San Bernard River Watershed Protection Plan

Houston-Galveston Area Council

5/23/2017

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LIST OF ABBREVIATIONS

ARRA	American Reinvestment and Recovery Act
BMP	Best Management Practice
CCWEP	Coastal Wetlands Ecosystems Program
CWI	Clean Water Initiative
DO	Dissolved Oxygen
EPA	Environmental Protection Agency
GIWW	Gulf Intercoastal Waterway
GPS	Global Positioning System
H-GAC	Houston-Galveston Area Council
HRU	Hydrologic Response Unit
MS4	Municipal Separate Storm Sewer System
NLCD	National Land Cover Dataset
NOAA	National Oceanic Atmospheric Administration
NRCS	Natural Resources Conservation Service
OSSF	On-site Sewage Facility
QAPP	Quality Assurance Project Plan
RMU	Resource Management Unit
SELECT	Spatially Explicit Load Enrichment Calculation Tool
SSO	Sanitary Sewer Overflow
STATSGO	State Soil Geographic database
SWAT	Soil and Water Assessment Tool
SWQMIS	Surface Water Quality Monitoring Information System
TCEQ	Texas Commission on Environmental Quality
TMDL	Total Maximum Daily Load

TPDES	Texas Pollutant Discharge Elimination System
TPM	Tidal Prism Model
TPWD	Texas Parks and Wildlife Department
TSARP	Tropical Storm Allison Recovery Program
TSSWCB	Texas State Soil and Water Conservation Board
USACE	United States Army Corps of Engineers
USDA	United States Department of Agriculture
USFWS	United States Fish and Wildlife Service
USGS	United States Geologic Survey
WMA	Wildlife Management Area
WPP	Watershed Protection Plan
WQMP	Water Quality Management Plan
WWTF	Wastewater Treatment Facility

1 – WATERSHED INTRODUCTION

WATERSHED PROTECTION PLANNING

The San Bernard Watershed Protection Plan (WPP) process was started in September 2009. Portions of the San Bernard River do not meet contact recreation standards due to elevated bacteria levels, and they have been placed on the Texas Commission on Environmental Quality (TCEQ) list of impaired waters (303d). The San Bernard River comprises two stream segments as defined by TCEQ. Stream segment 1302 is the San Bernard River above-tidal which flows from the city of New Ulm in Austin County to a point 2.0 mi upstream of State Highway 35 in Brazoria County. Stream segment 1301 is San Bernard River tidal which flows from 2.0 mi upstream of State Highway 35 in Brazoria County to the confluence with the Intracoastal Waterway in Brazoria County. There are also sections of the San Bernard that have excessive nutrients and low dissolved oxygen (DO), which may negatively affect fish and other aquatic life. Over the course of the project, the Houston-Galveston Area Council (H-GAC) has worked with community organizations, citizens, government agencies, and local industries. The overall goal of the WPP is to identify the causes and sources of water quality impairments and to bring water quality standards into compliance with state criteria. This WPP was conducted to bring the water quality up to acceptable standards on a voluntary basis before it declined to the point where a total maximum daily load (TMDL) would be required. The goal of the WPP is to improve water quality in the San Bernard Watershed so that it will meet standards for contact recreation by the year 2025 and will be able to maintain those standards through the year 2040.

The San Bernard WPP is a study of the entire watershed to identify pollutant sources and causes, and to form an action plan to control the pollutants entering the waterways. This plan integrates a number of studies to determine what may be causing changes in water quality. Ambient water quality monitoring has been going on in the watershed in some locations for as many as forty years, and a few studies have been done on the river to assess habitats and flooding. This WPP is a stakeholder driven process, which provides an opportunity for the local leadership to guide the process so that the outcome fits for their specific watershed and plans for potential future growth without further impairing the water quality. The population of the watershed is expected to more than double in the next thirty years, which could potentially have major impacts on water quality. Once completed, this plan will be reviewed for acceptance by the TCEQ and the Environmental Protection Agency (EPA).

WPPs address the causes and sources of pollution in watersheds. There are two types of pollution in the watershed: point source and nonpoint source. Point source pollution comes from a known source such as an outfall from a wastewater treatment facility (WWTF). Point sources are generally regulated by state and federal laws and require a permit. Nonpoint source pollution is the collection of all of the other runoff that flows into the waterways including agricultural uses, residential uses, commercial uses, and natural areas. When rainwater flows across the land in a watershed it takes with it all contaminants that are left behind by everyday uses. Since nonpoint source pollution is a combination of many types of pollutants, it is hard to determine where it is coming from and it is difficult to regulate. The vast majority of the San Bernard Watershed is devoted to agricultural uses and has scattered areas of residential development, with a few denser residential developments in the tidal portion of the watershed. Many areas of the tidal portion of the river are used for recreation by local residents.

Some of the upper portions of the watershed have very low flow due to overgrowth of vegetation along the waterways or siltation due to lack of vegetation.

The San Bernard WPP gives the local decision makers the tools necessary to improve water quality in the region, prepare for growth, incorporate best management practices (BMPs), and coordinate the framework for implementing and integrating protection and restoration strategies. This plan also identifies management techniques, sources of funding, and technical assistance for the problems identified in the watershed based on modeling efforts and expected population growth. The WPP will follow the Nine Key Elements of watershed-based plans as required by the EPA. Stakeholders have been very active in the watershed and were instrumental in the development of this WPP and will continue to be the major force that drives the implementation of this plan.

FIGURE 1 - SAN BERNARD WATERSHED BETWEEN AUSTIN AND COLORADO COUNTIES

2 – Watershed Inventory and Characterization

Physical and Natural Features

Watershed Boundaries

The San Bernard River Watershed is over 125 miles long and covers approximately 900 square miles. The headwaters of the San Bernard River originate in New Ulm in Austin County. The river flows through Austin, Colorado, Wharton, Fort Bend, and Brazoria Counties. The river ultimately drains to the Gulf of Mexico, just past the Gulf Intercoastal Waterway (GIWW). The San Bernard River watershed is bounded on the north and east by the Brazos River basin and on the south and west by the Colorado River basin and Caney Creek.

The San Bernard River comprises two stream segments defined by TCEQ. Stream segment 1302 is the San Bernard River above-tidal, which flows from the town of New Ulm in Austin County to a point 2.0 mi upstream of State Highway 35 in Brazoria County. Stream segment 1301 is San Bernard River tidal, which flows from 2.0 mi upstream of State Highway 35 in Brazoria County to the Gulf of Mexico in Brazoria County.

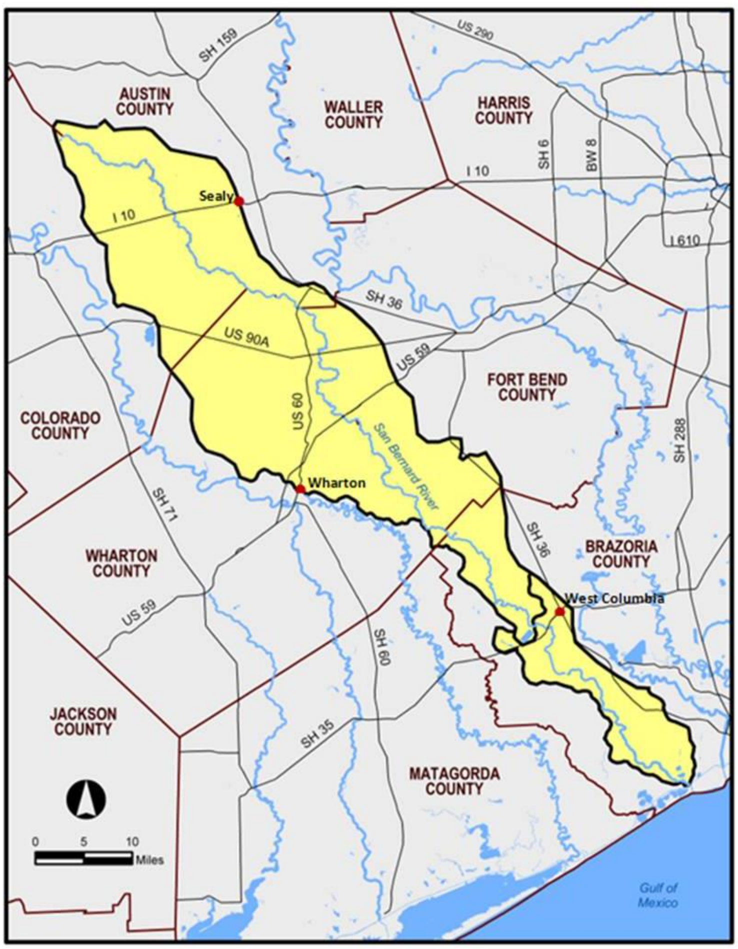

FIGURE 2 - LOCATION OF SAN BERNARD WATERSHED

Topography

The terrain throughout the watershed is characterized by level to undulating plains rising to the north with a timber belt of hardwoods along the river. Closer to the mouth of the river the terrain is Bay Prairie where prairie grasses, bunch grasses, mesquite, and oak predominate. Elevations in the watershed vary between 0 to 400 feet. The San Bernard Watershed is ideally suited for farming and ranching as the land is fairly flat.

The lower portion of the watershed near the Gulf Coast is characterized by Gulf Coast Prairies and Marshes Ecoregion. Elevation is generally 5 feet or less above mean sea level with a few areas 10 feet or more above sea level.

The Texas Gulf Coast has low-lying coastal landforms that include barrier islands, peninsulas, offshore sand bars, bays, mudflats, dunes, and shoals. These landforms are subject to the activities of waves, winds, storms, tides, climate, rising sea levels, and human activities.

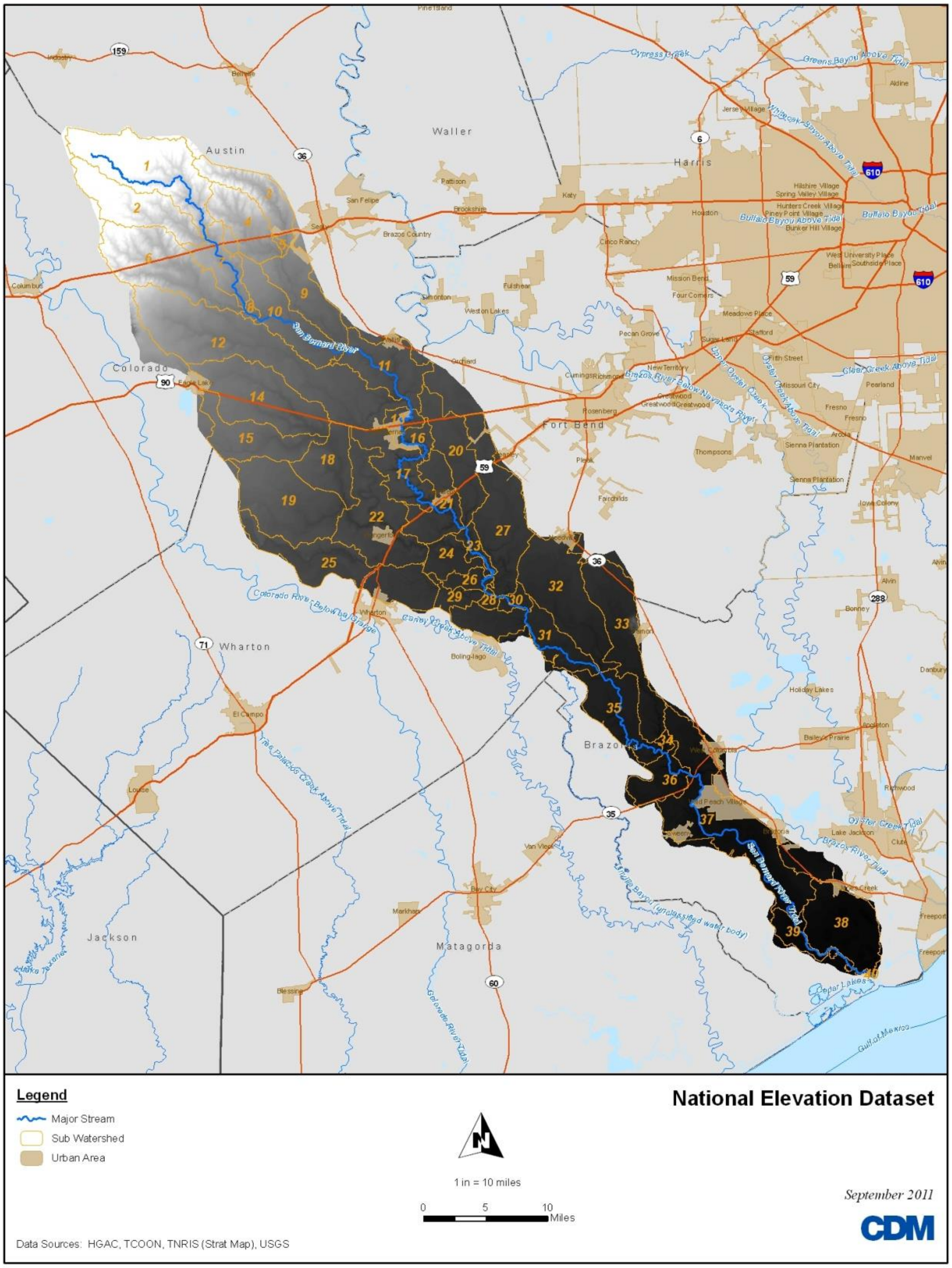

FIGURE 3 - WATERSHED ELEVATION

San Bernard River Watershed Topography

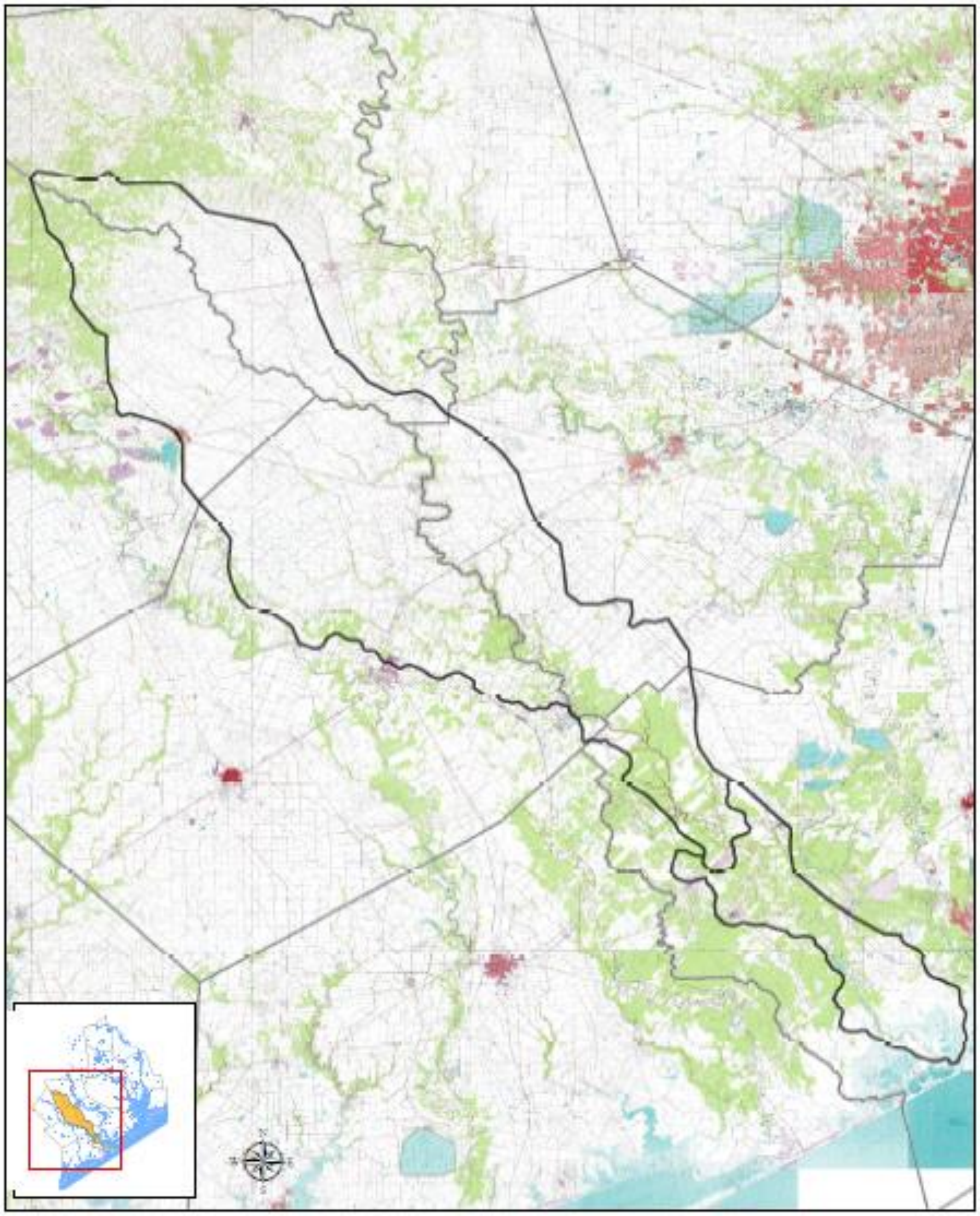

FIGURE 4 - SAN BERNARD WATERSHED TOPOGRAPHY

Soils

Soils include sand and gravels, sandy clay and silt with local sand, mud and other fluvial deposits. In the lower portion of the watershed near the Gulf, soils are primarily clays ranging from saline to non-saline. The land is nearly level and poorly drained.

The lower portion of Brazoria County is in the Gulf Coast Marsh Resource Area and is predominantly salty soils. Most of the soils in the county are clayey and loamy, dark in color and have very little slope. 82 percent of the county is deep, non-saline soils. The major soils in the county are: Aris, Asa, Bernard, Brazoria, Edna, Lake Charles, Norwood, and Pledger. The Asa and Norwood soils are loamy and well drained, but the remainder of the soils is more poorly drained and has very slowly permeable subsoil. These soils are good for agricultural uses – row crops and pastures, and perform best with a surface drainage system.

In Wharton County, soils range in slope from 1 percent to 8 percent, most are somewhat poorly drained, have moderate available water capacity, and have very low to moderately low permeability. Soil types include: Telferner fine sandy loam, Gladewater soils, Edna fine sandy loam, Hockley fine sandy loam, Fulshear-Kenney complex, and Bernard-Edna complex.

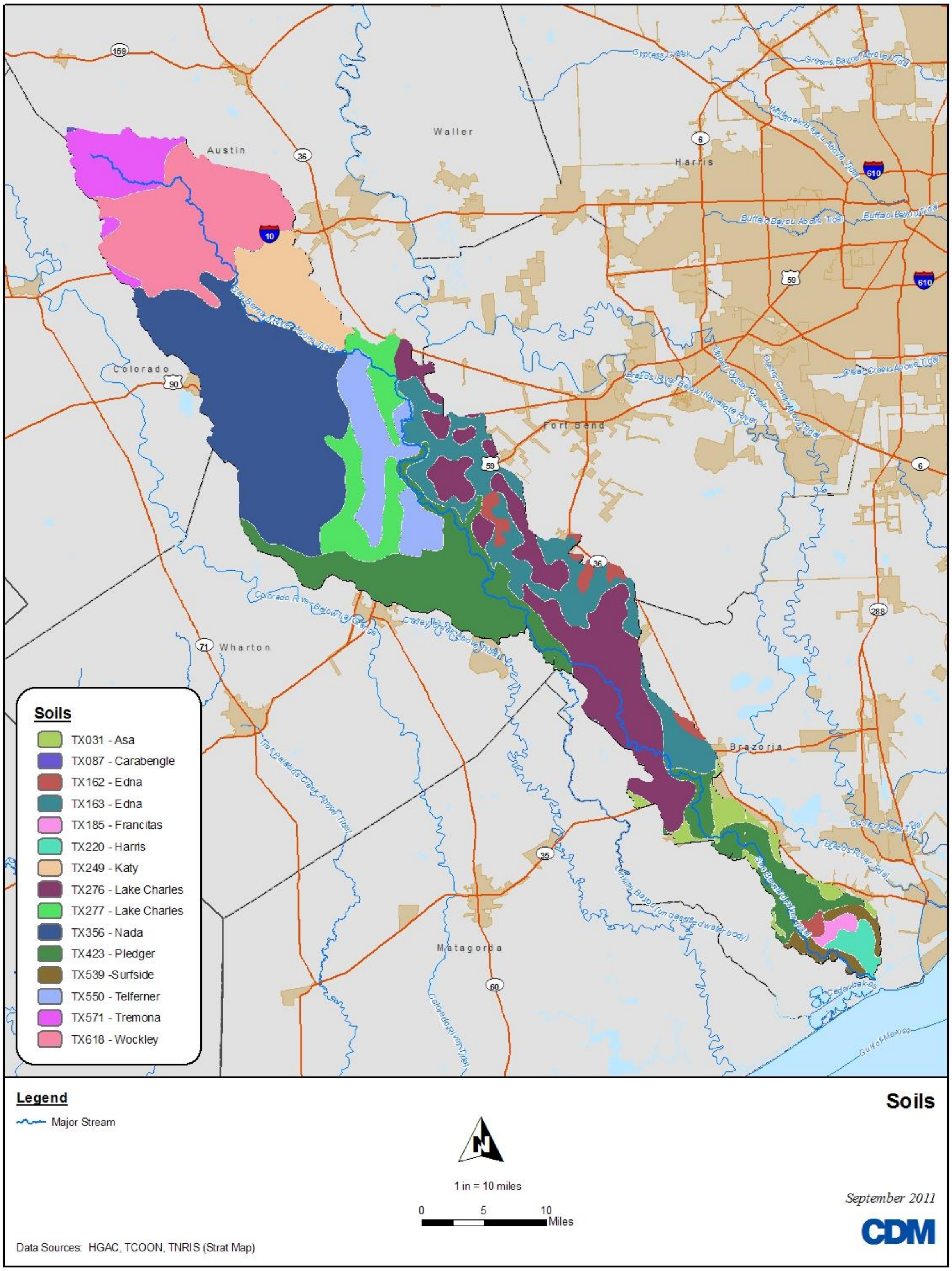

FIGURE 5 - SAN BERNARD WATERSHED SOILS

Climate

Average annual rainfall in the area is between 40 to 54 inches with increasing levels towards the coast. The portion of the watershed along the coast is characterized by rainfall throughout the year with 60 percent falling between April and September. Average annual rainfall along the coast is 52 inches. There are a few rain gauges located throughout the watershed at the Atwater Prairie Chicken refuge, the City of Wharton, and at East Bernard.

Weather data for the simulation was collected from five weather stations in and around the San Bernard Watershed: Brenham, Bellville, Wharton, Wharton Airport, and Freeport. Specific information on each type of weather data is provided in more detail subsequently.

Although precipitation data were collected from the five stations noted previously, three stations (Bellville, Wharton, and Freeport) are located closest to the watershed. Therefore, data from these three stations were used preferentially to generate most of the precipitation input for the modeling effort. If there were gaps in the data during the simulation period, the other two stations were used to complete these gaps. During the review of the weather data, one key discrepancy was noted for the precipitation data collected for Wharton County. One value noted on July 27, 2008 was noted to have a total of 13.98 inches of rainfall occurring but it could not be verified with other data sources such as the National Oceanic and Atmospheric Administration (NOAA), nearby weather stations. As such, it was removed from the rainfall dataset.

Wildlife and Habitat

There are three designated wildlife and habitat areas in the San Bernard Watershed: the San Bernard National Wildlife Refuge, the Justin Hurst Wildlife Management Area, and the Attwater Prairie Chicken National Wildlife Refuge. There are also vast areas of open space throughout the watershed that are inhabited by wildlife. Habitat types change appreciably between the headwaters in the upland prairie areas, through patches of post oak savannah and upland coastal prairie, to the low-lying wetland and coastal marshes at the mouth. Figure 6 displays the various ecoregions (based on EPA's level 4 classification system) and National Wildlife Refuge lands in the watershed.

Some of the birds found throughout the watershed include- gulls: Ring-billed, Laughing, Franklin's; terns: Caspian, Forster's; shorebirds: American Avocet, Willet; raptors: Red-Shouldered Hawk, Red-Tailed Hawk, Bald Eagle, Crested Caracara, Osprey; wading birds: Great Blue Heron, Great Egret, Snowy Egret, Little Blue Heron; and other birds: Belted Kingfisher, American Pelican, Brown Pelican, Neotropical Cormorant, Double-breasted Cormorant, and Snow Geese.

Some of the other wildlife in the watershed include - fish: Redfish, Black minnows, Gar, speckled trout, flounder, blue catfish, mammals: White-Tail Deer, Raccoons, feral hogs, reptiles: Red-eared sliders, Water Moccasins (cottonmouths), diamond-back water snakes, shellfish: Oysters (beds), crabs.

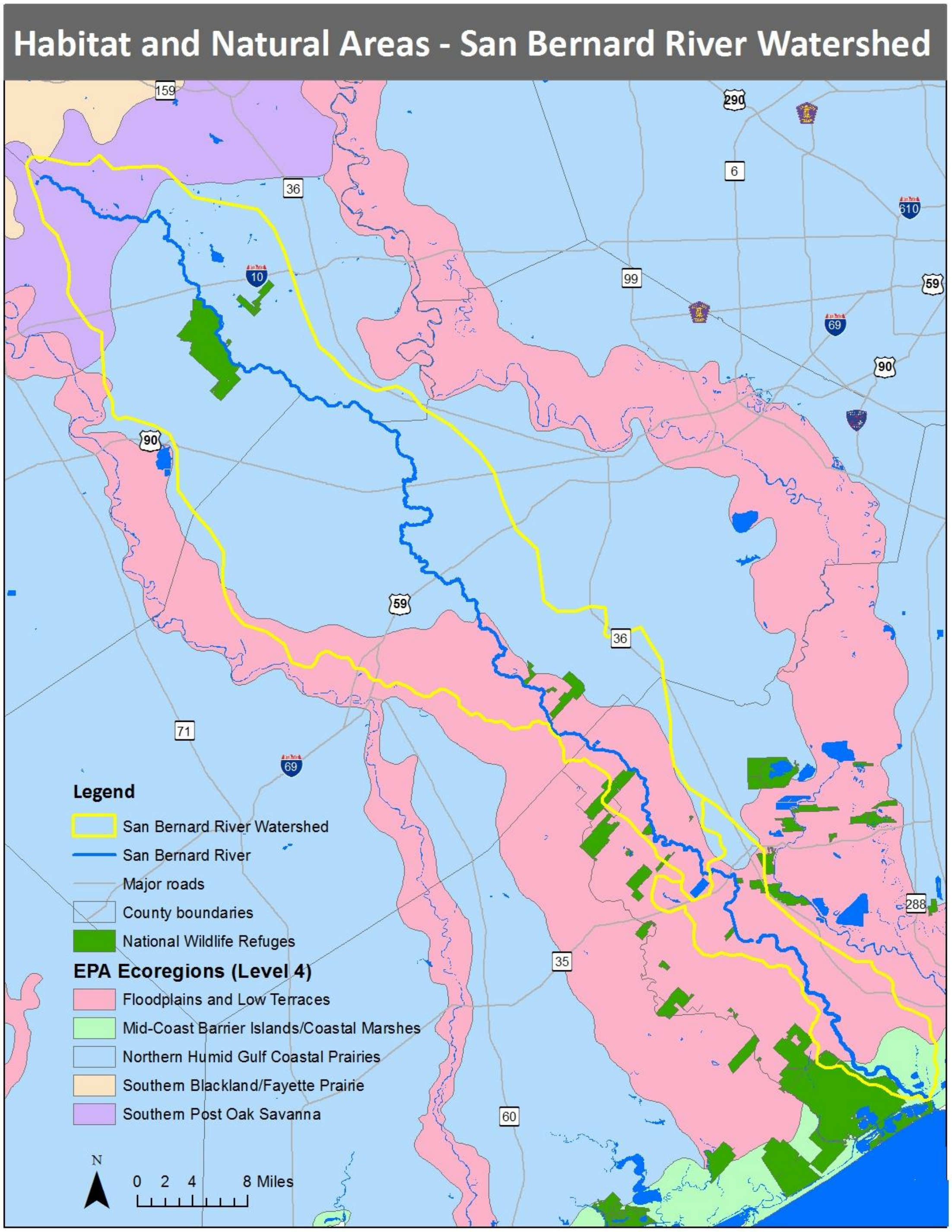

FIGURE 6 - WILDLIFE AND HABITAT AREAS IN THE SAN BERNARD WATERSHED

SAN BERNARD NATIONAL WILDLIFE REFUGE

The San Bernard National Wildlife Refuge is a 27,000-acre sanctuary established in 1968 to protect habitat for wintering waterfowl and estuarine systems for marine species. The United States Fish and Wildlife Service (USFWS) maintains the preserved land. Part of the refuge is open to the public for nature and wildlife viewing, and there are areas of permitted hunting on selected days throughout the year.

A portion of this refuge is in the southernmost part of the San Bernard watershed, and is an important coastal marsh wilderness and shelter for millions of migrating and nesting birds, including over 230 different species annually. Some of these include snow geese, warblers, herons, egrets, terns, and gulls, as well as neotropical bird species. The birds can be found in the marshy bottomlands, on several remote islands, or within the bottomland hardwood forests found throughout the refuge. Visitors may also see bobcats or alligators while touring the wildlife sanctuary. The refuge also supports estuaries that flourish with shell and fin fish and reefs of colonial oysters, supplying a feeding ground for adult fish and crabs.

Justin Hurst Wildlife Management Area

Justin Hurst Wildlife Management Area (WMA), formerly The Peach Point Wildlife Management Area, is another coastal preserve found in the southernmost portion of the San Bernard River watershed. The land, acquired between 1985 and 1988, is dedicated to sound biological conservation of all wildlife resources for the public's benefit. The WMA, managed by the Texas Parks and Wildlife Department (TPWD), contains over 10,000 acres of coastal prairie and marshes and is part of the Central Coast Wetlands Ecosystem Project (CCWEP).

The CCWEP aims to create and maintain habitat for indigenous and migratory species, particularly waterfowl. Research activities are prevalent throughout the WMA, with resulting information concerning the understanding of coastal ecosystems distributed to scientists, land managers, resource agencies, and other interested parties. Currently, researchers are studying small mammals, snakes, and vegetation within the WMA. In addition, researchers assist in bird banding, which provides data for the Monitoring Avian Productivity and Survivorship Program.

The San Bernard National Wildlife Refuge and the Justin Hurst Wildlife Management Area serve important functions in the conservation of native vegetation and migrating wildlife and in the understanding of coastal ecosystems. These sanctuaries not only provide important information to scientists and the public, but they also provide recreational opportunities for locals and tourists as well as economic benefits to the region.

Attwater's Prairie Chicken National Wildlife Refuge

The Attwater's Prairie Chicken National Wildlife Refuge is located near Eagle Lake. Today it includes about 10,000 acres of protected habitat. In 1983, the US Fish and Wildlife Service formed the Attwater's Prairie Chicken Recovery Team to carry out science-based efforts to help save the birds. As of 2009, 90 birds inhabit three reserve sites, but recovery efforts are still underway.

In the Central Portion of the Watershed

Bald cypress wetlands, and green ash and water hickory trees dominate the landscape in the southern half of the San Bernard area while green ash and water oak are the predominate woody species in the northern half of the San Bernard study area and the Middle Bernard Creek area. Where present, yaupon holly and Chinese privet dominate the understory layer with a dense herbaceous layer throughout the area. Vegetation within the areas can be classified as riparian, early-mid successional vegetation. The vegetation consists of a moderately dense overstory with the tree canopy averaging 60 feet in height, a moderately dense understory, and a dense herbaceous layer.

FIGURE 7 - SAN BERNARD RIVER IN WHARTON COUNTY

TIDAL PORTION OF THE WATERSHED NEAR THE MOUTH

The lower portion of the watershed is located in the Texan Biotic Province, an area which supports a wide variety of animals. The San Bernard River area provides feeding and nesting habitat for a large number of species of waterfowl, shore, and migratory birds traversing the Mississippi or Central Flyways. The bays and marshes contain shore and wading birds. Marshes and pasturelands in the area provide food and habitat for the other wildlife in the area. The beaches in the project area provide habitat for nesting sea turtles and are designated as critical habitat for the threatened piping plover.

FIGURE 8 - SAN BERNARD RIVER IN BRAZORIA COUNTY NEAR THE MOUTH

Land cover and Population Characteristics

Land Cover

Much of the land throughout the watershed is used for crop production and cattle grazing, and the river is used for boating and fishing. Today, small towns among vast open spaces, with no major metropolitan area, characterize the watershed. The major agribusiness types in the watershed are beef cattle grazing and hay production. The counties in the northern and west central portions of the San Bernard River watershed are among the top cattle/ calf producers in the state. Other common crops found throughout the watershed include rice, sorghum, corn, cotton, and soybeans. Land cover in the watershed is primarily rural and agricultural, with scattered areas of urbanization, in the lower part of the watershed there is a lot of barge traffic associated with the natural resource industry.

Minerals are another major natural resource found within the area. Oil, gas, sulfur, and salt are abundant subsurface features. Petrochemical services are another facet of the economy. Of particular geological significance, Boling Dome is situated on the western bank of the San Bernard River, in the easternmost part of Wharton County, near Boling-Lago. This subsurface structure contains petroleum, sulfur, and salt. The associated sulfur reserve has produced more sulfur than any other mine in the world. As of 1990, 80.5 million tons of sulfur had been removed, along with over 6,000 million cubic feet of natural gas, and over 25,500,000 barrels of oil.

Conoco-Phillips has a refinery located in Sweeny that contains a natural gas liquid processing center and petrochemical production facilities. The facility uses the river to transport tankers from the facility in Sweeny to the Port of Freeport. Products produced include gasoline, jet fuel, and diesel fuel.

TABLE 1 - LAND COVER IN THE SAN BERNARD WATERSHED, 2006

2006 National Land Cover Dataset	Acres	Percent of Total
Developed	33,048	5.7%
Cultivated	209,198	35.8%
Grassland	185,863	31.8%
Forest	45,394	7.8%
Woody Wetland	84,292	14.4%
Herbaceous Wetland	21,344	3.7%
Bare	1,303	0.2%
Open Water	4,194	0.7%
TOTAL ACRES	584,634	100%

Much of the lower part of the watershed is wetlands and forest with residential uses along the waterways, the central part of the watershed is barren land and cultivated lands, and the upper part of the watershed is barren land and forest.

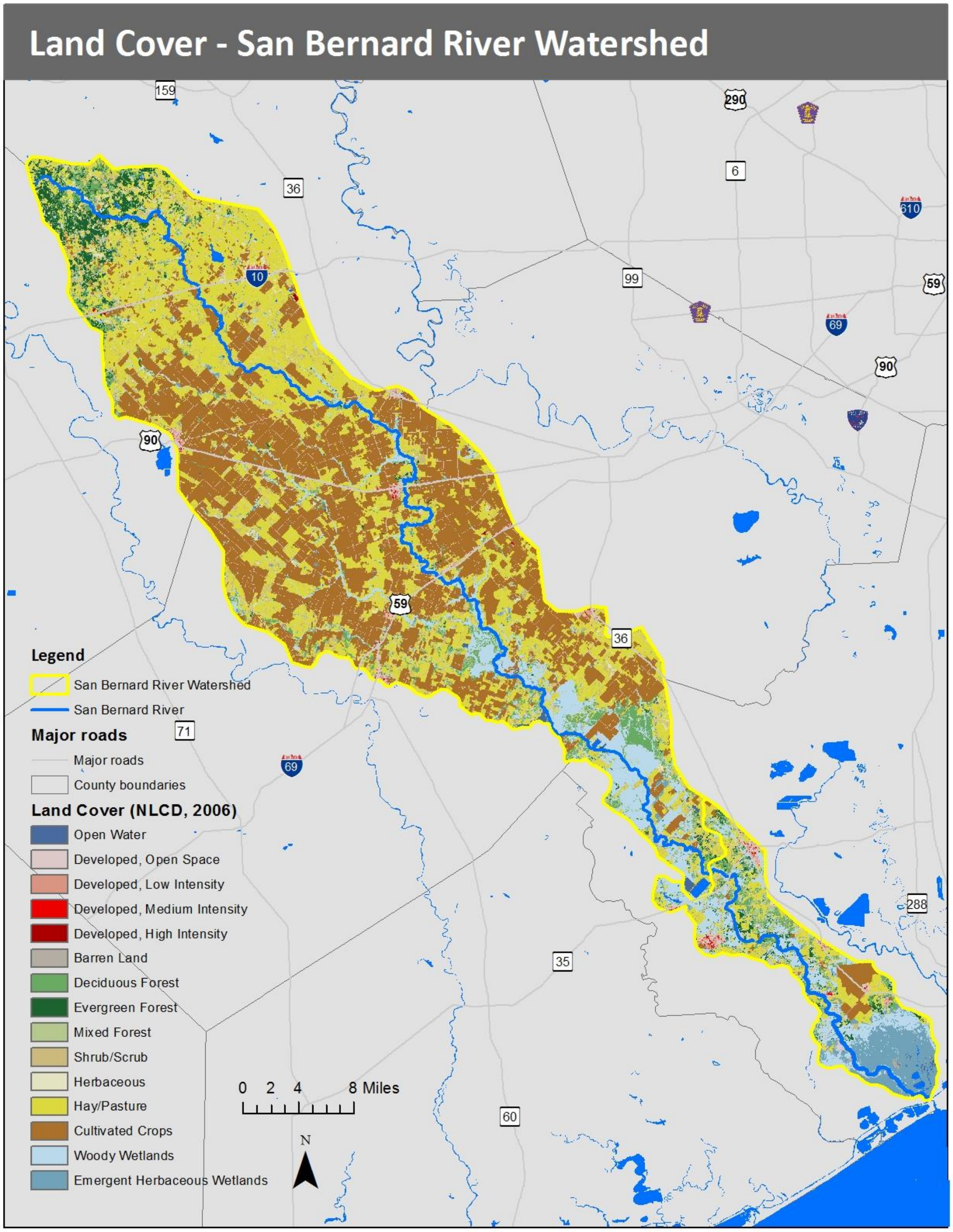

FIGURE 9- LAND COVER IN THE SAN BERNARD WATERSHED (NLCD, 2006)

EXISTING LAND MANAGEMENT PRACTICES

The Texas State Soil and Water Conservation Board (TSSWCB) has 152 Water Quality Management Plans (WQMPs) in the San Bernard Watershed. These WQMPs are site-specific plans that are developed and approved by soil and water conservation districts to include appropriate land treatment practices, production practices, management measures, technologies or combinations of these. The purpose of these plans is to achieve water pollution prevention and to be consistent with state water quality standards. There is no charge to develop a WQMP, but there are costs associated with implementation of practices to improve water quality, and there is financial assistance available.

Types of plans that have already been implemented in the San Bernard Watershed include: prescribed grazing, nutrient management, crop residue management, irrigation water management, forage harvest management, and pest management. The acreage in the San Bernard Watershed area under a WQMP is 64,383 acres and the total acreage is 680,435 (this includes the land area of all the soil and water conservation districts and doesn't align exactly with the watershed boundary), so approximately 9 percent of the watershed is under a plan currently. Table 2 shows the percentage of acreage under each type of management measure.

TABLE 2 - EXISTING AGRICULTURAL BEST MANAGEMENT PRACTICES, BY ACRES

Management Measure	Acres	Percent of Watershed
Prescribed Grazing	31,698	4.7%
Nutrient Management	46,444	6.8%
Crop Residue Management/ Conservation Crop Rotation	29,304	4.3%
Forage Harvest Management	2,846	0.4%
Wildlife Land	9,456	1.4%

POPULATION GROWTH

The household population growth was generated for the watershed by H-GAC. Growth was forecast for urban and rural areas over a thirty-year period in 5 year increments. The total population of the watershed is expected to more than double in the next thirty years (Table 3). It is expected that the majority of the new population growth will be in cultivated and grassland areas (80 percent) and in forest and wetland areas (20 percent). As the population in the watershed grows, it is expected that bacteria concentrations associated with urban and residential uses such as on-site sewage facilities (OSSFs) and pets will continue to increase as rural sources like livestock sources will decrease.

TABLE 3 - WATERSHED POPULATION BY DECADE

Year	2010	2015[1]	2020	2025	2030	2035	2040
Total Population	19,588	20,927	23,594	27,174	32,518	39,207	45,746

BIOLOGY

A recent water quality and biological study conducted by the United States Geological Survey (USGS; East and Hogan, 2003) on the San Bernard River found that fish diversity and numbers decreased as they sampled down river. The study reports only seven species including longnose gar (Lepisosteus osseus), channel catfish (Ictalurus punctatus), longear sunfish (Lepomis megalotis), freshwater drum (Aplodinotus grunniens), blackstripe topminnow (Fundulus notatus), blacktail shiner (Cyprinella venusta), and red shiner (Cyprinella lutrensis) from a collection station at West Columbia, approximately 25 miles upstream, from a list of 32 fish species found in the river at all sampling locations. With the near total closure of the mouth of the river and minimal flow or tidal exchange, it is assumed that the river supports a diverse fish population of more salt tolerant species.

GEOMORPHOLOGY

This very active coastal area has undergone significant change over the last 80 years, due in large part to impacts to coastal sediment budget resulting from the development of the Port of Freeport and the dredging of the GIWW.

[1] Throughout this document, numbers for 2010 and subsequent years were calculated during the original development of this WPP on the basis of earlier data, rather than on data collected in 2010 or later. In all cases, no significant variation in target outcomes, conditions, etc. are expected due to this methodology.

The diversion of the Brazos River for port development resulted in a significant increase in the amount of sediment transported southward to the San Bernard River area, while the GIWW provides a channel available to "capture" flow from the impeded river, further reducing the current necessary to keep the mouth of the river open. Apparently unaware of the 2002 U.S. Army Corps of Engineers (USACE) report (Kraus, 2002), TPWD's Coastal Fisheries Division evaluated the blockage of the river's mouth in 2004 in an attempt to determine the potential impact of the GIWW on the lower river (Chen and Buzan, 2004). Although their study was inconclusive as to the influence of the GIWW on the river, Chen and Buzan document that the mouth migrated from its 1974 location (the approximate location proposed for its restoration in this project), over 1.3 miles to the southwest by 2002. The 1974 location of the river's mouth is now blanketed by a substantial sand spit that was dredged through in this current restoration effort.

Additional Data Needed for Future Modeling

Assumptions have been made regarding *E. coli* levels in effluent from wastewater treatment facilities (WWTFs) in the watershed. Currently we do not have any data for these outfalls, so it is being assumed that they are releasing effluent that is within the current standards. As WWTFs renew their permits they will be required to start reporting *E. coli* levels.

Sources of Information

USGS in Cooperation with the Houston-Galveston Area Council and the Texas Commission on Environmental Quality; Hydrologic, Water-Quality, and Biological Data for Three Water Bodies, Texas Gulf Coastal Plain, 2000-2002; Open File Report 03-459

2008 Texas 303(d) List, March 19, 2008, Texas Commission on Environmental Quality

US Army Corps of Engineers, Galveston District; Draft Environmental Assessment – Restoration of the Mouth of the San Bernard River to the Gulf of Mexico, Brazoria County, Texas, June 2008

Halff Associates, Inc; San Bernard Watershed Flood Protection Planning Study Final Report, July 15, 2009.

3 – PUBLIC PARTICIPATION

PUBLIC PARTICIPATION

Public education and outreach are essential to the implementation of a successful WPP. In addition to the physical BMPs to be implemented by landowners and jurisdictions in the watershed, behavioral BMPs can be addressed by everyone in the watershed. Public Participation can include public education workshops, distribution of educational materials, and participation in activities to improve water quality.

PUBLIC PARTICIPATION LEAD AGENCY ROLES AND RESPONSIBILITIES

STAKEHOLDER FACILITATION

Stakeholder Group members have actively participated in the WPP process. Members have identified and presented insights, suggestions, and concerns from a community, environmental, or public interest perspective.

FIGURE 10 - STAKEHOLDERS AT WPP MEETING

Project Partners

H-GAC worked with TCEQ in the preparation of the WPP. A number of cities and school districts are located in the watershed. There are also a number of state and local agencies that operate within the watershed.

Partners List

Counties:
Austin
Brazoria
Colorado
Fort Bend
Wharton

Cities:
Eagle Lake
Wallis
East Bernard
Kendleton
Needville
Wharton
West Columbia
Sweeny
Brazoria
Jones Creek
Wild Peach Village

School Districts:
Belleville
Sealy
Columbus
Rice Consolidated
Kendleton
Needville
Brazos
Lamar Consolidated
Damon
Sweeny
Columbia-Brazoria
Brazosport
Boling
East Bernard
Wharton
El Campo

WPP Stakeholder Group

Stakeholder Group Structure

The Stakeholder Group was divided into committee members with voting privileges and at large stakeholder group members who will participate as available. Committee members will ultimately be responsible for plan implementation in the watershed.

Group Membership

Voting Committee Members:

Commissioner Dude Payne (Brazoria County)

Nancy and Fred Kanter (Friends of the San Bernard River (FOR))

John Phillips (Waters Davis SWCD)

Jeremy Jett (Industry/Walmart, Sealy)

Darrell Schwebel (Cradle of Texas Conservancy/DOW)

Carol Jones (Homeowner)

Roy and Jan Edwards (Homeowners, Rivers End)

Linda and Ken Wright (FOR)

William Todd (Ag producer)

Sheri and Melvin Ganske (Boling property owners)

Richard Forgason (Ag, Hungerford)

Harry Anderson (Ag, East Bernard)

Terry Hlavinka (Ag, East Bernard)

At Large Stakeholder Group Members:

Bill and Jackie Benson (Homeowners)

Valroy and Adalia Maudlin (Homeowners)

Greg Roque (Business/Industry, Sealy)

Karen Carroll (Brazoria Co. Health)

Charles Boettcher (Ag, East Bernard)

Harry Goudeau (Ag, Hungerford)

John Wallace (Landowner, Brazoria)

Michael Lange (USFWS)

Paul Wood (Engineer)

Subcommittees and workgroups

In order to carry out its responsibilities, the Stakeholder Group has discretion to form standing and ad hoc work groups to carry out specific assignments from the group.

Roles and Responsibilities

Stakeholder group members assisted with:

- Site visits, photos, sample site descriptions
- Advertising the plan
- Provide/gather information on issues and concerns of the watershed
- Knowledge of existing programs or plans to consider or integrate
- Technical assistance in developing and implementing the plan
- Responsible for implementation and communication to other affected parties
- Provide review and comments on plan as it is written.

Agencies Involved as Stakeholders

TCEQ
TPWD
USFWS
USACE
TSSWCB
Soil and Water Conservation Districts
Texas A&M Agrilife Extension (AgriLife Extension)
District Conservationists
US Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS)

Citizens Involved as Stakeholders

Friends of the River - San Bernard is a very active citizen group involved in the watershed. The group is currently organized into committees based on their interests and professional affiliations.

Goals Development

Stakeholder group members assisted with the goals and visioning of the project, and identified and prioritize programs and practices to achieve these goals. The stakeholder committee members are ultimately responsible for the implementation of projects to achieve these goals.

Implementation Roles

Friends of the River San Bernard, Stream Team members, and local Master Naturalists are currently doing a lot of work to help advance the WPP through public education and outreach measures. The TSSWCB is also advertising farm plans to property owners in the watershed. Counties and other authorized agents are updating and strengthening the OSSF regulation and permitting efforts.

FIGURE 11 **- STAKEHOLDERS PROVIDE LOCAL FEEDBACK**

4 - WATERSHED ANALYSIS

HYDROLOGY

The San Bernard River Watershed drains approximately 900 square miles, the river flows southeast to form the boundary between Austin and Colorado counties, then flows between Wharton and Fort Bend County and through Brazoria County before emptying into the Gulf of Mexico. The San Bernard River comprises two stream segments defined by TCEQ. Stream segment 1302 is the San Bernard River Above-Tidal, which flows from the city of New Ulm in Austin County to a point 2.0 mi upstream of State Highway 35 in Brazoria County. Stream segment 1301 is San Bernard River Tidal, which flows from 2.0 mi upstream of State Highway 35 in Brazoria County to the Gulf of Mexico. There are concerns about DO levels and nutrients, and the river is listed as impaired for bacteria on the 303d list of the Texas Integrated Report of Surface Water Quality.

FIGURE 12 - AERIAL PHOTO OF SAN BERNARD RIVER MOUTH IN 2010

In the upper portions of the watershed, the river has had minimal flow for most of the year over the past 20 years, however there used to be a more significant flow. A number of factors have contributed to the lack of flow, including recent drought, creation of retention ponds, more impervious surfaces which reduce inflow, and increased vegetation and tree cover along the river banks. The recent drought has caused a number of issues for the watershed, including limited flow in the non-tidal part of the watershed, increased salinity, changes in biological composition, and lower DO. The drought has also resulted in several drought-related problems such as fish kills and an occurrence of red tide along the coast. The period of time during the development of the WPP was not wholly representative of usual watershed conditions. The period of analysis for the watershed modeling was 2007-2009 when data was available.

The tidal and non-tidal portions of the watershed are separated by the salt barrier dam. This small dam is located on the river near West Columbia about one mile north of Highway 35. The purpose of the dam is to prevent saltwater from the Gulf from reaching the upper portions of the river that are used for water supply for industrial uses. There is also a diversion area on the Wharton-Fort Bend County line called the New Gulf Reservoir, it is owned by the Texas Gulf Sulfur Company and is used for municipal supply and irrigation.

The mouth of the San Bernard River has migrated about two miles to the southwest since the 1929 construction of the Diversion Channel and the 1940 construction of the GIWW, and almost closed at the Gulf of Mexico due to sand accretion from the delta formed by the Diversion Channel. Accretion has accelerated over the last ten years due to several factors, including flooding on the Brazos River. The result of the sediment buildup caused the river discharge to be insufficient to flush the shoaling at the mouth of the river and keep it open to the Gulf. The blockage of the river's mouth diverted flow into the GIWW, raising concerns for barge traffic along the GIWW (Kraus, 2002). The Galveston District, USACE, has received reports that barge tows traveling along the GIWW between the San Bernard and Brazos Rivers can experience an eastward flowing current that is sufficiently strong to pose a potential navigation hazard. To allow for a more effective, safe, and efficient waterway, the proposed restoration of the mouth of the San Bernard River would reduce treacherous currents resulting from diverted flow into the GIWW and Brazos River Floodgates.

In 2002, a study by the U.S. Army Engineer Research and Development Center (ERDC) addressed how to improve navigation safety and efficiency on the GIWW near the San Bernard River. The purpose of the project was to reconnect the San Bernard River with the Gulf of Mexico at its historic location. The conclusion of the study was that dredging a shorter, deeper channel to the Gulf would increase the hydraulic efficiency of the river sufficiently to keep the mouth open and flowing for perhaps 6 to 12 years, before longshore transport of sediment from the Brazos River would again overtake the channel. Unfortunately, due to the severe drought in 2012, the river mouth has once again closed as of December 2012. The opening of the mouth has been highlighted as a primary concern by project stakeholders and local leaders.

WATERBODY AND WATERSHED CONDITIONS

WATER QUALITY SAMPLING

Eight water quality monitoring stations are currently[2] located in the San Bernard Watershed. Five of the monitoring stations are located on the main stem of the San Bernard River and three are located on tributaries of the San Bernard River. Five of the stations are monitored by Clean Rivers Partners and three are monitored by TCEQ. Additional sites have been proposed to be monitored through the TSSWCB. The parameters tested for include flow rate at the stations above tidal, and at all sites a full suite of field, conventional, and bacteriological parameters common to all CRP sites, which are sampled on a quarterly basis.

Five Established Monitoring Sites:
San Bernard Tidal @ FM 2611 # 12146
San Bernard Tidal @ Hwy 35 # 20460
San Bernard @ FM 442 # 12147
San Bernard @ US 90A # 16373
San Bernard @ FM 3013 #16370

Three Newer Monitoring Sites:
Mound Creek @ CR 450 # 20723
Peach Creek @CR 117 # 20722
West Bernard Creek @ CR 225 # 20721

[2] At the time of this WPP revision in May, 2017, three additional sites (17420, 16371, and 16374) were also being sampled, though for 2017 only. These sites are not included in the original project analysis and are not part of this WPP effort.

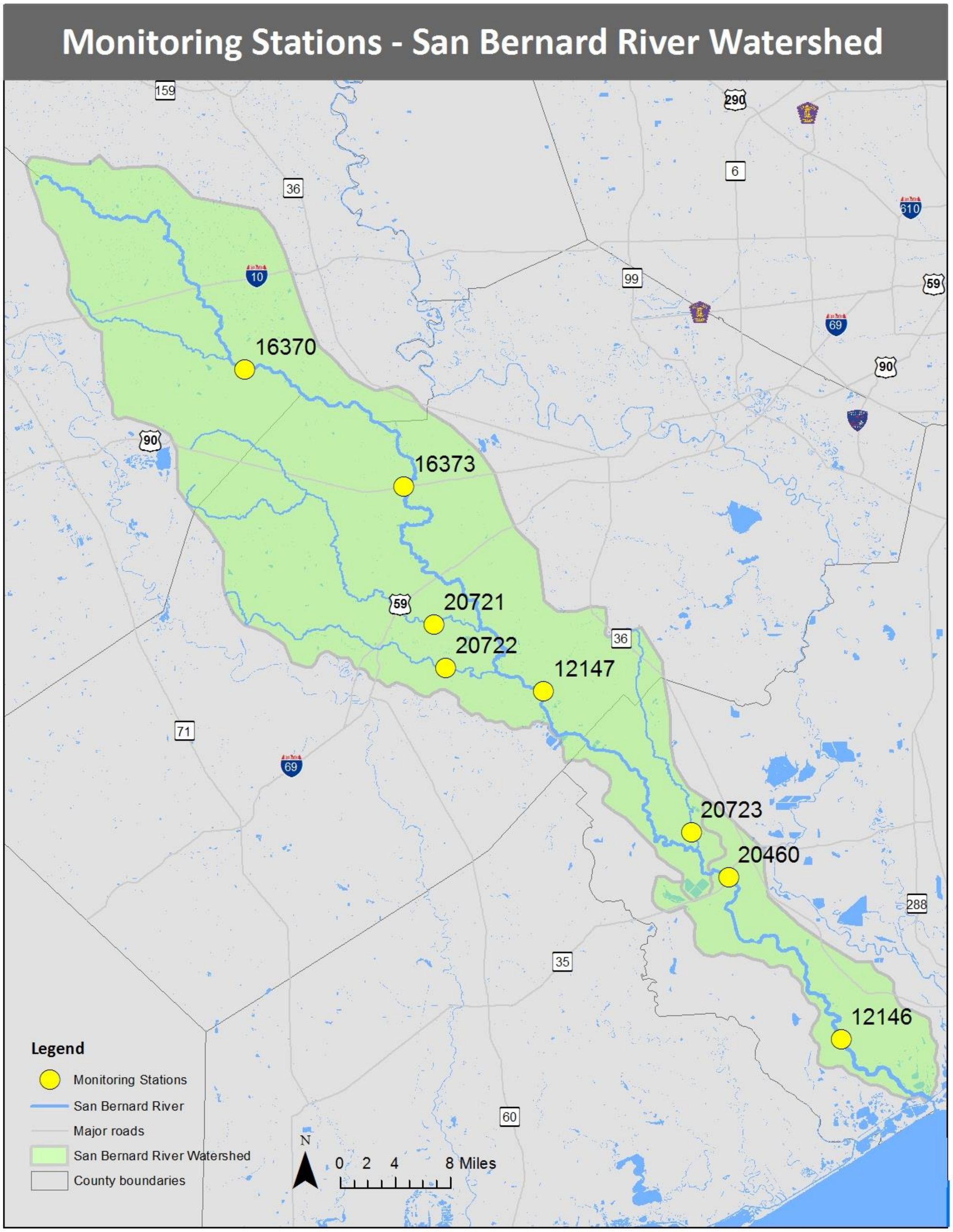

FIGURE 13 - MONITORING STATIONS IN THE SAN BERNARD RIVER WATERSHED

The San Bernard River is a water body consisting of Segment 1302, San Bernard River Above Tidal; and Segment 1301, San Bernard River Tidal, emptying into Segment 2501-05, Gulf of Mexico Area between

Freeport and Port Aransas. Under the Texas Surface Water Quality Standards, the designated uses of these segments are: Aquatic Life Use (ALU); Recreation Use; General Use; and Fish Consumption Use. According to the 2012 Texas Integrated Report on Surface Water Quality, Segment 1301 fully supported its ALU. There are no direct industrial or municipal discharges in the vicinity that could degrade water quality. However, Recreation Use is not supported in Segment 1301 because of fecal bacteria[3].

FIGURE 14 - PREPARING FOR FIELD SAMPLING IN THE SAN BERNARD WATERSHED

A data study was completed by USGS in 2002, and data collection at six stations began in late summer of 2000. One monitoring meter was installed in the non-tidal portion of the watershed to collect data continuously (every thirty minutes). This allowed scientists to monitor the levels of DO under varying conditions. Other parameters collected included pH, conductivity, and temperature. Additional water quality monitoring sites were sampled monthly and included the parameters listed above as well as Biological Oxygen Demand, nitrogen and phosphorus compounds, dissolved solids, bacteria, and flow. Recordings from a permanent USGS station near Boling supplied continuous flow measurements. (USGS Study)

Habitat and biological data collected along the San Bernard River and its tributaries have been summarized and compared with similar data from other streams in southeast Texas. Measures of stream habitat compare closely with other riverine settings, as opposed to tidally influenced, coastal bayous.

[3] The description of impairments and concerns in this section frequently reference the conditions existing during the development of the WPP, as described in footnote 4.

Similarly, measures of aquatic insect and fish population diversity are similar to water bodies with minimally impacted watersheds. Based on these biological data, along with selected water chemistry and water-quality data that were also collected during 2000-2002, the San Bernard River did not exhibit significant biological/habitat problems at the time. The river has been removed from the list of water bodies not meeting designated standards for high aquatic life use due to low DO concentrations. However, stakeholder concerns persist due to the impact of the closed mouth on wildlife populations and conditions in the tidal segment.

303(D) LIST

From the 2008 303d[4] list:

[4] The impairments listed here are as reported in the 2008 Integrated Report. However, the current 2014 Integrated Report impairments are identical, with the exception that several assessment categories changed from 5c to 5b as part of a broad change in TCEQ assessment practices applied statewide. The original listings are retained here to reflect the conditions current during the development of the WPP. While not specifically addressed in the WPP development process, it should be noted that Segment 1301 also exhibits a Concern (CS) for chlorophyll-a, and Segment 1302 (for AU's 1302_02 and 1302_03) and 1302A exhibit Concerns (CS) for depressed DO. Segment 1302B has Concerns (CS) for ammonia, depressed DO, and impaired habitat, as well as a Concern (CN) for bacteria. Segment 1302D has a Concern (CS) for depressed DO. While the impairments listed and discussed in the main body of text do not explicitly mention all these impairments and concerns, management measures reducing fecal pollution help address the other listed impairments and concerns, almost all of which are related to nutrients. It is the intent of the stakeholders to address all water quality issues in the watershed, including those that emerge subsequent to the development of the WPP. Additional information about the parameters and results of testing for these segments can be found in the current H-GAC CRP Basin Highlights Report at http://www.bsr2016.com/.

SegID: 1301 **San Bernard River Tidal**
From the confluence with the Intracoastal Waterway in Brazoria County to a point 3.2 km (2.0 miles) upstream of SH 35 in Brazoria County

Area		Category	Year First Listed
1301_01	*Entire Segment*		
	bacteria	5c	2006

SegID: 1302 **San Bernard River Above Tidal**
From a point 3.2 km (2.0 miles) upstream of SH 35 in Brazoria County to the county road southeast of New Ulm in Austin County

Area		Category	Year First Listed
1302_01	*Lower 25 miles of segment*		
	bacteria	5a	2002
1302_02	*25 miles from just upstream of FM 442 to downstream of US 90A*		
	bacteria	5a	2002
1302_03	*25 miles from downstream of US 90A to upstream of FM 3013*		
	bacteria	5a	2002

SegID: 1302A **Gum Tree Branch (unclassified water body)**
From the confluence with West Bernard Creek near Wharton CR 252 to the headwaters approximately 15 miles upstream near RR 102

Area		Category	Year First Listed
1302A_01	*The entire 15 miles of the segment*		
	bacteria	5c	2006

SegID: 1302B **West Bernard Creek (unclassified water body)**
From the confluence with the San Bernard River Above Tidal downstream of US highway 59 to the headwaters approximately 40 miles upstream near FM 1093

Area		Category	Year First Listed
1302B_01	*Lower 15 miles of segment*		
	depressed dissolved oxygen	5c	2006
1302B_02	*Upper 25 miles of segment*		
	bacteria	5c	2006

Figure 15 - Water Quality Impairments (2008 Integrated Report)

Pollutant Sources

Point Sources

Point source pollution comes from known sources such as outfalls that flow into the river. Along the San Bernard River, there are 6 industrial outfalls and 17 domestic outfalls from sources such as cities and schools. There is a total of 23 known outfalls into the San Bernard.

Nonpoint Sources

Nonpoint source pollution is the combination of all other sources that are carried into the river as rainfall runoff water runs across the land and into the waterways. Common sources of nonpoint source pollution include: malfunctioning septic systems, construction site runoff, agricultural sources, and runoff from streets and yards. Elevated levels of fecal indicator bacteria are the primary cause of water quality problems in the San Bernard River. Possible sources of bacteria include: humans, livestock, domestic animals, and other wildlife and non-domestic animals. Other sources of pollution include nutrients, sediment, and toxic and hazardous substances.

Water Quality Focus

While a number of water quality issues exist in the San Bernard River Watershed, the stakeholders prioritized bacteria as the contaminant of greatest concern. Most management measures designed to reduce fecal bacteria pollution also help address the other impairments and concerns that have been identified (primarily high levels of nutrients and low levels of dissolved oxygen). It is the intent of the stakeholders to address all water quality issues in the watershed, including those that emerge subsequent to the development of the WPP. These additional pollutants are characterized further in this section, but subsequent sections will focus specifically on fecal bacteria.

Bacteria

Portions of the San Bernard River do not meet standards for contact recreation due to elevated levels of bacteria. In the San Bernard watershed, bacteria levels average just over 126 and maximum levels are in the 400s. Although these numbers are higher than acceptable levels, they are not exceedingly high and can be managed to reach acceptable levels. Following are a table (Table 4) and a chart of bacteria levels for 5 monitoring stations along the San Bernard River and mean *E. coli* and enterococci by year for stations in the tidal and non-tidal parts of the watershed[5]. In the tidal portion of the river the criteria is for enterococcus and the above tidal criteria is for *E. coli*.

TABLE 4 - BACTERIA LEVELS FOR SAN BERNARD WATERSHED MONITORING STATIONS (2001-2011)

Station	Criteria (MPN)	Min	Max	Average
16370	126	10	413	99
16373	126	30	369	168
12147	126	41	243	135
20460	35	1	201	64
12146	35	0	86	46

[5] Throughout the document, water quality-related projections are based on the benchmark conditions existing during the WPP development process, and benchmark data, such as the values in Table 4, used for modeling efforts. In review of current water quality, as analyzed by the Clean Rivers Program as part of their Basin Summary Reports/Basin Highlights Reports, "current" data indicates a continuance of the water quality issues identified in the benchmark data. While some constituents have increased (nutrients), the bacteria indicators on which the project is based have not shown a statistically significant trend. More information on current water quality can be reviewed at http://www.bsr2016.com/watershed-summaries/documents/1301_San%20Bernard%20River%20Tidal.pdf for the Tidal segment, and http://www.bsr2016.com/watershed-summaries/documents/1302_San%20Bernard%20River%20Above%20Tidal.pdf for the Above Tidal segment.

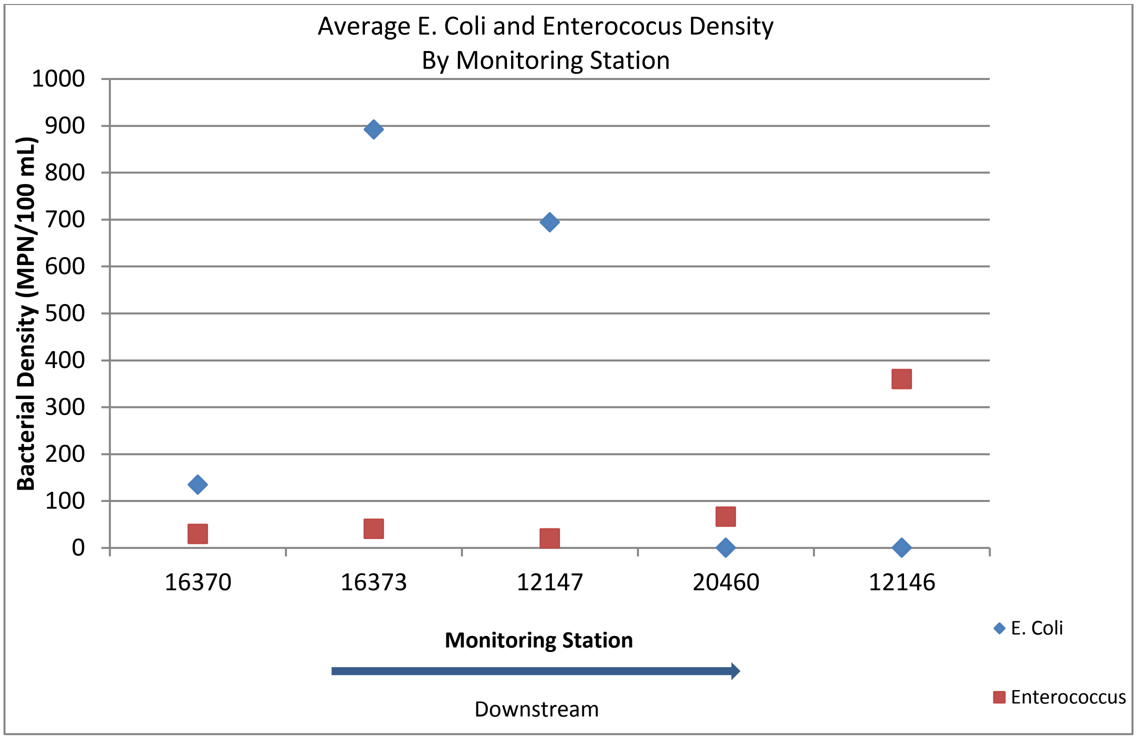

FIGURE 16 - AVERAGE *E. COLI* AND ENTEROCOCCUS DENSITY BY MONITORING STATION (2001-2011)_

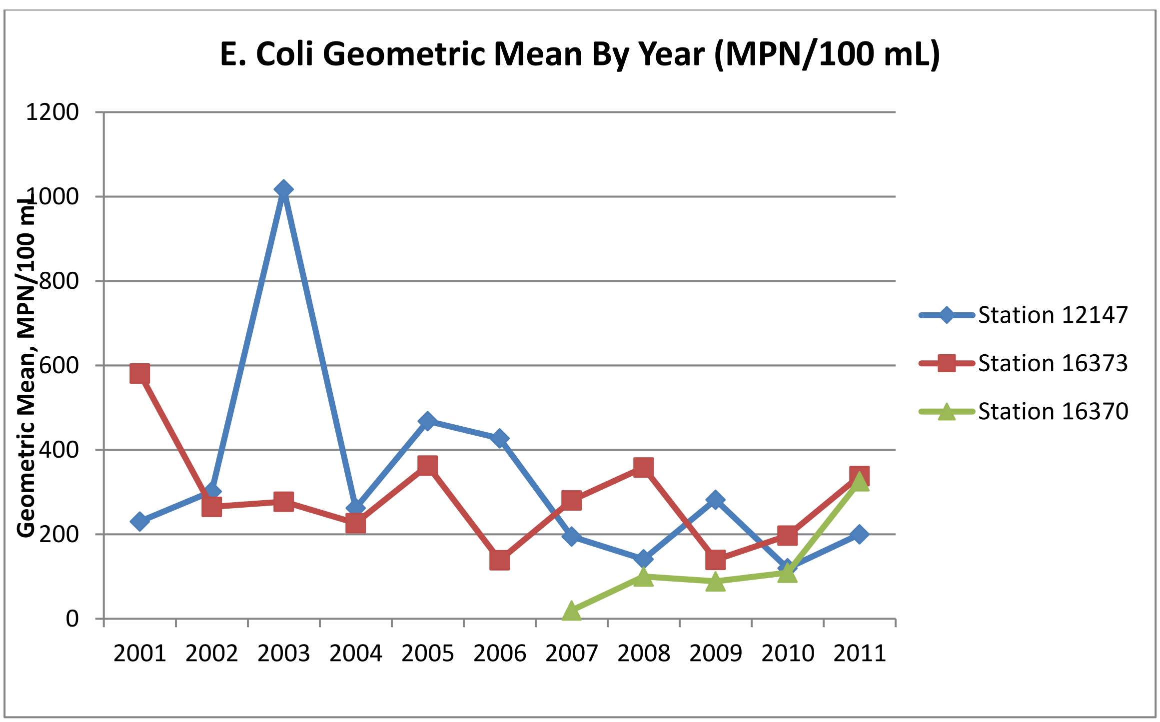

FIGURE 17 - *E. COLI* GEOMETRIC MEAN BY YEAR (2001-2011)

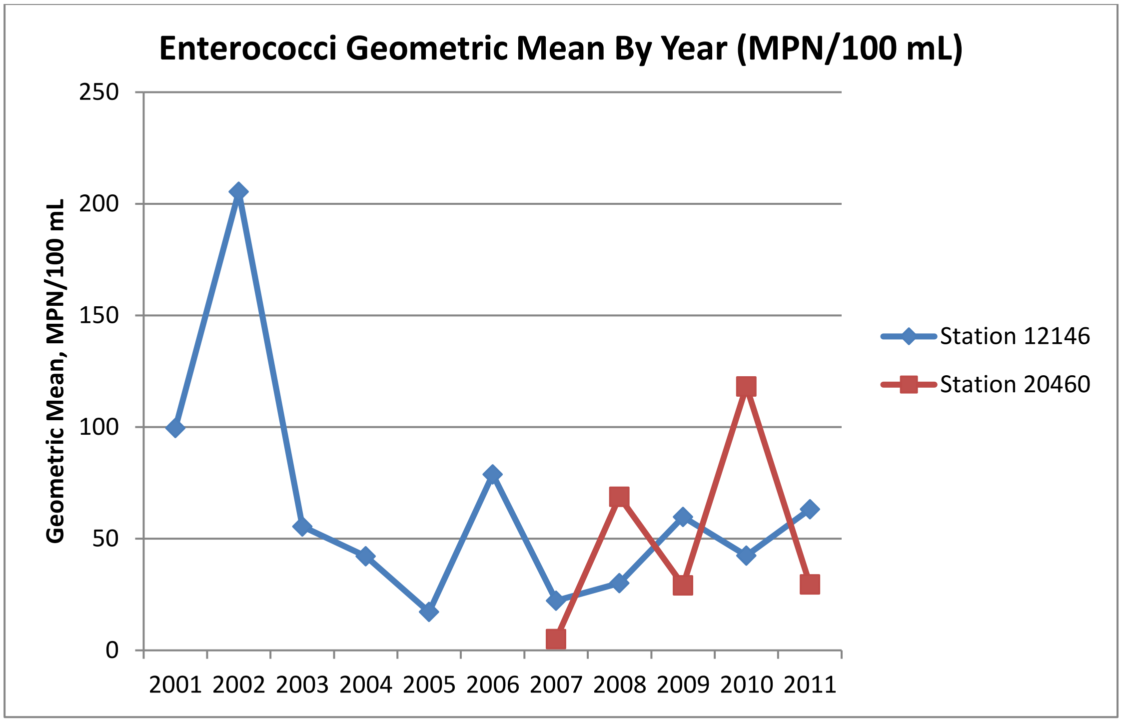

FIGURE 18 - ENTEROCOCCI GEOMETRIC MEAN BY YEAR

Nutrients

In addition to high levels of bacteria, there are also higher levels of nutrients found in the San Bernard River. There are no criteria for maximum nutrient levels allowed in a stream or river, but the "screening levels" at which a "concern" is registered are 1.95 mg/L nitrate nitrogen and 0.69 mg/L total phosphorous. Both nitrogen and phosphorous are found in the natural environment, but they are also found in fertilizers added by humans. They are necessary for plant growth, but at high levels they can cause overgrowth of plants. Below are five tables of nutrient mean concentrations by year for nitrate nitrogen, total phosphorus, orthophosphate, ammonia, and average mean by year.

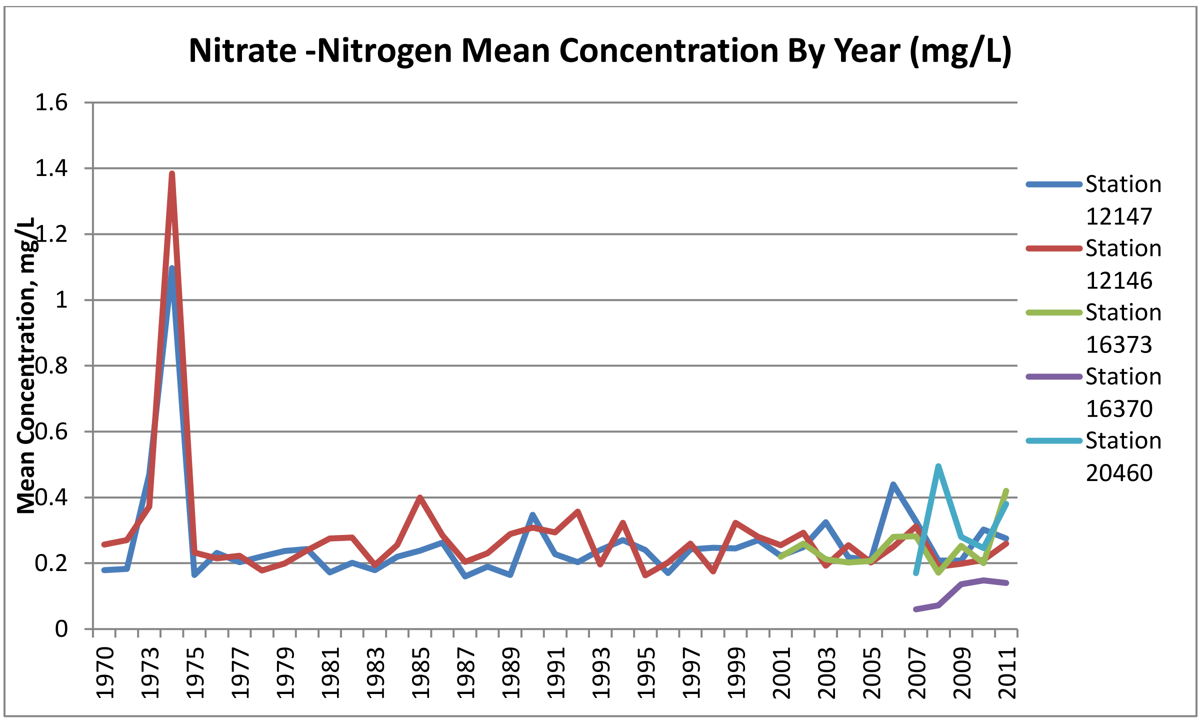

FIGURE 19 - NITRATE + NITRITE, AS NITROGEN MEAN BY YEAR, 1987 - 2010

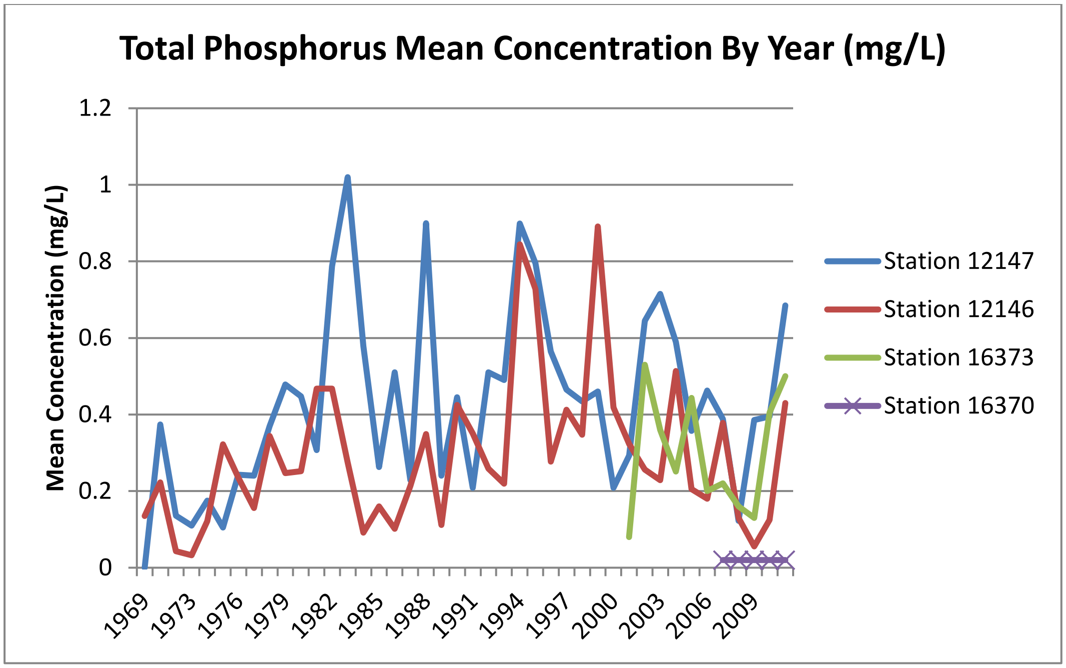

FIGURE 20 - TOTAL PHOSPHORUS MEAN CONCENTRATION BY YEAR

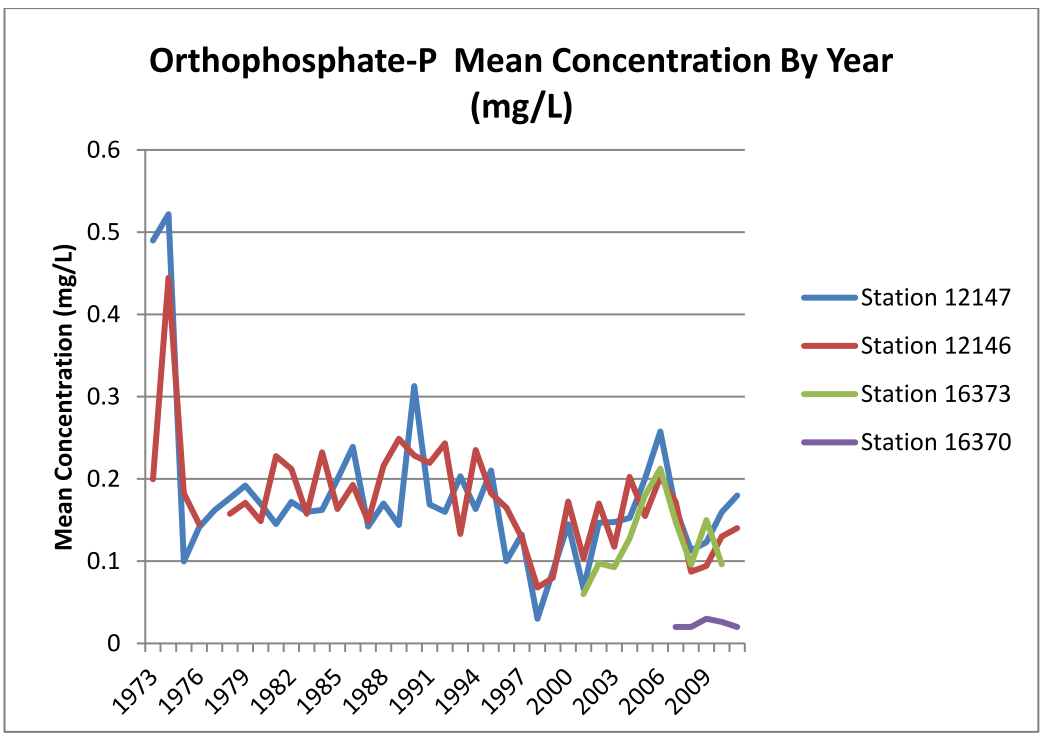

FIGURE 21 - ORTHOPHOSPHATE –P MEAN CONCENTRATION BY YEAR

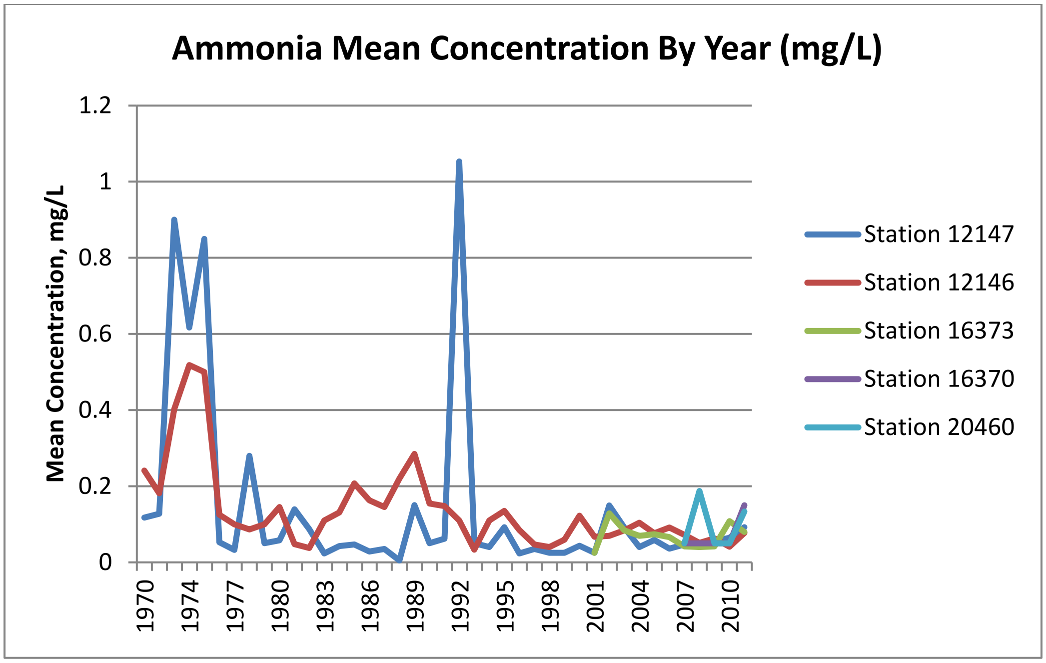

FIGURE 22 - AMMONIA MEAN CONCENTRATION BY YEAR

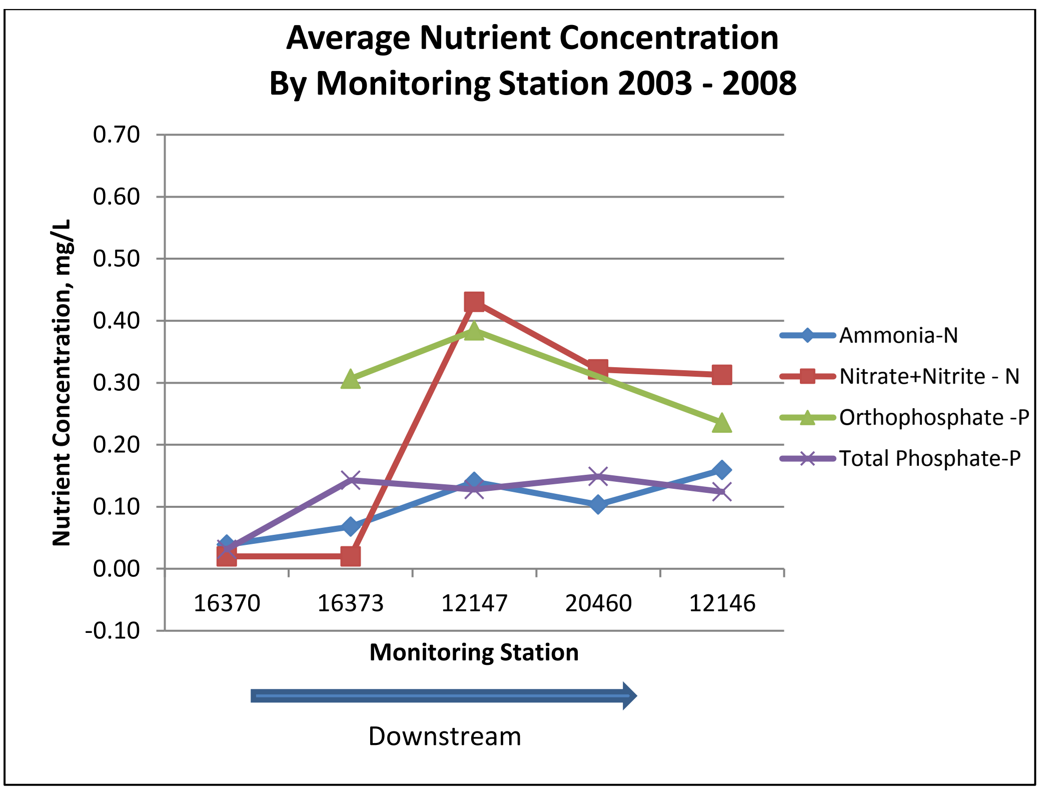

FIGURE 23 - AVERAGE NUTRIENT CONCENTRATION BY MONITORING STATION

Dissolved Oxygen

The San Bernard River has also had low DO levels, although DO levels had been returning to normal since the opening of the mouth of the river in March 2009. However, the mouth has closed again in subsequent years. Below are the rating system for DO levels and a chart showing the annual average DO levels found in the San Bernard River. The state screening level for DO for the above tidal segment is 5 and the screening level for below tidal is 4. To meet the state criterion for DO, no single grab sample can have a DO level below 3 in either segment.

- 1-2 mg/L = very polluted
- 3-5 mg/L = somewhat polluted
- 6-9 mg/L = moderately clean
- 10+ mg/L = very good

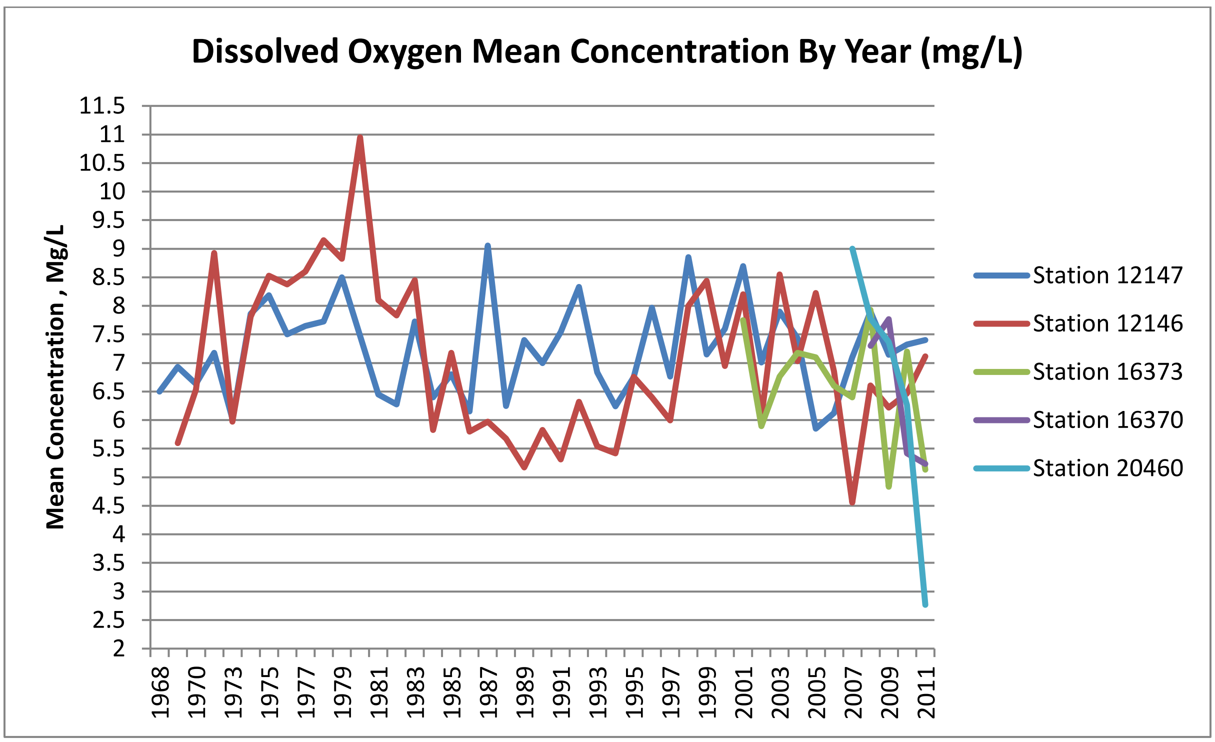

FIGURE 24 - AVERAGE DISSOLVED OXYGEN CONCENTRATION BY YEAR

Identification of Causes and Sources

During the series of open houses, participants were asked to include their comments and observations on a map of the San Bernard River Watershed regarding causes and sources of pollutants. In the northern portion of the watershed in Colorado and Austin Counties, it was noted that there are a number of small man made ponds and ditches that drain to these ponds. This diversion of water could cause lower flows in the main San Bernard River, and could cause a buildup of bacteria that would be flushed out during a rainfall event. In the southern part of Colorado County just north of Wharton County it was noted that there are sludge (municipal biosolids) applications adjacent to the river, it was unclear if this was a sludge drying process or application of already dried sludge. However, these sites were not considered a significant source for bacteria by the stakeholders, especially because they were treated biosolids. There is no sampling information to indicate that these sites are an appreciable contributor. It was noted that just south of Kendleton there is a dump site on the west side of the river.

At the confluence of Bee Tree Creek and the San Bernard River in Wharton County it was noted that the creek has been cleaned out and there is only bare soil on the banks and that a sandbar is forming in the river. In the area north of the saltwater dam in Brazoria County, it was noted that there is an area where trash, cars, and appliances are being dumped. It was also noted that along this stretch of river that animal carcasses are sometimes found, that cattle water in the river, there is fish carcass dumping, and there are a number of residential areas with potentially failing septic systems.

FIGURE 25 - TRASH DUMPED IN THE SAN BERNARD RIVER IN WHARTON COUNTY

In the vicinity of Riverbend and 344 south of Sweeny it was noted that there are drainage and garbage problems and that cattle are watering in the river. At the very southern end of the watershed, it was noted that there are some oil and gas drilling operations, some abandoned sunken vessels, and a raw sewage leak near River's End.

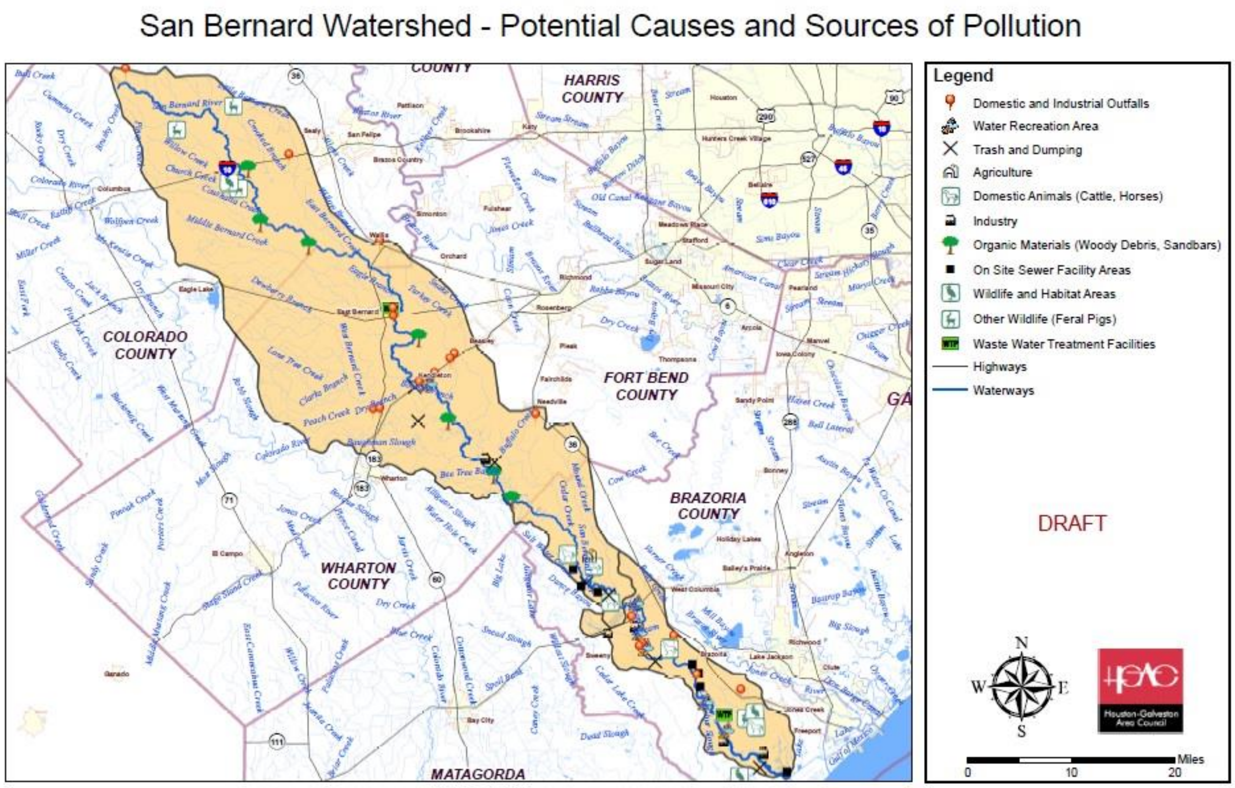

FIGURE 26 - POTENTIAL CAUSES AND SOURCES OF POLLUTION IN THE SAN BERNARD WATERSHED

At this time, not all causes and sources of the pollutants are known, but information received from stakeholders and public meetings have helped further identify areas that may be sources of bacteria to the San Bernard River. Additional monitoring will be implemented to further identify causes and sources of pollutants, and once identified, BMPs will be applied to lessen the amount of pollutants being carried into the San Bernard River.

An online survey was also conducted of watershed residents and landowners; the response rate was about 10 percent. Questions included asking respondents how they use their land in the watershed, how much land they have, and whether or not they have been involved in the WPP process. The respondents were asked to specify which BMPs they thought would best address the identified causes and sources of pollution. Respondents also had the opportunity to answer some open-ended questions about what they thought needed to be added to the plan, what the biggest obstacle in implementing the plan would be, and were given the opportunity to add any other additional comments. The following causes and sources of pollutants in the San Bernard Watershed were identified and graphed by the number of respondents who identified each as a priority.

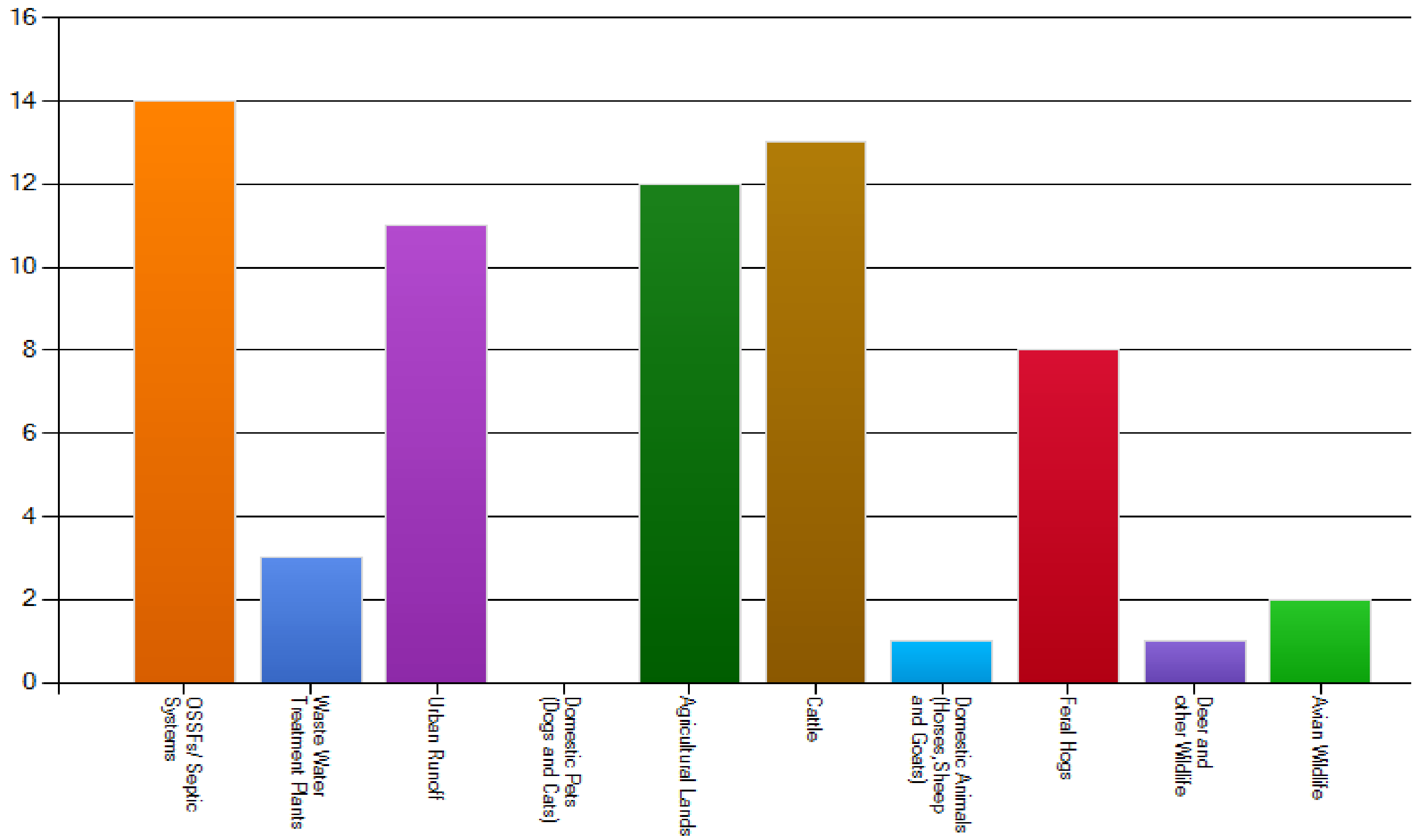

FIGURE 27 - STAKEHOLDER PRIORITIZATION OF CAUSES AND SOURCES OF POLLUTION IN THE SAN BERNARD WATERSHED

WATER QUALITY AND FLOW

H-GAC has been monitoring water quality and flow in the San Bernard watershed for an extended period of time, below is a snapshot of the sampling results for the eight sites currently being sampled. The data shown is the benchmark period for the plan, reflecting the current conditions when the plan was initially developed with stakeholders, and the inputs to the modeling[6].

TABLE 5- WATER QUALITY MONITORING DATA, BY MONITORING STATION[7]

Monitoring Station	Parameter	Number of Samples	Minimum	Maximum	Mean	Sampling Period
12146	Ammonia-N	169	0.01	1.9	0.14	1969-2010
	Dissolved Oxygen	180	2.9	18.1	7.5	1969-2010
	Enterococci	37	5	10462	385	1969-2010
	Nitrate-N	189	0.01	2.12	0.28	1969-2010
	Orthophosphate-P	147	0.02	1.66	0.18	1969-2010
	pH	138	6.5	9.9	7.7	1969-2010
	Total Phosphorus	166	0.01	6.18	0.29	1969-2010
	Total Suspended Solids	170	2	359	38	1969-2010
12147	Ammonia-N	165	0	3	0.14	1970-2011
	Dissolved Oxygen	188	3.8	12.5	7.3	1968-2011
	E. coli	44	10	9804	765	2001-2011
	Nitrate-N	187	0.01	3.26	0.43	1970-2011
	Orthophosphate-P	143	0.03	1.44	0.18	1973-2011
	pH	124	6.2	8.8	7.6	1973-2010
	Total Phosphorus	159	0.07	4.18	0.27	1970-2011
	Total Suspended Solids	162	1	320	61	1970-2011
16370	Ammonia-N	13	0.05	0.05	0.05	2007-2010
	Dissolved Oxygen	12	3.8	9.4	6.6	2007-2010
	E. coli	13	10	2000	257	2007-2010
	Nitrate-N	13	0.02	0.02	0.02	2007-2010
	Orthophosphate-P	13	0.02	0.05	0.02	2007-2010
	pH	12	6.9	7.9	7.5	2007-2010
	Total Phosphorus	13	0.03	0.41	0.12	2007-2010
	Total Suspended Solids	13	1	18	6	2007-2010
16373	Ammonia-N	35	0.03	0.3	0.07	2001-2010
	Dissolved Oxygen	40	4.1	10.9	6.8	2001-2010

[6] Refer to footnote 2 for additional description of more recent water quality conditions.
[7] pH is in "standard units"; enterococci or *E. coli* is in MPN/100 mL, all other parameters are measured in mg/L.

Monitoring Station	Parameter	Number of Samples	Minimum	Maximum	Mean	Sampling Period
	E. coli	37	62	3076	388	2001-2010
	Nitrate-N	37	0.02	1.17	0.29	2001-2010
	Orthophosphate-P	35	0.02	0.26	0.13	2001-2010
	pH	41	6.4	8	7.5	2001-2010
	Total Phosphorus	36	0.03	0.49	0.22	2001-2010
	Total Suspended Solids	34	2	109	33	2001-2010
20460	Ammonia-N	12	0.05	0.6	0.1	2007-2010
	Dissolved Oxygen	13	3.8	11.1	7.4	2007-2010
	Enterococci	12	5	410	116	2007-2010
	Nitrate-N	12	0.02	2.33	0.22	2007-2010
	Orthophosphate-P	12	0.02	0.27	0.15	2007-2010
	pH	13	7.5	8.3	7.8	2007-2010
	Total Phosphorus	12	0.09	0.94	0.33	2007-2010
	Total Suspended Solids	12	4	85	22	2007-2010
20721	Ammonia-N	5	0.05	0.2	0.08	2010
	Dissolved Oxygen	5	4.3	9.6	5.8	2010
	E. coli	5	41	170	96	2010
	Nitrate-N	5	0.02	0.37	0.24	2010
	Orthophosphate-P	5	0.09	0.23	0.16	2010
	pH	5	7.3	7.5	7.5	2010
	Total Phosphorus	5	0.22	0.49	0.35	2010
	Total Suspended Solids	5	11	84	44	2010
20722	Ammonia-N	5	0.05	0.05	0.05	2010
	Dissolved Oxygen	5	3.4	8.8	5.1	2010
	E. coli	5	31	290	135	2010
	Nitrate-N	5	0.02	0.16	0.11	2010
	Orthophosphate-P	5	0.19	0.41	0.27	2010
	pH	5	7.4	7.5	7.4	2010
	Total Phosphorus	5	0.23	0.56	0.37	2010
	Total Suspended Solids	5	8	49	26	2010
20723	Ammonia-N	5	0.05	0.05	0.05	2010
	Dissolved Oxygen	5	1.3	10.2	4.4	2010
	E. coli	3	5	150	62	2010
	Enterococci	2	120	1300	710	2010
	Nitrate-N	5	0.02	0.07	0.04	2010
	Orthophosphate-P	5	0.11	0.3	0.16	2010
	pH	5	7.3	7.9	7.7	2010
	Total Phosphorus	5	0.17	0.42	0.27	2010
	Total Suspended Solids	5	3	101	31	2010

TABLE 6 - SAN BERNARD RIVER AND TRIBUTARIES MONITORING STATIONS (USGS STUDY)

Station Number	Station Name	Drainage Area (sq. mi)	Population Density (people per sq. mi)	Data Collection Activity
294036096165001	Coushatta Creek at Attwater Prairie Chicken NWR	39.9	10	Bimonthly water-quality sampling/ Biological sampling
293211096110301	West Bernard Creek at CR 252	22.1	39	Bimonthly water-quality sampling/ Biological sampling
293123096073001	Gum Tree Branch at CR 252	35.1	29	Bimonthly water-quality sampling/ Biological sampling
292939096014001	San Bernard River at FM 2919	375	24	Bimonthly water-quality sampling/ Biological sampling
08117500	San Bernard River near Boling	727	30	Continuous stream flow/ Continuous water-quality monitoring/ Bimonthly water-quality sampling/ Biological sampling
290935095455601	San Bernard River at FM 1301	825	32	Continuous stream flow/ Continuous water-quality monitoring/ Bimonthly water-quality sampling/ Biological sampling

RAINFALL INFORMATION

Weather data for the simulation was collected from five weather stations in and around the San Bernard Watershed: Brenham, Bellville, Wharton, Wharton Airport, and Freeport. Specific information on each type of weather data is provided in more detail subsequently.

Although precipitation data were collected from the five stations noted previously, three stations (Bellville, Wharton, and Freeport) are located closest to the watershed. Therefore, data from these three stations were used preferentially to generate most of the precipitation input for SWAT. If there were gaps in the data during the simulation period the other two stations were used to complete these gaps.

SOURCES OF INFORMATION

USGS in Cooperation with the Houston-Galveston Area Council and the Texas Commission on Environmental Quality; Hydrologic, Water-Quality, and Biological Data for Three Water Bodies, Texas Gulf Coastal Plain, 2000-2002; Open File Report 03-459

2008 Texas 303(d) List, March 19, 2008, Texas Commission on Environmental Quality

US Army Corps of Engineers, Galveston District; Draft Environmental Assessment – Restoration of the Mouth of the San Bernard River to the Gulf of Mexico, Brazoria County, Texas, June 2008

Halff Associates, Inc; San Bernard Watershed Flood Protection Planning Study Final Report, July 15, 2009.

FIGURE 28 - WATER QUALITY MONITORING IN THE SAN BERNARD RIVER WATERSHED

5 - Causes and Sources of Pollution (Element A)

Bacteria come from a number of sources throughout the watershed. Land uses and land cover vary widely throughout the watershed from agriculture uses to urban uses. The upper portion of the watershed is more rural in nature and not densely populated, the lower part of the watershed is more residential in nature. A number of causes and sources of pollution have been identified by stakeholders throughout the watershed. These sources include: domestic animals, trash and dumping, agriculture, industry, organic materials, OSSFs, wildlife, and WWTFs. As the population in the watershed continues to grow, more land in the watershed will be developed and subdivided, and potentially contribute to water quality problems. This plan will identify prime sources through modeling and will identify BMPs to help reduce bacterial input into waterways now and in the future.

Modeling Approach

The progression of steps in the WPP process includes quantification of sources, modeling of existing conditions, and definition of reduction activities that will make an impaired stream meet state water quality standards (USEPA, 1999). When a water body does not meet the standard required for its designated use, it is listed as impaired on the Texas list of impaired waterways (303(d) list). These impairments are evaluated through the use of bacterial indicators of pathogen contamination. The EPA and the State of Texas have defined two types or indicator organisms, *Escherichia coli* (*E. coli*) for freshwaters and Enterococci for marine waters.

The standards for these indicators depend on the assigned use of the stream: contact or non-contact recreation. In Texas, there are two different levels of standards. The long-term trends in bacteria concentrations are evaluated using the geometric mean standard. Instantaneous concentrations are evaluated using the single sample, or the not-to-exceed standard.

San Bernard River and tributaries are classified as contact recreation water bodies; for this reason, the standards currently used are *E. coli* geometric mean and single sample standard for the non-tidal portion and Enterococci for tidal influenced streams. The *E. coli* 30-day geometric mean standard for contact recreation purposes is 126 colony forming units per deciliter (cfu/dL) and the single sample standard is 394 cfu/dL; while Enterococci standards are 35 cfu/dL and 89 cfu/dL respectively. Water quality estimates in this plan are projections based on the benchmark conditions (through 2010) available during the development of the WPP with the project stakeholders. However, more recent analysis of the water quality in the watershed indicates that there has not been a statistically significant trend in bacteria levels[8]. Therefore, these estimates are considered to be representative water quality trends in the watershed.

For the regulatory TMDL process addressing pathogen contamination, the EPA published recommendations to assess *E. coli* source contribution and identification, characterize the sources, and estimate the *E. coli* load produced by each source (USEPA, 2001). The EPA document recommends identification of the location and densities of *E. coli* contributing source populations to characterize the loads in a watershed. This process is assisted by the use of modeling in San Bernard River watershed. Models are, in the most basic sense, computer simulations of conditions. Models are used to describe and predict how different factors interact with each other. For the San Bernard Watershed, modeling was conducted to evaluate the total potential load from bacteria sources, how it will change over time, the impacts of source loads on instream concentrations, and the potential impact of BMPs. The end goal of modeling activities in a WPP is to inform stakeholder decisions about solutions.

Three modeling efforts were used to help characterize the potential source load and projected instream concentrations for bacteria in benchmark and future conditions:

- **SELECT -** The Spatially Explicit Load Enrichment Calculation Tool (SELECT) was used in the development of the San Bernard WPP to characterize the bacteria load associated to each individual source as well as the contribution of each source within the watershed. The methodology followed in the application of the model was based on Teague et al. (2007). SELECT provides the total potential source load.
- **SWAT -** The Soil and Water Assessment Tool (SWAT) is a watershed model that was used to understand relationships between source loads and instream concentrations of bacteria in the Above Tidal segment. SWAT provides the predicted instream concentrations based on future changes in sources and the impacts of BMPs.
- **TIDAL PRISM -** Tidal prism models (TPMs) are one-dimensional receiving water models that utilize the concept of “tidal flushing” to simulate the physical transport of pollutants in a tidal basin over

[8] See footnote 2.

time. A Tidal Prism approach was used to understand relationships between source loads, instream concentrations, and tidal removal of bacteria in the Tidal segment. Like SWAT, Tidal Prism modeling provides the predicted instream concentrations based on future changes in sources and the impacts of BMPs.

The assumptions and results of the models were reviewed at multiple stages with the project stakeholders, and amended to reflect local knowledge as appropriate. The SWAT and Tidal Prism models were re-run subsequent to the WPP development, to incorporate new data and address additional stakeholder and agency comments. The implications of the results of the SWAT and Tidal Prism models estimations of bacteria reductions are discussed more fully in Section 6 and Appendix B.

SELECT MODELING

SELECT was used to evaluate benchmark and future (subsequent 30 years) bacteria source loadings within the watershed. In order to obtain more accurate results, the entire San Bernard watershed was divided up into 10 subwatersheds based on the HUC-12 division for Texas, their proximity to the biggest tributaries, and location of water quality monitoring stations (Figure 29)

Variables reflecting the percent land cover were calculated using The National Land Cover Dataset (NLCD) from 2006. The land Information used to estimate bacterial loads for the subsequent 30 years were based on household forecast information obtained from H-GAC. Housing and jobs forecasts were obtained for urbanized areas within the watershed. These areas include: Beasley, Brazoria, Jones Creek, Kendleton, Needville, and Sweeny. The additional number of estimated households for rural versus urban areas was also obtained for the 10 subwatersheds for the years 2010 to 2040. The total population in 2010 was estimated to be 18,520 and the estimated population in 2040 is 44,006. The total rural population in 2010 was 10,144 and the urban population was 8,376. In 2040 it is projected that the total rural population will be 33,059 and the urban population will be 10,974. However, it was necessary to make several assumptions in the projection of bacteria source loadings. Although the population will change, it was assumed that the type of housing remained the same, single family homes. For growth of residential areas, an assumption that the new housing will be suburban single family homes on 1/2 acre lots. Additionally, land cover from pastures and farming was assumed to provide most of the area for growth. Finally, the increased number of households in rural areas is assumed to be on OSSFs and those projected to be in urban areas on WWTFs. Existing land cover is summarized in Table 7.

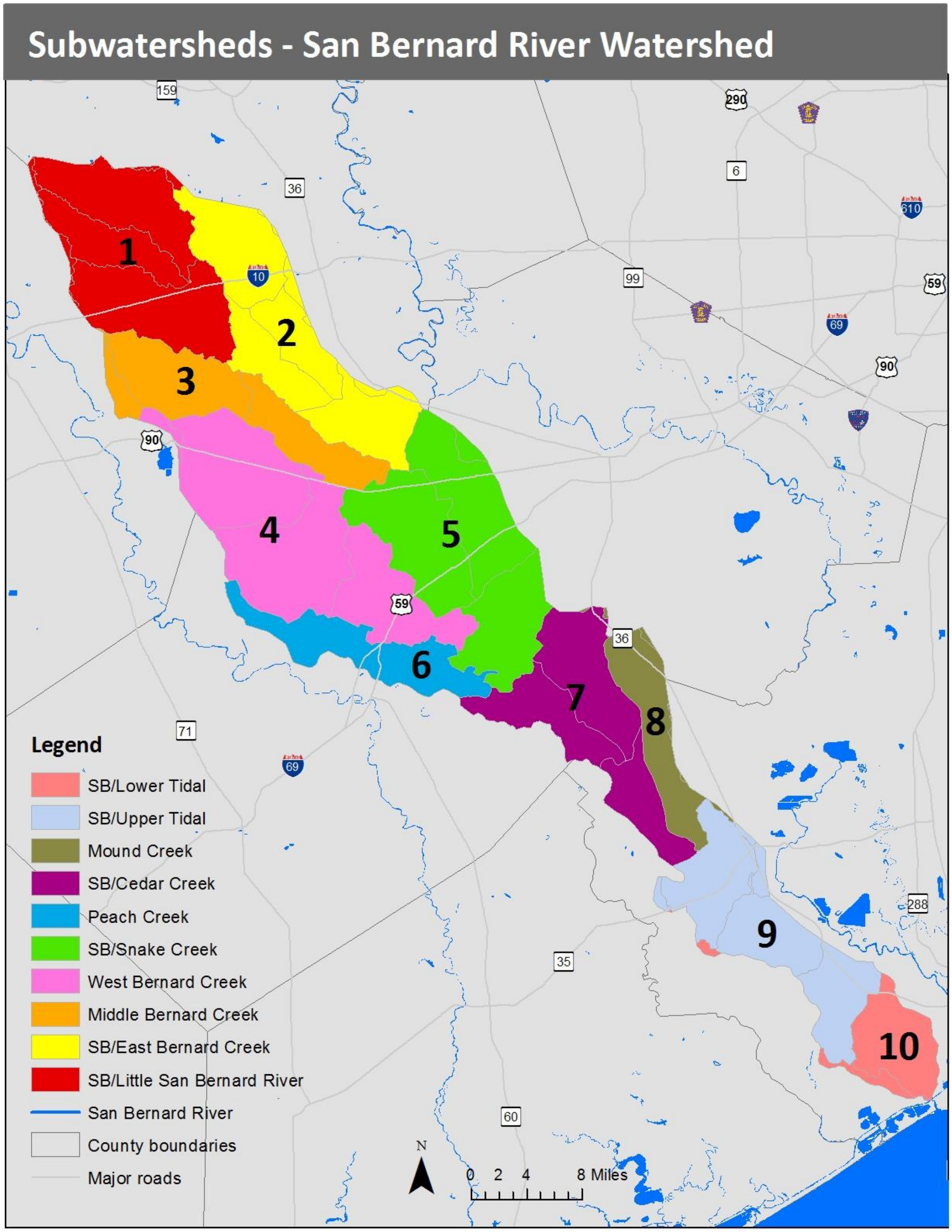

FIGURE 29- SAN BERNARD WATERSHED SUBDIVISIONS

TABLE 7- LAND COVER CATEGORIES BY SUBWATERSHED

Land Cover Category	SUBW 1	SUBW 2	SUBW 3	SUBW 4	SUBW 5	SUBW 6	SUBW 7	SUBW 8	SUBW 9	SUBW 10
High Intensity Developed	0%	0%	0%	0%	0%	0%	0%	0%	1%	0%
Low Intensity Developed	1%	1%	1%	2%	2%	4%	1%	1%	5%	1%
Open Space Developed	0%	0%	0%	0%	0%	0%	0%	0%	2%	1%
Cultivated	62%	87%	89%	85%	77%	68%	47%	60%	26%	7%
Grassland/Shrub	12%	5%	6%	7%	6%	14%	9%	15%	27%	5%
Forest	20%	1%	2%	1%	1%	7%	1%	1%	6%	3%
Woody Wetland	4%	4%	2%	3%	12%	6%	38%	21%	27%	7%
Herbaceous Wetland	1%	1%	1%	1%	1%	1%	2%	1%	4%	70%
Bare	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Open Water	0%	0%	0%	0%	0%	0%	1%	0%	2%	6%

Potential Sources Of Bacteria

Potential sources of bacteria were identified through discussions and map exercises with projects stakeholders. The primary categories identified were failing septic tanks (OSSFs), WWTFs, urban runoff, dogs, cattle, horses, sheep and goats, deer, and feral hogs.

The various sources were populated and evaluated in SELECT to evaluate the spatial extent of each source, and their relative and absolute contributions. Each source of *E. coli* was distributed to the appropriate subwatersheds and then bacteria loads were calculated. The average daily load for each source was calculated according to the methodology suggested by EPA (USEPA, 2001); this is multiplying an individual species' fecal coliforms (FC) excretion rate (Figure 30) by the corresponding species population. *E. coli* loads were assumed to be 50 percent of the fecal coliform concentration (Teague et al., 2007, Doyle and Erikson, 2006). *E. coli* sources were distributed to subwatersheds based on land cover distribution and loadings associated with each of the land covers. Next, all different sources of bacteria considered in the model are described. Results were reviewed during and after the plan development. The data utilized in the analyses below reflect the most current data available at the time of the development of the Plan (referred to as benchmark data or conditions throughout), for five-year increments between 2011 and 2040.

Source	Calculation
Cattle	$EC = \#cattle \cdot 2.7 \cdot 10^9 cfu\ d^{-1}\ head^{-1}$
Horses	$EC = \#horses \cdot 2.1 \cdot 10^8 cfu\ d^{-1}\ head^{-1}$
Sheep and goats	$EC = \#sheep \cdot 9 \cdot 10^9 cfu\ d^{-1}\ head^{-1}$
Deer	$EC = \#deer \cdot 1.75 \cdot 10^8 cfu\ d^{-1}\ head^{-1}$
Feral hogs	$EC = \#hogs \cdot 4.45 \cdot 10^9 cfu\ d^{-1}\ head^{-1}$
Dogs	$EC = \#households \cdot \frac{0.8\ dogs}{household} \cdot 2.5 \cdot 10^9 cfu\ d^{-1}\ head^{-1}$
Failing septic systems	$EC = \#failing\ systems \cdot \frac{5 \cdot 10^5 cfu}{100\ mL} \cdot \frac{2.65 \cdot 10^5 mL}{person/day} \cdot \frac{Avg\ \#\ persons}{household}$
WWTP	$EC = permitted\ MGD \cdot \frac{126\ cfu}{100\ mL} \cdot \frac{10^6\ gal}{MGD} \cdot \frac{3758.2\ mL}{gal}$

FIGURE 30 – BACTERIA SOURCE LOADING RATES

An important distinction should be made between the source loads presented in this section and in-stream loads which are presented later. The SWAT and Tidal Prism models were developed to route source loadings calculated by the model over the watershed and into the San Bernard River and its tributaries to calculate in-stream concentrations and loads of bacteria. These models were also used to evaluate impacts of the source loads on the river concentrations and confirm the type of reductions that are needed to achieve water quality standards. The loading associated with bacteria sources was found to be larger by an order of magnitude or greater than that observed for the in-stream bacteria loading. The lower loads in-stream reflect the attenuation of the source loading, which occurs as the loads are carried over the watershed, acted upon by natural processes and tidal removal, and into the river.

The specific process of evaluating each source is described as follows, and additional information can be found in Appendix A.

Point Sources

Waste Water Treatment Facilities

WWTFs are the primary point sources of bacteria in the SELECT model. The San Bernard River watershed has a total of 19 WWTFs; but two of them present intermittent flow, so no flow data is reported. Table 8 shows the name and location for WWTF outfall permits in the watersheds. Table 9 shows the permitted and self-reported flows for each subwatershed, and the number of WWTFs in each subwatershed (shown in the column entitled "Number").

TABLE 8 - WWTF OUTFALL PERMITS IN THE WATERSHED

Subbasin	Name	Location	Permitted Flow (MGD)
1	New ULM WSC WWTF	Bernard RD, 1 mi SE Intx FM New ULM, TX 78950	0.05
11	City of Wallis WWTF	FM RD 1093 & ST HWY 36 Wallis, TX 77485	0.2
13	Wharton County WCID No. 2	106 Fitzgerald St. East Bernard, TX 77435	0.4
21	City of Kendleton WWTF	1,500 Ft E Farm Market RD 2219 Kendleton, TX 77451	0.08
22	Hungerford Mud No. 1 WWTF	250 ft. NW Int W Live Oak & Haber Hungerford, TX 77448	0.08
	Straightway Inc. WWTF	Interx FM 1161 & CR 218 Hungerford, TX 77448	0.03
32	City of Needville	14206 Church Street, Needville, TX 77461	0.4
33	Needville ISD WWTF	Roesler RD and Danhouse RD, Needville, TX 77461	0.036
36	Autumn Shadows WWTF	Sthwy 35, 570 ft. East Sthwy 35 Danbury, TX 77534	0.007
37	City of Sweeny	N End of Ave. A on W Bank of Sweeny, TX 77480	0.975

Subbasin	Name	Location	Permitted Flow (MGD)
	Bernard Timbers WSC	USHWY 90A, 1.4M NE USHWY 90A & East Bernard, TX 77435	0.021
	City of Brazoria WWTF	One Mile West of Intersection Brazoria, TX 77422	0.75
	Wild Peach Elementary WWTF	1 mi S of STHWY 36 @ PT 4.5 mi S West Columbia, TX 77486	0.01
40	Clemens Unit WWTF	0.5 mi N Intx St hwy 36 & FM 200 Brazoria, TX 77422	0.54

At the time the project was developed, none of the WWTFS in the area were required to monitor for fecal contamination; however, two WWTFs reported values of 126 cfu/dL. For this reason, it was assumed that all WWTFs presented the same concentrations as the ones reporting. The stakeholders approved this calculation based on the water quality standard, and lack of information or anecdotal evidence to suggest any of the plants had significant issues. Daily load from each WWTF was calculated by multiplying average self-reported flow by bacteria concentration. WWTF loadings will rise slightly as the population in the watershed increases; however, they will not be a significant contribution to the total loading.

TABLE 9 - SAN BERNARD WWTF EFFLUENT FLOWS, BY SUBWATERSHED

SUBWATERSHED	Number (WWTF)	Permitted Flow (MGD)	Average Self Reported Flow (MGD)[1]
SW1- SB/Little San Bernard River	1	0.050	0.001
SW2- SB/East Bernard Creek	2	0.595	0.159
SW4- West Bernard Creek	0	0.000	0.000
SW3- Middle Bernard Creek	2	0.110	0.040
SW5- SB/Snake Creek	6	1.058	0.444
SW6- Peach Creek	0	0.000	0.000
SW7- SB/Cedar Creek	1	0.400	0.181
SW8- Mound Creek	0	0.000	0.000
SW9- SB/Upper Tidal	0	0.000	0.000
SW10- SB/Lower Tidal	5	2.282	1.250
TOTAL	**17**	**4.495**	**2.076**

[1]. From 01/2008

NONPOINT SOURCES

The San Bernard River is primarily agricultural, with light development. Therefore, nonpoint sources make up the vast majority of the number of bacteria sources in the watershed, as well as accounting for the majority of the total contribution.

OSSFs

OSSFs are the predominant form of wastewater treatment for many areas of the watershed. These systems are built to treat domestic wastewater where no sewer systems exist. Bacteria loading from failing systems can reach streams by overland flow from surface ponding during wet periods or through groundwater. When the systems are properly designed, installed, and maintained, they may not constitute a source of bacteria, but if they do not receive proper maintenance, eventually they will fail. According to a study conducted by Reed, Stowe & Yanke in 2001, regulated systems would have a failure rate of 12 percent, while unregulated systems would have a failure of 50 percent; OSSFs were regulated starting in 1989, while systems installed prior 1989 remain unregulated.

The number and location of households utilizing OSSFs was obtained from a database developed by H-GAC. In cases where no installation year was available, it was assumed that 60 percent of the systems were unregulated due to no installation date associated with them (Reed, Stowe & Yanke in 2001). The OSSF dataset is missing information for Wharton and Colorado Counties, so it would not provide a very accurate basis to estimate loadings for the watershed. Instead of using this dataset, average household data was used to determine where population exists that is not connected to a WWTF.

FIGURE 31- OSSF COVER

The *E. coli* load for each subwatershed was calculated based on an estimated 70 gal/person/day discharge and $5*10^6$ cfu/dL *E. coli* concentrations. The average number per household was obtained from the 2009 U.S Census (USCB 2009, Teague, 2009). The highest loadings from OSSFs are in the northeast part of the watershed, and the lowest loadings are at the mouth of the water by the coast where there is little population. Loadings from OSSFs will continue to increase as the population increases in the watershed, however with proper installation and maintenance, these OSSFs will not contribute as much bacteria loading to the watershed as older existing OSSFs.

LIVESTOCK

Waste generated by livestock animals can be directly deposited into the stream or carried by runoff from fields to the stream. Animal populations were obtained from the 2007 Census of Agriculture per each county (Table 10). The proportional number of animals based on a ratio of total appropriate land use in the county to the total appropriate land cover in the watershed area of that county was developed for each county. The resulting number of animals was uniformly distributed in 90 percent of hay/pasture and herbaceous areas; the density of cattle per mile was calculated and assigned to specific land covers within each subwatershed (Table 11). The number of animals within each subwatershed was multiplied by the fecal coliform excretion rate and then converted to *E. coli* load.

TABLE 10 - NUMBER OF ANIMALS PER COUNTY (CENSUS OF AGRICULTURE - 2007)

NUMBER OF LIVESTOCK ANIMALS PER COUNTY			
County	**Cattle[9]**	**Horses**	**Sheep & Goats**
Austin	70184/46271	3491	1930
Brazoria	78560/51440	5367	5481
Colorado	98283/56965	1897	1036
Fort Bend	46206/31225	3105	1258
Wharton	76780/52315	1942	3591

Habitats for livestock were determined based on literature and previous studies (Table 11). Animal numbers were distributed among the watersheds within each county based on land cover types.

TABLE 11 - ASSIGNED HABITATS FOR LIVESTOCK

Cattle	Herbaceous + 90% of Hay Pasture areas
Horses	Herbaceous + 90% of Hay Pasture areas
Sheep & Goats	Herbaceous + 90% of Hay Pasture areas

Bacteria loadings from livestock are expected to stay the same over the next thirty years as more residential development occurs in the watershed. The greatest loadings are in the south part of the watershed in the tidal portion where there are more areas covered by pasture and where there are greater numbers of horses, sheep and goats.

FIGURE 32- CATTLE IN AUSTIN COUNTY

[9] Cattle numbers represent total cattle (first number) and beef cattle (second number).

PETS

Dogs were the only pets considered to contribute to pet waste within the watershed. According to the Veterinary Medical Association, Texans own 5.4 million dogs; by dividing this number by the number of households in Texas, it was found there is a ratio of 0.8 dogs/household. With this ratio, the number of dogs per subwatershed was calculated. It was considered that dogs produce about 0.75 pounds of waste per day (USEPA, 2001). The ratio of 0.5 cfu E.coli/cfu fecal coliforms was used to calculate the load generated per subwatershed associated with this source. Bacteria loadings from pets are expected to increase with the rise in population in the watershed. The highest loadings will continue to come from the areas with population centers and residential populations.

URBAN RUNOFF

Urban runoff includes bacteria that accumulate on surfaces from domestic animals and human activities. In the calculation of bacteria loads generated by runoff, it was necessary to quantify bacteria concentration and runoff volumes generated during rainfall events. *E. coli* concentrations during wet periods were calculated by using a study performed by the engineering firm PBS&J (now Atkins). In this study, an empirical relationship between *E. coli* concentrations and percentage of imperviousness was developed. The fraction of impervious cover associated to each land cover was extracted from either a study conducted by the EPA (Exum et al. 2005) or guidance documents from the Tropical Storm Allison Recovery Project (TSARP). The simplest method was applied to calculate Runoff volumes and *E. coli* loading within each subwatershed. Urban Runoff loadings are associated to urban areas; for this reason, they are expected to increase as population and development increase in the watershed.

SANITARY SEWER OVERFLOWS

Sanitary sewer overflow (SSO) data was obtained for the entire San Bernard Watershed for the previous seven-year period. Seventy-one events were reported from four facilities during this time, 92 percent of which were generated by storm events at one specific facility. Due to the discrete nature of the data, the episodic nature of SSOs (as opposed to chronic loadings), and the likelihood that their loadings are reflected in urban runoff estimates, SSOs were not included as a separate source in the analysis. However, given their nature as a human waste source and their potential to create locally high bacteria levels in short term scenarios, SSOs remain an important consideration in improvements to human wastewater management.

TABLE 12 - SEWER SYSTEM OVERFLOWS REPORTED IN SAN BERNARD WATERSHED

SUBWAT.	EPA Permit	Date	# events	TOTAL DURATION (days)	TOTAL GALLONS	EC CONC. (#cfu/dL)	EC TOTAL LOADING (cfu/day)
1	TX0114880	8/29/2005	1	0.2083	0	1.00E+07	0.00E+00
5	TX0098949	5/23/2003	1	0.2083	9000	1.00E+07	1.18E+13
9	TX0024511	6/2/2002, 6/16/04	2	0.0417	200000	1.00E+07	1.31E+15
9	TX0025615	06/26/06-09/20/10	62	25.17	1418870	1.00E+07	1.54E+13

FERAL HOGS AND WILDLIFE

To estimate *E. coli* potential load generated by wildlife, deer and feral hogs[10] were considered the two major contributors (Teague, 2009). Other wildlife sources such as birds, raccoons, coyotes and opossums are present, but they were not evaluated due to lack of reliable information. The presence of seasonal populations of wintering waterfowl (geese and ducks) in the wildlife refuges and coastal areas was raised as an issue of potential investigation by the stakeholders. However, the lack of good information on populations (other than some limited data on geese from TPWD), the seasonality of the populations, and the limited solutions available to address these populations (due to protection under the Migratory Bird Treaty Act and other state and federal restrictions, as well as stakeholder preference to not address this source) meant these sources were not considered in this Plan.

Density population for deer was obtained from the TPWD; deer densities are reported for resource management units (RMUs). RMUs' shapefile and densities were used to calculate number of deer within each subwatershed. Then the fecal coliform excretion rate of 3.58*105 cfu/day-animal (Zeckoski et al., 2005) was used to obtain the *E. coli* loads generated by this source within each subdivision.

Feral hog population range from 3.2 to 6 hogs/km2 in the Rio Grande Plains and lower coastal prairie of Texas (Hellgren, 1997, Teague, 2009). Loadings from feral hogs are distributed throughout the watershed since they are found in all land covers and they reproduce rapidly. A density of 5 hogs/km2 was applied to the watershed and then the number of animals was distributed in forested areas and scrublands. It was considered a fecal coliform excretion rate of $4.45*10^9$ cfu/animal. *E. coli* was again assumed to account for 50 percent of fecal coliform concentration (Teague, 2009). Preferred habitats for wildlife were determined based on literature and previous studies. Animal numbers were distributed among the watersheds within each county based on land cover types (Table 13). As the human population grows in the watershed, it is expected that the loading from wildlife may decrease as their habitat areas are developed. The total loads from each source were calculated (Table 14) and distributed per subwatershed; their relative prominence in each subwatershed is displayed in Figure 33.

TABLE 13 - HABITATS ASSIGNED TO DEER AND FERAL HOGS

Deer	90% of Hay Pasture areas+ forest (mixed, deciduous, and evergreen)
Hogs	no hogs in developed areas, and open water
	3 hogs/Km^2 in bare land cover categories
	5 hogs/Km^2 in all other categories

[10] For the purpose of the estimations, feral hogs are included in the wildlife category. It should be noted that in general, and by specific designation by Texas Parks and Wildlife Department, feral hogs are not wildlife, but non-domestic animals, and invasive.

TABLE 14 - SOURCE CONTRIBUTION AS PERCENT OF TOTAL CONTRIBUTION, BY YEAR[11]

SOURCES	2011	2015	2020	2025	2030	2035	2040
OSSF	35%	36%	38%	41%	43%	47%	49%
WWTP	0%	0%	0%	0%	0%	0%	0%
Urban Runoff	2%	2%	2%	2%	2%	2%	1%
Dogs	14%	15%	16%	17%	18%	20%	21%
Cattle	39%	38%	36%	33%	30%	26%	23%
Horses	2%	2%	2%	2%	2%	1%	1%
Sheep/Goat	2%	2%	2%	1%	1%	1%	1%
Deer	0%	0%	0%	0%	0%	0%	0%
Feral Hogs	5%	4%	4%	4%	3%	3%	3%
Subtotals							
Livestock	43%	42%	39%	36%	33%	29%	26%
Wildlife[12]	5%	5%	4%	4%	4%	3%	3%

[11] In this and subsequent tables, estimated pollutant values for 2011, 2015, and other past years are not based on monitoring data collected in the years indicated (e.g. 2011 and 2015). Rather, they are modeled projections produced during the period in which the WPP was being developed, except where they are labeled "benchmark." See Table 4 and footnote 4 for further discussion.

[12] The inclusion of feral hogs with deer in the source category Wildlife is not intended to indicate feral hogs are wildlife. "Wildlife" is used here as a modeling shorthand for the category of non-livestock, non-domestic animals, specifically representing data on deer and feral hogs.

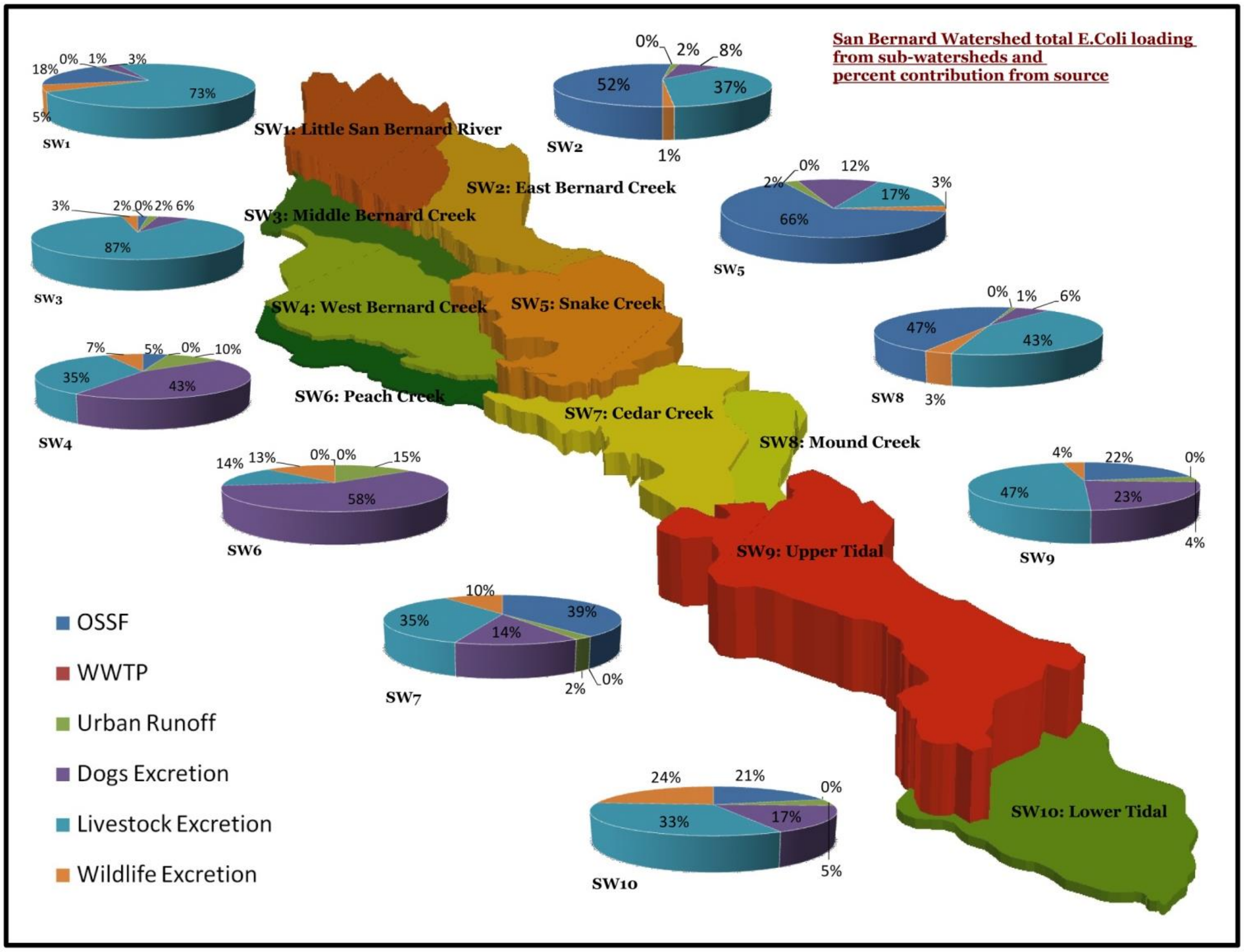

FIGURE 33 - RELATIVE PROMINENCE OF BACTERIA SOURCES IN EACH SUBWATERSHED, BY PERCENT OF TOTAL SOURCE LOAD

SELECT MODELING CONCLUSIONS

The results of the SELECT modeling effort, as summarized in Figure 33, serve to characterize the various sources in terms of their relative distribution and source loading throughout the subwatersheds. Several key conclusions were highlighted during the development and revision process:

- It was found that the highest contributing potential sources of bacteria were cattle and feral hogs. The relative contribution to each subwatershed varies according to land cover distribution and number of households in rural areas.
- There are potential bacteria sources such as urban runoff, WWTFs which are mainly associated with urban areas, whereas other sources like livestock, wildlife, OSSFs are predominant in rural areas.
- SELECT assumes that 100 percent of source loads will enter the stream in estimating total potential load, overestimating potential concentrations at all sampling locations. The application

of a buffer approach in which loads adjacent to riparian areas were weighted more heavily than those outside of the riparian corridor showed that source loads in rural areas were likely lower than the initial SELECT runs indicated.

More information on SELECT modeling and outcomes can be seen in Appendix A.

SWAT and Tidal Prism Modeling

The purpose of the SWAT and Tidal Prism modeling project was to evaluate benchmark and future in-stream bacterial concentrations in the San Bernard River and its major tributaries. The specific questions that are the focus of the study include:

- What are existing bacteria loads at the existing monitoring locations in the watershed?
- What is the effect of in-stream processes (decay) on bacteria loadings?
- What is the impact of tidal mixing on bacteria loading?
- How will implementation of BMPs impact in-stream bacteria loading?

A coupled system comprised of a receiving water model and a watershed model was developed to aid in the understanding of the San Bernard Above Tidal and Tidal Segments. More information on the structure, calibration and loading assumptions for the models can be found in Appendix B. The SWAT and Tidal Prism models were run initially during the project development. Based on subsequent stakeholder and agency comments, the watershed modeling was rerun after the end of the project. The results here represent the most current run. Both modeling efforts were conducted for benchmark (2010) and future conditions (2015, 2020, and 2025 time increments.)

SWAT - Above Tidal Watershed Modeling

Watershed pollutant loading models are based on topography, land cover, and hydrologic attributes and are used to predict stream flow and pollutant loadings delivered from the land surface of a watershed to the surface waters of a receiving stream, river, lake, or estuary. These models are an important means to account for nonpoint source pollution that will reach the receiving waters.

SWAT was developed in the early 1990s at Texas A&M University by the USDA Agricultural Research Service and is available in the public domain (Neitsch, Arnold et al. 2005). SWAT focuses on runoff and loadings from rural and agriculture-dominated watersheds. Thus, SWAT is a continuous model that simulates the effects of land management practices on water, sediment, and agricultural chemical yields for large-scale complex watersheds or river basins.

A key advantage of SWAT is its extensive BMP evaluation module that simulates BMPs through several very specific applications relevant to rural watersheds. The model can be used to evaluate operations that control the plant growth cycle (i.e., planting and harvesting); application of fertilizer (both inorganic and manure), grazing operations, use of grass filter strips and irrigation BMPs.

Based on the SWAT modeling, average annual *E. coli* concentrations were plotted against the river distance from the mouth of the watershed for the benchmark modeling year (2010) and future forecasting years.

The plot in Figure 34 shows the distribution of *E. coli* concentrations along the river. Mid sections of the above tidal segment of the river shows the higher concentrations than the other sections of the river. This is the area in the watershed that many bacteria loading activities can be observed. Such as septic systems, livestock farms, urban centers. The stream segments in the top part of the watershed are not impaired by the e coli. The concentrations are lower than the state water quality standards. The bacteria concentrations increase in each forecasting year.

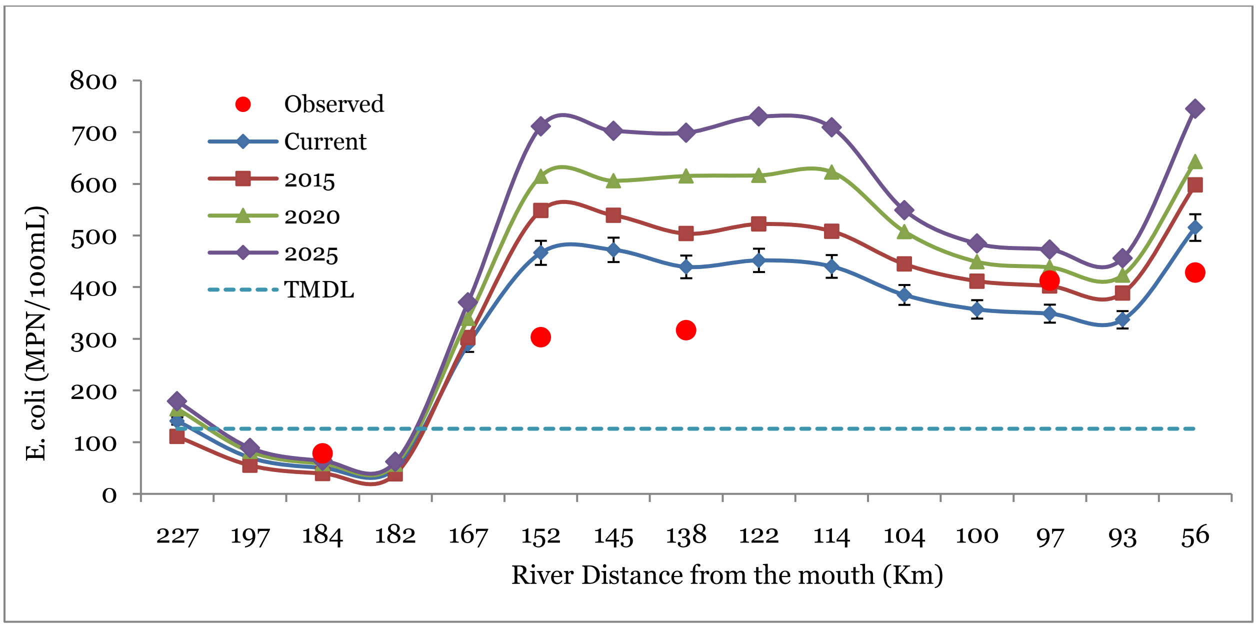

FIGURE 34 - SWAT BACTERIA RESULTS BY RIVER DISTANCE FROM MOUTH, BENCHMARK CONDITIONS

Tidal Prism - Tidal Watershed Modeling

Receiving water models are used to determine the fate and transport of pollutants in surface waters, as well as to predict the interactions between other water quality constituents of interest. Receiving water models for any tidal water body should account for the dynamics of stream flow, tidal flow, point source loading into the bayou, nonpoint source loading (which is estimated in the watershed models described above), and bacteria fate processes such as die-off, sedimentation, and re-suspension.

TPMs are one-dimensional steady-state receiving water models that utilize the concept of "tidal flushing" to simulate the physical transport of pollutants in a tidal basin over time. The theory of tidal flushing was originally developed by Ketchum in 1951, and several TPMs have been developed and refined to apply the concept towards water quality modeling of a variety of constituents, including bacteria (Kuo and Neilson 1988; Kuo, Park et al. 2005; Shen, Sun et al. 2005).

TPMs perform simulations on a tidal cycle time scale, which is on the order of 12 hours depending on the location. Data requirements are fairly low for TPMs compared to some other mechanistic receiving water models, and as such they can only be used for smaller tidal basins and estuaries since one of the key assumptions is that the tide rises and falls simultaneously throughout each modeled segment. Model hydrodynamics are typically validated using a conservative tracer, such as salinity. Simple bacteria dynamics of first order decay are generally assumed. Because no software has been developed for tidal prism model development, models are generally programmed in Microsoft Excel, FORTRAN, or other programming environments; as such, source code is generally available for the applications.

Based on the SWAT and Tidal Prism simulations, the bacteria reductions needed to meet the standards (126 MPN/dL) in each segment were estimated for each simulation year. The implications of these estimates for bacteria reduction are described in greater detail in Section 6. More information on the setup, calibration, and source assumptions used in the SWAT and Tidal Prism models is found in Appendix B.

Sources of Information

Calculation of Potential E. Coli loads from various sources in the watershed (Teague, A. E., 2007. Spatially Explicit Load Enrichment Calculation Tool and Cluster Analysis for Identification of E. coli Sources in Plum Creek Watershed, Unpublished MS thesis. Texas A&M University, Department of Biological and Agricultural Engineering, College Station, Texas)

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6 – ESTIMATED LOAD REDUCTIONS (ELEMENT B)

In order to estimate the extent or scale of management measures needed to meet water quality needs, the extent of needed reduction of source loads must be established. The sources and their relative contributions were established using the SELECT model (Section 5), and the impacts of watershed transport were modeled with SWAT and Tidal Prism. The modeling predicted water quality conditions for both segments in five year increments through 2025. This section discusses the source load reductions that were derived from these estimations, and the implications it has for the number of source units to be addressed. Source load refers to the total quantity of pollutant (e.g. *E. coli*) generated across the watershed by each source (e.g., dog feces) daily or annually, while in-stream loads refer to the quantity of the pollutant carried within the waterbody itself[13]. While the processes involved in fate and transport of bacteria are complex, it can be generally assumed that some amount of potential source load will not actually become instream load.

The results for the Above Tidal segment are summarized in Table 15. This table shows the simulated average *E. coli* concentrations under baseline conditions (without further efforts to reduce loads), the applicable standard (contact recreation standard), the percent reduction needed to meet the standards, the maximum load at which the standard would be met, and finally the number of bacteria that must be removed from the stream in order to meet the standards.

TABLE 15 - IN-STREAM BACTERIA REDUCTIONS NEEDED TO MEET THE CONTACT RECREATION STANDARD IN SAN BERNARD ABOVE TIDAL

	In-Stream					
	Average CFU/100 mL	**Standard**	**% Reduction Needed**	**Average CFU/day**	**TMDL (CFU/day)**	**Reduction needed (cfu/day)**
Benchmark (2010)	320.84	126	61%	3.76E+13	1.48E+13	2.28E+13
2015	360.81	126	65%	4.23E+13	1.48E+13	2.75E+13
2020	415.84	126	70%	4.88E+13	1.48E+13	3.40E+13
2025	468.22	126	73%	5.49E+13	1.48E+13	4.01E+13

Based on these in-stream reduction amounts needed, the source load reduction amounts needed were estimated (Table 16). For this purpose, the ratio between source loads (estimated using SELECT) and average in-stream bacteria loads (based on routine water quality monitoring data) was used. Using this conversion factor, the amounts of bacteria reduction needed from each source was estimated.

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[13] The average in-stream load is calculated by multiplying the average pollutant concentration in the water body by the average volume of water in the water body flowing past a particular location daily or annually.

TABLE 16 – BACTERIA SOURCE LOAD REDUCTIONS NEEDED TO MEET THE CONTACT RECREATION STANDARD IN SAN BERNARD ABOVE TIDAL

	Source Load	
	Ratio (source : stream)	Reduction needed (cfu/day)
Benchmark (2010)	4.96	1.13E+14
2015	4.59	1.26E+14
2020	4.30	1.46E+14
2025	4.14	1.66E+14

Using the SELECT estimated source loading percentages from each source, the load reduction needed from each source was estimated (i.e. the reduction load for each source is proportional to that source's relative contribution to total source loading.) Table 17 shows the calculated bacteria loads that needs to be reduced from each source for each simulated year.

TABLE 17 –BACTERIA SOURCE LOAD REDUCTIONS BY SOURCE, ABOVE TIDAL

Source	Source Load per Unit (cfu/Day)[14]	Load Reduction needed (cfu/day)			
Source Category		2010	2015	2020	2025
OSSF	1.99E+11[15]	4.50E+13	5.17E+13	6.34E+13	7.58E+13
WWTP	5.95E+08	2.38E+09	2.70E+09	2.97E+09	3.23E+09
Urban Runoff	7.01E+08	2.29E+12	2.46E+12	2.64E+12	2.78E+12
Dogs	2.00E+09	1.27E+13	1.51E+13	1.94E+13	2.40E+13
Cattle	2.39E+09	4.43E+13	4.73E+13	5.05E+13	5.28E+13
Horses	1.05E+09	2.45E+12	2.62E+12	2.80E+12	2.92E+12
Sheep/Goat	1.67E+09	1.50E+12	1.60E+12	1.71E+12	1.78E+12
Deer	3.51E+08	4.48E+11	4.80E+11	5.12E+11	5.34E+11
Feral Hogs	2.40E+10	4.64E+12	4.97E+12	5.31E+12	5.56E+12
TOTAL		1.09E+14	1.21E+14	1.41E+14	1.61E+14

[14] The load values per unit here represent the average load from the source category divided by the number of relevant source units that the model estimated. These loads differ slightly from literature values for loads per unit because the SELECT ratios were applied to the total modeled load to get category load portions. The SELECT loads do not generate loads in the same manner as the SWAT and Tidal Prism modeling, even using the same underlying literature values. An exception is made for OSSFs, as indicated in the following footnote.

[15] The source load per unit values are calculated based on average load in the actual watershed models, as described in the previous footnote. However, the OSSF load cannot be calculated as an average, as we are only targeting failing systems. For this reason, we use the actual full literature value used in the modeling processes as it represents the failing unit average, rather than an average of all OSSFs. As we will only target failing systems, using the average value of all OSSFs would result in a greater number of OSSFs to address because it is lower than the failing system average.

To ensure that enough source load would be addressed in the Above Tidal watershed to meet water quality standards, the estimated load reductions needed were subtracted from total estimated/projected source loading to calculate the load that should remain after the reductions are achieved. Table 18 shows the estimated total source loadings and loads remaining after the reductions.

TABLE 18 – BACTERIA SOURCE LOAD ASSESSMENT, ABOVE TIDAL

Source	Existing/Projected Load (cfu/day)[16]				Remaining Load (cfu/day)[17]			
	2010	2015	2020	2025	2010	2015	2020	2025
OSSF	7.40E+13	7.90E+13	9.10E+13	1.00E+14	2.88E+13	2.73E+13	2.75E+13	2.42E+13
WWTP	3.90E+09	4.10E+09	4.30E+09	4.40E+09	1.52E+09	1.13E+09	1.33E+09	8.30E+08
Urban Runoff	3.80E+12	3.80E+12	3.80E+12	3.80E+12	1.51E+12	1.34E+12	1.16E+12	1.02E+12
Dogs	2.10E+13	2.30E+13	2.80E+13	3.30E+13	8.30E+12	7.90E+12	8.60E+12	9.00E+12
Cattle	7.30E+13	7.30E+13	7.20E+13	7.20E+13	2.87E+13	2.57E+13	2.15E+13	1.92E+13
Horses	4.00E+12	4.00E+12	4.00E+12	4.00E+12	1.55E+12	1.38E+12	1.20E+12	1.08E+12
Sheep/Goat	2.50E+12	2.50E+12	2.40E+12	2.40E+12	9.99E+11	8.98E+11	6.90E+11	6.20E+11
Deer	7.40E+11	7.40E+11	7.30E+11	7.30E+11	2.92E+11	2.60E+11	2.18E+11	1.96E+11
Feral Hogs	7.60E+12	7.60E+12	7.60E+12	7.60E+12	2.94E+12	2.61E+12	2.27E+12	2.03E+12
Total	1.87E+14	1.94E+14	2.10E+14	2.24E+14	7.31E+13	6.73E+13	6.32E+13	5.73E+13

The number of units[18] whose waste needs to be addressed from each source type was calculated. Table 19 shows the number of units from each source need to be removed/control in order to meet the bacteria concentration standards in-stream of the above tidal segment of the river.

[16] Projected load is based on predicted changes in source units present in the watershed, which are assumed to have constant per unit loads.

[17] Because the number of units to address was rounded up to the nearest whole unit, the actual value projected to be reduced is greater than the required load reduction by small amounts. The load remaining reflects the remainder after the rounded-up reductions.

[18] Source units are based on literature values for load/per representative unit of that source (e.g., the literature value for the average daily load of an average dog). Depending on the removal efficiency of any given BMP, the real-world equivalent of 1 source unit's worth of bacteria may require more than one actual unit to be addressed. For example, a BMP with a 50% removal efficiency would need to address two dogs to account for 100% of the load of one source

TABLE 19 - SOURCE UNITS TO ADDRESS, ABOVE TIDAL

Source Unit	Number of Source Units to Address[19]			
	2010	2015	2020	2025
# of Septic systems	227	260	319	381
# of WWTFs	4	5	5	6
Urban area (Acres)	3267	3510	3767	3966
# Dogs	6350	7550	9700	12000
# of Cattle	18536	19791	21130	22093
# of Horses	2334	2496	2667	2781
# of Sheep/Goats	899	958	1024	1066
# of Deer	1277	1368	1458	1522
# of Feral Hogs	194	207	222	232

For help in developing BMPs, the number of units to be addressed was compared with the total number of source units. Table 20 indicates the number of source units to be addressed and the number of units remaining.

TABLE 20 -BACTERIA SOURCE UNIT ASSESSMENT, ABOVE TIDAL

Source Unit	Existing # of Units				Remaining/Untreated # of Units			
	2010	2015	2020	2025	2010	2015	2020	2025
# of Septic systems	6370	7358	9496	11858	6143	7098	9177	11477
# of WWTFs	12	13	13	13	8	8	8	7
Urban area (Acres)	4085	4128	4205	4331	818	618	438	365
# Dogs	8364	9291	11110	13159	2014	1741	1410	1159
# of Cattle	29728	29675	29560	29436	11192	9884	8430	7343
# of Horses	4218	4211	4195	4177	1884	1715	1528	1396
# of Sheep/Goats	1716	1715	1713	1710	817	756	689	644
# of Deer	1925	1921	1911	1901	648	553	452	379
# of Feral Hogs	274	273	272	270	80	65	50	38

unit. Source units are based on the literature value unit for the fecal bacteria loading rates. More information on reduction efficiency is included in Appendix B.

[19] Numbers in future years indicate total (cumulative) number to be addressed by that year, not an additional number to be addressed in the intervening time period.

The results of the SWAT modeling indicate that significant reduction is needed, ranging from 61 percent to 74 percent of source load between 2010 and 2025 respectively. However, the assessment also indicates there are ample source units to address.

FIGURE 35 - SOURCE UNITS (FERAL HOGS) ADDRESSED BY BMP (TRAP)

TIDAL PRISM RESULTS

The Tidal Prism modeling effort was designed to account for the impacts of tidal removal, as well as the effects of environmental conditions. The results of the model runs indicated that, while tidal action and other factors in the Tidal segment initially are very effective at reducing bacteria levels, the forecasted loading levels will breach the waterway's assimilative capacity in subsequent target years. Figure 36 depicts simulated in-stream concentrations along the river segment from the inter-coastal waterway[20]. According to these simulation results, enterococci concentrations increase towards the mouth of the watershed.

[20] While the model indicates that downstream concentrations may be lower on average that the observed data indicate, this is likely due in part to the limited extent of observed data and the uncertainties involved in utilizing a simple tidal model to fully describe the complex tidal action of the San Bernard system (intermittent closed mouth, interaction with the Intracoastal Waterway, etc.)

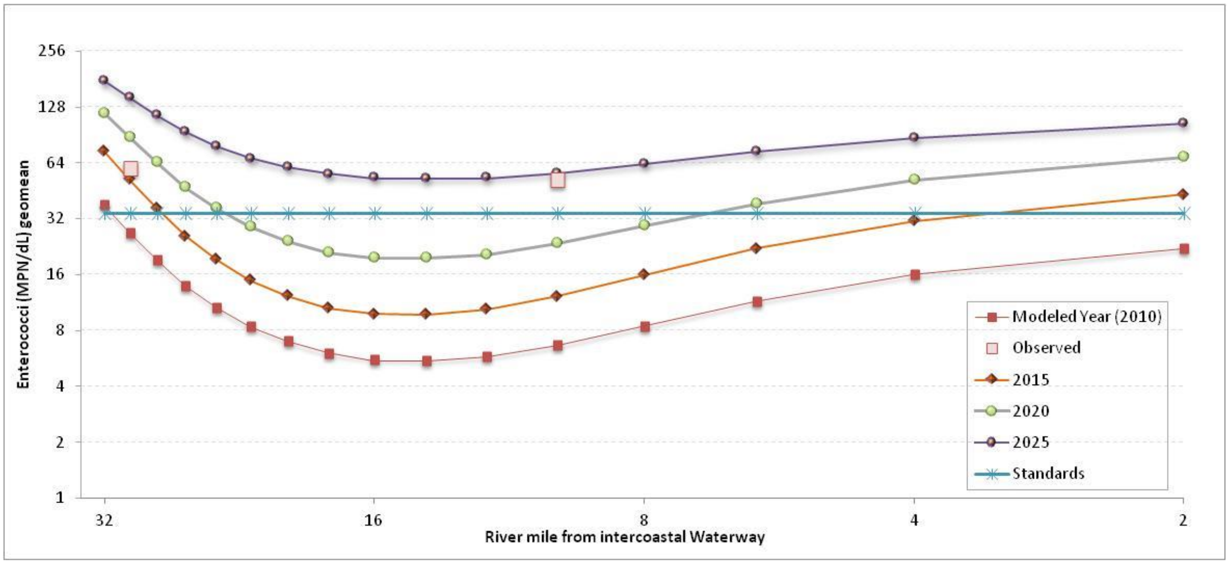

FIGURE 36 - TIDAL PRISM BACTERIA RESULTS BY RIVER DISTANCE FROM MOUTH

The in-stream reductions were generated first to determine the change necessary in in-stream conditions needed to meet the water quality standard, as summarized in Table 21 (results are given in *E. coli* equivalent.)

TABLE 21 - IN-STREAM BACTERIA REDUCTIONS NEEDED TO MEET THE CONTACT RECREATION STANDARD IN SAN BERNARD TIDAL SEGMENT

	In-Stream					
	Enterococci Average CFU/100mL	Enterococci Standard	% Reduction Needed	*E. coli* Average CFU/day	*E. coli* TMDL (CFU/day)	*E. coli* Reduction needed (cfu/day)
2010	13.19	35	0	6.58E+12	1.70E+13	0.00E+00
2015	25.00	35	0	1.25E+13	1.70E+13	0.00E+00
2020	43.60	35	22%	2.18E+13	1.70E+13	4.79E+12
2025	83.83	35	59%	4.18E+13	1.70E+13	2.49E+13

The source load reductions were generated subsequently, as derived from the loading ratios. These results are summarized in Table 22. Results are given in *E. coli* equivalent.

TABLE 22 – BACTERIA SOURCE LOAD REDUCTIONS NEEDED TO MEET THE CONTACT RECREATION STANDARD IN SAN BERNARD TIDAL

	Source Load (*E. coli*)	
	Ratio (source: stream)	Reduction needed (cfu/day)
Benchmark (2010)	10.71	0.00E+00
2015	5.65	0.00E+00
2020	3.24	1.55E+13

2025	1.69	4.19E+13

The load reductions were broken out into the source categories, and the number of source units needing to be addressed to meet the reduction targets was then generated. The units were based on loading values of a representative unit for each source. The results of this process are summarized in Table 23-25.

TABLE 23 - BACTERIA LOAD REDUCTIONS BY SOURCE, TIDAL PRISM

Source	Load Reduction needed (cfu/day)			
Source Category	Benchmark	2015	2020	2025
OSSF	-	-	3.61E+12	1.07E+13
WWTP	-	-	1.31E+09	3.41E+09
Urban Runoff	-	-	4.52E+11	1.15E+12
Dogs	-	-	3.66E+12	1.03E+13
Cattle	-	-	6.11E+12	1.54E+13
Horses	-	-	3.90E+11	9.85E+11
Sheep/Goat	-	-	4.04E+11	1.02E+12
Deer	-	-	5.18E+10	1.31E+11
Feral Hogs	-	-	8.55E+11	2.17E+12
TOTAL	-	-	1.55E+13	4.19E+13

TABLE 24 – BACTERIA SOURCE LOAD ASSESSMENT, TIDAL

Source	Existing/Projected Load (cfu/day)[21]				Remaining Load (cfu/day)[22]			
	2010	2015	2020	2025	2010	2015	2020	2025
OSSF	1.60E+13	1.60E+13	1.70E+13	2.00E+13	1.60E+13	1.60E+13	1.32E+13	9.25E+12
WWTP	5.90E+09	6.00E+09	6.10E+09	6.30E+09	5.90E+09	6.00E+09	4.32E+09	2.73E+09
Urban Runoff	2.10E+12	2.10E+12	2.10E+12	2.10E+12	2.10E+12	2.10E+12	1.65E+12	9.50E+11
Dogs	1.60E+13	1.60E+13	1.70E+13	1.90E+13	1.60E+13	1.60E+13	1.33E+13	8.70E+12
Cattle	2.90E+13	2.90E+13	2.90E+13	2.80E+13	2.90E+13	2.90E+13	2.29E+13	1.26E+13
Horses	1.80E+12	1.80E+12	1.80E+12	1.80E+12	1.80E+12	1.80E+12	1.41E+12	8.14E+11
Sheep/ Goat	1.90E+12	1.90E+12	1.90E+12	1.90E+12	1.90E+12	1.90E+12	1.50E+12	8.80E+11

[21] Projected load is based on predicted changes in source units present in the watershed, which are assumed to have constant per unit loads.

[22] The units to address are rounded up to the nearest whole number. Therefore, the projected reduction values are slightly higher than the modeled reduction needs. The difference is attributable to the rounding up of the units, and is negligible. The remaining load value here represents the remainder after the rounded-up load reductions are applied, rather than the straight modeled load reductions.

Deer	2.40E+11	2.40E+11	2.40E+11	2.40E+11	2.40E+11	2.40E+11	1.88E+11	1.09E+11
Feral Hogs	4.00E+12	4.00E+12	4.00E+12	4.00E+12	4.00E+12	4.00E+12	3.14E+12	1.82E+12
TOTAL	7.10E+13	7.10E+13	7.30E+13	7.70E+13	7.10E+13	7.10E+13	5.73E+13	3.51E+13

Lastly, the number of units to be addressed was compared to the total number of source units available to ensure compliance was feasible. The results of this analysis are summarized in Tables 25 and 26.

TABLE 25 – BACTERIA SOURCE UNITS TO ADDRESS, TIDAL

Source Unit	Number of Source Units to Address			
	Benchmark	2015	2020	2025
# of Septic systems	-	-	19	54
# of WWTFs	-	-	3	5
Urban area (Acres)	-	-	645	1641
# Dogs	-	-	1830	5150
# of Cattle	-	-	2557	6444
# of Horses	-	-	372	939
# of Sheep/Goats	-	-	242	611
# of Deer	-	-	148	374
# of Feral Hogs	-	-	36	91

TABLE 26 - EVALUATION OF BACTERIA SOURCE UNIT AVAILABILITY, TIDAL SEGMENT

Units	Existing # of Units				Remaining/Untreated # of Units			
Source Unit	Bench mark	2015	2020	2025	Bench mark	2015	2020	2025
# of Septic systems	3774	3851	4096	4896	3774	3851	4077	4842
# of WWTFs	5	5	5	5	5	5	2	0
Urban area (Acres)	4291	4315	4356	4427	4291	4315	3711	2786
# Dogs	6452	6590	6840	7577	6452	6590	5010	2427
# of Cattle	12719	12714	12697	12643	12719	12714	10140	6199
# of Horses	1386	1385	1384	1378	1386	1385	1012	439
# of Sheep/Goats	898	898	898	897	898	898	656	286
# of Deer	869	869	868	864	869	869	720	490
# of Feral Hogs	210	210	210	209	210	210	174	118

The results of the analysis indicate that the Tidal segment does not need to be addressed immediately, but will likely need to be the focus of efforts by 2020. Ample opportunities exist based on existing source units to meet estimated reduction goals. Additionally, progress made upstream in the Above Tidal segment will potentially benefit the Tidal segment.

Table 27 is the summary of the results for the entire watershed that shows in-stream E. coli loading and reduction targets. It also indicates the equivalent source load reductions necessary to meet the standard. Table 28 indicates a goal of source units to address by subwatershed area[23].

TABLE 27 - TOTAL BACTERIA INSTREAM AND SOURCE LOAD ASSESSMENT, ENTIRE WATERSHED

	In-Stream		Source Load
	E. Coli (CFU/day)	E. Coli Reduction (cfu/day)	Source Load Reduction (cfu/day)
2010	4.42E+13	2.28E+13	1.13E+14
2015	5.48E+13	2.75E+13	1.26E+14
2020	7.05E+13	3.88E+13	1.62E+14
2025	9.67E+13	6.50E+13	2.08E+14

[23] It should be noted that the distribution of source units to address by subwatershed should not be taken to indicate a specific plan of action for implementation. It is based on a proportional breakdown of the total source units to address proportional to the percentage of contributions, by source, from each subwatershed. It is included as a conceptual way of demonstrating the spatial distribution of BMPs relative to the concentration of sources. This WPP emphasizes a flexible and opportunistic approach to BMP siting, making use of available resources and opportunities as they arise, even if out of proportion to a specific subwatershed's conceptual reduction percentage.

TABLE 28 - SOURCE UNITS TO ADDRESS BY 2025, PER SUBWATERSHED

Source Units	*Above Tidal*	*Tidal*	Total Units	Source Units to address by 2025, per Subwatershed 1	2	3	4	5	6	7	8	9	10
# of Septic systems	*381*	*54*	435	29	74	1	2	162	2	59	41	60	11
# of WWTFs	*6*	*5*	11	1	1	0	1	3	0	1	0	7	0
Urban area (Acres)	*3966*	*1641*	5607	309	467	145	896	812	485	372	120	1791	215
# Dogs	*12000*	*5150*	17150	597	1240	178	1487	3520	806	2398	661	5596	671
# of Cattle	*22093*	*6444*	28537	8459	3672	1800	710	1730	36	2048	2022	7416	650
# of Horses	*2781*	*939*	3720	580	356	101	375	338	222	336	252	1085	78
# of Sheep/Goats	*1066*	*611*	1677	284	133	49	56	107	25	143	153	683	48
# of Deer	*1522*	*374*	1896	573	99	81	190	141	132	127	86	431	40
# of Feral Hogs	*232*	*91*	323	54	12	6	16	35	12	65	16	60	52

SWAT and Tidal Prism Reduction Modeling Conclusions

The results of the SWAT and Tidal Prism modeling efforts indicate that significant reductions need to be made, especially in the Above Tidal segment, to achieve and maintain water quality standard compliance. A summary of reductions and the potential ramifications of future change is discussed in Section 6.

Table 28 shows the percent load reductions needed by source as determined in the SWAT modeling. Overall a 70 percent reduction in the bacteria geomean is required in the watershed. Percent load reductions were determined by the following equations: (Baseline *E. coli* concentration – *E. coli* concentration when source removed) / Baseline *E. coli* concentration.

The BMPs identified by the stakeholders in this and subsequent sections are designed and scaled to meet this reduction goal. Based on the commitments from stakeholders in the development of the WPP and the ongoing participation in implementing solutions and outreach activities, the goal is believed to be attainable. The nature of future growth and factors outside stakeholder control (hydrologic modifications, wildlife contributions, etc.) may cause these numbers to shift as implementation continues. However, the stakeholders are committed to working toward the ultimate goal of attaining water quality compliance with all applicable standards.

Bacteria Source Analysis

There are several potential sources of bacteria in the San Bernard River Watershed. These include permitted sources, such as WWTFs that do not completely disinfect their effluent and SSOs. Other sources, such as livestock, wildlife, domestic pets, and failing on-site sewage facilities (septic systems) are not permitted but may also contribute to bacteria loading in the San Bernard River.

To explore the impact of each of these sources, several scenarios were run using SWAT and Tidal Prism with each source eliminated. The change in the in-stream concentrations of bacteria indicate how significant an impact each of the sources have on the San Bernard River. The results of the analysis are presented in Figures 37 and 38.

The figures demonstrate that all bacteria sources in the watershed play a role in maintaining the bacteria levels in the River. This is an important finding as it suggests that improving water quality in the River can be achieved in multiple ways. It is important to note that these scenarios are used as a tool to understand the watershed; it is not expected that any of the source elimination scenarios would be physically implemented in the watershed.

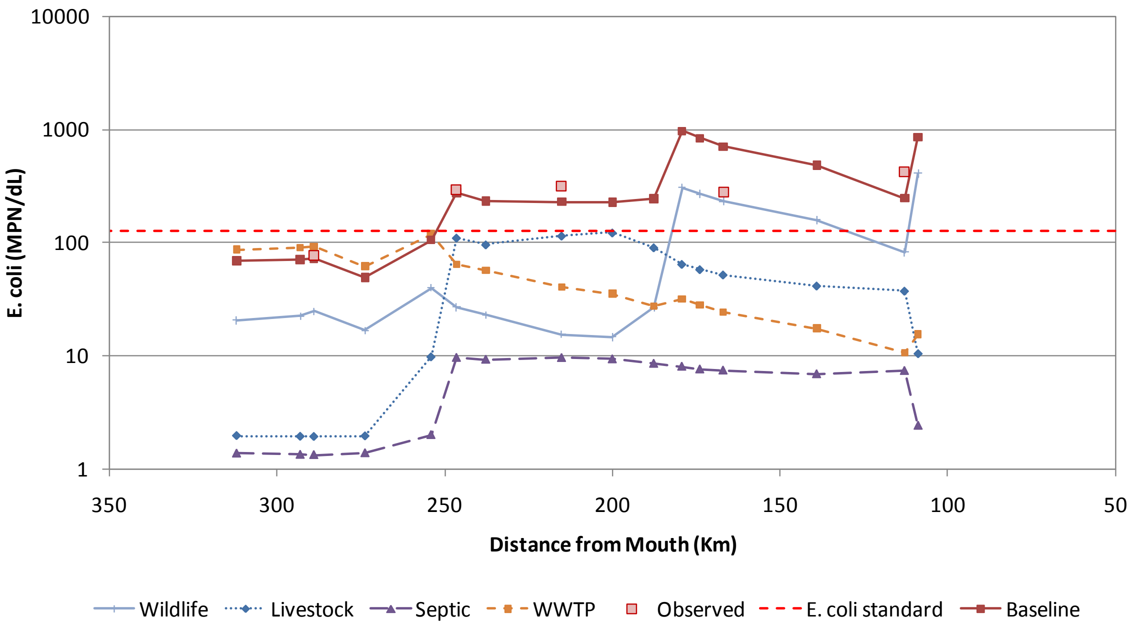

FIGURE 37- BACTERIA SOURCE ANALYSIS - SWAT MODEL

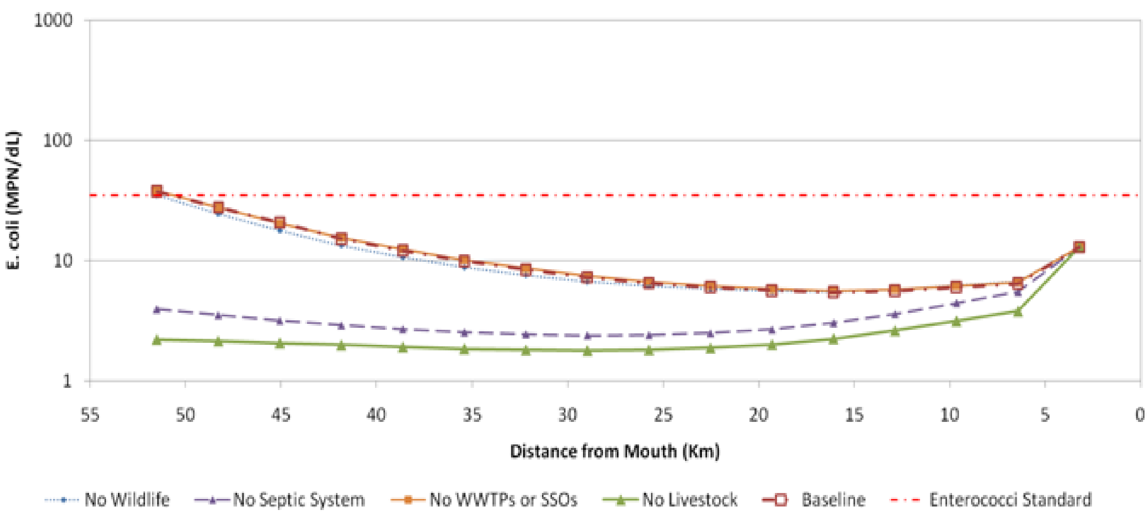

FIGURE 38 - BACTERIA SOURCE ANALYSIS – TIDAL PRISM MODEL

A summary table of the reductions based on each source is presented in Table 29 for the SWAT model and Table 30 for the Tidal Prism model.

TABLE 29 - SUMMARY OF E. COLI CONCENTRATIONS AND PERCENT REDUCTION FROM BASELINE CONDITION – SWAT MODEL

Subbasin	River Km	Baseline	No WWTFs or SSOs		No Feral Hogs & Wildlife		No Septic Systems		No Livestock	
		E. coli (MPN/dL)	*E. coli* (MPN/dL)	Percent Reduction	*E. coli* (MPN/dL)	Percent Reduction	*E. coli* (MPN/dL)	Percent Reduction	*E. coli* (MPN/dL)	Percent Reduction
1	312.09	87.8	87.2	-1%	20.7	-76%	1.4	-98%	2.0	-98%
7	293.11	90.4	90.1	0%	22.5	-75%	1.3	-99%	1.9	-98%
8	289.04	93.6	93.4	0%	24.7	-74%	1.3	-99%	1.9	-98%
10	273.77	62.1	62.0	0%	16.8	-73%	1.4	-98%	2.0	-97%
11	254.09	122.9	117.6	-4%	40.0	-67%	2.0	-98%	9.8	-92%
13	246.50	332.2	318.8	-4%	26.9	-92%	9.6	-97%	110.7	-67%
16	237.75	282.3	272.6	-3%	23.0	-92%	9.3	-97%	96.3	-66%
17	215.14	279.0	273.1	-2%	15.5	-94%	9.6	-97%	115.3	-59%
21	200.00	274.8	256.6	-7%	14.7	-95%	9.4	-97%	122.9	-55%
23	187.65	272.8	268.6	-2%	26.8	-90%	8.5	-97%	90.8	-67%
26	179.27	1085.0	1079.6	0%	305.9	-72%	8.0	-99%	64.7	-94%
28	173.90	956.8	953.8	0%	268.7	-72%	7.6	-99%	58.1	-94%
30	166.97	818.5	817.1	0%	233.3	-71%	7.4	-99%	52.1	-94%
31	139.05	554.9	554.7	0%	159.3	-71%	6.9	-99%	41.6	-93%
35	112.85	291.8	273.9	-6%	82.8	-72%	7.4	-97%	37.5	-87%
34	108.76	1246.9	1246.9	0%	412.1	-67%	2.4	-100%	10.5	-99%

TABLE 30 - SUMMARY OF ENTEROCOCCI CONCENTRATIONS AND PERCENT REDUCTION FROM BASELINE CONDITION – TIDAL PRISM MODEL

River KM/Segment	Baseline	No WWTFs or SSOs		No Feral Hogs & Wildlife		No Septic Systems		No Livestock	
	Enterococci (MPN/dL)	Enterococci (MPN/dL)	Percent Reduction	Enterococci (MPN/dL)	Percent Reduction	Enterococci (MPN/dL)	Percent Reduction	Enterococci (MPN/dL)	Percent Reduction
32.00	37.8	38.4	2%	35.1	-7%	4.0	-89%	2.2	-94%
30.00	27.7	27.8	0%	24.6	-11%	3.5	-87%	2.2	-92%
28.00	20.8	20.6	-1%	17.9	-14%	3.2	-85%	2.1	-90%
26.00	15.3	15.6	2%	13.5	-12%	2.9	-81%	2.0	-87%
24.00	12.2	12.5	2%	10.7	-12%	2.7	-78%	1.9	-84%
22.00	10.0	10.2	2%	8.8	-11%	2.6	-74%	1.9	-81%
20.00	8.4	8.7	3%	7.6	-10%	2.5	-71%	1.8	-79%
18.00	7.3	7.5	3%	6.7	-8%	2.4	-67%	1.8	-75%
16.00	6.5	6.7	3%	6.1	-6%	2.4	-63%	1.8	-72%
14.00	6.0	6.2	3%	5.8	-4%	2.5	-58%	1.9	-69%
12.00	5.6	5.8	3%	5.6	-1%	2.7	-52%	2.0	-64%
10.00	5.5	5.6	3%	5.5	1%	3.0	-44%	2.3	-59%
8.00	5.6	5.8	3%	5.8	3%	3.6	-36%	2.6	-53%
6.00	6.0	6.2	2%	6.2	4%	4.5	-26%	3.2	-48%
4.00	6.5	6.6	2%	6.7	3%	5.5	-15%	3.8	-41%
2.00	13.0	13.0	0%	13.0	0%	13.0	0%	13.0	0%

Key findings are as follows:

- WWTFs: It was assumed that the discharge associated with WWTFs would be 126 MPN/dL for the baseline condition, which is the current water quality standard for *E. coli*. SSOs were assigned a concentration of 500,000 MPN/dL which is consistent with dilute sewage concentrations. The source elimination scenario eliminated all bacteria in the effluent discharge. In practice, the concentrations associated with the discharges will vary based upon a wide range of factors such as plant condition, plant maintenance, and occurrence of rainfall. However, it is clear from the modeling that wastewater treatment plants do play a small role in maintaining the elevated bacteria concentrations in the benchmark baseline model.

- Septic systems: Septic systems proved to be a significant factor in the elevated concentrations observed in the San Bernard River. This scenario assumed that all malfunctioning septic systems were fixed and therefore no discharge of bacteria occurred. The difference in bacteria concentrations with and without failing septic systems is striking and suggests that there is a significant impact from the systems on the San Bernard River.

- Livestock: The modeling suggests that bacteria runoff from livestock manure is another key factor that maintains the elevated bacteria in the San Bernard River. Livestock have more impact on the upper reaches of the watershed than the lower. It is important to note that the livestock (and feral hogs and wildlife) estimates for some subbasins were calibrated higher than what would be predicted based on the animal census data to match the in-stream bacteria levels.

- Feral Hogs, wildlife and domesticated animals: Feral Hogs, wildlife and domesticated animal loading in the watershed is another key source of bacteria in the region. Eliminating their contributions alone does not permit the San Bernard to meet water quality standards.

BMP Scenario Evaluation

Modeling determined that there are a number of different causes and sources of pollution in the San Bernard Watershed, and that there are a number of BMPs that will work to reduce pollution levels in the watershed. Vegetative filter strips and grassed waterways were both evaluated by the SWAT model for their effectiveness in pollution removal for the four categories of pollution that were examined. There are also a number of other BMPs that were not modeled specifically for the San Bernard watershed, but that have been tested in other watersheds for effectiveness. Some BMPs are multi-purpose such as the vegetative filter strips and the grassed waterways, and some are more source specific, such as fixing failing OSSFs. WQMPs are common throughout the watershed, and are specific to each property they protect.

After evaluating the impact of each bacteria source on the San Bernard River watershed, the next step was to evaluate some specific BMPs that could be implemented in the watershed to improve water quality. The following section outlines some potential BMP solutions.

BMP Scenario 1 - Vegetative Filter Strips

One important management practice for water pollution in agricultural areas is a vegetative filter strip. Vegetative filter strips (VFSs) are also known as buffer strips, riparian zones, protection strips, and streamside management zones. Filter strips are located adjacent to the stream to help protect water quality of the stream or lake. These strips are used to minimize the effect of agricultural uses, grazing, and urban activity around the watershed. Filter strips prevent bacteria, sediments, organics, nutrients, pesticides, and other contaminant loadings from entering the streams and thus improving water quality.

SWAT models VFSs with two approaches: one that receives modest flow densities and one that receives concentrated flows. The VFS channel geometry is defined as a trapezoidal with 8:1 side slope; the required inputs for waterways are length, width, depth, and slope. In SWAT, the VFS functionality is simulated in two sections; section 1 represents the bulk of the VFS area receiving the lower flows (i.e., is more diffuse) and section 2 receives about 25 percent to 75 percent of the field runoff (the "headwaters" of the VFS that receives more concentrated flow). One important point to note is that in VFSs, bacteria are assumed to be absorbed and captured within the sediment and the soluble particles are captured on the runoff.

The VFSs were applied to agriculture (AGRR), hay (HAY), rangeland shrub (RNGB), and rangeland grassland/herbaceous (RNGE) land covers. The filter strip was assumed to start at the beginning of the simulation period. Several other key variables were specified for the VFS[24]:

- VFSRATIO is the ratio of field area to filter strip (ha^2/ha^2), ranges from 0 ha^2/ha^2 to 300 ha^2/ha^2 with 40 ha^2/ha^2 to 60 ha^2/ha^2 being common values, the value tested in the model was 45 ha^2/ha^2

- The VFSCON variable refers to the fraction of the HRU that drains the most concentrated 10 percent of the filters strip area, value of 50 percent was used per SWAT guidance.

- VFSCH is the fraction of the flow of the most concentrated 10 percent of the filter strip; this value was set to 0 percent per SWAT guidance (Waidler et al, 2011).

Once all the variables were set, the edits were extended to all the subbasins containing the desired land covers for all the different slopes.

The results of the analysis are presented in Figure 39. A summary of the concentrations in tabular form are presented in Table 31 as well. As the figures demonstrate, vegetated filter strips implemented in the watershed could have a very significant impact on the in-stream concentrations of bacteria. It is important to note that the middle portion of the River is just above the water quality standard when the most significant improvements are observed, indicating that some additional efforts will be required to reduce failing septic systems, improve wastewater treatment or otherwise exclude cattle/wildlife from the streams.

[24] The names of the modeling variables are modeling shorthand rather than abbreviations, and therefore are not spelled out.

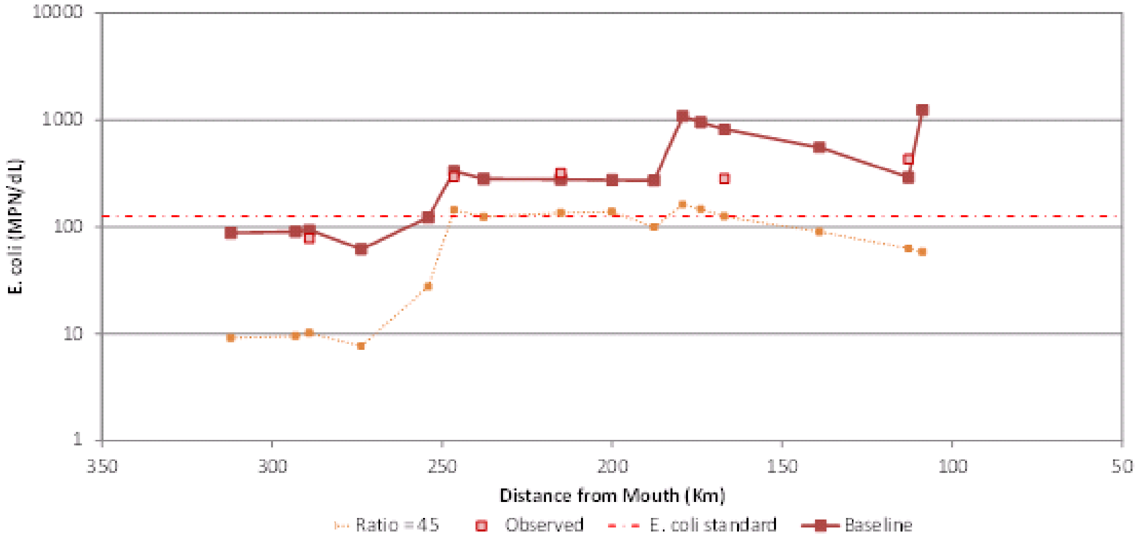

FIGURE 39- VEGETATED FILTER STRIP - SWAT RESULTS

TABLE 31 - SUMMARY OF E. COLI CONCENTRATIONS AND PERCENT REDUCTION FROM BASELINE CONDITION – VEGETATED FILTER STRIP RESULTS

Subbasin	River Km	Baseline	Ratio of field area to filter strip area = 45	
		E. coli (MPN/dL)	*E. coli* (MPN/dL)	Percent Reduction
1	312.09	87.8	9.2	-90%
7	293.11	90.4	9.5	-89%
8	289.04	93.6	10.2	-89%
10	273.77	62.1	7.7	-88%
11	254.09	122.9	27.6	-78%
13	246.5	332.2	144.2	-57%
16	237.75	282.3	124.2	-56%
17	215.14	279.0	135.1	-52%
21	200	274.8	138.8	-49%
23	187.65	272.8	99.5	-64%
26	179.27	1085.0	162.1	-85%
28	173.9	956.8	147.1	-85%
30	166.97	818.5	125.4	-85%
31	139.05	554.9	90.2	-84%
35	112.85	291.8	62.9	-78%
34	108.76	1246.9	58.2	-95%

The model does not specify a specific sorption rate, but does have several parameters that specify the relationship between bacteria and soil: Bacteria soil partitioning coefficient (BACTKDQ) is the ratio of the bacteria concentration in the surface 10 mm of soil water to the concentration of bacteria in surface runoff. Higher values result in lower concentrations of bacteria in the surface runoff. The value for the San Bernard watershed was set to 175; this default value has been found to be appropriate in several other SWAT modeling applications. Bacteria percolation coefficient (BACTMIX) is the ratio of bacteria concentrations in the top 10 mm of soil to the concentration of bacteria in the percolate. The model default value is 10.0 and the value can range from 7.0 to 20.0. The value for the San Bernard watershed was set to 10.0 based on other studies that have applied the default value.

BMP Scenario 2 - Grassed Water Ways

Grassed waterways are another type of BMP for bacterial water pollution. Grassed waterways are grassy areas where water concentrates or flows off a field. These waterways are planted with strong grasses to stabilize the soil, greatly reduce erosion and increase infiltration and removal of sediment and nutrients from the runoff. They provide benefits such as reducing the flow velocity, trapping sediment and bacteria, absorbing chemicals and nutrients from the runoff water, and providing enhancements to wildlife.

SWAT models grassed waterways as a trapezoidal channel. SWAT simulates the channel as broad and shallow with side slopes of 8:1. The reduction of sediments, bacteria and nutrients are calculated in a similar fashion to the way the model simulates sediment and organic nutrient loss for subbasin tributary channels. The main inputs are width and length. Grassed waterway is simulated on an HRU basis, meaning that they can be varied by land cover.

The grassed waterways were applied to the same land covers as VFSs, agriculture (AGRR), hay (HAY), rangeland shrub (RNGB), and rangeland grassland/herbaceous (RNGE) land covers. The grassed waterways were assumed to be in place at the beginning of the simulation period. The following key variables were used to simulate grassed waterways

- GWATN: SWAT requires a Manning's N used for overland flow, under the variable GWATN. The Manning's n selected was 0.35 to represent the overland flow.
- GWATSPCON is a linear parameter for the sediments in the waterways, the default value of 0.005 was used for the variable.
- GWATL is the length of the grassed waterway is entered under the GWATL variable. The length was varied between 5, 25 and 50 km in length. This default is the length of a single side of a squared HRU.
- GWATD is the depth of the channel from top of the bank to the bottom in meters. If a depth is not selected the program sets the depth as 3/64 of GWATW. For the 5 and 25 m long channels, a value of 1 m was used. For the channel with 50 m in length, a value of 2 m was used.
- GWATW is the average width in meters of the grassed waterway. For the evaluation of the alternative widths of 100 meters were used.
- GWATS is the average slope of the channel in meters. The default value of 0.005 was used for the slope. If the slope is not entered SWAT calculates the slope as 75 percent of the HRU slope.

Results from the analyses are presented in Figure 40. A tabular summary of the results is presented in Table 32. As shown, there is some reduction in bacteria concentrations when the BMPs are implemented. The results suggest that implementing grassed waterways in the San Bernard River watershed will result in an improvement in water quality; however, the impact of these BMPs will not be as significant as the vegetated filter strips.

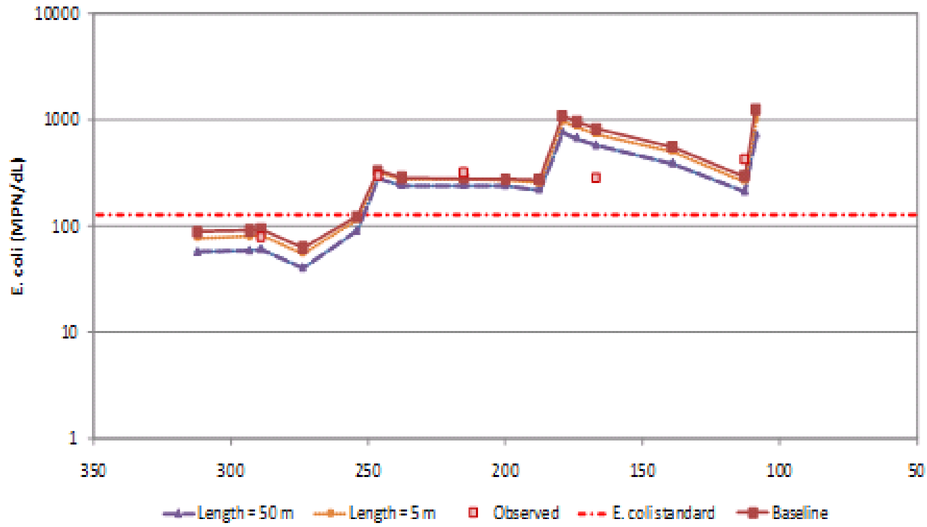

FIGURE 40 - GRASSED WATERWAYS – SWAT RESULTS

TABLE 32 - SUMMARY OF E. COLI CONCENTRATIONS AND PERCENT REDUCTION FROM BASELINE CONDITION – GRASSED WATERWAY RESULTS

Subbasin	River Km	Baseline	Waterway length = 5 m		Waterway length = 25 m		Waterway length = 50 m	
		E. coli (MPN/dL)	*E. coli* (MPN/dL)	Percent Reduction	*E. coli* (MPN/dL)	Percent Reduction	*E. coli* (MPN/dL)	Percent Reduction
1	312.09	87.8	78.4	-11%	57.8	-34%	57.8	-34%
7	293.11	90.4	80.7	-11%	59.4	-34%	59.4	-34%
8	289.04	93.6	83.2	-11%	61.1	-35%	61.1	-35%
10	273.77	62.1	55.6	-11%	41.1	-34%	41.1	-34%
11	254.09	122.9	116.7	-5%	91.4	-26%	91.4	-26%
13	246.5	332.2	329.9	-1%	287.9	-13%	287.9	-13%
16	237.75	282.3	280.2	-1%	244.9	-13%	244.9	-13%
17	215.14	279.0	277.0	-1%	245.6	-12%	245.6	-12%
21	200	274.8	273.0	-1%	243.6	-11%	243.6	-11%
23	187.65	272.8	258.5	-5%	222.5	-18%	222.5	-18%
26	179.27	1085.0	991.1	-9%	774.5	-29%	774.5	-29%
28	173.9	956.8	871.5	-9%	679.6	-29%	679.6	-29%
30	166.97	818.5	742.2	-9%	577.6	-29%	577.6	-29%
31	139.05	554.9	504.2	-9%	393.2	-29%	393.2	-29%
35	112.85	291.8	268.4	-8%	213.6	-27%	213.6	-27%
34	108.76	1246.9	1037.0	-17%	733.7	-41%	733.7	-41%

BMP Scenario 3 – OSSF Repair and Replacement

OSSFs are a significant factor in the elevated bacteria concentrations observed in the San Bernard Watershed. This BMP scenario focused on the repair and replacement of OSSFs limited to two specific subbasins: 36 and 25. The model was fairly insensitive to the OSSF densities within the subbasins, so the analysis was focused on assuming that all OSSFs in a subbasin would be repaired or replaced. The results show an immediate decrease in bacteria downstream of these two subbasins, as shown in the figures below.

TABLE 33 - SUMMARY OF E. COLI CONCENTRATIONS AND IN-STREAM LOAD REDUCTIONS FROM BASELINE CONDITION – OSSF REPAIR AND REPLACEMENT

Sub-basin	Project Subbasin [25]	River Km	Baseline Concentration	Concentration After Implementation		Baseline In-Stream Load[26]	In-Stream Load After Implementation	
			E. coli (MPN/dL)	*E. coli* (MPN/dL)	Percent Reduction	*E. coli* (MPN/day)	*E. coli* (MPN/day)	Load Reduction (MPN/day)
25	25	n/a[27]	451.6	1.3	-100%	2.04E+13	1.36E+13	6.84E+12
28	25	173.9	956.8	636.9	-33%	1.89E+13	1.34E+13	5.49E+12
30	25	166.97	818.5	581.0	-29%	1.35E+13	1.04E+13	3.07E+12
31	25	139.05	554.9	428.7	-23%	7.98E+12	7.31E+12	6.77E+11
35	25	112.85	291.8	267.0	-8%	6.84E+11	1.93E+09	6.82E+11
36	36	94.7	359.3	265.7	-26%	1.06E+13	7.86E+12	2.77E+12

[25] The Project Subbasin is the subbasin in which the OSSF work occurred, and which also influences downstream reaches. Only subbasins affected by the limited OSSF work modeled in Scenario 3 (work occurring in Subbasins 25 and 36 only) are included in this table.

[26] These in-stream loads are based on average flow in segment multiplied by *E. coli* geometric mean concentration

[27] Subbasin 25 is found on a tributary to the San Bernard main stem.

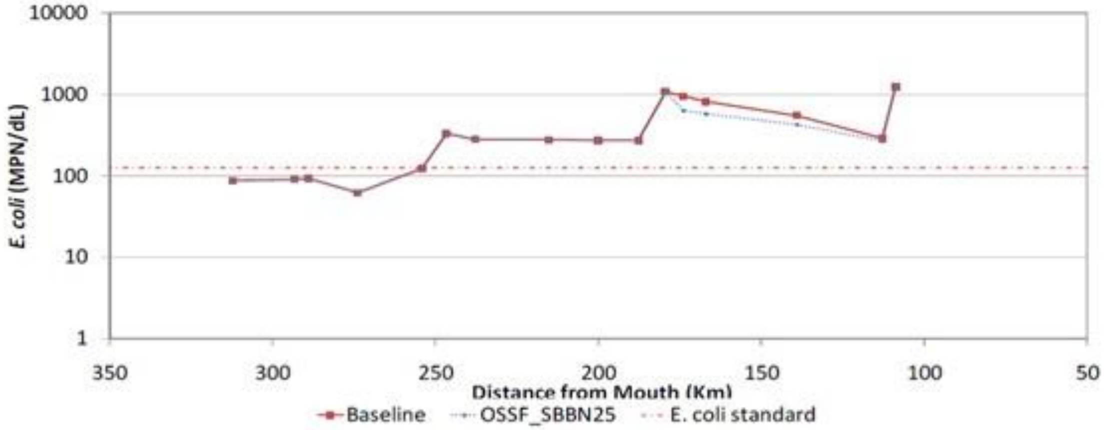

FIGURE 41 - OSSF REPAIR AND REPLACEMENT: E. COLI AND DISTANCE FROM MOUTH

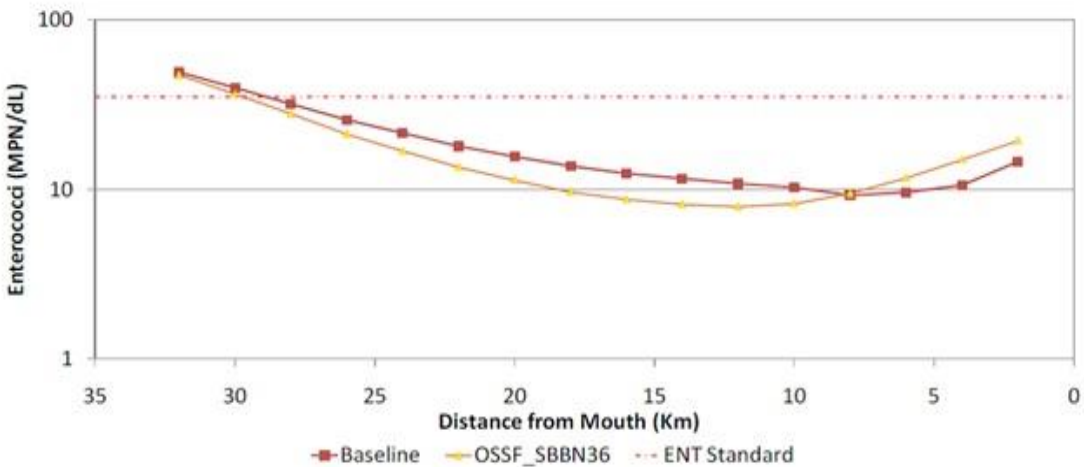

FIGURE 42 - OSSF REPAIR AND REPLACEMENT: ENTEROCOCCI AND DISTANCE FROM MOUTH

BMP Scenario 4 – Prescribed Grazing

Prescribed grazing is another BMP for bacterial water pollution. Prescribed grazing is the management of the removal of vegetation by grazing animals with respect to plant production limits, sensitivities and management goals. The rate of growth and physiological condition of the plants, duration and intensity of grazing, and expected productivity of the forage species are other management objectives that are taken into account when preparing a prescribed grazing program.

The focus of this BMP was on grazing analysis for pasture and range land covers, and included modification to several parameters to simulate grazing. These parameters include: moisture, harvest efficiency, and soil loss. Moisture values represent soil permeability, land cover, and antecedent moisture conditions. Higher moisture values indicate improved crop management, but lower permeability coverage, while lower values indicate higher permeability, but poorer crop management. For this BMP, the values were lowered to simulate improved crop management. Harvest efficiency is defined as the fraction of biomass removed by harvesting equipment. For the model, the value was increased which equates to increased cuttings being left on the ground. The sensitivity analysis performed showed that the bacteria levels in the San Bernard watershed were not sensitive to changes in harvest efficiency. Soil loss is the ratio of the erosion that would occur when a crop is grown using a specific management practice as compared to leaving the continuously tilled fallow state without vegetation. This value was already quite high for the San Bernard watershed, so it was not further adjusted. With these adjustments made, it was found that there were only small reductions in bacteria levels compared with the baseline conditions.

TABLE 34- SUMMARY OF E. COLI CONCENTRATIONS AND PERCENT REDUCTION FROM BASELINE CONDITION – PRESCRIBED GRAZING

		Baseline	Prescribed Grazing Scenario	
Subbasin	River Km	*E. coli* (MPN/dL)	*E. coli* (MPN/dL)	Percent Reduction
1	312.09	87.8	87.7	0%
7	293.11	90.4	91.1	-1%
8	289.04	93.6	92.6	-1%
10	273.77	62.1	61.5	-1%
11	254.09	122.9	118.9	-3%
13	246.5	332.2	322.1	-3%
16	237.75	282.3	273.8	-3%
17	215.14	279.0	272.7	-2%
21	200	274.8	267.6	-3%
23	187.65	272.8	264.4	-3%
26	179.27	1085.0	1060.9	-2%
28	173.9	956.8	939.5	-2%
30	166.97	818.5	802.7	-2%
31	139.05	554.9	549.4	-1%
35	112.85	291.8	289.3	-1%
34	108.76	1246.9	1093.5	-4%

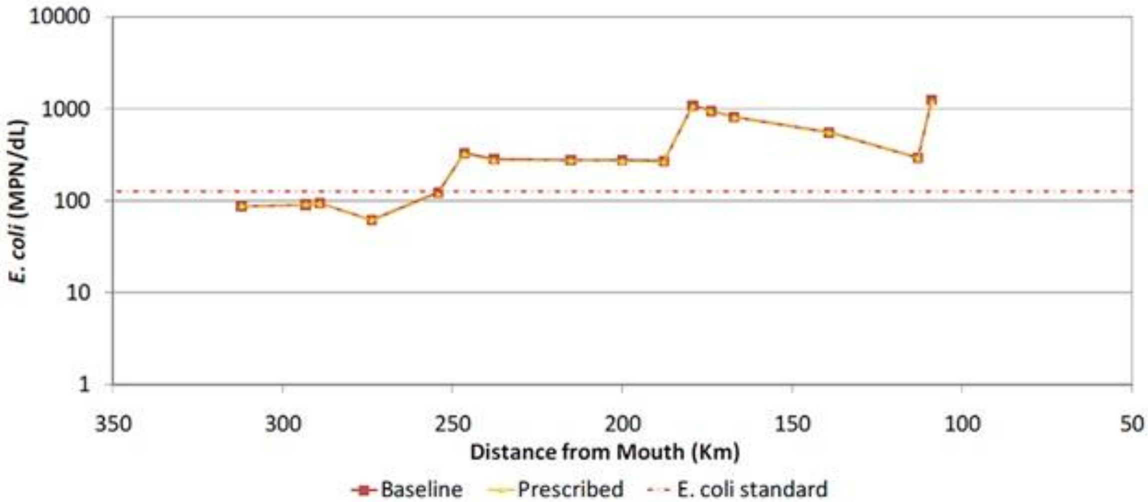

FIGURE 43 - PRESCRIBED GRAZING SWAT RESULTS

A summary of **in-stream load reductions** for each scenario is presented below. Full detail on the methodology for calculating these load reductions is discussed in Appendix B. Source loading is translated into in-stream loading which as presented below:

- Vegetative filter strips implanted in agriculture (AGRR), hay (HAY), rangeland (RNGE, RNGB) land covers, covering 448,642 acres): in-stream load reductions range from 1.42E+12 MPN/day at TCEQ monitoring station 17420 to 1.60E+13 MPN/day at TCEQ monitoring station 12147.
- Grassed water ways implanted in agriculture (AGRR), hay (HAY), rangeland (RNGE, RNGB) land covers, covering 448,642 acres: in-stream load reductions range from 3.30E+11 MPN/day at TCEQ monitoring station 17420 to 5.57E+12 MPN/day at TCEQ monitoring station 12147.
- Septic Systems implanted in two subwatersheds (25 and 36) that cover 5,381 acres: in-stream load reductions range from 0.00E+00 MPN/day at TCEQ monitoring station to 5.49E+12 MPN/day at TCEQ monitoring station 12147.
- Prescribed Grazing implanted in pasture and range land cover, covering 21,485 acres: in-stream load reductions range from 6.24E+10 MPN/day at TCEQ monitoring station 17420 to 3.64E+11 MPN/day at TCEQ monitoring station 12147.
- Feral Hog Control Techniques implemented across the San Bernard watershed: in-stream load reductions range from 8.02E+08 MPN/day at TCEQ monitoring station 17420 to 4.58E+10 MPN/day at TCEQ monitoring station 12147.

TABLE 35 - SUMMARY OF INSTREAM LOAD REDUCTIONS FOR MODELED BMPS

BMP Category	Load Reduction at Station 17420 (in MPN/day)	Load Reduction at Station 12147 (in MPN/day)

Vegetative Filter Strips	1.42E+12	1.60E+13
Grassed Waterways	3.30E+11	5.57E+12
Septic System Remediation	0.00E+00	5.49E+12
Prescribed Grazing	6.24E+10	3.64E+11
Feral Hog Control	8.02E+08	4.58E+10

5 – Feral Hog Management

Feral hogs and other wildlife are appreciable contributors of bacteria in the San Bernard watershed. Feral hog densities in the watershed are estimated to be about 5 hogs per square kilometer, which results in about 10,000 hogs being found in the watershed. Feral hog management strategies were simulated at 30 percent, 50 percent and 75 percent reductions in loading from the benchmark levels in the watershed, although none showed a significant reduction in *E. coli* levels. While hog manure production can make up a significant portion of the wildlife loading in some watersheds, wildlife manure generally provides a much smaller contribution (usually 1 percent or less) than livestock manure loading. Therefore while hogs may make significant contributions, the overall impact of modeled feral hog reduction scenarios is more modest.

TABLE 36- SUMMARY OF E. COLI CONCENTRATIONS AND PERCENT REDUCTION FROM BENCHMARK CONDITION – FERAL HOG MANAGEMENT

		Baseline	50% Reduction in Feral Hogs		75% Reduction in Feral Hogs	
Subbasin	River Km	*E. coli* (MPN/dL)	*E. coli* (MPN/dL)	Percent Reduction	*E. coli* (MPN/dL)	Percent Reduction
1	312.09	87.8	87.6	0%	87.5	0%
7	293.11	90.4	90.1	0%	89.8	-1%
8	289.04	93.6	93.2	0%	92.9	-1%
10	273.77	62.1	61.9	0%	61.7	-1%
11	254.09	122.9	122.6	0%	122.3	0%
13	246.5	332.2	332.0	0%	331.7	0%
16	237.75	282.3	282.1	0%	281.9	0%
17	215.14	279.0	287.8	0%	278.6	0%
21	200	274.8	274.6	0%	274.4	0%
23	187.65	272.8	272.7	0%	272.5	0%
26	179.27	1085.0	1082.4	0%	1081.1	0%
28	173.9	956.8	955.8	0%	953.3	0%
30	166.97	818.5	818.0	0%	816.5	0%
31	139.05	554.9	555.0	0%	554.6	0%
35	112.85	291.8	291.9	0%	291.8	0%
34	108.76	1246.9	1246.8	0%	1246.5	0%

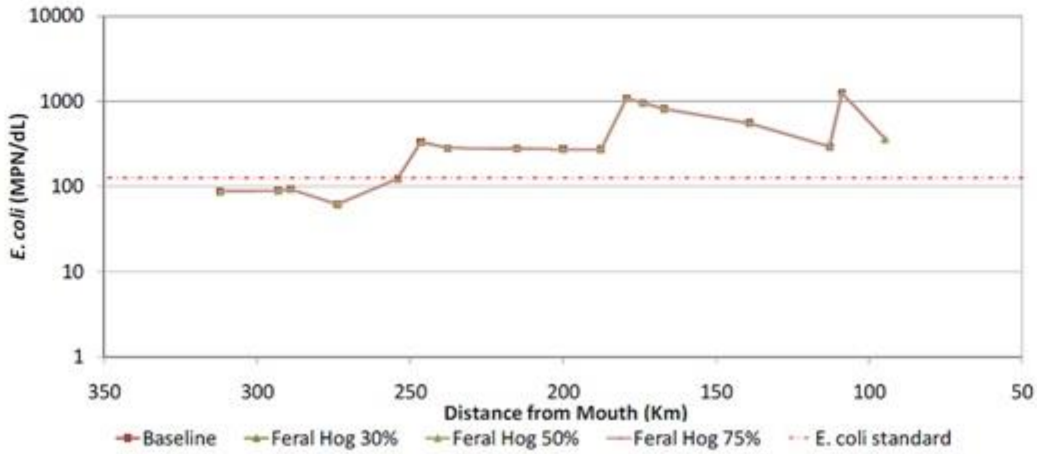

FIGURE 44 - FERAL HOG MANAGEMENT SWAT RESULTS

Modeling Conclusions

The vegetative filter strips, grassed waterways, and OSSF repairs and replacements are all effective in removing pollutants from runoff before it enters waterway, however the vegetative filter strips and OSSF repairs and replacements are the most effective. The location of the waterway and slope of the surrounding lands makes a difference in the effectiveness of the BMP. The SWAT and Tidal Prism modeling demonstrates that there are a number of ways in which to improve the water quality in the San Bernard watershed. Sources of the most concern in the watershed include OSSFs, livestock, and feral hogs. BMPs that help treat and prevent runoff from these sources from entering the waterways will be most useful in lowering bacteria levels in the watershed. The modeling also demonstrated that significantly improving just one or two of the sources would help improve the overall water quality in the watershed. The two sources that would most significantly improve the water quality if they were at least partially remedied would be OSSFs and livestock. A few of the subwatersheds in particular that contribute greater inputs should be prioritized. Subwatersheds with the highest overall loadings are: SW9 Upper Tidal, SW5 Snake Creek, and SW2 East Bernard Creek. Loadings from these Subwatersheds are primarily from Livestock and OSSFs.

7 - MANAGEMENT MEASURES (ELEMENT C)

A number of BMPs were reviewed for the San Bernard WPP. These BMPs came from other WPPs, WQMPs, and the TSSWCB's list of approved BMPs. A list of currently approved and implemented BMPs in the watersheds was also examined. The primary focus of BMPs was on bacteria reduction, with the expectation that most measures to reduce fecal matter pollution would have ancillary benefits in nutrient reduction and DO improvement. A comprehensive list of BMPs were presented to stakeholders to rank based on what they thought was most needed in the watershed and what was likely to be implemented. The BMP activities that were ranked the highest were: feral hog programs, repair and replacement of OSSFs, enforcement of illegal dumping and disposal, and filter strips surrounding agricultural practices. The two most effective BMPs that were modeled in the watershed were vegetated filter strips and grasses waterways. The modeling determined that vegetated filter strips would be most effective in removing pollutants before they reach waterways. This is a BMP that would be effective across a number of different land cover types.

OSSFS

OSSFs have been identified as a major contributor to the loadings in the San Bernard watershed. When conducting the SELECT and SWAT modeling it was assumed that 50 percent of the OSSFs installed prior to 1989 and 15 percent of the OSSFs installed after 1989 were failing. A lot of the OSSFs in the watershed are older systems that may be malfunctioning and need to be replaced. In many cases the system owners may not be aware that their OSSF is malfunctioning. Malfunctioning systems are the result of over use, lack of maintenance, lack of owner education, and inappropriate soils for the type of system. OSSFs are prevalent throughout the watershed, but there are fewer in proximity to the waterways in Colorado and Austin Counties. Brazoria County should be a priority for repair and replacement of existing systems.

- Updating design criteria and placement for new systems to ensure adequate space and soil types
- Work with Authorized Agents to create a uniform reporting system, use of global positioning system (GPS) in placement
- Voluntary repair and replacement of older systems
- Homeowner education workshops
- Enforcement of new or existing OSSF regulations by authorized agents

FERAL HOGS AND WILDLIFE

Feral hogs have been identified as having a major impact in general, and as a contributing source to the bacteria loadings, in the watershed. Feral hogs are found throughout the watershed in urban and rural areas and are known to cause a lot of damage. There are not a lot of BMPs that are highly effective in controlling the populations; however, programs are being developed in other watersheds that are helping build awareness and effectiveness. In addition to feral hogs there are also a number of other wild animals in the watershed including raccoon, opossums, deer, and avian wildlife. Programs to control feral hog populations should be a top priority for all the jurisdictions of the watershed since it is a statewide problem.

- Feral Hog Programs with Texas AgriLife Extension Service and Texas Parks and Wildlife
- Hog hunting and trapping programs to help reduce numbers

Livestock

Modeling has identified cattle as a source of concern in the San Bernard Watershed. A lot of pasture land directly fronts the San Bernard River and its tributaries. Management measures for livestock can voluntarily be implemented to keep cattle and their waste from entering the waterways. The TSSWCB also offers WQMPs to landowners in the watershed, and once approved landowners may be eligible for funding to help implement the practices identified in the plan. Controlling animal waste entering streams can have a 50 percent to 75 percent reduction of pollutants being released into streams (SWERPC, 2008). WQMPs that contain livestock BMPs are already occurring throughout the watershed.

- Alternate Water Sources to provide water sources for livestock
- Prescribed Grazing to manage vegetation with the use of grazing animals to reduce soil erosion

Agriculture

Agricultural lands are not a major contributor to the total loadings in the San Bernard watershed; however agricultural lands do make up the majority of the land cover in the watershed. The TSSWCB offers WQMPs to landowners in the watershed, and once approved, landowners may be eligible for funding to help implement the practices identified in the plan. Conservation practices that help filter pollutants can have up to a 50 percent reduction in the amount of pollutants released into waterways (SWERPC, 2008). WQMPs that contain agriculture BMPs are already occurring throughout the watershed. Watershed modeling demonstrated that contour buffer strips and filter strips were the most effective in removing pollutants from runoff. These two BMPs should be given priority in WQMPs.

- Nutrient Management to manage the amount, timing and placement of nutrients
- Crop Residue Management to leave a protective layer of previous crop behind to help reduce erosion
- Conservation Crop Rotation to grow various crops in rotation to reduce erosion and improve soil
- Terracing to create ridges and channels to reduce slope length and reduce erosion and sediment runoff
- Contour Buffer Strips to convey runoff without erosion and protect water quality
- Filter Strips to reduce sediment, organics and pollution from entering the waterway with a grassy strip
- Waste Utilization to apply agricultural waste in an environmentally friendly manner
- Soil Testing to determine the actual amount of nutrients needed

Wastewater Treatment Plants/Outfalls

Wastewater Treatment Plants are a point source pollution found in the watershed from which the contribution of pollution can be directly measured. Currently effluent from these outfalls is not being monitored, but bacterial monitoring can be added to monitor outputs and determine if any of the facilities are non-compliant. SELECT and SWAT modeling both used the standard 126 for the wastewater effluent, however if this number was lower the baseline data for the watershed would be lowered. As WWTFs renew their permits, they will begin testing their effluent for bacteria. Priority should be given to facilities that are just upstream of monitoring stations with higher levels of bacteria. Additionally, SSOs in related collection systems can be a direct (though usually episodic) source of high-concentration bacterial input to waterways.

- Enforcement and testing of effluent from the 23 area WWTFs
- Proper reporting of SSOs, and evaluation of SSO data[28]

Pets

Pet waste can be a major contributor to loadings in the watershed, especially in residential areas. As population increases, so do the number of pets. Pet waste collection does not require any a lot of resources and can voluntarily be implemented. Pet waste control programs can have up to a 5 percent reduction in the amount of pollutants released to waterways (SWERPC, 2008).

- Pet waste cleanup in residential areas
- Spay and Neuter programs to control number of feral animals in the watershed

Land Management

Land management in the San Bernard watershed includes a number of BMPs that have been done by land owners and city and county governments. A number of conservation easements exist in the watershed along the waterways. Conservation easements are a good way for a landowner to preserve their property and prevent development from occurring adjacent to the waterways. There are concerns in the watershed about vegetation management along the waterways, some areas have been clear cut and are eroding, and some are overgrown to the point where water cannot flow. There are also a number of sites throughout the watershed where trash and appliances have been dumped off of bridges.

Urban Runoff is not a major contributor to the loads in the San Bernard Watershed, especially in the upper part of the watershed. However, there is appreciable residential development along the river in the lower

[28] SSO data for the region is evaluated currently by other water quality efforts, including Clean Rivers Program partners and 604(b) project efforts by H-GAC. It is expected these efforts will continue periodically for the foreseeable future.

part of the watershed, and more areas will develop as the population in the watershed continues to grow. Urban Runoff BMPs are also effective for flooding events which occur in the lower part of the watershed and wash pollutants into the river. A number of dump sites have also been identified in the watershed, where residents are dumping household trash and large appliances. Residential land management practices can have a 2 percent to 10 percent reduction in the pollutants released to area waterways (SWERPC, 2008). Cleanup events should be prioritized for counties where there is a lot of trash dumped at bridges that cross the San Bernard River and its tributaries.

- Conservation Easements to acquire land along waterways
- Reforestation of riparian areas where appropriate
- City/County enforcement of illegal dumping and disposal
- Brush management would help in the removal of invasive species to help protect soils, control erosion, reduce sedimentation, and improve water quality
- Identification and removal of abandoned boats
- Trash pickup events
- Good Housekeeping/yard care in residential areas and neighborhoods

Model Ordinances

Model ordinance could be used by the jurisdictions in the San Bernard watershed to design nonpoint source pollution control ordinances or storm water pollution prevention plans. A number of example ordinances have been collected and posted to the San Bernard Watershed website.

- Storm Water Pollution Prevention Plan
- Nonpoint Source Pollution Control Ordinance

Hydrologic Changes

The opening of the mouth of the River in the Tidal section has been consistently highlighted as a priority by local stakeholders. While this effort is not in the scope of this watershed project, the WPP does recommend that other parties (including but not limited to Brazoria County, the General Land Office, the USACE, and local, state and national representatives) continue to pursue opportunities for a long-term solution for the mouth. Towards that end, the stakeholders will seek to actively support of grant applications, projects and outreach efforts that further this goal. No specific bacteria reduction is anticipated for this support activity. Opening the mouth, however, is expected to have a beneficial impact on dissolved oxygen levels in the Tidal segment, and to increase the efficiency of tidal flushing which may reduce bacteria levels in some conditions.

Addressing DO and Nutrient Issues

While bacteria was the primary focus of this WPP effort[29], stakeholders and project staff considered the impact of many BMPs to have ancillary benefit in reducing nutrient loads and improving dissolved oxygen. Bacteria reduction measures almost invariably impact nutrient levels, especially those related to the waste from which the bacteria originate. Therefore, the suite of practices recommended for bacteria reduction have reasonable expectations of nutrient reductions as well. These include reduction of nutrient load from human waste with OSSF remediation and WWTF improvements; reduction of nutrient loads from animal waste from pets, feral hog and especially livestock measures; and particular reduction from proposed land management BMPs. The latter are specifically utilized for the purpose of nutrient reduction in many cases. Some elements discussed in terms of bacteria reduction, like WQMPs, already have integrated nutrient management components. While DO is not directly increased by these BMPs (i.e. through aeration, etc.) and may be impacted by other causes (temperature, hydrology, etc.), it is expected that improved land management and reduction in fecal matter pollution will remove a large portion of the NPS contribution to the river's nutrient load.

Removal Efficiency of BMPs

As indicated throughout this section, the number of source units to be addressed to meet reduction targets is based on 100% reduction of the literature value of waste for a representative unit for a given bacteria source. For example, a target goal of 100 cattle source units means eliminating the waste equivalent of 100 representative cows. However, the removal efficiency of most BMPs is less than 100%. Source units are representative values; achieving reduction equivalent to 1 representative cattle source may require addressing multiple actual cattle. For example, if a given BMP has a removal efficiency of 50%, it would need to address the waste of two actual cattle to achieve a reduction equivalent to one representative source unit (2 X 0.5 = 1). Because many sources are not addressed by a single BMP, may vary greatly in application (e.g., WQMPs), or may be very specific to a given location, source units are used as a conceptual representation when the actual reduction efficiency is not easily estimated. More information on BMP removal efficiency is included in Appendix B.

[29] The choice of water quality goals for the projects was made by the stakeholders, as facilitated by H-GAC and TCEQ. During the development of the project, bacteria was the existing impairment and therefore was the primary project driver. Subsequent changes in more current 303d lists, discussed in Section 4, add additional weight to concern over nutrient and DO issues. While these issues were not specifically modeled as part of this project, based on the existing conditions during project development, stakeholders are mindful of them as implementation moves forward and heavy emphasis has been put on solutions that yield multiple water quality benefits.

8 – Technical and Financial Needs (Element D)

Technical and financial needs need to be identified to find potential sources of funding for implementation of the BMPs identified in this plan. Needs and costs are identified by BMP category, and summarized at the end of the section. Responsible parties are indicated in parentheses following each specific BMP. It is the intent of the WPP to support the commitment from local governments to the greatest degree possible by continually seeking additional funding and technical support.

OSSFs[30]

- Updating design criteria and placement for new systems to ensure adequate space and soil types
  - $ 30,000/ per code (local governments)
- Enforcement of existing or new OSSF regulations
  - $ 50,000/ year/ per authorized agent (authorized agents)
- Work with Authorized Agents to create a uniform reporting system and use of GPS in placement
  - Training of Authorized Agents through grant funds (authorized agents)
- OSSF workshops and assistance
  - $2,500/ per event (H-GAC, AgriLife)
- Voluntary repair and replacement of older systems
  - Repair of older systems $5,000/ system (residents, H-GAC SEP)
  - Replacement of systems $10,000/ system (residents, H-GAC SEP)
  - Connection to existing sewer systems $2,000/ per house (residents, H-GAC SEP)

Feral Hogs and Wildlife

- Feral Hog Programs
  - Texas AgriLife Extension Service and Texas Wildlife Service workshops for property owners $8,000/ workshop (H-GAC, AgriLife)
  - Pork Choppers permitted to hunt hogs in the region (Governments, State of Texas, landowners, commercial vendors)

Livestock

- WQMPs
  - $10,000 - $15,000/ plan (TSSWCB, landowners/producers)
  - Done through the TSSWCB and are free to landowners, however practices identified in the plan are not paid for, but funding may be available
    - Alternate Water Sources to provide water for livestock
    - Prescribed Grazing to manage vegetation with the use of grazing animals to reduce soil erosion

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[30] It is expected that the bulk of the costs for OSSF repair and replacement will be borne by residents as part of the natural life cycle of OSSFs. Additional sources of funding (319, SEP) will be targeted sparingly to address highest risk areas and specifically toward lower income households.

AGRICULTURE

- Ag Waste Collection Days
    - $75,000/ per event (Counties)
- WQMPs
    - $10,000 - $15,000/ plan (TSSWCB, landowner/producers)
    - Done through the TSSWCB and are free to landowners, however practices identified in the plan are not paid for, but funding may be available
        - Nutrient Management to manage the amount, timing and placement of nutrients
        - Crop Residue Management to leave a protective layer of previous crop behind to help reduce erosion
        - Conservation Crop Rotation to grow various crops in rotation to reduce erosion and improve soil
        - Terracing to create ridges and channels to reduce slope length and reduce erosion and sediment runoff
        - Contour Buffer Strips to convey runoff without erosion and protect water quality
        - Filter Strips to reduce sediment, organics and pollution from entering the waterway with a grassy strip
        - Waste Utilization to apply agricultural waste in an environmentally friendly manner
- Soil Testing to determine the actual amount of nutrients needed
    - $10/sample (AgriLife, landowners)

WASTEWATER TREATMENT PLANTS/OUTFALLS

- Enforcement and testing of effluent for *E. coli*
    - ➢ $25/month/facility (WWTFs, industry)

URBAN RUNOFF

- Trash pickup events along waterways
    - Sponsored by Friends of the River San Bernard
- Good Housekeeping/Yard care in residential areas and neighborhoods
    - Educational materials $15,000 (H-GAC, interested local partners)

PETS

- Pet waste
    - Spay and Neuter Program $35,000/ per jurisdiction (local governments)

LAND MANAGEMENT

- Conservation Easements to acquire land along waterways
    - Varies based on size and location. Technical assistance includes program support from easement holding entities. (Land trusts, landowners)

- City/County enforcement of illegal dumping and disposal
    - County enforcement officers (Counties)
- Brush management to help in the removal of invasive species to help protect soils, control erosion, reduce sedimentation, and improve water quality
    - WQMPs (up to $15,000 in financial incentives per plan, in addition to landowner costs [variable] (TSSWCB, landowners)

Illegal Dump Site Cleanup

- $40,000/per site (Local governments)

- Identification and removal of abandoned boats
    - Removal and disposal $25,000/ per boat (GLO, industry)

New Ordinances and Plans

- Storm Water Pollution Prevention Plan
    - See San Bernard WPP Website (H-GAC, local governments)
- Nonpoint Source Pollution Control Ordinance
    - See San Bernard WPP Website (H-GAC, local governments)

Forecast of Potential Costs of Implementation

The total cost of implementation for all BMPs and target reduction goals is expected to vary greatly depending on the location/siting, number, and efficiency of specific BMPs. While this WPP sets forth target goals and distributions of BMPs, actual implementation may differ based on opportunities that arise throughout the implementation period. This summary is provided as a conceptual forecast of the scope of total costs, which includes both costs expected to be borne by funding sources through the purview of this or successor projects and those expected to be borne by other sources (e.g. homeowner contribution, etc.) The intent of the summary is to provide a sense of the scale of financial resources needed. For some tasks, potential costs are not able to be reliably predicted, and are noted as such.

Many of the bacteria sources are addressed through a combination of multiple BMPs. For the sake of this illustrative summary, it is assumed that each BMP listed in Table 37 is addressing all source units for that bacteria source. In reality, each BMP will address some portion of that source. For the number of source units to address or total years, the base number of units for the combined Tidal and Above Tidal source units is used unless more specific information is available. Some items (trash reduction, etc.) do not equate specifically to bacteria source units. New Ordinances and plans are not included here as they are not specific to source units and do not have projectable costs.

TABLE 37 - POTENTIAL COSTS OF IMPLEMENTATION

Bacteria Source BMP Category	BMP	Cost per Source Unit, Year, or Instance	Total Source Units to Address/Total Years	Total Potential Cost	Source of Funds
OSSFs	Update Design Criteria	NA	435 units	$30,000	Authorized Agents
OSSFs	Enforce Regulations	$50,000/ year	8 years	$400,000	Authorized Agents
OSSFs	Train Authorized Agents to Report OSSF Locations	Variable	435 units	NA	Authorized Agents, H-GAC 604b WQMP project
OSSFs	OSSF Workshops	$2,500 per event	435 units	NA	H-GAC, 604b, AgriLife
OSSFs	Repair/ Replace	$5,000/$10,000 / unit	435 units	$2,175,000/$4,350,000	Homeowners, SEP funds
Feral Hogs	Feral Hog Workshops	$8,000 per event	323 units	NA	AgriLife, 319h
Feral Hogs	Permit Helicopter Hunting	Unknown	323 units	NA	Multiple
Livestock / Agriculture	WQMPs	$10,000-$15,000 per plan (TSSWCB funding[31])	• 28,537 Cattle • 3720 Horses • 1677 Sheep and Goats	Variable depending on number of WQMPs and livestock covered by each.	TSSWCB, Landowners and Agricultural Producers
Agriculture	Waste Collection Days	$75,000 per event	NA	Variable depending on the number of events held	Counties, Agricultural Organizations
Agriculture	Soil Testing	$10/sample	NA	NA	Landowners
WWTFs	*E. coli* testing	$25/month/ facility	NA	NA	WWTFs
Urban Runoff	Trash Pickup Events	Variable by scope of event	NA	Variable by scope and number of events	Friends of the River San Bernard
Urban Runoff	Educational Materials	$15,000 for materials	NA	$15,000	H-GAC via 319h or other grant sources, other local partners with

[31] WQMPs typically involve funding from TSSWCB and the landowner. The TSSWCB contribution is a maximum of $15,000 per plan. Landowner costs can vary greatly dependent on the nature, scale, acreage, focus, and other factors of the specific WQMP.

Bacteria Source BMP Category	BMP	Cost per Source Unit, Year, or Instance	Total Source Units to Address/Total Years	Total Potential Cost	Source of Funds
					existing materials
Pets	Spay and Neuter Programs	$35,000 per event	17,150 units	Variable depending on the number of events and units addressed per event	Local Governments
Land Management	Conservation Easements	Variable depending on size and cost of easements	NA	Variable depending on size and cost of easements	Land trusts, landowners
Land Management	Dumping Enforcement	Variable depending on amount of dumping and jurisdiction.	NA	Variable depending on amount of dumping and jurisdiction.	Local governments
Land Management	Brush Management	(See Livestock / Agriculture - WQMPs)	(See Livestock / Agriculture - WQMPs)	(See Livestock / Agriculture - WQMPs)	(See Livestock / Agriculture - WQMPs)
Land Management	Dumpsite Cleanup	$40,000 per site	NA	Variable depending on the number of sites	Local Governments
Land Management	Identify and Remove Abandoned Boats	$25,000 per boat	NA	Variable depending on the number of boats	GLO, Industry, Owners

Sources of Funding

In order to implement BMPs identified in this document, sources of funding are also identified. Many of the BMPs identified in this plan are currently available in the watershed and funding sources are also available.

- Individual Landowners
- Local funds from area Counties and Cities (including revenue from utilities)
- Section 319(h) Grants – Federal Clean Water Act
- Section 106 Water Pollution Control Grants
- SEP – Supplemental Environmental Projects

    - Conservation Easements
    - OSSF repair and replacement
- WQMPs – TSSWCB
    - Agricultural plans
- Clean Water State Revolving Fund (CWSRF, for transitioning OSSF areas to sewer service).
- State agency programs (e.g. GLO for marine debris removal)
- Other Foundations and NGOs with applicable grant funding
- RESTORE Act funding, as appropriate to specific areas

9 – Outreach and Education (Element E)

Outreach and Education

Public education and outreach are essential to the implementation of a successful WPP. In addition to the physical BMPs to be implemented by landowners and jurisdictions in the watershed, behavioral BMPs can be addressed by everyone in the watershed. Public participation can include public education workshops, distribution of educational materials, and participation in activities to improve water quality. H-GAC will continue meeting with stakeholders to gather input on watershed planning, results on continued modeling, and implementation of BMPs in the watershed. Targeted audiences of outreach and education include, but are not limited to: residents (including those with OSSFs), landowners (including agricultural producers who may be interested in implementing recommended BMPs), city and county officials, MUDs, Soil and Water Conservation Districts, state agencies, WWTFs, OSSF Authorized Agents, and non-profit groups.

Public Outreach and Education

Advertising

H-GAC advertises the project through press releases, direct mailing, emails, phone calls, the website, and through community newsletters. Efforts are being made to gather public support, diverse public participation, and community input for this project through several different outreach efforts. H-GAC will continue to notify stakeholders about upcoming events as appropriate when they pertain to the watershed and activities laid out in the WPP.

Media Relations

Press Kit

H-GAC has produced a watershed brochure titled "San Bernard Watershed". It has been updated and is used to educate stakeholders about the impacts of individual activities on water quality and how to reduce those impacts. The watershed brochure gives an overview of the area economy and resources, historic water quality, BMPs, and water monitoring results. The watershed brochure will be updated annually to include the most current monitoring results. H-GAC also produces an annual report of all waterways in the region and highlights improvements and degradations over the past year.

News Releases

H-GAC creates and submits news releases to numerous media outlets, including 5 local newspapers and approximately 50 additional local and regional newspapers, magazines, radio programs and TV stations. Press releases have been used throughout the WPP process. Additional public information articles will be developed and submitted to key outlets to announce completion of the watershed plan and to encourage stakeholder involvement in the implementation process.

Media Database

Press releases for the San Bernard WPP have been and continue to be distributed to:

Alvin Sun / Alvin Advertiser

Banner Press Newspaper

The Bulletin of Brazoria County
The Bellville Times
Eagle Lake Headlight
Colorado County Citizen
Houston/Fort Bend Lifestyle & Homes
Fort Bend Herald
Sealy News
El Campo Leader-News
Coastal Broadcasting
Fort Bend Spotlight
Gulf Coast Tribune
Wallis News-Review
The Weimar Mercury
Fort Bend Mirror
The Brazosport Facts
Greatwood / New Territory / Pecan Grove
Richmond/Rosenberg Herald-Coaster
Las Noticias de Fort Bend
The Pearland Journal
Fort Bend Star
Brazoria County News
Katy Times
The Brazosport Facts
Pearland Reporter
La Vida News/The Ebony Voice
KULP Radio
Radio Station KULM-FM

EDUCATION

PROACTIVE OUTREACH/RESPONSE

Texas Stream Team

Texas Stream Team is a network of trained volunteers and supporting partners working together to collect information about the natural resources of Texas to ensure the information is available to all citizens. Volunteers are trained to collect quality-assured information that can be used to make environmentally sound decisions. The Stream Team is administered by H-GAC in the San Bernard Watershed and does not receive any federal funding. Volunteers complete three phases of training and are certified at various levels depending on their environmental goals and concerns. The Texas Stream Team program will continue recruiting members in the San Bernard Watershed and will hold periodic training sessions for new members.

FIGURE 45 - TEXAS STREAM TEAM CLASS IN SAN BERNARD WATERSHED

Clean Waters Initiative Program

The Clean Waters Initiative (CWI) program offers workshops that will help local governments, landowners, and citizens develop strategies to reduce pollution in area waterways. Workshops will focus on a variety of issues such as leaking septic tanks and pollution from urban development and agriculture, or broader issues of watershed protection, planning, and stormwater permitting. H-GAC makes individual presentations and can tailor workshops to the needs of specific areas. Workshops are held approximately every 6 weeks throughout the year.

FIGURE 46 – CLEAN WATERS IINITIATIVE WORKSHOP AT H-GAC

Watershed Signage

Road signs have been developed as a way to notify residents and visitors that they are entering the watershed and encourage them to take action and protect water quality in the area. These have been posted on major roads and highways and when crossing a tributary of the San Bernard.

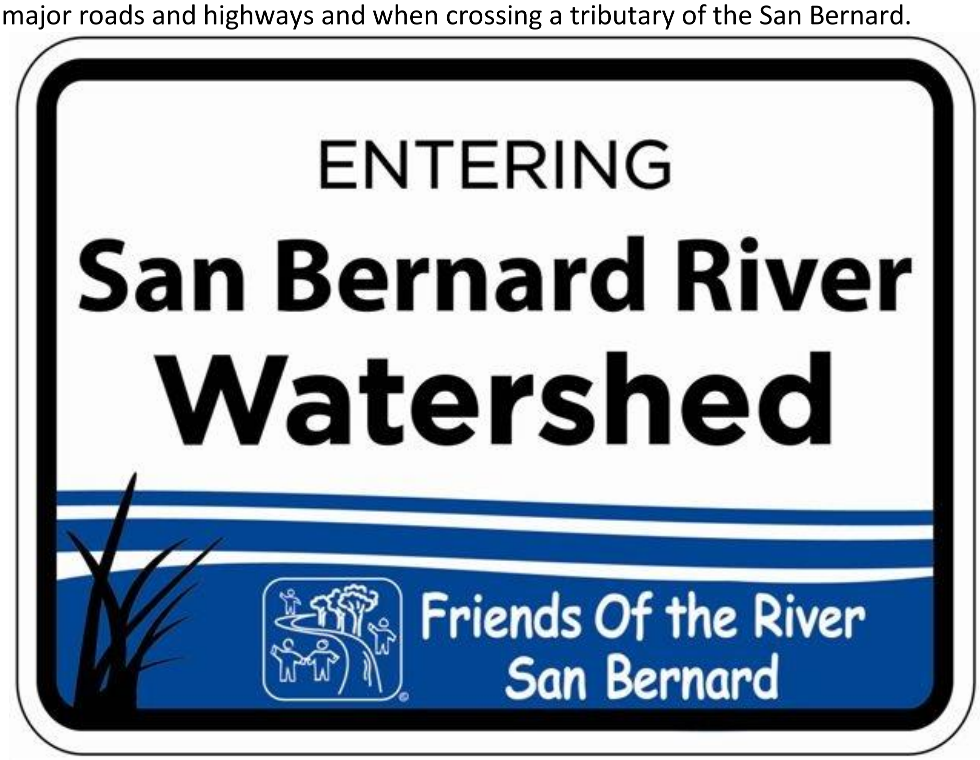


FIGURE 47 - SAN BERNARD RIVER WATERSHED SIGN

Texas Watershed Stewards

Texas Watershed Stewards is a science-based watershed education program designed to help citizens identify and take action to address local water quality impairments. The focus of the group is public participation in local watershed management. The program is open to all watershed residents, including homeowners, business owners, agricultural produces, decision makers, community leaders, and all other citizens. The program has been implemented through the Texas AgriLife Extension Service and TSSWCB and is now also available online. The goal is to engage as many citizens as possible in the implementation process.

FIGURE 48 - TEXAS WATERSHED STEWARDS WORKSHOP

Classroom Presentations

The Friends of the River San Bernard has a River Ranger program that presents to local students about the importance of a healthy San Bernard River watershed. The group generally does one program each quarter of the year.

Trash Clean Up

The Friends of the River San Bernard holds an annual river clean up event each April. They host four collection sites in the tidal portion of the river, where residents can deposit items collected from the river by boat. This clean up event could be extended to the non-tidal portion of the river, particularly in areas where there is a lot of illegal dumping.

FIGURE 49 - TRASH DUMPED AT A BRIDGE CROSSING ON SAN BERNARD RIVER

WEB SITE

The San Bernard Watershed website is updated and maintained by H-GAC. The website contains information about the watershed, press releases, upcoming meeting announcements, and information presented at previous meetings. There are also links to different types of BMPs along the urban-to-rural transect and links to sample ordinances on how to reduce nonpoint source pollution. Draft copies of deliverables can also be viewed by downloading them from the website. The URL is www.h-gac.com/go/sanbernard.

PROGRAM PROMOTION

H-GAC will seek to advertise/promote programs and technical services available to watershed residents and landowners to the greatest degree possible. The intent of these efforts is to extend the reach of entities with existing and proven programs, instead of duplicating efforts. For example, H-GAC will assist TSSWCB, AgriLife, local Soil and Water Conservation Districts, and other agricultural entities in promoting relevant programs to producers and landowners when there is a water quality connection (e.g. WQMPs). H-GAC and other stakeholders will seek to do this through established communications means (websites, newsletters, email, etc.) as well as cross-promoting related efforts at events.

10 – Project Implementation and Interim Milestones for Progress (Elements F & G)

Watershed monitoring and modeling have demonstrated a need to implement BMPs in the San Bernard watershed to improve water quality. Previous chapters have identified causes and sources of pollution in the watershed, management practices to improve water quality, and possible sources of funding to help implement measures to improve water quality. This chapter will identify implementation of BMPs and benchmarks to determine if water quality goals are being met.

OSSFs

OSSFs are a major contributor to the water quality impairments in the watershed. It was identified in the SWAT modeling that eliminating OSSF bacteria sources would help significantly improve water quality in the watershed. With the creation of the H-GAC OSSF database tracking of new OSSF systems in the watershed will become a more streamlined process. H-GAC worked with the area Authorized Agents to create a uniform system for reporting and identifying OSSF locations. Many Agents have also updated standards to ensure systems are placed and sized properly. It was noted during the public participation process that a few of the counties in the watershed have tightened up their OSSF regulations and are now requiring regular maintenance on permitted systems.

For the OSSF systems already in place in the watershed, a number appear to be failing or poorly maintained. Voluntary repair and replacement with funding through SEP funds and 319 grants will help eliminate sources of bacteria. Homeowner education workshops will also help OSSF owners maintain their systems, therefore lowering the cost of potential repairs and replacement. Over 6,800 potentially failing systems have been identified in the San Bernard Watershed. This means that over 4,700 systems will need to be repaired or replaced in the watershed.

TABLE 38- OSSF IMPLEMENTATION SCHEDULE[32]

Activity	Responsible entity	Implementation	Timeframe
Updating design criteria and placement for new systems to ensure adequate space and soil types	Authorized Agents/Counties	As codes are updated	Start within 5 years
Enforcement of existing or new OSSF regulations	Counties	Immediate by Authorized agents	Within 1 year
Work with Authorized Agents to create a uniform reporting system and use of GPS in placement	H-GAC	Continue ongoing programs as funds are available	Has been implemented

[32] In this and subsequent tables in this chapter, timeframes refer to the length of time after the acceptance of this WPP by EPA.

Activity	Responsible entity	Implementation	Timeframe
Training of Authorized Agents through grant funds	H-GAC	As funds are available	Has been implemented
OSSF workshops and assistance	Texas AgriLife	As funds are available	Has been implemented, Continuous
Voluntary repair and replacement of older systems	Homeowners	Through SEP funds	Within 1 year
Repair of older systems – county by county (see Table 39 below for exact number by subwatershed that require repair)	Authorized Agents/counties	Through SEP funds	Within 5 years
Connection to existing sewer systems	Cities/counties/homeowners	As funds and systems are available	Within 10 years

TABLE39 - NUMBER OF OSSF REPAIRS NEEDED TO MEET CONTACT RECREATION STANDARDS[33]

Subbasin	Septic Density (km^{-1})	Distance from the Stream (km)	Subbasin Area (km^2)	Number of Septics/Subbasin potentially failing	How many need to be improved/repaired – to reduce bacteria by 70%	Number of OSSFs to repair each year to meet target within 5 years
1	5.48	0.422	19.06	104	72.8	14.56
2	4.89	0.422	13.01	64	44.8	8.96
3	12.40	0.422	7.16	89	62.3	12.46
4	13.80	0.422	6.90	95	66.5	13.3
5	9.33	0.422	0.45	4	2.8	0.56
6	6.16	0.422	14.63	90	63	12.6
7	7.78	0.422	4.19	33	23.1	4.62
8	10.28	0.422	0.67	7	4.9	0.98
9	11.65	0.422	9.13	106	74.2	14.84
10	20.05	0.422	6.08	122	85.4	17.08

[33] The figures for this table are based on the SWAT modeling outcomes. More information about the SWAT model process is available in Appendix B.

Subbasin	Septic Density (km^{-1})	Distance from the Stream (km)	Subbasin Area (km^2)	Number of Septics/Subbasin potentially failing	How many need to be improved/repaired – to reduce bacteria by 70%	Number of OSSFs to repair each year to meet target within 5 years
11	17.75	0.422	7.23	128	89.6	17.92
12	7.73	0.422	17.58	136	95.2	19.04
13	9.53	0.422	3.32	32	22.4	4.48
14	15.69	0.422	10.74	169	118.3	23.66
15	16.17	0.422	6.39	103	72.1	14.42
16	21.41	0.422	1.74	37	25.9	5.18
17	25.80	0.422	5.19	134	93.8	18.76
18	27.63	0.422	3.03	84	58.8	11.76
19	16.40	0.422	10.84	178	124.6	24.92
20	36.91	0.422	4.13	152	106.4	21.28
21	21.88	0.422	5.66	124	86.8	17.36
22	18.89	0.422	9.36	177	123.9	24.78
23	32.28	0.422	0.96	31	21.7	4.34
24	17.82	0.422	3.31	59	41.3	8.26
25	17.91	0.422	18.33	328	229.6	45.92
26	60.93	0.422	0.54	33	23.1	4.62
27	33.69	0.422	7.34	247	172.9	34.58
28	19.10	0.422	0.68	13	9.1	1.82
29	42.52	0.422	1.12	48	33.6	6.72
30	23.26	0.422	1.07	25	17.5	3.5
31	33.20	0.422	5.48	182	127.4	25.48
32	24.24	0.422	11.35	275	192.5	38.5
33	21.21	0.422	9.21	195	136.5	27.3

Subbasin	Septic Density (km^{-1})	Distance from the Stream (km)	Subbasin Area (km^2)	Number of Septics/Subbasin potentially failing	How many need to be improved/repaired – to reduce bacteria by 70%	Number of OSSFs to repair each year to meet target within 5 years
34	10.02	0.422	0.90	9	6.3	1.26
35	37.38	0.422	4.32	162	113.4	22.68
36	129.31	0.422	3.45	446	312.2	62.44
37	77.54	0.422	27.56	2137	1495.9	299.18
38	61.05	0.422	4.00	244	170.8	34.16
39	51.49	0.422	4.16	214	149.8	29.96
40	7.70	0.422	0.14	1	0.7	0.14

Wastewater Treatment Plants/Outfalls

Wastewater Treatment Plants are a point source pollution found in the watershed, and their outputs can be directly measured. WWTFs in the watershed are currently testing the treated wastewater for bacteria[34]. In addition, monitoring bacteria at WWTF outfalls is part of a continued monitoring program under a 319 (h) grant from the TSSWCB. WWTF bacteria limit testing began about two years ago to monitor outputs from plants.

In doing the SELECT and SWAT monitoring, it was assumed that their output was at the 126 standard – which does contribute to the baseline bacteria level in the watershed. However, if their outputs are lower, this will help lower the baseline bacteria levels. Bacteria monitoring at the wastewater treatment plant outfalls will help determine if and where bacteria levels need to be lowered. Enforcement of permits and standards will help keep the baseline levels low as permits are required to be renewed and will be enforced by TCEQ.

[34] During the development of the WPP, many plants' permits had not yet been updated to include bacteria limits. This text has been updated subsequent to the development process to indicate progress on this item.

TABLE 40- WWTF BMP IMPLEMENTATION SCHEDULE

Enforcement Activity	Responsible Entity	Implementation	Timeframe
Testing of effluent for *E. coli*	WWTF	As permits are renewed	Within 1 year, as permits are renewed on a 5-year cycle.
Testing of outfalls for *E. coli*	H-GAC	As part of expanded monitoring program under 319 grant	2 years

Feral Hogs and Wildlife/Pets

Feral hogs have been identified as a major contributing factor to the bacteria levels in the watershed. However, the contribution is not significant enough to meet the standard if the source were eliminated. Pets are a contributing source, but not considered a significant source. However, the watershed would benefit from a spay/neuter program to help control feral populations of cats and dogs.

Wildlife contributions are primarily from deer, feral hogs, and other minor sources such as raccoons, coyotes, opossums, and birds. Deer and feral hog populations were applied to certain land cover areas in the watershed. Deer populations were applied to pasture and forested areas. Feral hogs were applied to all land categories except developed areas and open water. Feral hogs are the major contributor in this category and programs are being implemented statewide to help landowners deal with the destruction and damage caused by feral hogs.

TABLE 41 - FERAL HOGS/WILDLIFE/PETS BMP IMPLEMENTATION SCHEDULE

Activity	Responsible Entity	Implementation	Timeframe
Feral Hog Programs	Texas AgriLife, Texas Wildlife Service	Ongoing with TWS	Have been implemented
Texas AgriLife Extension Service and Texas Wildlife Service workshops for property owners	Landowners	Bring programs to the watershed, coordination with AgriLife extension and TWS	Have been implemented
Pork Choppers permitted to hunt hogs in the region	Landowners	Ongoing – private contract with landowners	Have been implemented
Pet waste pickup	Pet owners	Enforcement – municipal codes	Start programs within 2-5 years
Spay and Neuter Program	Pet owners	City and County programs	Start programs within 2-5 years

LIVESTOCK

Modeling has identified cattle as a source of concern in the San Bernard Watershed. While agricultural lands are not the only contributor to the total loadings in the San Bernard watershed, they do make up the majority of its land cover by area. The TSSWCB offers WQMPs to landowners in the watershed, and once approved, landowners may be eligible for funding to help implement the practices identified in the plan. These plans include best management practices specific to the property help reduce bacteria introduction into area waterways. Soil testing is also available for landowners to determine the necessary amount of nutrients to apply to their land.

Currently WQMPs are applied to approximately 10 percent of the land area in the San Bernard Watershed. In a survey conducted among watershed residents, there was little knowledge of the availability of these plans. Advertisement of these plans will help increase implementation in the watershed, and lowering of bacteria levels associated with livestock and agricultural uses. Additional plans could be added throughout the watershed – if an additional 1 percent of the watershed area was added to a WQMP each year, which would protect an additional 6,800 acres.

TABLE 42 - LIVESTOCK AND AGRICULTURE BMP IMPLEMENTATION SCHEDULE

Activity	Responsible Entity	Implementation	Timeframe
WQMPs	Landowners	TSSWCB	Ongoing, currently being implemented, with more implementation required.
Ag Waste Collection Days (Counties)	Counties, landowners	County by county	Within 1 year
Soil Testing to determine the actual amount of nutrients needed	landowners	Through AgriLife extension	Ongoing, already being implemented.

TABLE 43- DISTRIBUTION OF EXISTING WQMPS IN THE SAN BERNARD WATERSHED

HUC-12	Project Subwatershed	# WQMPs	Acreage under WQMP	HUC-12 Acreage	Prescribed Grazing	Nutrient Management	Crop Residue Management	Forage Harvest Management	Wildlife Land	Conservation Crop Rotation	%Acreage under WQMP
120904010101	1	1	113	30419	113	113	0	0	0	0	0.004
120904010102	1	0	0	18213	0	0	0	0	0	0	0.000
120904010103	2	1	109	36802	0	109	0	109	0	0	0.003
120904010104	1	1	11744	15587	9094	5817	2447	189	5913	2447	0.753
120904010105	2	1	376	27683	284	375	0	91	0	0	0.014
120904010106	2	1	1162	14004	1162	1162	0	0	0	0	0.083
120904010107	2	5	416	15979	1377	1520	105	38	39	105	0.026
120904010108	3	0	0	26935	0	0	0	0	0	0	0.000
120904010109	2	16	4377	29444	434	4945	4465	46	40	4465	0.149
120904010201	4	22	2414	34069	1053	2219	1039	281	14	1039	0.071
120904010202	4	8	2742	17383	1444	2401	2401	89	5	2401	0.158
120904010204	4	8	4560	38836	131	4010	2767	1112	505	2767	0.117
120904010203	5	11	11118	44591	1273	11398	10103	22	168	10103	0.249
120904010205	5	22	2890	29113	546	2708	1959	203	170	1959	0.099
120904010206	6	13	448	32892	137	386	82	167	4	82	0.014
120904010207	5	9	2965	16542	402	2940	2523	15	0	2523	0.179
120904010301	7	4	280	29696	208	265	0	57	0	0	0.009
120904010208	7	12	2788	31122	841	1941	1276	77	509	1276	0.090
120904010302	7	4	880	38781	646	433	137	160	0	137	0.023
120904010304	7	3	2670	26081	1796	1796	0	0	0	0	0.102
120904010303	8	3	910	35917	757	870	0	113	869	0	0.025
120904010305	9	2	202	21877	194	194	0	0	0	0	0.009
120904010306	9	4	878	23236	765	842	0	77	0	0	0.038
120904010307	9	1	10341	45233	9041	0	0	0	1220	0	0.229
TOTAL		**152**	**64383**	**680435**	**31698**	**46444**	**29304**	**2846**	**9456**	**29304**	10%

Land Management

Land management in the San Bernard watershed includes a number of BMPs that could be used by land owners and city and county governments. A number of conservation easements exist in the watershed along the waterways, conservation easements are a good way for a landowner to preserve their property and prevent development from occurring adjacent to the waterways. A SEP fund account has been implemented in the watershed to purchase conservation easements along the San Bernard River.

There are concerns in the watershed about vegetation management along the waterways, some areas have been clear cut and are eroding, and some are overgrown to the point where water cannot flow. There are also a number of sites throughout the watershed where trash and appliances have been dumped off of bridges. There is an annual clean up hosted by the Friends of the River San Bernard to help combat this dumping. Currently Counties and Cities lack funding to clean up and monitor these sites. There is also a lack of sites in which to properly dispose of household hazardous waste, and some are prohibitively expensive for some residents.

Model ordinances could be used by the jurisdictions in the San Bernard watershed to design nonpoint source pollution control ordinances or storm water pollution prevention plans. A number of example ordinances have been collected and posted to the San Bernard Watershed website.

TABLE 44- LAND MANAGEMENT BMP IMPLEMENTATION SCHEDULE

Activity	Responsible Entity	Implementation	Timeframe
Trash pickup events along waterways	Friends of the River San Bernard	Ongoing, can be expanded/frequency increased	Already implemented
Good Housekeeping/Yard care in residential areas and neighborhoods	Homeowners	Education activities implemented by counties/cities	Already implemented
Conservation Easements to acquire land along waterways	Landowners, Friends of the River San Bernard	Expand existing programs, use of SEP funds	Already implemented
City/County enforcement of illegal dumping and disposal	Cities and counties	By city and county, apply for grants on annual cycle	Within 1 year
Brush management to help in the removal of invasive species to help protect soils, control erosion,	Cities and counties	By county and city	Within 5 years

reduce sedimentation, and improve water quality			
Identification and removal of abandoned boats	Boaters	By county as boats are identified	Immediate
Storm Water Pollution Prevention Plan	Cities and counties	As cities/counties create	Updated every 2-5 years
Nonpoint Source Pollution Control Ordinance	Cities and counties	As cities/counties create	Updated every 2-5 years

Stakeholders participated in a survey in order to rank their priorities for implementing BMPs in the watershed. Stakeholders were asked to rank the BMPs below 1 through 10, 1 being their top priority and 10 being the lowest. Below are the aggregated results of this survey, the right-hand column shows the average rank that each of the BMPs received. The overwhelming majority of stakeholders ranked public education and involvement programs as their highest priority. Other BMPs that ranked high included: repair and replacement of OSSFs, enforcement and testing of WWTFs, and feral hog programs. These BMPs will be prioritized for implementation and have already been started in the watershed.

TABLE 45 - RESULTS OF STAKEHOLDER SURVEY OF BMP IMPLEMENTATION PRIORITIES

Activity	Avg.
Public Education and Involvement Programs	2.85
Cattle Management Plans	5.67
Crop Management Plans	7.08
Waste Collection Days (ag, appliances, haz)	5.00
Feral Hog Programs	4.69
Pet Management Programs	9.00
Enforcement and Testing at WWTF	4.15
Repair and Replacement of old OSSFs	4.08
Filter strips surrounding waterways	6.77
Connecting homes to sewer systems	5.00

Projected Interim Milestones by Units Addressed

In addition to the descriptions in the sections above, and in relation to the project schedule and load reduction goals, Table 46 indicates the projected interim milestones for each 5-year modeled period. The milestones reflect the number of units to be addressed by each year. The descriptions of the means to address them are described in the preceding sections of this Section and in Section 7.

TABLE 46 - INTERIM MILESTONES BY NUMBER OF ADDRESSED UNITS[35]

Source Unit	Number of Source Units to Address, Above Tidal				Number of Source Units to Address, Tidal				Number of Source Units to Address, Total			
	Benchmark	2015	2020	2025	2015	2015	2020	2025	2015	2015	2020	2025
# of Septic systems	227	260	319	381	-	-	19	54	227	260	338	435
# of WWTFs	4	5	5	6	-	-	3	5	4	5	8	11
Urban area (Acres)	3267	3510	3767	3966	-	-	645	1641	3267	3510	4412	5607
# Dogs	6350	7550	9700	12000	-	-	1830	5150	6350	7550	11530	17150
# of Cattle	18536	19791	21130	22093	-	-	2557	6444	18536	19791	23687	28537
# of Horses	2334	2496	2667	2781	-	-	372	939	2334	2496	3039	3720
# of Sheep/Goats	899	958	1024	1066	-	-	242	611	899	958	1266	1677
# of Deer	1277	1368	1458	1522	-	-	148	374	1277	1368	1606	1896
# of Feral Hogs	194	207	222	232	-	-	36	91	194	207	258	323

[35] The number of BMPs needed to address some of these units is dependent on the size and scale and efficiency of an individual BMP. For example, WQMPs are applied to a large range of acreages of differing livestock types. However, as a hypothetical example, a 1000-acre operation with a stocking rate of 0.2 cows per acre might involve 200 head of cattle.

11 – Water Quality Monitoring and Measures of Success (Elements H & I)

The WPP includes a suggested monitoring element and measures of success by which to gauge the progress of implementation. This section describes the extent of each, and provides for a framework for adaptive management through continual water quality data review and periodic adjustment of the WPP.

Measures of Success

The ultimate success of the project is measured by compliance with the water quality standard as measured and evaluated based on Clean Rivers Program monitoring data. However, the implementation of the plan itself also yields programmatic measures of success that are useful in determining how well it is being implemented. This WPP uses a mix of both water quality and programmatic measures, but the primary means of measuring success remains compliance with the state water quality standard for contact recreation.

Programmatic measures

- Data collected are of known and acceptable quality and sufficient to assess the water body for attainment of the water quality standard throughout the planning period (and beyond if impairments remain) at the existing monitoring stations listed on Table 6 (p. 50) and shown on the map in Figure 62 (p. 146).
    - Criteria – The criteria for measuring success will be the successful implementation of quality-assured sampling efforts and transfer of data to the State Water Quality Monitoring Information System (SWQMIS) as appropriate, without a quality issue that would endanger the further use of the data in quality-assured contexts.
- Water quality data are used periodically to evaluate progress in implementing the San Bernard River WPP
    - Criteria – The stakeholders will review water quality data from SWQMIS and basin summaries produced by the Clean River Program every five years to evaluate whether progress is being made toward meeting the water quality standard. H-GAC will evaluate water quality trends and DMR/SSO data yearly as part of the CRP and 604b efforts, respectively.
- Implementation of BMPs based on WPP recommendations
    - Criteria – the criteria for this measure is the successful implementation of prescribed BMPs and related measures of the WPP. This is a non-numeric criterion; it does not entirely depend on the number of BMPs implemented. It is generally a qualitative measure to be considered by the stakeholders during periodic review. However, ultimate achievement will be a quantitative measure of whether implementation meets milestone

projections. The combination of the qualitative and quantitative approaches is intended to reflect the general standing of implementation efforts.

Water Quality measures

- Water Quality meets standards for contact recreation by 2025
    - Criteria – The criterion is the state water quality standard, as measured by TCEQ segment assessments.
- Water Quality standard thence maintained
    - Criterion – the criterion is the state water quality standard, as measured by TCEQ segment assessments.

Monitoring

Monitoring or water quality is an essential part of WPP progress evaluation. Routine ambient monitoring of the project area is conducted by H-GAC under the Clean River Program. This data, along with related data in SWQMIS for the segments, will be the primary source of water quality assessment for the waterway. Evaluation of water quality trends for these segments are conducted by H-GAC on a yearly basis as part of the CRP Basin Summary/Highlights Reports and as part of an ongoing 604b regional water quality project. Data is available for review on the H-GAC Water Resources Information Map (WRIM) by stakeholders and other interested parties.

H-GAC previously received a 319(h) grant from the TSSWCB to do additional monitoring in the San Bernard Watershed. This grant included adding additional quarterly monitoring sites, increasing some sites to monthly monitoring, wet weather monitoring, and monitoring of WWTFs in the watershed. This data helped to provide a broader view of the fluctuating water quality and potential sources in the waterway, and will be useful for comparison to subsequent targeted monitoring efforts. Subsequent efforts will be determined by the stakeholders as part of adaptive management review, to meet the character of implemented BMPs or data needs at the time of the review.

Adaptive Management

Continual review of intended actions, milestones, and progress indicators is an integral part of this WPP. The ultimate measures of progress for these efforts will be the impact on water quality as shown through decreases in concentrations of indicator bacteria. However, because positive and negative changes in bacteria concentrations may result from factors outside the influence of this WPP (pace of development, economic conditions impact on funding availability, etc.) a framework for assessing the success of the WPP is necessary. For the purpose of these evaluations, “stakeholders” as evaluators are inclusive of all interested parties rather than a set managing entity or committee, and meetings will be open to the public and advertised in advance.

Stakeholders will formally review WPP progress at least every five years, as facilitated by H-GAC and TCEQ, or their successor agencies in this project[36]. They will use a combination of three assessments as the criteria to determine if changes are necessary.

- Water Quality (Primary Criteria) – Stakeholders will review the assessment of the San Bernard River and its associated stream segments found in the TCEQ Integrated Reports issued since their last review. As appropriate or available, they will use additional water quality data analysis from the Clean Rivers Program as contained in the most current Basin Summary or Basin Highlights Report for the Houston-Galveston Region, and/or the current Regional Water Quality Management Plan analyses conducted as part of H-GAC's ongoing 604b grant project. The evaluation will focus on whether any change in impairment status has been achieved, or whether a trend in geomeans in the individual segments is apparent.
    - Outcome – In conjunction with the other two assessments (below), stakeholders will interpret a negative change in water quality as a need for review and change the WPP.

- Review of Timeline, Milestones and Secondary Indicators – Stakeholders will review the overall progress of the WPP in meeting the anticipated timeline, based on expected milestones and secondary indicators. This evaluation will be reviewed for each category of BMPs.
    - Outcome – In conjunction with the other two assessments, stakeholders will interpret delays or lower-than expected numbers for the secondary indicators as a need to review and change the WPP

- Consideration of External Factors – Stakeholders will evaluate, as appropriate, available data concerning growth trends in the area (H-GAC regional population projections, etc.), the then-current ability of the stakeholders to meet committed activities (based on economic conditions), aggravating factors such as expansion of feral hog populations or hydrologic changes in the watershed.
    - Outcome – In conjunction with the other two assessments, stakeholders will interpret negative change (increase in growth of pollutant sources above projections or decrease in available or committed funding) as a need to review and change the WPP.

Stakeholders will make changes to the WPP based on the adaptive management criteria in the following circumstances:

- If the outcome of the assessments indicates that additional action is needed, stakeholders will meet to discuss potential options, including increasing the scale of implementation activities, or changing old activities out for new solutions, as appropriate to current economic conditions and local decision-making. A WPP amendment will be initiated to account for these modifications.

[36] While a formal review will be undertaken every 5 years, H-GAC currently meets with stakeholders on a yearly basis (as part of an ongoing 604b grant project) to coordinate and assess implementation. During the period between the five-year review cycles, these yearly meetings and other ad hoc gatherings of the stakeholders will be the primary vehicle for addressing interim concerns/problems, and water quality trends. Specific interim triggers will include new listings, de-listings, significant worsening trends identified in the BHR/BSR, or notable source issues.

- If the outcome indicates a positive change, and that no additional action is needed, stakeholders will review the scheduled implementation activities to identify any activities that may be scaled down or delayed. A WPP amendment may be initiated to account for these modifications.
- If no specific trend or need is noted, but individual activities are identified as either more or less successful than anticipated, the stakeholders may elect to change the scale of implementation of individual activities, or replace them. A WPP Amendment may be initiated if these changes are substantial to the balance of activities in the WPP.

All considerations and meetings will be promoted to the stakeholders by H-GAC through email, direct mailings, web links, or direct contact as appropriate.

San Bernard Watershed Protection Plan Appendices

APPENDIX A – SELECT MODEL ASSUMPTIONS

A summary of the assumptions used in the application of the SELECT model in the San Bernard Watershed is presented next. Assumptions were reviewed with stakeholders for input and suggestions. These assumptions include:

- Effluent concentrations from WWTFs were assumed to be 126 cfu/dL;
- Increases in WWTF effluent were considered proportional to households (HH) growth in urban areas;
- Non-regulated (installed prior to 1989) and regulated OSSFs systems presented a failure rate of 50 percent and 12 percent respectively (Reed, Stowe, and Yanke, 2001);
- Increase in the number of OSSFs were considered proportional to households (HH) growth in rural areas;
- New households in rural areas were considered to occupy 1/2 ac per HH and were located in cultivated, hay/pasture, herbaceous, forest, wetlands, forest and wetlands in proportion (40, 30, 10, 10, and 10 percent). Livestock were located mainly in herbaceous and 90 percent of hay/pasture land cover categories and wildlife were located in forest and wetland areas (Teague, 2009);
- Densities of livestock and wildlife were considered to remain constant at benchmark values during forecast;
- A buffer zone of 100 m was delimited around streams. It was assumed that 100 percent of the loadings within the buffer and 25 percent of the loadings outside the buffer reach the streams.

TABLE 47 – BACTERIA LOADING FROM EACH SUBWATERSHED BY SOURCE

SUBW.	SUBWATERSHED	OSSFs	WWTF	Urban Runoff	Dogs	Cattle	Deer	Hogs	Horse	Sheep Goat
SW1	SW1- SB/Little San Bernard River	8%	0%	11%	2%	23%	28%	16%	17%	11%
SW2	SW2- SB/East Bernard Creek	8%	8%	12%	8%	21%	18%	13%	24%	18%
SW3	SW3- Middle Bernard Creek	2%	0%	6%	1%	10%	7%	8%	5%	5%
SW4	SW4- West Bernard Creek	8%	2%	19%	12%	15%	11%	18%	10%	20%
SW5	SW5- SB/Snake Creek	16%	21%	15%	11%	7%	9%	15%	13%	8%
SW6	SW6- Peach Creek	5%	0%	8%	7%	6%	5%	5%	4%	8%
SW7	SW7- SB/Cedar Creek	9%	9%	7%	9%	6%	7%	10%	8%	8%
SW8	SW8- Mound Creek	5%	0%	3%	2%	3%	3%	4%	6%	5%
SW9	SW9- SB/Upper Tidal	34%	60%	18%	45%	6%	11%	9%	13%	16%
SW10	SW10- SB/Lower Tidal	4%	0%	2%	4%	1%	1%	1%	1%	1%

TABLE 48 – BACTERIA LOADINGS BY SOURCE IN EACH SUBWATERSHED

SUBW.	SUBWATERSHED	OSSFs	WWTF	Urban Runoff	Dogs	Cattle	Deer	Hogs	Horses	Sheep & Goat
SW1	SW1- SB/Little San Bernard River	2%	0%	6%	2%	72%	1%	14 %	0%	4%
SW2	SW2- SB/East Bernard Creek	2%	0%	7%	8%	65%	1%	11 %	0%	6%
SW3	SW3- Middle Bernard Creek	1%	0%	7%	1%	69%	1%	17 %	0%	4%
SW4	SW4- West Bernard Creek	2%	0%	11%	13%	49%	0%	17 %	0%	7%
SW5	SW5- SB/Snake Creek	5%	0%	13%	18%	36%	1%	22 %	0%	5%
SW6	SW6- Peach Creek	3%	0%	11%	19%	47%	1%	12 %	0%	7%
SW7	SW7- SB/Cedar Creek	4%	0%	9%	20%	41%	1%	19 %	0%	6%
SW8	SW8- Mound Creek	6%	0%	8%	8%	50%	1%	18 %	0%	9%
SW9	SW9- SB/Upper Tidal	7%	0%	10%	47%	20%	0%	8%	0%	6%
SW1 0	SW10- SB/Lower Tidal	9%	0%	10%	44%	21%	0%	11 %	0%	5%

FORECAST OF SOURCES BASED ON 2006 LAND COVER TYPE DATA

The loadings associated with each land cover type have been projected out to the year 2040 in five year increments based on the projected household population growth in the five counties. Household forecasts were obtained from the Forecast Group at H-GAC. This data was for urban and rural areas in five year increments over the period of 30 years. This information was used to project additional households in the subwatershed which were associated with additional impervious surfaces, OSSFs, and pets.

TABLE 49 - RELATIVE CONTRIBUTION BY SOURCE AND YEAR

ALL CATEGORIES- Percent distribution							
SOURCES	2011	2015	2020	2025	2030	2035	2040
OSSFs	34.93%	30.91%	32.35%	36.48%	40.03%	43.89%	46.84%
WWTPs	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Urban Runoff	2.29%	2.40%	2.29%	2.08%	1.87%	1.66%	1.49%
Dogs	14.41%	16.16%	17.39%	18.19%	19.55%	20.79%	21.79%
Livestock	43.46%	45.40%	43.09%	38.84%	34.60%	30.19%	26.79%
Feral Hogs and Wildlife	4.91%	5.13%	4.88%	4.41%	3.95%	3.46%	3.09%
TOTAL	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%

The results of the forecast model show that cattle will continue to be a high potential source of bacteria in the watershed, and OSSFs will continue to become a highest potential source of bacteria as the population grows. As agricultural areas are developed, loadings from livestock and wildlife will be reduced as loadings from pets rise with the number of households.

TABLE 50 - BACTERIA LOADING BY SOURCE AND SUBWATERSHED

NLDC 2006 EC LOADING (CFU/day)

SUB W.	SUBWATERSHED	OSSFs	WWTF	Urban Runoff	Dogs	Cattle	Horses	Sheep & Goat	Feral Hogs	Deer	Geese
SW1	SW1- SB/Little San Bernard River	1.1E+12	6.4E+06	1.3E+12	1.7E+12	3.9E+13	9.3E+10	2.2E+12	7.2E+12	6.0E+11	1.4E+10
SW2	SW2- SB/East Bernard Creek	1.1E+12	7.5E+08	1.5E+12	3.2E+12	3.7E+13	1.3E+11	3.6E+12	6.5E+12	4.1E+11	5.8E+10
SW3	SW3- Middle Bernard Creek	3.3E+11	0.0E+00	6.9E+11	5.2E+11	1.9E+13	3.0E+10	1.1E+12	4.3E+12	1.6E+11	6.5E+11
SW4	SW4- West Bernard Creek	1.1E+12	1.9E+08	2.3E+12	4.1E+12	2.7E+13	5.6E+10	4.1E+12	9.3E+12	2.6E+11	5.0E+12
SW5	SW5- SB/Snake Creek	2.2E+12	2.1E+09	1.8E+12	5.1E+12	1.5E+13	7.2E+10	2.1E+12	8.1E+12	2.3E+11	4.1E+11
SW6	SW6- Peach Creek	6.4E+11	0.0E+00	9.3E+11	2.3E+12	1.1E+13	2.2E+10	1.8E+12	2.7E+12	1.2E+11	0.0E+00
SW7	SW7- SB/Cedar Creek	1.3E+12	8.6E+08	9.1E+11	3.6E+12	1.1E+13	4.8E+10	1.6E+12	5.3E+12	1.5E+11	8.5E+10
SW8	SW8- Mound Creek	7.2E+11	0.0E+00	3.5E+11	1.2E+12	6.7E+12	3.6E+10	1.2E+12	2.2E+12	9.1E+10	0.0E+00
SW9	SW9- SB/Upper Tidal	4.7E+12	5.9E+09	2.3E+12	1.6E+13	1.1E+13	7.4E+10	3.3E+12	4.9E+12	2.6E+11	2.0E+10
SW10	SW10- SB/Lower Tidal	4.9E+11	0.0E+00	2.0E+11	1.4E+12	1.4E+12	7.5E+09	3.3E+11	8.0E+11	2.7E+10	5.3E+11
TOTAL	TOTAL	1.4E+13	9.8E+09	1.2E+13	3.9E+13	1.8E+14	5.7E+11	2.1E+13	5.1E+13	2.3E+12	6.8E+12

MODEL CALIBRATION

Model calibration is the process where the model input parameters are adjusted until the simulated data from the model match with observed data. Model inputs and parameters (as identified in this section) related to watershed/landscape processes were adjusted to match the measured and simulated flow, sediment, and nutrients at key locations in the watershed. During the calibration process, model parameters will be adjusted within literature recommended ranges or based on site-specific considerations as appropriate. Model calibration is an iterative procedure that is achieved using a combination of best professional judgment and quantitative comparison with a subset of the measured data.

The SELECT model does not utilize a traditional calibration process. However, model parameters for both the SWAT and Tidal Prism Models were adjusted to minimize differences between measured and simulated flow and water quality trends at key locations. All model parameters will be adjusted within reasonable ranges recommended in published literature or based on site-specific considerations.

APPENDIX B – SWAT AND TIDAL PRISM WATERSHED MODELS

MODEL SETUP

The first task was to compile and review available physical, water quality and source data for the system. This evaluation included the water quality data at all eight monitoring sites, flow data from the USGS gauge in the San Bernard River watershed (USGS gage number 08117500), local meteorological data, land cover data, and topographic information. With data compiled, the next step was to set up the watershed model and the stream model, using the available topographic information.

WATERSHED DELINEATION

The watershed delineation for the San Bernard River, as outlined in the project quality assurance project plan (QAPP), was proposed to be based on the boundaries used for the SELECT modeling. However, there were several streams that were not adequately represented in the SELECT model that warranted additional refinement of the subbasins. Additionally, the SELECT subbasins were not aligned with monitoring station in the watershed. Therefore, the subbasins were re-delineated using the SWAT automatic delineation process (Table 51).

TABLE 51 - SUBWATERSHED COMPARISONS

Project Sub-watersheds	SWAT Sub-watersheds
SW1- SB/Little San Bernard River	1, 2, 6, 7
SW2- SB/East Bernard Creek	3, 4, 5, 8, 9, 10, 11
SW3- West Bernard Creek	12
SW4- Middle Bernard Creek	14, 15, 18, 19, 22
SW5- SB/Snake Creek	13, 16, 17, 20, 21, 23, 24, 26, 27, 28
SW6- Peach Creek	25, 29
SW7- SB/Cedar Creek	30, 31, 32, 35
SW8- Mound Creek	33, 34
SW9- SB/Upper Tidal	36, 37, 39
SW10- SB/Lower Tidal	38, 40

The automatic delineation requires input a Digital Elevation Model (DEM), which for the San Bernard River was based on the USGS National Elevation Dataset (NED). During the automatic delineation process, the model identifies stream segments and calculates flow direction and accumulation. Each subbasin contains only one reach and the length is determined by the subbasins boundary. The DEM used for watershed delineation is presented in Figure 50.

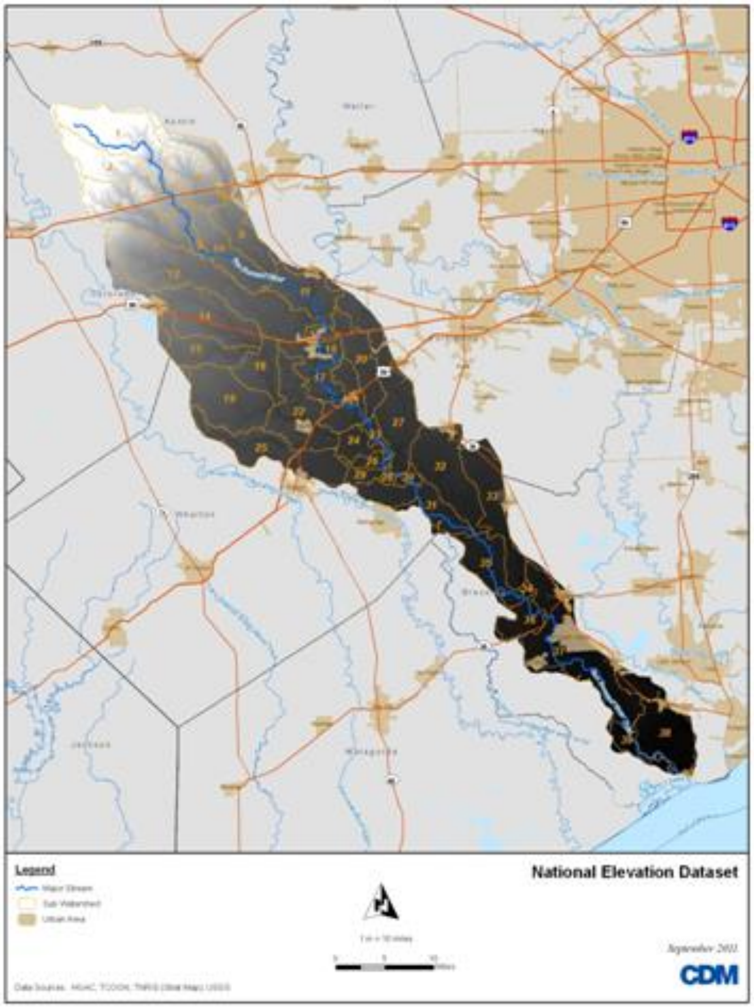


FIGURE 50 - DIGITAL ELEVATION MODEL USED FOR SUBBASIN DELINEATION

Next, subbasin outlets, inlets of draining watershed and point sources input were manually added to the model after the stream network had been created. SWAT will add an outlet to each connection of streams linking two subbasins. The user has the opportunity of altering these outlets by adding more outlets (e.g., at monitoring stations of interest), removing outlets or redefining the outlet. The last step for setting the model is the selection of watershed outlets. SWAT will have the user select the watershed outlet that drains the watershed. After all outlets, inputs and point sources have been input, SWAT will calculate the subbasin geomorphic parameters and the relative reaches for each subbasin and finishes setting up the project. SWAT calculates the length for each reach.

After delineation of the subbasins, SWAT conducts a Hydrologic Response Unit (HRU) analysis. An HRU is a portion of the watershed that contains a representative soil type, land cover classification, and slope. To derive the HRUs for each subbasin, SWAT requires inputs of land cover and soil files. Land cover data for the SWAT model was obtained from the USGS 2006 Land Cover. These land cover classifications were aligned with SWAT classifications as shown in Table 52. The land cover dataset used for HRU analysis is presented in Figure 51 and the relative areas of land covers within the model are presented in Table 53.

TABLE 52 - LAND COVER ASSIGNMENTS FOR SWAT

HGAC Class	Classification
Open Water	WATR
Developed, Low Intensity	URLD
Developed, Medium Intensity	URMD
Deciduous Forest	FRSD
Evergreen Forest	FRSE
Mixed Forest	FRST
Shrub/ Scrub	RNGB
Herbaceous	RNGE
Hay/Pasture	HAY
Cultivated Crops	AGRR
Emergent Herbaceous Wetlands	WETF
Woody Wetlands	WETN

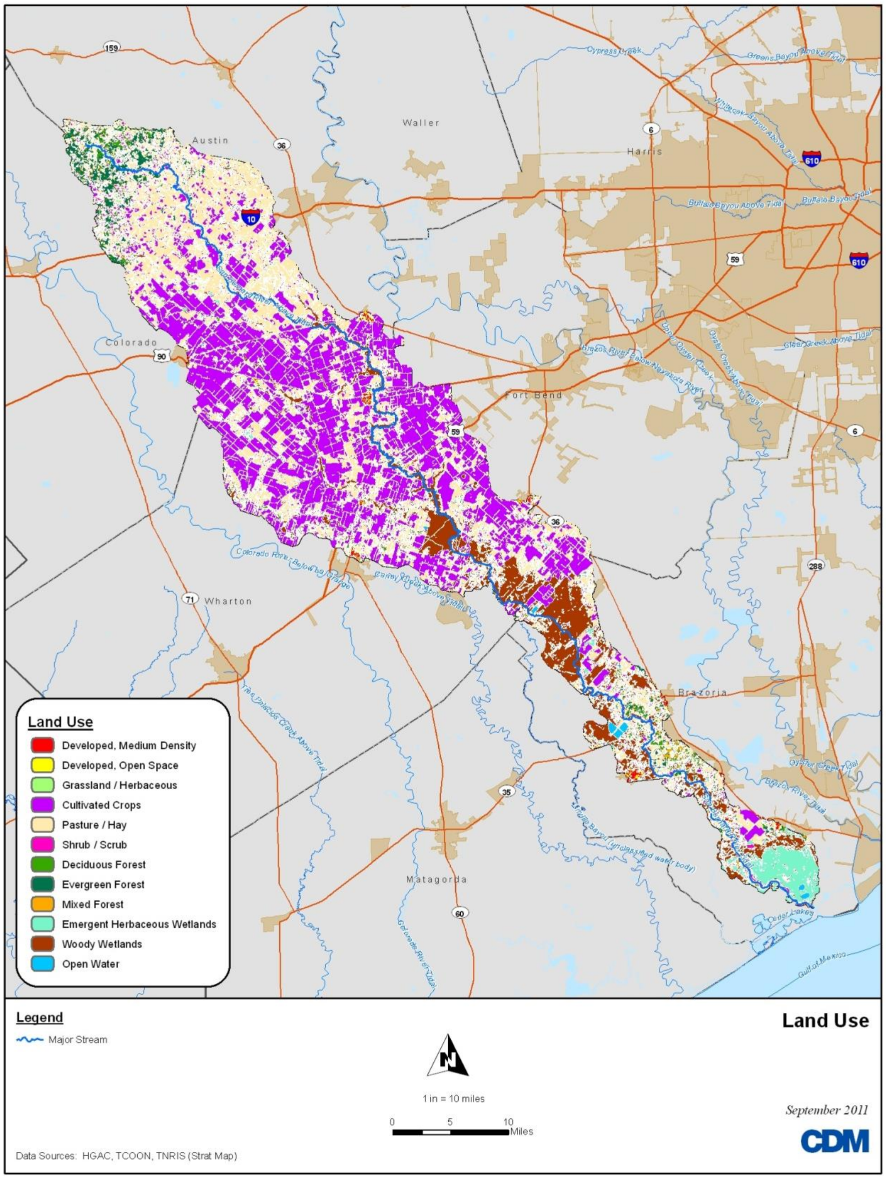


FIGURE 51 - LAND COVER IN SWAT

Soils for the HRU analysis were based on the State Soil Geographic Database (STATSGO) soils dataset available from EPA through their BASINS datasets. Soil data were classified based on the STATSGO polygon number (i.e., MUID) to link the dataset to the U.S. Soils database within SWAT and then imported in the SWAT model. The soils dataset used for HRU analysis is presented in Figure 52 and is summarized in Table 53.

TABLE 53- LAND COVER DISTRIBUTION IN SWAT

Land cover	Area (hectares)	Percentage
AGRR	87570.57	36.4%
FRSD	7172.578	3.0%
FRSE	7032.947	2.9%
FRST	24.39151	0.0%
HAY	85294.46	35.4%
RNGB	8666.688	3.6%
RNGE	28.0254	0.0%
URLD	4444.126	1.8%
URMD	89.40324	0.0%
WATR	625.8691	0.3%
WETF	33383.01	13.9%
WETN	6457.821	2.7%
Grand Total	240789.9	100.0%

TABLE 54 - SOILS INCLUDED IN THE SWAT MODEL

Soil Type	Major Soil Component	Area (hectare)	Percentage	Curve Number Range
TX031	Asa	2839.38	1%	54 - 61
TX162	Edna	1012.45	0%	74 - 78
TX163	Edna	22172.06	9%	72 - 84
TX185	Francitas	1449.66	1%	79 - 79
TX220	Harris	2820.74	1%	75 - 87
TX249	Katy	12895.77	5%	74 - 84
TX276	Lake Charles	34767.71	14%	74 - 87
TX277	Lake Charles	12256.73	5%	74 - 84
TX356	Nada	53565.36	22%	74 - 84
TX423	Pledger	38558.42	16%	72 - 87
TX539	Surfside	3609.70	1%	74 - 87
TX550	Telferner	14330.38	6%	74 - 84
TX571	Tremona	10207.62	4%	65 - 72
TX618	Wockley	30303.92	13%	65 - 80
Total		240789.8897	100%	54 - 87

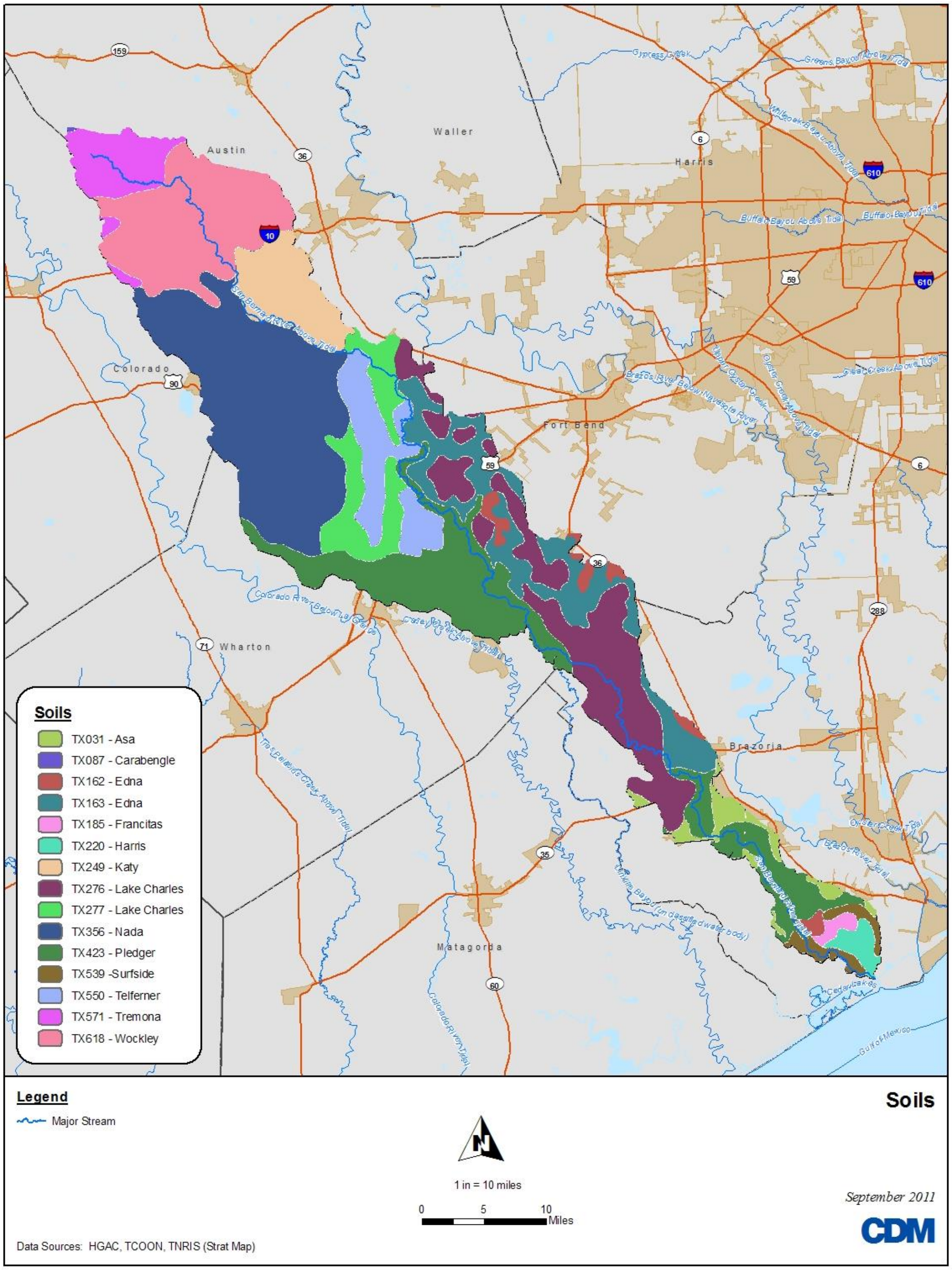


FIGURE 52 - SOILS IN SAN BERNARD RIVER WATERSHED

Finally, information on slopes was required to complete the HRU analysis. Slope characterization was based on the NED data used for the watershed delineation earlier in the model set-up process. The San Bernard Watershed was considered to be relatively flat. The slopes were defined with two classes. The first class ranged from 0 to 1 percent and the second class ranged greater than 1 percent.

To define an individual HRU, SWAT requires that thresholds be established for each data type. For example, a threshold of 25 percent for land cover would mean that any land cover within the watershed having less than 5 percent total area would not be included as one of the key land cover types within that HRU. The threshold for the land cover was set to 5 percent over the subbasin area. The soil threshold was set to 25 percent and the slope threshold was set to 20 percent. After the thresholds were established, the model calculated the appropriate HRUs for each subbasin and populated the model files with default values.

Weather Data

The SWAT model requires several key pieces of weather data including precipitation, temperature, as well as humidity, wind speed and direction. Weather data for the simulation was collected from five weather stations in and around the San Bernard Watershed: Brenham, Bellville, Wharton, Wharton Airport, and Freeport. Specific information on each type of weather data is provided in more detail subsequently.

Although precipitation data were collected from the five stations noted previously, three stations (Bellville, Wharton, and Freeport) are located closest to the watershed. Therefore, data from these three stations were used preferentially to generate most of the precipitation input for SWAT. If there were gaps in the data during the simulation period, the other two stations were used to complete these gaps. During the review of the weather data, one key discrepancy was noted for the precipitation data collected for Wharton County. One value noted on July 27, 2008 was noted to have a total of 13.98 inches of rainfall occurring but it could not be verified with other data sources such as NOAA, nearby weather stations. As such, it was removed from the rainfall dataset. A graph of the precipitation data is shown in Figure 54; a map of the subbasins assigned to each gage is presented in Figure 55.

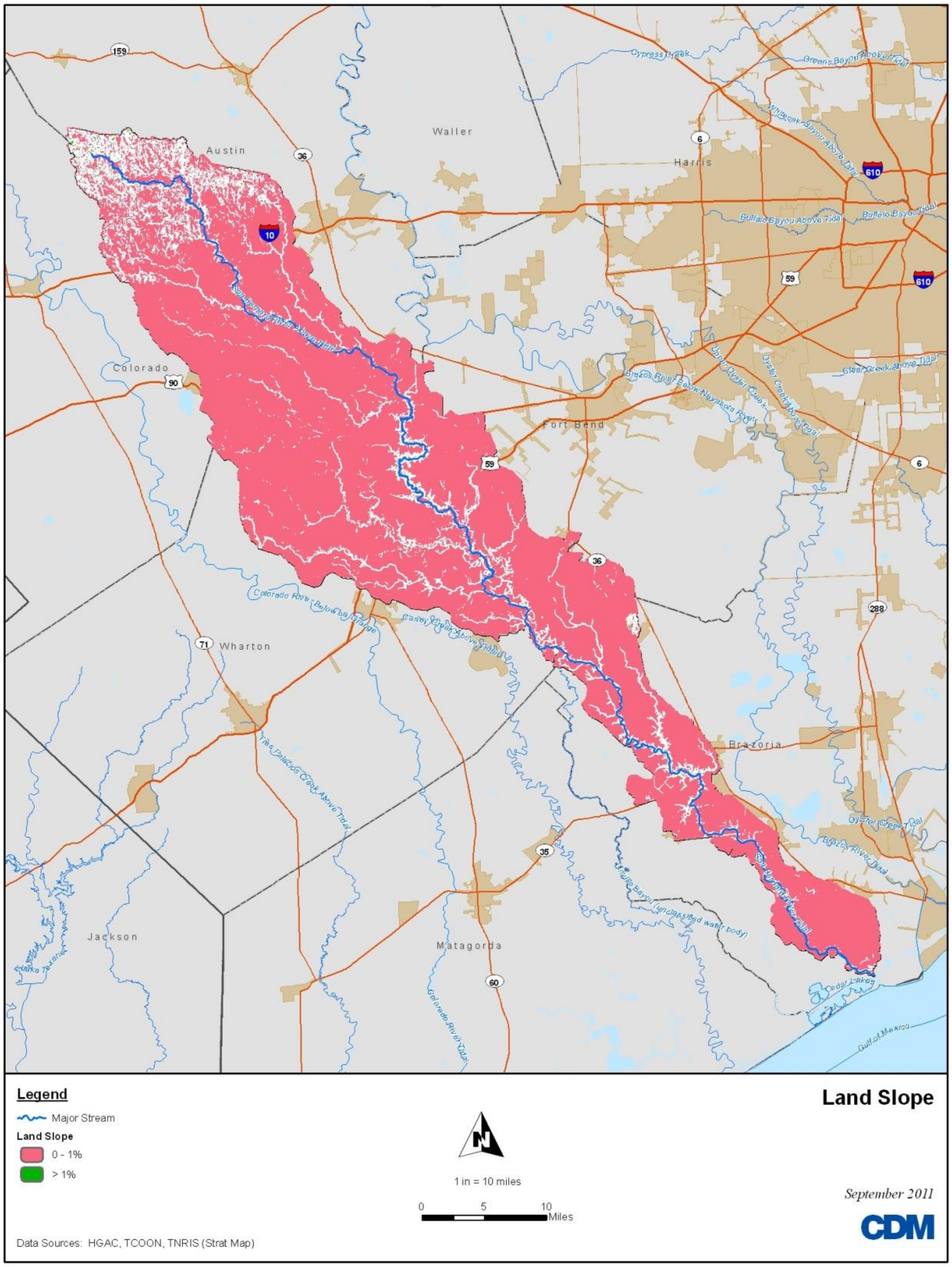


FIGURE 53 - SLOPES IN THE SAN BERNARD WATERSHED

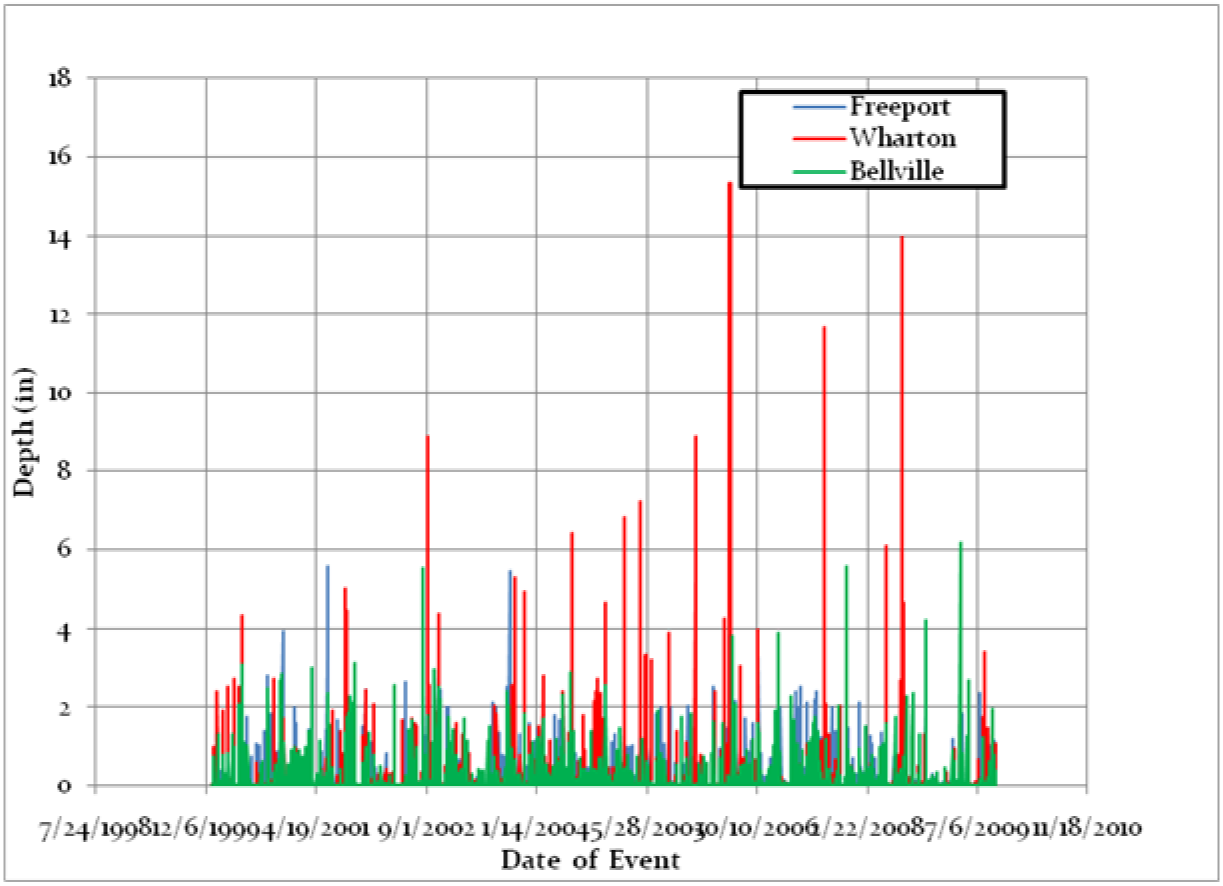


FIGURE 54 - PRECIPITATION FOR 3 RAINFALL GAGES IN SWAT

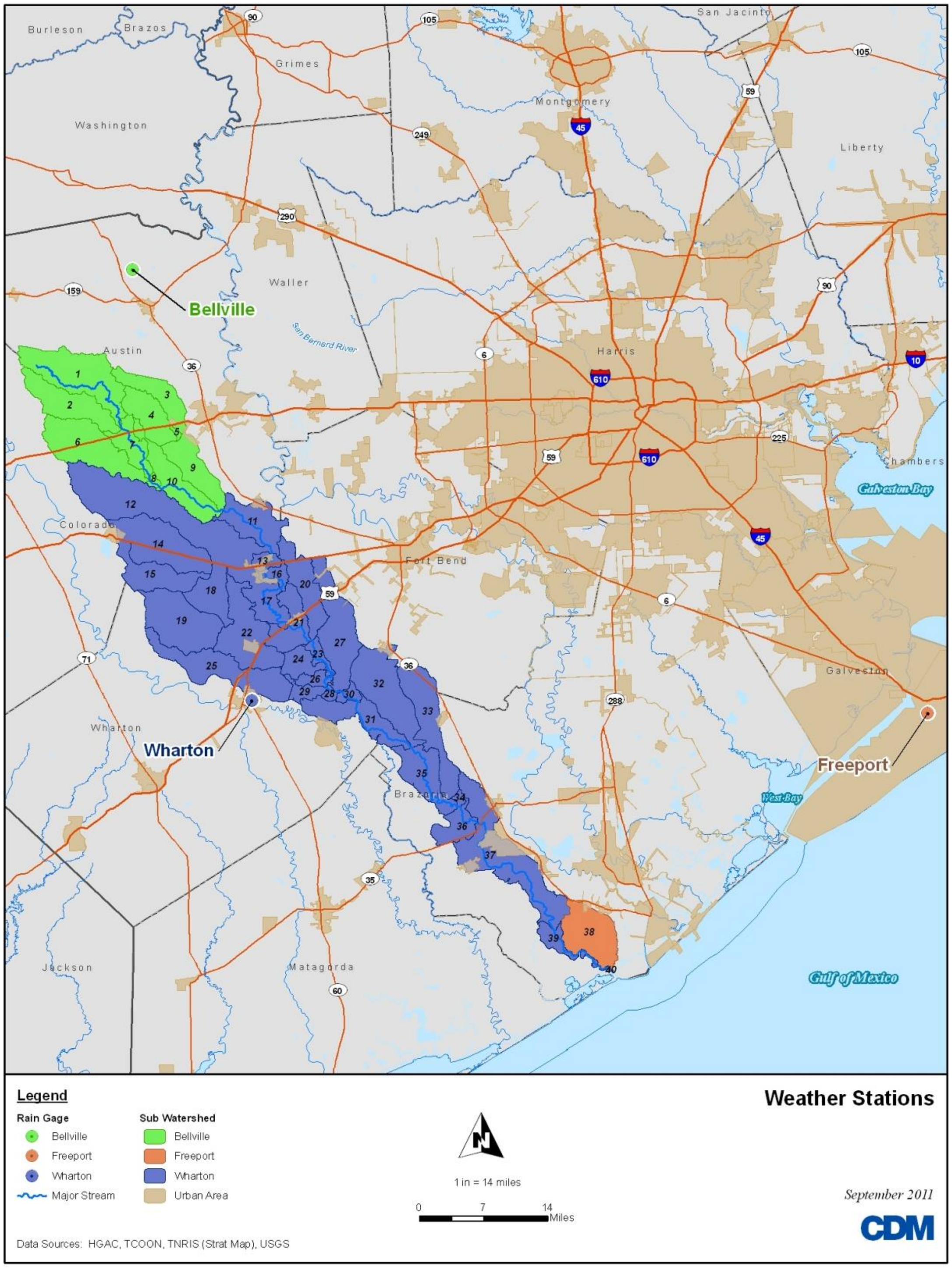


FIGURE 55 - PRECIPITATION GAGES ASSIGNED BY BASIN IN SWAT

The temperature data were collected from the Freeport, Brenham, and the Wharton airport stations. For the model the temperature stations were set up in Freeport and Wharton. The only gage that had relative humidity and wind data for the entire period of modeling was the station located in Wharton.

SWAT has the ability to calculate a few of weather parameters such as solar radiation and evapotranspiration. Some of the chosen gages did not contain any information on solar radiation and evapotranspiration and the gages that did had data for the parameters had very little data. Therefore, the SWAT model was used to generate both of these parameters. The Penham-Monteith Equation was used to calculate evapotranspiration. Plots of both the SWAT-generated solar radiation and evapotranspiration are presented in Figure 56 and 57.

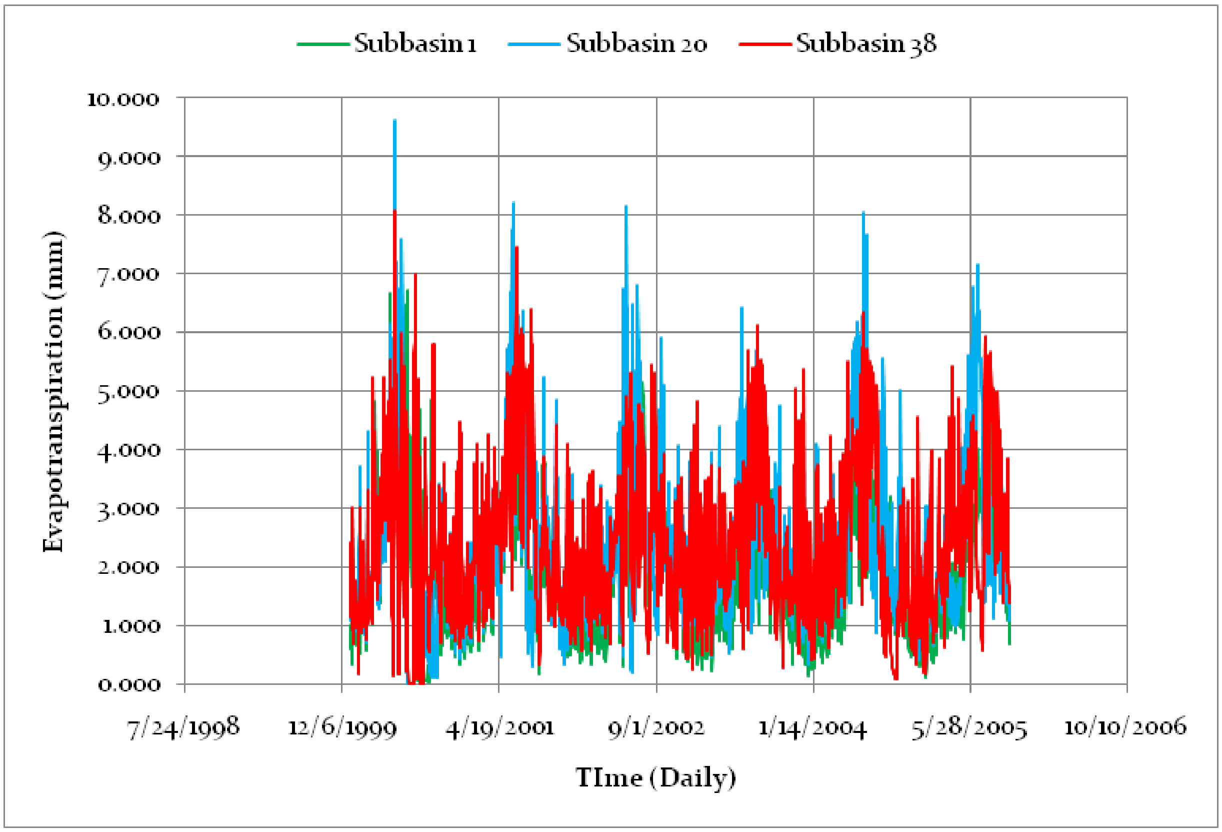


FIGURE 56 - EVAPOTRANSPIRATION GENERATED BY SWAT

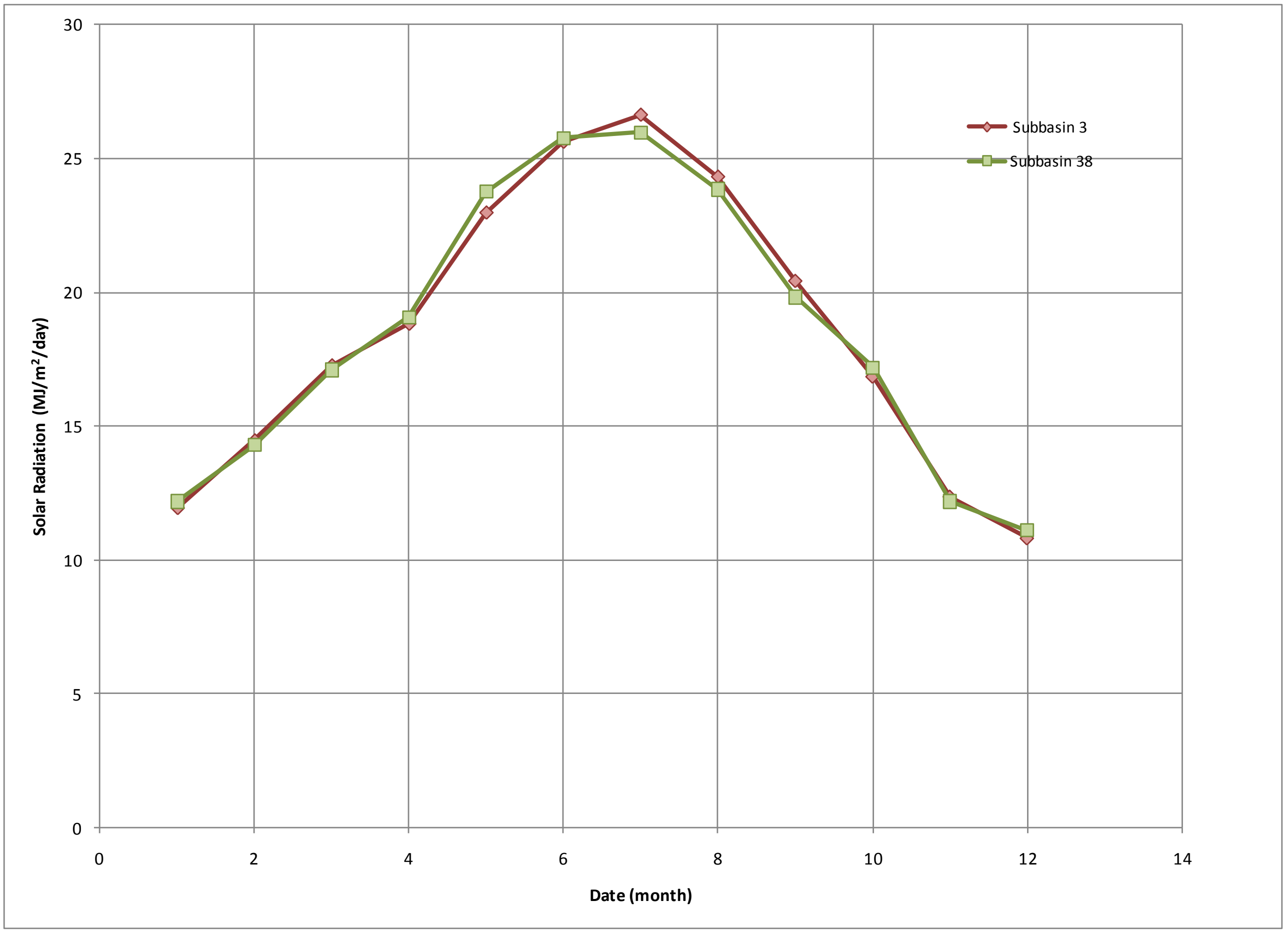


FIGURE 57 - SOLAR RADIATION GENERATED BY SWAT

Hydrology Set-up and Calibration Approach

Upon set-up, the SWAT model is populated with default values based upon the information provided in the soils, DEM, land cover and slope data sets. The hydrologic balance of SWAT is largely based on several "reservoirs" of water including precipitation, infiltration, surface runoff, lateral flow, evapotranspiration, percolation and transmission losses that are simulated in four control volumes: surface runoff, soil profile or root zone, shallow aquifer and deep aquifer (Neitsch, S.L., Arnold, J.G., Kiniry, J.R.., Srinivasan, R, and Williams, J.R., 2010).

For the purposes of the San Bernard watershed, the model was set up to simulate daily flows based on the Curve Number method. These daily flows were compared to the USGS gage at USGS ID 08117500 (San Bernard River near Boling, Texas) which reports flow from 1954 to now. The Lower Colorado River Authority also maintains a gage in the upper portion of the San Bernard River. This gage was not used in the calibration process because the data quality could not be verified.

There were several sensitive parameters within the hydrology portion of the model. One of the key sensitive parameters in the model was the Curve Number. The curve numbers were established in SWAT based on the soil type and land cover specified for each hydrologic unit. The curve numbers were calibrated within a range of +/- 5 to achieve the best fit for the flow simulation as will be discussed subsequently. A table of curve numbers used in the model is presented in Table 55.

TABLE 55 - CURVE NUMBERS ESTABLISHED BY SUBBASIN

Subbasin	Initial Curve Number		Subbasin	Initial Curve Number	
	Minimum	Maximum		Minimum	Maximum
1	65	72	21	74	84
2	65	72	22	74	84
3	67	84	23	74	84
4	67	84	24	74	84
5	74	84	25	74	84
6	65	84	26	78	84
7	67	84	27	74	84
8	74	84	28	74	84
9	74	84	29	74	84
10	74	84	30	74	84
11	74	84	31	74	84
12	74	84	32	74	84
13	74	84	33	74	84
14	74	84	34	72	84
15	74	84	35	74	84
16	74	84	36	74	87
17	74	84	37	54	78
18	74	84	38	54	79
19	74	84	39	74	87

Other key parameters that were found to be sensitive in the model were the following:

- SURLAG, which is surface runoff lag coefficient, was set to 2.0. This value is treated as a calibration parameter; larger values of SURLAG will result in surface runoff being generated more quickly from the watershed and in greater amounts;

- ESCO, which is the soil evaporation compensation factor, was set to 0.25. This is the maximum value for ESCO. As the value for ESCO increases, the model extracts less evaporative demand from lower soil levels.

- EPCO, which is the plant uptake compensation factor, was set to 0.0 which is the minimum value for EPCO. As EPCO approaches 0, the model allows less water update demand to be met by lower layers of the soil.

- ALPHA_BF, which is the baseflow alpha factor, was set to 0.9. ALPHA_BF is a key factor in controlling the baseflow recession in SWAT.

The above parameters were treated as calibration coefficients in the model and adjusted to achieve the best fit with the model output to the observed data from the USGS gage as will be described in the next section.

Hydrology Model Performance

A calibration period of up to two years was selected as per the project QAPP, with representative weather conditions that contain a reasonable amount of monitoring data. Additionally, the simulation period excludes the first year of the SWAT simulation to allow the model hydrologic “reservoirs” time to “spin-up” and come to equilibrium. Therefore, the simulation period use for the SWAT model was from January 1, 2001 through December 31, 2005. The first year of the SWAT simulation was not included in the calibration period to allow the model adequate “spin-up” time, which is standard practice for SWAT and other hydrologic modeling approaches. A validation period was also selected to assess how well the model was performing on data that were not used to calibrate the model. The validation period was January 1, 2005 through September 30, 2009.

Model performance was evaluated on the basis of several criteria including:

- Annual and seasonal flow volume comparisons;
- Cumulative frequency distributions of observed and simulated flows; and
- Time series plots of observed and simulated flows.

The results from the modeling are presented in Table 56 for the calibration period. As can be seen from the table, the model performance can be considered “good” and the hydrology validation “very good” based upon typical calibration guidelines (Donigian et al., 2002).

TABLE 56 - HYDROLOGY PERFORMANCE TABLE (VOLUMES IN CUBIC METERS)

Data Source	Simulation Period	Total Volume	90th Percentile	10th Percentile	30th Percentile	Summer Volume
Observed	Calibration Period	2.78E+09	3.17E+09	1.10E+07	7.77E+07	6.31E+08
	Validation Period	1.50E+09	3.57E+06	3.21E+04	1.07E+05	4.73E+08
Modeled	Calibration Period	3.32E+09	3.89E+09	2.53E+06	6.48E+07	5.04E+08
	Validation Period[2]	1.56E+09	2.39E+06	3.94E+04	1.25E+05	7.62E+08
Relative Error[1]	Calibration Period	15%	22%	-82%	-21%	-22%
	Validation Period	2%	-35%	9%	12%	59%

Note:

1. Relative Error computed as the difference between observed volume minus modeled volume divided by the observed volume.
2. The time period between June 6, 2006 and June 20, 2006 was excluded from the validation period. This event showed large amounts of rainfall on several gages; the USGS gage in the watershed however did not show a response. This resulted in a very poorly simulation for that period which skewed validation results by 70%.

Model performance was also evaluated using time series and cumulative frequency distribution plots. Figure 58 presents a time series of flows for a portion of the calibration period while Figure 59 presents the entire calibration period for comparison. As can be seen from the time series, there are some days where the modeled flows exceed the observed flows and there are other days where the model is less than the observed value.

Figure 60 presents a comparison of the observed and modeled frequency distribution curves for both the calibration and validation time periods. As can be observed from the charts, the flows match quite well throughout the entire range of potential flow values.

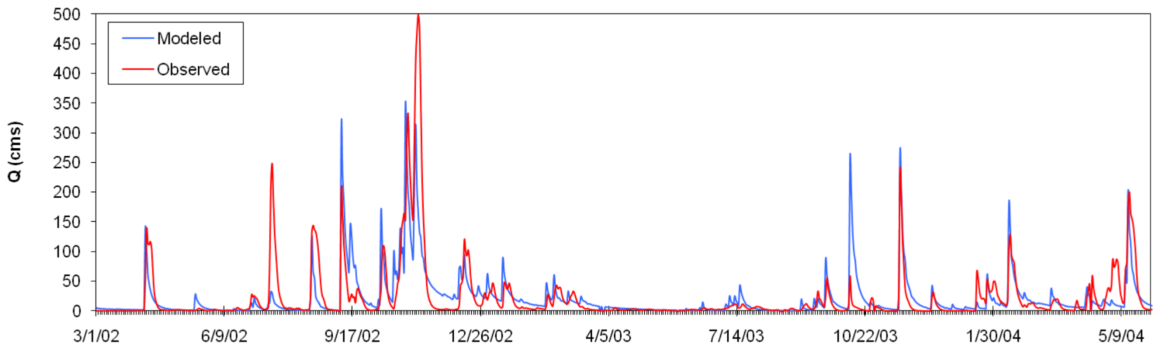


FIGURE 58 – SWAT FLOW TIME SERIES FOR PORTION OF CALIBRATION PERIOD

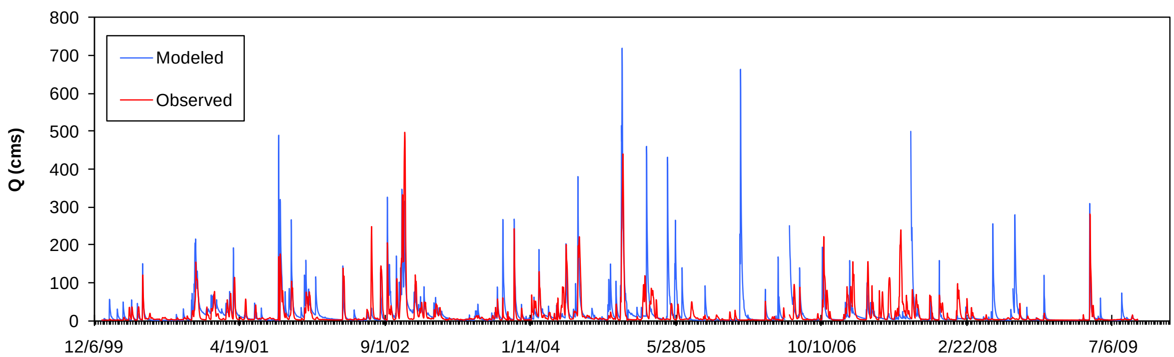


FIGURE 59 – SWAT FLOW TIME SERIES FOR ENTIRE SIMULATION PERIOD

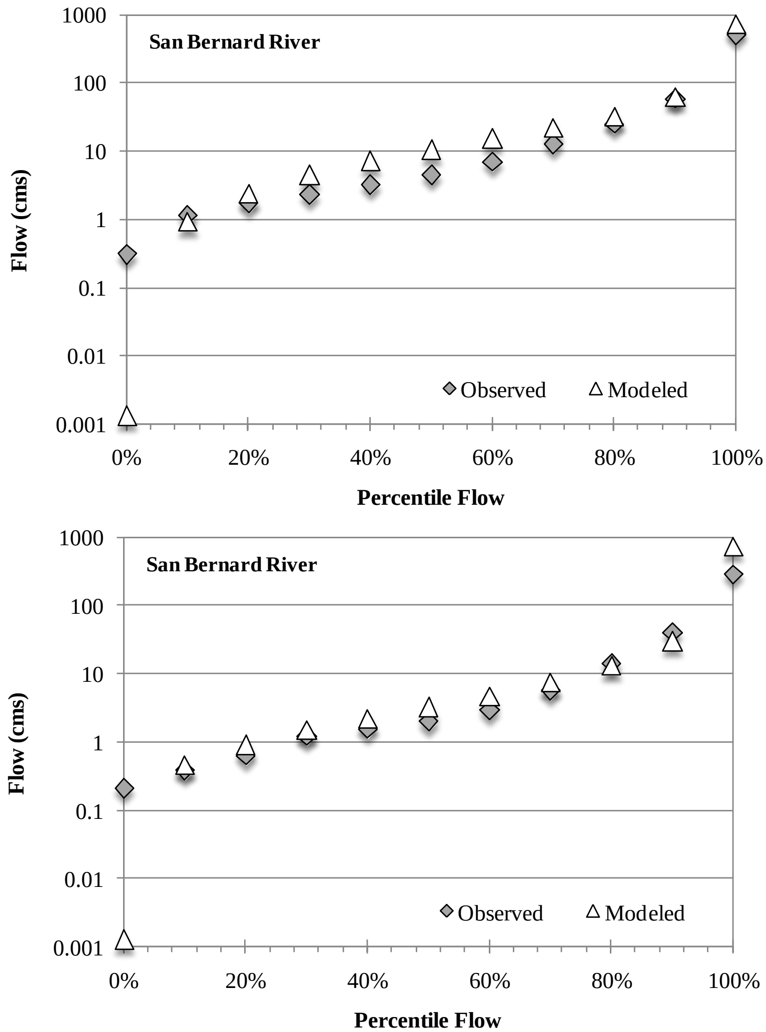


FIGURE 60 – SWAT FLOW FREQUENCY CURVE FOR CALIBRATION AND VALIDATION PERIODS

BACTERIA SET-UP, CALIBRATION APPROACH AND MODEL PERFORMANCE

The bacteria set-up process for SWAT focused on characterizing the bacteria sources for the San Bernard watershed and adjusting the parameters describing these sources within appropriate ranges to match the observed bacteria data.

The bacteria sub-model for SWAT was developed in 2002 by Sadeghi and Arnold. As noted in Coffey et al. (2010), it has been tested on a watershed in Missouri and Kansas. Other recent applications are noted in Miami (Sakura-Lemessy, 2009). The bacteria sub-model in SWAT can simulate both nonpersistent bacteria and persistent bacteria; this application only examined persistent bacteria. The model simulates bacteria transport associated with sediment, surface runoff, and riverine flows. Additionally, the model simulates bacteria associated with foliage as well as in soil water. The literature suggests there is a dearth of information regarding bacteria sorption/attachment to sediment and when that attachment occurs (per Coffey et al., 2010 Chin et al., 2009;). The key parameters for the bacteria calibration are described in this section further:

- Manure loading: One of the key components simulated in the SWAT model is manure loading on the land surface from grazing livestock and continuous deposition for livestock. For livestock grazing, the dry weight of manure deposited daily (MANURE_KG) was specified for each HRU associated with Hay and Range land covers. Continuous deposition of fertilizer (i.e., manure) and bacteria associated with the manure (BACTPDB)) and continuous deposition by wildlife. This was specified using a range of values and the wildlife/livestock/domestic pet estimates based on information from the National Agricultural Census and other sources in the watershed. In some cases, the amount of manure loading was adjusted outside these ranges in order to calibrate the model. These "unknown" sources were assigned to the manure loading category based on knowledge that livestock and wildlife estimates in the watershed were based on county-wide data and may not have captured the true number of animals within the San Bernard River basin. Therefore, in order to calibrate the model, the watershed loading from the animals was adjusted to best represent long-term geometric mean concentrations in the watershed.

- Bacteria die-off coefficients: As noted previously, SWAT can simulate bacteria on foliage, soil, associated with sediment and in-streams. Die-off coefficients are specified for all of these conditions in the model. For the San Bernard River modeling effort, die-off coefficients for bacteria were set as follows: on foliage (WDPF) set to 0.04 per day; in soil solution (WDPQ) set to 0.4 per day, adsorbed to soil particles (WDPS) set to 0.04 per day, and in-stream associated with moving water (WDPRCH) set to 0.3 per day. These values are within the typical range reported for these parameters in the SWAT modeling literature.

- Bacteria soil partitioning coefficient (BACTKDQ): This value is the ratio of the bacteria concentration in the surface 10 mm of soil water to the concentration of bacteria in surface runoff. Higher values result in lower concentrations of bacteria in the surface runoff. The value for the San Bernard watershed was set to 175; this default value has been found to be appropriate in several other SWAT modeling applications.

- Bacteria percolation coefficient (BACTMIX): The bacteria percolation coefficient is the ratio of bacteria concentrations in the top 10 mm of soil to the concentration of bacteria in the percolate. The model default value is 10.0 and the value can range from 7.0 to 20.0. The value for the San Bernard watershed was set to 10.0 based on other studies that have applied the default value.

The above parameters were treated as calibration coefficients in the model and adjusted to achieve the best fit with the model output to the observed data from the Clean Rivers Program and TCEQ monitoring stations within the watershed, with the focus on long-term geometric mean concentrations at each station.

Receiving Water Model

To simulate bacteria in the tidal portion of the watershed, a time-variable tidal prism model was developed in Microsoft Excel for the same simulation period as the SWAT model, January 1, 2007 through September 1, 2009. The tidal prism model was developed to simulate in-stream loading in the tidal portion of the San Bernard River by taking into account the volume of water that is carried upstream by the tidal fluctuations. Also included in the tidal model are runoff inputs from the SWAT model, WWTF discharges, and SSO discharges.

The model segmentation in the tidal prism model was based on 2-mile long sections along the length of the tidal portion of the river, for a total of 16 segments. The model segmentation is presented in Figure 61.

Model Set-Up – Hydraulics

The change in volume associated with change in water level as a result of tidal fluctuations is a critical component that must be accounted for in the tidal prism model. Because cross-section data were not available in the lower portion of the San Bernard River, volume estimates were generated based on simple trapezoidal cross-sections. The top-width of the cross-sections were established based on measurements taken from Google Earth elevation data. These cross-sections, while not detailed, provide the best available data upon which to base the volume calculations. The San Bernard River is divided into a tidal and non-tidal portion by a salt water barrier dam. The Tidal Prism Model was used to determine tidal fluctuations in the tidal part of the watershed.

To define the volumes, the first step was to define a tidal boundary condition. For the San Bernard River model, the tidal boundary was developed using tide data from the Texas Coastal Ocean Observation Network from the United States Coast Guard Station at Freeport near Surfside Beach which is shown on Figure 62. Tide data at this station were collected from September 2006 through the present. Although this tide gauge is located 10 miles northeast of the project boundary, it is the closest tide gage to the watershed and was used as the basis for the tide boundary. Values range from 24.9 ft. to 35.1 ft., but there is no datum associated with that monitoring station. The average value of the tide measurements for this station was assumed to be mean sea level, and values were adjusted to match accordingly; adjusted values range from -3.9 ft. to 6.4 ft. After water levels were determined, they were used in conjunction with the cross-sectional area, estimated invert elevations from the Google Earth and length of the segment to calculate the volume at various locations throughout the tidal portion of the San Bernard River.

The tidal prism model also received flow inputs for WWTF discharges, SSO discharges, upstream boundary condition from SWAT, and watershed runoff from the SWAT model. These inputs were included as point sources to each segment of the tidal prism model where appropriate. For the SWAT model, WWTF discharges were based on monthly flows reported in CFS while SSO discharges were based on reported flows for SSOs provided by H-GAC.

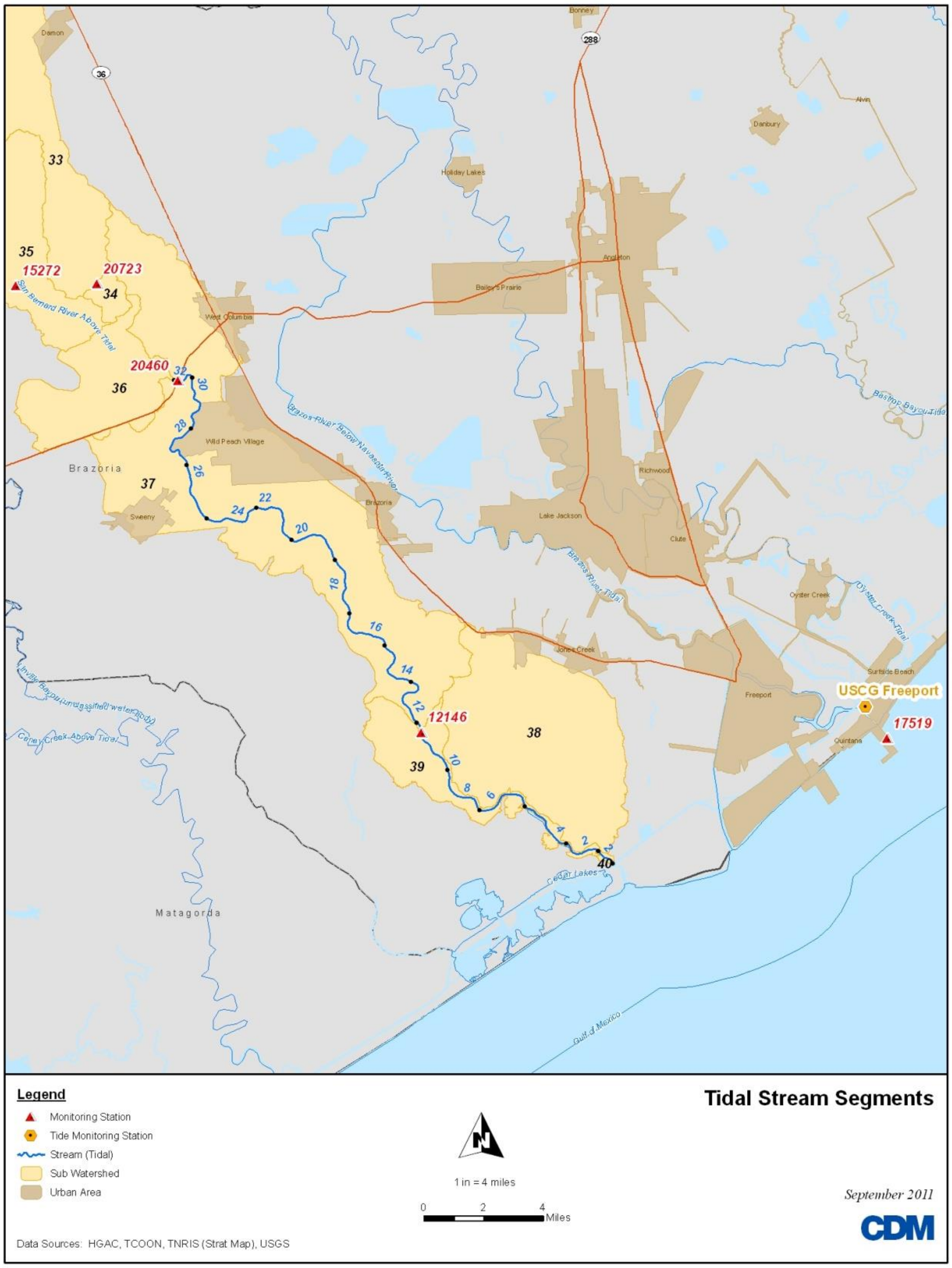


FIGURE 61 - TIDAL PRISM SEGMENTATION

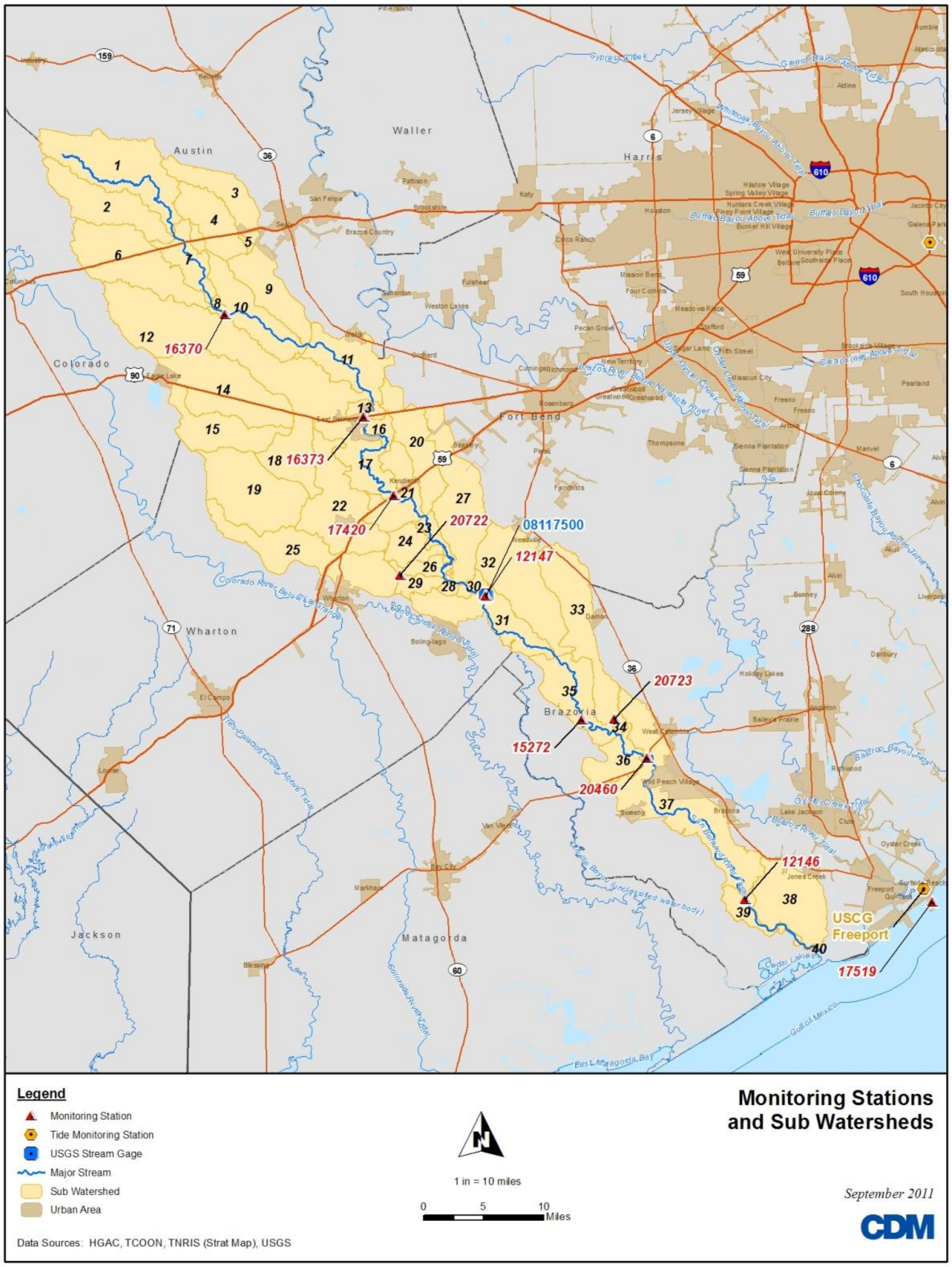


FIGURE 62 - MONITORING STATION AND TIDAL BOUNDARY LOCATIONS

Model Set-Up – Bacteria

The model includes sources of enterococci bacteria, such as WWTFs, SSOs, and SWAT inflow, as well as downstream boundary data and reductions as a result of die-off. It is important to note that the tidal prism model is set up for enterococci bacteria because that is the indicator of interest in tidal, or salt-water, rivers. The SWAT model, however, was set-up and calibrated for *E. coli*. Therefore, a conversion process was necessary to transition the *E. coli* from SWAT into enterococci for the tidal prism model. To do this, the ratio of the two geometric mean standards (126 MPN/dL for *E. coli* and 34 MPN/dL for enterococci) was used to convert *E. coli* to enterococci.

TCEQ monitoring station 17519 was used to specify the boundary condition for the tidal prism model. This station is close to the outlet of the San Bernard River, as shown in Figure 62, and generally has concentrations near the detection limit with an average concentration of 22 MPN/dL.

Additional sources of bacteria to the model included the SWAT inflows from the watershed, WWTF discharges, and SSO discharges. WWTF discharges were a value of 35 MPN/dL based on modeling completed in SELECT. The SSO discharges were assigned typical enterococci concentrations associated with SSOs (1.9x105 MPN/dL).

Calibration Strategy

Because tide elevation data were not available prior to 2007, the calibration period was selected as a different period than the SWAT model, from January 1, 2007 through December 31, 2008. The validation period was considered January 1, 2009 through September 30, 2009. Additionally, because of the limited data available to specify hydraulic parameters in the model, calibration of an observed change in water depth with respect to tidal fluctuations could not be performed. Instead, the model was tested with salinity which acts as a conservative tracer to confirm the adequacy of the model hydraulics. After the salinity calibration process, bacteria concentrations were calibrated.

A plot of the average salinity concentrations longitudinally along the watershed are presented in Figure 63. The overall average error between observed and modeled salinities was between 25 and 354 percent. Based on the salinity model runs, the model hydraulics are sufficient to simulate salinity with a satisfactory level of accuracy.

For bacteria calibration, the SWAT model watershed loadings were adjusted to better match in-stream concentrations but the primary calibration effort focused on adjusting bacteria decay rates to ultimately arrive at a value of 0.25.

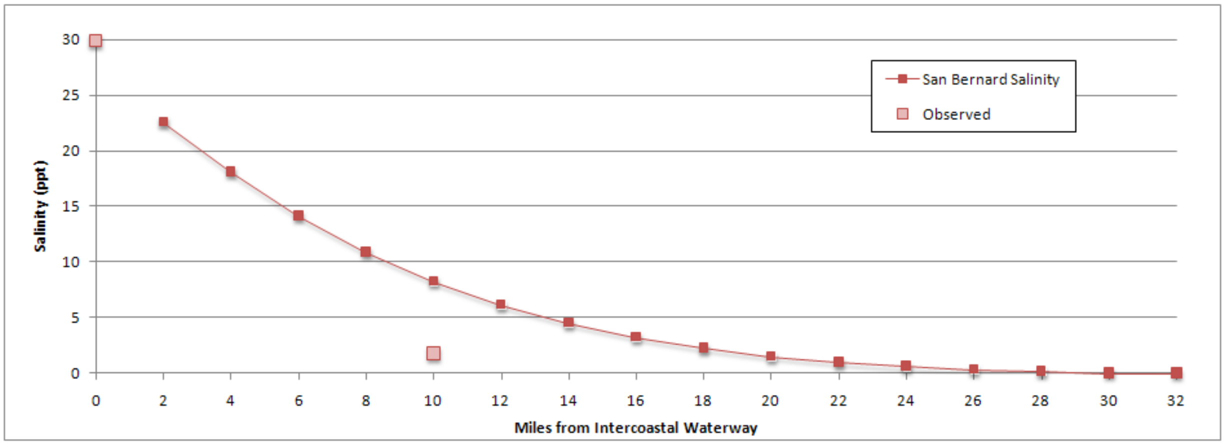


FIGURE 63 - SAN BERNARD RIVER SALINITY BY MILES FROM INTERCOASTAL WATERWAY

SWAT Model Performance

A plot of the geometric mean for the entire calibration period compared with observed data is shown in Figure 64. The minimum and maximum values presented on the plot are the minimum and maximum geometric means calculated for 2001, 2002, 2003, 2004 and 2005. This figure demonstrates that while the errors at some individual stations are fairly high, the model does capture the variability observed in the watershed and matches overall trends fairly well.

Finally, time series plots of simulated bacteria concentrations over time compared with observed data points are included in Figure 65 and 66. These figures demonstrate the wide variability on a day-to-day basis that was observed in the bacteria concentrations in the San Bernard River and its tributaries.

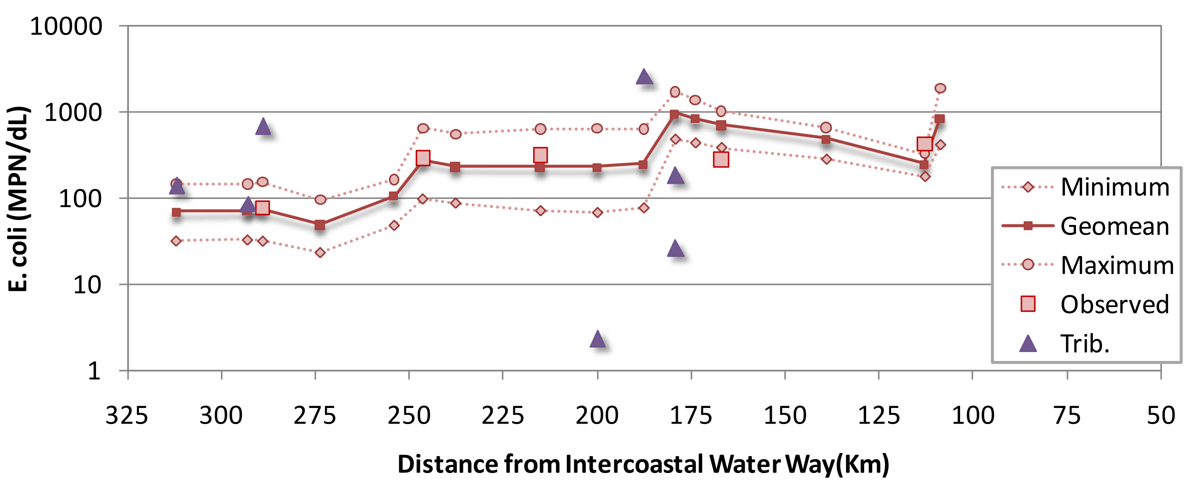
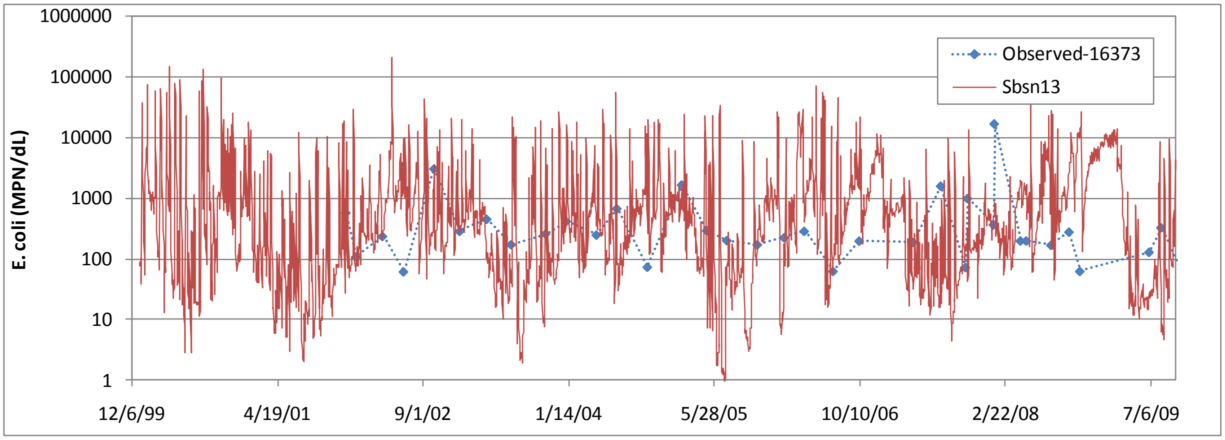
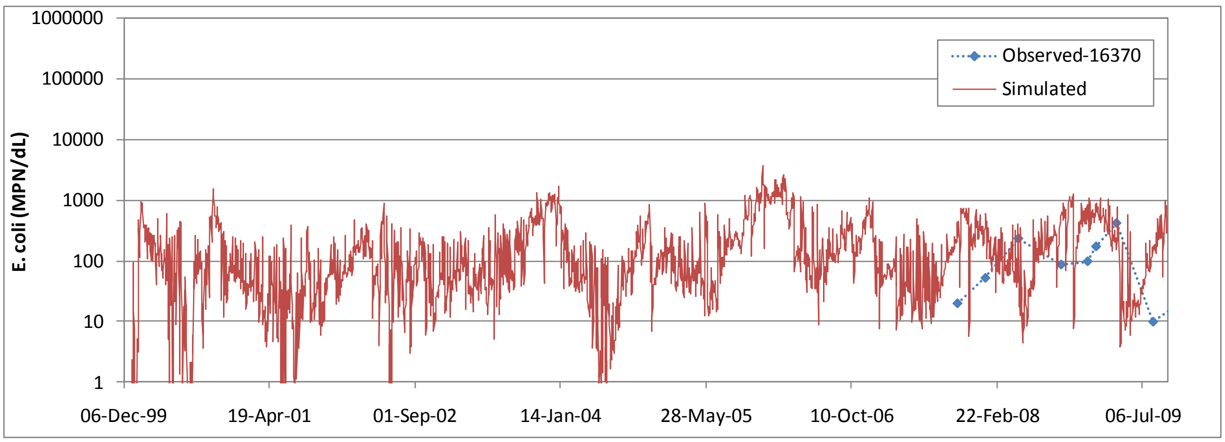
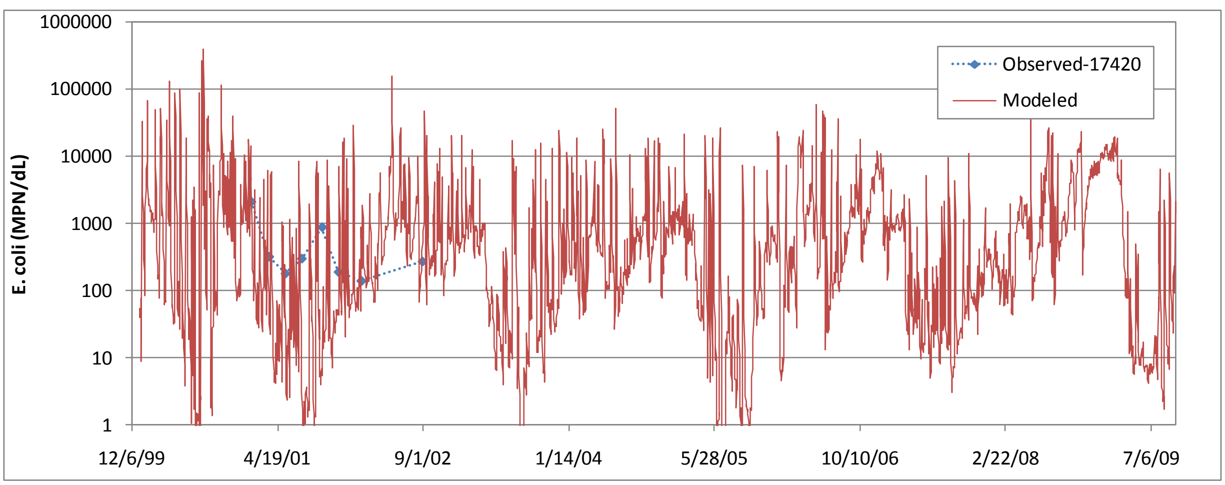


FIGURE 64 – SWAT RESULTS BY DISTANCE FROM INTERCOASTAL WATERWAY


1000000
100000
10000
1000
100
10
1
E. coli (MPN/dL)
Observed-16373
Sbsn13
12/6/99
4/19/01
9/1/02
1/14/04
5/28/05
10/10/06
2/22/08
7/6/09


1000000
100000
10000
1000
100
10
1
E. coli (MPN/dL)
Observed-16370
Simulated
06-Dec-99
19-Apr-01
01-Sep-02
14-Jan-04
28-May-05
10-Oct-06
22-Feb-08
06-Jul-09


1000000
100000
10000
1000
100
10
1
E. coli (MPN/dL)
Observed-17420
Modeled
12/6/99
4/19/01
9/1/02
1/14/04
5/28/05
10/10/06
2/22/08
7/6/09

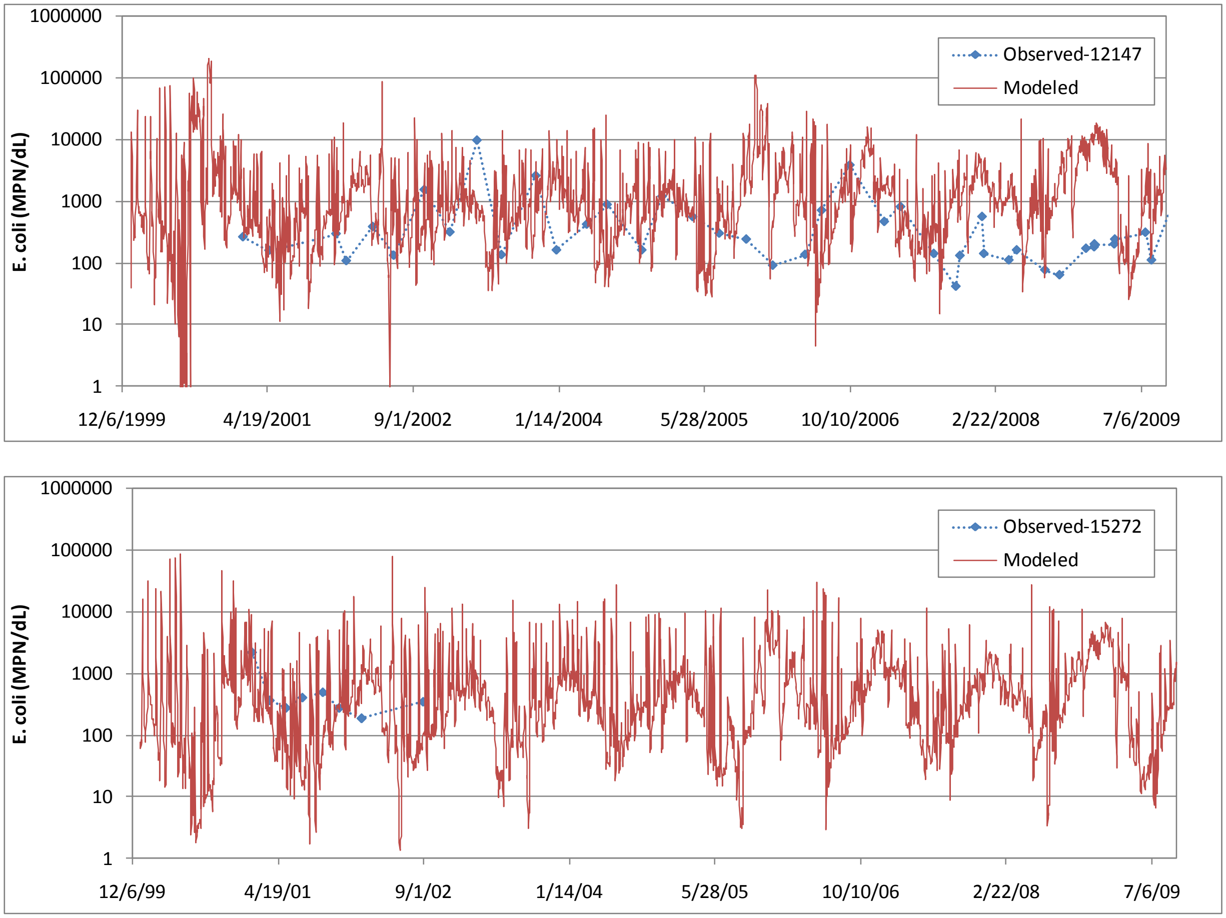


FIGURE 64 - GEOMETRIC MEAN COMPARISON IN SWAT

TABLE 57 – PERCENT OF BACTERIA LOAD REDUCTIONS REQUIRED BY SUBWATERSHED

Distance from Inter-coastal Water-way (km)	**Geometric Mean**	***Based on Overall Geometric Mean***	**Based on Overall Geometric Mean and Median Flow**			
	E. coli	Enterococci	% Reduction from *E. coli* Geomean Std	% Reduction from Enterococci Geomean Std	Load reduction from Geometric Mean Std (cfu/day)	% Reduction from Enterococci Geomean Std
312.1	87.8	-	n/a[1]	-	n/a[1]	-
293.1	90.4	-	n/a[1]	-	n/a[1]	-
289.0	93.6	-	n/a[1]	-	n/a[1]	-
273.8	62.1	-	n/a[1]	-	n/a[1]	-
254.1	122.9	-	n/a[1]	-	n/a[1]	-
246.5	332.2	-	62%	-	0.0E+00 - 2.5E+12	-
237.8	282.3	-	55%	-	0.0E+00 - 2.1E+12	-
215.1	279.0	-	55%	-	0.0E+00 - 2.5E+12	-
200.0	274.8	-	54%	-	0.0E+00 - 2.8E+12	-
187.7	272.8	-	54%	-	0.0E+00 - 1.9E+12	-
179.3	1085.0	-	88%	-	8.0E+12 - 7.3E+12	-
173.9	956.8	-	87%	-	7.5E+12 - 6.8E+12	-
167.0	818.5	-	85%	-	6.7E+12 - 6.1E+12	-
139.1	554.9	-	77%	-	4.2E+12 - 3.8E+12	-
112.9	291.8	-	57%	-	1.6E+12 - 2.1E+12	-
108.8	1246.9	-	90%	-	8.5E+12 - 2.0E+12	-
94.7	359.3	-	65%	-	2.1E+12 - 2.8E+12	-

Distance from Inter-coastal Water-way (km)	**Geometric Mean**	***Based on Overall Geometric Mean***	**Based on Overall Geometric Mean and Median Flow**			
51.5	-	19.2	-	n/a[1]	-	n/a[1]
48.3	-	15.7	-	n/a[1]	-	n/a[1]
45.1	-	12.8	-	n/a[1]	-	n/a[1]
41.8	-	10.4	-	n/a[1]	-	n/a[1]
38.6	-	8.7	-	n/a[1]	-	n/a[1]
35.4	-	7.4	-	n/a[1]	-	n/a[1]
32.2	-	6.5	-	n/a[1]	-	n/a[1]
29.0	-	5.7	-	n/a[1]	-	n/a[1]
25.7	-	5.2	-	n/a[1]	-	n/a[1]
22.5	-	4.9	-	n/a[1]	-	n/a[1]
19.3	-	4.7	-	n/a[1]	-	n/a[1]
16.1	-	4.7	-	n/a[1]	-	n/a[1]
12.9	-	5.0	-	n/a[1]	-	n/a[1]
9.7	-	5.4	-	n/a[1]	-	n/a[1]
6.4	-	5.9	-	n/a[1]	-	n/a[1]
3.2	-	13.0	-	n/a[1]	-	n/a[1]

*Sub-watersheds not showing a load reduction needed are at or below the standard.

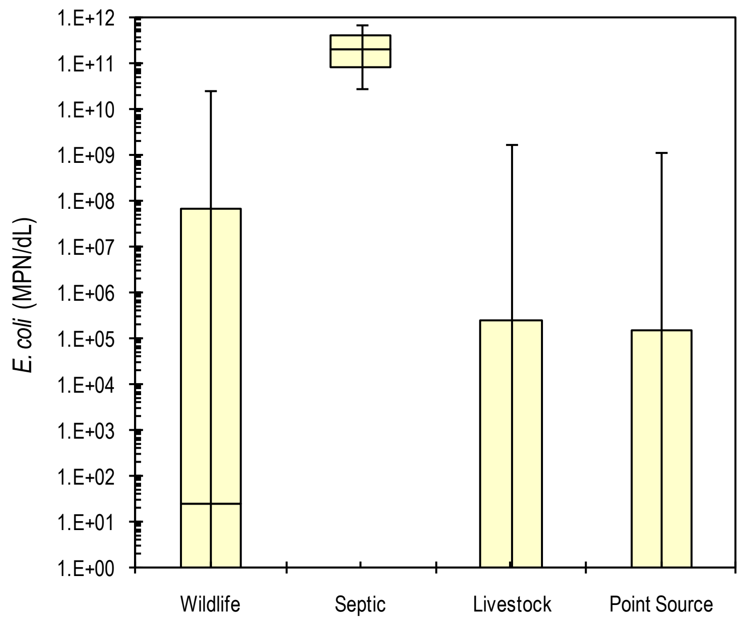


FIGURE 65 - SOURCE LOADING BOX PLOT IN SWAT

Subbasin	River KM	Average Flow (cms)	Ratio = 45		Waterway length = 5 m		Waterway length = 25 m		*E. coli* geometric means (MPN/dL) / % Reduction													
									Baseline	OSSF_SBBN36		OSSF_SBBN25		Prescribed		Feral Hog 30%		Feral Hog 50%		Feral Hog 75%	
1	312.09	1.25	9.2	-90%	78.4	-11%	57.8	-34%	87.8	87.8	0%	87.8	0%	87.7	0%	87.7	0%	87.6	0%	87.5	0%
7	293.11	2.26	9.5	-89%	80.7	-11%	59.4	-34%	90.4	90.4	0%	90.4	0%	91.1	1%	90.3	0%	90.1	0%	89.8	-1%
8	289.04	3.21	10.2	-89%	83.2	-11%	61.1	-35%	93.6	93.6	0%	93.6	0%	92.6	-1%	93.5	0%	93.2	0%	92.9	-1%
10	273.77	3.74	7.7	-88%	55.6	-11%	41.1	-34%	62.1	62.1	0%	62.1	0%	61.5	-1%	62.0	0%	61.9	0%	61.7	-1%
11	254.09	6.19	27.6	-78%	116.7	-5%	91.4	-26%	122.9	122.9	0%	122.9	0%	118.9	-3%	122.8	0%	122.6	0%	122.3	0%
13	246.50	10.23	144.2	-57%	329.9	-1%	287.9	-13%	332.3	332.3	0%	332.3	0%	322.1	-3%	332.1	0%	332.0	0%	331.7	0%
16	237.75	10.48	124.2	-56%	280.2	-1%	244.9	-13%	282.3	282.3	0%	282.3	0%	273.8	-3%	282.2	0%	282.1	0%	281.9	0%
17	215.14	11.41	135.1	-52%	277.0	-1%	245.6	-12%	279.0	279.0	0%	279.0	0%	272.7	-2%	278.9	0%	278.8	0%	278.6	0%
21	200.00	12.38	138.8	-49%	273.0	-1%	243.6	-11%	274.8	274.8	0%	274.8	0%	267.6	-3%	274.7	0%	274.6	0%	274.4	0%
23	187.65	13.77	99.5	-64%	258.5	-5%	222.5	-18%	272.8	272.8	0%	272.8	0%	264.4	-3%	272.8	0%	272.7	0%	272.5	0%
25	n/a	1.75							451.6	451.6	0%	1.3	-100%								
26	179.27	22.60	162.1	-85%	991.1	-9%	774.5	-29%	1085.0	1085.0	0%	1085.0	0%	1060.9	-2%	1083.7	0%	1082.4	0%	1081.1	0%
28	173.90	24.74	147.1	-85%	871.5	-9%	679.6	-29%	956.7	956.7	0%	636.9	-33%	939.5	-2%	956.7	0%	955.8	0%	953.3	0%
30	166.97	26.77	125.4	-85%	742.2	-9%	577.6	-29%	818.5	818.5	0%	581.0	-29%	802.7	-2%	818.5	0%	818.0	0%	816.5	0%

Subbasin	River KM	Average Flow (cms)	Ratio = 45		Waterway length = 5 m		Waterway length = 25 m		*E. coli* geometric means (MPN/dL) / % Reduction Baseline	OSSF_SBBN36		OSSF_SBBN25		Prescribed		Feral Hog 30%		Feral Hog 50%		Feral Hog 75%	
31	139.05	28.17	90.2	-84%	504.2	-9%	393.2	-29%	554.9	554.9	0%	428.7	-23%	549.4	-1%	554.9	0%	555.0	0%	554.6	0%
35	112.85	31.67	62.9	-78%	268.4	-8%	213.6	-27%	291.8	291.8	0%	267.0	-8%	289.3	-1%	291.7	0%	291.9	0%	291.8	0%
34	108.76	1.88	58.2	-95%	1037.0	-17%	733.7	-41%	1247.0	1247.0	0%	1247.0	0%	1193.5	-4%	1246.9	0%	1246.8	0%	1246.5	0%

Subbasin	River KM	Average Flow (cms)	Rough Estimate Load Reduction (MPN/year) Baseline	Ratio = 45	WW = 25m	OSSF_SBBN36	OSSF_SBBN25	Prescribed	Feral Hog 30%	Feral Hog 50%	Feral Hog 75%	Ratio = 45	Ratio = 55	WW = 5m	WW = 25m	OSSF_SBBN36	OSSF_SBBN25	Prescribed	Feral Hog 30%	Feral Hog 50%	Feral Hog 75%
1	312.09	1.25	3.46E+13	3.62E+12	2.28E+13	3.46E+13	3.46E+13	3.45E+13	3.45E+13	3.45E+13	3.45E+13	3.09E+13	3.34E+13	1.18E+13	1.18E+13	0.00E+00	0.00E+00	9.24E+09	1.98E+10	5.26E+10	1.02E+11
7	293.11	2.26	6.43E+13	6.79E+12	4.23E+13	6.43E+13	6.43E+13	6.48E+13	6.42E+13	6.41E+13	6.39E+13	5.75E+13	6.16E+13	2.20E+13	2.20E+13	0.00E+00	0.00E+00	-5.16E+11	7.86E+10	2.11E+11	4.09E+11
8	289.04	3.21	9.48E+13	1.03E+13	6.20E+13	9.48E+13	9.48E+13	9.38E+13	9.47E+13	9.45E+13	9.42E+13	8.45E+13	9.08E+13	3.29E+13	3.29E+13	0.00E+00	0.00E+00	1.03E+12	1.29E+11	3.45E+11	6.67E+11
10	273.77	3.74	7.33E+13	9.07E+12	4.86E+13	7.33E+13	7.33E+13	7.26E+13	7.32E+13	7.30E+13	7.28E+13	6.42E+13	6.95E+13	2.47E+13	2.47E+13	0.00E+00	0.00E+00	7.20E+11	9.95E+10	2.63E+11	5.08E+11
11	254.09	6.19	2.40E+14	5.39E+13	1.78E+14	2.40E+14	2.40E+14	2.32E+14	2.39E+14	2.39E+14	2.39E+14	1.86E+14	2.20E+14	6.13E+13	6.13E+13	0.00E+00	0.00E+00	7.72E+12	2.34E+11	6.09E+11	1.18E+12
13	246.50	10.23	1.07E+15	4.65E+14	9.29E+14	1.07E+15	1.07E+15	1.04E+15	1.07E+15	1.07E+15	1.07E+15	6.07E+14	9.06E+14	1.43E+14	1.43E+14	0.00E+00	0.00E+00	3.27E+13	3.62E+11	9.57E+11	1.90E+12
16	237.75	10.48	9.33E+14	4.10E+14	8.09E+14	9.33E+14	9.33E+14	9.05E+14	9.33E+14	9.32E+14	9.31E+14	5.23E+14	7.81E+14	1.24E+14	1.24E+14	0.00E+00	0.00E+00	2.84E+13	3.14E+11	8.18E+11	1.60E+12
17	215.14	11.41	1.00E+15	4.86E+14	8.84E+14	1.00E+15	1.00E+15	9.81E+14	1.00E+15	1.00E+15	1.00E+15	5.18E+14	7.58E+14	1.20E+14	1.20E+14	0.00E+00	0.00E+00	2.28E+13	2.93E+11	7.71E+11	1.52E+12

			Rough Estimate Load Reduction (MPN/year)																		
Subbasin	**River KM**	**Average Flow (cms)**	**Baseline**	**Ratio = 45**	**WW = 25m**	**OSSF_SBBN36**	**OSSF_SBBN25**	**Prescribed**	**Feral Hog 30%**	**Feral Hog 50%**	**Feral Hog 75%**	**Ratio = 45**	**Ratio = 55**	**WW = 5m**	**WW = 25m**	**OSSF_SBBN36**	**OSSF_SBBN25**	**Prescribed**	**Feral Hog 30%**	**Feral Hog 50%**	**Feral Hog 75%**
21	200.00	12.38	1.07E+15	5.42E+14	9.51E+14	1.07E+15	1.07E+15	1.04E+15	1.07E+15	1.07E+15	1.07E+15	5.31E+14	7.82E+14	1.22E+14	1.22E+14	0.00E+00	0.00E+00	2.82E+13	3.03E+11	7.94E+11	1.56E+12
23	187.65	13.77	1.18E+15	4.32E+14	9.66E+14	1.18E+15	1.18E+15	1.15E+15	1.18E+15	1.18E+15	1.18E+15	7.53E+14	6.63E+14	2.19E+14	2.19E+14	0.00E+00	0.00E+00	3.66E+13	2.65E+11	6.72E+11	1.37E+12
25	n/a	1.75	2.50E+14			2.50E+14	7.06E+11									0.00E+00	2.49E+14				
26	179.27	22.60	7.73E+15	1.16E+15	5.52E+15	7.73E+15	7.73E+15	7.56E+15	7.72E+15	7.72E+15	7.71E+15	6.58E+15	1.60E+15	2.21E+15	2.21E+15	0.00E+00	0.00E+00	1.72E+14	8.90E+12	1.84E+13	2.75E+13
28	173.90	24.74	7.46E+15	1.15E+15	5.30E+15	7.46E+15	4.97E+15	7.33E+15	7.46E+15	7.46E+15	7.44E+15	6.32E+15	1.51E+15	2.16E+15	2.16E+15	0.00E+00	2.50E+15	1.34E+14	1.17E+11	7.21E+12	2.69E+13
30	166.97	26.77	6.91E+15	1.06E+15	4.88E+15	6.91E+15	4.90E+15	6.78E+15	6.91E+15	6.90E+15	6.89E+15	5.85E+15	1.40E+15	2.03E+15	2.03E+15	0.00E+00	2.00E+15	1.33E+14	3.91E+11	4.19E+12	1.67E+13
31	139.05	28.17	4.93E+15	8.01E+14	3.49E+15	4.93E+15	3.81E+15	4.88E+15	4.93E+15	4.93E+15	4.93E+15	4.13E+15	9.94E+14	1.44E+15	1.44E+15	0.00E+00	1.12E+15	4.82E+13	-2.64E+11	-9.25E+11	2.15E+12
35	112.85	31.67	2.91E+15	6.28E+14	2.13E+15	2.91E+15	2.67E+15	2.89E+15	2.91E+15	2.92E+15	2.91E+15	2.29E+15	5.43E+14	7.80E+14	7.80E+14	0.00E+00	2.47E+14	2.41E+13	5.87E+11	-8.77E+11	-8.68E+11
34	108.76	1.88	7.38E+14	3.45E+13	4.34E+14	7.38E+14	7.38E+14	7.06E+14	7.38E+14	7.38E+14	7.38E+14	7.03E+14	4.68E+14	3.04E+14	3.04E+14	0.00E+00	0.00E+00	3.17E+13	7.34E+10	1.71E+11	3.54E+11
Min												3.09E+13		1.18E+13		0.00E+00	0.00E+00	-5.16E+11	-2.64E+11	-9.25E+11	-8.68E+11
Max												6.58E+15		2.21E+15		0.00E+00	2.50E+15	1.72E+14	8.90E+12	1.84E+13	2.75E+13

BMP Removal Efficiency

The estimated number of units to reduce for each source category is based on the average load for that representative unit. This in turn assumes that the entire load for a unit is addressed. However, many classes of BMPs may partially address loads from units. Additionally, the location of specific BMP implementation sites in the watershed may change the realized reductions. Lastly, each source category may be addressed by a number of BMPs, or a number of varying instances of BMP scaling (e.g. wet bottom detention basins of varying sizes) so the reduction efficiency may be affected by the mix of BMPs put into place. The following is a discussion of factors affecting the efficiency for reductions for each source category. For all units, the discussion focuses on source load as opposed to the potential impact on instream concentrations. Potential BMPs that could be added in the future but are not yet part of the WPP are addressed as needed.

OSSFs

Because the target actions for OSSFs (remediation) address the entire problem, reduction efficiency for physical OSSF BMPs is expected to be near 100 percent. Behavioral BMPs (education/outreach) are likely to have a much-reduced efficiency as they are not a physical fix, but they are intended as supplemental measures to OSSF remediation so the cumulative impact should be highly efficient.

WWTFs

WWTF output is regulated, and thus efficiency depends to some degree on the impact of regulatory controls. It will also be dependent on the success of adaptation of systems to new growth in the watershed. SSOs cannot ever be wholly eliminated in high rainfall areas, so the reduction efficiency of BMPs targeting them is dependent on the percent reduction in flow achieved.

Urban Runoff

Urban runoff is addressed both by the WPP and by municipal separate storm sewer system (MS4) Texas Pollutant Discharge Elimination System (TPDES) permits for stormwater utilities. The reduction efficiency of MS4 practices is not modeled under this WPP, but can be expected to vary widely based on the type and scale of BMPs implemented by the utility. Trash and yard waste reduction events are expected to have a low reduction efficiency per urban acre as they are not intended to address bacteria directly. Conservation easements in urban areas can have a high rate of removal efficiency per acre for sheet flow to waterways or prior to interception by the stormwater system, depending on the width, vegetative type, slope, and soils involved.

Dogs

Dog waste removal efficiency is the most problematic because dogs deposit waste at multiple times, in multiple locations. Pet waste collections BMPs (pet waste stations, etc.) may address a large number of dogs in a central public area, but the reduction efficiency of the BMP can only account for a portion of the dog's waste. So, for example, if pet waste stations are installed in a park, and utilized by 200 dogs a day, and the waste collected per dog represents a third of their daily waste, then the reduction efficiency is 33 percent. Therefore, meeting a daily reduction goal of 100 dogs would require this BMP to address 300 dogs. Spay and Neuter programs do not directly reduce the waste from the animals they address, but instead remove future waste by reducing pet and feral populations. Population reduction is a greater than 100 percent removal efficiency, as cats and dogs have litters greater than one, and may have many litters throughout a lifetime. However, it is a reduction of potential load rather than existing load.

Livestock (Cattle, Sheep/Goats, and Horses)

Reduction efficiency for livestock BMPs varies depending on the type and scale of BMP used. The WPP includes additional information on modeling that specifically addresses some removal impacts. Efficiency is dependent on the degree to which waste is relocated from the riparian corridor, and the transmission of resulting waste. Literature values indicate that even small riparian barriers or cross fencing can have a dramatic impact on transmission of bacteria. For example, a 1994 study showed that manure deposited 2.1 meters from a waterway transmitted 95 percent less bacteria than manure deposited directly in the waterway[37]. Other practices have differing rates of efficiency in different studies. Because the animal is not physically removed from the watershed, efficiency is not 100 percent.

Wildlife and Feral Hogs

Reduction of deer and feral hogs directly through hunting and trapping has a 100 percent removal efficiency for that animal. However, BMPs aimed at education and outreach can only be considered supplemental, contributing to physical BMPs.

[37] Larsen RE, Buckhouse JC, Moore JA, Miner JR. 1988. Rangeland cattle and manure placement: A link to water quality. Proceedings of Oregon Academy of Science 24:7.

APPENDIX C – NINE ELEMENT TABLE

TABLE 58- NINE ELEMENT TABLE

Nine Element Table									
A. Causes and Sources of Bacteria and Associated *E. coli* Loads	**C. Implementation Activities**	**B. Source Load Reductions**	**D. Technical and Financial Needs**	**E. Education Component**	**F. Schedule for Implementation**	**G. Interim, Measurable Milestones**	**H. Indicators to measure progress**	**I. Monitoring Component**	**Responsible Entity**
OSSFs									
2.47E+11 MPN/day	Identification and repair of malfunctioning systems	2.47E+11 MPN/day	SEP funds, 319 grant funding, AgriLife extension Repair: $5,000 Replacement: $10,000	Homeowner workshops, Authorized agent training	Ongoing identification and repair of failing systems	Number of systems repaired and inspected on an annual basis	*E. coli* reductions, determining locations of systems	reports from Authorized Agents, tracking of systems on website	Authorized Agents to inspect, homeowners to repair and replace, H-GAC to inventory and map
Feral Hogs and Wildlife									
2.68E+07 MPN/day	Landowner workshops to facilitate identification of damage from and capture of feral hogs	1.34E+06 MPN/day	Technical: Texas Agrilife extension, SEP funds Workshops: $8,000	Landowner workshops	Ongoing and expanding programs	Number of hogs managed each year, number of pork choppers flying area	*E. coli* reductions, number of hogs reported killed	reports on damage	Texas Parks and Wildlife and Texas AgriLife extension

Nine Element Table

A. Causes and Sources of Bacteria and Associated *E. coli* Loads	C. Implementation Activities	B. Source Load Reductions	D. Technical and Financial Needs	E. Education Component	F. Schedule for Implementation	G. Interim, Measurable Milestones	H. Indicators to measure progress	I. Monitoring Component	Responsible Entity
Livestock									
3.01E+11 MPN/day	WQMPs that include fencing, alternate water sources and/or prescribed grazing, measures to reduce soil and sediment loss to area waterways	2.26E+11 MPN/day	Technical: TSSWCB Cost: $10,000 - $15,000 each	Advertisement of WQMPs	Ongoing	Number of plans implemented each year	*E. coli* reductions, number of plans implementing livestock management measures	reports of plans	TSSWCB, landowners
WWTFs									
2.68E+07 MPN/day	Monitoring of WWTF effluent to determine bacteria levels as part of permitted bacteria discharge limits	1.34E+06 MPN/day	Technical: TCEQ, TSSWCB grant funding additional monitoring Testing: $25/month/facility	Facility operator education	Implementation of bacteria testing with permit renewal	number of facilities meeting standards and within limits	reductions in base levels based on actual bacteria counts	reports to TCEQ of bacteria levels, monitoring levels	Facility operators/Cities/MUDs, TCEQ
Total									
5.48E+11 MPN/day		4.48E+11 MPN/day							

Nine Element Table									
A. Causes and Sources of Bacteria and Associated *E. coli* Loads	**C. Implementation Activities**	**B. Source Load Reductions**	**D. Technical and Financial Needs**	**E. Education Component**	**F. Schedule for Implementation**	**G. Interim, Measurable Milestones**	**H. Indicators to measure progress**	**I. Monitoring Component**	**Responsible Entity**
Other Land Management Measures to reduce bacteria from multiple sources and land uses.[38]									
NA/multiple	Model ordinances	NA/multiple	Technical: H-GAC	landowner education	Ongoing	Number of ordinances or pollution prevention plans created	*E. coli* reductions in areas with ordinances	reports from cities	Cities
NA/multiple	Conservation easements/Filter Strips/Grassed Waterways	NA/multiple	Technical: Counties, SEP funds Cost: Dependent on size & location	Landowner education	Ongoing	number of conservation easements/acres protected	*E. coli* reductions in areas with easements	reports of conservation easement contracts	Landowners, nonprofits
NA/multiple	Clean up of illegal dumping and trash and organic matter	NA/multiple	Technical: Counties, solid waste grants Cost: $40,000	Landowner education	ongoing	number of sites cleaned up/tons of trash collected	reduction in number of items dumped in waterways	reports from counties about cleanups,	Counties

[38] The management measures discussed here impact multiple sources already discussed, so do not have discrete loads attributed to them in column A. Model ordinances and Conservation easements (etc.) are intended to support Column B reductions already indicated for other sources. Trash reduction is aimed at a stakeholder concern, and not specifically for bacteria reduction potential.