4.5).
5. A calibration factor was calculated for each source of *E. coli*. The calibration factor was used to normalize the estimated *E. coli* source loads to the measured *E. coli* concentrations in the Dry Comal Creek and Comal River to account for (1) assumptions in the estimation process (e.g., that every cow produces the same *E. coli* load or the number of deer estimated in the Watershed and subwatersheds) and (2) the number of bacteria actually reaching the stream, which depends on several environmental factors including proximity to the creek, bacteria die-off, geomorphology, riparian conditions, connectivity of stream network, temperature and other factors. The calibration factor was calculated by normalizing the theoretical *E. coli* production to the *E. coli* load actually measured in the waterbodies for each source. As an example, without this calibration factor, the loading of *E. coli* produced by one cow in the Watershed, at 3.32×10^{10} CFU/day *E. coli* per cow, would exceed the total loading of *E. coli* measured in

[9] Calculations typically assume current source populations are stable and immobile. Calculations do not account for natural increases or declines in populations (i.e., human or other animals) over time or the natural movement of populations (e.g., the movement of deer in and out of the Watershed).

the Dry Comal Creek ($3.15x10^9$ CFU/day). Refer to Appendix G: Estimated *E. coli* Load Reduction Calculations for detailed calculations.

6. For each BMP, a goal was defined. For example, goals included the number of people reached by educational activities, the number of pet waste stations installed, and the percentage of the non-native wildlife population reduced. Refer to Section 5 and Appendix G: Estimated *E. coli* Load Reduction Calculations.
7. The goal was used to estimate the number of pollutant sources reduced (e.g., number of deer reduced, such that their *E. coli* no longer reached the river or creek). Several assumptions were made during this process, including values based upon literature or prior studies, discussions with TAG members and other experts, and best engineering judgement. Assumptions are provided in the effectiveness calculations, and information sources are listed, where available (refer to Appendix G: Estimated *E. coli* Load Reduction Calculations).
8. For each BMP, the number of pollutant sources (i.e., animals) reduced was multiplied by the theoretical rate of *E. coli* produced by each source and the calibration factor to obtain an estimate of the total potential *E. coli* reduced for each source based upon the defined goals. Refer to Appendix G: Estimated *E. coli* Load Reduction Calculations.
9. Estimated potential reductions were summed for all BMPs for each source, and then across all sources to calculate the total potential load reduction achieved if all recommended source-specific BMPs (i.e., all BMPs except for stormwater BMPs) are implemented over a 10-year implementation period. Refer to Appendix G: Estimated *E. coli* Load Reduction Calculations.
10. The potential *E. coli* loading in stormwater was estimated by subtracting the total potential *E. coli* reduction from source-specific BMPs from the total *E. coli* load for each waterbody. Refer to Appendix G: Estimated *E. coli* Load Reduction Calculations.
11. The estimated additional *E. coli* reduction from stormwater BMPs was estimated based upon the potential *E. coli* loading in stormwater, and estimates of the effectiveness of each BMP on reducing *E. coli*. Refer to Appendix G: Estimated *E. coli* Load Reduction Calculations.
12. The total potential load reduction achieved if all BMPs (i.e., including stormwater BMPs) are implemented over a 10-year implementation period was calculated by adding the potential *E. coli* reduction from source-specific BMPs to the potential *E. coli* reduction from stormwater BMPs. Refer to Appendix G: Estimated *E. coli* Load Reduction Calculations.

Note that in many cases, the estimated load reduction in the Comal River is greater than in the Dry Comal Creek. In some cases, this is due to more aggressive goals in the area draining to the Comal River (e.g., the focus of non-native avian wildlife and deer BMPs are within the City limits). However, in other cases, this is due to the much closer proximity of pollutant sources to the Comal River, resulting in a greater percentage of the *E. coli* reaching the waterbody. This was accounted for in the load reduction estimation process, using the calibration factors described above.

5.3.2 Development of BMP and Outreach and Education Activity Cost Estimates

Cost estimates were also developed for each planned activity to aid the Watershed Partnership in budgeting appropriately and identifying funding sources. AACE International Class 5 (AACE International, 2005) opinions of probable cost ("cost estimates") were developed. Class 5 cost estimates are for projects with "concept level" definition and typically range from -50 percent to +100 percent. Cost estimates for each BMP and outreach and education activity are detailed in Appendix F. The cost estimates were developed without regard to the potential source of funding (e.g., in-kind contribution or a grant), but rather account for the total cost of implementation to the agencies leading implementation of each BMP. Note that estimated costs do not reflect all resources and time (e.g., community volunteers) that will be expended on these BMPs. The Watershed Partnership will use these estimates, during implementation, to assess which strategies can be funded partly or in full by the Watershed Partnership and stakeholders (e.g., as in-kind or through volunteering), and which activities will require additional funding sources. Potential sources of additional funding are summarized for each BMP and described in detail in Section 9.2. Cost estimates were reviewed with TAG members (e.g., the Natural Resources Conservation Service (NRCS), TPWD, Comal County) and other subject matter experts, as applicable, to confirm the estimates were in line with costs for similar prior work. In addition, the cost estimates were based upon the following assumptions and methods:

- Cost estimates for each BMP and outreach and education activity were typically broken down into line items and unit costs. As noted, cost estimates were developed using prior experiences, engineering best judgement and peer-reviewed literature, where available and as noted. Costs also account for goals (i.e., implementation milestones, as further described in Sections 7 and 8) set for each BMP (e.g., number of WQMPs to be implemented) to meet the *E. coli* load reduction targets.
- Burdened City staff labor rates of $25/hour and $40/hour were assumed for "on-the-ground" implementation support, with the higher rate assigned to tasks requiring more specialized or technical expertise.
- A 30 percent contingency was added to most cost estimates.[10]
- A 10-year implementation timeframe was assumed. Timing for implementation of each strategy is currently based upon the prioritization of BMPs during the planning process, and the number of BMPs that could practically be implemented in any given year.

[10] The standard percentage used for contingency depends on the class of cost estimate provided. For a Class 5 Cost Estimate, the expected accuracy (on the high end) ranges from 30 percent to 100 percent. A contingency of 30 percent (i.e., the lower end of this range) was selected for cost calculations.

- Costs for general overabundant and non-native urban wildlife BMPs (i.e., BMPs that benefited both urban deer and non-native avian wildlife) were split 70/30 between overabundant urban deer and non-native urban avian wildlife.
- A three percent annual escalation factor was applied across the 10-year timeframe.[11]

5.4 Overabundant Urban and Non-Native Wildlife BMPs

Non-native and overabundant urban wildlife were identified by BST analysis as a significant portion of bacteria pollution in the Dry Comal Creek and Comal River. Migration of native deer and non-native avian wildlife to urban areas has resulted in significant bacteria loading to the Watershed. Additionally, feral hogs have been observed in rural areas of the Watershed with deeper soils. Thus, the Watershed Partnership recommends a collaborative effort to reduce the density of overabundant urban and non-native wildlife populations to reduce their impact on water quality. While other native wildlife, such as whitetail deer in rural areas, raccoons, opossums, and native bird species, also contribute to bacterial pollution, native wildlife sources are not specifically addressed in the BMPs. However, BMPs addressing urban deer and non-native wildlife, such as Do Not Feed campaigns, may also reduce other native wildlife sources.

The BMPs recommended to address bacteria loading from overabundant urban and non-native wildlife are described in the following sections, and the implementation strategy for each *E. coli* source is summarized in tables. Refer to Appendix D for a list of additional BMPs that were considered but ranked low priority for this Watershed. Additional details on implementation, including the implementation schedule, costs and effectiveness are provided in Section 7, and additional details on technical and financial resources are provided in Section 9.

5.4.1 Overabundant Urban Deer BMPs

Five BMPs were selected by the Watershed Partnership for management of overabundant urban deer. Each BMP is described in the sections below with a summary of the implementation strategy provided in Table 13. Management of overabundant deer will focus on implementation of Do-Not-Feed Wildlife campaigns but will be supplemented by active management and modification of riparian areas, when appropriate. The program will aim to reduce the population to a target density agreed upon by TPWD and City Council during an initial reduction phase, followed by a maintenance phase to maintain deer densities near target levels. Social carrying capacity, also known as cultural carrying capacity, is the maximum number of deer that society will accept within an area. Social carrying capacity depends on human attitudes towards deer, which can change over time depending on a person's education and experiences (Alderson, 2008). Social carrying capacity is reached when the deer population is high enough to cause widespread conflict with people. Conflict arises when deer begin

[11] Escalation factor selected based upon review of recent and historical data on the Producers Price Index (U.S. Bureau of Labor Statistics, 2018), commonly used by Texas agencies managing water resources.

causing landscape damage, deer-vehicle collisions and negatively impacting water quality. Social carrying capacity statistics and results of continued water quality monitoring will be analyzed to assess the effectiveness of these BMPs.

Do-Not-Feed Wildlife Ordinance and Campaign within City Limits

The City will work toward implementation of an ordinance in the City limits that will reduce the population of urban deer by restricting the feeding of all wildlife within the City limits. By including ordinance language that addresses a broad-spectrum of wildlife, the City will have flexibility to enforce no-feeding of other wildlife species observed in future years. The ordinance will be communicated to the community and visitors through both permanent signage and enforcement of the ordinance by issuing warnings and penalties for feeding wildlife. An intensive public outreach campaign will be also conducted to inform and educate residents, businesses and visitors about the harm that feeding wildlife may cause both to the wildlife and to the Watershed. Refer to Section 6 for additional information on the outreach and education campaign.

Deer Population Assessment

The Watershed Partnership will annually review social carrying capacity measures, such as the number of traffic accidents and emergency vehicle damage caused by deer, the number of deer removed from roadways in the City limits or its extraterritorial jurisdiction (ETJ) and water quality. Data on deer-related vehicle accidents will be collected from third parties, such as insurance companies, and/or from the City's Environmental Services Division on collection of road-side carcasses. Data will be used to assess the effectiveness of reducing the urban deer population following implementation of the relevant BMPs.

Voluntary Do-Not-Feed Wildlife Campaign in Rural Neighborhoods

In more rural areas, including neighborhoods along Hwy 46, Hwy 1863, Schoenthal Road, and Hwy 3009, an outreach and education campaign will be conducted to communicate the impact of overabundant urban deer on water quality; the safety concerns due to the number of vehicular collisions with wildlife in the Watershed, and the impact of feeding on the health of the wildlife. Promotional and educational materials will be distributed biennially. Outreach and education will be coordinated with the WPP Outreach and Education Plan (Section 6).

Wildlife Management Workshops

Additionally, as wildlife management is a large component of the strategy to reduce *E. coli* in the Watershed, periodic wildlife management workshops will be advertised to share information and resources available on wildlife management. TAMU Wildlife and Fisheries Department and the Texas Wildlife Association host webinars on wildlife management, which are available for free online at http://wildlife.tamu.edu/publications/webinars/ and http://www.texas-wildlife.org/resources/webcasts/category/webinars/. As they become available, these Webinars will be advertised in the watershed through social media, the WPP website and news releases. Additionally, the Watershed Partnership will work with Texas A&M AgriLife and TPWD to plan and host in-person wildlife workshops in the Watershed. Refer to Section 6 for additional information.

Active Management of Deer with City Council Approval

To supplement the proactive Do-Not-Feed Wildlife campaigns, the Watershed Partnership will conduct active management of deer, as necessary and contingent upon City Council approval, to meet the WPP population reduction goals to improve water quality. The Watershed Partnership will work directly with the TPWD to communicate the benefits of the active management program to the community. There are many factors that are considered in the management of urban deer, including carrying capacity of the land, number of deer-vehicle collisions, human-deer interactions, and management preferences of the community.

The Texas Hunters for the Hungry Program may be a viable option for active management of deer in some parts of the Watershed. Administered by the Texas Association of Community Action Agencies (TACAA), the Texas Hunters for the Hungry Program is a statewide wild game and hunger relief program that provides a healthy source of protein to needy Texans. Hunters and licensed trappers can bring their legally tagged and field-dressed deer to participating meat processors.[12] Game is processed for a nominal fee and then distributed to food banks and similar entities. Statewide, venison has been the staple for the Hunters for the Hungry Program. The Watershed Partnership will work with TACAA, Texas Department of Agriculture (TDA), licensed trappers, and others to explore the feasibility of integrating management of overabundant animal populations with the generation of low-cost food products for community groups and low-income families.

[12] There are two processing facilities within 25 miles of the Watershed that participate in the Hunters for the Hungry Program: Granzin's Meat Market in New Braunfels; and Trinity Oaks Processing in Garden Ridge.

Table 13: BMPs to Address Overabundant Urban Deer

Goals

- To reduce *E. coli* loading from overabundant urban deer
- To reduce the population density of deer in urban areas through passive (i.e., education on not feeding wildlife) and active management programs

Description

Management of overabundant deer will focus on implementation of Do-Not-Feed Wildlife campaigns, which will be supplemented by active management, as necessary.

BMPs	Location	Implementation Timeline	Responsible Party	Estimated Cost
Do-Not-Feed Wildlife Ordinance and Campaign within City Limits	City limits	Years 1 – 10 with ordinance development in Year 1 and signs installed in Years 2 and 6 *(Priority = Critical)*	City	$142,200
Deer Population Assessment	City limits and ETJ	Years 1 – 10 *(Priority = High)*	City	$68,000
Voluntary Do-Not-Feed Wildlife Campaign in Rural Neighborhoods	Rural areas and Hwy 46, 1863 and 3009	Biennial; Years 1 – 9 *(Priority = High)*	City	$26,700
Wildlife Management Workshops	Online and Headwaters Facility	Biennial; Years 2 – 10 *(Priority = High)*	Texas A&M AgriLife & TPWD	$11,800
Active Management of Deer with City Council Approval	Urban Areas	Years 3 – 10 with planning/permitting in Year 2 *(Priority = High)*	City	$368,100

Estimated Potential *E. coli* Load Reduction

Reductions in the overabundant urban deer population will reduce bacteria loading in the Watershed. Estimates of expected potential load reductions are summarized below totaling $1.21x10^{11}$ CFU/day in the Comal River and $1.89x10^{7}$ CFU/day in the Dry Comal Creek.

BMPs	Comal River (CFU/day)	Dry Comal Creek (CFU/day)
Do-Not-Feed Wildlife Ordinance and Campaign within City limits	$5.91x10^{10}$	$8.15x10^{6}$
Deer Population Assessment	0.0	0.0
Voluntary Do-Not-Feed Wildlife Campaign in Rural Neighborhoods	$4.62x10^{9}$	$3.58x10^{6}$
Wildlife Management Workshops	$2.31x10^{9}$	0.0
Active Management of Deer with City Council approval	$5.54x10^{10}$	$7.15x10^{6}$

Technical Resources

- City Legal Department and Public Works Department
- TPWD
- City of Austin
- GBRA
- Watershed Coordinator and WPP Consultant
- Texas A&M AgriLife
- Engineering Biologists/Ecologists
- Licensed Trappers

Financial Resources

- Section 319(h) Federal Clean Water Act - TCEQ *
- City of New Braunfels In-Kind contributions
- Section 104(b) Programs

* 319(h) funding will not be used to fund any active wildlife management BMPs.

Priority Subwatershed Nos.

1, 2, 3, 4, 5, 6, 9, 16, 20, 21, 22, 26, 28, 29, 32, 40, 43, 48, 49, 55, 56, 57, 58, 59, 64, 65, 66, 69, 70, 71, 74, 76, 77

5.4.2 Non-Native Avian Wildlife BMPs

Seven BMPs were selected by the Watershed Partnership for management of non-native avian wildlife in the Watershed. BMPs will focus on Landa Park and the surrounding neighborhoods, as the Stakeholder Group agreed that the largest population of non-native avian wildlife is located in Landa Park. Each BMP is described below with a summary of the implementation strategy provided in Table 14. Management of non-native avian wildlife in Landa Park will focus on implementation of Do-Not-Feed Wildlife campaigns. Intensive public outreach and education to reduce the feeding of non-native avian wildlife is important because these species predominantly gather in public locations where residents and tourists are likely to feed them. Effectively conveying the need to reduce the non-native avian wildlife population will be necessary to reduce the bacteria loading to the Dry Comal Creek and Comal River. While BMPs will focus on outreach and education, active BMPs, such as oil-coating non-native duck eggs or "scare" tactics, will also be used. The program will aim to remove as many non-native ducks and geese as practicable from Landa Park (refer to Section 7 for implementation goals).

▶ Do-Not-Feed Wildlife Ordinance and Campaign

As described previously in the overabundant urban deer BMPs (Section 5.4.1), the City will work to implement an ordinance that will reduce the population of non-native avian wildlife by restricting the feeding of all wildlife within the City limits. The Watershed Partnership will also conduct an intensive Do-No-Feed Wildlife public outreach campaign. Promotional and educational materials will be distributed annually within the City limits. Refer to Section 6 for additional information on the outreach and education campaign.

▶ Non-Native Duck and Goose Population Assessment

The Watershed Partnership will review the number of non-native duck eggs/nests located during oil coating exercises. These data will be used to assess the effectiveness of reducing the non-native avian wildlife population following implementation of the associated BMPs.

▶ Discourage Non-Native Ducks and Geese from Congregating in the Park

Efforts will be made to discourage non-native ducks and geese from settling in Landa Park and make the riparian habitats less desirable. Decreasing the time that wildlife is in the riparian corridor will reduce bacteria loading in these areas and improve water quality. Tactics, which will be considered include wailers, a fan-powered waving tube-man, water-based drones (e.g.,

"Goosinator"), floating alligator heads, lasers, and firing a soft-gun into waterfowl gatherings. Two of these, or similar, tactics will be selected for implementation at Landa Park.

Rapid Removal of Dead Animals

Quickly removing dead animals in the riparian area will reduce the attraction of any outside non-native scavenging wildlife (e.g., racoons), which may contribute additional *E. coli* and also reduce *E. coli* associated with the carcasses. The City will enhance existing programs[13] to quickly remove dead animals from within the City limits and ETJ, especially from parks and public areas. Quick removal of dead animals is a low-cost BMP for general watershed health.

Wildlife Management Workshops

As described above in the overabundant urban deer BMPs (Section 5.4.1), the Watershed Partnership will communicate and provide education to the community on wildlife management.

Trap Non-Native Ducks and Geese

The City will implement a program to trap non-native ducks and geese in Landa Park. The City will hire a contractor to perform trapping. The Watershed Partnership will evaluate alternatives, in consultation with TPWD and City Council, for handling the trapped non-native ducks and geese, such as relocation outside the Watershed or donation to programs, such as the Hunters for the Hungry program described in Section 5.4.1 on overabundant deer BMPs.

Oil Coat Non-Native Duck Eggs

The City has an ongoing non-native duck-egg oil coating program to prevent non-native duck eggs from hatching, thereby, reducing the number of non-native ducks. The City will either provide training for City staff in improved techniques for oil-coating and identifying the locations of non-native duck eggs or hire a professional contractor to perform oil coating in Landa Park. The program will target use of 100 percent food grade corn oil to avoid licensing requirements associated with the use of paraffin.

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[13] Residents may contact Animal Services through the Humane Society of New Braunfels at (830) 608-2183 to have dead animals removed from streets.

Table 14: BMPs to Address Non-Native Avian Wildlife

Goals

- To reduce *E. coli* loading from non-native avian populations
- To reduce the population of non-native ducks and geese in Landa Park to the extent practicable through passive (i.e., education on not feeding wildlife) and active management

Description

Management of non-native avian wildlife will focus on implementation of Do-Not-Feed Wildlife campaigns in rural areas and will be supplemented by active management.

BMPs	Location	Implementation Timeline	Responsible Party	Estimated Cost
Do-Not-Feed Wildlife Ordinance and Campaign within City Limits	City limits	Years 1 – 10 with ordinance development in Year 1and signs installed in Years 2 and 6 *(Priority = Critical)*	City	$68,900
Non-Native Duck and Goose Population Assessment	Landa Park	Years 1 – 10 *(Priority = High)*	City	$23,000
Discourage Non-Native Ducks and Geese from Congregating in the Park	Landa Park	Years 2 – 10 with purchase of new equipment in Year 2 *(Priority = High)*	City	$83,900
Rapid Removal of Dead Animals	City limits and ETJ	Years 1 – 10 *(Priority = High)*	City	$152,6000
Wildlife Management Workshops	Online / NBU Headwaters Facility	Biennial; Years 2 – 8 *(Priority = High)*	Texas A&M AgriLife & TPWD	$5,000
Trap Non-Native Ducks and Geese	Landa Park, Fischer Park	Years 1 – 10 *(Priority = High)*	City	$73,200
Oil Coat Non-Native Duck Eggs	Landa Park	Years 1 – 10 *(Priority = High)*	City	$22,300

Estimated Potential *E.coli* Load Reduction

Reducing non-native avian wildlife will reduce bacteria loading in the Watershed. Estimates of expected potential load reductions are summarized below totaling 9.47×10^{10} CFU/day in the Comal River.

BMP	Comal River (CFU/day)	Dry Comal Creek (CFU/day)
Do-Not-Feed Wildlife Ordinance and Campaign within City Limits	2.96×10^{10}	0.00
Non-Native Duck and Goose Population Assessment	0.00	0.00
Discourage Non-Native Ducks and Geese from Congregating in the Park	3.55×10^{10}	0.00
Rapid Removal of Dead Animals	0.00	0.00
Wildlife Management Workshops	1.17×10^{10}	0.00
Trap Non-Native Ducks and Geese	9.25×10^{7}	0.00
Oil Coat Non-native Duck Eggs	1.78×10^{10}	0.00

Technical Resources

- TPWD
- Watershed Coordinator and WPP Consultant
- Engineering Biologists/Ecologists
- City Parks Department and Public Works Department
- GBRA

Financial Resources

- Section 319(h) Federal Clean Water Act – TCEQ
- City of New Braunfels In-Kind contributions
- Section 104(b) Programs

Priority Subwatershed Nos.

6, 28, 29, 32

5.4.3 Feral Hog BMPs

Four BMPs were selected by the Watershed Partnership for management of feral hog populations. Each strategy is described below with a summary of the implementation strategy provided in Table 15. Management of feral hogs will focus on implementation of voluntary management programs and education, because much of the Watershed, particularly around the City limits, does not have soil conducive to feral hog habitation. The program will aim to reduce the current population by about 80 percent (i.e., about 1200 hogs). The number of hogs trapped or killed and reported by landowners will be reviewed to assess the effectiveness of these BMPs.

The Watershed Partnership will draw on the expertise and resources of Texas Wildlife Services (TWS), a division of Texas A&M AgriLife, which works to protect Texans from resource and property damages due to wildlife. TWS serves rural and urban areas with technical assistance, education, and direct control of both native wildlife and non-domestic animals.

Feral Hog Workshops

The Watershed Partnership will work with TWS and TPWD to provide Feral Hog Workshops within the Watershed. TWS will provide the training and associated materials as part of ongoing workshops they host. The Watershed Partnership will identify locations to host the workshops and will publicize the workshops in the Watershed. The workshops are intended to inform landowners and the public about feral hogs, the problems caused by feral hogs, and management solutions. The purpose of the workshops is to encourage voluntary management of feral hogs by fencing of deer feeders, trapping, and hunting. Additionally, in coordination with the workshops, the Watershed Partnership will collect information from land owners about the numbers, movement and management of feral hogs on their land.

Bounty Program

To incentivize landowners to trap or kill feral hogs, the Watershed Partnership will work with Comal and Guadalupe Counties to identify funding for and implement a feral hog bounty program. The program would provide a bounty (e.g., $5 to 10 per hog) and a short training video when citizens collect their bounty. Bounty programs have been very successful in other watersheds (e.g., Plum Creek). The Watershed Partnership will also provide information on the Texas Hunters for the Hungry Program, as described in Section 5.4.1 on overabundant urban deer BMPs, to landowners trapping and killing feral hogs.

Trapping Intensity Assessment

To assess the effectiveness of the feral hog BMPs, the Watershed Partnership will track the trapping intensity reported by landowners. The Watershed Partnership will directly reach out to landowners every two years.

Feral Hog Website

The Watershed Partnership will work to develop a feral hog website to provide the public access to information on BMPs and locations of hog activity in the Watershed. The website will include a method for reporting hog sightings. The website may be incorporated into the existing WPP Website, or the Watershed Partnership may reach out to the Plum Creek Watershed Partnership to discuss the expansion of existing feral hog websites to include the Dry Comal Creek and Comal River watersheds. Data collected during outreach to landowners, discussed as part of the feral hog workshops, will be entered into the website. The website may also include information on or a link to information on management measures, such as fencing deer feeders, trapping, hunting and shooting.

Table 15: BMPs to Address Feral Hogs

Goals

- To reduce *E. coli* loading from feral hogs
- To reduce the total number of hogs in the Watershed

Description

Management of feral hogs will focus on implementation of voluntary management programs and education, because much of the Watershed does not have soil conducive to feral hog habitation. The number of hogs trapped or killed and reported by landowners will be reviewed to assess the effectiveness of these BMPs.

BMPs	Location	Implementation Timeline	Responsible Party	Estimated Cost
Feral Hog Workshops	Various	Biennial Years 1 – 9 *(Priority = High)*	Texas A&M AgriLife	$13,900
Bounty Program	Comal and Guadalupe Counties	Years 2 – 10 with video and program development in Year 2 *(Priority = High)*	Comal and Guadalupe Counties	$65,500
Trapping Intensity Assessment	Comal County	Years 2 – 10 *(Priority = High)*	Comal County	$30,500
Feral Hog Website	Online	Years 4 – 10 with website development in Year 4 *(Priority = Moderate)*	City	$32,300

Estimated Potential *E. coli* Load Reduction

Reductions in the time that feral hogs use the riparian corridor will reduce bacteria loading in the Watershed. Estimates of expected potential load reductions are summarized below totaling 8.57×10^{10} CFU/day in the Comal River and 2.92×10^{8} CFU/day in the Dry Comal Creek.

BMPs	Comal River (CFU/day)	Dry Comal Creek (CFU/day)
Feral Hog Workshops	7.68×10^{9}	1.21×10^{7}
Bounty Program	7.80×10^{10}	2.79×10^{8}
Trapping Intensity Assessment	0.0	0.0
Feral Hog Website	0.0	0.0

Technical Resources

- TWS
- Watershed Coordinator and WPP Consultant
- City of Austin
- Plum Creek Watershed Partnership
- Comal and Guadalupe Counties
- Texas Wildlife Damage Management Service
- Geronimo and Alligator Creek Watershed Partnership

Financial Resources

- Section 319(h) Federal Clean Water Act – TSSWCB
- Feral Hog Abatement Grant Program

Priority Subwatershed Nos.

9, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 34, 46, 48, 50, 53, 54, 60, 63, 66, 68, 73, 74, 76, 77

5.5 Livestock BMPs

Livestock potentially contribute significant bacteria to the Dry Comal Creek and Comal River. Because the implementation of livestock and range BMPs will depend on participation by landowners on their private property, the proposed BMPs focus on outreach and education, and preparation of voluntary WQMPs. The program will aim to implement 60 WQMPs (seven per year, on average) in the Watershed, in addition to providing education to existing and future rural landowners. Two BMPs are described below and in Table 16. Refer to Appendix D for list of additional BMPs that were considered but ranked low priority for this Watershed. Additional details on implementation, including the schedule, costs and effectiveness are provided in Section 7, and additional details on technical and financial resources are provided in Section 9.

▶ Water Quality Management Plans

The Stakeholder Group recommended that multiple site-specific BMPs be integrated, where appropriate, into local operations in order to address all potential agricultural-related sources of bacteria carried in runoff or directly deposited into waterbodies. They further recommended that this can best be done by developing voluntary, site-specific management plans for individual farms.

Both the NRCS and TSSWCB offer agricultural producers technical guidance as well as financial incentives for “on-the-ground” implementation. To receive financial incentives from TSSWCB, the landowner must develop a WQMP with the local Soil and Water Conservation District (SWCD) that is customized to fit the needs of their operation. The NRCS offers options for development and implementation of both individual practices and whole farm Conservation Plans. Although WQMPs will be initially targeted, as needed to meet water quality goals, the Project Partners will also consider and recommend the development of Conservation Plans. Any implemented Conservation Plans will contribute toward overall WQMP goals.

The livestock Work Group also considered the practical number of WQMPs that could be implemented in the Watershed. Calculations were based upon USDA Census and Agriculture data from 2007 to 2012 (and projections for 2017) for Comal County, SELECT results using current land-use type (refer to Section 4.5), local stakeholder knowledge and discussions with TAG members. It appears that the average ranch size (in acres) in Comal County is decreasing, while the number of livestock is relatively stable. Based upon all of these considerations, an average operation was assumed to have 20 cattle and 20 sheep and goats.

Utilizing this information, along with results from the SELECT and load reductions required based upon LDC analyses (refer to Section 4.2), the number of WQMPs targeted for livestock operations in the subwatersheds draining to the Dry Comal Creek totaled 60 (seven per year, on average). To help achieve this goal, the Watershed Partnership will pursue funding and support, and assist the SCWD in developing and delivering educational materials to landowners. Alternatively, the WPP goals will be met if the loading from livestock is reduced in

areas draining to the Comal River by 50 percent and in areas draining to the Dry Comal Creek by 34 percent, based upon the reductions in livestock due to rural real estate development and the number of livestock addressed with WQMPs.

Due to the nature of NPS pollution, a combination of BMPs will be selected to address bacteria from livestock operations. Selection of BMPs for WQMP development is site specific and will be tailored to each property. Based on ranch-specific characteristics, plans will likely include one or more of the following management practices to reduce pollutant loads from livestock operations:

- Establishment of grass cover in critical areas with high erosion potential or stormwater flow rates to reduce pollutant loading in runoff;
- Range management to improve or maintain the desired grass height and species composition;
- Placing livestock watering sources (e.g., stock tanks, troughs) outside the riparian corridor wherever possible;
- Construction of stream crossings or structures to provide a travel way for people, livestock, equipment, or vehicles across waterbodies; and
- Creation of alternative shade to reduce the time livestock spend resting near streams and riparian areas.

▶ Livestock Outreach and Education

Additionally, the Watershed Partnership will work with Texas A&M AgriLife to provide Livestock Workshops within the Watershed. Texas A&M AgriLife will provide the training and associated materials as part of ongoing Livestock and Agriculture Workshops they host (e.g., *Lone Star Healthy Streams*), and the Watershed Partnership will work together to identify venues to host the workshops and publicize the workshops in the Watershed. Education activities will provide information on structural and operational BMPs that will promote good range management practices and reduce the time animals spend in the creek or riparian corridor. Outreach programs will provide information on education activities, in addition, to advertising technical assistance and funding programs to aid landowners in implementing BMPs. Outreach and education activities will focus on the more rural Dry Comal Creek Watershed. However, outreach and education will also include landowners in the Comal River Watershed. Although the Comal River Watershed is mostly developed, BST analysis (see Section 4.3) highlighted that livestock account for approximately 16 percent of bacteria in the Comal River Watershed.

Table 16: BMPs to Address Livestock

Goals

- To reduce *E. coli* loading from direct and indirect fecal loading, riparian degradation, and overgrazing
- To develop 60 WQMPs[1] focused on minimizing the time spent by livestock in the riparian corridor

Description

WQMPs[2] will be developed in areas to most appropriately address direct and indirect fecal deposition from cattle and other livestock and prescribe BMPs that will reduce time spent in the creek or riparian corridor, likely focusing on prescribed grazing, cross-fencing and watering facilities.

BMPs	Location	Implementation Timeline	Responsible Party	Estimated Cost
WQMPs[2]	Individual Operations	Years 2 – 10 *(Priority = High)*	SWCD, NRCS[2] and TSSWCB	$1,064,700
Livestock Outreach and Education	Various	Biennial; Years 2 – 10 *(Priority = High)*	Texas A&M AgriLife	$21,200

Estimated Potential *E. coli* Load Reduction

Reductions in the time that livestock use the riparian corridor will reduce bacteria loading in the Watershed. Estimates of expected potential load reductions are summarized below totaling $1.74x10^{10}$ CFU/day in the Comal River and $4.47x10^{8}$ CFU/day in the Dry Comal Creek.

BMPs	Comal River (CFU/day)	Dry Comal Creek (CFU/day)
WQMPs	0	$3.65x10^{8}$
Livestock Outreach and Education	$1.74x10^{10}$	$8.18x10^{7}$

Technical Resources

- TSSWCB
- SWCD
- NRCS District Conservationists
- Watershed Coordinator and WPP Consultant
- Texas A&M AgriLife

Financial Resources

- 319(h) Federal Clean Water Act – TSSWCB
- Water Quality Management Plan Program (503 Program)
- NRCS – Environmental Quality Incentives Programs[2]
- NRCS – Grazing Lands Conservation Initiative[2]

Priority Subwatershed Nos.

4, 18, 20, 21, 23, 40, 41, 43, 44, 47, 49, 51, 52, 54, 55, 56, 59, 60, 67, 68, 69, 70, 72, 73, 74, 75, 77, 78

1 - Alternatively, the WPP goals will be met if the loading from livestock is reduced in areas draining to the Comal River by 50 percent and in areas draining to the Dry Comal Creek by 34 percent, based upon the reductions in livestock due to rural real estate development and the number of livestock addressed with WQMPs.
2 – As needed to meet water quality goals, Conservation Plans funded through NRCS will also be considered and recommended, in addition to WQMPs.

5.6 Stormwater and Infrastructure BMPs

Bacteria pollution from stormwater and infrastructure includes *E. coli* from OSSFs, urban and non-urban stormwater runoff, pets, and wastewater. BMPs in the urban areas of the City must also account for future population growth and expansion of related infrastructure. Thus, the Watershed Partnership developed a series of recommendations for each potential source. In addition, the City will continue to develop and expand this existing MS4 program and EAHCP program, described in Section 2.10, which will be supplemented by the new BMPs recommended by the Watershed Partnership. The BMPs are described in the following sections, and the implementation strategy for each *E. coli* source is summarized in tables. Refer to Appendix D for list of additional BMPs that were considered but ranked low priority for this Watershed. Additional details on implementation, including the schedule, costs and effectiveness are provided in Section 7, and additional details on technical and financial resources are provided in Section 9.

5.6.1 OSSF BMPs

Two BMPs were selected by the Watershed Partnership for management of OSSFs. Each strategy is described below with a summary of the implementation strategy provided in Table 17. Management of OSSFs will focus on implementation of an enhanced inspection and maintenance program, supplemented by education and assistance programs for homeowners. The Watershed Partnership estimates that by inspecting two OSSFs per week in the rural areas, targeting OSSFs most likely to exhibit failures (e.g., older systems), most failing OSSFs could be identified and corrected by the end of the 10-year implementation period. Failing OSSFs are generally considered to include systems with leaks and systems that are undersized or improperly maintained, resulting in untreated wastewater overflows.

▶OSSF Education and Assistance Programs

The Watershed Partnership will provide education and assistance programs on proper operation and maintenance of septic systems, including how to identify a failing system, and guidance on how to repair or replace a system (e.g., Comal County and the Extension service both have training courses for aerobic systems to certify landowners to do their own maintenance). In January of each year, Comal County also conducts free training (8-hour course providing CEUs) titled "How to Obtain a Comal County OSSF Permit" for engineers, installers, and maintenance firms. Several times each year, the County also conducts training for homeowners with OSSFs. The Watershed Partnership will encourage the continuation of these existing programs, collaborating to ensure the programs are publicized and made available to landowners throughout the Watershed.

Mandatory OSSF Inspection and Maintenance Program

Since any malfunctioning OSSFs are contributing human waste, the potential pathogenicity to humans is very high. Though only a small percentage of the overall bacteria load, the Stakeholders and TCEQ consider malfunctioning OSSFs, to be a high priority for management. As shown in Section 4.5.5, Figure 45 and Appendix C, page 17, there are limited OSSFs within the City Limits. The City regulates OSSFs within City Limits. Comal County regulates OSSFs in the County.

Comal County ordinances for OSSFs follow the TCEQ Edwards Aquifer recharge zone requirements in 30 TAC 285.4. Aerobic system owners must have a professional OSSF maintenance contract for the first two years after installation. After the initial contract period, owners of a single-family residence can do their own maintenance as long as the system is operating properly. Additionally, per 30 TAC 285.70, if the County documents a noncompliance and notifies the OSSF homeowner, owners are put on a probation period and must have a maintenance contract during that period.

Comal County will expand its existing program to add a trained professional Inspector (in addition to owners) to inspect targeted OSSFs. Based upon the calculations performed for the SELECT analysis (refer to Section 4.4 for methodology), there are approximately 336 failing OSSFs in the Watershed, primarily in areas that drain to the Dry Comal Creek. The locations of OSSFs are provided in a map in Appendix C. OSSF inspections will target locations based upon system type, age, and proximity to the creek or river. This program will seek funding to assist owners with needed repairs of failing OSSFs or replacement of the estimated 336 failing OSSFs in the Watershed. Owners receiving funding will be prioritized based upon the proximity of OSSFs to the creek and river, the extent of repair required, and other factors. The Inspector will follow-up with landowners to ensure any failures identified are properly corrected.

Comal County will also continue to update the existing OSSF permit database, compiling data on system age, location, and condition in electronic format for quick access. With incorporation of any new information, this central database will allow patterns of system installation and failure to be monitored to predict, prevent, and respond to problems in the future.

Table 17: BMPS to Address OSSFS

Goals

- To reduce *E. coli* loading from failing OSSFs
- To professionally inspect at least two OSSFs per week over a 7-year implementation period
- To work with owners to repair or replace failing OSSFs
- To provide education and assistance to OSSF owners

Description

Management of OSSFs will focus on implementation of an enhanced inspection and maintenance program, supplemented by education and assistance programs for landowners.

BMPs	Location	Implementation Timeline	Responsible Party	Estimated Cost
OSSF Education and Assistance Programs	Various	Biennial; Years 2 – 10 *(Priority = High)*	Comal County	$19,200
Mandatory OSSF Inspection and Maintenance Program	OSSFs	Years 3 – 10 *(Priority = High)*	Comal County	$498,700

Estimated Potential *E. coli* Load Reduction

Reductions in OSSF failures will reduce bacteria loading in the Watershed. Estimates of expected potential load reductions are summarized below totaling $6.90x10^9$ CFU/day in the Comal River and $7.78x10^7$ CFU/day in the Dry Comal Creek.

BMPs	Comal River (CFU/day)	Dry Comal Creek (CFU/day)
OSSF Education and Assistance Programs	$6.90x10^9$	$1.71x10^7$
Mandatory OSSF Inspection and Maintenance Program	0.0	$6.06x10^7$

Technical Resources

- Texas A&M AgriLife
- Comal County
- Watershed Coordinator and WPP Consultant
- City Public Works Department

Financial Resources

- Section 319(h) Federal Clean Water Act – TCEQ
- USDA-Rural Development Program, Clean Water Act State Revolving Fund
- Supplemental Environmental Project Program

Priority Subwatershed Nos.

26, 46, 52, 60, 61, 62, 66

5.6.2 Urban Runoff and Stormwater BMPs

Three BMPs were selected by the Watershed Partnership for management of urban runoff and stormwater. Each BMP is described below with a summary of the implementation strategy provided in Table 18. The City already has an MS4 program (detailed in Section 2.10), therefore management of stormwater will focus on implementation of non-structural BMPs that are not covered within the physical or regulatory limits of the City's MS4 program, outreach and education specific to *E. coli,* and engineering analysis of opportunities for additional structural BMPs. As stormwater BMPs address a wide-range of *E. coli* sources, the goal is implementation of these three new programs. The Watershed Partnership anticipates the concentration of *E. coli* in stormwater will decrease with the implementation of the source-specific BMPs identified for the Watershed. Thus, the potential *E. coli* loading in the stormwater, and thus the potential load reduction, was estimated based upon the potential *E. coli* reduction estimated from the source-specific BMPs.

Non-Structural Stormwater BMPs Outside of the City's MS4 Physical or Regulatory Jurisdiction

The Watershed Partnership will collaborate to implement non-structural stormwater control measures outside of the City's MS4 program such as:

- Control for stormwater runoff from construction sites;
- Detection and elimination of illicit discharges or illegal dumping;
- Pollution prevention and "good housekeeping" measures, such as street sweeping;
- And/or a recognition program for voluntary bacteria reduction measures incorporated in new developments.

Stormwater Outreach and Education

The Watershed Partnership will also enhance existing stormwater outreach and education programs. Within the City's MS4 program, the City will augment an education program on Fats, Oils and Grease (FOG) to include *E. coli* pollution education. In areas not included in the City's MS4 program, the Watershed Partnership will implement new outreach and education activities specific to stormwater quality and management that target HOAs and businesses in rural areas of the Watershed.

Engineering Analysis of Opportunities for Structural Stormwater BMPs

The Watershed Partnership will work with the WPP Consultant (see Section 5.2) to analyze opportunities for implementation[14], and implement structural stormwater BMPs (e.g., stormwater detention facilities or enhancements to reduce *E. coli*) outside of the City's MS4 program, such as:

- Structural improvements outside of the City's MS4 physical limits (e.g., in the County);
- Retrofitting existing developments in the City, which is not required by the City's MS4 permit;
- Modification of riparian areas to restore or add vegetation to trap contaminants in runoff from reaching streams; and/or
- Identification and implementation of up to $500,000[15] in additional LID and reduced impervious cover infrastructure.

[14] Areas such as those in Figure 19 that are outside of the MS4 will be considered in this analysis.

[15] A small budget is included for LID and impervious cover projects planned for implementation years 6 through 10. However, the budget was limited as the Stakeholder Group requested focusing resources on reduction of animal populations and related outreach efforts, which contribute the largest percentage to the *E. coli* concentrations in the Watershed based upon BST results. Additionally, NBU has an active MS4 program, described in Section 2.10.1.

Table 18: BMPS to Address Urban Runoff and Stormwater

Goals

- To reduce *E. coli* loading from urban and stormwater runoff
- To implement additional management practices outside of the City's MS4 permit activities

Description

As the City already has an existing MS4 program, management of stormwater will focus on implementation of non-structural BMPs outside the City's MS4, outreach and education, and engineering analysis of opportunities for additional structural BMPs.

BMPs	Location	Implementation Timeline	Responsible Party	Estimated Cost
Non-Structural Stormwater BMPs Outside of the City's MS4 Jurisdiction	Outside City's MS4 Jurisdiction	Years 2 – 10 with new programs beginning in Years 2 and 5 *(Priority = High)*	Comal County	$380,700
Stormwater Outreach and Education	Various	Years 1 – 10 with new signs in Year 2 and new materials in Years 1 and 6 *(Priority = High)*	New Braunfels Utilities and Comal County	$37,400
Engineering Analysis of Opportunities for Structural Stormwater BMPs	Various	Years 4 – 10 with analysis beginning in Year 4 *(Priority = Moderate)*	City	$1,584,000

Estimated Potential *E. coli* Load Reduction

Improvements to stormwater management will reduce bacteria loading in the Watershed. Estimates of expected potential load reductions are summarized below totaling 4.78×10^{10} CFU/day in the Comal River and 5.77×10^{8} CFU/day in the Dry Comal Creek.

BMPs	Comal River (CFU/day)	Dry Comal Creek (CFU/day)
Non-Structural Stormwater BMPs Outside of the City's MS4 Jurisdiction	0.0	2.31×10^{8}
Stormwater Outreach and Education	2.21×10^{10}	1.38×10^{8}
Engineering Analysis of Opportunities for Structural Stormwater BMPs	2.58×10^{10}	2.08×10^{8}

Technical Resources

- City Public Works Department
- Comal County
- Professional Engineers
- TCEQ and EPA
- Watershed Coordinator and WPP Consultant

Financial Resources

- Section 319(h) Federal Clean Water Act – TCEQ
- Supplemental Environmental Project Program
- Texas Capital Fund

Priority Subwatershed Nos.

N/A

5.6.3 Pet Waste BMPs

Four BMPs were selected by the Watershed Partnership for management of pet and feral cat (hereafter referred to as "pet") waste. Each BMP is described below with a summary of the implementation strategy provided in Table 19. Management of pet waste will focus on enforcement of existing waste pick-up codes and installation of additional pet waste stations, supplemented with additional outreach and education to the community and visitors. As the recommended strategies focus on management of pet waste (i.e., not reduction in the pet population), the goals for this strategy focuses on the implementation of these expanded programs (e.g., the implementation of 200 new pet waste stations over the 10-year implementation period). Efforts will prioritize areas in the Watershed where the most dogs reside (e.g., within City limits and in rural neighborhoods) and where dogs are walked in public areas (e.g., restaurants downtown, parks and trails, green areas outside City buildings).

Pet Owner Outreach and Education

The Watershed Partnership will expand existing pet waste public outreach programs to target both the City limits and residential developments in unincorporated areas of Comal County. The Watershed Partnership will provide public education information at locations where pet vaccinations and adoptions are performed, pets are walked, and pet owners reside or visit. Outreach and education will be coordinated with the WPP Outreach and Education Plan (Section 6). For example, outreach at local events may include educational materials on picking up pet waste. The Watershed Partnership will also provide signage informing readers of the need to properly dispose of pet waste in the Watershed.

Pet Waste Stations

Although the City previously established a dog park with pet waste stations and has also installed pet waste stations in other parks, there are still a large number of public areas in the City where dogs are walked and no pet waste stations are available. The City will install and maintain pet waste stations (bags and disposal unit) on City property to encourage proper management of pet waste. Efforts will focus on properties owned by the City with impervious cover areas, such as hike/bike trails, Landa Park, Panther Canyon, City Hall, and the Civic Center. The City is targeting installation of 200 new pet waste stations within the City limits over a 10-year implementation period. As the City has experienced vandalism of existing pet waste stations, this goal assumes replacement stations will be required.

Pet Code Enforcement

The City has a pet waste code (i.e., City Code Sec. 6-80) that requires pet owners to remove any deposits from public walks, recreation areas, or private property including the property of the pet owner. In addition, City code requires that all pets, including cats, be confined to their owner's property, and on a leash when off their property. The code also restricts pet ownership to no more than four cats or dogs per household. Enforcement of these codes is conducted by City Park Rangers, City Police, and the New Braunfels Animal Control Department. Public education and notification of these codes is made available at locations where pet vaccinations and adoptions are carried out, as well as through signage in the high traffic areas of Landa Park. The City will increase enforcement activities, and expand outreach and education (e.g., signage) to other areas of the City with a high volume of dog walkers.

Tailored Pet Solutions

Lastly, the City will identify individual areas, based on their needs and the likely impacts, that may make good candidates for tailored pet waste solutions. Initial focus will include identification of apartment complexes that have dog parks and/or do not have existing pet waste pickup programs. The City will meet with the apartment managers to communicate the importance of active pet waste programs and assist with identification of program goals and potential pet waste station locations. Contingent upon available funding, the City will provide up to 200 pet waste stations to apartment communities to encourage the implementation of pet waste programs. Other target areas may include rural neighborhoods and short-term rentals.

Table 19: BMPS to Address Pet Waste

Goals

- To reduce *E. coli* loading from pet waste
- To reduce the amount of pet waste not picked-up by pet owners
- To conduct additional outreach and education on the existing City pet waste codes and importance of picking up pet waste

Description

Management of pet waste will focus on enforcement of existing waste pickup codes and installation of additional pet waste stations, supplemented with additional outreach and education to the community and visitors.

BMPs	Location	Implementation Timeline	Responsible Party	Estimated Cost
Pet Owner Outreach and Education	City limits and rural residential developments	Years 1 – 10 *(Priority = Moderate)*	City	$33,400
Pet Waste Stations	Areas with high volumes of pet walkers	Years 2 – 10 with largest installation in Year 2 *(Priority = Moderate)*	City	$205,200
Pet Code Enforcement	City limits	Years 4 – 10 with notification effort in Year 4 *(Priority = Moderate)*	City	$71,200
Tailored Pet Solutions	Apartment complexes	Years 2 – 10 with analysis in Years 2 and 6 *(Priority = Moderate)*	City	$109,700

Estimated Potential *E. coli* Load Reduction

Improvements to stormwater management will reduce bacteria loading in the Watershed. Estimates of expected potential load reductions are summarized below totaling 2.56×10^9 CFU/day in the Comal River and 7.77×10^6 CFU/day in the Dry Comal Creek.

BMPs	Comal River (CFU/day)	Dry Comal Creek (CFU/day)
Pet Owner Outreach and Education	1.28×10^9	2.46×10^6
Pet Waste Stations	1.17×10^9	5.29×10^6
Pet Code Enforcement	1.15×10^8	2.46×10^4
Tailored Pet Solutions	0.0	0.0

Technical Resources	Financial Resources
• Watershed Coordinator and WPP Consultant • City Law Enforcement and Park Rangers • City Public Works Department	• Section 319(h) Federal Clean Water Act – TCEQ • Section 106 State Water Pollution Control Grants • Environmental Education Grants (both outreach & education)

Priority Subwatershed Nos.

6, 7, 8, 10, 11, 13, 14, 24, 28, 29, 32, 33, 34

5.6.4 Wastewater BMPs

Although human *E. coli* has a higher infection risk than wildlife *E. coli*, the percentage of the total *E. coli* that was identified in Watershed BST sampling as "human" was very low. There are currently only two permitted discharges in the Watershed (described in Section 2.7), in addition to a couple of facilities treating wastewater, but not discharging treated wastewater into the Watershed (described in Section 2.7), and any unintentional discharges from the existing wastewater collection system will be located and corrected quickly through NBU's SSO and maintenance programs (described in Section 4.5.7). Thus, the cost and practicality of implementing wastewater BMPs to reduce *E. coli* loading from human origin does not justify a significant effort at this time. All potential BMPs considered were ranked low priority (refer to Appendix D) and not included in the WPP, except for a tracking effort to monitor the current, and any future, wastewater discharges (Table 20). If, in the future, there are new wastewater discharges or data shows that the wastewater discharges are a significant source of *E. coli*, the BMPs will likely be revisited and may be elevated in priority.

Wastewater Discharge Water Quality Assessment

The Watershed Partnership will track wastewater treatment plant discharge water quality data (i.e., *E. coli* data) submitted to the TCEQ on wastewater discharges (i.e., TPDES permits) within the Watershed. The Watershed Partnership will analyze the results[16] submitted to the State annually and will note any trends or significant *E. coli* concentrations in discharges. Data will be used to evaluate whether additional BMP measures are necessary to reduce *E. coli* loading. Note that while the WPP Partnership may also track new wastewater treatment, land application or sludge holding tank permits in the Watershed, data analysis will be limited to wastewater discharges.

As mentioned previously, NBU maintains an aggressive SSO program for inspecting, cleaning and repairing its wastewater collection system. NBU reports all SSOs to the TCEQ. The SSO public records are also available for review by the Watershed Partnership.

[16] The Watershed Partnership will develop an Acquired Data Quality Assurance Project Plan (QAPP) for this water quality assessment.

Table 20: BMPS to Address Wastewater

Goals

- To reduce *E. coli* loading from wastewater discharges and overflows
- To monitor water quality of existing wastewater discharges

Description

Management of wastewater will focus on tracking water quality data submitted to the TCEQ for wastewater discharges (i.e., TPDES permits).

BMPs	Location	Implementation Timeline	Responsible Party	Estimated Cost
Wastewater Discharge Water Quality Assessment	Wastewater discharges in the Watershed	Years 2 – 10 *(Priority = Moderate)*	City	$9,100

Estimated Potential *E. coli* Load Reduction

As no improvements to the wastewater discharges are planned, no improvements in *E. coli* loading from wastewater is anticipated.

Technical Resources	Financial Resources
• Watershed Coordinator and WPP Consultant • New Braunfels Utilities • City Public Works Department • Professional Engineers • Comal County	• Section 319(h) Federal Clean Water Act – TCEQ • Stakeholder In-Kind contributions[17]

Priority Subwatershed Nos.

51, 60, 15, 24

[17] These BMPs cover activities outside the scope of the City's MS4 (Section 2.10.1) program and NBU's SSO (Section 2.10.3) program. The City and NBU will continue these programs in parallel with these additional activities.

5.7 Estimated WPP Potential Effectiveness at Reducing *E. coli* Loading

Using the implementation milestones selected for each BMP and assuming a 10-year implementation period, an estimated potential *E. coli* load reduction was calculated for each BMP. Estimated potential reductions for each BMP and the methodology were presented in Sections 4 and 5.3 and are summarized in Table 21 and detailed in Appendix G. The estimated total potential reduction of *E. coli* for the WPP BMPs exceeds the targeted potential reduction for the Comal River, the Dry Comal Creek and the entire Watershed, as shown in Figure 48. Thus, implementation of the selected BMPs is expected to reduce the *E. coli* loading in the Watershed with the goal of returning both waterbodies to water quality conditions for bacteria that are acceptable for recreational activity. However, as the number of bacteria actually reaching the stream depends on several environmental factors, including proximity to the creek, bacteria die-off, geomorphology, connectivity of stream network, temperature and other factors, it is difficult to predict the exact reduction that will occur in the Watershed. Thus, the Watershed Partnership will follow the process described in Section 8 to continually assess progress, and adapt the WPP implementation plan, as needed.

Table 21: Estimated Potential *E. coli* Load Reduction by Source

Source	*E. coli* Load (CFU/day)		
	Comal River	Dry Comal Creek	Total Watershed
Overabundant Urban Deer	120×10^9	0.019×10^9	120×10^9
Urban Non-Native Avian Wildlife	95×10^9	-	95×10^9
Feral Hogs	86×10^9	0.29×10^9	86×10^9
Livestock	17×10^9	0.45×10^9	18×10^9
OSSFs	6.9×10^9	0.078×10^9	7.0×10^9
Pets	2.6×10^9	0.00078×10^9	2.6×10^9
Stormwater	48×10^9	0.58×10^9	48×10^9
Wastewater	-	-	-
Total Potential Reduction ESTIMATED for WPP BMPs	**380×10^9**	**1.42×10^9**	**380×10^9**
Total Potential Reduction TARGETED	**350×10^9**	**1.07×10^9**	**350×10^9**

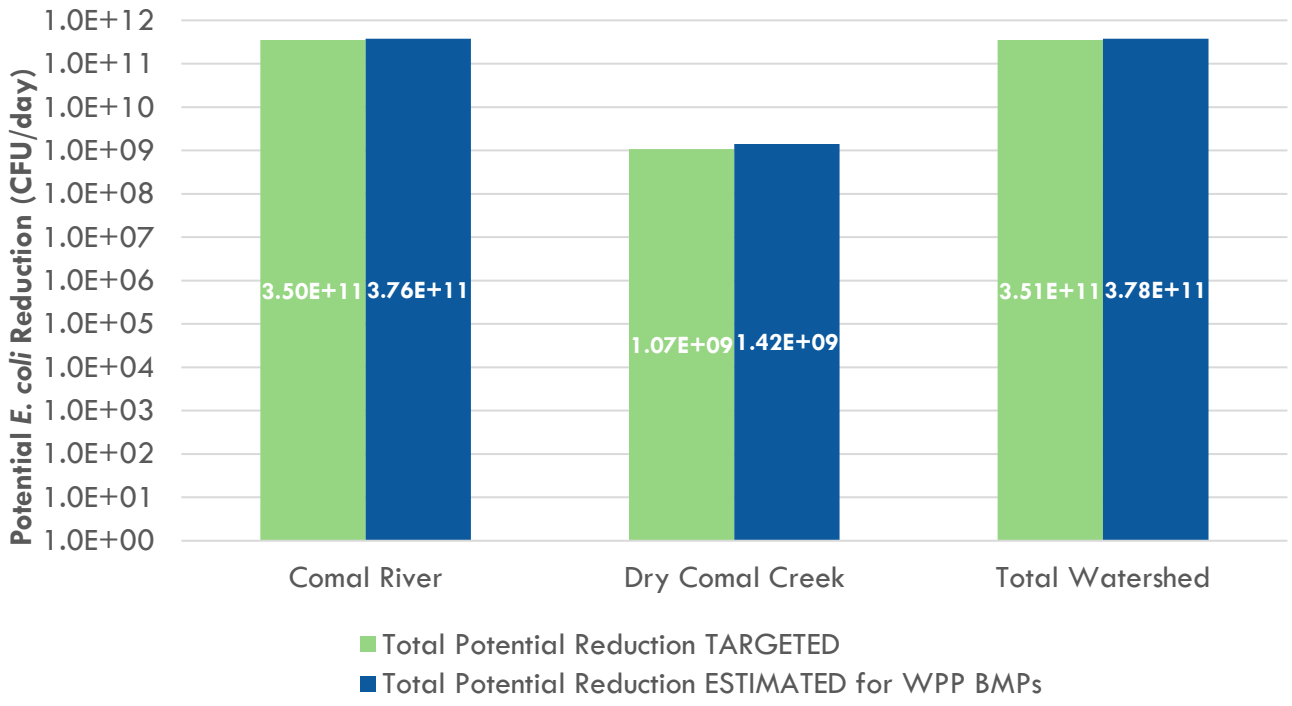


Figure 48: Potential *E. coli* Reduction Estimated Based Upon Selected BMPs

Figure 49 and Figure 50 show a comparison between the potential *E. coli* reduction for the Comal River and the Dry Comal Creek for each *E. coli* pollution source on a loading and percentage basis, respectively. A significant reduction in *E. coli* concentrations in the Comal River is expected due to BMPs addressing wildlife (i.e., overabundant urban deer, overabundant non-native urban avian wildlife, and feral hogs) and stormwater. The greatest reduction in *E. coli* loading to the Dry Comal Creek is expected to be due to stormwater, livestock, and feral hog BMPs. The estimated bacteria loading reduction by source category aligns with the portion of *E. coli* loading attributed to each source based upon BST testing, and thus, the sources focused on more intensely in the implementation plan.

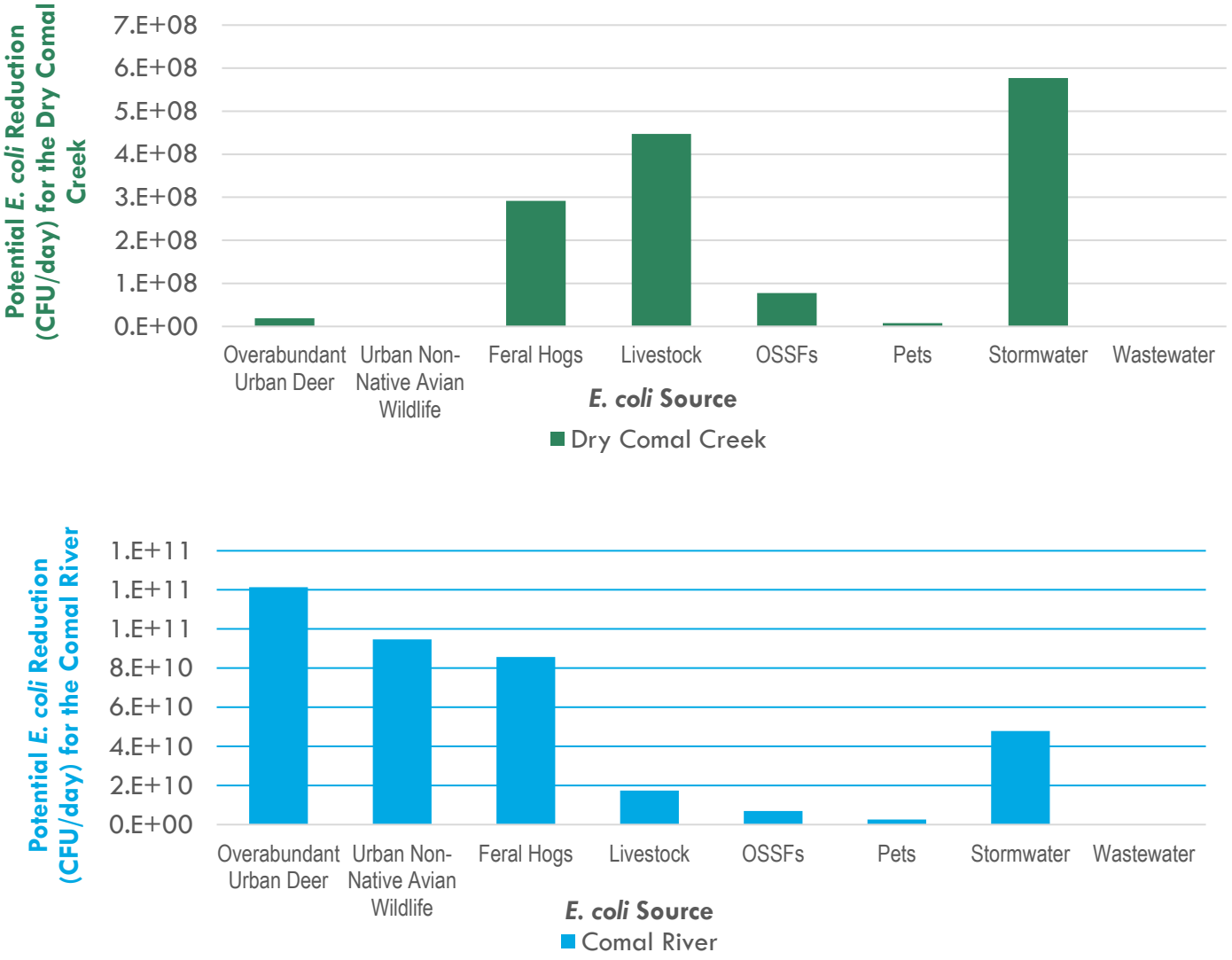


Figure 49: Potential *E. coli* Reduction Estimated for Selected BMPs

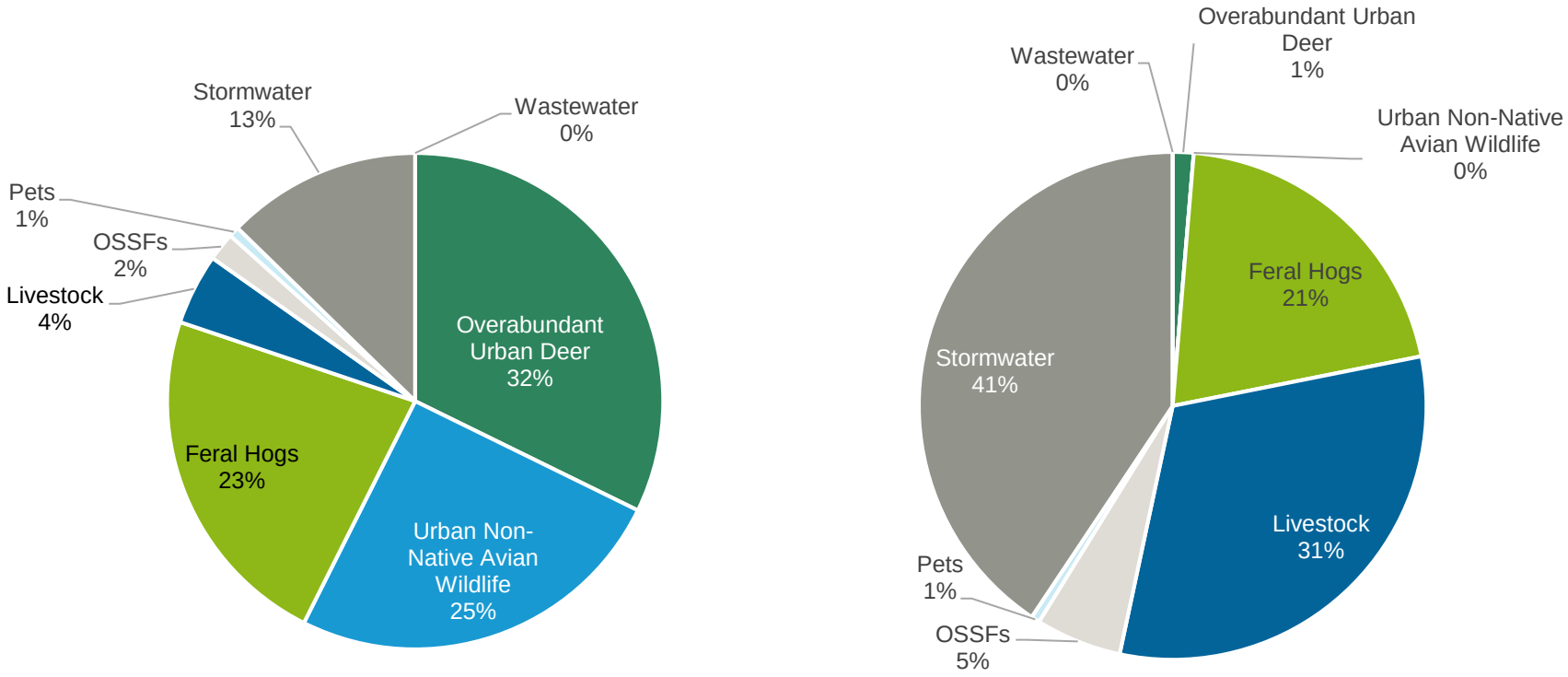


Figure 50: Potential *E. coli* Reduction Estimated for Selected BMPS for the Comal River (Left) and Dry Comal Creek (Right)

6. Outreach and Education Plan

Outreach and education is a very important component of this WPP and is required for successful implementation of most of the recommended BMPs (Section 5). Involvement and long-term commitment by the community and all stakeholders is especially critical in the Watershed because the population of the largest *E. coli* source (i.e., overabundant urban wildlife) has been increased by feeding of deer and non-native avian wildlife by people within the community. Thus, this outreach and education plan documents activities which have been completed or are ongoing, and also identifies additional measures that are planned as part of the implementation process.

6.1 Completed and Ongoing Outreach and Education Activities

A key achievement of the Watershed Partnership was the engagement of stakeholders in the development of the WPP. Stakeholders' knowledge of the Watershed and the potential community reaction to different BMPs, and outreach and education strategies was invaluable to the selection of activities that will be implementable in the Watershed. The Watershed Partnership also led outreach and education activities within the community throughout the WPP development process. The goal of all of these activities was to increase awareness of the WPP program and to begin changing behaviors, in accordance with the WPP goals, to ultimately improve water quality.

Stakeholder and Work Group Meetings

Stakeholder Group meetings were held throughout the WPP development process, as described in Section 3, to inform stakeholders of ongoing activities and to incorporate their ideas, experiences and local expertise. The Stakeholder Group participated in many of the outreach and education activities described in this section. In addition, four Work Groups were formed from among the stakeholders to focus on the selection of BMPs and outreach and education activities with the greatest potential for success in the Watershed. The Work Groups are outlined in Figure 51.

Figure 51: Stakeholder Work Groups

To evaluate potential outreach and education activities with the greatest potential to encourage behaviors in support of the WPP goals, the Watershed Partnership formed an Outreach and Education Work Group. The Outreach and Education Work Group met three times during the planning process, and had the following goals:

- Define target audiences and locations for outreach and education activities;
- Select the outreach and education activities that will have the greatest potential to create behaviors that improve water quality in the Watershed; and
- Develop a core message to share with the community to encourage both residents and visitors to take actions that will protect and improve water quality in the Dry Comal Creek and Comal River.

After the general orientation and background provided in the initial Stakeholder Group meetings, the Work Group held three focused meetings to review and select activities. After these meetings, the Work Group made presentations to solicit feedback from the entire Stakeholder Group, as shown in Figure 52. The final deliverable from the Outreach and Education Work Group was a prioritized list of activities, which are summarized in Section 6.4, including target audiences, communication methods and locations for each activity. Based upon the broad spectrum of identified audiences (e.g., residents, tourists, business owners, youth, community organizations) and the identified sources of bacteria (e.g., wildlife, pets, livestock), the Outreach and Education Work Group identified a range of activities for implementation in the Watershed. Ultimately, the Work Group agreed that communicating the potential impacts of feeding wildlife was a critical priority for the Watershed.

Work Group Meeting 1: Review data and activities proposed by other WPPs

↓

Work Group Meeting 2: Brainstorm activities for the WPP, including target audiences and locations

↓

Develop complete list of activities, audiences and locations

↓

Present draft list to all stakeholders for feedback

↓

Work Group Meeting 3: Review and edit list; prioritize activities

↓

Present prioritized list to all stakeholders for approval

Resources:
- Stakeholder knowledge
- EPA Getting In Step Guide
- WPPs for Plum Creek, Geronimo and Alligator Creek, Mill Creek, Buck Creek and the Attoyac Bayou

Figure 52: Outreach and Education Work Group Process

WPP Website

The WPP website (http://www.nbtexas.org/wpp [Figure 53]) is maintained and hosted by the City. The website includes an overview of the WPP process, water quality data, Stakeholder Group and Work Group meeting information and presentations, an overview of the Watershed, tips for reducing bacteria loading to the water bodies, contact information, and links to other helpful information. The City will continue to update this website during implementation of the BMPs identified in the WPP.

Figure 53: WPP Website

WPP Infographic

The Watershed Partnership also developed a two-page infographic (Figure 54 and Figure 55) to facilitate effective communication with the community and visitors about the WPP development process and initiatives. It is available on the WPP website and has been or will be distributed at Stakeholder Group meetings, by email, and at educational events. Updated versions of the infographic will be created, as needed, to communicate new information about the WPP program and accomplishments following implementation of the identified BMPs.

What is our mission?

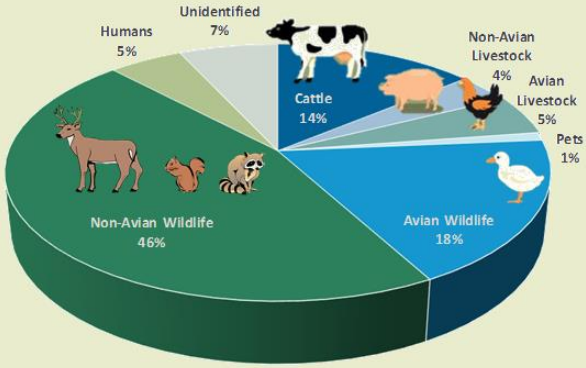
It is our responsibility to protect our springs, rivers and watersheds. In support of this, the community is taking proactive steps to protect the water quality in the Dry Comal Creek and Comal River by developing a Watershed Protection Plan (WPP). Decreased water quality may occur as a result of high density wildlife populations, as well as other sources, and may be exacerbated by low flow during droughts. The WPP outlines best management practices to mitigate bacteria levels and enhance water quality, and will allow the community to engage in opportunities for funding to implement the identified strategies.

What are we protecting against?

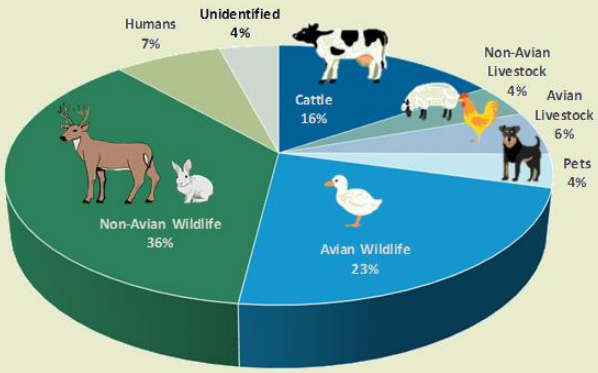
Escherichia coli (*E. coli*) are a bacteria found in the intestines of warm-blooded animals. *E. coli* are associated with many other human diseases and infections through ingestion or skin contact.

Where does the bacteria come from?

The City of New Braunfels conducted Bacterial Source Tracking sampling to genetically test bacteria colonies collected from the waterbodies to identify their origins. The resulting pie charts show the sources identified and the percentage of bacteria that came from each source in the Comal River and Dry Comal Creek.



Comal River



Dry Comal Creek

What is our goal?

To protect water quality by reducing bacteria and other pollutants in the Comal River and Dry Comal Creek

Figure 54: WPP Infographic Page 1

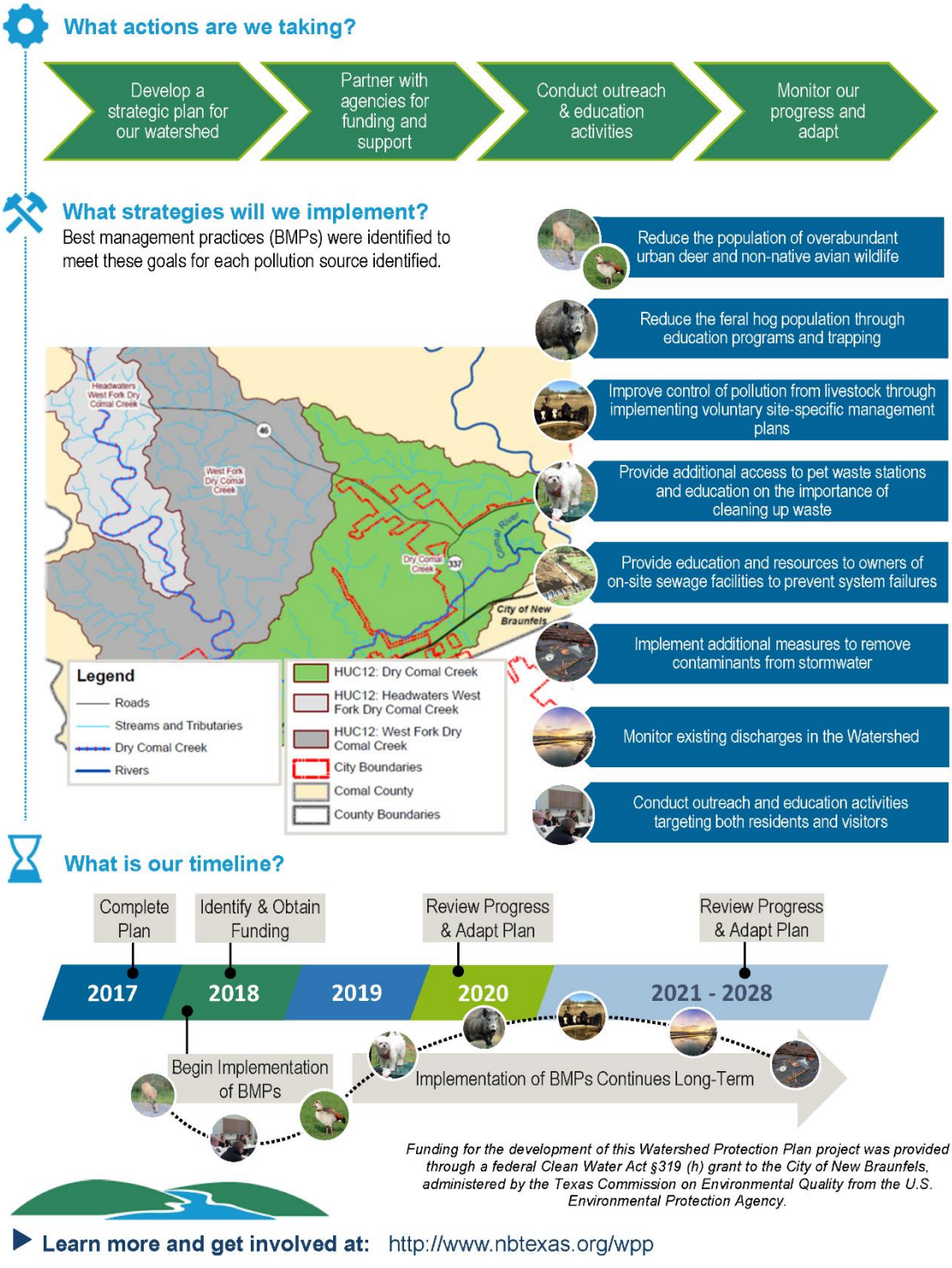


Figure 55: WPP Infographic Page 2

News Releases

The City created and submitted news releases through different outlets during development of the WPP. Table 22 summarizes the news releases completed to-date. Additional articles will be developed and submitted to announce the completion of the WPP and encourage stakeholder participation in the implementation of BMPs and outreach and education strategies (see Section 6.4).

Table 22: News Releases Completed To-Date

Name of Event	Date(s)	# of Copies Distributed	Communication Methods
WPP Stakeholder Meetings The City put out a media release on Oct. 13th, 2016 to announce the October 24th Stakeholder Group meeting. Stakeholder Group meetings are also posted on the City's WPP website.	October 13th, 2016; Various	Unknown	Media release and WPP Website
Making the Most of our Resources Guide Included article/write-up on pet waste management in the guide (Fall 2015 Edition), which was distributed as an insert in the Herald-Zeitung.	Sunday October 4th, 2015	10,500	Guide distributed in the newspaper and at local events
Making the Most of Our Resources Guide Included article/write-up on pet waste management in the guide (Fall 2016 Edition), which was distributed as an insert in the Herald-Zeitung.	Sunday, Sept 25th, 2016	10,500	Guide distributed in the newspaper and at local events
Making the Most of our Resources Guide Included article/write-up on bacteria pollution management and the WPP management in the guide (Winter 2016 Edition), which was distributed as an insert in the Herald-Zeitung.	Sunday, December 25th, 2016	10,500	Guide distributed in the newspaper and at local events

Watershed Tour

Several watershed tours were conducted to familiarize the project team and City staff with the Watershed. The tours also included reconnaissance and evaluation of potential sources of bacteria loading. These tours were conducted on the following dates:

- Dec 8th, 2015: Tour with City and Arcadis staff
- March 1st, 2016: Tour with City engineering and planning staff
- October 13th, 2016: Tour with Arcadis, Adisa, and City staff
- May 22nd, 2017: Tour with Arcadis and City staff

Texas Watershed Stewards Workshop

The Watershed Stewards Workshop is a science-based education program designed to educate citizens on strategies for improving watershed water quality, including reducing bacteria loading. The City hosted a Texas Watershed Stewards Workshop on February 7th, 2017 at the New Braunfels City Hall. The workshop was prepared and delivered by Texas A&M AgriLife, and had 60 attendees. In addition to the general public, all WPP stakeholders were invited to participate. Advertising for the workshop included:

- City issued Media Release on Jan 25th, 2017
- Article in Herald-Zeitung on Saturday, February 4th, 2017 publicizing the workshop.
- General advertisement by Texas A&M AgriLife

Similar workshops will be held in the future to reach as many people as possible with this important background information on watersheds and watershed health.

Fischer Park Nature Education Center

The Fischer Park Nature Education Center (Figure 56) provides a variety of programs and activities, such as wildlife and nature interpretive classes, to ignite the community's interest and curiosity in the natural world. Key park features include:

- A Monarch Waystation,
- An Archaeology Dig for kids, and
- Two fishing ponds.

The Center also offers a variety of community and youth educational classes and camps, which provide information on preserving water quality. Following completion of the WPP, additional youth education on water quality, bacteria nonpoint source pollution and identified best management practices, will be located at the Fischer Nature Education Center (see Section 6.3). To learn more, visit: http://www.nbtexas.org/1873/Fischer-Park-Nature-Center

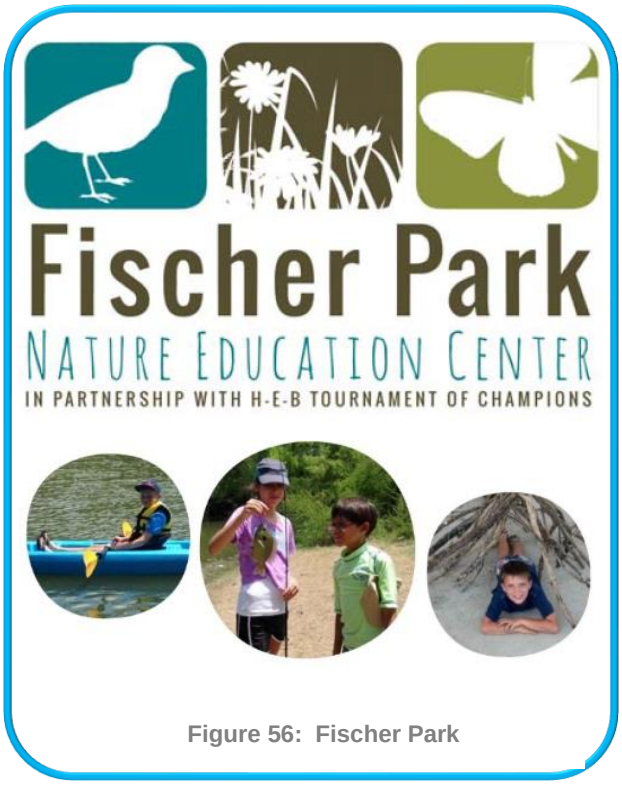


Figure 56: Fischer Park

New Braunfels Utilities Headwaters at the Comal Facility

A new indoor and outdoor environmental facility is under design and construction. The project is being led by NBU and is located at NBU's former utility service center and maintenance yard. The Headwaters at the Comal (Figure 57), scheduled for completion in 2021, is a $22.9 million environmental showcase on the banks of the Comal Springs and Blieders Creek. The Headwaters at the Comal will highlight the hydrological, environmental and cultural history of the region and will be a living demonstration of sustainable practices for the local community, Texas and the nation. More than 16 acres of asphalt parking lots and former buildings will be transformed into native landscape, thereby removing 85 percent of the impervious cover currently on the property. Plant groupings will replicate regional typologies while newly introduced berms and bioswales will filter and cleanse stormwater before returning it to the waterbodies. Public amenities will include a central courtyard, event lawn, display gardens, walking trails, outdoor classrooms, natural Comal Spring overlooks, wastewater treatment wetlands, composting facilities, and more.

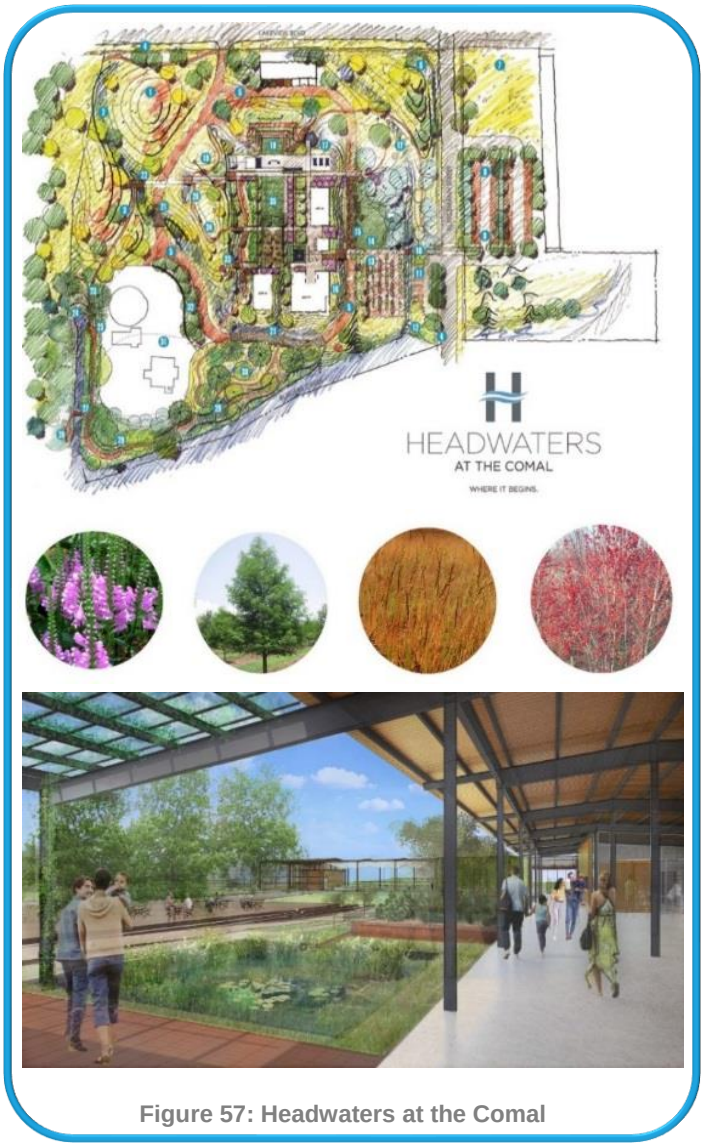


Figure 57: Headwaters at the Comal

The Headwaters at the Comal supports the reconnection of the New Braunfels community to its natural water and ecological resources by providing a large event space, various sized meeting areas for communal use, and multiple outdoor venues that align with the educational and ecological mission. The existing structures will be repurposed, and on-site materials will be salvaged and incorporated as landscape elements where possible. Many energy savings measures, regional materials, and passive design strategies will be implemented throughout the architecture.

Following the completion of the WPP, a variety of community activities on water quality, bacteria NPS and identified BMPs, may be located at this facility (see Section 6.4). To learn more, visit: http://www.nbutexas.com/Headwaters.aspx.

Youth Outreach Activities

The City has conducted many activities since May of 2015 reaching over 370 youth in the community. In addition, GBRA has also been conducting youth activities in the Watershed. A key strategy of the Watershed Partnership, and the Outreach and Education Work Group has been educating youth in the community, who will in turn educate their families. Table 23 summarizes youth activities completed to-date while developing the WPP. In addition to these activities, GBRA is actively working with New Braunfels Independent School District (ISD) to incorporate the "GBRA Journey Through the Guadalupe River Basin" program into the curriculum for all fourth-grade students. This program has already been incorporated into the Comal ISD curriculum, and includes a section on water quality, which can be viewed online at http://www.gbra.org/education/elementary.aspx. Additional youth activities are planned following completion of the WPP (see Section 6.4).

Table 23: Youth Activities Completed To-Date

Name of Event	Date(s)	# of Participants	Communication Methods
New Braunfels Christian Academy (Mrs. Lee's Science Class) The City presented to Seventh and Eighth graders (3 classes) on watershed management and water pollution.	5/15/2015	40	PowerPoint presentation
New Braunfels Christian Academy Summer Science Camp The City performed field exercises and demonstrations on watershed and stormwater pollution management, water quality, impacts of wildlife feeding and the EAHCP to middle school science camp at Landa Park.	6/08/2015 6/09/2015 6/15/2015	10	Field exercises and demonstrations
New Braunfels High School The City presented watershed management, stormwater pollution prevention, and LID/stormwater treatment options overview to Mr. Nowotony's class.	11/9/2015	20	Presentation
New Braunfels Middle School The City presented watershed education to middle school students, including stormwater pollution prevention information and pollutant/runoff simulation with the watershed model.	1/15/2016	100	Presentation and model simulation
Comal County ISD Elementary School-TPE The City presented watershed education to middle school students, including stormwater pollution prevention information and pollutant/runoff simulation with the watershed model.	1/22/2016	25	Presentation and model simulation

Table 23: Youth Activities Completed To-Date (Continued)

Name of Event	Date(s)	# of Participants	Communication Methods
City Parks: Spring Ventures Day Camp in Landa Park The City discussed stormwater pollution prevention and performed watershed model runoff simulation with elementary-aged kids attending the City Spring Break Camp.	3/16/2016	30	Discussion and watershed model runoff simulation
Comal ISD Community Education Program The City presented watershed and stormwater pollution prevention education to elementary school aged-children at Freheit Elementary.	7/1/2016	65 (three classes of 20-25 students)	Displays, runoff simulation, questions, and discussions
New Braunfels Middle School The City presented to Mr. Donley's six middle school science classes on watershed management, water pollution, and water quality. Included information on wildlife feeding and bacteria pollution management.	4/4/2017	120 (6 science classes)	Presentation and watershed model demonstration
Earth Day Event-Oak Creek Elementary The City participated in Earth Day event at Oak Creek Elementary School. Provided watershed and pollution prevention information to elementary children and parents.	4/21/2017	Unknown	Watershed booth and poster board display, brochures, and watershed runoff model demonstrations
Smithson Valley Middle School GBRA presented the River Basin Model and discussed watershed and water quality.	3/20/2017	70	Presentation and watershed model demonstration
New Braunfels Middle School GBRA presented the River Basin Model and discussed watershed and water quality.	4/5/2017	200	Presentation and watershed model demonstration
Macroinvertebrates GBRA presented to Memorial Elementary School students about water quality at the Seguin Outdoor Learning Center.	4/7/2017	100	Presentation
Macroinvertebrates GBRA presented to Carl Schurz Elementary School students about water quality at the Seguin Outdoor Learning Center.	5/12/2017	80	Presentation
Macroinvertebrates GBRA presented to County Line Elementary School students about water quality at the Seguin Outdoor Learning Center.	5/15/2017	100	Presentation
Macroinvertebrates GBRA presented to Lamar Elementary School students about water quality at the Seguin Outdoor Learning Center.	5/18/2017	70	Presentation
Macroinvertebrates GBRA presented to Lone Star Elementary School students about water quality at the Seguin Outdoor Learning Center.	5/19/2017	100	Presentation

Community Outreach Activities

The City has also provided watershed education at numerous community events. Table 24 summarizes community activity participation to-date. Since April of 2015, the City has participated in 11 events reaching over 200 community members, in addition to the WPP stakeholders. These events included presentations, handouts, discussions and/or displays provided by the City to communicate strategies for preserving water quality in the Watershed. Additional community activities are planned following completion of the WPP (see Section 6.4).

Table 24: Community Activity Completed To-Date

Name of Event	Date(s)	# of Participants	Communication Methods
Earth Day 2015 at the Library Table and displays at the New Braunfels Library Earth Day celebration. Distributed information on stormwater pollution prevention, EAHCP, WPP and negative impacts of wildlife feeding.	4/22/2015	Approximately 50	Displays, brochures, handouts and discussions
Fischer Park Lunch and Learn at Fischer Park Presented at the City's Lunch and Learn at Fischer Park. Presented to residents and City Parks Department staff on stormwater management education, WPP, and EAHCP.	6/25/2015	5	Display posters, presentation, and discussion
Kiwanis Club Presentation Presented stormwater pollution prevention material covering stormwater, water resources, EAAHCP and the WPP at Kiwanis Club meeting.	8/13/2015	15	Presentation and discussion
Earth Day 2016 at the Library and Westside Community Center Table and displays at the New Braunfels Library and Westside Community Center Earth Day celebration. Distributed information on stormwater pollution prevention, EAHCP, and wildlife feeding. Collaborated with NBU's Conservation Department.	4/22/2016	40	Displays, brochures, handouts and discussions
Earth Day 2016 at the New Braunfels Farmer's Market Distributed stormwater pollution prevent brochures ("Managing Stormwater Pollution") at the event.	4/23/2016	20	Distributed brochures
Through the Chute Watershed booth and displays at the City event. Distributed stormwater pollution prevention brochures, and shared information regarding stormwater pollution prevention and EAHCP with attendees. Demonstrated watershed runoff simulations with the watershed model. Participated with other water-related organizations (EAA and GBRA).	4/30/2016	Unknown	Displays, brochures, handouts, runoff simulation and discussions
Tree Climbing Competition in Landa Park Watershed booth and displays at the City event. Distributed stormwater pollution prevention brochures, and shared information regarding stormwater pollution prevention and HCP with attendees. Demonstrated watershed runoff simulations with the watershed model.	5/21/2016	25	Displays, brochures, handouts, runoff simulation and discussions

Table 24: Community Activity Completed To-Date (Continued)

Name of Event	Date(s)	# of Participants	Communication Methods
Watershed Program (including MS4) Overview to Chamber of Commerce Presented to the New Braunfels Chamber of Commerce Natural Resources Committee on MS4, WPP, and EAHCP programs.	9/1/2016	25	Presentation and question/answer session
Friends of Landa Park Presentation Presentation at a Friends of Landa Park meeting on the City's stormwater program, water quality, and the WPP.	4/10/2017	25	Presentation
Alligator/ Geronimo Creek Clean-up Event Participated in the Alligator/Geronimo Creek Clean-up event held by the Alligator/Geronimo Creek Partnership. One City employee participated at the City airport station, and the City provided roll-off dumpsters to dispose of collected trash.	4/8/2017	Unknown	Clean-Up Event
Earth Day Event-Westside Community Center Participated in the Community Earth Day event at the New Braunfels Westside Community Center. Provided watershed and pollution prevention information to attendees.	4/22/2017	Unknown	Watershed booth and poster board display, brochures, and model demonstrations

6.2 Core Message

The Outreach and Education Work Group developed a core message, to be used by stakeholders to communicate with residents and visitors. The Watershed Partnership began distributing this message in April of 2017 to ensure that all audiences were hearing a consistent message that focused on the aspects of the WPP approach that were most important to the stakeholders. The Watershed Partnership will continue using this message as a key part of all proposed outreach and education activities. Key aspects of the core message include:

- A positive and proactive approach to preserving and protecting the Watershed;
- Incorporation of the message on the New Braunfels Watershed Management logo;
- Terminology that is concise, clear, and understandable to a diverse audience;
- A broad focus on water quality, in addition to the specific message regarding bacteria; and
- A call-to-action to engage the community in implementing the identified BMPs.

Our Core Message

It is our responsibility to protect our springs, rivers, and watersheds. In support of this, the community is taking proactive steps to protect the water quality in the Dry Comal Creek and Comal River by developing a Watershed Protection Plan (WPP). Decreased water quality may occur as a result of high density wildlife populations, as well as other sources, and may be exacerbated by low flow during droughts and following storm events. The WPP outlines best management practices to mitigate bacteria levels and enhance water quality, and will allow the community to engage in opportunities for funding to implement the identified strategies.

A new mascot and/or logo may also be developed to compliment the core message. The Outreach and Education Work Group set the following guidelines for a mascot and/or logo:

- Should be consistent with the City of New Braunfels' Watershed Management logo Figure 58),
- Should communicate that reducing the urban wildlife population will improve water quality, and
- May include an illustration in support of the message.

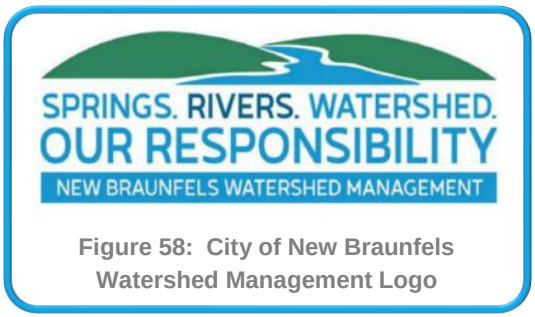


Figure 58: City of New Braunfels Watershed Management Logo

6.3 Outreach and Education Roles

The outreach and education strategy developed by the Watershed Partnership integrates science with local input and stakeholder knowledge (Figure 59). Engagement of stakeholders and the broader community has been and will continue to be an integral component in the success of this WPP. Each of the key roles involved in implementation of outreach and education activities are summarized below.

Figure 59: Implementation of Outreach and Education Activities will be a Collaborative Process

▶ Watershed Coordinator

The City's Watershed Coordinator (refer to Section 5.2) will continue to fill a critical role at the heart of the WPP implementation by facilitating between the Watershed Partnership, stakeholders, and the community. The Watershed Coordinator will organize and host Stakeholder Group and public meetings, regularly update the WPP website and provide information to the community on WPP activities, and maintain working relationships and frequent communication with all stakeholders, agencies and partners participating in outreach and education activities. Additionally, the Watershed Coordinator will lead the coordination and implementation of outreach and education activities.

▶ Stakeholders

The Stakeholder Group will continue to be engaged in the transition from WPP development to WPP implementation, and throughout the implementation process. Frequent communication from the Watershed Partnership will provide information on new implementation opportunities, technical and financial assistance, volunteer opportunities, water quality data, and progress updates. Periodic meetings will be held with the WPP

stakeholders, in addition to public input opportunities such as updates provided to the City Council and other groups. The WPP website and email will be used to provide updates in between meetings and to any stakeholders unable to attend.

Stakeholder meetings will also provide a platform to discuss adaptive management (Section 8.4) during implementation of the WPP. Implementation goals and milestones will be reviewed at least annually, followed by active discussions about potential improvements to the implementation process. Feedback from stakeholders and the public will be incorporated into WPP updates and/or addendums, as appropriate.

► Community Volunteers

The Watershed Partnership will reach out to engage active individual volunteers and volunteer groups in the Watershed. Volunteers may assist by conducting education and outreach activities, such as setting up and manning booths; dispersing information (e.g., distributing door hangers); collecting water quality data through the Texas Stream Team program[18] and/or promoting new educational activities (e.g., Girl/Boy Scout Troops).

Volunteer groups in the watershed likely to share interest in preserving the water quality of the Dry Comal Creek and Comal River include, but are not limited to, Friends for the Preservation of Landa Park, Comal Master Gardeners, Lindheimer Master Naturalists, New Braunfels Conservation Society, and Girl and Boy Scouts.

► WPP Consultant

The WPP Consultant (refer to Section 5.2), will continue to support the Watershed Coordinator with technical expertise, assistance in development of content and graphics for publications, tracking progress toward outreach and education goals, and documenting outcomes from outreach and education activities. The WPP Consultant will coordinate among the Watershed Partnership to facilitate implementation of outreach and education activities, and will provide presentations and/or facilitation for meetings. The WPP Consultant will also recommend adaptive implementation strategies, as needed, during the WPP implementation process.

[18] Texas Stream Team is a volunteer-based water quality monitoring program. There are active Texas Stream Team volunteers in the Watershed, and the City has worked with the program to host training in the City. The program includes training for volunteers, and allows volunteers to both learn about water quality and collect data to support implementation of WPPs. There are also several educational curricula targeting grades 3 through 12 that meet Texas Essential Knowledge and Skills requirements for science and math. GBRA is the local sponsor for the Texas Stream Team monitors.

6.4 Planned Outreach and Education Activities

Six Outreach and Education Activities were Identified as Most Critical:

- **Social Media Campaign**
- **News Campaign**
- **Youth Activities**
- **Local Community Events**
- **Wildlife Feeding Campaign**
- **Wildlife Workshops**

Community education programs will provide information on the current sources of *E. coli* identified in the Watershed and strategies for reducing *E. coli* pollution. Education programs will also encourage community participation in changing behaviors where necessary (e.g., not feeding urban wildlife) and educating other members of the community and visitors. A description of each of the six prioritized activities is provided in this section, along with an outline of the goals, target audiences, locations, implementation partners, timeline and estimated cost. Several outreach and education activities were also identified as part of the BMPs for each individual *E. coli* source, and are summarized at the end of this section.

The frequency and timing for community activities will be adapted based upon WPP activities, stakeholder feedback, and implementation effectiveness. Additional implementation details are provided in Section 7. As these programs are implemented, an adaptive implementation strategy (Section 8.4) will allow for modification of the schedule, goals and resources, as appropriate.

There were several additional outreach and education opportunities identified by the Stakeholder Group. Although not ranked as an immediate priority, the Stakeholder Group noted that these activities, listed in Appendix D, would be beneficial to the community in the future, if and when funding and resources become available. This list of activities will be revisited during routine reviews of the WPP implementation progress to determine whether the priority for implementing these activities has increased based upon changes in the Watershed, land use, or bacteria sources.

Promotional materials (Table 25) will be used, in association with the planned outreach and education activities, to communicate with the community members and visitors. Promotional materials may include the logo or mascot and/or a shortened or full version of the Core Message, as applicable. For example, a magnet may include a logo and short phrase, such as “It’s our responsibility to protect our springs, rivers and watershed” or “Feeding wildlife harms both the wildlife and our water.”

Table 25: Promotional Materials

Example Promotional Materials	Target Audience / Location
Informational Giveaways – magnets, pens, t-shirts, etc.	Local outreach and education events
Strategic Printed Materials (minimizing paper waste) – brochures, flyers, etc.	Local outreach and education events
Door Hangars	Neighborhoods near Landa Park and Hinman Island
Temporary / Portable Signs – Billboards, posters, window decals, etc.	Local outreach and education events; organizations
Fact Sheet / Infographic – WPP summary and/or focus on FAQs and facts on feeding wildlife	Social media and news campaigns, WPP Website, organizations, feed stores, Schlitterbahn, area vets, etc.

Social Media Campaign

The Watershed Partnership will continue to use social media sites (see sidebar) to share information and updates on the implementation of the WPP, facilitate collaboration and communication among community members and volunteers, recruit volunteers, and highlight accomplishments of the WPP and community. The Watershed Partnership will use the City's existing platforms to share information, will encourage the other members of the Watershed Partnership to share messages on their platforms, and will also consider forming new platforms, specifically for the WPP. Social media will also highlight the results of other WPPs that successfully improved water quality (e.g., Buck Creek) to gain community buy-in on the WPP approach. A list of NPS success stories is available online at: https://www.epa.gov/nps/nonpoint-source-success-stories#tx.

Source Targeted:

All *E. coli* sources

Implementation Timeline:

Years 1 – 10, with videos developed in Years 2, 4 and 6

Goal:

At minimum, 2 social media posts per month

Estimated Cost:

$73,600

Target Audience(s):

- School students
- Residents
- Organizations (e.g., Master Naturalist; Moms of NB)
- Tourists/visitors
- Business community

Potential Locations:

- Facebook, Twitter and Instagram
- RSS feeds
- Podcasts
- YouTube
- Widgets

Implementation Partners:

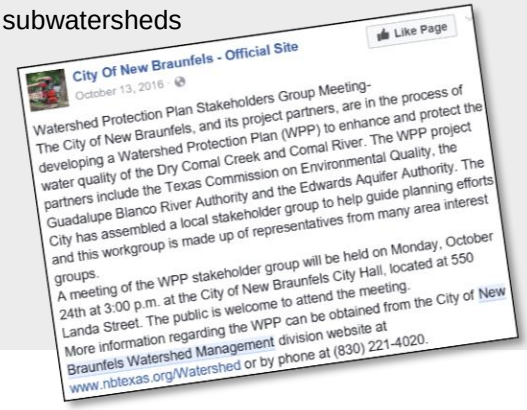
- Watershed Coordinator and WPP Consultant
- City Communications Department
- GBRA
- Stakeholders

Financial Resources

- City of New Braunfels In-Kind Contributions; Stakeholder In-Kind Contributions

Priority Subwatersheds Nos.

- All subwatersheds



News Campaign

The Watershed Partnership will continue to develop and publish updates and information on BMPs through the news media (see sidebar). Announcements for public meetings and WPP activities will also be advertised through news outlets. Information provided will include eligibility requirements, timing, and locations to sign-up for activities. A variety of media sources will be used to reach a diverse audience.

Source Targeted:

All *E. coli* sources

Implementation Timeline:

Years 1 – 10, with new ads developed in Years 2, 4 and 6

Goal:

At minimum, 3 different media types and 6 total news releases per year

Estimated Cost:

$369,500

Target Audience(s):

- Residents/locals (including school students, retirees and City employees)
- Visitors and tourists
- Homeowners (HOAs) and apartment communities
- Organizations
- Business community

Potential Locations:

- Movie theatre ads*
- Cable advertisements
- Newspapers
- E-Newsletters
- HOA Newsletters and Meetings
- Youth Education Newsletters/Comics
- Radio advertisements**
- Community Connection Program (provided at no charge to non-profits)

Implementation Partners:

- Watershed Coordinator and WPP Consultant
- City Communications Department
- GBRA

Financial Resources

- City of New Braunfels In-Kind Contributions; Section 319(h) Federal Clean Water Act – TCEQ; Texas Clean Rivers Program; Section 106 State Water Pollution Control Grants

Priority Subwatershed Nos.

- 5, 6, 7, 8, 10, 11, 13, 14, 17, 18, 29, 31, 32, 33

* The City notes that movie theater ads have not yielded good results in prior efforts.
** The City notes that the local radio station has changed formats and dropped news, so their listening has dropped. Due to this change, the City has stopped advertising on the radio.

Youth Activities

A key strategy of the Watershed Partnership is to educate youth in the community, who will in turn educate their families. The Watershed Partnership will host activities (see sidebar) to teach youth in the community about the importance of and strategies for protecting the Watershed. Activities may be coordinated with ongoing programs already in place, such as those at the Fischer Outdoor Learning Center or Landa Park. Project Partners will also identify and promote the use of educational resources in local schools. Activities may include, but not be limited to the following:

- Positive activities at parks (incentives, contests, crafts, building signs, etc.) to replace feeding wildlife as an activity
- Youth programs similar to the historical Texas Department of Transportation seat belt program
- Wildlife interpretive tours (i.e., "Junior Ranger" activities)
- A role for the Landa Park Train Conductor educating kids
- Youth teaching Youth (e.g., train Girl and Boy Scouts to teach other Youth groups)
- School Projects (i.e., project-based learning) and contests (art, essay, poster) and field trips
- High school student 30-second movies and/or commercials
- Open House in the Park (e.g., Earth Day)

* The City currently holds wildlife and nature interpretive classes at the Nature Education Center at Fischer Park.

Source Targeted:

All *E. coli* sources

Implementation Timeline:

Years 1 – 10, with new materials developed in Years 1 and 6

Goal:

At minimum, 8 youth activities per year

Estimated Cost:

$125,000

Target Audience(s):

- Teachers
- School students
- Youth groups
- Park and event attendees

Potential Locations:

- Schools (NBISD and CISD)
- Parks (especially Fischer and Landa)
- Headwaters Center
- Youth Group (e.g., Boy/Girl Scout) Meetings
- Outdoor Learning Center*

Implementation Partners:

- Watershed Coordinator and WPP Consultant
- NBISD and CISD
- GBRA
- New Braunfels Utilities
- Girl and Boy Scouts

Financial Resources

- City of New Braunfels In-Kind Contributions; Stakeholder In-Kind Contributions; Section 319(h) Federal Clean Water Act – TCEQ; Texas Clean Rivers Program; Section 106 State Water Pollution Control Grants; Environmental Education Grants

Priority Subwatershed Nos.

- 5, 6, 7, 8, 10, 11, 13, 14, 17, 18, 29, 31, 32, 33

Outreach at Local Events

The Watershed Partnership will target opportunities at local public events (see sidebar) to incorporate education on the WPP and the identified BMPs. Activities may include booths, public displays, temporary signs and banners, distribution of educational materials, demonstrations, etc. The Partnership will coordinate activities and recruit and train local volunteers to assist at the events. Events may be coordinated with activities planned for other City outreach and education programs. The Partnership will also consider new community events, such as an Earth Day event at Landa Park, to educate the community about the WPP. A program that includes a portable display and handouts will be developed for use at the events to communicate strategies for preserving water quality in the Watershed.

The Watershed Partnership coordinated the first Dos Rios Watershed Clean-Up event in September 2017. The clean-up event will be held on an annual basis, and will be focused in the Comal River, Dry Comal Creek, and Guadalupe River watersheds. The event will be open to any volunteers or volunteer groups who wish to participate, and sponsors will be asked to provide donations for t-shirts, breakfast, water, and clean-up supplies.

Source Targeted:

All *E. coli* sources

Implementation Timeline:

Years 1 – 10

Goal:

At minimum, 4 events per year

Estimated Cost:

$118,500

Target Audience(s):

- Tourists and visitors
- Residents
- Event workers

Potential Locations:

- Organization Meetings
- Wurstfest
- Wassailfest
- Wein and Saengerfest
- County Fair
- Chamber of Commerce Events
- Earth Day

Implementation Partners:

- Watershed Coordinator and WPP Consultant
- GBRA
- Community Organizations
- Chamber of Commerce
- Wurstfest Association

Financial Resources

- City of New Braunfels In-Kind Contributions; Stakeholder In-Kind Contributions; Section 319(h) Federal Clean Water Act – TCEQ; Section 319(h) Federal Clean Water Act – TSSWCB; Texas Clean Rivers Program; Section 106 State Water Pollution Control Grants

Priority Subwatershed Nos.

- 5, 6, 7, 8, 10, 11, 13, 14, 17, 18, 29, 31, 32, 33

Do-Not-Feed Wildlife Ordinance and Campaign within City Limits

The Watershed Partnership recognizes that changing public behavior with regard to feeding wildlife in Landa Park and other areas in the Watershed will be critical to the success of this WPP. As described previously in the overabundant urban deer and non-native avian wildlife BMPs (Section 5.4), an intensive public outreach campaign will be also conducted to inform and educate residents, businesses and visitors about the harm that feeding wildlife may cause both to the wildlife and to the Watershed. The campaign will also address safety concerns due to the number of vehicular collisions with wildlife in the Watershed. In addition, the Do-Not-Feed Wildlife ordinance (refer to Section 5.4.1) will be communicated to the community and visitors through permanent signage. Signage (e.g., "We're Glad You're Here, Don't Feed the Deer") may include permanent signs in the park or on roadways and/or wraps on Park Ranger trucks, garbage trucks, buses, benches, etc. informing public of the reasons behind feeding restrictions. Promotional and educational materials will be distributed within the City limits annually, targeting locations where extensive wildlife feeding occurs. The campaign will be coordinated with other outreach and education activities, such as TPWD and Texas A&M AgriLife programs on wildlife management.

* Included in the Wildlife Management BMPs. Refer to Tables 13 and 14 in Section 5.3 for more details.

Source Targeted:

Overabundant urban wildlife

Implementation Timeline:

Years 1 – 10 with signs installed in Years 2 and 6

Goal:

Installation of 20 – 30 signs; Material distribution within City limits during Years 1 – 10 and outside City limits once per year every other year

Estimated Cost:

$211,100*

Target Audience(s):

- Citizens and visitors
- Apartment communities
- Home or property owner associations (HOA/POA)
- School students
- Organizations
- Business community
- Retirees
- City employees

Potential Locations:

- City Parks (Landa Park and Fischer Park)
- Potential sign locations: parks, roads, billboards, watershed boundaries
- Watershed neighborhoods
- Feed/ag supply stores

Implementation Partners:

- Watershed Coordinator and WPP Consultant
- Community Organizations
- City Parks Department
- TPWD
- GBRA

Financial Resources

- City of New Braunfels In-Kind Contributions; Stakeholder In-Kind Contributions; Section 319(h) Federal Clean Water Act – TCEQ

Priority Subwatershed Nos.

- 5, 6, 7, 8, 9, 10, 11, 13, 14, 17, 18, 26, 27, 28, 29, 31, 32, 33, 41, 42, 45, 46, 47, 48, 50, 51, 58, 59, 60, 61, 62, 65, 66, 67, 68, 70, 71, 72, 73, 75

(Klingener, 2016)

Wildlife Management Workshops

Additionally, as wildlife management is a large component of the strategy to reduce *E. coli* in the Watershed, periodic wildlife management workshops will be advertised to share information and resources available on wildlife management. TAMU Wildlife and Fisheries Department and the Texas Wildlife Association host webinars on wildlife management (see sidebar), which are available for free online at http://wildlife.tamu.edu/publications/webinars/ and http://www.texas-wildlife.org/resources/webcasts/category/webinars/. As they become available, these webinars will be advertised in the watershed through social media, the WPP website and news releases. Additionally, the Watershed Partnership will work with Texas A&M AgriLife and TPWD to plan and host in-person wildlife workshops in the Watershed. Refer to Section 5.4 on wildlife BMPs for additional information.

Source Targeted:

Overabundant urban wildlife

Implementation Timeline:

Biennial

Goal:

Advertisement of webinars, as available; Hosting of at least three in-person wildlife management workshops

Estimated Cost:

$16,800*

Target Audience(s):

- Citizens
- Homeowners/Landowners
- Organizations
- Business community
- Retirees
- City employees
- Owners of Natural Bridge Wildlife Ranch

Potential Locations:

- Online
- Workshops
- National Bridge Wildlife Ranch
- NBU Headwaters Facility

Implementation Partners:

- Watershed Coordinator and WPP Consultant
- Texas A&M AgriLife
- TPWD
- GBRA

Financial Resources

- City of New Braunfels In-Kind Contributions; Stakeholder In-Kind Contributions; Section 319(h) Federal Clean Water Act – TCEQ

Priority Subwatershed Nos.

- 5, 6, 7, 8, 10, 11, 13, 14, 17, 18, 28, 29, 31, 32, 33

* Included in the Wildlife Management BMPs. Refer to Tables 13 and 14 in Section 5.3 for more details

Outreach and Education Activities Targeting Individual *E. coli* Sources

The Stakeholder Group also identified a number of outreach and education activities to supplement the BMPs identified for each *E. coli* source. These activities are detailed in Section 5 on BMPs, but are also summarized in Table 26, as they will also be important components of a successful outreach and education campaign for the Watershed. These activities will be advertised through social media, the WPP website and news releases.

Table 26: Source Targeted Outreach and Education Activities

E. coli Source Targeted	Activity	BMPs
Overabundant Urban Deer and Non-Native Avian Wildlife	Intensive public outreach and a Wildlife Feeding Campaign	Refer to Table 13 for Overabundant Urban Deer Strategies and Table 14 for Urban Non-Native Avian Wildlife Strategies
Overabundant Urban Deer and Non-Native Avian Wildlife	Voluntary Do-Not-Feed Wildlife Ordinance and Campaign	Refer to Table 13 for Overabundant Urban Deer Strategies and Table 14 for Urban Non-Native Avian Wildlife Strategies
Feral Hogs	Maintain a feral hog website	Refer to Table 15 for Feral Hog BMPs
Feral Hogs	Conduct feral hog management workshops	Refer to Table 15 for Feral Hog BMPs
Livestock	Conduct outreach and education (e.g., Lone Star Healthy Streams) to landowners in the Watershed	Refer to Table 16 for Livestock BMPs
OSSF	OSSF Education and Assistance Programs	Refer to Table 17 for OSSF BMPs
Stormwater	Augment the City's Education Program on Fats, Oils and Grease with *E. coli* pollution education	Refer to Table 18 for Stormwater BMPs
Pets	Conduct intensive public outreach targeting residents in the City limits, apartment complexes in the Watershed, and residential developments in unincorporated areas of Comal County	Refer to Table 19 for Pet BMPs

7. Implementation Schedule, Estimated Load Reductions and Estimated Costs

This WPP implementation plan is based on a variety of factors, including the prioritization of the BMPs selected by the Stakeholder Group, available and potential resources, and goals (i.e., implementation milestones) established for each BMP to meet the overall WPP goals for *E. coli* loading reduction. Figure 61 provides an overview of the outreach and education activities and BMPs selected. Based upon review of the Watershed Characterization data (Section 4), overabundant urban and non-native wildlife and livestock are the largest sources of *E. coli* in the Dry Comal Creek and Comal River. As urban wildlife populations have increased due to feeding of wildlife, community education on the impact of feeding wildlife on both the health of the wildlife and water quality is a key focus of the WPP. Thus, the overall approach for implementation is to focus on outreach and education, initially, followed by implementation of costlier active control measures.

7.1 Implementation Schedule

The Watershed Partnership developed a projected BMP and outreach and education implementation schedule based upon prioritization of the selected BMPs, the overall implementation approach and the identified implementation milestones. Over a 10-year implementation period, most activities will transition from a more intense initial implementation phase to a longer-term maintenance phase. Figure 62 summarizes the WPP implementation schedule over the 10-year implementation period, along with a summary of implementation milestones for each activity. A checkpoint is scheduled for the end of the third year to review progress and adjust the implementation schedule and goals, as necessary, to meet the WPP goals. All BMPs are scheduled to start by Year 5, and the majority will continue through the 10-year implementation period. By Year 7, most activities are projected to have moved into a maintenance phase. Additionally, most workshops are currently projected to be provided on a biennial basis (i.e., occurring every other year). The Watershed Partnership will use this schedule, and the implementation milestones identified, to plan for required resources and to assess progress toward completing the proposed activities in a timely manner (refer to Section 8.1 for additional discussion of implementation milestones).

Figure 61: Summary of BMPs and Outreach and Education Activities Selected for the Dry Comal Creek and Comal River WPP

Implementation Phase $$

Higher intensity initial efforts to implement a BMP or activity, generally including development of new materials or purchase of new equipment, and thus, generally costing more per year.

Maintenance Phase $

Lower intensity efforts over the long-term to maintain the reduction and/or control of *E. coli* in the Watershed. This phase is anticipated to cost less per year, as expenses are projected to be lower (e.g., materials may be reused or redistributed).

Figure 62: Implementation and Maintenance Phase Definitions

Table 27: WPP Implementation Schedule

Category	BMP or Outreach and Education Activity	Priority	Implementation Timeline	Years 1 2 3 4 5 6 7 8 9 10	Implementation Milestone(s)
KEY:	◆ Purchase of new equipment, development of new materials, etc.			Initial Implementation / Maintenance Phase / No Activity	
Outreach and Education	Social Media Campaign	High	Years 1 - 10, with videos developed in Years 2, 4 & 6	◆ ◆ ◆	At minimum, 2 social media posts per month
	News Campaign	High	Years 1 - 10, with new ads developed in Years 2, 4, & 6	◆ ◆ ◆	At minimum, 3 different media types and 6 total news releases per year
	Youth Activities	High	Years 1 - 10, with new materials developed in Years 1 & 6	◆ ◆	At minimum, 8 youth activities per year
	Local Event Outreach	High	Years 1 - 10		At minimum, 4 events per year
	Wildlife Management Workshops	High	Biennial		Same BMP as described under the Overabundant Urban Deer and Urban Non-Native Avian Wildlife categories
	Do-Not-Feed Wildlife Ordinance and Campaign within City Limits	Critical	Years 1 - 10 with ordinance development in Year 1 and signs installed in Years 2 & 6	◆ ◆	Same BMP as described under the Overabundant Urban Deer and Urban Non-Native Avian Wildlife categories
Overabundant Urban Deer	Do-Not-Feed Wildlife Ordinance and Campaign within City Limits	Critical	Years 1 - 10 with ordinance development in Year 1 and signs installed in Years 2 & 6	◆ ◆	Pass the new ordinance (in coordination with the Urban Non-Native Avian Wildlife BMP), and begin enforcement; install 20-30 new signs in the Watershed
	Deer Population Assessment	High	Years 1 - 10		Review data indicating population changes at least every 2 years
	Voluntary Do-Not-Feed Wildlife Campaign in Rural Neighborhoods	High	Bienial; Years 1-9 with signs installed in Years 2 & 6	◆ ◆	Reach at least 1200 residents or visitors in the Watershed or conduct outreach events every two years
	Wildlife Management Workshops	High	Biennial; Years 2-10		Reach at least 500 residents or visitors in the Watershed or conduct at least 10 workshops in the Watershed (in coordination with the Urban Non-Native Avian Wildlife BMP)
	Active Management of Deer with City Council Approval	High	Years 3 - 10 with planning/permitting in Year 2	◆	Implement an active deer management program, in consultation with TPWD and City Council

Table 27: WPP Implementation Schedule (Continued)

Category	BMP or Outreach and Education Activity	Priority	Implementation Timeline	Years 1 2 3 4 5 6 7 8 9 10	Implementation Milestone(s)
KEY:	◆ Purchase of new equipment, development of new materials, etc.			Initial Implementation / Maintenance Phase	No Activity
Non-Native Avian Wildlife	Do-Not-Feed Wildlife Ordinance and Campaign within City Limits	Critical	Years 1 - 10 with ordinance development in Year 1 and signs installed in Years 2 & 6	◆ ◆	Pass the new ordinance (in coordination with the Overabundant Urban Deer BMP), and begin enforcement; install 20-30 new signs in the Watershed
	Non-Native Duck and Goose Population Assessment	High	Years 1 - 10		Review data indicating population changes at least every 2 years
	Discourage Non-Native Ducks and Geese from Congregating in the Park	High	Years 2 - 10 with purchase of new equipment in Year 2	◆	Implement at least 2 tactics in Landa Park
	Rapid Removal of Dead Animals	High	Years 1 - 10		Continue the existing City of New Braunfels program
	Wildlife Management Workshops	High	Biennial		Reach at least 500 residents or visitors in the Watershed or conduct at least 10 workshops in the Watershed (in coordination with the Overabundant Urban Deer BMP)
	Trap Non-Native Ducks and Geese	High	Years 1 - 10		Hire a progressional trapper to trap 50 non-native ducks and geese
	Oil Coat Non-Native Duck Eggs	High	Years 1 - 10		Hire a professional contractor to oil coat non-native duck eggs in Landa Park
Feral Hog	Feral Hog Workshops	High	Biennial; Years 1-9		Reach at least 55 targeted landowners across the Watershed or conduct at least 10 workshops in the Watershed
	Bounty Program	High	Years 1 - 10 with video and program development in Year 2	◆	Remove at least 1175 feral hogs from the Watershed
	Trapping Intensity Assessment	High	Years 2 - 10		Reach out to landowners biennially to track trapping intensities and analyze trends over time
	Feral Hog Website	Moderate	Years 4 - 10 with website development in Year 4	◆	Develop and regularly update a feral hog website
Livestock	Water Quality Management Plans (WQMPs)	High	Years 2 - 10		Complete at least 60 WQMPs or reduce the potential loading from livestock in the Watershed by 50 and 34 percent, respectively
	Livestock Outreach and Education	High	Biennial; Years 2-10		Reach at least 60 targeted landowners across the Watershed or conduct at least 10 workshops in the Watershed
OSSF	OSSF Education and Assistance Programs	High	Biennial; Years 2-10		Reach at least 250 OSSF owners or conduct at least 10 workshops in the Watershed
	Mandatory OSSF Inspection and Maintenance Program	High	Years 3 - 10		Inspect 2 targeted OSSFs per week, on average, with a trained inspector and follow-up to ensure any failures are corrected
Stormwater	Non-Structural Stormwater BMPs Outside of the City's MS4 Jurisdiction	High	Years 2 - 10 with new programs beginning in Years 2 & 4	◆ ◆	Implementation of at least 4 new practices outside the MS4 program, such as signage and monitoring programs
	Stormwater Outreach and Education	High	Years 1 - 10 with new signs in Year 2 and new materials in	◆ ◆	Reach at least 600 community members across the Watershed
	Engineering Analysis of Opportunities for Structural Stormwater BMPs	Moderate	Years 4 - 10 with analysis beginning in Year 4	◆	Complete an analysis of opportunities for additional structural stormwater BMPs and implement 5 new BMPs
Pet Waste	Pet Owner Outreach and Education	High	Years 1 - 10		Reach at least 800 households across the Watershed or conduct outreach activities at least annually
	Pet Waste Stations	High	Years 2 - 10 with largest installation in Year 2	◆	Purchase and install 200 pet waste stations across the Watershed on City property
	Pet Code Enforcement	Moderate	Years 4 - 10 with notification effort in Year 4	◆ ◆	Reach at least 200 households in the City Limits through enforcement and notification of increased enforcement
	Tailored Pet Solutions	Moderate	Years 2 - 10 with analysis in Years 2 & 6	◆ ◆	Complete an analysis of beneficial locations for tailored pet solutions and implement identified solutions; installation of 200 pet waste stations, as funding allows
Wastewater	Wastewater Discharge Water Quality Assessment	Moderate	Years 2 - 10		Review of water quality data from wastewater discharges annually

7.2 Estimated Costs for WPP Implementation

AACE Class 5 opinions of probable cost ("cost estimates") were developed for each BMP and outreach and education activity. The methodology for estimating costs for the BMPs and outreach and education activities was presented in Section 5.3.2 and costs are detailed in Appendix E. The costs do not consider the source of funding (e.g., in-kind versus a grant), but rather account for the total cost of implementation to the agencies leading implementation of each BMP. Note that estimated costs do not reflect all resources and time (e.g., community volunteers) that will be expended on these BMPs. Table 28 summarizes the total costs for implementation by year over the 10-year implementation period.

Figure 63 is a visual representation of the BMP costs in Table 28. The estimated total cost for implementation of all BMPs and outreach and education activities for the WPP over the 10-year implementation period is approximately $6.8M with 30 percent contingency or approximately $4.8M without contingency. The total annual cost for any given year is expected to range from $108,000 to $1,090,000 (assuming implementation follows the projected schedule). Year 1 has the lowest implementation cost per year, due to the initial focus on low-cost outreach and education activities, while Year 6 has the highest costs per year. The Watershed Partnership has planned a checkpoint at Year 3 to review progress to date before implementation of a second phase of costlier BMPs. Additionally, although most activities require resources and funding, a small revenue from enforcement fines is projected for three BMPs[19], including the Do-Not-Feed Wildlife Ordinance, as well as enhanced enforcement of the existing pet waste codes.

[19] OSSF homeowner fines are deposited into the Environmental Health revenue line item of the County. As these fines are not anticipated to reduce the overall net cost of implementing OSSF BMPs, no revenue is reported.

Table 28: WPP Cost Summary Table

BMP or Activity	Cost/Year 1	2	3	4	5	6	7	8	9	10	TOTAL
General Outreach and Education Activities	$59,000	$120,000	$110,000	$129,000	$117,000	$142,000	$31,000	$31,000	$33,000	$34,000	**$806,000**
Overabundant Urban Deer BMPs	$24,000	$41,000	$87,000	$89,000	$87,000	$77,000	$78,000	$77,000	$82,000	$78,000	**$617,000**
Urban Non-Native Avian Wildlife BMPs	$61,000	$80,000	$76,000	$57,000	$57,000	$37,000	$35,000	$37,000	$36,000	$37,000	**$429,000**
Feral Hog BMPs	$4,000	$19,000	$15,000	$33,000	$18,000	$13,000	$18,000	$15,000	$18,000	$16,000	**$144,000**
Livestock BMPs	$0	$8,000	$147,000	$157,000	$157,000	$150,000	$151,000	$160,000	$158,000	$167,000	**$1,087,000**
OSSF BMPs	$0	$4,000	$33,000	$80,000	$78,000	$78,000	$75,000	$82,000	$80,000	$87,000	**$518,000**
Stormwater BMPs	$1,000	$64,000	$7,000	$61,000	$400,000	$528,000	$412,000	$269,000	$271,000	$271,000	**$2,002,000**
Pet Waste BMPs	$6,000	$69,000	$40,000	$61,000	$59,000	$64,000	$46,000	$47,000	$49,000	$51,000	**$421,000**
Wastewater BMPs	$0	$1,000	$1,000	$1,000	$1,000	$1,000	$1,000	$1,000	$1,000	$1,000	**$9,000**
TOTAL (with Contingency)	**$155,000**	**$406,000**	**$516,000**	**$669,000**	**$975,000**	**$1,090,000**	**$847,000**	**$720,000**	**$728,000**	**$741,000**	**$6,847,000**
TOTAL (without Contingency)	**$108,500**	**$284,200**	**$361,200**	**$468,300**	**$682,500**	**$763,000**	**$592,900**	**$504,000**	**$509,600**	**$518,700**	**$4,792,900**

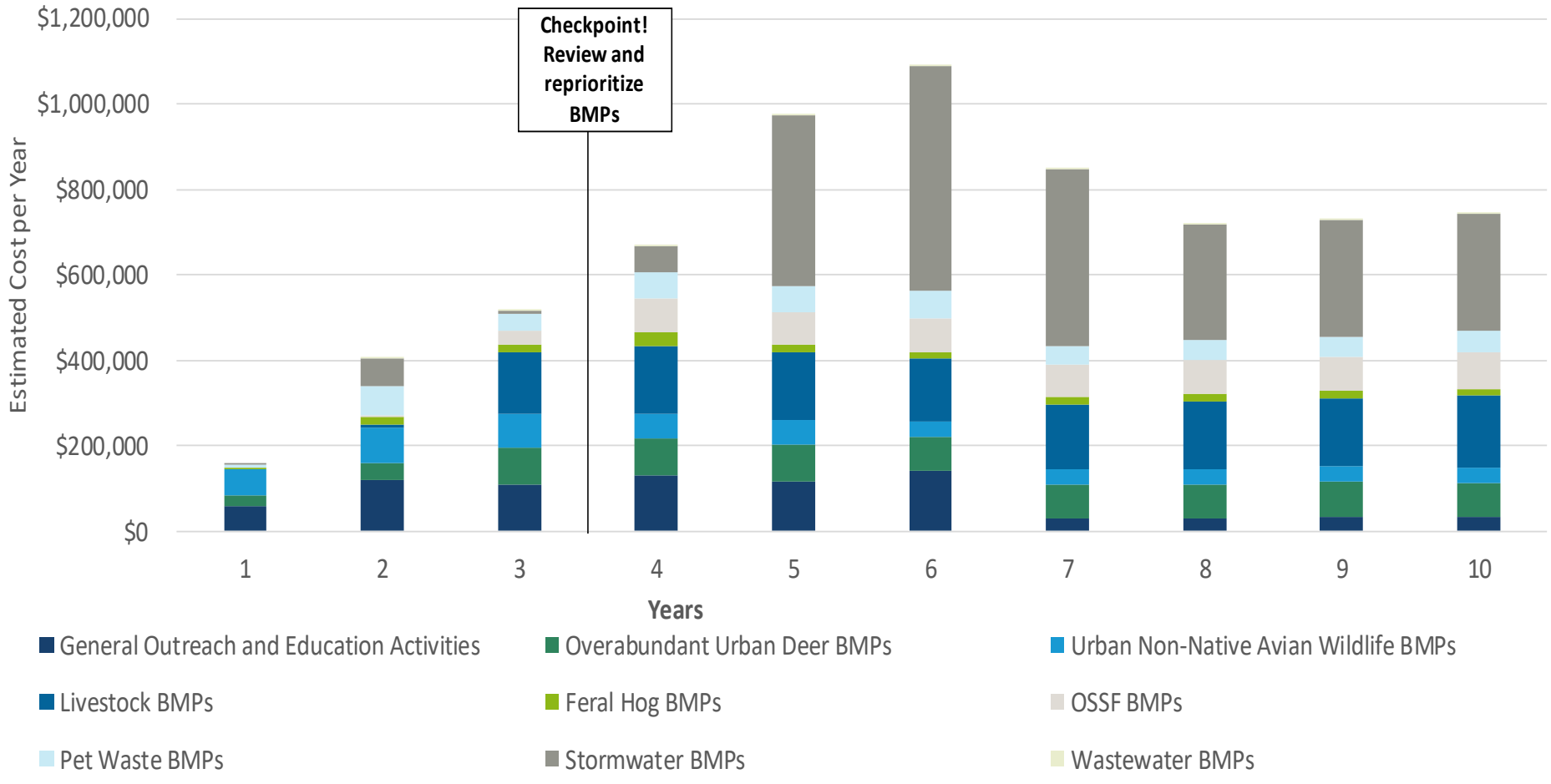


Figure 63: Estimated Cost of BMP Implementation Per Year

Figure 64 compares the estimated cost per *E. coli* source during Years 2 through 4 (left) and Years 1 through 10 (right). Years 2 through 4 represent the first three-year period eligible for funding through the Clean Water Act Section 319(h) grant funds. As shown, the spending on BMPs related to overabundant urban and non-native wildlife constitutes a much higher portion of the total estimated costs during the initial grant period than over the entire 10-year WPP implementation timeframe. In fact, over the initial grant period, BMPs addressing overabundant urban deer, non-native avian wildlife, and outreach and education total 50 percent of funding, which will be requested, illustrating the Watershed Partnership's focus on reducing *E. coli* from overabundant urban and non-native wildlife. Many of the efforts focused on managing the overabundant urban deer population and non-native wildlife are relatively inexpensive (e.g., outreach and education campaigns), but are anticipated to be very effective, as shown in Figure 64. The pie charts also show that a large portion of money is dedicated to Livestock BMPs. However, there is specific funding allocated for this by the TSSWCB.

Costs for stormwater BMPs in Years 1 through 4 are limited to a total investment of $110,900. More expensive stormwater BMPs will be delayed until Year 5, to maintain focus on the wildlife BMPs during the initial years after BMP implementation. By this time, the effectiveness of the already implemented overabundant urban deer and non-native avian BMPs will be known and can be considered in the decision-making process (refer to Section 8.4 for a discussion of the Adaptive Implementation approach that will be implemented). Stormwater BMPs are a key component of how the watershed operates as a whole. Although the BST results indicate that a majority of the *E. coli* originated from deer and non-native avian populations, a majority of this *E. coli* is carried into the Dry Comal Creek and Comal River by stormwater during rainfall events. It is anticipated that better management practices of stormwater will significantly reduce the number of bacteria entering the water system—bacteria from urban deer and non-native avian wildlife, as well as pets, humans, and livestock. Further, although stormwater BMPs are the costliest over the 10-year implementation period, due to required engineering and construction, implementation of stormwater BMPs are not limiting the Watershed Partnership's investment in wildlife BMPs.

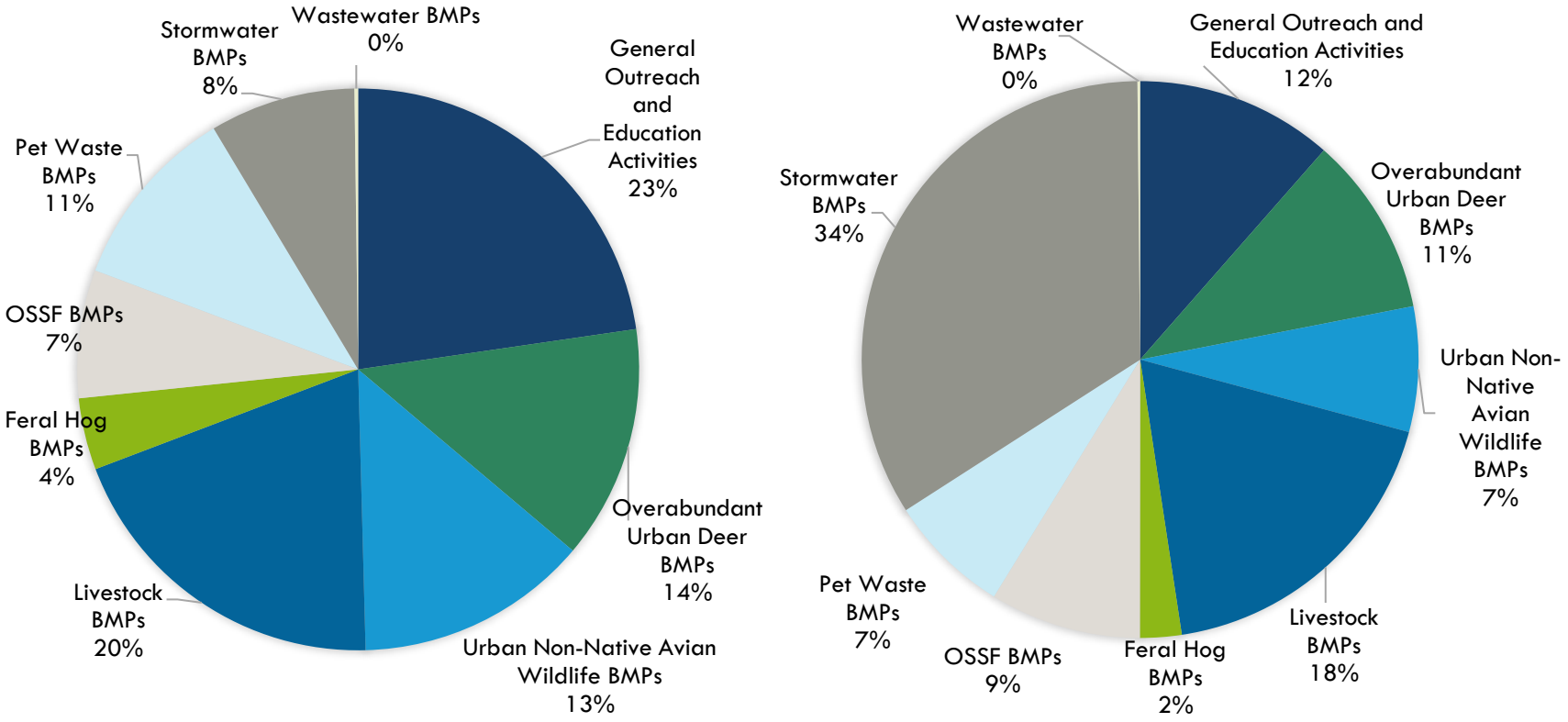


Figure 64: Estimated Costs per *E. coli* Source in Years 2-4 (left) and Years 1-10 (right)

8. Measures of Success

E. coli loading to waterbodies depends on several environmental factors including proximity to the creek, bacteria die-off, geomorphology, connectivity of stream network, temperature and other factors. These multiple and diverse factors make it complicated to estimate and measure the impact BMPs will have on *E. coli* loading, and quantify the success of BMPs. Thus, the Watershed Partnership is taking an adaptive implementation approach, as described in Section 8.4. The Watershed Partnership will regularly evaluate progress towards water quality goals and BMP objectives, and determine if modifications to the implementation strategy should be implemented to improve the BMP results or better adapt to the current conditions in the Watershed. The Watershed Partnership will evaluate the effectiveness of the BMPs by focusing on the three key factors outlined in Figure 65 as part of the "adaptive implementation" of the WPP.

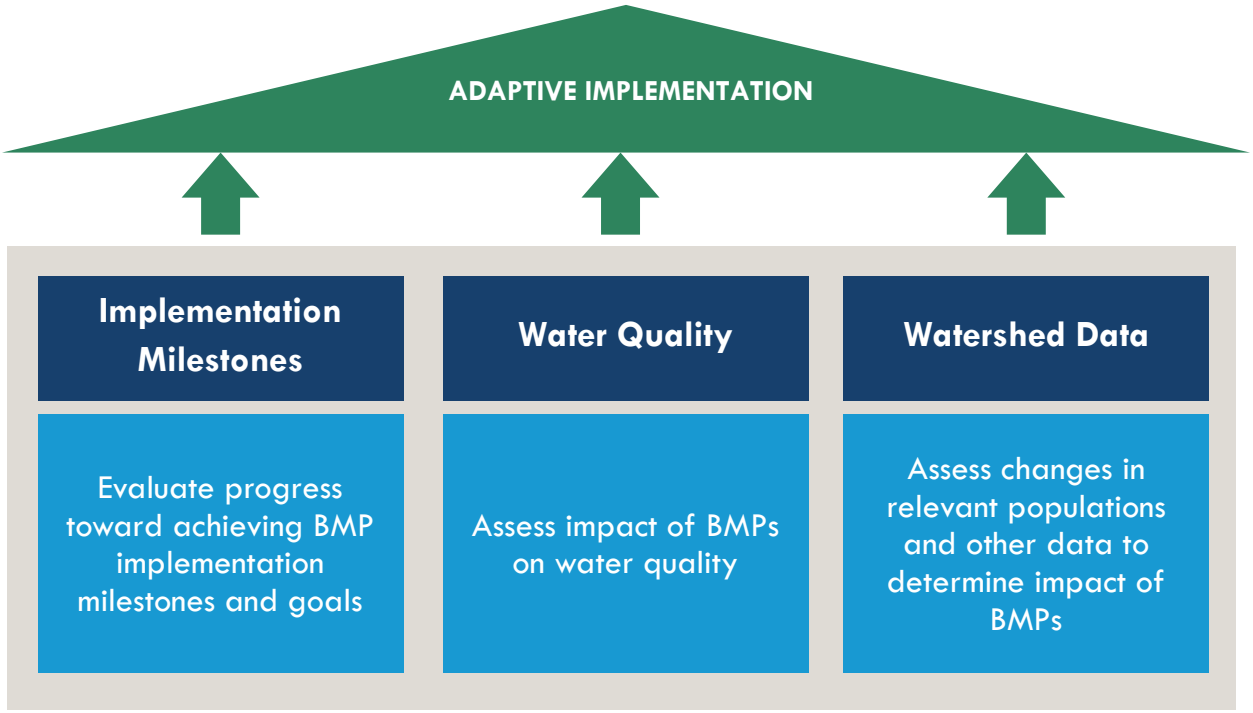


Figure 65: Adaptive Implementation Strategy

8.1 Measurable Implementation Milestones

The Watershed Partnership defined measurable goals (i.e., implementation milestones) for all the BMPs and outreach and education activities. Implementation milestones were established to track progress toward implementing the strategies for reducing *E. coli* loading to the Dry Comal Creek and the Dry River. Implementation milestones are outlined in the implementation schedule in Section 7. When possible, milestones are specific, measurable, achievable, and related specifically to the goals used to estimate potential load reductions. All implementation milestones are targeted for completion by the end of the 10-year implementation period, and as outlined in the implementation schedule.

Since there are several factors (e.g., funding, governmental approvals and personnel availability), which could interfere with reaching these milestones, the Watershed Partnership defined actions that could be taken in response to deviations from the plan. Actions based upon the completion status of each milestone are outlined in Figure 66. The Watershed Partnership will routinely review progress compared to these milestones and the implementation timeline assigned to each activity to assess progress toward the overall WPP goals.

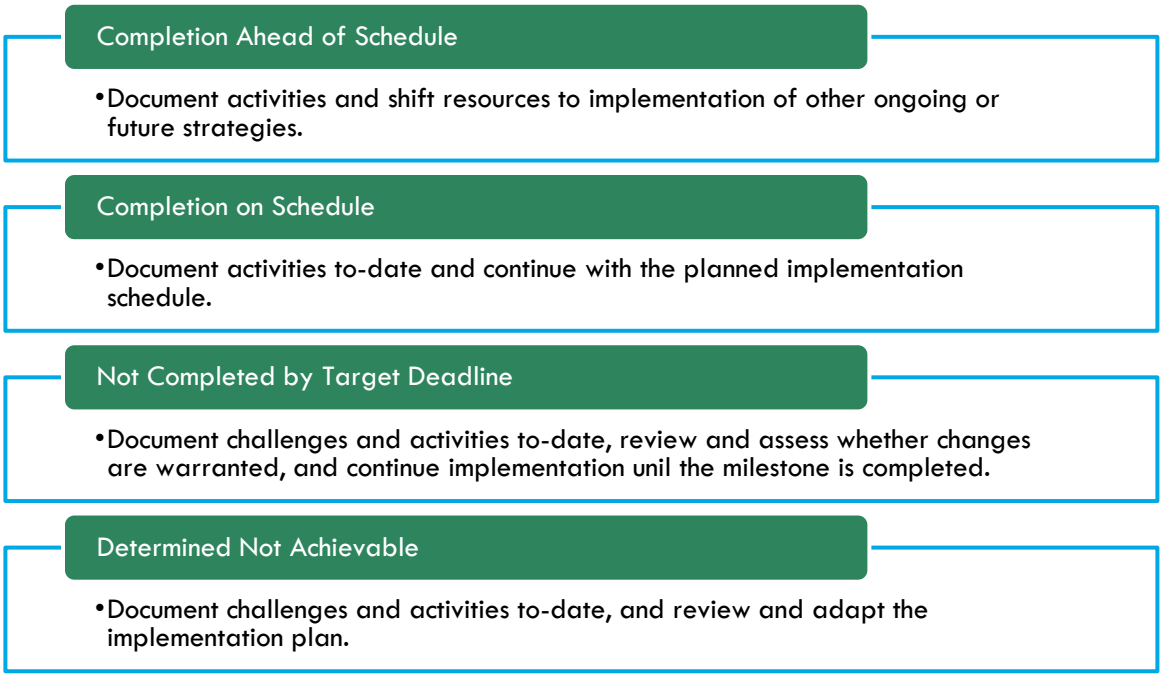


Figure 66: WPP Implementation Milestone Status and Response

8.2 Monitoring and Water Quality Criteria

The Watershed Partnership will continue to track water quality in the Dry Comal Creek and Comal River. Analysis of water quality will provide a quantitative assessment of trends and of changing conditions within the Watershed. Based upon water quality data, the implementation strategy will be adjusted, as necessary, to meet the goals outlined in this WPP. Water quality trends to be analyzed, include the following:

- Trends in general water quality parameters over time at each monitoring site included in the CRP, City-GBRA, and EAHCP water quality monitoring programs;
- Trends in the difference in general water quality parameters between the Comal Springs and Comal River; and
- Trends in *E. coli* concentrations over time at each monitoring site and across the Watershed, compared to *E. coli* target concentrations.

8.2.1 Water Quality Monitoring Program

Ongoing general water quality monitoring is being conducted by EAA and GBRA[20] and will continue to be monitored during WPP implementation for the parameters and at the locations discussed in Section 2, Table 3. Continued monitoring at these sites will provide a comprehensive assessment of water quality changes over time. Although these water quality parameters do not directly correlate with reductions in bacteria, they will allow for detection of new water quality problems and identification of any improvements to other water quality parameters due to the BMPs implemented. For purposes of this WPP, there are no specific water quality targets other than bacteria. However, any improvements in water quality in the Dry Comal Creek and/or Comal River (i.e., quality of the Comal River more closely matches the quality of the Comal Springs) may be an indication of successful BMP implementation. Additionally, any decreases in overall water quality may indicate significant changes in the Watershed conditions that may impact the success of the BMPs in the WPP. Trends identified will be documented and reviewed as part of a holistic adaptive implementation (Section 7.4) approach to WPP implementation.

8.2.2 *E. coli* Targets

E. coli reduction targets were developed based upon a 10-year implementation period. In other words, the targets assume that all BMPs will be implemented within 10 years, and that the target will be met by the end of 10 years. As some BMPs will be implemented in the first year, while other BMPs will require almost the full 10 years to complete, reductions in pollution loads, and associated *E. coli* concentrations in the Dry Comal Creek and Comal River may occur gradually. Thus, the Watershed Partnership established projected benchmarks (Table 29) to assess progress toward reducing *E. coli* loading. Although there are many variables outside the Watershed Partnership's control that impact the feasibility of meeting these targets (e.g., land use changes, effectiveness of BMPs, source population changes, weather, etc.), the Watershed Partnership identified a critical target of no more than 10 years for achieving improvement in the water quality in the Comal River and Dry Comal Creek. Thus, critical BMPs anticipated to have the greatest impact on water quality are planned for implementation as soon as funding is available. If the identified *E. coli* targets are not met by the proposed schedule, the Watershed

[20] EAA and GBRA will continue to maintain QAPPs, as needed, for these data.

Partnership will adapt the WPP to either implement BMPs more aggressively, implement new BMPs, or, in the case that unforeseen circumstances arise, extend the proposed schedule. Milestone years 3, 6, and 10 were selected for WPP review and revisions as part of an adaptive implementation approach (Section 8.4).

A seven-year geomean for *E. coli* bacteria will be calculated every year to analyze trends in the Comal River and Dry Comal Creek. Additionally, 1-year and 2-year geomeans may be used to assess more recent trends. Although these projections may not precisely match future water quality due to changing water and Watershed conditions, these estimates can be used to facilitate evaluation of the need for any adjustments to the WPP implementation strategies.

Table 29: Projected *E. coli* Benchmarks

Year	Comal River at Hinman Island (Station ID 12653)		Dry Comal Creek at Seguin St. (Station ID 12570)	
	E. coli Geomean Concentration (CFU/100mL)	Percent Reduction in *E. coli* Loading	*E. coli* Geomean Concentration (CFU/100mL)	Percent Reduction in *E. coli* Loading
Baseline (2011-2017)	164	0	237	0
Year 3 (2021)	149	15	200	10
Year 6 (2024)	133	30	163	20
Year 10 (2028)	113	50	113	34

8.3 Population Dynamics

Changes to the number, density, and location of warm-blooded animals within the Watershed may have significant impacts on water quality and the effectiveness of the selected BMPs. As these factors are difficult to control, the Watershed Partnership did not set any specific targets for reduction in any of these factors. However, the following data will be documented and considered during reviews of the WPP implementation program.

- **Human Population Densities / Population Growth** – Increase in population within the Watershed in the City, Garden Ridge or Comal County will impact water quality and BMP effectiveness. For example, as the population in the City increases, there will likely be an increase in the number of pets in the Watershed and the number of park visitors who may be tempted to feed the wildlife.
- **Land Use Changes** – Any major changes in land use (e.g., new residential developments in the county) may cause *E. coli* sources to change locations or impact the amount of *E. coli* reaching the river or creek. For example, a new residential development in the unincorporated area of the Watershed may remove a natural deer habitat, increase the number and density of people, increase stormwater by adding impervious cover, or decrease stormwater if low impact development strategies are incorporated.

- **Statistics on the Vehicle Collisions / Damage due to Wildlife** – Decreases in the number of vehicle collisions due to wildlife (i.e., primarily deer) may correlate with decreases in the deer population.
- **Statistics on Dead Animal Pick-up** – Decreases in the number of dead animals picked up by City or County staff may also be indicative of decreases in the animal populations.
- **Social Carrying Capacity Statistics** – Additionally, as discussed in Section 5, social carrying capacity factors will be tracked for overabundant urban deer.

8.4 Adaptive Implementation

Adaptive implementation is often referred to as "learning by doing" (USDA, 2007). The adaptive management process is an ongoing science-based approach (i.e., a defined natural resource management approach that promotes decision making through on-going, cyclic monitoring and evaluating strategies) that will incorporate new information (resulting from continual testing, constant input of watershed information, and the establishment of intermediate and final water quality targets) into the WPP, as it arises (USEPA, 2000). As the implementation of this WPP occurs, the plan will act as a living document meant to develop and evolve with better understanding of the nature of this specific watershed and the effectiveness of protective mitigating actions. Stakeholders benefit from the adaptive management process as it lends itself to flexible decision-making to reduce uncertainty and improve the performance of designated BMPs over time (Williams et al., 2009). Through adaptive implementation, the Watershed Partnership will implement strategies known to address manageable pollutant loadings within the Watershed to focus project efforts and optimize impacts.

The Dry Comal Creek and Comal River are good candidates for adaptive implementation as impairment is dominated by NPS pollutants. Complete implementation of the WPP expects accomplishment of targeted E. coli reduction by the end of the 10-year project period. Reductions in pollutant loads and associated concentrations may initially be gradual, as some of the BMPs to be implemented early during the project period will be relatively simple, while others will involve more complexity requiring more time, energy, and funding. Thus, each milestone will be an additional indication of the need to either maintain or adjust planned activities. While water quality conditions likely will change and may not precisely follow the projections indicated in this WPP, adaptive implementation will serve as a tool to facilitate stakeholder evaluation and decision-making.

Stakeholders, with support from the WPP Coordinator and WPP Consultant, will review data, including progress toward achieving implementation milestones (Table 27 and Section 8.1), water quality data in comparison to projected targets (Section 8.2), population dynamics (Section 8.3), and funding/resource availability. Although an official checkpoint is scheduled for the end of the third year to review progress and adjust the implementation schedule and goals, as necessary, to meet the WPP goals, should any of the following triggers be identified during annual reviews, the WPP will be redirected, as needed:

- The need for additional funding or funding sources to implement planned BMPs;

- Significant weather changes (e.g., severe droughts or flooding);
- Unanticipated changes to water quality, including *E. coli* concentrations or other biological indictors monitored through the EAHCP, in the Watershed;
- Schedule delays or inability to implement planned BMPs (see Figure 67);
- Strong community (e.g., legal action) or City Council opposition to implementation or continuance of BMPs;
- Changes to population dynamics (as described in Section 8.3); and/or
- Any other factors determined to influence the efficacy of the WPP.

9. Technical and Financial Resources

Implementation of this WPP will be a collaborative process, requiring cooperation among the City, stakeholders, and agencies involved in land and water resources management. The existing Stakeholder Group and TAG (refer to Section 3.2) will remain involved throughout the implementation of the WPP. Additionally, the Watershed Partnership has identified additional technical resources, which will be consulted during the execution of the identified BMPs and outreach and education strategies (Section 9.1), and a preliminary list of potential funding sources to support the implementation activities (Section 9.2).

9.1 Technical Assistance

Continued direction and commitment from the City's officials and staff will be critical to successful implementation of this WPP. Many of the existing Stakeholder Group and TAG members have extensive knowledge of specific subject areas; however, additional, technical resources may be required during implementation to provide specialized expertise. Technical assistance needs vary depending upon the specific bacteria source and applicable BMPs, as discussed in Section 5. Table 30 summarizes technical resources currently planned for this WPP. Additional technical assistance needs may be identified as BMPs are implemented. If so, such resources will be identified and consulted, as needed, to effectively implement this WPP. Additionally, the Watershed Coordinator and WPP Consultant will be leveraged as technical resources for all of these activities.

Table 30: Summary of Planned Technical Assistance for WPP Implementation by Source of Pollution

Pollution Source	Technical Resource(s)	Key Support Activities
All Sources	City, Comal County Guadalupe County, GBRA, Plum Creek Watershed Partnership, Geronimo and Alligator Creek Watershed Partnership, EPA Getting In Step Guide and other references, TCEQ NPS Team and references	Support general outreach and education programs: • Disseminate WPP information • Publicize WPP education and training events • Provide knowledge regarding prior activities conducted in the Watershed • Assess potential impacts on water quality

Table 30: Summary of Planned Technical Assistance for WPP Implementation by Source of Pollution (Continued)

Pollution Source	Technical Resource(s)	Key Support Activities
Urban Wildlife	City Legal Department, City Public Works Department, TPWD, City of Austin	• Draft wildlife do-not-feed ordinance language and present to the City Council for approval
	TPWD and Texas A&M AgriLife	• Conduct community education regarding wildlife management • Provide information and resources to the Watershed Partnership
Overabundant Urban Deer	TPWD, City Public Works Department	• Assess deer population through social carrying capacity statistics
	Biologists/Ecologists, City Public Works Department	• Assess riparian corridors for opportunities to increase vegetation, and re-vegetation of identified areas
	TPWD, Texas A&M AgriLife Service	• Identify optimal locations, frequencies and numbers of overabundant urban deer to actively manage, and assist implementation of an active management program
	Licensed Trappers	• Trap and remove overabundant urban deer
Non-Native Avian Wildlife	TPWD, City Public Works Department and Parks Department	• Assess non-native duck and geese population through the number of non-native eggs/nests found
	Biologists/Ecologists, City Public Works Department and Parks Department	• Identify effective and culturally acceptable tactics for use in Landa Park to prevent congregation of non-native ducks and geese • Procure and install or operate acceptable tactics
	TPWD, City Public Works Department and Parks Department	• Develop programs to trap non-native ducks and geese, and oil-coat non-native eggs
Feral Hogs	Texas A&M AgriLife, TWS, Texas Wildlife Damage Management Service (TWDMS), City Public Works Department	• Develop and deliver education on feral hog biology, habits, control techniques, and options for disposal
	City of Austin, Plum Creek Watershed Partnership, Geronimo and Alligator Creek Watershed Partnership, Comal and Guadalupe Counties, Texas A&M AgriLife	• Implementation and operation of a feral hog bounty program
	Texas A&M AgriLife, TWDMS, Plum Creek Watershed Partnership, Geronimo and Alligator Creek Watershed Partnership, City Public Works Department	• Track feral hog management efforts (e.g., trapping intensities) and estimated number of feral hogs removed; development or expansion of a feral hog website

Table 30: Summary of Planned Technical Assistance for WPP Implementation by Source of Pollution (Continued)

Pollution Source	Technical Resource(s)	Key Support Activities
Livestock	TSSWCB/SWCD Technicians; NRCS Staff	• Coordinate with landowners to complete development and implementation of WQMPs that support the owner's goals and improve water quality • As needed, coordinate with landowners to complete Conservation Plans funded through NRCS
	TSSWCB/SWCD/NRCS	• Assist landowners in development of WQMPs • Track the number of WQMPs implemented • As needed, coordinate with landowners to complete Conservation Plans funded through NRCS
	Texas A&M AgriLife	• Develop and deliver education programs (e.g., Lone Star Healthy Streams Program) on livestock management practices that improve water quality
OSSFs	Texas A&M AgriLife, Comal County	• Develop and deliver education on proper design, construction, and operation and maintenance of OSSFs • Disseminate information on the State and County rules and regulations regarding OSSFs
	Comal County, City Public Works Department	• Identification of high priority OSSFs based upon SELECT analysis, age and stakeholder knowledge
	Comal County	• Support and enhance OSSF inspection program within the Watershed
Urban Runoff and Stormwater	City Public Works Department, Comal County, Professional Engineers	• Select, plan and implement non-structural stormwater BMPs outside the New Braunfels MS4 permit
	City Public Works Department, Professional Engineers	• Identify, design and construct new structural improvements and upgrades to existing systems
	City Public Works Department, TCEQ, EPA	• Develop and deliver education on best management practices to reduce stormwater *E. coli* pollution
Pets	City Public Works Department	• Develop and deliver education on the benefits of picking up pet waste
	City Public Works Department	• Identify locations for installation of pet waste stations • Coordinate with apartment complexes to encourage and assist with pet waste education and installation of stations
	City Law Enforcement and Park Rangers	• Enforce the pet code through fines

Table 30: Summary of Planned Technical Assistance for WPP Implementation by Source of Pollution (Continued)

Pollution Source	Technical Resource(s)	Key Support Activities
Wastewater	City Public Works Department, Professional Engineers, New Braunfels Utilities, Comal County	• Track and assess water quality data submitted to the TCEQ on permitted wastewater discharges in the Watershed

9.2 Sources of Funding

Successful implementation of the identified BMPs, and outreach and education activities will require identification and acquisition of funding for both initial and sustained implementation. Costs for implementation were developed by the WPP Consultant with input from the TAG and Stakeholder Group (refer to Section 5.3 and Appendix F). To reduce the required funding, the Watershed Partnership is committed to supporting the activities through in-kind contributions from the City, stakeholders and local volunteers. However, partial or full funding will be required to cover expenses, consulting fees, installation and construction of new strategies, and administration of new programs.

Development of this WPP was supported through funding from the EPA through TCEQ as part of the Section 319(h) program. The Watershed Partnership will apply for additional funding from the 319(h) program in 2017 to support implementation of the initial BMPs and outreach and education activities (if awarded, funding will be available in late 2018 or early 2019). Additionally, the Watershed Partnership will seek funding from other programs, as outlined in Figure 67 and Table 31. Over 30 different grant, loan, and cost-share programs were identified by the Watershed Partnership. The Watershed Partnership selected the programs that were potentially applicable to BMPs, and outreach and education activities selected for this WPP, and prioritized each funding source based upon the scale below.

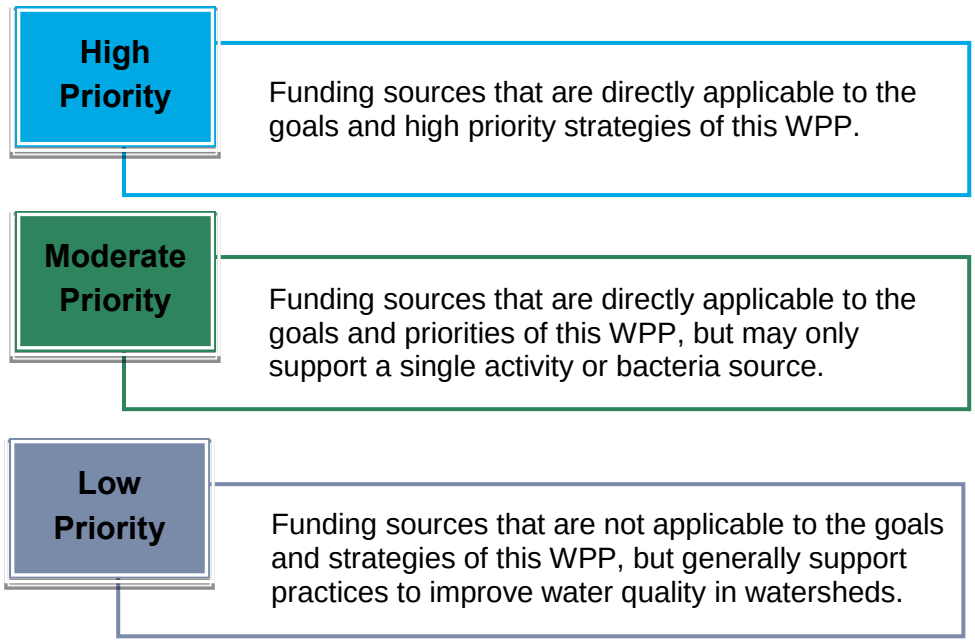


Figure 67: Funding Source Prioritization

Table 31: Summary of Potential Funding Sources

Priority	Potential Funding Source	Funding Administrator	Description	Potential Eligible Activities	Application Schedule	Website Information
High	City In-Kind Contributions	City	The City is currently planning to fund through existing City budgets the salary costs for its staff who will remain highly involved in implementation activities.	• Watershed Coordinator • City's public communication staff • City's legal staff (e.g., new wildlife do-not-feed ordinance) • City's public works staff • City's parks department and park rangers • Continued *E. coli* data monitoring	Annually with fiscal year calendar	NA
High	Stakeholder In-Kind Contributions	Stakeholders	Some of the Stakeholder organizations are planning to pay some of the implementation costs within annual program budgets.	• Water quality monitoring (EAA) • CRP monitoring (GBRA) • Wildlife education and outreach (TPWD) • EAHCP Restoration Projects	Varies	NA
High	Section 319(h) Federal Clean Water Act - TCEQ	EPA	Through its Clean Water Act §319(h) Nonpoint Source Grant Program, EPA provides grant funding to TCEQ to implement NPS pollution reduction projects. The TCEQ receives funds to support urban and other non-agricultural nonpoint source projects.	BMPs and outreach and education activities related to: • Stormwater (outside the existing MS4 program) • Pets (e.g., education, waste stations) • Wildlife (e.g., education, scare tactics, signage)	Annually on June 1st	https://www.tceq.texas.gov/waterquality/nonpoint-source/grants/ grant-pgm.html

Table 31: Summary of Potential Funding Sources (Continued)

Priority	Potential Funding Source	Funding Administrator	Description	Potential Eligible Activities	Application Schedule	Website Information
High	Section 319(h) Federal Clean Water Act - TSSWCB	EPA	Through its Clean Water Act §319(h) Nonpoint Source Grant Program, EPA provides grant funding to the state to implement NPS pollution reduction projects. The TSSWCB receives funds to support agricultural and silvicultural nonpoint source projects.	BMPs and outreach and education activities related to: • Livestock (i.e., WQMPs and education) • Feral Hogs (i.e., education, tracking efforts) • OSSFs in rural areas	Annually in October on federal schedule	https://www.tsswcb.texas.gov/programs/texas-nonpoint-source-management-program
High	Water Quality Management Plan Program (503 Program)	TSSWCB	Supports the development and implementation of WQMPs. Implementation funding is provided up to $15,000 per operating unit.	WQMP implementation	Continuous	https://www.tsswcb.texas.gov/programs/water-quality-management-plan
High	Grazing Lands Conservation Initiative	NRCS	Technical assistance and public awareness activities that improve management of private grazing lands.	Conservation Plans Note: As needed to meet water quality goals, Conservation Plans funded through NRCS will also be considered and recommended, in addition to WQMPs.	Annually in November	https://www.nrcs.usda.gov/wps/portal/nrcs/main/national/people/partners/glci/
High	Environmental Quality Incentives Program	NRCS	Up to 10-year incentive and cost-share contracts for agricultural controls and management measures.	Conservation Plans Note: As needed to meet water quality goals, Conservation Plans funded through NRCS will also be considered and recommended, in addition to WQMPs.	Continually	https://www.nrcs.usda.gov/wps/portal/nrcs/main/national/programs/financial/eqip/
High; Funding through Partners	Texas Clean Rivers Program	TCEQ	Statewide water quality monitoring, assessment and public outreach programs	Monitoring and educational activities conducted by GBRA	Annually on January 1	https://www.tceq.texas.gov/waterquality/clean-rivers

Table 31: Summary of Potential Funding Sources (Continued)

Priority	Potential Funding Source	Funding Administrator	Description	Potential Eligible Activities	Application Schedule	Website Information
High; Funding through Partners	Feral Hog Abatement Grant Program	Texas Department of Agriculture	Funding provided to the Texas A&M AgriLife – Wildlife Services and the TPWD for feral hog abatement	Feral hog management and education (through programs administered by Texas A&M AgriLife and TPWD)	Annually in summer	https://www.texasagriculture.gov/GrantsServices/TradeandBusinessDevelopment/FeralHogGrantProgram
Moderate	USDA-Rural Development Program	USDA	The program provides grants and low interest loans for construction, repair or rehabilitation of wastewater systems.	Repair, rehabilitation, and replacement of OSSFs	Continuous	https://www.rd.usda.gov/programs-services/water-waste-disposal-loan-grant-program
Moderate	Clean Water Act State Revolving Fund	TWDB	Provides loans at low interest rates for projects related to wastewater and nonpoint source pollution control. Some loans may have flexible terms and principal forgiveness.	Repair, rehabilitation, and replacement of OSSFs, stormwater improvements, and wastewater projects	Continuous	http://www.twdb.texas.gov/financial/programs/CWSRF/index.asp
Moderate	Supplemental Environmental Project Program	TCEQ	Directs fines, fees, and penalties from environmental violators toward environmentally-beneficial uses	Single, one-time projects such as OSSF repair, riparian vegetation or structural stormwater BMPs	Continuous as funds are available	https://www.tceq.texas.gov/legal/sep/
Moderate	Section 106 State Water Pollution Control Grants	TCEQ	Assistance for water quality monitoring, development of water quality standards and permits, and development of groundwater protection strategies	Water quality monitoring and assessments; outreach and education activities	As available for eligible agencies	https://www.tceq.texas.gov/agency/funding/

Table 31: Summary of Potential Funding Sources (Continued)

Priority	Potential Funding Source	Funding Administrator	Description	Potential Eligible Activities	Application Schedule	Website Information
Moderate	Environmental Education Grants	EPA	Provides grants for environmental education projects ranging from $15,000 to $25,000.	Outreach and education activities (e.g., local events, tours, youth activities)	Annually	https://www.epa.gov/education/environmental-education-ee-grants
Moderate	Texas Capital Fund	Texas Department of Agriculture	Funding for infrastructure projects including water and sewer lines, and drainage improvements.	Structural stormwater improvements	Monthly	https://www.texasagriculture.gov/GrantsServices/RuralEconomicDevelopment/TexasCapitalFund.aspx
Moderate	Section 104(b) Programs	USGS	Provides funding ranging from $10,000 to $580,000 per fiscal year for water related research. Priorities for 2016 included training, surveys and watershed planning and management.	Watershed management activities, training, and nonpoint source planning	Annually in first quarter of the year	https://www.cfda.gov/index?s=program&mode=form&tab=step1&id=5f551abf2269859e01a5f110d9da6c60
Low	Outdoor Recreation Grants	TPWD	Provides a 50% matching grant for the acquisition, development or renovation of parkland for local units of government with populations less than 500,000.	No high or moderate priority BMPs selected for this WPP are eligible; however, this funding source may be useful in the future as new BMPs are considered	Annually on October 1	http://tpwd.texas.gov/business/grants/recreation-grants

Table 31: Summary of Potential Funding Sources (Continued)

Priority	Potential Funding Source	Funding Administrator	Description	Potential Eligible Activities	Application Schedule	Website Information
Low	Conservation Reserve Program	FSA / NRCS	In exchange for a yearly rental payment, farmers enrolled in the program agree to remove environmentally sensitive land from agricultural production and plant species that will improve environmental health and quality. Contracts for land enrolled in Conservation Reserve Program are 10-15 years in length.	Removing agricultural land from production (in lieu of a WQMP); improved grass cover in CRP areas can reduce runoff and improve water quality Note: As needed to meet water quality goals, Conservation Plans funded through NRCS will also be considered and recommended, in addition to WQMPs.	Continuous	https://www.fsa.usda.gov/programs-and-services/conservation-programs/conservation-reserve-program/index
Low	Regional Water Supply and Wastewater Facility Planning Program	TWDB	Grants for feasibility assessments for water and wastewater facilities, and identify institutional arrangements to extend wastewater services	No high or moderate priority BMPs selected for this WPP are eligible; however, this funding source may be useful in the future as new BMPs are considered	Annually on August 1 and February 1	http://www.twdb.texas.gov/financial/programs/RWPG/index.asp
Low	Agricultural Conservation Easement Program	NRCS	Financial assistance for purchasing Agricultural Land Easements covering 50-100 percent of the easement value.	No high or moderate priority BMPs selected for this WPP are eligible; however, this funding source may be useful in the future as new BMPs are considered Note: As needed to meet water quality goals, Conservation Plans funded through NRCS will also be considered and recommended, in addition to WQMPs.	Continually	https://www.nrcs.usda.gov/wps/portal/nrcs/main/tx/programs/easements/acep/

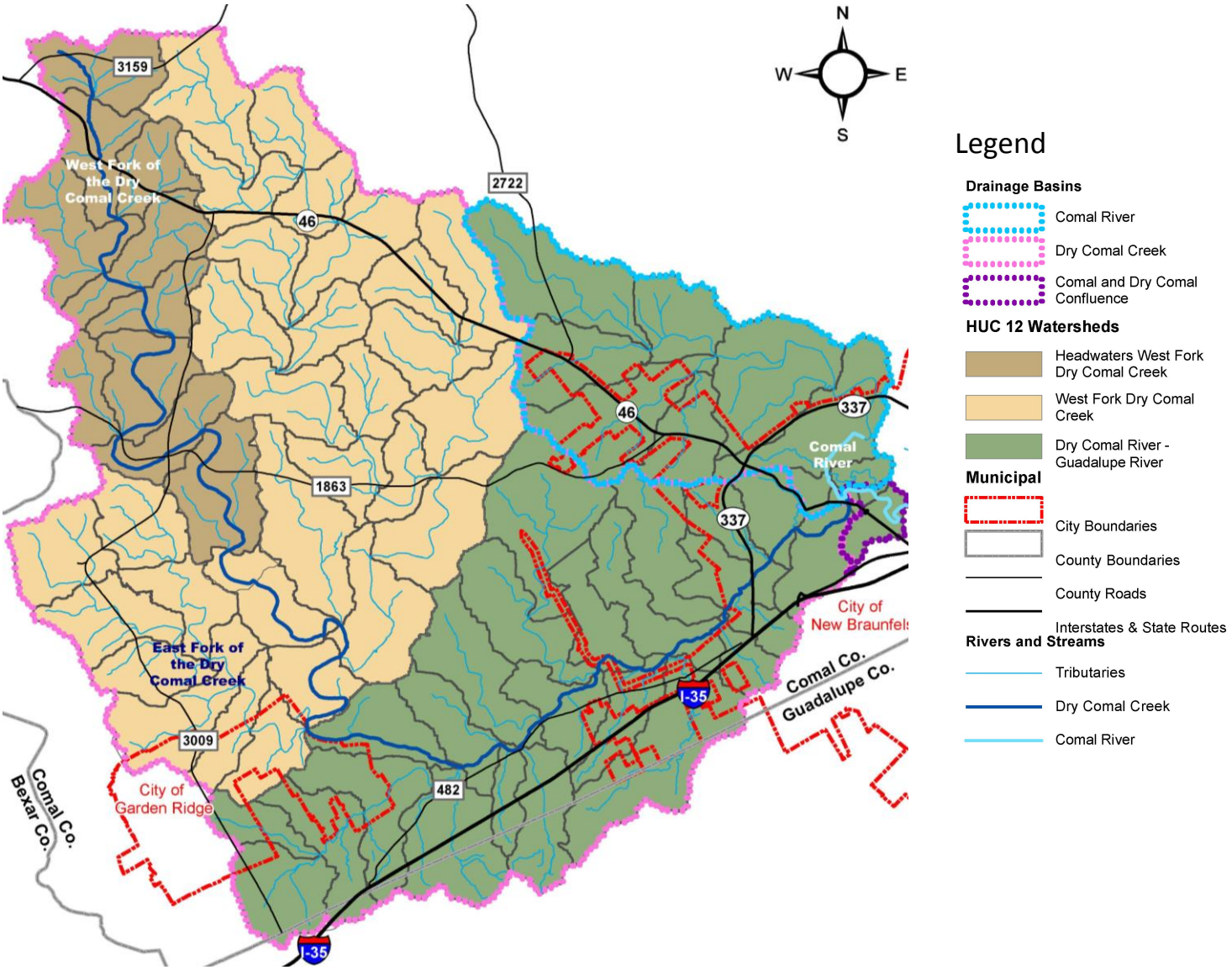
Table 31: Summary of Potential Funding Sources (Continued)

Priority	Potential Funding Source	Funding Administrator	Description	Potential Eligible Activities	Application Schedule	Website Information
Low	Conservation Stewardship Program	NRCS	Minimum annual payment of $1,500 to improve land management and increase conservation activities for agriculture and farms.	No high or moderate priority BMPs selected for this WPP are eligible; however, this funding source may be useful in the future as new BMPs are considered Note: As needed to meet water quality goals, Conservation Plans funded through NRCS will also be considered and recommended, in addition to WQMPs.	Continually	https://www.nrcs.usda.gov/wps/portal/nrcs/main/national/programs/financial/csp/
Low	Agricultural Water Conservation Program	TWDB	Grants and low-interest loans for agricultural water conservation and/or improvement projects.	No high or moderate priority BMPs selected for this WPP are eligible; however, this funding source may be useful in the future as new BMPs are considered	Continually	http://www.twdb.texas.gov/financial/programs/AWCG/index.asp
Low	Texas Farm & Ranch Lands Conservation Program	TPWD	Grants to landowners for the sale of conservation easements.	No high or moderate priority BMPs selected for this WPP are eligible; however, this funding source may be useful in the future as new BMPs are considered	Annually in March	http://tpwd.texas.gov/landwater/land/private/farm-and-ranch/
Low	Landowner Incentive Program	TPWD	Grants to support conserving land for rare or at-risk species	No high or moderate priority BMPs selected for this WPP are eligible; however, this funding source may be useful in the future as new BMPs are considered	Continually	http://tpwd.texas.gov/landwater/land/private/lip/

Table 31: Summary of Potential Funding Sources (Continued)

Priority	Potential Funding Source	Funding Administrator	Description	Potential Eligible Activities	Application Schedule	Website Information
Low	Meadows Foundation	Meadows Foundation	Financial assistance for programs that help Texas preserve and sustain its environmental resources for future generations.	Land conservation, water quality management and habitat conservation	Continually	https://www.mfi.org/GrantAppGuide.html

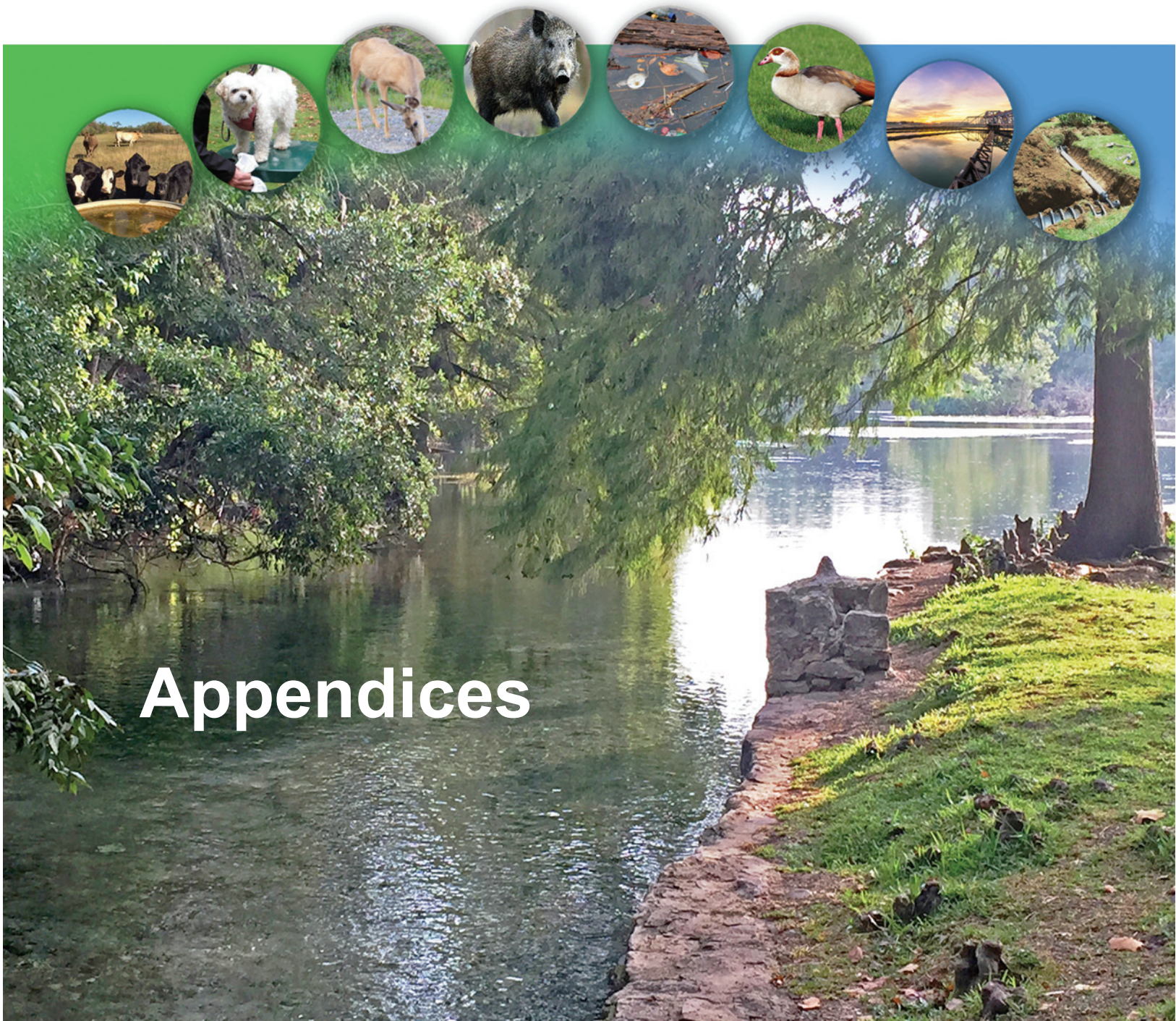
www.nbtexas.org/wpp



Dry Comal Creek and Comal River Watershed Protection Plan

Developed by the Dry Comal Creek and Comal River Watershed Partnership

AUGUST 2018



Appendices

Contents

Appendix A: Reference Table for EPA's Nine Elements for WPPs.....1

Appendix B: Analysis of General Water Quality in the Comal River from the Edwards Aquifer Habitat Conservation Plan Monitoring Program.....3

Appendix C: Maps of Locations of *E. coli* Sources Observed by Stakeholders.....12

Appendix D: Low Priority BMPs Not Included in the WPP.....21

Appendix E: Low Priority Outreach and Education Activities Not Included in the WPP ...31

Appendix F: Estimated Probable Cost Calculations for BMP implementation.....35

Appendix G: Estimated *E. coli* Load Reduction Calculations.....45

Appendix H: Citations.....57

List of Tables

Table A-1. Nine Minimum Elements to be Included in a WPP Using 319 Funds and Where the Elements are Located in the Dry Comal Creek and Comal River WPP 1
Table A-1. Nine Minimum Elements to be Included in a WPP Using 319 Funds and Where the Elements are Located in the Dry Comal Creek and Comal River WPP (Continued).. 2
Table D-1: Low Priority BMPs 22
Table D-1: Low Priority BMPs (Continued).....23
Table D-1: Low Priority BMPs (Continued).....24
Table D-1: Low Priority BMPs (Continued).....25
Table D-1: Low Priority BMPs (Continued).....26
Table D-1: Low Priority BMPs (Continued).....27
Table D-1: Low Priority BMPs (Continued).....28
Table D-1: Low Priority BMPs (Continued).....29
Table D-1: Low Priority BMPs (Continued).....30
Table E-1: Additional Outreach and Education Activities.....32
Table E-1: Additional Outreach and Education Activities (Continued) 33
Table E-1: Additional Outreach and Education Activities (Continued) 34
Table F-1: Estimated Probable Cost Calculations for WPP Implementation: Project Management.....36

Table F-2: Estimated Probable Cost Calculations for WPP Implementation: Outreach and Education Activities 37
Table F-3: Estimated Probable Cost Calculations for WPP Implementation: Overabundant Urban Deer BMPs 38
Table F-4: Estimated Probable Cost Calculations for WPP Implementation: Urban Non-Native Avian Wildlife BMPs 39
Table F-4: Estimated Probable Cost Calculations for WPP Implementation: Urban Non-Native Avian Wildlife BMPs (Continued) 40
Table F-5: Estimated Probable Cost Calculations for WPP Implementation: Feral Hog BMPs 41
Table F-6: Estimated Probable Cost Calculations for WPP Implementation: Livestock BMPs 42
Table F-7: Estimated Probable Cost Calculations for WPP Implementation: OSSF BMPs 42
Table F-8: Estimated Probable Cost Calculations for WPP Implementation: Stormwater BMPs 43
Table F-9: Estimated Probable Cost Calculations for WPP Implementation: Pet Waste BMPs 44
Table F-10: Estimated Probable Cost Calculations for WPP Implementation: Wastewater BMPs 44
Table G-1: Estimated Potential *E. coli* Load Reduction By Source 48
Table G-2: Estimated Potential *E. coli* Load Reduction by BMP 49
Table G-3: Estimated Potential *E. coli* Load Reduction Calculations 50
Table G-3: Estimated Potential *E. coli* Load Reduction Calculations (Continued) 51
Table G-3: Estimated Potential *E. coli* Load Reduction Calculations (Continued) 52
Table G-3: Estimated Potential *E. coli* Load Reduction Calculations (Continued) 53
Table G-3: Estimated Potential *E. coli* Load Reduction Calculations (Continued) 54
Table G-3: Estimated Potential *E. coli* Load Reduction Calculations (Continued) 55
Table G-3: Estimated Potential *E. coli* Load Reduction Calculations (Continued) 56

List of Figures

Figure B-1: 2016 and 2017 Average Monthly Dissolved Oxygen Concentrations 4
Figure B-2: 2016 and 2017 Average Monthly pH Values 5
Figure B-3: 2016 and 2017 Average Monthly Conductivity Values 6
Figure B-4: Precipitation and Conductivity Measured at Comal Spring 3 7
Figure B-5: Precipitation and Conductivity Measured at Landa Lake 7
Figure B-6: Precipitation and Conductivity Measured at the Comal River 8
Figure B-7: Precipitation and Temperature Measured at Comal Spring 3 9
Figure B-8: 2016 and 2017 Monthly Average Temperature Values 9
Figure B-9: Turbidity and Precipitation Measured at the Comal River Sampling Location 10

Figure B-10: 2016 and 2017 Monthly Average Turbidity....10
Figure C-1: Locations *of* Overabundant Urban Deer in the Watershed....13
Figure C-2: Locations of Native and Non-Native Avian Wildlife in the Watershed....14
Figure C-3: Locations of Feral Hogs in the Watershed....15
Figure C-4: Locations of Livestock in the Watershed....16
Figure C-5: Locations of OSSFs in the Watershed....17
Figure C-6: Locations of stormwater Sources in the Watershed....18
Figure C-7: Locations of Pet Waste in the Watershed....19
Figure C-8: Locations of Wastewater Discharges in the Watershed....20

Appendix A: Reference Table for EPA's Nine Elements for WPPs

All WPPs funded with 319 Funds are required to meet USEPA's nine elements for watershed-based plans. These nine elements form the foundation for the development of a successful WPP. Table A-1 summarizes the nine minimum elements to be included in a WPP and the corresponding sections of the WPP that address each required element.

Table A-1. Nine Minimum Elements to be Included in a WPP Using 319 Funds and Where the Elements are Located in the Dry Comal Creek and Comal River WPP

EPA WPP Element	Corresponding Section(s) in this WPP
Element A: Identification of Causes and Sources	Sections 2 and 4
1. Sources identified, described and mapped	4.3, 4.4.3, 4.5
2. Subwatershed sources	4.4.2, 4.4.3. 4.5
3. Data sources are accurate and identifiable	2.8, 4.2, 4.3, 4.4, 4.5, Appendix H
4. Data gaps	2.8, 2.9, 4.3, 4.5, 4.6
Element B: Expected Load Reductions	Section 5
1. Load reductions achieve environmental goal	5.7, Appendix G
2. Load reductions linked to sources	5.3.1, 5.7, Appendix G
3. Model complexity appropriate	5.3.1, 5.7, Appendix G
4. Basis of effectiveness estimates explained	5.3.1, 5.7, Appendix G
5. Methods and data cited and verifiable	5.3.1, 5.7, Appendix G, Appendix H
Element C: Management Measures Identified	Sections 3 and 5
1. Specific management measures are identified	5.4.1, 5.4.2, 5.4.3, 5.5, 5.6.1, 5.6.2, 5.6.3, 5.6.4
2. Priority areas	5.4.1, 5.4.2, 5.4.3, 5.5, 5.6.1, 5.6.2, 5.6.3, 5.6.4
3. Measure selection rationale documented	5.4.1, 5.4.2, 5.4.3, 5.5, 5.6.1, 5.6.2, 5.6.3, 5.6.4, 3.2, Appendix D
4. Technically sound	5.4.1, 5.4.2, 5.4.3, 5.5, 5.6.1, 5.6.2, 5.6.3, 5.6.4, Appendix D

Table A-1. Nine Minimum Elements to be Included in a WPP Using 319 Funds and Where the Elements are Located in the Dry Comal Creek and Comal River WPP (Continued)

EPA WPP Element		Corresponding Section(s) in this WPP
Element D: Technical and Financial Assistance		
1.	Estimate of technical assistance	Potential sources of financial and technical assistance summarized in Sections 5 and 6; detailed in Section 9
2.	Estimate of financial assistance	Costs provided in Sections 5 and 6; summarized in Section 7; detailed in Appendix F.
Element E: Education/Outreach		Sections 3 and 6
1,	All relevant stakeholders are identified in outreach process	3.1, 6.1, 6.3
2.	Public education/information	3.2, 6.1, 6.2, 6.3, 6.4
3.	Stakeholder outreach	3.2, 6.1, 6.3, 6.4
4.	Public participation in plan development	3.2, 6.1, 6.2, 6.3, 6.4
5.	Emphasis on achieving water quality standards	6.1, 6.2, 6.3, 6.4
6.	Operation & maintenance of BMPs	6.3, 6.4
Element F: Implementation Schedule		
1.	Includes completion dates	Summarized in Sections 5 and 6 for each activity and detailed in Section 7
2.	Schedule is appropriate	
Element G: Milestones		Listed in Section 7 as “Implementation Milestones”; described in Section 8
1.	Milestones are measurable and attainable	7.1, 8.1
2.	Milestones include completion dates	7.1, 8.1
3.	Progress evaluation and course correction	7.1, 8.1, 8.2, 8.3, 8.4
4.	Milestones linked to schedule	7.1, 8.1
Element H: Load Reduction Criteria		Section 8
1.	Criteria are measurable and quantifiable	8.2
2.	Criteria measure progress toward load reduction goal	8.2
3.	Data and models identified	8.2
4.	Target achievement dates for reduction	8.2.2
5.	Review of progress toward goals	8.2, 8.3
6.	Criteria for revision	8.2
7.	Adaptive management	8.4
Element I: Monitoring		Section 8
1.	Description of how monitoring used to evaluate implementation	8.2
2.	Monitoring measures evaluation criteria	8.2, 8.3
3.	Routine reporting of progress and methods	8.1, 8.2, 8.3, 8.4
4.	Parameters are appropriate	8.2
5.	Number of sites is adequate	8.2
6.	Frequency of sampling is adequate	8.2
7.	Monitoring tied to QAPP	5.6.4, 8.2
8.	Can link implementation to improved water quality	8.1, 8.2, 8.4

Appendix B: Analysis of General Water Quality in the Comal River from the Edwards Aquifer Habitat Conservation Plan Monitoring Program

The EAHCP water quality monitoring program was developed in accordance with the directives of the EAHCP to identify and assess potential impairments to water quality within the Comal River and headwaters of the San Marcos River systems. The program includes surface water (base flow) sampling, sediment sampling, real-time instrument water quality monitoring, stormwater sampling and passive diffusion sampling. The EAHCP provided data collected in 2016 and 2017 to the Watershed Partnership to assess general water quality. During the periods of June 5, 2016 through December 31, 2016 and of January 10, 2017 through May 12, 2017 samples were collected by EAHCP at four locations; Comal Spring 3, Comal Spring 7, Comal River at Hinman Island and Landa Lake for dissolved oxygen (DO), pH, conductivity, temperature and turbidity. Data from the Comal Springs and Comal River sites were analyzed in the first sampling period and Landa Lake data were analyzed at the beginning of 2017. The sampling locations can be seen in Section 2, Figure 16.

It is generally agreed that water quality parameters, including dissolved oxygen, pH, conductivity, temperature and turbidity, are the most appropriate for assessing the health of a water body (SCDHEC, 2013). Since aquatic flora and fauna rely on DO to survive, it is measured as an indicator to understand the waterway's habitability. Oxygen is more easily dissolved in cold waters with low levels of dissolved and suspended solids. pH is an important limiting chemical factor for aquatic life. If water is too acidic or basic, stream wildlife may not survive. Conductivity is the measure of how well water can pass an electrical current, and is an indirect measure of the presence of inorganic dissolved solids. Inorganic dissolved solids are essential for aquatic life, but high concentrations of dissolved solids can decrease dissolved oxygen levels. Temperature is a controlling factor for aquatic life and affects the concentration of DO in a water body. Turbidity is a measure of the cloudiness of water caused by suspended solids. High turbidity blocks out light needed by aquatic vegetation and can raise surface water temperatures by particle absorption of heat from sunlight. Turbid waters often carry pollutants through a waterway, and can be low in DO (Missouri Department of Natural Resources, n.d.). The Watershed Partnership reviewed data on these parameters in the Comal River and springs that feed the Comal River. The following sections present the results of the 2016 and 2017 general water quality sampling.

Dissolved Oxygen

DO levels below 3.0 milligrams per liter (mg/L) are generally considered to be stressful to organisms. DO levels from the two spring locations and Landa Lake averaged 5.2 mg/L with a minimum value of approximately 2.6 mg/L at the Landa Lake location. The Comal River sampling point had higher DO levels averaging 8.7 mg/L. Monthly averages for DO can be seen below in Figure B-1.

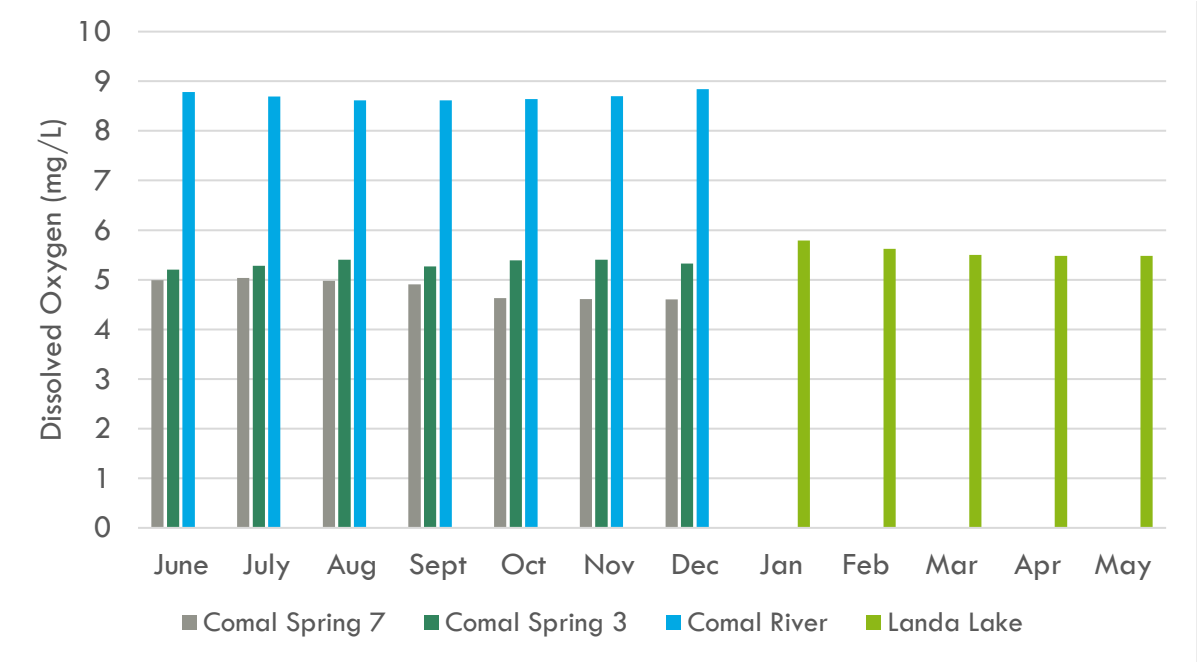


Figure B-1: 2016 and 2017 Average Monthly Dissolved Oxygen Concentrations

pH

Streams generally have a pH between 6.0 and 9.0, depending on the geographic conditions in the area. The minimum pH measured at all three sampling locations in the Dry Comal Creek was 7.0 and the minimum at the Comal River was 7.4. The maximum pH at any sampling point was 7.9 at the Comal River station. The average pH measured at all four sites was 7.3 over the period. The Comal River sampling location consistently has a slightly higher pH than the springs, likely due to the contact time that the water has had with dissolved substances in the surface water of the river versus the aquifer. Following rain events, pH was shown to elevate slightly. Monthly averages for pH are illustrated in Figure B-2.

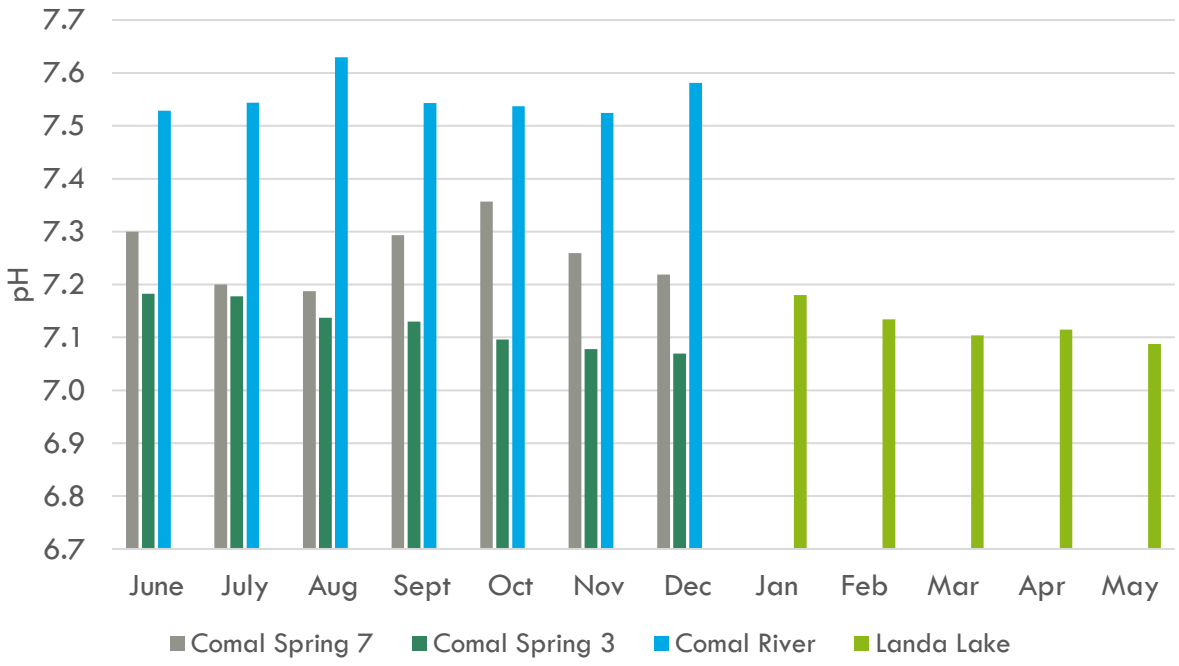


Figure B-2: 2016 and 2017 Average Monthly pH Values

Conductivity

Conductivity is an indicator of the amount of total dissolved solids or the total amount of dissolved ions in water. Freshwater streams typically have a conductivity range of 200 to 1,000 microsiemens per centimeter (µS/cm). The conductivity measured at the four sampling locations averaged between 570 and 579 µS/cm. The minimum conductivity value measured at the Comal River site was 202 µS/cm in August.

As expected, measured conductivity levels at three sampling locations (Spring 3, Landa Lake and Comal River) decreased after rain events due to addition of fresh water to the streams. A similar, though less pronounced, effect was observed at Spring 7. Monthly average conductivity values are illustrated in Figure B-3. Temporal correlations between conductivity and precipitation observed at Spring 3, Landa Lake and the Comal River can be seen in Figure B-4, Figure B-5, and Figure B-6, respectively.

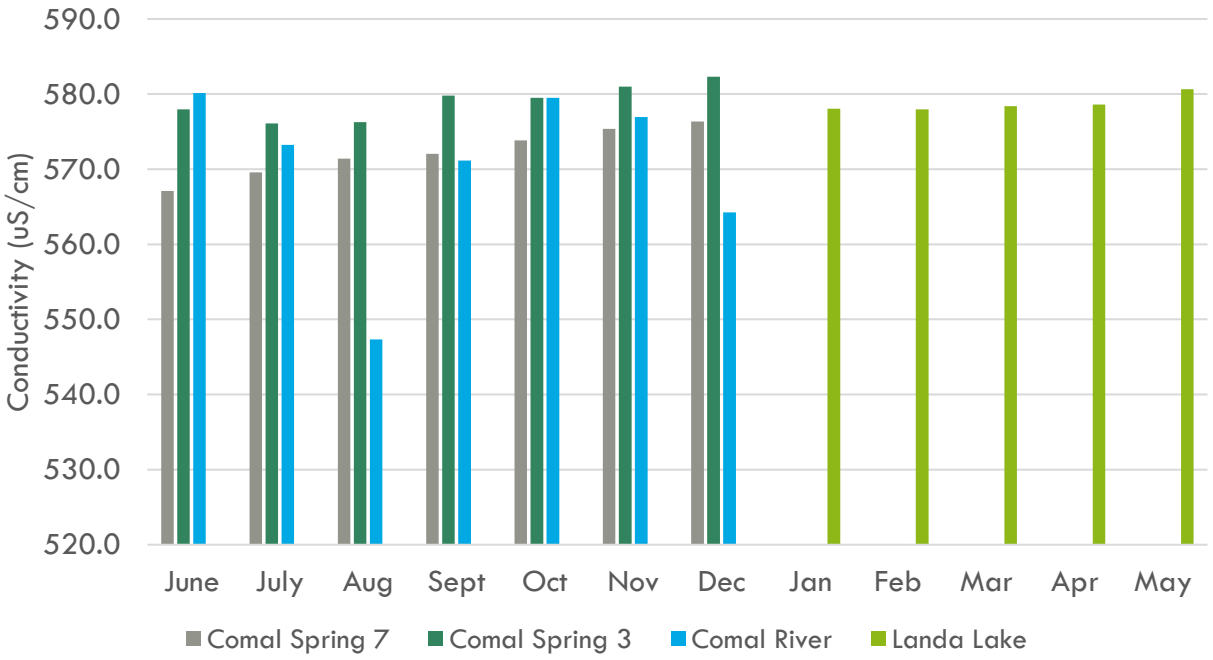


Figure B-3: 2016 and 2017 Average Monthly Conductivity Values

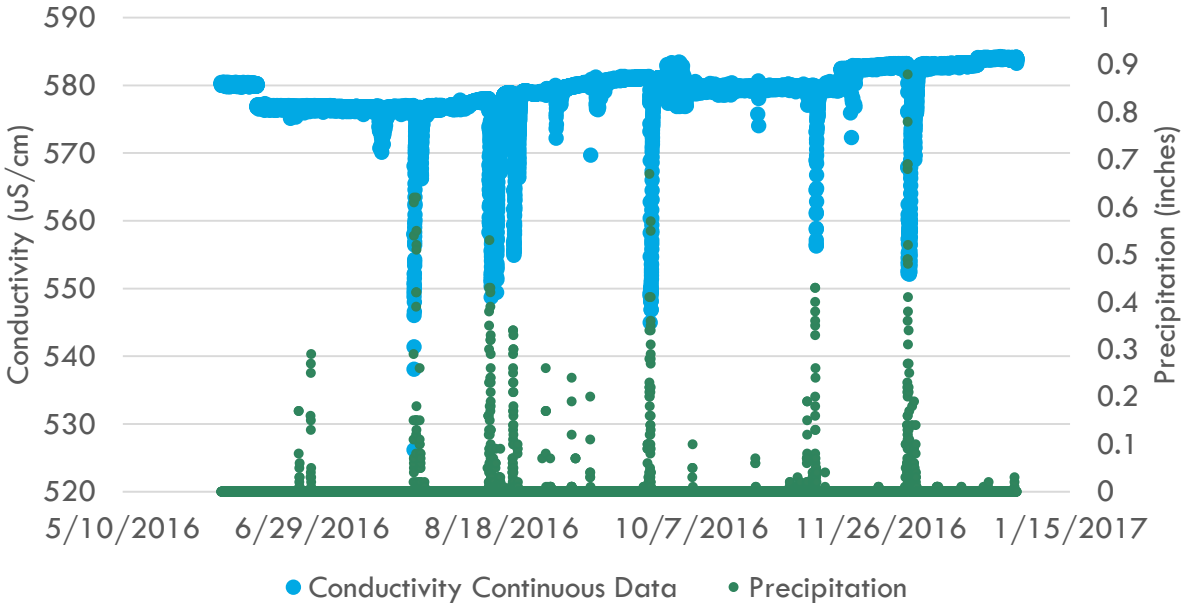


Figure B-4: Precipitation and Conductivity Measured at Comal Spring 3

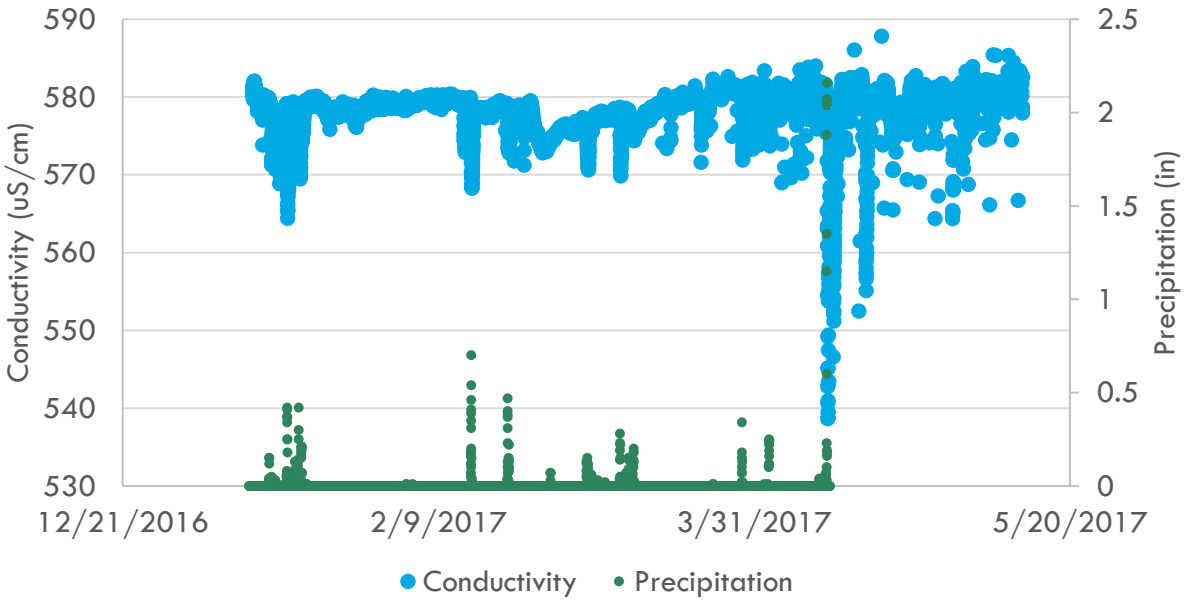


Figure B-5: Precipitation and Conductivity Measured at Landa Lake

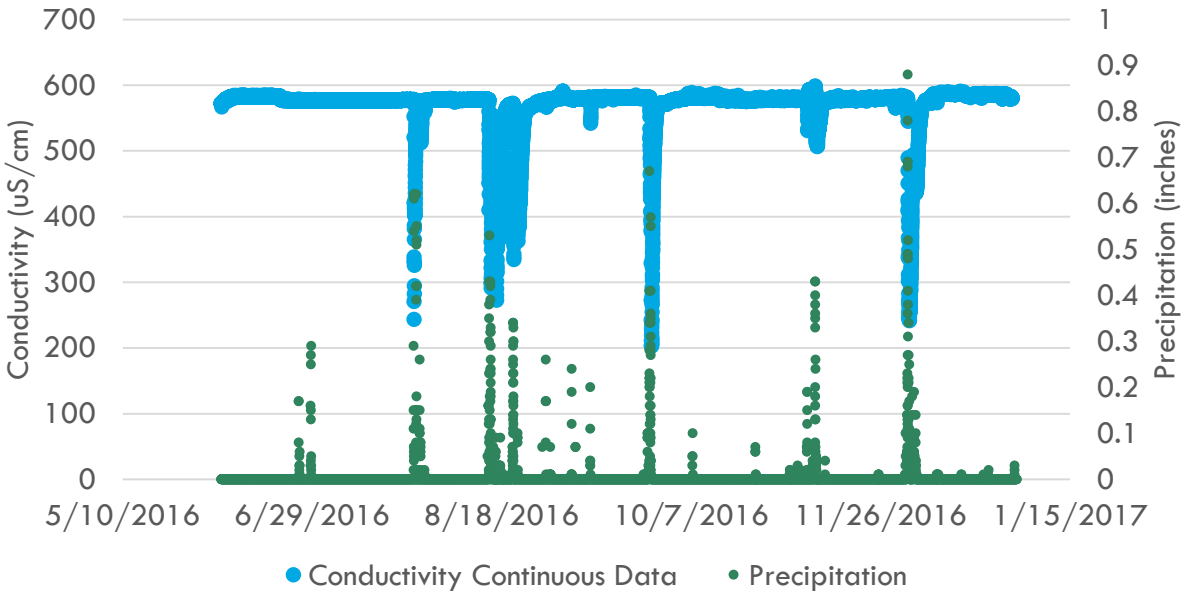


Figure B-6: Precipitation and Conductivity Measured at the Comal River

Temperature

The temperature values measured at Comal Spring 3 and 7 remained fairly constant through the entire data collection period, which is expected for groundwater. The temperature in the Comal River and at Landa Lake varied slightly with seasonal changes, as would be expected in surface water. Temperature generally decreased with precipitation events, an example of which can be seen below in Figure B-7. Monthly average temperatures are illustrated in Figure B-8.

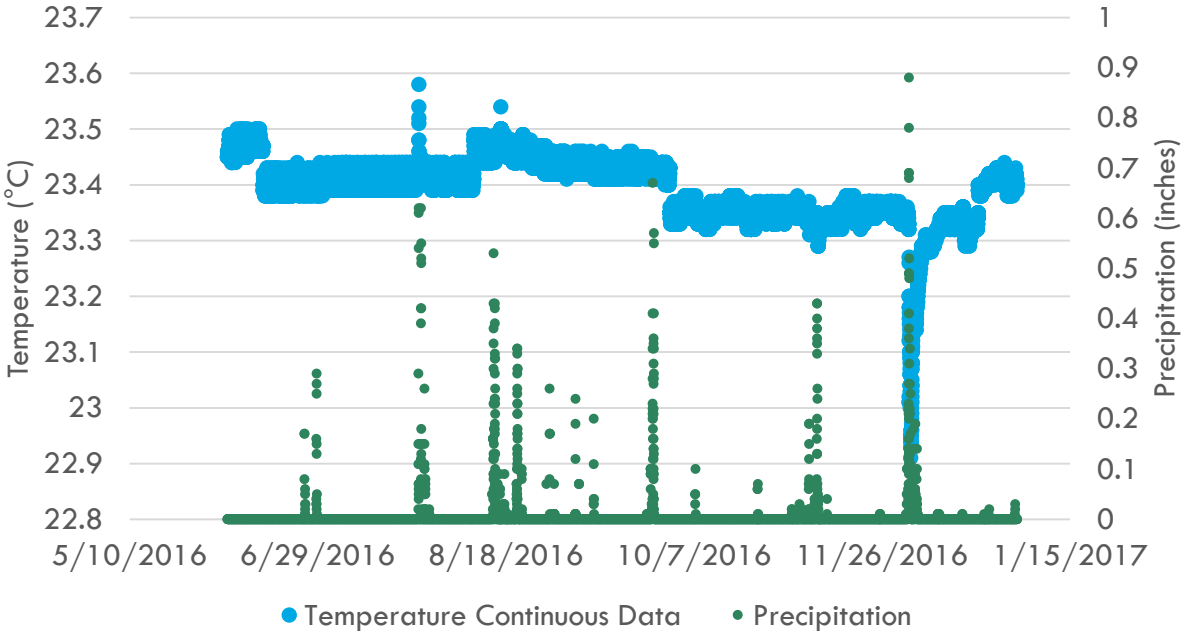


Figure B-7: Precipitation and Temperature Measured at Comal Spring 3

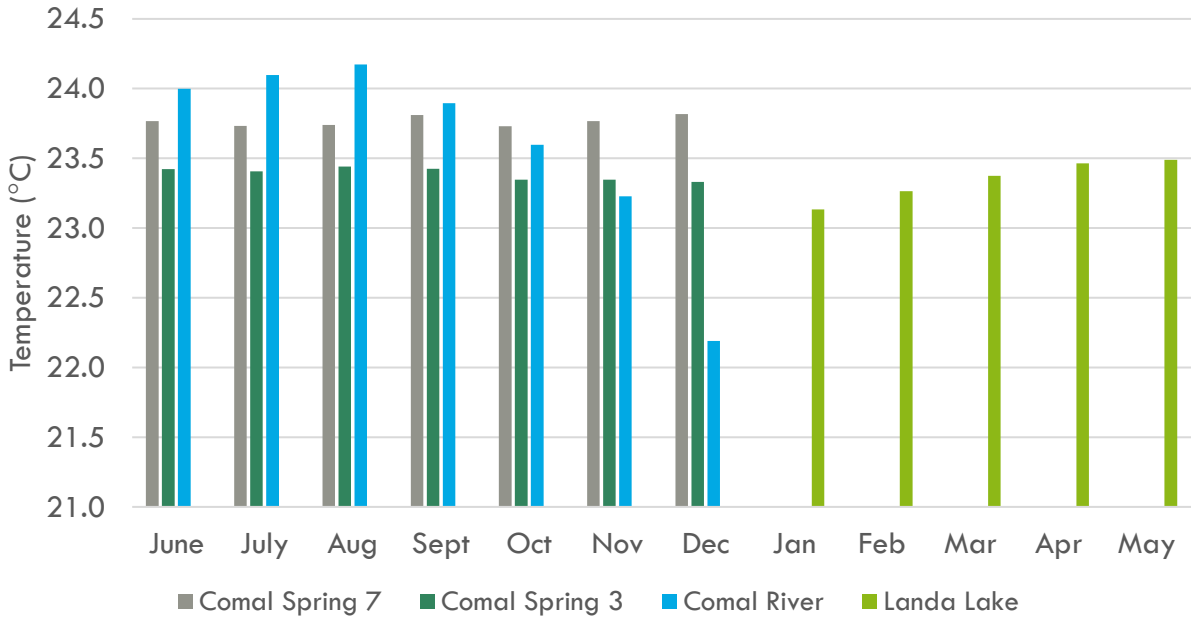


Figure B-8: 2016 and 2017 Monthly Average Temperature Values

Turbidity

The average turbidity values measured at Comal Spring 3 and 7 were consistently below 0.7 nephelometric turbidity units (NTUs), consistent with values typically measured in these springs. Measurements taken at Landa Lake, not far downstream of the springs averaged 1.0 NTU. The

turbidity measured in the Comal River averaged 9.7 NTUs throughout the period with maximum values measured in August, September and December. The spikes in turbidity in the Comal River are generally correlated with precipitation events, as can be seen in Figure B-9. Large rain events resulted in large increases in turbidity suggesting that there was either a significant amount of particles washed into the river or sediment in the river was disturbed. Landa Lake showed slight correlations between turbidity and precipitation, but was not as prominent as the correlation in the Comal River. Monthly averages for turbidity can be seen below in Figure B-10.

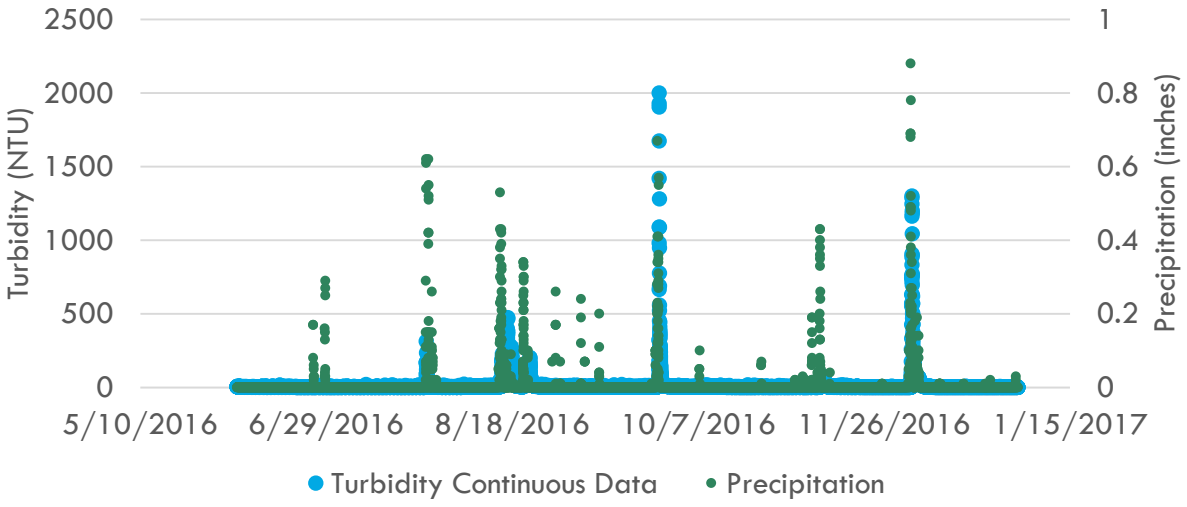


Figure B-9: Turbidity and Precipitation Measured at the Comal River Sampling Location

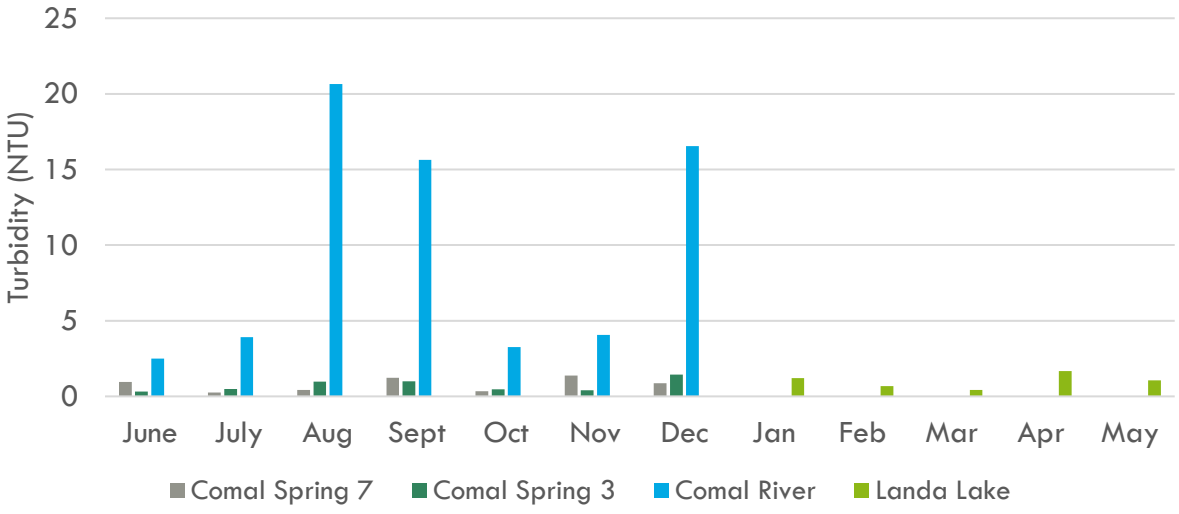


Figure B-10: 2016 and 2017 Monthly Average Turbidity

Summary and Relevance to WPP

General water quality parameters measured in 2016 and 2017, described above, indicate typical water quality in the Comal River and Comal Springs. Conductivity and temperature in the Comal River generally decreases due to rain events, and turbidity generally increases due to rain events. Fecal coliform indicators, such as *E. coli*, are often used to understand the extent to which a water body is impaired due to bacteria levels. However, bacteria samples were not collected as part of this monitoring program. While there is not a strong understanding of the direct impact of DO, pH, and turbidity on the persistence of *E. coli*, temperature and turbidity have been shown in some studies to directly impact *E. coli* concentrations in the water column.

Many studies have found that there is a correlation between precipitation events and fecal coliform indicators due to NPS pollution caused by the addition of runoff to waterways (Craig et. al., 2004). Summer months generally have more intense rainstorms which lead to accumulation of fecal bacteria in waterways (SCDHEC, 2013). These conditions of elevated fecal contaminant levels, as compared to the baseline, can persist for days after a precipitation event (Craig et al., 2004). Runoff can contribute not only bacteria, but can lead to increased turbidity by accumulating overland pollutants and disturbing sediments (Craig et al., 2004). During storm events, turbidity can be between eight to ten times greater than dry weather samples due to sediment runoff and resuspension of bottom sediment (Lawrence 2008).

The Watershed Partnership will continue to review the data collected as part of the EAHCP monitoring program as the WPP is implemented. This summary will serve as a baseline, so that any trends of increasing or decreasing water quality can be identified and reviewed. Any improvements in these water quality parameters identified in correlation with the implementation of the identified BMPs for this Watershed will be noted by the Watershed Partnership in future updates on the WPP implementation.

Appendix C: Maps of Locations of *E. coli* Sources Observed by Stakeholders

The following maps summarize potential *E. coli* source locations based upon local knowledge of the Stakeholder Group. These maps were reviewed while selecting BMPs and outreach and education activities that were most likely to be effective in the Watershed. The maps will also be a resource to the Watershed Partnership during review of progress toward achieving the WPP goals.

E. coli Pollution Source:

Overabundant Urban Deer

1 – Landa Park area (especially golf course, Panther Canyon, Seale Elementary); and the neighborhoods between Landa Park and Loop 337

2 – Neighborhoods along Hwy 46 (deer feeding; especially Hunter's Creek)

3 – Neighborhoods near Hwy 3009 in Garden Ridge (deer feeding; prior deer management program was suspended due to community feedback)

4 – Urban Area along IH 35 (especially Golf Course, Olympia; not aware of any active management programs)

Areas with high densities of OSSFs are likely to also have a high density of homes, and could have a higher density deer population due to feeding.

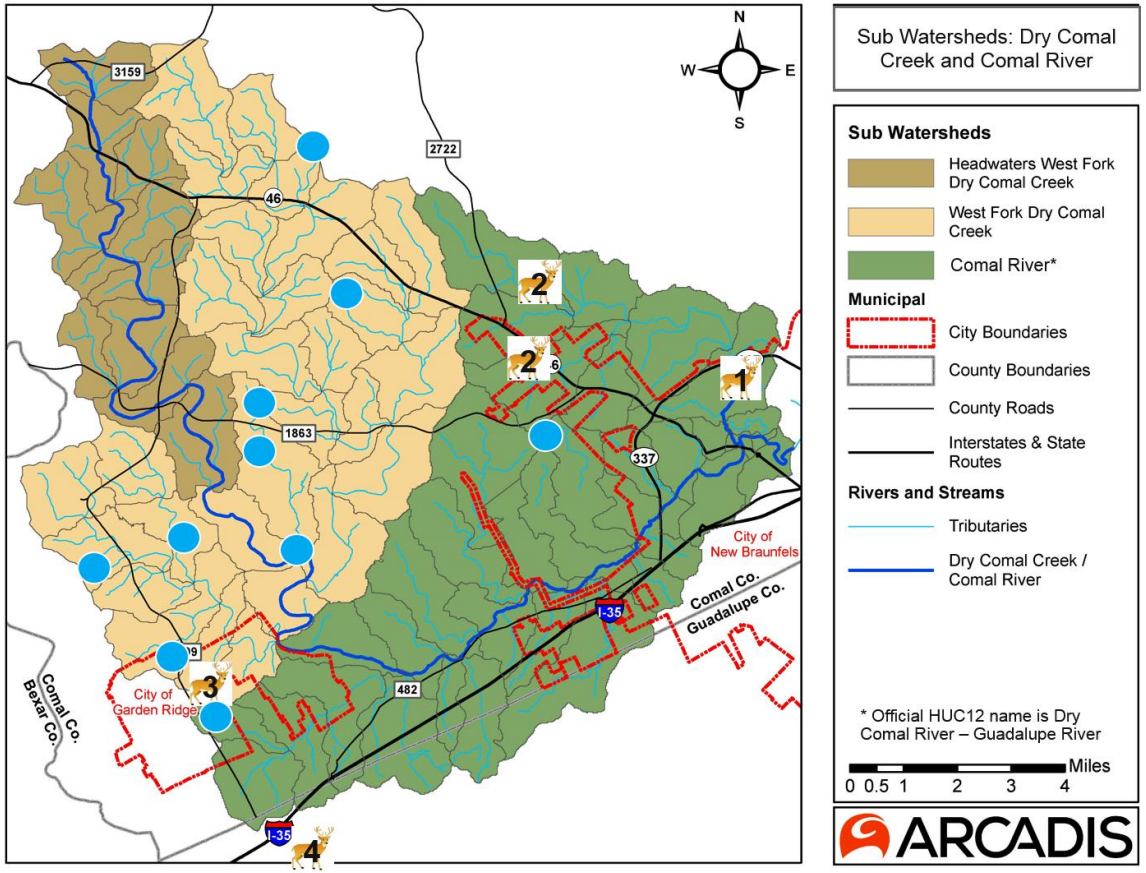


Figure C-1: Locations *of* Overabundant Urban Deer in the Watershed

E. coli Pollution Source:

Non-Native Avian Wildlife

1 – Landa Park (especially Landa Lake) has a high density of non-native ducks and geese and native vultures.

2 – Natural Bridge Caverns Wildlife Ranch has exotic animals. A large bat colony is also in this area.

3 – There is a native and non-native duck population on Mill Pond on the Comal River.

4 – There is a goose population on a farm on Algelt Road.

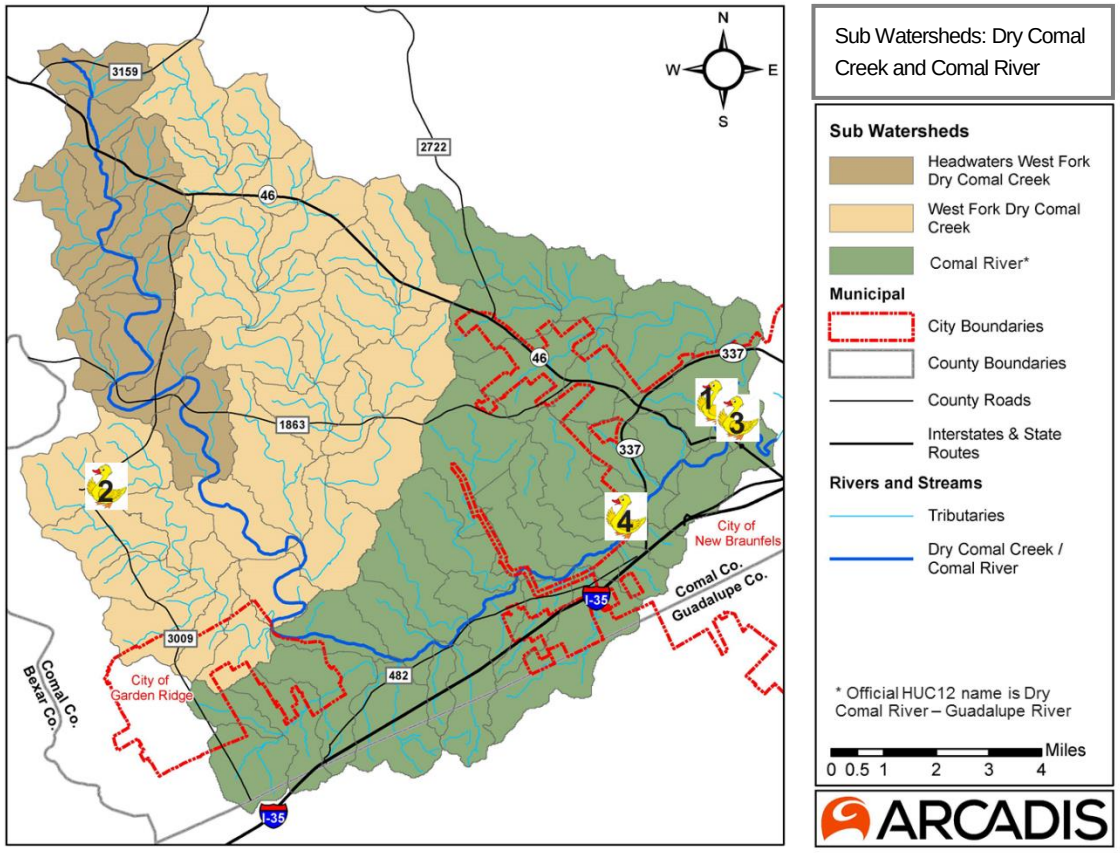


Figure C-2: Locations of Native and Non-Native Avian Wildlife in the Watershed

E. coli Pollution Source:

Feral Hogs

No locations of significant feral hog pollutions within the Watershed were identified. However, stakeholders identified the locations in the Watershed where feral hogs are most likely to live due to favorable soil conditions.

1 - Stakeholders noted the use of professional hog trappers in this area.

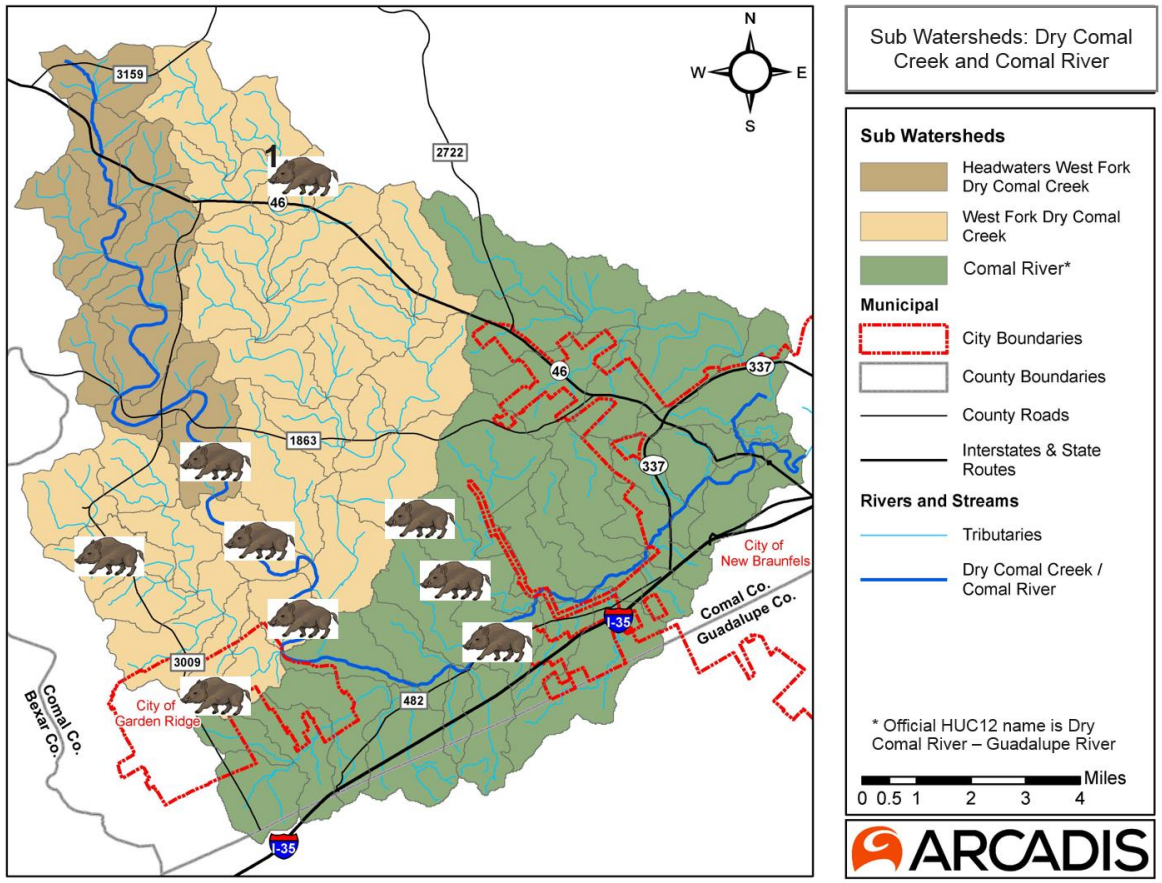


Figure C-3: Locations of Feral Hogs in the Watershed

E. coli Pollution Source:

Livestock

More/Concentrated Livestock:

1 – Natural Bridge Wildlife Ranch

2 – Cattle (and minor exotic) Ranch

3 – Horse Ranch*

4 – Private ranch with high density of hogs, sheep, cattle; two ponds may catch runoff

5 – Extension Office (hogs and goats)

* Although horses were not considered one of the larger contributing sources to E. coli bacteria in the Watershed, locations of horses in the Watershed were noted and will be reassessed during WPP implementation.

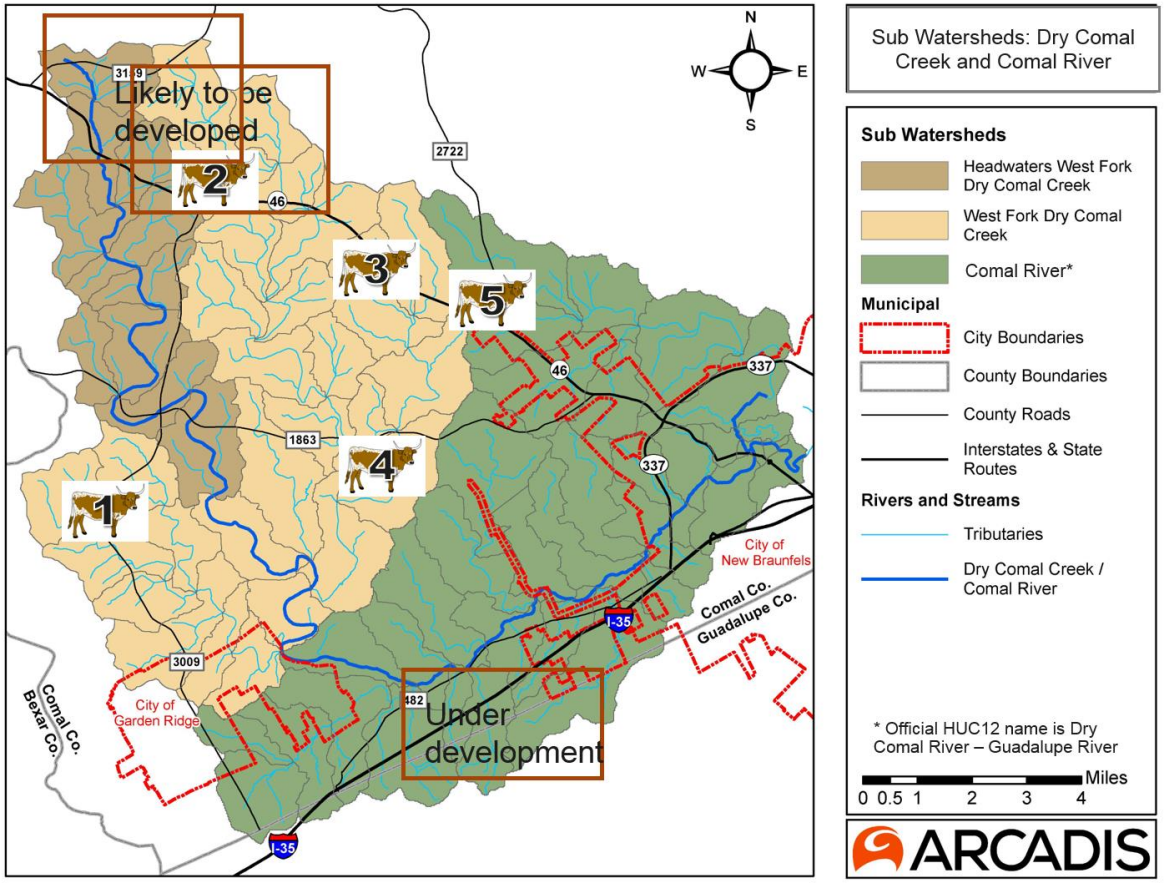


Figure C-4: Locations of Livestock in the Watershed

E. coli Pollution Source:

- OSSFs
- OSSF Hotspots

Rural Subdivisions: All locations have approximately equal chance of failure. Older systems are more likely to fail, but the newer aerobic systems have a greater potential for impacting water quality if not properly maintained.

1 – NBU's Trinity Aquifer wells at this location have shown groundwater in this area may be under the influence of surface water during rain events.

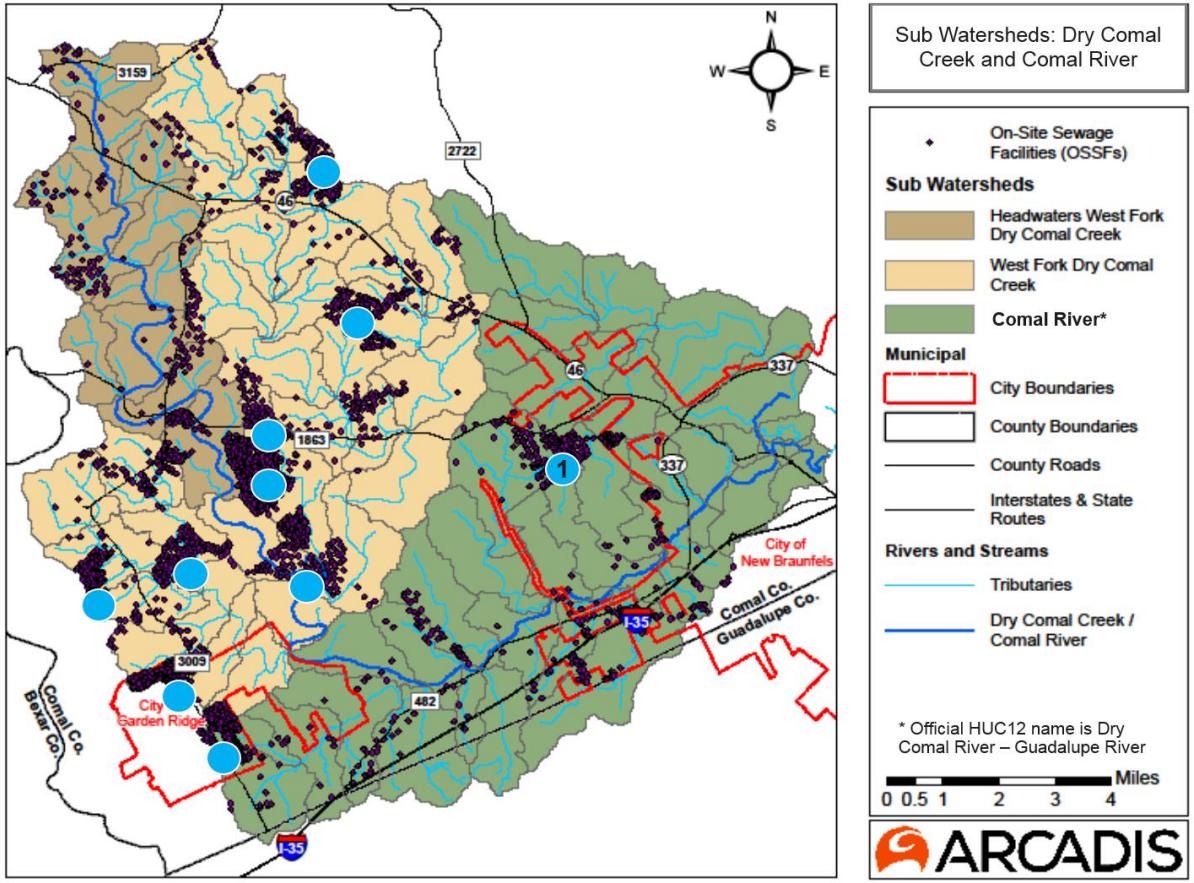


Figure C-5: Locations of OSSFs in the Watershed

E. coli Pollution Source:

Stormwater

1 – Cattle feed lot

2 – City Limits

3 – Garden Ridge City Limits

Other locations considered but not significant sources:

- Garbage collection trucks and facilities - all wash water is captured.

- County Recycling Center; however, operations are inside a building.

- Local industries

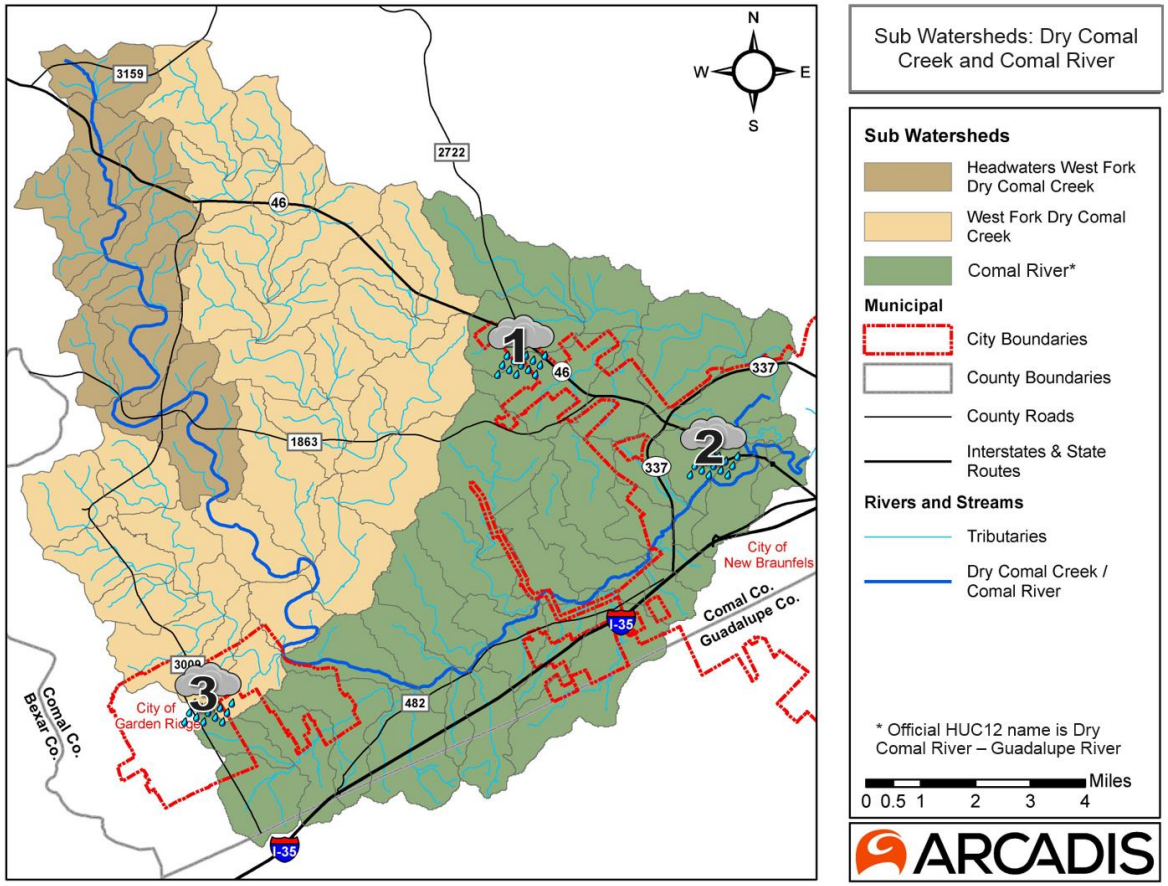


Figure C-6: Locations of stormwater Sources in the Watershed

E. coli Pollution Source:

Pet Waste

1 – City (Target areas should include Panther Canyon, neighborhoods, Gruene and apartment communities)

2 – City of Garden Ridge

3 – Gruene area visitors

4 – Hueco Springs area visitors

● Areas with high densities of OSSFs are likely to also have a high density of homes, and could have a higher density of pets.

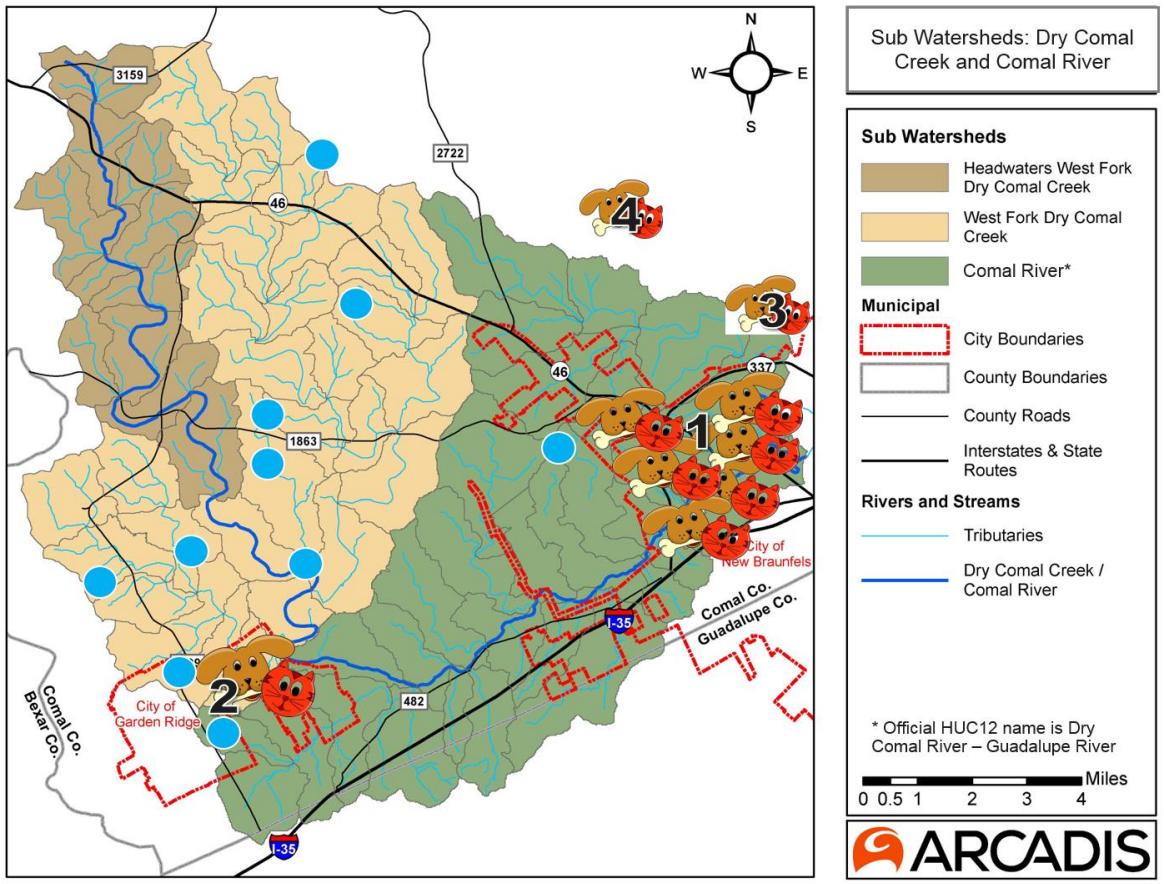


Figure C-7: Locations of Pet Waste in the Watershed

E. coli Pollution Source:

Wastewater

(Excluding OSSFs)

No locations of significant wastewater discharge/pollution within the Watershed were identified beyond the two permitted discharges.

Specific Locations Considered:

1 – Meyer Ranch Wastewater Treatment Facility

2 – Vintage Oaks wastewater package plant; however, no untreated discharge

3 – NBU WW system serves City of New Braunfels; participates in the TCEQ SSO initiative that focuses on collection system maintenance and protection from sewer overflows

4 – Failing home foundations on Gardenia Drive and Magnolia Ave

5 – Aggregate and cement plant ponds; however, have discharge permits to control quality

6 – Northcliffe Wastewater Treatment Facility

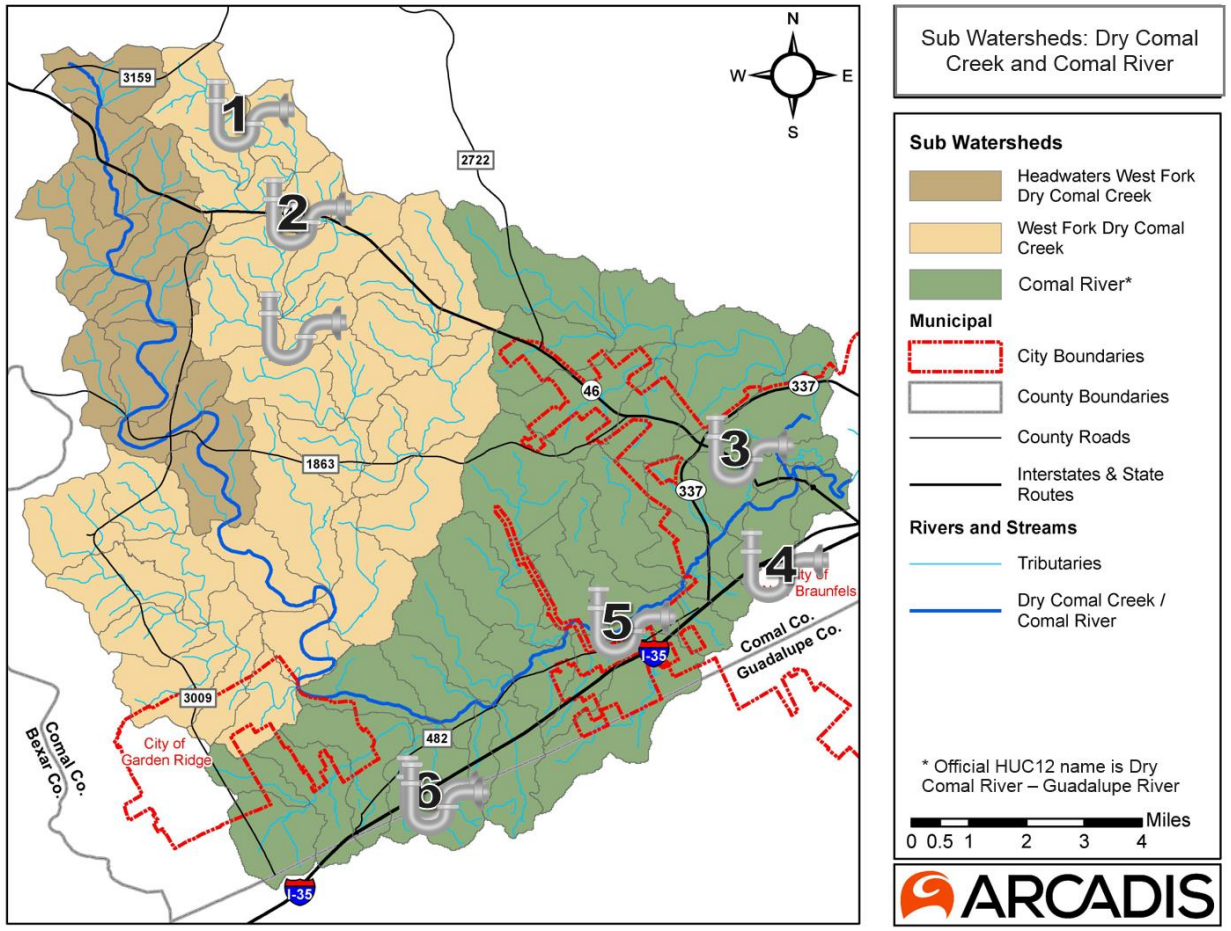


Figure C-8: Locations of Wastewater Discharges in the Watershed

Appendix D: Low Priority BMPs Not Included in the WPP

The following table lists additional BMPs considered for each BMP source. These BMPs, although relevant, were suggested to be of lower priority than those discussed in the WPP. This list will be revisited during routine reviews of the WPP implementation. As funding is available or if priorities change, these activities may be considered for implementation.

Table D-1: Low Priority BMPs

E. coli Source	Low Priority BMPs	Details	Rational for Prioritization	Regional WPPs that Implemented this BMP
Overabundant Urban Deer	Active management of native wildlife for water quality purposes is generally not promoted … and will not be included Recommended for select subwatersheds in Comal County in Geronimo and Alligator Creek WPP.	• Considered wildlife a "background" source • No BMPs targeted at reduction of *E. coli* loading from wildlife	Wildlife are a large percentage of the *E. coli* measured in this watershed	• Plum Creek • Mill Creek • Geronimo and Alligator Creeks
Overabundant Urban Deer	Construct deer-proof fencing	• Construct fencing to keep deer out of the watershed	May interfere with floodplains; difficult to implement due to large area that would require fencing	• None
Overabundant Urban Deer	Scare deer away	• Scare deer away using noise, soft-guns, etc.	As deer are not only in one location, this would be difficult to implement and likely not effective	• None

Table D-1: Low Priority BMPs (Continued)

E. coli Source	Low Priority BMPs	Details	Rational for Prioritization	Regional WPPs that Implemented this BMP
Overabundant Urban Deer	Relocate deer	• Trap and relocate deer to another area	Requires trapping in neighborhoods (deer often get hurt; capture myopathy); limited potential locations for relocation due to maximum densities allowed	• None
Overabundant Urban Deer	Sterilize deer	• Costly (e.g., $1000/deer) • Not humane • Toxins can get washed into watershed and are not a registered pesticide in Texas • Not legal without a University research permit • Must treat almost all females and population must be relatively immobile to be effective • Requires either trapping for surgery or recovery of dart/needles	See description	• None

Table D-1: Low Priority BMPs (Continued)

E. coli Source	Low Priority BMPs	Details	Rational for Prioritization	Regional WPPs that Implemented this BMP
Wildlife	Active management of native wildlife for water quality purposes is generally not promoted … and will not be included Recommended for select subwatersheds in Comal County in Geronimo and Alligator Creek WPP.	• Considered wildlife a "background" source • No BMPs targeted at reduction of *E. coli* loading from wildlife	Wildlife are a large percentage of the E. coli measured in this watershed	• Plum Creek • Mill Creek • Geronimo and Alligator Creeks
Non-Native Urban Avian Wildlife	Sterilization	• Catch and sterilize ducks and geese to prevent population growth • Difficult to implement • Costly • Not legal without University research permit	See description	• None
Feral Hogs	Aerial gunning of feral hogs Recommended for select subwatersheds in Comal County in Geronimo and Alligator Creek WPP.	• Aerial gunning can be implemented in less populous areas. • Explore the Texas Hunters for the Hungry Program.	Densities are not high enough in Comal County to be effective; Bounty program is a better method for active management	• Plum Creek • Mill Creek • Geronimo and Alligator Creeks • Buck Creek • Attoyac Bayou

Table D-1: Low Priority BMPs (Continued)

E. coli Source	Low Priority BMPs	Details	Rational for Prioritization	Regional WPPs that Implemented this BMP
Feral Hogs	Actively manage hogs using sodium nitrite	• Not a poison, but kills hogs by asphyxiation (acts metabolically); • Two years from any field trials, five years from any public use; • Would require removal of carcasses	See description	• None
Feral Hogs	Actively manage hogs using specialized feeders with intoxicant	• Still under TDA review • Not available for use in Texas at this time	See description	• None
Feral Hogs	Full-time position to focus on feral hog management Recommended for select subwatersheds in Comal County in Geronimo and Alligator Creek WPP.	• Hire a full-time manager to track numbers of individuals and implement management strategies.	High densities of feral hogs have not been identified in the watershed	• Plum Creek • Mill Creek • Geronimo and Alligator Creeks
OSSFs	Identify funding sources to extend sanitary sewer service and/or stormwater conveyance Recommended for select subwatersheds in Comal County in Geronimo and Alligator Creek WPP	• Acquire funding sources for design and construction of a stormwater conveyance system. • Identifying funding to extend sanitary sewer services to areas not served by the collection system. • Engineering analysis, financial planning, critical public outreach and education.	Human contribution is relatively low compared to other sources, and the County is quickly notified of any failing systems and reacts quickly	• Buck Creek • Geronimo and Alligator Creeks

Table D-1: Low Priority BMPs (Continued)

E. coli Source	Low Priority BMPs	Details	Rational for Prioritization	Regional WPPs that Implemented this BMP
OSSFs	Update septic system permits and create a centralized database Recommended for select subwatersheds in Comal County in Geronimo and Alligator Creek WPP	• Central database will allow patterns of system installation and failure to be monitored in order to predict, prevent and respond to future issues.	Permits are updated within Comal County	• Plum Creek • Buck Creek • Mill Creek • Geronimo and Alligator Creeks • Attoyac Bayou

OSSFs	Regional Compact (Interlocal Agreement) to address septic systems	• Compact could serve to mitigate effects of failing septic systems.
		• Key components could include:
		  ○ Where possible, connect developments of 10 or more homes to a wastewater facility.
		  ○ For long-term operation, WWTFs should be operated by public entities.
		• Compact parties jointly review proposed wastewater projects/plans.
			Human contribution is relatively low compared to other sources, and the County is quickly notified of any failing systems and reacts quickly	• Plum Creek

OSSFs	Investigate incorporation or construction of WWTF	• Could include construction or tie-in to neighboring facilities. • Could ensure new facilities comply with TPDES permits.	Human contribution is relatively low compared to other sources, and the County is quickly notified of any failing systems and reacts quickly	• Plum Creek

Table D-1: Low Priority BMPs (Continued)

E. coli Source	Low Priority BMPs	Details	Rational for Prioritization	Regional WPPs that Implemented this BMP
Livestock	Prescribe BMPs that will reduce time animals spend in the creek or riparian corridor	• Identify opportunities (i.e. fencing, filter strips, prescribed grazing, stream crossing, or alternative water sources) to keep livestock out of the waterways.	There are limited livestock ranches in the watershed, and implementation funding would be challenging without a WQMP	• Buck Creek (discussed but implemented WQMPs) • Attoyac Bayou (discussed but implemented WQMPs)
Stormwater	Implement Stormwater BMPs within City limits[1]	• These are covered under the existing MS4 permit (will be discussed but cannot receive additional funding)	See description	• Mill Creek • Geronimo and Alligator Creeks
Pet Waste	Spay/Neuter Program Recommended for City of New Braunfels in Geronimo and Alligator Creek WPP	• Provide funding to dog and cat owners to have pets spayed or neutered at little or no cost.	Overpopulation isn't currently an issue in this watershed	• Mill Creek • Geronimo and Alligator Creeks
Pet Waste	Move Animal Shelter(s) Upland	• Identify any animal facilities located near streams and consider relocating.	No animal shelters were identified in the watershed that were adjacent to the creek or river	• Mill Creek

1 - BMP implementation funding can only be used for BMPs not already covered in the City's MS4 program or funded as part of a prior WPP. The Geronimo and Alligator Creek WPP recommended, for the City of New Braunfels, to implement non-structural components of MS4 permits on a voluntary basis in advance of program requirements and to maximize public outreach and participation on MS4 implementation. The City will also continue implementing the current MS4 activities in parallel (subdivisions in the ETJ are covered under this permit).

Table D-1: Low Priority BMPs (Continued)

***E. coli* Source**	Low Priority BMPs	**Details**	Rational for Prioritization	**Regional WPPs that Implemented this BMP**
Wastewater	Daily inspections of wastewater collection system	• Inspect lift stations and equip stations with dialers and/or supervisory control and data acquisition (SCADA) systems.	NBU has an inspection program in place, and has online SCADA monitoring	• Plum Creek
Wastewater	Apply for grants to replace, rehab or clean pipelines	• Process will involve engineering analysis, financial planning, critical public outreach and education. • Specific areas can be targeted using smoke testing or closed-circuit television (CCTV) inspection.	NBU has a maintenance and replacement program in place	• Plum Creek
Wastewater	Explore the possibility of extending sewer collection/treatment systems Recommended for New Braunfels Utilities in Geronimo and Alligator Creek WPP	• Locate septic systems within the City limits and connect those residences to central wastewater treatment. • Explore the possibility of extending or adding stormwater collection/treatment systems.	The relative contribution of human *E. coli* compared to other sources is low	• Plum Creek • Mill Creek • Geronimo and Alligator Creeks

Table D-1: Low Priority BMPs (Continued)

E. coli Source	Low Priority BMPs	Details	Rational for Prioritization	Regional WPPs that Implemented this BMP
Wastewater	Implement actions in Sanitary Sewer Overflow Initiatives (SSO) Recommended for City of New Braunfels in Geronimo and Alligator Creek WPP	• Identify high risk areas and documented problems in a collection system, and establish a plan to address current and future issues. • Could include: ○ Establishment of maintenance schedule for lift stations ○ Inspection, replacement, rehab and cleaning of the wastewater collection system ○ Procedure for involving operations personnel in engineering design review ○ Expansion of the fats, oils and grease program ○ Corrective action when acts of vandalism are found • Possible tools: smoke testing, CCTV, and cleanout cap inspection	NBU has an SSO Initiative which is currently being implemented.	• Mill Creek • Geronimo and Alligator Creeks

Table D-1: Low Priority BMPs (Continued)

E. coli Source	Low Priority BMPs	Details	Rational for Prioritization	Regional WPPs that Implemented this BMP
Wastewater	Texas Pollutant Discharge Elimination System (TPDES) permits (for future discharges in Comal WPP)	• Adopt a 5/5/2/1 Biochemical Oxygen Demand, Total Suspended Solids, Ammonia, and Total Phosphorus effluent standards. • "More stringent effluent limits should affect a reduction in bacteria entering the waterway." – Plum Creek WPP • TCEQ could implement an unannounced inspection program for wastewater treatment facilities (WWTFs) to encourage and ensure compliance with permit requirements.	No future discharges are currently planned, and the relative contribution of human *E. coli* compared to other sources is low	• Plum Creek • Mill Creek
Wastewater	Wastewater compact (for future discharges in the watershed)	• WWTFs will agree to work towards better effluent water quality. • Increase WWTF self-monitoring. • Increase training for WWTF operators.	No future discharges are currently planned, and the relative contribution of human *E. coli* compared to other sources is low	• Plum Creek

Appendix E: Low Priority Outreach and Education Activities Not Included in the WPP

The list of activities in Table E-1 were identified by stakeholders, but not ranked high or moderate priority for implementation. This list will be revisited during routine reviews of the WPP implementation. As funding is available or if priorities change, these activities may be considered for implementation.

Table E-1: Additional Outreach and Education Activities

Source	Potential Activities	Potential Audience(s)	Potential Location(s)
Stormwater	Rainwater Harvesting Education program to provide information on the benefits, methods, and costs of installation. The program could also include demonstrations.	• Homeowners and businesses in the City's MS4 jurisdiction • Master Gardeners / Master Naturalists	• TAES Seminars • Workshops
	Stormwater management education and outreach[1] to address management practices for the control of stormwater. The program may also include field demonstrations.	• Homeowners and businesses • Outside City of New Braunfels' existing MS4 program • Master Gardeners / Master Naturalists • City departments (other than public works) • County workers	• Online • Workshops
Urban Sources	Nonpoint Education for Municipal Officials[2] (NEMO) workshops covering topics such as smart growth, low impact development and stormwater management.	• New Braunfels City staff and elected officials • City of Garden Ridge staff and elected officials • Comal County staff and elected officials	• City Hall • NBU Headwaters Facility

1 - As part of the Plum Creek WPP, GBRA developed an online stormwater training tool for municipal operations employees. The tool is available at: http://www.gbra.org/stormwater/default.aspx The WPP Partners may use this tool within the Dry Comal and Comal River Watersheds as well, if approved by GBRA.
2 - NEMO is a national program focused on protecting natural resources through improved land use planning.

Table E-1: Additional Outreach and Education Activities (Continued)

Source	Potential Activities	Potential Audience(s)	Potential Location(s)
Wildlife and Non-Domestic Animals	Stream and Riparian Workshops covering the importance of these areas for wildlife habitation, water quality and overall watershed health.[1]	• Livestock ranchers • Rural homeowners on large lots • Master Naturalists • Fencing contractors	• Texas Agriculture Extension Service (TAES) seminars • County fair events • Natural Bridge Wildlife Ranch
All *E. coli* Sources	Expanded WPP Project website to provide updates on BMP and outreach and education activity implementation	• School students • Homeowners / landowners • Apartment communities • Organizations • Tourists / visitors • Business community • Retirees—messages where they congregate • City employees (other departments)	• Online advertisements • Links to page from relevant websites
All *E. coli* Sources	Additional Watershed Stewards Workshops with focus on training community members to share the WPP message	• Businesses • Technical professions needing continuing education credits	• New Braunfels City Hall

1 - Training was scheduled to be provided by the Texas Water Resources Institute (TWRI) to the Attoyac Bayou watershed in 2014. The WPP Partners may consider reaching out to the TWRI and the Attoyac Bayou WPP team to determine if the training program was developed, and whether it could be made available within the Dry Comal and Comal River Watershed.

Table E-1: Additional Outreach and Education Activities (Continued)

Source	Potential Activities	Potential Audience(s)	Potential Location(s)
All *E. coli* Sources	Additional public outreach targeting residents	• Residents	• Public meetings • Public agencies and trade associations • Universities • Speakers Bureau
All *E. coli* Sources	Watershed Tours / Field Days	• Local including families, organizations, and businesses • School groups • Scout groups • Master Gardeners / Master Naturalists	• Landa Park • Fischer Park • Open House • Learning Centers

Appendix F: Estimated Probable Cost Calculations for BMP implementation

The calculations in Appendix F estimate the probable cost calculations for implementation of each BMP and outreach and education activity. The information obtained from these calculations was used to generate the overall cost summary for the WPP. Costs are provided in Sections 5 and 6 with the descriptions of the BMPs and outreach and education activities, and in Section 7.

Table F-1: Estimated Probable Cost Calculations for WPP Implementation: Project Management

BMP	Description of Costs	Units	No. of Units	Cost per Unit	Subtotal	0% Contingency	Total	Notes	Implementation Years	1	2	3	4	5	6	7	8	9	10
WPP Consultant																			
WPP Consultant	Percentage of BMP Cost	LS	1	20%	20%	0%	20%	Assume junior engineer coordinates daily WPP implementation activities	200% Year 1 100% Years 2 - 5; 50% Years 6 - 10	$44,280	$67,120	$84,880	$109,560	$158,880	$97,620	$75,630	$64,090	$64,750	$65,610
	TOTAL per Year									$44,280	$67,120	$84,880	$109,560	$158,880	$97,620	$75,630	$64,090	$64,750	$65,610
	TOTAL per Year Escalated			3%				Percent Escalation		**$44,300**	**$69,200**	**$90,000**	**$119,500**	**$178,000**	**$112,300**	**$89,300**	**$77,600**	**$80,300**	**$83,400**
	TOTAL for Implementation	WPP	-	-	-	-	**$943,900**												
TOTAL per Year Escalated										**$44,300**	**$69,200**	**$90,000**	**$119,500**	**$178,000**	**$112,300**	**$89,300**	**$77,600**	**$80,300**	**$83,400**
TOTAL for Implementation							**$943,900**												

Table F-2: Estimated Probable Cost Calculations for WPP Implementation: Outreach and Education Activities

BMP	Description of Costs	Units	No. of Units	Cost per Unit	Subtotal	30% Contingency	Total	Notes	Implementation Years	1	2	3	4	5	6	7	8	9	10
Outreach and Education BMPs																			
Social Media Campaign (Priority = High)	Facebook, Twitter, RSS Feeds, Widgets, Instagram, YouTube, etc.	hrs	208	$25	$5,200	$1,560	$6,760	One staff, 4 applications, 1 hr/week/application, 12 months	100% 1 - 5; 50% 5-10	$6,760	$6,760	$6,760	$6,760	$6,760	$3,380	$3,380	$3,380	$3,380	$3,380
	Video Production	hrs	160	$25	$4,000	$1,200	$5,200	Four staff, one full week for video development, planning, shooting and editing; Conducted in coordination with video editing for news	100% in years 2, 4 & 6		$5,200		$5,200		$5,200				
	TOTAL per Year									$6,760	$11,960	$6,760	$11,960	$6,760	$8,580	$3,380	$3,380	$3,380	$3,380
	TOTAL per Year Escalated			3%				Percent Escalation		**$6,800**	**$12,400**	**$7,200**	**$13,100**	**$7,600**	**$9,900**	**$4,000**	**$4,100**	**$4,200**	**$4,300**
	TOTAL for Implementation	WPP	-	-	-	-	**$73,600**												
News Campaign (Priority = High)	Create Video / Advertisement	hrs	160	$25	$4,000	$1,200	$5,200	Four staff, one full week for video development, planning, shooting and editing; Conducted in coordination with video editing for social media	100% in years 2, 4, & 6		$5,200		$5,200		$5,200				
	Allowance for Movie Theater, Cable, Radio or Other Video/Audio Advertisement	LS	1	$45,000	$45,000	$13,500	$58,500	$300/commercial, once a day for six months; or one movie ad per month at $1,345 per ad for six months; or $150 for 30 second radio ad running once a day for 12 months; Assumes just one outlet	100% Years 2 - 6		$58,500	$58,500	$58,500	$58,500	$58,500				
	Create Newspaper Ad	hrs	40	$25	$1,000	$300	$1,300	Staff Time per Year	Year 2, 4, & 6		$1,300		$1,300		$1,300				
	Newspapers Ad	ea	2	$500	$1,000	$300	$1,300	One large newspaper ad; Twice per year	Years 2 - 10		$1,300	$1,300	$1,300	$1,300	$1,300	$1,300	$1,300	$1,300	$1,300
	E-Newsletters, HOA Newsletters, Youth Education Newsletters	hrs	15	$25	$375	$113	$488	Staff Time per Year	Years 2 - 10		$488	$488	$488	$488	$488	$488	$488	$488	$488
	TOTAL per Year									$0	$66,788	$60,288	$66,788	$60,288	$66,788	$1,788	$1,788	$1,788	$1,788
	TOTAL per Year Escalated			3%				Percent Escalation		**$0**	**$68,900**	**$64,000**	**$72,900**	**$67,600**	**$76,900**	**$2,200**	**$2,200**	**$2,400**	**$2,400**
	TOTAL for Implementation	WPP	-	-	-	-	**$359,500**												
Youth Activities (Priority = High)	Development of Youth Materia	hrs	320	$40	$12,800	$3,840	$16,640	Estimated hours	Years 1 & 6	$16,640					$16,640				
	Conduct / Attend Youth Programs	hrs	120	$25	$3,000	$900	$3,900	4 programs per year; 30 hrs per program (6 hr program + preparation)	Years 1 - 10	$3,900	$3,900	$3,900	$3,900	$3,900	$3,900	$3,900	$3,900	$3,900	$3,900
	Walklife Interpretive Tour	hrs	40	$25	$1,000	$300	$1,300	1 tour per year; 20 hrs per tour (6 hr tour + preparation)	Years 1 - 10	$1,300	$1,300	$1,300	$1,300	$1,300	$1,300	$1,300	$1,300	$1,300	$1,300
	Train Scouts Program	hrs	40	$25	$1,000	$300	$1,300	2 programs per year; 20 hrs per program (6 hr program + preparation)	Years 1 - 10	$1,300	$1,300	$1,300	$1,300	$1,300	$1,300	$1,300	$1,300	$1,300	$1,300
	Field Trips	hrs	40	$25	$1,000	$300	$1,300	2 trips per year; 20 hrs per trip (6 hr tour + preparation)	Years 1 - 10	$1,300	$1,300	$1,300	$1,300	$1,300	$1,300	$1,300	$1,300	$1,300	$1,300
	TOTAL per Year									$24,440	$7,800	$7,800	$7,800	$7,800	$24,440	$7,800	$7,800	$7,800	$7,800
	TOTAL per Year Escalated			3%				Percent Escalation		**$24,500**	**$8,100**	**$8,300**	**$8,600**	**$8,800**	**$28,200**	**$9,300**	**$9,500**	**$9,700**	**$10,000**
	TOTAL for Implementation	WPP	-	-	-	-	**$125,000**												
Local Event Outreach (Priority = High)	Print Materials (signs, booths, posters, etc.)	ea	4	$1,000	$4,000	$1,200	$5,200	Per event; 4 events per year	Years 1 - 10	$5,200	$5,200	$5,200	$5,200	$5,200	$5,200	$5,200	$5,200	$5,200	$5,200
	Staff Time for Local Events (Community Connection Program, Chamber of Commerce, County Fair, Speakers Bureau, County Fair)	hrs	160	$25	$4,000	$1,200	$5,200	4 events per year; 20 hrs per staff per event; 2 staff per event	Years 1 - 10	$5,200	$5,200	$5,200	$5,200	$5,200	$5,200	$5,200	$5,200	$5,200	$5,200
	TOTAL per Year									$10,400	$10,400	$10,400	$10,400	$10,400	$10,400	$10,400	$10,400	$10,400	$10,400
	TOTAL per Year Escalated			3%				Percent Escalation		**$10,400**	**$10,800**	**$11,100**	**$11,400**	**$11,700**	**$12,000**	**$12,300**	**$12,600**	**$12,900**	**$13,300**
	TOTAL for Implementation	WPP	-	-	-	-	**$118,500**												
Wildlife Management Workshops (Priority = High)	Staff Time	hrs	0	$25	$0	$0	$0	Covered under Overabundant Urban Deer and Urban Non-Native Avian BMPs	Years 1 - 10	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
	Total per Year									$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
	TOTAL per Year Escalated			3%				Percent Escalation		**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**
	TOTAL for Implementation	WPP	-	-	-	-	**$0**												
Do-Not-Feed Wildlife Ordinance and Campaign (Priority = High)	Staff Time	hrs	0	$25	$0	$0	$0	Covered under Overabundant Urban Deer and Urban Non-Native Avian BMPs	Years 1 - 10	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
	Total per Year									$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
	TOTAL per Year Escalated			3%				Percent Escalation		**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**
	TOTAL for Implementation	WPP	-	-	-	-	**$0**												
TOTAL per Year Escalated										$41,700	$100,200	$90,600	$106,000	$95,700	$127,000	$27,800	$28,400	$29,200	$30,000
TOTAL for Implementation							**$676,600**												

Table F-3: Estimated Probable Cost Calculations for WPP Implementation: Overabundant Urban Deer BMPs

BMP	Description of Costs	Units	No. of Units	Cost per Unit	Subtotal	30% Contingency	Total	Notes	Implementation Years	1	2	3	4	5	6	7	8	9	10
Overabundant Urban Deer BMPs																			
Do-Not-Feed Wildlife Ordinance and Campaign within City Limits (Priority = Critical)	Staff Time to Create Draft Ordinance Language	hrs	80	$40	$3,200	$960	$4,160	One staff for two weeks of time drafting wildlife specific ordinance plan and coordinating with TPWD	Year 1; 70% of Total Cost	$2,912									
	Lawyer Time to Write Ordinance	hrs	40	$250	$10,000	$3,000	$13,000	One lawyer, one week	Year 1; 70% of Total Cost	$9,100									
	Enforcement Officer	hrs	520	$25	$13,000	$3,900	$16,900	10 hours per week starting in Year 2	Years 2 - 4 100%; Years 5-10 50%; 70% of Total Cost (30% of cost applied to Urban Avian Enforcement Officer)		$11,830	$11,830	$11,830	$5,915	$5,915	$5,915	$5,915	$5,915	$5,915
	Revenue from Fine	ea	24	($75)	($1,800)	($540)	($2,340)	City of Austin fine estimate; assuming revenue used for program; 2 fines per month	Years 1 - 3 100%; Years 4-10 50%; 70% of Total Cost	($1,638)	($1,638)	($1,638)	($819)	($819)	($819)	($819)	($819)	($819)	($819)
	Signs in Park for Not Feeding Animals	ea	30	$50	$1,500	$450	$1,950	Plexiglass signs	ears 2, 6; 70% of Total Cost		$1,365				$1,365				
	Installation of Signs	hrs	60	$25	$1,500	$450	$1,950	2 hrs/sign	ears 2, 6; 70% of Total Cost		$1,365				$1,365				
	Flyers and promotional material (within City Limits)	ea	1	$500	$500	$150	$650	Per Year	Years 1-10; 70% of Total Cost	$455	$455	$455	$455	$455	$455	$455	$455	$455	$455
	Staffing Time for Distribution of Materials / Conducting Outreach within City Limits	hrs	240	$25	$6,000	$1,800	$7,800	Estimated time to supplement general WPP O&E w/ ordinance and no-feed specific materials and outreach	Years 1-10; 70% of Total Cost	$5,460	$5,460	$5,460	$5,460	$5,460	$5,460	$5,460	$5,460	$5,460	$5,460
	TOTAL per Year							Other 30% covered by Urban Avian		$16,289	$18,837	$16,107	$16,926	$11,011	$13,741	$11,011	$11,011	$11,011	$11,011
	TOTAL per Year Escalated			3%				Percent Escalation		**$4,400**	**$19,500**	**$17,100**	**$18,500**	**$12,500**	**$15,900**	**$13,100**	**$13,400**	**$13,700**	**$14,100**
	TOTAL for Implementation	WPP	-	-	-	-	**$142,200**												
Deer Population Assessment (Priority = High)	Assessment of Deer Population by tracking "social carrying capacity" issues	hrs	156	$40	$6,240	$1,872	$8,112	3 hrs/week	100% Years 1 - 5; 50% Years 6 - 10	$8,112	$8,112	$8,112	$8,112	$8,112	$4,056	$4,056	$4,056	$4,056	$4,056
	TOTAL per Year									$8,112	$8,112	$8,112	$8,112	$8,112	$4,056	$4,056	$4,056	$4,056	$4,056
	TOTAL per Year Escalated			3%				Percent Escalation		**$8,200**	**$8,400**	**$8,600**	**$8,900**	**$9,100**	**$4,700**	**$4,800**	**$5,000**	**$5,100**	**$5,200**
	TOTAL for Implementation	WPP	-	-	-	-	**$68,000**												
Voluntary Do-Not-Feed Wildlife Campaign in Rural Neighborhoods (Priority = High)	Flyers and promotional material (outside City Limits)	ea	1	$500	$500	$150	$650	Per Year	Years 1, 3, 5, 7, 9	$650		$650		$650		$650		$650	
	Staffing Time for Distribution of Materials / Conducting Outreach outside City Limits	hrs	120	$25	$3,000	$900	$3,900	10 hr/month for a staff member to encourage Do-Not-Feed practices outside City Limits	Years 1, 3, 5, 7, 9	$3,900		$3,900		$3,900		$3,900		$3,900	
	TOTAL per Year									$4,550	$0	$4,550	$0	$4,550	$0	$4,550	$0	$4,550	$0
	TOTAL per Year Escalated			3%				Percent Escalation		**$4,800**	**$0**	**$5,100**	**$0**	**$5,300**	**$0**	**$5,600**	**$0**	**$5,900**	**$0**
	TOTAL for Implementation	WPP	-	-	-	-	**$26,700**	**Includes outreach related to the Ordinance when passed**											
Wildlife Management Workshops (Priority = High)	Develop Materials and Implement Workshop	hrs	80	$25	$2,000	$600	$2,600	Texas AgriLife provides free workshops online and will work with other agencies **(e.g., TPWD)** to develop in-person workshops	Years 2, 4, 6, 8; 70% of Costs		$1,820		$1,820		$1,820		$1,820		
	Refreshments	LS	2	$100	$200	$60	$260		Years 2, 4, 6, 8; 70% of Costs		$182		$182		$182		$182		
	Workshop Coordination (invites, advertising, scheduling, etc.)	hrs	20	$25	$500	$150	$650	2 events per year; 1 staff; 10 hours per event	Years 2, 4, 6, 8; 70% of Costs		$455		$455		$455		$455		
	TOTAL per Year							Other 30% covered by Urban Avian		$0	$2,457	$0	$2,457	$0	$2,457	$0	$2,457	$0	$0
	TOTAL per Year Escalated			3%				Percent Escalation		**$0**	**$2,700**	**$0**	**$2,900**	**$0**	**$3,000**	**$0**	**$3,200**	**$0**	**$0**
	TOTAL for Implementation	WPP	-	-	-	-	**$11,800**												
Active Management of Deer, Contingent upon City Council Approval (Priority = High)	Reduction of Deer Population (Based on discussions with TPWD and Trapper)	ea	150	$200	$30,000	$9,000.0	$39,000.0	Assume annual fee + trapping (decreasing deer per year to fixed minimum number); Ref: https://tpwd.texas.gov/publications/pwdpubs/media/pwd_bk_w7000_1197.pdf	Years 3 - 10			$39,000	$39,000	$39,000	$39,000	$39,000	$39,000	$39,000	$39,000
	Purchase Feeders for Trapping	ea	3	$800	$2,400	$720.0	$3,120.0	Per discussion with TPWD	Year 2		$3,120								
	Permitting with Texas parks and Wildlife	hrs	1	$25	$25	$7.5	$32.5	One staff for annual permitting with TPWD.	Years 3 - 10		$33	$33	$33	$33	$33	$33	$33	$33	$33
	TOTAL per Year									$0	$3,153	$39,033	$39,033	$39,033	$39,033	$39,033	$39,033	$39,033	$39,033
	TOTAL per Year Escalated			3%				Percent Escalation		**$0**	**$3,400**	**$41,500**	**$42,700**	**$43,800**	**$45,000**	**$46,200**	**$47,300**	**$48,500**	**$49,700**
	TOTAL for Implementation	WPP	-	-	-	-	**$368,100**								**FALSE**				
TOTAL per Year Escalated										$17,400	$34,000	$72,300	$73,000	$70,700	$68,600	$69,700	$68,900	$73,200	$69,000
TOTAL for Implementation							**$616,800**												

Table F-4: Estimated Probable Cost Calculations for WPP Implementation: Urban Non-Native Avian Wildlife BMPs

BMP	Description of Costs	Units	No. of Units	Cost per Unit	Subtotal	30% Contingency	Total	Notes	Implementation Years	1	2	3	4	5	6	7	8	9	10
Urban Non-Native Avian Wildlife BMPs																			
Do-Not-Feed Wildlife Ordinance and Campaign within City Limits (Priority = Critical)	Staff Time to Create Draft Ordinance Language	hrs	80	$40	$3,200	$960	$4,160	One staff for two weeks of time drafting wildlife specific ordinance plan and coordinating with TPWD	Year 1; 30% of Total Cost	$1,248									
	Lawyer Time to Write Ordinance	hrs	40	$250	$10,000	$3,000	$13,000	Estimated time	Year 1; 30% of Total Cost	$3,900									
	Enforcement Officer	hrs	520	$25	$13,000	$3,900	$16,900	10 hours per week starting in Year 2	Years 2 - 4 100%; Years 5-10 50%; 70% of Total Cost (70% of cost applied to Urban Deer Enforcement Officer)		$5,070	$5,070	$2,535	$2,535	$2,535	$2,535	$2,535	$2,535	$2,535
	Revenue from Fine	ea	24	($75)	($1,800)	($540)	($2,340)	City of Austin fine estimate; assuming revenue used for program; 2 fines per month	Years 1 - 3 100%; Years 4-10 50%; 30% of Total Cost	($702)	($702)	($702)	($351)	($351)	($351)	($351)	($351)	($351)	($351)
	Signs in Park for Not Feeding Animals	ea	30	$50	$1,500	$450	$1,950	Plexiglass signs	Years 2, 6; 30% of Total Cost		$585				$585				
	Installation of Signs	hrs	60	$25	$1,500	$450	$1,950	2 hrs/sign	Years 2, 6; 30% of Total Cost		$585				$585				
	Flyers and promotional material	ea	1	$500	$500	$150	$650		Years 1-10; 30% of Total Cost	$195	$195	$195	$195	$195	$195	$195	$195	$195	$195
	Staffing Time for Distribution of Materials	hrs	240	$25	$6,000	$1,800	$7,800	Estimated time to supplement general WPP O&E w/ ordinance and no-feed specific materials and outreach	Years 1-10; 30% of Total Cost	$2,340	$2,340	$2,340	$2,340	$2,340	$2,340	$2,340	$2,340	$2,340	$2,340
	TOTAL per Year							Other 70% covered by Urban Deer		$6,981	$8,073	$6,903	$4,719	$4,719	$5,889	$4,719	$4,719	$4,719	$4,719
	TOTAL per Year Escalated			3%				Percent Escalation		**$3,300**	**$9,900**	**$8,900**	**$6,000**	**$6,200**	**$7,600**	**$6,500**	**$6,700**	**$6,800**	**$7,000**
	TOTAL for Implementation	WPP	-	-	-	-	**$68,900**												
Non-Native Duck and Goose Population Assessment (Priority = High)	Assessment of Non-Native Duck and Goosse Population by tracking "social carrying capacity" issues	hrs	52	$40	$2,080	$624	$2,704	1 hr/week	100% Years 1 - 5; 50% Years 6 - 10	$2,704	$2,704	$2,704	$2,704	$2,704	$1,352	$1,352	$1,352	$1,352	$1,352
	TOTAL per Year									$2,704	$2,704	$2,704	$2,704	$2,704	$1,352	$1,352	$1,352	$1,352	$1,352
	TOTAL per Year Escalated			3%				Percent Escalation		**$2,800**	**$2,800**	**$2,900**	**$3,000**	**$3,100**	**$1,600**	**$1,600**	**$1,700**	**$1,700**	**$1,800**
	TOTAL for Implementation	WPP	-	-	-	-	**$23,000**												
Discourage Non-Native Ducks and Geese from Congregating in the Park (Priority = High)	Dancing Air Man Passive Protection	ea	2	$700	$1,400	$420	$1,820	Two dancing tube men	Year 2		$1,820								
	Installation of Dancing Air Man	hrs	2	$25	$50	$15	$65	One Staff for installation	Year 2		$65								
	Electricity for Dancing Air Man	ea	1	$500	$500	$150	$650	1 year of power for dancing tube man	Years 2-10		$650	$650	$650	$650	$650	$650	$650	$650	$650
	Sound Deterrents	hrs	156	$50	$7,800	$2,340	$10,140	3 hrs/week for a year	Years 2-5 100%; Years 6-10 50%		$10,140	$10,140	$10,140	$10,140	$5,070	$5,070	$5,070	$5,070	$5,070
	TOTAL per Year									$0	$12,675	$10,790	$10,790	$10,790	$5,720	$5,720	$5,720	$5,720	$5,720
	TOTAL per Year Escalated			3%				Percent Escalation		**$0**	**$13,200**	**$11,500**	**$11,900**	**$12,200**	**$6,700**	**$6,800**	**$7,000**	**$7,200**	**$7,400**
	TOTAL for Implementation	WPP	-	-	-	-	**$83,900**												
Rapid Removal of Dead Animals (Priority = High)	Staff for Removal	hrs	520	$25	$13,000	$3,900.0	$16,900.0	10 hr/week for a staff member	Years 1-5 100%; Years 6-10 50%	$16,900	$16,900	$16,900	$16,900	$16,900	$8,450	$8,450	$8,450	$8,450	$8,450
	Vehicle for removal	ea	1	$1,000	$1,000	$300.0	$1,300.0	Lease plan and maintenance for vehicle for pickup	Years 1-5 100%; Years 6-10 50%	$1,300	$1,300	$1,300	$1,300	$1,300	$650	$650	$650	$650	$650
	TOTAL per Year									$18,200	$18,200	$18,200	$18,200	$18,200	$9,100	$9,100	$9,100	$9,100	$9,100
	TOTAL per Year Escalated			3%				Percent Escalation		**$18,200**	**$18,900**	**$19,400**	**$20,000**	**$20,500**	**$10,600**	**$10,800**	**$11,100**	**$11,400**	**$11,700**
	TOTAL for Implementation	WPP	-	-	-	-	**$152,600**												
Wildlife Management Workshops (Priority = High)	Develop Materials and Implement Workshop	ea	80	$25	$2,000	$600	$2,600	Texas AgriLife provides free workshops online and will work with other agencies **(e.g., TPWD)** to develop in-person workshops	Years 2, 4, 6, 8; 30% of Costs		$780		$780		$780		$780		
	Refreshments	LS	2	$100	$200	$60	$260		Years 2, 4, 6, 8; 30% of Costs		$78		$78		$78		$78		
	Workshop Coordination (invites, advertising, scheduling, etc.)	hrs	20	$25	$500	$150	$650	2 events per year; 1 staff; 10 hours per event	Years 2, 4, 6, 8; 30% of Costs		$195		$195		$195		$195		
	TOTAL per Year							Other 70% covered by Urban Deer		$0	$1,053	$0	$1,053	$0	$1,053	$0	$1,053	$0	$0
	TOTAL per Year Escalated			3%				Percent Escalation		**$0**	**$1,200**	**$0**	**$1,200**	**$0**	**$1,300**	**$0**	**$1,300**	**$0**	**$0**
	TOTAL for Implementation	WPP	-	-	-	-	**$5,000**												

Table F-4: Estimated Probable Cost Calculations for WPP Implementation: Urban Non-Native Avian Wildlife BMPs (Continued)

BMP	Description of Costs	Units	No. of Units	Cost per Unit	Subtotal	30% Contingency	Total	Notes	Implementation Years	1	2	3	4	5	6	7	8	9	10
Urban Non-Native Avian Wildlife BMPs, cont.																			
Trap Non-Native Ducks and Geese (Priority = High)	Duck and Goose Trapping Service	hrs	468	$25	$11,700	$3,510	$15,210	Cost for a trapping service for a year. Three visits per week for 3 hours per visit	Years 1-3 100%; Years 4-10 25%	$15,210	$15,210	$15,210	$3,803	$3,803	$3,803	$3,803	$3,803	$3,803	$3,803
	TOTAL per Year									$15,210	$15,210	$15,210	$3,803	$3,803	$3,803	$3,803	$3,803	$3,803	$3,803
	TOTAL per Year Escalated			0%				Percent Escalation		**$15,300**	**$15,300**	**$15,300**	**$3,900**	**$3,900**	**$3,900**	**$3,900**	**$3,900**	**$3,900**	**$3,900**
	TOTAL for Implementation	WPP	-	-	-	-	**$73,200**												
Oil Coat Non-Native Duck Eggs (Priority = High)	Personnel Time for Oiling	hrs	130	$25	$3,250	$975	$4,225	2.5 hrs/week	Years 1-3 100%; Years 4-10 25%	$4,225	$4,225	$4,225	$1,056	$1,056	$1,056	$1,056	$1,056	$1,056	$1,056
	TOTAL per Year									$4,225	$4,225	$4,225	$1,056	$1,056	$1,056	$1,056	$1,056	$1,056	$1,056
	TOTAL per Year Escalated			0%				Percent Escalation		**$4,300**	**$4,400**	**$4,500**	**$1,200**	**$1,200**	**$1,300**	**$1,300**	**$1,300**	**$1,400**	**$1,400**
	TOTAL for Implementation	WPP	-	-	-	-	**$22,300**												
TOTAL per Year Escalated										**$43,900**	**$65,700**	**$62,500**	**$47,200**	**$47,100**	**$33,000**	**$30,900**	**$33,000**	**$32,400**	**$33,200**
TOTAL for Implementation							**$428,900**												

Table F-5: Estimated Probable Cost Calculations for WPP Implementation: Feral Hog BMPs

BMP	Description of Costs	Units	No. of Units	Cost per Unit	Subtotal	30% Contingency	Total	Notes	Implementation Years	1	2	3	4	5	6	7	8	9	10
Feral Hog BMPs																			
Feral Hog Workshops (Priority = High)	Develop Materials and Implement Workshop	ea	16	$40	$640	$192	$832	Assume **TWS** provides workshops at no cost as part of ongoing Feral Hog Workshops they host	Years 1, 3, 5, 7, 9	$832		$832		$832		$832		$832	
	Workshop Refreshments	ea	2	$100	$200	$60	$260		Years 1, 3, 5, 7, 9	$260		$260		$260		$260		$260	
	Workshop Coordination (invites, advertising, scheduling, etc.)	hrs	40	$25	$1,000	$300	$1,300	2 events per year; 1 staff; 20 hours	Years 1, 3, 5, 7, 9	$1,300		$1,300		$1,300		$1,300		$1,300	
	TOTAL per Year									$2,392	$0	$2,392	$0	$2,392	$0	$2,392	$0	$2,392	$0
	TOTAL per Year Escalated			3%				Percent Escalation		**$2,500**	**$0**	**$2,600**	**$0**	**$2,700**	**$0**	**$3,000**	**$0**	**$3,100**	**$0**
	TOTAL for Implementation	WPP	-	-	-	-	**$13,900**												
Bounty Program (Priority = High)	Bounty Reimbursement	ea	131	$10	$1,310	$393	$1,703	$10 Bounty per hog, goal of 1175 hogs over 9 years; Administered by **Guadalupe and Comal Counties**	Years 2 - 10		$1,703	$1,703	$1,703	$1,703	$1,703	$1,703	$1,703	$1,703	$1,703
	Bounty Program Development and Administration	hrs	120	$25	$3,000	$900	$3,900	One staff member, 10 hrs/month	Years 2 - 10		$3,900	$3,900	$3,900	$3,900	$3,900	$3,900	$3,900	$3,900	$3,900
	Staff time for developing and distributing training video	hrs	160	$33	$5,200	$1,560	$6,760	Four staff, 40 hours each; 2 technical staff	Year 2		$6,760								
	TOTAL per Year									$0	$12,363	$5,603	$5,603	$5,603	$5,603	$5,603	$5,603	$5,603	$5,603
	TOTAL per Year Escalated			3%				Percent Escalation		**$0**	**$12,800**	**$6,000**	**$6,200**	**$6,300**	**$6,500**	**$6,700**	**$6,800**	**$7,000**	**$7,200**
	TOTAL for Implementation	WPP	-	-	-	-	**$65,500**												
Trapping Intensity Assessment (Priority = High)	Staff outreach time	hrs	40	$40	$1,600	$480	$2,080	One staff, 40 hrs per year to survey trappers in the watershed	Years 2 - 10		$2,080	$2,080	$2,080	$2,080	$2,080	$2,080	$2,080	$2,080	$2,080
	Staff data analysis time	hrs	16	$40	$640	$192	$832	One staff, 16 hrs per year	Years 2 - 10		$832	$832	$832	$832	$832	$832	$832	$832	$832
	TOTAL per Year									$0	$2,912	$2,912	$2,912	$2,912	$2,912	$2,912	$2,912	$2,912	$2,912
	TOTAL per Year Escalated			3%				Percent Escalation		**$0**	**$3,000**	**$3,100**	**$3,200**	**$3,300**	**$3,400**	**$3,500**	**$3,600**	**$3,700**	**$3,700**
	TOTAL for Implementation	WPP	-	-	-	-	**$30,500**												
Feral Hog Website (Priority = Moderate)	Web Programmer Time	hrs	80	$120	$9,600	$2,880	$12,480	One programmer, 80 hours of programming time for web developer to create or modify an existing site	Year 4				$12,480						
	Project Manager Time	hrs	20	$40	$800	$240	$1,040	One staff member reviewing information to be put on website	Year 4				$1,040						
	Staff Data Collection Time	hrs	40	$40	$1,600	$480	$2,080	One staff member collecting information and organizing for upload onto website	Years 4 - 10				$2,080	$2,080	$2,080	$2,080	$2,080	$2,080	$2,080
	TOTAL per Year									$0	$0	$0	$15,600	$2,080	$2,080	$2,080	$2,080	$2,080	$2,080
	TOTAL per Year Escalated			3%				Percent Escalation		**$0**	**$0**	**$0**	**$17,100**	**$2,400**	**$2,400**	**$2,500**	**$2,600**	**$2,600**	**$2,700**
	TOTAL for Implementation	WPP	-	-	-	-	**$32,300**												
TOTAL per Year Escalated										$2,500	$15,800	$11,700	$26,500	$14,700	$12,300	$15,700	$13,000	$16,400	$13,600
TOTAL for Implementation							**$142,200**												

Table F-6: Estimated Probable Cost Calculations for WPP Implementation: Livestock BMPs

BMP	Description of Costs	Units	No. of Units	Cost per Unit	Subtotal	30% Contingency	Total	Notes	Implementation Years	1	2	3	4	5	6	7	8	9	10
Livestock BMPs																			
Water Quality Management Plans (WQMPs) (Priority = High)	Select Operations for Implementation	hrs	32	$25	$800	$240	$1,040	Estimated staff time	Years 2, 4		$1,040		$1,040						
	Coordinate Funding Application and Follow-Up	hrs	200	$25	$5,000	$1,500	$6,500	Assume 80 WQMPs; 20 hrs per plan; assume **SWCD** assists with WQMP development, funding and implementation outside this budget; assuming volunteers assist with meeting WQMP	Years 2 - 9		$1,463	$1,463	$1,463	$1,463	$1,463	$1,463	$1,463	$1,463	
	WQMP Implementation	ea	60	$15,000	$900,000	$0	$900,000	Per discussions with soil board representatives	Years 3 - 10			$112,500	$112,500	$112,500	$112,500	$112,500	$112,500	$112,500	$112,500
	TOTAL per Year									$0	$2,503	$113,963	$115,003	$113,963	$113,963	$113,963	$113,963	$113,963	$112,500
	TOTAL per Year Escalated			3%				Percent Escalation		**$0**	**$2,700**	**$120,900**	**$125,400**	**$127,700**	**$131,100**	**$134,600**	**$138,000**	**$141,400**	**$142,900**
	TOTAL for Implementation	WPP	-	-	-	-	**$1,064,700**												
Livestock Outreach and Education (Priority = High)	Develop Materials and Implement Workshop	ea	40	$40	$1,600	$480	$2,080	Assume AgriLife Provides Materials for Free as part of ongoing Workshops they host	Years 2, 4, 6, 8, 10		$2,080		$2,080		$2,080		$2,080		$2,080
	Workshop Refreshments	LS	2	$100	$200	$60	$260		Years 2, 4, 6, 8, 10		$260		$260		$260		$260		$260
	Workshop Coordination (invites, advertising, scheduling, etc.)	hrs	40	$25	$1,000	$300	$1,300	2 events per year; 1 staff; 20 hours	Years 2, 4, 6, 8, 10		$1,300		$1,300		$1,300		$1,300		$1,300
	TOTAL per Year									$0	$3,640	$0	$3,640	$0	$3,640	$0	$3,640	$0	$3,640
	TOTAL per Year Escalated			3%				Percent Escalation		**$0**	**$3,800**	**$0**	**$4,000**	**$0**	**$4,200**	**$0**	**$4,500**	**$0**	**$4,700**
	TOTAL for Implementation	WPP	-	-	-	-	**$21,200**												
TOTAL per Year Escalated										$0	$6,500	$120,900	$129,400	$127,700	$135,300	$134,600	$142,500	$141,400	$147,600
TOTAL for Implementation							**$1,085,900**												

Table F-7: Estimated Probable Cost Calculations for WPP Implementation: OSSF BMPs

BMP	Description of Costs	Units	No. of Units	Cost per Unit	Subtotal	30% Contingency	Total	Notes	Implementation Years	1	2	3	4	5	6	7	8	9	10
OSSF BMPs																			
OSSF Education and Assistance Programs (Priority = High)	Develop Materials and Implement Workshop	ea	2	$1,000	$2,000	$600	$2,600	**Comal County** puts on free OSSF training each year for both engineers, installers and maintenance firms, and for homeowners.	Biennial		$2,600		$2,600		$2,600		$2,600		$2,600
	Workshop Coordination (invites, advertising, scheduling, etc.)	hrs	20	$25	$500	$150	$650	2 events per year; 1 staff; 10 hours per event	Biennial		$650		$650		$650		$650		$650
	TOTAL per Year									$0	$3,250	$0	$3,250	$0	$3,250	$0	$3,250	$0	$3,250
	TOTAL per Year Escalated			3%				Percent Escalation		**$0**	**$3,400**	**$0**	**$3,700**	**$0**	**$3,800**	**$0**	**$4,000**	**$0**	**$4,300**
	TOTAL for Implementation	WPP	-	-	-	-	**$19,200**												
Mandatory OSSF Inspection and Maintenance Program (Priority = High)	Additional Staff for Inspection, Training, and Evaluating	hrs	624	$25	$15,600	$4,680	$20,280	One staff member for conducting inspections and training people. 12 hours per week to inspect 2 OSSFs.	Years 3 - 10			$20,280	$20,280	$20,280	$20,280	$20,280	$20,280	$20,280	$20,280
	Lease Vehicle for New Staff Inspection	ea	1	$4,000	$4,000	$1,200	$5,200		Years 3 - 10			$5,200	$5,200	$5,200	$5,200	$5,200	$5,200	$5,200	$5,200
	Repairs/Replacement	ea	34	$5,000	$170,000	$51,000	$221,000	Total labor, parts, equipment for 10% of failing OSSFs	Years 4 - 10				$31,571	$31,571	$31,571	$31,571	$31,571	$31,571	$31,571
	TOTAL per Year									$0	$0	$25,480	$57,051	$57,051	$57,051	$57,051	$57,051	$57,051	$57,051
	TOTAL per Year Escalated			3%				Percent Escalation		**$0**	**$0**	**$27,100**	**$62,200**	**$63,900**	**$65,700**	**$67,400**	**$69,100**	**$70,800**	**$72,500**
	TOTAL for Implementation	WPP	-	-	-	-	**$498,700**												
TOTAL per Year Escalated										$0	$3,400	$27,100	$65,900	$63,900	$69,500	$67,400	$73,100	$70,800	$76,800
TOTAL for Implementation							**$517,900**												

Table F-8: Estimated Probable Cost Calculations for WPP Implementation: Stormwater BMPs

BMP	Description of Costs	Units	No. of Units	Cost per Unit	Subtotal	30% Contingency	Total	Notes	Implementation Years	1	2	3	4	5	6	7	8	9	10
Stormwater BMPs																			
Non-Structural Stormwater BMPs Outside of the City's MS4 Jurisdiction (Priority = High)	Procure/Install signs on storm grates and at creek crossings for no dumping	LS	1	$20,000	$20,000	$6,000	$26,000		Year 2		$26,000								
	Monitoring allowance (e.g., illicit Discharge / investigations)	hrs	80	$25	$2,000	$600	$2,600	One staff, two weeks/year	100% Years 2 - 6; 50% Years 7 - 10		$2,600	$2,600	$2,600	$2,600	$2,600	$1,300	$1,300	$1,300	$1,300
	Allowance for low tech surveillance equipment	LS	1	$15,000	$15,000	$4,500	$19,500		Year 2		$19,500								
	Allowance for recognition (or other related) program	ea	1	$2,000	$2,000	$600	$2,600	Per year	100% Years 2 - 6; 50% Years 7 - 10					$2,600	$2,600	$1,300	$1,300	$1,300	$1,300
	Inspector and/or program administrator	hrs	780	$40	$31,200	$9,360	$40,560	15 hours a week	100% Years 2 - 6; 50% Years 7 - 10					$40,560	$40,560	$20,280	$20,280	$20,280	$20,280
	Allowance for equipment, supplies, or construction of engineered structure	ea	1	$75,000	$75,000	$22,500	$97,500	One time purchase	Year 4					$97,500					
	TOTAL per Year									$0	$48,100	$2,600	$2,600	$143,260	$45,760	$22,880	$22,880	$22,880	$22,880
	TOTAL per Year Escalated			3%				Percent Escalation		**$0**	**$49,600**	**$2,800**	**$2,900**	**$160,500**	**$52,700**	**$27,000**	**$27,700**	**$28,400**	**$29,100**
	TOTAL for Implementation	WPP	-	-	-	-	**$380,700**												
Stormwater Outreach and Education (Priority = High)	Print Materials	ea	1	$500	$500	$150	$650	Per year	Years 2 - 10		$650	$650	$650	$650	$650	$650	$650	$650	$650
	Post Print Materials around City at Likely High Risk Areas	hrs	80	$25	$2,000	$600	$2,600	Two weeks per year	Years 2 - 10		$2,600	$2,600	$2,600	$2,600	$2,600	$2,600	$2,600	$2,600	$2,600
	Staff Hours to Create Print Materials	hrs	40	$25	$1,000	$300	$1,300	Four staff (8 hours each) needed for review and composition + 8 hours graphics	Years 1, 5	$1,300					$1,300				
	TOTAL per Year									$1,300	$3,250	$3,250	$3,250	$3,250	$4,550	$3,250	$3,250	$3,250	$3,250
	TOTAL per Year Escalated			3%				Percent Escalation		**$1,300**	**$3,400**	**$3,500**	**$3,700**	**$3,800**	**$5,300**	**$3,900**	**$4,000**	**$4,200**	**$4,300**
	TOTAL for Implementation	WPP	-	-	-	-	**$37,400**												
Engineering Analysis of Opportunities for Structural Stormwater BMPs (Priority = Moderate)	Engineering Consulting allowance	hrs	480	$140	$67,200	$20,160	$87,360	12 weeks; 2 engineers; 20 hours per week	Years 4 & 5; 50% each				$43,680	$43,680					
	Allowance for construction of LID features (e.g., bioretention ponds)	LS	1	$80,000	$80,000	$24,000	$104,000	Per year allowance	Years 6 - 10						$104,000	$104,000	$104,000	$104,000	$104,000
	Research funding methods	hrs	40	$140	$5,600	$1,680	$7,280	2 engineers; 20 hours each	Year 5					$7,280					
	Engineering Services for Evaluating Critical Improvement Zones	ea	1	$30,000	$30,000	$9,000	$39,000	Consulting fees to evaluate results of survey and environmental evaluation	Year 6						$39,000				
	Revegetation by Contractor	ea	10	$5,000	$50,000	$15,000	$65,000	Assume 40 locations for revegetation within county at $5,000 for plant costs and planting	Years 6 - 7						$65,000	$65,000			
	Survey Streams and Riparian Areas	ea	1	$40,000	$40,000	$12,000	$52,000	Surveying and Phase 1 Environmental Evaluation	Year 5					$52,000					
	TOTAL per Year									$0	$0	$0	$43,680	$102,960	$208,000	$169,000	$104,000	$104,000	$104,000
	TOTAL per Year Escalated			3%				Percent Escalation		**$0**	**$0**	**$0**	**$43,700**	**$162,300**	**$416,000**	**$338,000**	**$208,000**	**$208,000**	**$208,000**
	TOTAL for Implementation	WPP	-	-	-	-	**$1,584,000**												
TOTAL per Year Escalated										**$1,300**	**$53,000**	**$6,300**	**$50,300**	**$326,600**	**$474,000**	**$368,900**	**$239,700**	**$240,600**	**$241,400**
TOTAL for Implementation							**$2,002,100**												

Table F-9: Estimated Probable Cost Calculations for WPP Implementation: Pet Waste BMPs

BMP	Description of Costs	Units	No. of Units	Cost per Unit	Subtotal	30% Contingency	Total	Notes	Implementation Years	1	2	3	4	5	6	7	8	9	10
Pet BMPs																			
Pet Owner Outreach and Education (Priority = High)	Material Printing	ea	2	$500	$1,000	$300	$1,300	2 events per year	100% Years 1 - 5; 50% Years 6 - 10	$1,300	$1,300	$1,300	$1,300	$1,300	$650	$650	$650	$650	$650
	Material Development and Event Coordination	hrs	80	$25	$2,000	$600	$2,600	Based on rate for city staff personnel for setup, cleanup, and operation; 2 events per year, 40 hours per event	100% Years 1 - 5; 50% Years 6 - 10	$2,600	$2,600	$2,600	$2,600	$2,600	$1,300	$1,300	$1,300	$1,300	$1,300
	TOTAL per Year									$3,900	$3,900	$3,900	$3,900	$3,900	$1,950	$1,950	$1,950	$1,950	$1,950
	TOTAL per Year Escalated			3%				Percent Escalation		**$3,900**	**$4,100**	**$4,200**	**$4,400**	**$4,500**	**$2,300**	**$2,400**	**$2,400**	**$2,600**	**$2,600**
	TOTAL for Implementation	WPP	-	-	-	-	**$33,400**												
Pet Waste Stations (Priority = High)	Waste Station Purchase (including replacement stations)	ea	40	$270	$10,800	$3,240	$14,040	Based upon Zero Waste USA Dog Waste Station with Zero Waste Bag System (amazon.com) plus taxes; assumes replacement stations are required due to vandalism	Year 2 100%; Years 3 - 10 50%		$14,040	$7,020	$7,020	$7,020	$7,020	$7,020	$7,020	$7,020	$7,020
	Waste Station Installation	hrs	120	$25	$3,000	$900	$3,900	3 hrs per year per station	Year 2 100%; Years 3 - 10 50%		$3,900	$1,950	$1,950	$1,950	$1,950	$1,950	$1,950	$1,950	$1,950
	Pet Waste Bag Costs per Station	pkg	40	$70	$2,800	$840	$3,640	Based upon Zero Waste Dog Waste Roll Bags, 10 rolls of 200, Total 2,000 bags $63.63 (amazon.com) plus taxes; 1 roll per year per station	Years 2 - 10		$3,640	$3,640	$3,640	$3,640	$3,640	$3,640	$3,640	$3,640	$3,640
	Pet Waste Liners	pkg	80	$35	$2,800	$840	$3,640	Based upon Dogipot Trash Liner Bags, 50 (amazon.com) plus taxes; 2 per year per station	Years 2 - 10		$3,640	$3,640	$3,640	$3,640	$3,640	$3,640	$3,640	$3,640	$3,640
	Annual Maintenance	hrs	80	$25	$2,000	$600	$2,600	Based upon City rate for maintenance level person; 2 hrs per year per station	Years 2 - 10		$2,600	$2,600	$2,600	$2,600	$2,600	$2,600	$2,600	$2,600	$2,600
	TOTAL per Year									$0	$27,820	$18,850	$18,850	$18,850	$18,850	$18,850	$18,850	$18,850	$18,850
	TOTAL per Year Escalated			3%				Percent Escalation		**$0**	**$28,700**	**$20,100**	**$20,600**	**$21,200**	**$21,800**	**$22,300**	**$23,000**	**$23,500**	**$24,000**
	TOTAL for Implementation	WPP	-	-	-	-	**$205,200**												
Pet Code Enforcement (Priority = Moderate)	Notify Homeowners Near Creek/River	hrs	80	$25	$2,000	$600	$2,600	Based on two city employees going door to door, one week	Years 4, 6				$2,600						
	Enforcement Officer	hrs	520	$25	$13,000	$3,900	$16,900	10 hours per week on average	100% Years 4 - 6; 50% years 7 - 10				$16,900	$16,900	$16,900	$8,450	$8,450	$8,450	$8,450
	Revenue Gained from Fines	ea	20	($200)	($4,000)	($1,200)	($5,200)	20 fines per year; assuming revenue used for program	100% Years 4 - 6; 50% years 7 - 10				($5,200)	($5,200)	($5,200)	($2,600)	($2,600)	($2,600)	($2,600)
	TOTAL per Year									$0	$0	$0	$14,300	$11,700	$11,700	$5,850	$5,850	$5,850	$5,850
	TOTAL per Year Escalated			3%				Percent Escalation		**$0**	**$0**	**$0**	**$15,600**	**$13,200**	**$13,500**	**$7,000**	**$7,100**	**$7,300**	**$7,500**
	TOTAL for Implementation	WPP	-	-	-	-	**$71,200**												
Tailored Pet Solutions (Priority = Moderate)	Allowance to Analyze Watershed and Identify Locations (e.g., Apartment Complexes)	hrs	160	$40	$6,400	$1,920	$8,320	Assumes two staff members going door to door for two weeks in a neighborhood	Year 2		$8,320				$8,320				
	Allowance to Implement Solutions	hrs	20	$40	$800	$240	$1,040	Assumes two staff members working with two apartment complexes a year at 10 hrs/complex; Assumes apartments cover implementation costs	Years 2 - 10		$1,040	$1,040	$1,040	$1,040	$1,040	$1,040	$1,040	$1,040	$1,040
	Waste Station Purchase (including replacement stations)	ea	40	$270	$10,800	$3,240	$14,040	Based upon Zero Waste USA Dog Waste Station with Zero Waste Bag System (amazon.com) plus taxes; assumes replacement stations are required due to vandalism	Year 2 100%; Years 3 - 10 50%		$14,040	$7,020	$7,020	$7,020	$7,020	$7,020	$7,020	$7,020	$7,020
	TOTAL per Year									$0	$9,360	$1,040	$1,040	$1,040	$9,360	$1,040	$1,040	$1,040	$1,040
	TOTAL per Year Escalated			3%				Percent Escalation		**$0**	**$24,200**	**$8,700**	**$8,900**	**$9,100**	**$18,900**	**$9,600**	**$9,800**	**$10,100**	**$10,400**
	TOTAL for Implementation	WPP	-	-	-	-	**$109,700**												
TOTAL per Year Escalated										$3,900	$57,000	$33,000	$49,500	$48,000	$56,500	$41,300	$42,300	$43,500	$44,500
TOTAL for Implementation							**$419,500**												

Table F-10: Estimated Probable Cost Calculations for WPP Implementation: Wastewater BMPs

BMP	Description of Costs	Units	No. of Units	Cost per Unit	Subtotal	30% Contingency	Total	Notes	Implementation Years	1	2	3	4	5	6	7	8	9	10
Wastewater BMPs																			
Wastewater Discharge Water Quality Assessment (Priority = Moderate)	Annual review of permitted discharge water quality data submitted to the State	hrs	16	$40	$640	$192	$832	One staff, two days/year	Years 2 - 10		$832	$832	$832	$832	$832	$832	$832	$832	$832
	TOTAL per Year									$0	$832	$832	$832	$832	$832	$832	$832	$832	$832
	TOTAL per Year Escalated			3%				Percent Escalation		**$0**	**$900**	**$900**	**$1,000**	**$1,000**	**$1,000**	**$1,000**	**$1,100**	**$1,100**	**$1,100**
	TOTAL for Implementation	WPP	-	-	-	-	**$9,100**												
TOTAL per Year Escalated										**$0**	**$900**	**$900**	**$1,000**	**$1,000**	**$1,000**	**$1,000**	**$1,100**	**$1,100**	**$1,100**
TOTAL for Implementation							**$9,100**												

Appendix G: Estimated *E. coli* Load Reduction Calculations

The potential load reduction calculations for each BMP were slightly different based on information available. However, an example potential *E.coli* load reduction is provided below for reference. This specific example is for the installation of pet (dog) waste stations in the areas draining to the Comal River.

Watershed Data Analysis:

- The median total E. coli load in the Comal River was calculated as 6.96 x10^{11} CFU/day, using historic data (refer to Section 4 of the WPP).
- The average E. coli load due to dogs was estimated using the average portion of E. coli attributed to pets from the 2013 and 2016 BST analyses, which is 4.0% (refer to Section 4 of the WPP).
- Estimated E. coli production rate per dog was documented from literature as 3.15 x 10^{9} CFU/day.
- Based upon calculations performed in the SELECT analysis, there are 3490 dogs in the Watershed (refer to Section 4 of the WPP).
- A goal was established to install 180 pet (dog) waste stations in the Comal River Watershed over the 10-year WPP implementation period.

1. Determine the *E. coli* load due to dogs in the Comal River:

***E. coli* load due to dogs in the Comal River**

$$= mean\ total\ E.coli\ load\ in\ the\ Comal\ River\ \times\ average\ E.coli\ load\ due\ to\ dogs$$

$$= 6.96\ x\ 10^{11}\left(\frac{CFU}{day}\right)\ \times\ 4.0\ (\%)$$

$$=\ 2.79\ x\ 10^{10}\left(\frac{CFU}{day}\right)$$

2. Determine the calibration factor to adjust the dog *E. coli* production rate to the amount of *E. coli* that reached the waterbody:

Calibration factor for dogs

$= E.coli$ load from dogs in the Comal River
$\div$ Number of dogs in the Watershed $\times$ $E.coli$ production rate for dogs

$= 2.79\ x10^{10}\left(\frac{CFU}{day}\right) \div 3490\ (dogs)\ \times\ 3.15\ x10^{9}\left(\frac{CFU}{day}\right)$

$= \mathbf{2.53\ x\ 10^{-3}}\ (\boldsymbol{unitless})$

3. Determine the number of additional dogs whose waste will be picked up due to additional waste stations:

Assumptions:

The following assumptions (referenced from literature, where possible) were made to calculate the *E. coli* load reduction due to the installation of 180 pet waste stations:

- 50% of the dog population is walked in public areas
- Percentage of dog owners in public areas that do not pick up dog waste is 40%.
- Percentage of dog owners that would start picking up dog waste if stations were available is 35%.
- Percentage of public areas in New Braunfels that already have dog waste stations is 40%

Number of dogs walked in public areas

$= number\ of\ dogs\ in\ the\ Watershed\ \times\ dog\ population\ walked\ in\ public\ areas$
$= 3{,}490\ (dogs)\ \times\ 50(\%)$
$= 1{,}745\ dogs$

Number of dogs whose waste is not picked up

$= number\ of\ dogs\ walked\ in\ public\ areas$
$\times\ dog\ owners\ in\ public\ areas\ that\ do\ not\ pick\ up\ dog\ waste$
$= 1{,}745\ (dogs)\ \times\ 40\ (\%)$
$= 698\ dogs$

Number of dogs whose waste would be picked up if waste stations available
$= number\ of\ dogs\ whose\ waste\ is\ not\ picked\ up$
$\times\ dog\ owners\ that\ would\ start\ picking\ up\ dog\ waste\ if\ stations\ available$
$= 698\ (dogs)\ \times\ 35\ (\%)$
$= 244\ dogs$

Number of additional dogs whose waste will be picked up due to waste stations
$= number\ of\ dogs\ whose\ waste\ would\ be\ picked\ up\ if\ waste\ stations\ available$
$\times\ (1 - portion\ of\ Watershed\ already\ covered\ by\ waste\ stations)$
$= 244\ dogs\ \times\ (1 - 40\%)$
$= \mathbf{147\ dogs}$

4. Determine the potential reduction in *E. coli* load in the Comal River due to dogs with the installation of additional waste stations:

Potential Reduction in *E.coli* load in the Comal River due to dogs because of installed waste stations
$= number\ of\ additional\ dogs\ whose\ waste\ will\ be\ picked\ up\ due\ to\ waste\ stations$
$\times\ E.coli\ production\ rate\ per\ dog \times\ calibration\ factor\ for\ dogs$
$= 147\ (dogs)\ \times\ 3.15\ x\ 10^{9}\left(\frac{CFU}{day}\right) \times\ 2.53\ x\ 10^{-3}(unitless)$
$= \mathbf{1.17\ x\ 10^{9}}\ \left(\frac{\boldsymbol{CFU}}{\boldsymbol{day}}\right)$

Thus, the potential reduction in *E. coli* load in the Comal River due to dogs with the installation of additional waste stations is approximately $= \mathbf{1.17x10^{9}}\left(\frac{CFU}{day}\right)$.

The following two tables summarize the estimated potential *E. coli* load reduction by BMP source and by each BMP, respectively. Detailed calculations are provided on the following pages. For more information, refer to Sections 5 and 7 of the WPP.

Table G-1: Estimated Potential *E. coli* Load Reduction By Source

Source	*E. coli* Load (CFU/day) Comal River	Dry Comal Creek	Total Watershed
Overabundant Urban Deer	1.21E+11	1.89E+07	1.21E+11
Urban Non-Native Avian Wildlife	9.47E+10	0.00E+00	9.47E+10
Feral Hogs	8.57E+10	2.92E+08	8.60E+10
Livestock	1.74E+10	4.47E+08	1.78E+10
OSSFs	6.90E+09	7.78E+07	6.97E+09
Pets	2.56E+09	7.77E+06	2.57E+09
Stormwater	4.78E+10	5.77E+08	4.84E+10
Wastewater	0	0	0
Total Potential Reduction ESTIMATED for WPP BMPs	**3.76E+11**	**1.42E+09**	**3.78E+11**
Total Potential Reduction TARGETED	**3.50E+11**	**1.07E+09**	**3.51E+11**

Table G-2: Estimated Potential *E. coli* Load Reduction by BMP

Source	BMP	*E. coli* Load (CFU/day)		
		Comal River	Dry Comal Creek	Total
Overabundant Urban Deer	Wildlife Do-Not-Feed Ordinance and Campaign within City Limits	5.91E+10	8.15E+06	5.91E+10
Overabundant Urban Deer	Deer Population Assessment	0.00E+00	0.00E+00	0.00E+00
Overabundant Urban Deer	Voluntary Do-Not-Feed Wildlife Campaign in Rural Neighborhoods	4.62E+09	3.58E+06	4.62E+09
Overabundant Urban Deer	Wildlife Management Workshops	2.31E+09	0.00E+00	2.31E+09
Overabundant Urban Deer	Active Management of Deer with City Council Approval	5.54E+10	7.15E+06	5.54E+10
Urban Non-Native Avian Wildlife	Wildlife Do-Not-Feed Ordinance and Campaign within City	2.96E+10	0.00E+00	2.96E+10
Urban Non-Native Avian Wildlife	Non-Native Duck and Goose Population Assessment	0.00E+00	0.00E+00	0.00E+00
Urban Non-Native Avian Wildlife	Discourage Non-Native Ducks and Geese from Gathering in the Park	3.55E+10	0.00E+00	3.55E+10
Urban Non-Native Avian Wildlife	Rapid Removal of Dead Animals	0.00E+00	0.00E+00	0.00E+00
Urban Non-Native Avian Wildlife	Wildlife Management Workshops	1.17E+10	0.00E+00	1.17E+10
Urban Non-Native Avian Wildlife	Trap Non-Native Ducks and Geese	9.25E+07	0.00E+00	9.25E+07
Urban Non-Native Avian Wildlife	Oil Coat Non-Native Duck Eggs	1.78E+10	0.00E+00	1.78E+10
Feral Hogs	Feral Hog Workshops	7.68E+09	1.21E+07	7.69E+09
Feral Hogs	Bounty Program	7.80E+10	2.79E+08	7.83E+10
Feral Hogs	Trapping Intensity Assessment	0.00E+00	0.00E+00	0.00E+00
Feral Hogs	Feral Hog Website	0.00E+00	0.00E+00	0.00E+00
Livestock	Water Quality Management Plans (WQMPs)	0.00E+00	3.65E+08	3.65E+08
Livestock	Livestock Outreach and Education	1.74E+10	8.18E+07	1.75E+10
OSSFs	OSSF Education and Assistance Programs	6.90E+09	1.71E+07	6.91E+09
OSSFs	Mandatory OSSF Inspection and Maintenance Program	0.00E+00	6.06E+07	6.06E+07
Stormwater	Non-Structural Stormwater BMPs Outside of the City's MS4 Jurisdiction	0.00E+00	2.31E+08	2.31E+08
Stormwater	Stormwater Outreach and Education	2.21E+10	1.38E+08	2.22E+10
Stormwater	Engineering Analysis of Opportunities for Structural Stormwater BMPs	2.58E+10	2.08E+08	2.60E+10
Pets	Pet Owner Outreach and Education	1.28E+09	2.46E+06	1.28E+09
Pets	Pet Waste Stations	1.17E+09	5.29E+06	1.18E+09
Pets	Pet Code Enforcement	1.15E+08	2.46E+04	1.15E+08
Pets	Tailored Pet Solutions	0.00E+00	0.00E+00	0.00E+00
Wastewater	Wastewater Discharge Water Quality Assessment	0.00E+00	0.00E+00	0.00E+00

Table G-3: Estimated Potential *E. coli* Load Reduction Calculations

Assumptions, Sources and Conversions		Comal River	Dry Comal Creek	Total for Watershed
***E. coli* Goals Based Upon Geomean Data**				
Target E. Coli Concentration (CFU/mL)	Refer to Chapter 4 in the WPP	113	113	113
Median (i.e., at Medium Flows) E. coli Load Reduction Needed to Meet Target (Percentage)	Refer to Chapter 4 in the WPP	50%	34%	50%
Median (i.e., at Medium Flows) E. coli Load (CFU/year)	Refer to Chapter 4 in the WPP	2.53E+14	1.15E+12	2.54E+14
Median (i.e., at Medium Flows) E. coli Target (CFU/year)	Refer to Chapter 4 in the WPP	1.26E+14	7.57E+11	1.27E+14
Median (i.e., at Medium Flows) E. coli Load Reduction Needed to Meet Target (CFU/year)	Refer to Chapter 4 in the WPP	1.27E+14	3.92E+11	1.28E+14
Median (i.e., at Medium Flows) E. coli Load (CFU/day)	**Refer to Chapter 4 in the WPP**	**6.96E+11**	**3.15E+09**	**7.00E+11**
Median (i.e., at Medium Flows) E. coli Target (CFU/day)	**Refer to Chapter 4 in the WPP**	**3.47E+11**	**2.07E+09**	**3.49E+11**
Median (i.e., at Medium Flows) E. coli Load Reduction Needed to Meet Target (CFU/day)	**Refer to Chapter 4 in the WPP**	**3.50E+11**	**1.07E+09**	**3.51E+11**
Median Percentage of E. coli Load From Each Source Based on BST Results				
Overabundant Urban Deer	Based on Median Value of BST Results for Non-avian Wildlife, Assume 70% Deer	34.0%	25.9%	-
Urban Non-Native Avian Wildlife	Based on Median Value of BST Results for Avian Wildlife	17.0%	21.5%	-
Feral Hogs	Based on Median Value of BST Results for Non-avian Wildlife, Assume 30% Feral Hogs	14.6%	11.1%	-
Livestock	Based on Median Value of BST Results for Avian and Non-avian Livestock (non-avian livestock included cattle, sheep and goats)	16.0%	25.0%	-
OSSFs	Based on Median Value of BST Results for Human; Assume 33% of Human	1.3%	2.5%	-
Pets	Based on Median Value of BST Results for Pets	4.0%	4.0%	-
Wastewater	Based on Median Value of BST Results for Human; Assume 33% of Human	1.3%	2.5%	-
Unidentified	Not addressed in current WPP	11.9%	7.4%	-
Total Percentage	**Refer to Chapter 4 in the WPP**	**100%**	**100%**	**-**
Potential E. coli Loads per Source Based on Measured Loads and BST Results				
Overabundant Urban Deer (CFU/day)	Based on Median E. coli Load and BST Results	2.36E+11	8.15E+08	2.37E+11
Urban Non-Native Avian Wildlife (CFU/day)	Based on Median E. coli Load and BST Results	1.18E+11	6.76E+08	1.19E+11
Feral Hogs (CFU/day)	Based on Median E. coli Load and BST Results	1.01E+11	3.49E+08	1.02E+11
Livestock (CFU/day)	Based on Median E. coli Load and BST Results	1.11E+11	7.87E+08	1.12E+11
OSSFs (CFU/day)	Based on Median E. coli Load and BST Results	9.19E+09	7.79E+07	9.27E+09
Pets (CFU/day)	Based on Median E. coli Load and BST Results	2.79E+10	1.26E+08	2.80E+10
Wastewater (CFU/day)	Based on Median E. coli Load and BST Results	9.19E+09	7.79E+07	9.27E+09
Unidentified (CFU/day)	Based on Median E. coli Load and BST Results	8.26E+10	2.32E+08	8.28E+10
Total Potential E. coli Load (CFU/day)	**Not accounting for stormwater, which duplicates individual E. coli sources**	**6.96E+11**	**3.14E+09**	**7.00E+11**
Overabundant Urban Deer				
	Estimated number of deer in watershed, Source: Bates, 2016	5123	22783	27906
	Average daily Fecal coli production rate per deer (CFU/day), Source: EPA, 2001	3.50E+08	3.50E+08	3.50E+08
	E. coli per deer (CFU/day/deer), Conversion Factor of 0.63 E. coli per Fecal coli, Source: Source: EPA, 2001; Porras, et al., 2013	2.21E+08	2.21E+08	2.21E+08
	Total Potential E. coli for all Deer (CFU/day)	1.13E+12	5.02E+12	6.15E+12
	Calculated Calibration Factor (percentage based impact factor that accounts for proximity to stream, average annual stream flow, accuracy of assumptions for population and E. coli concentrations, etc.)	2.09E-01	1.62E-04	3.86E-02
Wildlife Do-Not-Feed Ordinance and Campaign within City Limits				
	GOAL: Pass the ordinance and begin enforcement	Completion	Completion	Completion
	Percentage of deer population reduced accounting for population increase over time, Source: Abbott and Ferguson, 2012	25%	1%	5%
	Number of deer reduced	1281	228	1281
	Estimated Potential E. coli Reduction (CFU/day)	**5.91E+10**	**8.15E+06**	**5.91E+10**

Table G-3: Estimated Potential *E. coli* Load Reduction Calculations (Continued)

	Assumptions, Sources and Conversions	Comal River	Dry Comal Creek	Total for Watershed
Deer Population Assessment				
	Estimated Potential Reduction in E. coli (CFU/day), Assessments are not intended to reduce the population, but to inform the extent of implementation required for the other BMPs selected.	**0.00E+00**	**0.00E+00**	**0.00E+00**
Voluntary Do-Not-Feed Wildlife Campaign in Rural Neighborhoods				
	GOAL: Number of residents and visitors reached	1000	200	1200
	Percentage of residents and visitors that change behavior based on education, Source: Fore, L., 2013 and Green et al., 2000	10%	10%	10
	Number of people impacted	100	20	120
	Number of deer reduced per person	1	5	-
	Number of deer impacted	100	100	200
	Estimated Potential E. coli Reduction (CFU/day)	**4.62E+09**	**3.58E+06**	**4.62E+09**
Wildlife Management Workshops				
	GOAL: Number of residents and visitors reached	500	-	500
	Percentage of residents and visitors that change behavior based on education, Source: Fore, L., 2013 and Green et al., 2000	10%	-	10
	Number of people impacted	50	-	50
	Number of deer reduced per person	1	-	-
	Number of deer impacted	50	-	50
	Estimated Potential E. coli Reduction (CFU/day)	**2.31E+09**	**0.00E+00**	**2.31E+09**
Active Management of Deer with City Council Approval				
	GOAL: Number of deer reduced in the urban area, Source: recommendation from TPWD	1200	200	1400
	Percentage of deer population reduced	23%	1%	5%
	Number of deer reduced	1200	200	1400
	Estimated Potential E. coli Reduction (CFU/day)	**5.54E+10**	**7.15E+06**	**5.54E+10**
Total number of deer controlled or reduced		2631	528	3159
Total percentage of deer controlled or reduced		51%	2%	11%
TOTAL ESTIMATED POTENTIAL LOAD REDUCTION (CFU/day)		**1.21E+11**	**1.53E+07**	**1.21E+11**
Urban Non-Native Avian Wildlife				
	Estimated number of ducks and geese in Landa Park, Source: Surveys conducted by the City of New Braunfels	253	-	253
	Estimated number of vultures in Landa Park, Source: Surveys conducted by the City of New Braunfels	35	-	35
	Average daily Fecal coli production rate per bird (CFU/day), Source: EPA, 2001	1.42E+10	-	1.42E+10
	E. coli per bird (CFU/day/bird), Conversion Factor of 0.63 E. coli per Fecal coli, Source: EPA, 2001; Porras, et al., 2013	8.97E+09	-	8.97E+09
	E. coli per vulture (CFU/day/vulture), assumed based upon literature suggesting that vulture digestive systems are very effective at destroying pathogens, Source: TPWD, 2017 and Roggenbuck, 2014	0.00E+00		0.00E+00
	Total Potential E. coli for all Birds (CFU/day)	2.27E+12	-	2.58E+12
	Calculated Calibration Factor (percentage based impact factor that accounts for proximity to stream, average annual stream flow, accuracy of assumptions for population and E. coli concentrations, etc.)	5.22E-02	-	-
Wildlife Do-Not-Feed Ordinance and Campaign within City Limits				
	GOAL: Pass ordinance and begin enforcement	Completion	-	Completion
	Percentage of ducks and geese reduced, Source: Abbott and Ferguson, 2012	25%	0%	25%
	Number of ducks and geese reduced	63.25	-	63.25
	Estimated Potential E. coli Reduction (CFU/day)	**2.96E+10**	**0.00E+00**	**2.96E+10**
Non-Native Duck and Goose Population Assessment				
	Estimated Potential Reduction in E. coli (CFU/day), Assessments are not intended to reduce the population, but to inform the extent of implementation required for the other BMPs selected.	**0.00E+00**	**0.00E+00**	**0.00E+00**

Table G-3: Estimated Potential *E. coli* Load Reduction Calculations (Continued)

	Assumptions, Sources and Conversions	Comal River	Dry Comal Creek	Total for Watershed
Discourage Non-Native Ducks and Geese from Gathering in the Park				
	GOAL: Number of tactics implemented	2	-	2
	Percentage of ducks, geese and vultures reduced, Source: JBSA 2016	30%	0%	-
	Number of ducks and geese reduced	76	-	76
	Estimated Potential E. coli Reduction (CFU/day)	**3.55E+10**	**0.00E+00**	**3.55E+10**
Rapid Removal of Dead Animals				
	GOAL: Continuation of existing program to remove dead animals	Completion	-	Completion
	Percentage of vultures reduced, Source: Margalida and Colomer, 2012	50%	-	-
	Number of vultures reduced	12%	-	12%
	Estimated Potential E. coli Reduction (CFU/day)	**0.00E+00**	**0.00E+00**	**0.00E+00**
Wildlife Management Workshops				
	GOAL: Number of residents and visitors reached	500	-	500
	Percentage of residents and visitors that change behavior based on education, Source: Fore, L., 2013 and Green et al., 2000	10%	-	10
	Number of people impacted	50	-	50
	Number of ducks and geese reduced per person	0.5	-	-
	Number of ducks and geese impacted	25	-	25
	Estimated Potential E. coli Reduction (CFU/day)	**1.17E+10**	**0.00E+00**	**1.17E+10**
Trap Non-Native Ducks and Geese				
	GOAL: Estimated number of ducks and geese trapped	50	0	50
	Percentage of population relocated, based upon limited locations for relocation and difficulty of trapping, Source: USEPA, 2016	20%	-	20%
	Estimated E. coli Reduction (CFU/day)	**9.25E+07**	**0.00E+00**	**9.25E+07**
Oil Coat Non-Native Duck Eggs				
	GOAL: Hire a professional contractor	Completion	-	Completion
	Percentage of population targeted	15%	0%	-
	Effectiveness when implemented following correct schedule, Source: Baker et al., 1993	100%	100%	100%
	Number of ducks and geese reduced	38	-	38
	Estimated Potential E. coli Reduction (CFU/day)	**1.78E+10**	**0.00E+00**	**1.78E+10**
Total number of ducks and geese controlled or reduced		252	-	252
Total percentage of ducks and geese controlled or reduced		100%	-	100%
Estimated E. coli Reduction (CFU/day)		**9.47E+10**	**0.00E+00**	**9.47E+10**
Feral Hogs				
	Estimated number of feral hogs in watershed, Source: Luepke, 2016 and Stakeholders	33	1438	1471
	Average daily Fecal coli production rate per hog (CFU/day), Source: EPA, 2001	1.10E+10	1.10E+10	1.10E+10
	E. coli per hog (CFU/day/hog), Conversion Factor of 0.63 E. coli per fecal coliform, Source: EPA, 2001; Porras, et al., 2013	6.93E+09	6.93E+09	6.93E+09
	Total Potential E. coli for all Hogs (CFU/day)	2.29E+11	9.97E+12	1.02E+13
	Calculated Calibration Factor (percentage based impact factor that accounts for proximity to stream, average annual stream flow, accuracy of assumptions for population and E. coli concentrations, etc.)	4.43E-01	3.50E-05	9.98E-03
Feral Hog Workshops				
	GOAL: Estimated average number of landowners reached	5	50	55
	Percentage of landowners (in addition to those participating in the bounty program) reached who eliminate feral hogs, Source: Green and Skumatz, 2000; Fore, L., 2013; TAMU, 2010	10%	10%	10%
	Number of landowners (in addition to those participating in the bounty program) reached who eliminate feral hogs	1	5	6
	Average number of feral hogs eliminated per landowner	5	10	15
	Number of feral hogs eliminated	3	50	83
	Estimated Potential E. coli Reduction (CFU/day)	**7.68E+09**	**1.21E+07**	**7.69E+09**

Table G-3: Estimated Potential *E. coli* Load Reduction Calculations (Continued)

	Assumptions, Sources and Conversions	Comal River	Dry Comal Creek	Total for Watershed
Bounty Program				
	GOAL: Number of feral hogs reduced	25	1150	1175
	Feral hog population reduction (percentage), Source: California Hunting Post, 2016; Koski, 2016; Plum Creek WPP Update, 2014	80%	80%	-
	Estimated Potential E. coli Reduction (CFU/day)	**7.80E+10**	**2.79E+08**	**7.83E+10**
Trapping Intensity Assessment				
	Estimated Potential Reduction in E. coli (CFU/day), Tracking are not intended to reduce the population, but to inform the extent of implementation required for the other BMPs selected.	**0.00E+00**	**0.00E+00**	**0.00E+00**
Feral Hog Website				
	Estimated Potential Reduction in E. coli (CFU/day), Website not intended to reduce the population, but to compliment the tracking BMP and outreach and education BMP.	**0.00E+00**	**0.00E+00**	**0.00E+00**
Total number of feral hogs reduced		28	1200	1228
Total percentage of feral hogs reduced		85%	83%	84%
TOTAL ESTIMATED POTENTIAL LOAD REDUCTION (CFU/day)		**8.57E+10**	**2.92E+08**	**8.60E+10**
Livestock				
	Estimated number of cattle in watershed, Source: National Agricultural Statistics Service, 2016 and Homer, et al., 2015	320	2428	2748
	Average daily Fecal coli production rate per cattle (CFU/day), Source: EPA, 2001	5.27E+10	5.27E+10	5.27E+10
	E. coli per cattle (CFU/day/cattle), Conversion Factor of 0.63 E. coli per fecal coliform, Source: EPA, 2001; Porras, et al., 2013	3.32E+10	3.32E+10	3.32E+10
	Estimated number of sheep and goats in watershed, Source: National Agricultural Statistics Service, 2016 and Homer, et al., 2015	309	2192	2501
	Average daily fecal coliform production rate per sheep and goats (CFU/day), Source: EPA, 2001	1.20E+10	1.20E+10	-
	E. coli per sheep and goats (CFU/day/sheep and goats), Conversion Factor of 0.63 E. coli per fecal coliform, Source: EPA, 2001; Porras, et al., 2013	7.56E+09	7.56E+09	-
	Total Potential E. coli for all Livestock (CFU/day)	1.30E+13	9.72E+13	1.10E+14
	Calculated Calibration Factor (percentage based impact factor that accounts for proximity to stream, average annual stream flow, accuracy of assumptions for population and E. coli concentrations, etc.)	8.60E-03	8.09E-06	1.02E-03
Water Quality Management Plans (WQMPs)				
	GOAL: Estimated number of operations that could be targeted for WQMPs based upon Stakeholder Knowledge	0	60	60
	Estimated number of cattle addressed per WQMP based upon Stakeholder Knowledge, stocking rates, and allowance for overstocking	20	20	20
	Estimated number of sheep and goats addressed per WQMP	20	20	20
	BMP Effectiveness Rate (Percentage), Reference: Buck Creek ad Attoyac Bayou WPPs (Tables F-2 and D-2 respectively) based upon likely BMPs for livestock	0.62	0.62	-
	Anticipated reduction in cattle due to land use changes	10	400	0
	Anticipated reduction in sheep and goats due to land use changes	10	200	0
	Estimated Potential E. coli Reduction (CFU/day)	**0.00E+00**	**3.65E+08**	**3.65E+08**
Livestock Outreach and Education				
	GOAL: Estimated number of operations (in addition to those implementing WQMPs) reached, Source: Stakeholder identification of operations	10	50	60
	Percentage of operations (in addition to those implementing WQMPs) reached who implement BMPs, Source: Fore, L., 2013; Green and Skumatz, 2000; discussions with Stakeholders	40%	40%	10%
	Number of operations implementing BMPs	4.0	20.0	6.0
	Estimated number of cattle addressed per operation, Assumed smaller operations targeted	20	20	20
	Estimated number of sheep and goats addressed per operation, Assumed smaller operations targeted	20	20	20
	BMP Effectiveness Rate (Percentage), Source: Buck Creek and Attoyac Bayou WPPs (Tables F-2 and D-2 respectively) based upon likely BMPs for livestock	0.62	0.62	-
	Estimated Potential *E. coli* Reduction (CFU/day)	**1.74E+10**	**8.18E+07**	**1.75E+10**

Table G-3: Estimated Potential *E. coli* Load Reduction Calculations (Continued)

Assumptions, Sources and Conversions		Comal River	Dry Comal Creek	Total for Watershed
Total number of sheep and goats controlled or reduced		90	1800	1890
Total percentage of sheep and goats controlled or reduced		29%	82%	76%
Total number of cattle controlled or reduced		90	2000	2090
Total percentage of cattle controlled or reduced		28%	82%	76%
TOTAL ESTIMATED POTENTIAL LOAD REDUCTION (CFU/day)		**1.74E+10**	**4.47E+08**	**1.78E+10**
OSSFs				
	Number of OSSFs in the Watershed, Source: Comal County Engineer's Office, 2016; City of New Braunfels, 2016	17	2783	2800
	Estimated Percent of Failing OSSFs, Source: Reed, Stowe & Yanke, LLC, 2001	12%	12%	12%
	Estimated Number of Failing OSSFs	2	334	336
	Fecal coli in OSSF Effluent (CFU/mL), Source: Metcalf and Eddy, 1991; Canter and Knox, 1985; Cogger and Carlie, 1984	1.00E+05	1.00E+05	1.00E+05
	OSSF Volume (gal/day), Source: Horsley and Witten, 1996; Geronimo and Alligator Creek WPP; Mill Creek WPP	210	210	210
	Fecal coliform per OSSF (CFU/day/OSSF), Conversion Factor of 3758.4mL/1gal	7.89E+10	7.89E+10	7.89E+10
	E. coli per OSSF (CFU/day/OSSF), Conversion Factor of 0.63 E. coli per fecal coliform, Source: EPA, 2001; Porras, et al., 2013	4.97E+10	4.97E+10	4.97E+10
	Total Potential E. coli per all Failing OSSFs	9.94E+10	1.66E+13	1.67E+13
	Calculated Calibration Factor (percentage based impact factor that accounts for proximity to stream, average annual stream flow, accuracy of assumptions for population and E. coli concentrations, etc.)	9.24E-02	4.69E-06	5.55E-04
OSSF Education and Assistance				
	GOAL: Number of OSSF owners reached	5	245	250
	Percentage of households that change behavior based on education, Source: Green et al., 2000, Fore, L., 2013 and Houston-Galveston Area Council and conversations with Comal County Representative who provides OSSF Training	30%	30%	-
	Estimated Number of FAILING OSSFs Improved over 10 Years	2	74	75
	Estimated Potential E. coli Reduction (CFU/day)	**6.90E+09**	**1.71E+07**	**6.91E+09**
Mandatory OSSF Inspection and Maintenance Program				
	GOAL: Estimated Number of OSSFs Inspected per Week	0	2	2
	Estimated Percentage of OSSFs Inspected that are Failing, based upon program targeting OSSFs most likely failing, Source: Conversations with Comal County Representative	25%	25%	25%
	Percentage of Failing OSSFs Improved	100%	100%	100%
	Number of OSSFs Improved per Week	0.00	0.50	0.50
	Number of OSSFs Improved per 10 Years	0.0	260.0	260.0
	Estimated Potential E. coli Reduction (CFU/day)	**0.00E+00**	**6.06E+07**	**6.06E+07**
TOTAL Number of OSSFs Improved over 10 Years		2	334	335
TOTAL Percentage of FAILING OSSFs Improved over 10 Years		75%	100%	100%
TOTAL ESTIMATED POTENTIAL LOAD REDUCTION (CFU/day)		**6.90E+09**	**7.78E+07**	**6.97E+09**
Stormwater				
	Estimated Potential Total E. coli from Stormwater (CFU/day)	3.68E+11	2.31E+09	3.70E+11
Non-Structural Stormwater BMPs Outside of the City's MS4 Jurisdiction				
	GOAL: Number of new practices implemented outside of the MS4 program, such as signage, monitoring, recognition program, etc.	0	4	
	Estimated percentage change in E. coli per practice, Source: Fore, L., 2013 for reporting of illicit discharges	-	10%	-
	Estimated Potential E. coli Reduction (CFU/day)	**0.00E+00**	**2.31E+08**	**2.31E+08**
Stormwater Outreach and Education				
	GOAL: Number of community members reached	300	300	600
	Percentage of residents and businesses that change behavior based on education program, Source: Fore, L., 2013	40%	40%	-
	Estimated percentage change in E. coli per resident	0.05%	0.05%	-
	Estimated Potential E. coli Reduction (CFU/day)	**2.21E+10**	**1.38E+08**	**2.22E+10**

Table G-3: Estimated Potential *E. coli* Load Reduction Calculations (Continued)

	Assumptions, Sources and Conversions	Comal River	Dry Comal Creek	Total for Watershed
Engineering Analysis of Opportunities for Structural Stormwater BMPs				
	GOAL: Number of structural BMPs implemented	2	3	5
	Assumed percent of E. coli from wildlife carried by stormwater or urban runoff to streams	70%	90%	-
	Assumed percent of stormwater and urban runoff addressed by structural BMPs	20%	20%	-
	Potential effectiveness of BMPs at reducing E. coli, Source: Clary, J. et al., 2008	50%	50%	
	Estimated Potential E. coli Reduction (CFU/day)	**2.58E+10**	**2.08E+08**	**2.60E+10**
TOTAL ESTIMATED POTENTIAL LOAD REDUCTION (CFU/day)		**4.78E+10**	**5.77E+08**	**4.84E+10**
Pet Waste				
	Estimated number of dogs in watershed, Source: American Veterinary Medical Association, 2007 and Comal County and Guadalupe County Tax Assessor's Parcel Database	3490	8198	11688
	Average daily fecal coliform production rate per dog (CFU/day), Source: EPA, 2001	5.00E+09	5.00E+09	5.00E+09
	E. coli per dog (CFU/day/dog), Conversion Factor of 0.63 E. coli per fecal coliform, Source: EPA, 2001; Porras, et al., 2013	3.15E+09	3.15E+09	3.15E+09
	Total Potential E. coli for all Dogs (CFU/day)	1.10E+13	2.58E+13	3.68E+13
	Calculated Calibration Factor (percentage based impact factor that accounts for proximity to stream, average annual stream flow, accuracy of assumptions for population and E. coli concentrations, etc.)	2.53E-03	4.87E-06	7.60E-04
Pet Owner Outreach and Education				
	GOAL: Number of households reached	400	400	800
	Number of dogs per household, Source: American Veterinary Medical Association, 2007	0.8	0.8	-
	Percentage of households that change behavior based on education, Source: Green and Skumatz, 2000; Fore, L., 2013; Montgomery County, 2014	50%	50%	-
	Number of dogs impacted	160	160	320
	Estimated Potential E. coli Reduction (CFU/day)	**1.28E+09**	**2.46E+06**	**1.28E+09**
Pet Waste Stations				
	GOAL: Number of pet waste stations installed	180	20	200
	Percentage of dogs walked in public areas, Source: Montgomery County, 2014	50%	50%	-
	Number of dogs walked in public areas	1745	4099	5844
	Percentage of owners not picking up waste in public areas, Source: Washington State Dept. of Ecology	40%	40%	-
	Percentage of owners not picking up waste in public areas, Source: Washington State Dept. of Ecology	698	1640	2338
	Percentage of owners not picking up waste in public areas that will if waste stations are readily available, Source: Montgomery County, 2014	35%	35%	-
	Percentage of public areas already covered with pet waste stations in New Braunfels, Source: Conversations with City of New Braunfels	40%	40%	-
	Number of dogs whose waste will get picked up with additional waste stations	147	344	491
	Estimated Potential E. coli Reduction (CFU/day)	**1.17E+09**	**5.29E+06**	**1.18E+09**
Pet Code Enforcement				
	GOAL: Number of households reached	180	20	200
	Number of dogs per household, Source: American Veterinary Medical Association, 2007	0.8	0.8	-
	Percentage of households that change behavior based on stricter enforcement of the code, Source: Montgomery County, 2014	10%	10%	-
	Number of dogs impacted	14.4	1.6	16
	Estimated Potential E. coli Reduction (CFU/day)	**1.15E+08**	**2.46E+04**	**1.15E+08**
Tailored Pet Solutions				
	Estimated Potential Reduction in E. coli (CFU/day), Unquantifiable at this time as locations are unknown.	**0.00E+00**	**0.00E+00**	**0.00E+00**

Table G-3: Estimated Potential *E. coli* Load Reduction Calculations (Continued)

Assumptions, Sources and Conversions		Comal River	Dry Comal Creek	Total for Watershed
Total number of dogs controlled		321	506	827
Total percentage of dogs controlled		9%	6%	7%
TOTAL ESTIMATED POTENTIAL LOAD REDUCTION (CFU/day)		**2.56E+09**	**7.77E+06**	**2.57E+09**
Wastewater				
	Number of wastewater discharges in the Watershed	0	2	2
Wastewater Discharge Water Quality Assessment				
	Estimated Potential Reduction in E. coli (CFU/day), Tracking is not intended to improve, but to inform whether additional BMPs are required.	**0.00E+00**	**0.00E+00**	**0.00E+00**
TOTAL ESTIMATED POTENTIAL LOAD REDUCTION (CFU/day)		**0.00E+00**	**0.00E+00**	**0.00E+00**

TOTAL ESTIMATED POTENTIAL LOAD REDUCTION (CFU/day)				
Source		**Comal River**	**Dry Comal Creek**	**Total Watershed**
Overabundant Urban Deer (CFU/day)		1.21E+11	1.53E+07	1.21E+11
Urban Non-Native Avian Wildlife (CFU/day)		9.47E+10	0.00E+00	9.47E+10
Feral Hogs (CFU/day)		8.57E+10	2.92E+08	8.60E+10
Livestock (CFU/day)		1.74E+10	4.47E+08	1.78E+10
OSSFs (CFU/day)		6.90E+09	7.78E+07	6.97E+09
Stormwater (CFU/day)		4.78E+10	5.77E+08	4.84E+10
Pet Waste (CFU/day)		2.56E+09	7.77E+06	2.57E+09
Wastewater (CFU/day)		0.00E+00	0.00E+00	0.00E+00
Total Potential E. coli Reduction (CFU/day)	**PASSES TARGET REDUCTION**	**3.76E+11**	**1.42E+09**	**3.78E+11**
Median (i.e., at Medium Flows) E. coli Load Reduction Needed to Meet Target (CFU/day)		**3.50E+11**	**1.07E+09**	**3.51E+11**
Factor of Safety [Difference Between Potential Reduction and Goal (CFU/day)		**0.08**	**0.32**	**0.08**

Appendix H: Citations

Comal County Engineer's Office. (2008, June). Recent Subdivision Development in Unincorporated Comal County. Retrieved July 22, 2017, from http://www.cceo.org/documents/Comal_Subdivisions_June2008.jpg

Eckhardt, G. (n.d.). Comal Springs and Landa Park. Retrieved July 31, 2017, from http://www.edwardsaquifer.net/comal.html

Eckhardt, G. (n.d.). Endangered Species of the Edwards Aquifer. Retrieved July 31, 2017, from http://www.edwardsaquifer.net/species.html

U.S. Census Bureau. (2016, July 1). QuickFacts for New Braunfels, Texas. Retrieved July 22, 2017, from https://www.census.gov/quickfacts/fact/table/newbraunfelscitytexas/PST045216

SELECT Citations

American Veterinary Medical Association. (2007). U.S. Pet Ownership and Demographics Source Book. Schaumburg, IL: Center for Information Management, American Veterinary Medical Association.

Bates, E. (2016, March 17). Discussion on County Deer Densities. (R. Bowman, Interviewer).

City of Austin. (1990). Stormwater Pollutant Loading Characteristics for Various Land Uses in the Austin Area. Austin, TX: City of Austin.

City of Austin. (1997). Characterization of Stormwater Pollution for the Austin, TX Area. Austin, TX: City of Austin.

City of Austin. (2009). Stormwater Runoff Quality and Quantity from Small Watersheds in Austin. Austin, TX: City of Austin.

City of New Braunfels. (2016). On-Site Sewage Facilities. Retrieved from City of New Braunfels: http://www.nbtexas.org/index.aspx?NID=543.

Comal County Engineer's Office. (2016). On-Site Septic Systems GIS Dataset. Retrieved from Comal County Engineer's Office: http://www.cceo.org/environmental/septic_search.asp.

ESRI Water Resources Team. (2015, June 25). Surface Water (Arc Hydro). Retrieved from ArcGIS Resources: http://resources.arcgis.com/en/communities/hydro/01vn00000010000000.htm.

Geronimo and Alligator Creeks Watershed Partnership. (2012). *Geronimo and Alligator Creeks Watershed Protection Plan*.

Glick, R. (2016, March 31). Discussion about Modeling *E. coli* from Urban Runoff. (R. Bowman, Interviewer).

Google Earth. (2016, April). Dry Comal Watershed. Retrieved March 2016, from http://www.earth.google.com.

Homer, C., et al. (2015). Completion of the 2011 National Land Cover Database for the conterminous United States-Representing a decade of land cover change information. Photogrammetric Engineering and Remote Sensing, 81(5), 345-354.

Luepke, T. (2016, March 24). Discussion on Feral Hog Densities. (R. Bowman, Interviewer).

Morrison, D., Munster, C., Karthikeyan, R., & Jacob, J. (2013). Assessment of *E. coli* Pollution from Failing On-Site Sewage Facilities to Dickinson Bayou. Austin, TX: Texas General Land Office - Coastal Management Program.

Napier, J., Rahn, K., & Kramer, S. (2015). Homeowners' Knowledge and Responsibilities of Residential Wastewater Treatment Systems in Rural Texas. Windsor, CO: Associated Schools of Construction.

National Agricultural Statistics Service. (2016, April). Quick Stats. Retrieved from United States Department of Agriculture, National Agricultural Statistics Service: https://quickstats.nass.usda.gov/.

National Agricultural Statistics Survey. (2014). Cattle Methodology and Quality Measures. Washington, D.C.: Agricultural Statistics Board, United States Department of Agriculture. Retrieved from http://www.nass.usda.gov/.

PBS&J. (2000). Predicting Effects of Urban Development on Water Quality in the Cities of New Braunfels, San Marcos, Seguin and Victoria. Austin, TX: Guadalupe-Blanco River Authority and the Texas Natural Resources Conservation Commission.

Reed, Stowe & Yanke, LLC. (2001). Study to Determine the Magnitude of, and Reasons for, Chronically Malfunctioning On-Site Sewage Facility Systems in Texas. Austin, TX: Texas On-Site Wastewater Treatment Research Council.

Teague, A., Karthikeyan, R., & Babbar-Sebens, M. (2009). Spatially Explicit Load Enrichment Calculation Tool to Identify Potential *E. coli* Sources in Watersheds. American Society of Agricultural and Biological Engineers, 52(4), 1109-1120.

U.S. Environmental Protection Agency. (2001). Protocol for Developing Pathogen TMDLs. EPA 841-R-00-002. Office of Water (4503F), United States Environmental Protection Agency, Washington, DC. 132 pp.

U.S. Geological Survey, The National Map. (2016, January 1). 3DEP Products and Services. Retrieved 2016, from The National Map, 3D Elevation Web page: http://nationalmap.gov/3dep_prodserv.html.

Water Quality Planning Division, Office of Water. (2012). Eight Total Maximum Daily Loads for Indicator Bacteria in Dickinson Bayou and Three Tidal Tributaries. Austin, TX: Texas Center for Environmental Quality.

Load Duration Curve Citations

Cleland, B. (2003). TMDL Development From the "Bottom Up" e Part III: Duration Curves and Wet-Weather Assessments. National TMDL Science and Policy 2003e WEF Specialty Conference.

U.S. Environmental Protection Agency. (2007). An approach for Using Load Duration Curves in the Development of TMDLs. Retrieved from: www.epa.gov/owow/tmdl/techsupp.html.

Implementation Schedule, Estimated Load Reductions, and Estimated Cost Citations

AACE International. (2005). *Cost Estimate Classification System – As Applied in Engineering Procurement, and Construction for the Process Industries.* AACE International Recommended Practice No. 18R-97. Morgantown, WV: AACE International.

Abbott, R. and Ferguson, T. (2012). Deer in Northwest Austin Observations and Recommendations. Presented by DeerAustin to the Austin City Council, Public Health and Human Services Committee. Retrieved July 1, 2017 from http://www.austintexas.gov/edims/document.cfm?id=165899.

Alderson, J. (2008). Assessment of the Urban Public's Knowledge of Whitetailed Deer Management in Two Texas Communities. Master's Thesis. Texas A&M University.

American Veterinary Medical Association. (2007). U.S. Pet Ownership and Demographics Source Book. Schaumburg, IL: Center for Information Management, American Veterinary Medical Association.

Attoyac Bayou Watershed Partnership. (2014). *Attoyac Bayou Watershed Protection Plan*.

Baker, S. J., C. J. Feare, C. J. Wilson, D. S. Malam, and G. R. Sellars. (1993). Prevention of breeding of Canada geese by coating eggs with liquid paraffin. International Journal of Pest Management 39:246‑249.

Bounty Hunting Hogs in Texas. (2016, April 28). Retrieved April 20, 2017, from https://huntingboar.org/b/bounty-hunting-hogs-texas/3688

Buck Creek Watershed Partnership. (2012). *Buck Creek Watershed Protection Plan*.

Canter, L. W., & Knox, R. C. (1991). *Septic tank system effects on ground water quality*. Chelsea, MI: Lewis.

City of New Braunfels. (2016). On-Site Sewage Facilities. Retrieved from City of New Braunfels: http://www.nbtexas.org/index.aspx?NID=543.

Clary J., Jones J., Urbonas B., Quigley M., Strecker E., Wagner T. (2008). Can stormwater BMPs remove bacteria? New findings from the International Stormwater BMP Database. Stormwater Magazine. 2008; 9:14.

Cogger, C.G. and B.L. Carlile. (1984). Field Performance of Conventional and Alternative Septic Systems in Wet Soils. J. Env. Qual. 13:137-142.

Comal Appraisal District. (2017). Retrieved from http://comalad.org/index.php/Appraisal_Information

Comal County Engineer's Office. (2016). On-Site Septic Systems GIS Dataset. Retrieved from Comal County Engineer's Office: http://www.cceo.org/environmental/septic_search.asp.

Considerations for the Selection and Use of Pet Waste Collection Systems in Public Areas [PDF].

Egg Oiling with Liquid Paraffin BP. Retrieved from http://www.pigeoncontrolresourcecentre.org/html/reviews/egg-oiling-liquid-paraffin-bp.html.

EPA. (2001). Protocol for Developing Pathogen TMDLs. Office of Water, United States Environmental Protection Agency.

EPA. (2006). An Approach for Using Load Duration Curves in Developing TMDLs. Office of Wetlands, Oceans, and Watersheds, United States Environmental Protection Agency.

Fore, L. S. (2013). Effectiveness of Public Education and Outreach Programs for Reducing Impacts of Stormwater on Rivers and Streams (Rep.). Seattle, Washington: Statistical Design.

Geronimo and Alligator Creeks Watershed Partnership. (2012). *Geronimo and Alligator Creeks Watershed Protection Plan*.

Green, J., & Skumatz, L. A. (n.d.). Evaluating the Impacts of Education/Outreach Programs: Lessons on Impacts, Methods, and Optimal Education. Consumer Behavior and Non-Energy Effects, 8, 123-136.

Horsley & Witten, Inc. (1996). Identification and Evaluation of Nutrient and Bacterial Loadings to Maquoit Bay, Brunswick, and Freeport, Maine. Casco Bay Estuary Project, Portland, ME

Houston-Galveston Area Council. (n.d.). Pollution Prevention Fact Sheet: Septic System Controls.

International Stormwater BMP Database. (2014, December). Retrieved from http://www.bmpdatabase.org/Docs/2014%20Water%20Quality%20Analysis%20Addendum/BMP%20Database%20Categorical_StatisticalSummaryReport_December2014.pdf

Jaeckle, P. (2016). Bounty Hunting Hogs in Texas. Retrieved from https://huntingboar.org/b/bounty-hunting-hogs-texas/3688

Joint Base San Antonio-Randolph Public Affairs. (2016, July 20). BASH program decreases bird strikes, makes air space safer for pilots. *Joint Base San Antonio News*. Retrieved from http://www.jbsa.mil/News/News/Article/850533/bash-program-decreases-bird-strikes-makes-air-space-safer-for-pilots/

Klingener, N. (Photographer). (2016, November 9). *Signs all over Big Pine Key warn against feeding Key deer.* [digital image]. Retrieved from http://wlrn.org/post/saving-key-deer-means-new-relationships-wild-animals

Koski, R. (2016, February 11). Bounty Program in Calwell Co. for Feral Hogs may be Model for State. Retrieved from http://www.fox7austin.com/news/local-news/89152214-story

Luepke, T. (2016, March 24). Discussion on Feral Hog Densities. (R. Bowman, Interviewer).

Margalida, A., & Colomer, M. A. (2012). Modelling the effects of sanitary policies on European vulture conservation. Scientific Reports, (753).

Metcalf and Eddy, Inc. (1991) Wastewater Engineering: Treatment, Disposal, and Reuse. 3rd Edition, McGraw-Hill, Inc., Singapore.

Mill Creek Watershed Partnership. (2015). *Mill Creek Watershed Protection Plan*.

Montgomery County. (n.d.). *Public Outreach and Stewardship Workplan: Pet Waste Management.* Author. Retrieved from https://www.montgomerycountymd.gov/DEP/Resources/Files/ReportsandPublications/Water/Countywide%20Implementation%20Strategy/Pet-waste-Factsheet-September2014.pdf

Plum Creek Watershed Partnership. (2008). *Plum Creek Watershed Protection Plan*.

Pollution Prevention Fact Sheet: Septic System Controls. Retrieved from https://www.h-gac.com/community/water/ossf/Pollution-Prevention-Septic-System.pdf

Porras, A., Richter, A., & Herrington, C. (2013). Relationship of fecal indicator bacteria to demographic patterns and land use. *City of Austin Watershed Protection*. Retrieved from http://www.austintexas.gov/watershed_protection/publications/document.cfm?id=203918

Public Outreach and Stewardship workplan [PDF]. (2014, September). Retrieved from http://www.jbsa.mil/News/News/Article/850533/bash-program-decreases-bird-strikes-makes-air-space-safer-for-pilots/

Reed, Stowe & Yanke, LLC. (2001). Study to Determine the Magnitude of, and Reasons for, Chronically Malfunctioning On-Site Sewage Facility Systems in Texas. Austin, TX: Texas On-Site Wastewater Treatment Research Council.

Roggenbuck, M., Schnell, I. B., Blom, N., Baelum, J., Bertelsen, M. F., Sicheritz-Ponten, T., . . . Hansen, L. H. (2014). The microbiome of New World Vultures. Nature Communications, (5498). Retrieved from https://www.nature.com/articles/ncomms6498.

TAMU. (n.d.). Feral Hog Project Accomplishments. Retrieved from http://feralhogs.tamu.edu/files/2010/05/Final-2-year-F-HOG-ACCOMPLISHMENTS-2010.pdf

U.S. Bureau of Labor Statistics. (2018). Producer Price Indexes. Retrieved April 13, 2018, from https://www.bls.gov/ppi/

U.S. Environmental Protection Agency. (2001). Protocol for Developing Pathogen TMDLs. EPA 841-R-00-002. Office of Water (4503F), United States Environmental Protection Agency, Washington, DC. 132 pp.

U.S. Environmental Protection Agency. (2016). Best Management Practices, Infrastructure Improvements, and. *Nonpoint Success Story: Texas*. Retrieved from http://www.ugra.org/pdfs/SuccessStoryFinal.pdf

Washington State Department of Ecology. (n.d.). Pet Waste Management. Retrieved from http://www.ecy.wa.gov/programs/wq/nonpoint/PetWaste/PetwasteStation.pdf

Weisman, D. (2017, March). Gruesome Gliders. Retrieved from http://tpwmagazine.com/archive/2017/mar/ed_2_vultures/index.phtml

Williams, B.K., Szaro, R.C., Shapiro, C.D. 2009. Adaptive Management: The U.S. Department of the Interior Technical Guide. Washington D.C.: The U.S. Department of the Interior, Adaptive Management Working Group. Available at: www.doi.gov/initiatives/AdaptiveManagement/. Accessed September 7, 2011.

Water Quality Citations

Craig, D.L., Fallowfield, H.J., & Cromar, N.J. (2004). Use of microcosms to determine persistence of Escherichia coli in recreational coastal water and sediment and validation with in situ measurements. *Journal of Applied Microbiology , 96*:*922-930.*

Lawrence, S. (2008). Escherichia coli bacteria density in relation to turbidity, streamflow characteristics, and season in the Chattahoochee River near Atlanta, Georgia, October 2000 through September 2008−Description, statistical analysis, and predictive modeling. *Scientific Investigations Report 2012*. Retrieved from http://pubs.er.usgs.gov/publication/sir20125037

Missouri Department of Natural Resources (n.d.) Water Quality Parameters. Retrieved from https://dnr.mo.gov/env/esp/waterquality-parameters.htm#Conductivity

Swistock, B. (2017). *Water Facts 13: Coliform Bacteria* [PDF]. The Pennsylvania State University.

Van Elsas, J. D., Semenov, A. V., Costa, R., & Trevors, J. T. (2011). Survival of *Escherichia coli* in the environment: fundamental and public health aspects. *The ISME Journal*, *5*(2), 173–183. http://doi.org/10.1038/ismej.2010.80

Watershed Water Quality Assessment: Santee River Basin. (2013). *South Carolina Department of Health & Environmental Control (SCDHEC)*. Retrieved from http://www.scdhec.gov/HomeandEnvironment/docs /San_Whole.pdf

www.nbtexas.org/wpp