NONPOINT SOURCE MODELING OF THE WATERSHEDS OF ADAMS AND COW BAYOUS

ORANGE COUNTY TOTAL MAXIMUM DAILY LOAD PROJECT

Prepared For:

TEXAS COMMISSION ON ENVIRONMENTAL QUALITY
POST OFFICE BOX 13087
AUSTIN, TEXAS 78711-3087

Prepared By:

PARSONS

JANUARY 2006

NONPOINT SOURCE MODELING OF THE WATERSHEDS OF ADAMS AND COW BAYOUS

ORANGE COUNTY TOTAL MAXIMUM DAILY LOAD PROJECT

Prepared For:

TEXAS COMMISSION ON ENVIRONMENTAL QUALITY
POST OFFICE BOX 13087
AUSTIN, TEXAS 78711-3087

Prepared By:

PARSONS

JANUARY 2006

Table of Contents

List of Figures

List of Tables

Table A11. Annual average ammonia nitrogen loads (in pounds/year) to Adams Bayou and tributaries by reach 71

Acronyms and Abbreviations

BOD	Biochemical Oxygen Demand
CFR	Code of Federal Regulations
cfs	Cubic Feet per Second
cfu	Colony Forming Units
IH	Interstate Highway
HSPF	Hydrologic Simulation Program - Fortran
km	Kilometers
L	Liter
lbs	Pounds
m	Meter
mg	Milligram
MGD	Million Gallons per Day
mL	Milliliter
NADP	National Atmospheric Deposition Program
NO3-N	Nitrate nitrogen
NH3-N	Ammonia nitrogen
NPDES	National Pollutant Discharge Elimination System
NPS	Nonpoint Source
NRCS	Natural Resource Conservation Service
OSSF	On-site Sewerage Facility
PO4-P	Phosphate Phosphorus
SH	State Highway
SOD	Sediment Oxygen Demand
SRA	Sabine River Authority of Texas
SSURGO	Soil Survey Geographic Database of the NRCS
TCEQ	Texas Commission on Environmental Quality
TKN	Total Kjeldahl Nitrogen
TMDL	Total Maximum Daily Load
TSS	Total Suspended Solids
TWC	Texas Water Commission (a predecessor agency to TCEQ)
USDA	United States Department of Agriculture
USEPA	United States Environmental Protection Agency
USGS	United States Geological Survey
VSS	Volatile suspended solids
WASP	Water Quality Analysis Simulation Program
yr	Year

Introduction

This report summarizes the development of a model of the watersheds of Adams and Cow Bayous using the Hydrologic Simulation Program - Fortran (HSPF). Because Adams Bayou and most of Cow Bayou are tidal streams, with reversing flows which the HSPF model is incapable of simulating, in-stream flow and water quality will be simulated with RMA2 and Water Quality Analysis Simulation Program (WASP) models, respectively. The output from the HSPF model will be linked to the in-stream models of Adams and Cow Bayous and their tributaries, for use in developing total maximum daily loads (TMDLs) for fecal bacteria, dissolved oxygen, and pH. The models will be useful for several purposes:

- to aid understanding of the processes affecting water quality,
- to quantify pollutant loadings to the bayous and allocate them among sources,
- to link in-stream water quality impairments to pollutant loadings,
- to quantify the loading reductions required to achieve water quality standards, and
- to evaluate the benefits of various water quality management options.

This report addresses only the HSPF watershed model. A separate report will describe development of the in-stream water quality and hydrodynamic models.

Regulatory Background

Water quality standards serve the dual purposes of establishing the water quality goals for a specific water body and serve as the regulatory basis for the establishment of water-quality-based treatment controls and strategies (40 CFR 131.10). Water quality standards are comprised of designated uses and water quality criteria. The federal Clean Water Act requires that states designate for each water body desirable and appropriate uses to be achieved and protected. These designated uses of water bodies include recreation in and on the water, public water supply, navigation, agricultural and industrial water supply, and protection and propagation of fish, shellfish and wildlife. States must then set water quality criteria necessary to protect those designated uses. Criteria are expressed as constituent concentrations, levels, or narrative statements, representing a quality of water that supports a particular use. When criteria are met, water quality will generally protect the designated use (40 CFR 131.3).

Section 303(d) of the Federal Clean Water Act and U.S. Environmental Protection Agency (USEPA) regulations (40 CFR Part 130) require states to develop TMDLs for water bodies that do not meet water quality standards. A TMDL is an allocation of allowable point and nonpoint source pollutant loadings that will enable the water body to meet water quality standards when implemented.

The Texas Commission on Environmental Quality (TCEQ) has determined that Adams Bayou, Cow Bayou, and several of their tributaries do not meet water quality standards and require TMDLs (TCEQ 2002). Adams and Cow Bayous are adjacent streams that flow into the Sabine River just upstream of Sabine Lake in Orange County, in the southeast corner of Texas (Figure 1). The unsupported designated uses include contact recreation, aquatic life support, and general uses.

The TCEQ has divided Adams and Cow Bayous and their tributaries into multiple segments for water quality management purposes. The segments not meeting water quality standards are described as follows:

- Segment 0508 (Adams Bayou Tidal) - from the confluence with the Sabine River in Orange County to a point 1.1 kilometers (km) (0.7 miles) upstream of IH-10 in Orange County (a classified tidal stream of 8 miles in length). Does not support aquatic life or contact recreation uses.

- Segment 0508A (Adams Bayou above Tidal) - from a point 1.1 km (0.7 miles) upstream of IH-10 in Orange County to the upstream perennial portion of the stream northwest of Orange in Orange County (an unclassified freshwater stream of 8 miles in length). Does not support aquatic life or contact recreation uses.

- Segment 0508B (Gum Gully) - From the confluence of Adams Bayou to the upstream perennial portion of the stream northwest of Orange in Orange County (an unclassified freshwater stream of 3.5 miles in length). Does not support aquatic life or contact recreation uses.

- Segment 0508C (Hudson Gully) - From the confluence with Adams Bayou to the headwaters near US 890 in Pinehurst in Orange County (an unclassified tidal stream of 0.5 miles in length). Does not support aquatic life or contact recreation uses.

- Segment 0511 (Cow Bayou Tidal) - from the confluence with the Sabine River in Orange County to a point 4.8 km (3.0 miles) upstream of IH-10 in Orange County (a classified tidal stream of 20 miles in length). Does not support aquatic life, contact recreation, or general uses.

- Segment 0511A (Cow Bayou above Tidal) – from a point 4.8 km (3.0 miles) upstream of IH-10 in Orange County to the upstream perennial portion of the stream northeast of Vidor in Orange County (an unclassified freshwater stream of 10.6 miles in length). Does not support aquatic life use.

- Segment 0511B (Coon Bayou) – from the confluence with Cow Bayou up to the extent of tidal limit in Orange County (an unclassified tidal stream of 4.7 miles in length). Does not support aquatic life or contact recreation uses.

- Segment 0511C (Cole Creek) – from the confluence with Cow Bayou west of Orange in Orange County to the upstream perennial portion of the stream south of Mauriceville in Orange County (an unclassified tidal stream of 9.5 miles in length). Does not support aquatic life or contact recreation uses.

- Segment 0511E (Terry Gully) – from the confluence with Cow Bayou in Orange County to the headwaters northeast of Vidor in Orange County (an unclassified freshwater stream of 8.6 miles in length). Does not support contact recreation use.

The specific criteria used to determine non-support of the contact recreation use in these bayous were based on levels of fecal coliform and E. coli bacteria. The assessment of nonsupport of the aquatic life use was based on levels of dissolved oxygen. Non-support of general uses was determined from measurements of pH. A more thorough review of water quality standards and assessment of water quality conditions in these bayous can be found in a prior report of this project "*Assessment of Water Quality Impairments In Adams Bayou Tidal (Segment 0508), Cow Bayou Tidal (Segment 0511) and their Tributaries*" (Parsons 2002).

Figure 1. Adams and Cow Bayou Stream Segments

Objectives

Following their determination that the water quality standards of Adams and Cow Bayous were not supported, the TCEQ selected Parsons and the Sabine River Authority (SRA) as contractors to assist in developing TMDLs. An assessment of existing water quality data (Parsons 2002) concluded with a high degree of confidence that water quality in Adams and Cow Bayou did not meet water quality standards, but that the sources of pollutants were not adequately quantified, and the impacts of sources were not known with sufficient confidence to develop a TMDL. The assessment also indicated that, because both nonpoint sources and in-stream conditions likely contributed to the impairment, it was advisable to develop and calibrate both a watershed model and an in-stream model to aid in identifying the TMDLs and allocating the allowable load among various point and nonpoint sources of pollutants. A "point source" pollutant is one that originates from a specific point, such as a wastewater discharge pipe of a wastewater treatment plant, or a large confined animal feeding lot. In practice, the term "point source" is applied to facilities required to have a National Pollutant Discharge Elimination System (NPDES) permit for wastewater discharges to water. Nonpoint source pollutants are those not released from pipes but originating over a large land area. Examples of nonpoint sources include failing septic tanks, improper animal husbandry practices, soil erosion, and urban runoff.

Parsons prepared a model selection technical memorandum (Parsons 2003a) that evaluated the capabilities of the available models to simulate water quality in Adams and Cow Bayous, as well as the loadings of pollutants from their watersheds. The HSPF model was recommended for its capacity to simulate watershed loading processes in both urban and rural areas. The WASP water quality model, coupled with the DYNHYD hydrodynamic model and the HSPF watershed model, was recommended as the best available model system to simulate water quality processes in the bayous. It was later discovered that DYNHYD was not able to accurately simulate the tidal cycles occurring in the bayous during the intensive surveys of May through August of 2004. Therefore, hydrodynamic models of Adams and Cow Bayou were developed using RMA2, a more full-featured hydrodynamic model developed by the U.S. Army Corps of Engineers.

A water quality monitoring plan (Parsons 2003b) and quality assurance project plan (Parsons 2003c) were then developed to collect data necessary to develop and calibrate the watershed, hydrodynamic, and water quality models. This data was collected by Parsons and the SRA between January and November 2004. The data collection effort consisted of 1) runoff sampling to calibrate pollutant loading factors for the watershed model, 2) sediment oxygen demand surveys, and 3) several intensive surveys addressing instream flows, water quality, and pollutant loading from wastewater discharges in Adams and Cow Bayou.

Watershed Overview

Adams and Cow Bayous are sluggish streams that flow into the Sabine River (USGS Hydrologic Unit Code 12010005) just upstream of Sabine Lake in Orange County, Texas. Adams Bayou extends from its confluence with the Sabine River in a northerly direction across Orange County to near the Newton County Line. Adams Bayou previously extended into southern Newton County, but this flow has been redirected eastward through a ditch to the Sabine River. Cow Bayou extends from its confluence with the Sabine River in a northerly direction, roughly parallel to but west of Adams Bayou, across Orange County to Buna in southern Jasper County (Figure 1).

The lower portions of both bayous have been channelized, straightened, and dredged for navigation, creating numerous oxbows in the former, more sinuous, channels. Both bayous are under tidal influence below and a short distance above Interstate Highway (IH)-10. The tidal portions of Adams and Cow Bayous extend approximately 8 and 20 miles, respectively, above their confluences with the Sabine River.

A U.S. Geological Survey (USGS) gaging station measured flow in Cow Bayou at the State Highway (SH) 12 bridge near Mauriceville from 1952 to 1986, and was re-activated in October of 2002. The annual average, maximum, and 7-day, 2-year minimum flow (7Q2) at this site were 104.4 cubic feet per second (cfs), 4600 cfs, and 0.05 cfs, respectively, over the period of record.

There is no flow gaging station on Adams Bayou, but field surveys indicate that under low-flow conditions there is essentially no base flow (TWC 1986). Under these conditions, water movement occurs due to tidal ebb and flow, downstream water diversions, and wastewater discharges to the bayou. Upper reaches of Adams Bayou and non-tidal tributaries are intermittent streams.

The Adams Bayou watershed of approximately 37 square miles lies almost entirely within Orange County, though it includes a small portion of southern Newton County. The Cow Bayou watershed comprises approximately 199 square miles covering substantial portions of Orange and Jasper Counties, as well as a small corner of Newton County. The combined watersheds cover 41% of Orange County, 8% of Jasper County, and 0.3% of Newton County.

Population and Municipalities

Portions of the cities of Orange, West Orange, Pinehurst and Mauriceville lie within the Adams Bayou watershed, while portions of Bridge City, Vidor, Mauriceville, Evadale, and Buna lie within the Cow Bayou watershed. In the year 2000, the population of the Cow Bayou watershed (~23,900) was slightly higher than that of Adams Bayou (~17,500). Between 1990 and 2000, the population of the Adams Bayou watershed increased only 2%, while the Cow Bayou watershed population grew by 17%. Figure 2 shows the 2000 population density within the study area at the census block level.

Economy

The major industries in the watersheds include chemical manufacturing, oil and gas production, forestry, and beef production. The major agricultural activities within the watersheds include beef cattle ranching and hay production. The 2002 U.S. Department of Agriculture (USDA) census of agriculture provides a more detailed inventory of agricultural activities at the county level (Tables 1 - 3). In addition to hay and other forage, the other major crop in Orange County is rice, but this is primarily outside the watersheds of Adams and Cow Bayou. Cattle are the most abundant livestock by a large margin. Other abundant livestock include chickens and horses.

Table 1. Count of farms by county and type: 2002 agricultural census

Type	Orange	Jasper	Newton
Farms	496	763	385
Acres harvested	4,326	9,545	4,415
Irrigated farms	27	31	6
Oilseed and grain farming	4	3	9
Vegetable and melon farming	3	24	-
Fruit and tree nut farming	13	19	4
Greenhouse, nursery, and floriculture production	8	4	12
Sugarcane farming, hay farming, and all other crop farming	30	100	58
Beef cattle ranching and farming	283	454	228
Cattle feedlots	16	20	2
Dairy cattle and milk production	1	-	-
Hog and pig farming	4	11	9

Poultry and egg production	3	13	9
Sheep and goat farming	12	13	8
Animal aquaculture and other animal production	119	102	46

Table 2. Crops planted by county, in acres: 2002 agricultural census

Crop	Orange	Jasper	Newton
Rice	878	-	-
Forage - hay and haylage, grass silage, and greenchop	3259	9054	4225
Vegetables	12	93	1
Orchards	58	176	20
Corn for grain	-	-	45
Wheat for grain	-	-	D
Soybeans	-	-	D
Potatoes	-	7	-
Sugarcane	-	-	D

D -Withheld to avoid disclosing data from individual farms

- represents zero

Table 3. Domestic livestock populations by county: 2002 agricultural census

Type	Orange	Jasper	Newton
Cattle and calves*	10,402	15,006	6,492
Hogs/pigs	120	380	89
Horses/ponies	1,125	1,152	631
Sheep/lamb	117	76	27
Goats	580	585	572
Mules/burros/donkeys	94	20	20
Rabbits	64	-	16
Chickens/layers& pullets	1,150	2,448	802
Chickens/broilers	D	402	436
Turkeys	27	55	60
Pheasants	D	110	16
Pigeons and squab	257	-	D
Quail	D	284	D
Ducks	688	147	156

Geese	80	40	148
Other poultry	D	D	516

* all were beef cattle except 13 dairy cows in Orange County

D -Withheld to avoid disclosing data from individual farms

- represents zero

Climate

Adams and Cow Bayou experience a subtropical humid climate. The average temperature varies from 50 degrees Fahrenheit in January to 83 degrees in August. Rain is abundant in this corner of Texas, with average annual rainfall of almost 60 inches. The frequency of significant rainfall (one half inch or more in a 24-hour period) has averaged approximately 3.2 days per month, or roughly one in ten days, over the last 30 years. Seasonal variations in precipitation frequency and magnitude are not great. July, December, and January have the most frequent rainfall, and June, October, and April have the least frequent.

Geology, Topography, and Soils

Adams and Cow Bayou are located in the Gulf of Mexico coastal plain. The southeastern parts of their watersheds lie in the ecological region known as Gulf prairies and marshes, while the northwestern parts lie in the piney woods region. The terrain is level and low. The elevation of Adams Bayou varies from sea level at the Sabine River to 4.5 feet at its uppermost extent (TWC 1986), with an average slope of only 6 cm/km, or 0.006%. The elevation of Cow Bayou varies from sea level at the Sabine River to 7 feet at its uppermost extent (TWC 1986), and also has an average slope of 6 cm/km (TWC 1988).

Sedimentary rocks comprise the geologic base of the watersheds of Adams and Cow Bayou. The Beaumont Clay is the surface formation over the entire watershed. It is composed of mixed sand, silt, clay and gravel. Soils are primarily fine sands, silts, and clays. Most are fine-textured, have high water holding capacity, and very slow water permeability. Soils also tend to be acid and have high organic matter content in the surface layer. Some soils have frequent flooding and/or surface ponding of water for long durations in the cooler months of the year. Finally, many of the soils are saturated in the cooler months, with water tables at or near the surface. Together with the low and level topography, these soil properties give rise to an abundance of wetlands within the watersheds. Table 4 describes some of the properties of the major soil map units found in the watersheds of Adams and Cow Bayou. Appendix A includes a more detailed listing of the major map units by sub-watershed.

Land Use and Land Cover

Land use in the Adams and Cow Bayou watersheds is illustrated in Figure 3, from the Multi-Resolution Land Cover Consortium's National Land Cover Dataset (USGS 1999a). This land use classification is based on Landsat Thematic Mapper satellite imagery from the early 1990's. Overall, 14 percent of the Adams Bayou watershed and 6 percent of the Cow Bayou watershed were considered developed or built-up land (residential, commercial, industrial, or transportation) at that time (Table 5). More than 65 percent of the Cow Bayou watershed, and one third of the Adams Bayou watershed, is covered by forest, primarily evergreen and mixed evergreen/deciduous forest. Approximately 15 percent of the Cow Bayou watershed and 27 percent of the Adams Bayou watershed is used for pasture or hay production for grazing animals. Water and wetlands comprise approximately 10 percent and 22 percent, respectively, of the Cow and Adams Bayou watersheds.

Table 4. Properties of major soil map units of Adams and Cow Bayou watersheds

Map Unit		Area %		Slope	Runoff	Flooding		Surface Ponding?		High Water Table		Hydraulic Permeability		Available Water Capacity in/in			Zone Depths (in)		pH		Organic	
Symbol	Map Unit Name	Adams	Cow	%	Potential	Frequency	Duration	Frequency	Duration	Depth (ft)	months	Percolation?	inch/hr	Rating	upper	lower	Upper	Lower	Upper	Lower	matter	Natural Vegetation
AnA	ANAHUAC VERY FINE SANDY LOAM	0.2%	1.0%	0-2	medium	none		none		4-6	Nov-Apr	very slow	<0.06	high	0.17	0.16	22	80	5.50	5.25	2%	prairie grasses
AsA	ANAHUAC-ARIS COMPLEX	2.5%	0.6%	0-1	medium	none		none		4-6	Nov-Apr	very slow	<0.06	high	0.17	0.16	22	80	5.50	5.25	2%	prairie grasses
AuA	ANAHUAC-URBAN LAND COMPLEX	0.0%	0.2%	0-2	medium	none		none		4-6	Nov-Apr	very slow	<0.06	very low	0.17	0.16	22	80	5.50	5.25	2%	prairie grasses
BwA	BLEAKWOOD LOAM	0.0%	2.3%	0-1	negligible	frequent	long	none		0-1.5	Nov-May	moderate	0.6-2.0	high	0.13	0.17	3	80	5.50	5.00	2%	bottomland woodlands
CaA	CAMPTOWN SILT LOAM	2.9%	0.9%	0-1	negligible	none		frequent	long	0	Dec-Aug	very slow	<0.06	moderate	0.15	0.15	17	80	4.50	5.00	2%	freshwater marsh sedges
CeA	CAPLEN MUCKY PEAT	0.0%	0.9%	0-1	negligible	frequent	very long	frequent	very long	0	all year	very slow	<0.06	moderate	0.18	0.08	12	80	7.00	7.00	40%	saltgrass - marsh vegetation
CrA	CRAIGEN LOAMY FINE SAND	0.0%	2.9%	0-2	very low	none		none		3-5	Jan-Apr	moderate	0.6-2.0	moderate	0.09	0.14	7	80	4.50	5.50	2%	loblolly pine, other pine, sweetgum
EaA	EVADALE SILT LOAM	0.0%	6.7%	0-1	very high	none		none		0-1.5	Dec-Apr	very slow	<0.06	high	0.19	0.17	17	65	5.25	5.00	<2%	loblolly pine, water oak
EgB	EVADALE-GIST COMPLEX	0.0%	20%	0-3	very high	none		none		0-1.5	Dec-Apr	very slow	<0.06	high	0.19	0.17	10	70	5.25	5.00	<2%	loblolly pine, water oak
EvA	EVADALE-VIDRINE COMPLEX	2.6%	3.4%	0-1	high	none		none		0-1.5	Dec-Apr	very slow	<0.06	high	0.19	0.17	9	80	5.25	5.00	1%	loblolly pine, water oak
FaA	FAUSSE CLAY	2.1%	0.0%	0-1	negligible	frequent	very long	frequent	very long	0-1.5	all year	very slow	<0.06	high	0.19	0.19	6	80	5.55	4.75	9%	bald cypress, water tupelo, red maple
ImA	IJAM CLAY	0.7%	0.9%	0-2	very high	frequent	brief	none		0-3	Sep-May	very slow	<0.06	moderate	0.11	0.11	8	80	7.80	7.80	1%	saltgrass - marsh vegetation
KWB	KIRBYVILLE-WALLER ASSOCIATION	0.0%	1.5%	0-4	medium	none		none		1.5-2.5	Jan-Mar	moderate	0.6-2.0	high	0.13	0.18	18	75	5.25	5.00	<1	loblolly pine, other pine, sweetgum
LaA	LABELLE SILT LOAM	10.2%	2.0%	0-1	high	none		none		0.5-1.5	Jan-Mar	very slow	<0.06	high	0.18	0.15	12	80	6.80	7.00	2%	prairie grasses
LbA	LABELLE-ANAHUAC COMPLEX	0.0%	0.4%	0-1	high	none		none		0.5-1.5	Jan-Mar	very slow	<0.06	high	0.18	0.15	12	80	6.80	7.00	2%	prairie grasses
LdA	LABELLE-LEVAC COMPLEX	4.4%	1.0%	0-1	high	none		none		0.5-1.5	Jan-Mar	very slow	<0.06	high	0.18	0.15	16	80	6.80	7.00	2%	prairie grasses
LvA	LEERCO MUCK	3.7%	0.0%	0-1	negligible	frequent	very long	frequent	very long	0	all year	very slow	<0.06	high	0.35	0.16	5	80	6.45	6.70	40%	saltgrass - marsh vegetation
MaB	MALBIS FINE SANDY LOAM	0.0%	1.7%	1-5	medium	none		none		2.5-4.0	Dec-Mar	slow	0.2-0.6	high	0.13	0.15	13	72	5.25	5.00	1%	loblolly pine, other pine, mixed hardwoods
MKB	MALBIS-KIRBYVILLE ASSOCIATION	0.0%	4.6%	1-5	medium	none		none		2.5-4.0	Dec-Mar	slow	0.2-0.6	high	0.13	0.15	24	72	5.25	5.00	1%	loblolly pine, other pine, mixed hardwoods
MmA	MOLLCO FINE SANDY LOAM	0.0%	1.2%	0-1	negligible	frequent	brief	frequent	very long	0	Oct-May	moderate	0.6-2.0	moderate	0.13	0.15	16	80	4.50	5.00	4%	water-tolerant sedges and grasses
MoA	MOLLCO-CRAIGEN COMPLEX	0.0%	1.9%	0-1	negligible	frequent	brief	frequent	very long	0	Oct-May	moderate	0.6-2.0	moderate	0.13	0.15	20	80	4.50	5.00	4%	water-tolerant sedges and grasses
MrA	MOREY-LEVAC COMPLEX	0.0%	0.9%	0-1	medium	none		none		2-2.5	Dec-Feb	very slow	<0.06	high	0.13	0.17	9	80	5.60	7.25	3%	prairie grasses
NuC	NEEL-URBAN LAND COMPLEX	0.7%	0.2%	2-5	very high	rare	very brief	none		3-6	Sep-May	rapid	>2	moderate	0.11	0.11	12	80	6.50	6.50	1%	coastal prairie
OaB	ORCADIA SILT LOAM	1.9%	2.6%	0-2	very high	none		none		0.8-1.5	Jan-Mar	very slow	<0.06	high	0.18	0.15	10	80	4.50	4.50	2%	prairie grasses
OcA	ORCADIA-ANAHUAC COMPLEX	17.3%	5.9%	0-1	high	none		none		0.8-1.5	Jan-Mar	very slow	<0.06	high	0.18	0.15	15	80	4.50	4.50	2%	prairie grasses
OsA	ORCADIA-ARIS COMPLEX	6.6%	6.7%	0-1	medium	none		none		0.8-1.5	Jan-Mar	very slow	<0.06	high	0.18	0.15	27	80	4.50	4.50	2%	prairie grasses
OuA	ORCADIA-URBAN LAND COMPLEX	18.4%	3.4%	0-2	very high	none		none		0.8-1.5	Jan-Mar	very slow	<0.06	high	0.18	0.15	10	80	4.50	4.50	2%	prairie grasses
TaA	TEXLA SILT LOAM	15.1%	3.2%	0-1	high	none		none		0.5-1.5	Jan-Mar	very slow	<0.06	high	0.18	0.15	13	80	4.25	5.25	2%	mixed forest
TeB	TEXLA-EVADALE COMPLEX	1.5%	14%	0-1	high	none		none		0.5-1.5	Jan-Mar	very slow	<0.06	high	0.18	0.15	6	80	4.25	5.25	2%	mixed forest
TgA	TEXLA-GIST COMPLEX	6.8%	3.6%	0-1	high	none		none		0.5-1.5	Jan-Mar	very slow	<0.06	high	0.18	0.15	9	80	4.25	5.25	2%	mixed forest
WAA	WALLER-EVADALE ASSOCIATION	0.0%	1.4%	0-1	high	none		none		0-2.5	Nov-Jun	very slow	<0.06	high	0.19	0.17	17	72			<2%	loblolly pine, other pine, water oak, sweetgum

Table 5. Land use/land cover in the Adams and Cow Bayou watersheds

Land Use/Land Cover Category	Adams Bayou	Cow Bayou
Open water	4.0%	1.0%
Low density residential	7.8%	2.8%
High density residential	3.0%	1.6%
Commercial, industrial, & transportation	3.6%	2.0%
Bare rock, sand, or clay	0.1%	0.1%
Quarries, strip mines, and gravel pits	0.0%	0.2%
Transitional	0.0%	1.8%
Deciduous Forest	9.3%	10.6%
Evergreen forest	14.5%	21.3%
Mixed forest	9.9%	33.2%
Grasslands/ herbaceous	0.5%	0.1%
Pasture/hay	27.1%	15.4%
Row crops	0.0%	0.0%
Small grains	0.4%	0.4%
Urban & recreational grasses	2.0%	0.8%
Woody wetlands	11.5%	6.3%
Emergent herbaceous wetlands	6.5%	2.6%

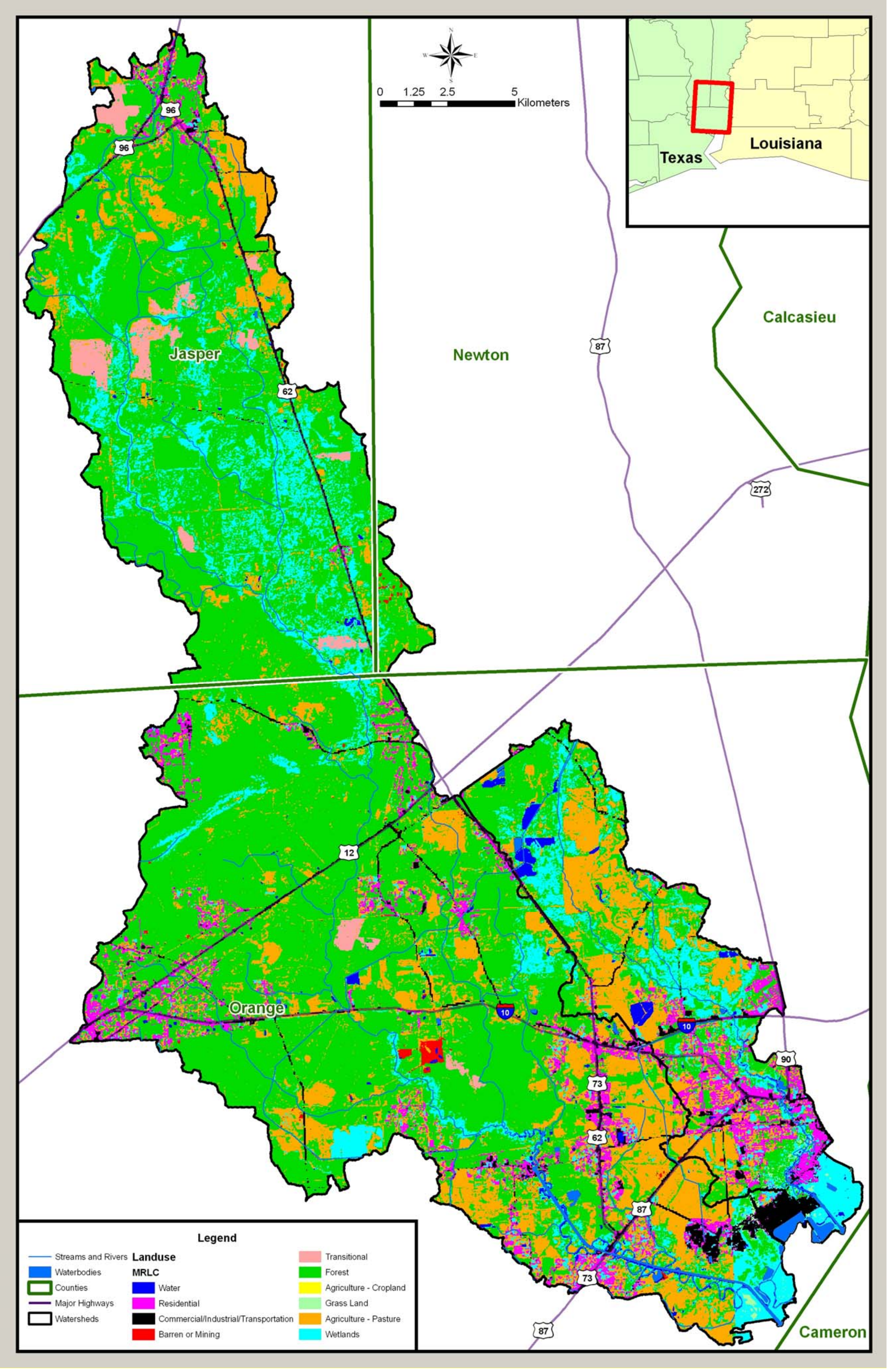

Figure 3. Land use/land cover in the Adams and Cow Bayou watersheds

HSPF Model Description and Structure

The HSPF models of Adams and Cow Bayou watersheds were developed to be run under HSPF version 12.0 either as the stand-alone executable program or using WinHSPF version 2.3 or WinHSPFLt, components of the USEPA BASINS modeling software. The models utilized algorithms developed for version 12 for high water table, low topography conditions, and will not run under older versions of HSPF.

Both models run for the period January 1, 2001 through March 28, 2005, on an hourly time step. However, the year 2001 is used only to allow the model to stabilize, and minimize the effects of errors in assumed initial conditions.

A stream and its watershed are subdivided into reaches and sub-watersheds in the HSPF model. Within each sub-watershed, multiple land uses are simulated, each having different parameters for the processes being simulated. Adams and Cow Bayou were subdivided into reaches and sub-watersheds at their confluence with major tributaries and at a few other sampling stations or tidal/non-tidal boundaries, to coincide with the segmentation of the instream WASP and RMA2 models. Adams Bayou was subdivided into 12 reaches with 11 sub-watersheds, as displayed in Figure 4. Note that reaches 3 and 6 share a common sub-watershed. Cow Bayou was subdivided into 18 reaches and 18 sub-watersheds, as shown in Figure 5. The methods used to sub-divide and delineate sub-watersheds are described in the following paragraph.

Because of the flat topography of the watersheds, where roads and levees cause major impacts on drainage patterns, the contributing watersheds of Adams and Cow Bayou were delineated using an iterative process. First, watersheds were delineated automatically using ArcHydro software (Environmental Systems Research Institute, Redlands, CA) and 10-meter resolution digital elevation models from the National Elevation Dataset (USGS 1999b). Next, these watersheds were compared to the detailed hydrography of the National Hydrologic Dataset (NHD) (USGS 2002). Where streams appeared to cross watershed boundaries, digital line graphs and digital orthophoto quadrangles maps from the USGS were inspected to verify the actual drainage, then watershed boundaries were manually re-drawn to reflect the observed drainage pattern. Due to the flat topography and extensive wetlands, the exact location of some portions of the watershed boundaries remains uncertain.

The model land use categories are those of the Multi-Resolution Land Cover Consortium's National Land Cover Dataset (USGS 1999a). According to this classification, there are seventeen different land uses in the Adams and Cow Bayou watersheds, as previously shown in Table 5 and Figure 3. Appendix A includes land use classifications for individual sub-watersheds.

The HSPF model simulates pervious land use surfaces (which allow water to pass through) and impervious land uses (such as concrete or asphalt) differently. It was assumed that 30% of the surface area of low-density residential, 60% of high-density residential, and 85% of commercial/industrial/ transportation land uses were impervious. All other land use categories were assumed to be 100% pervious.

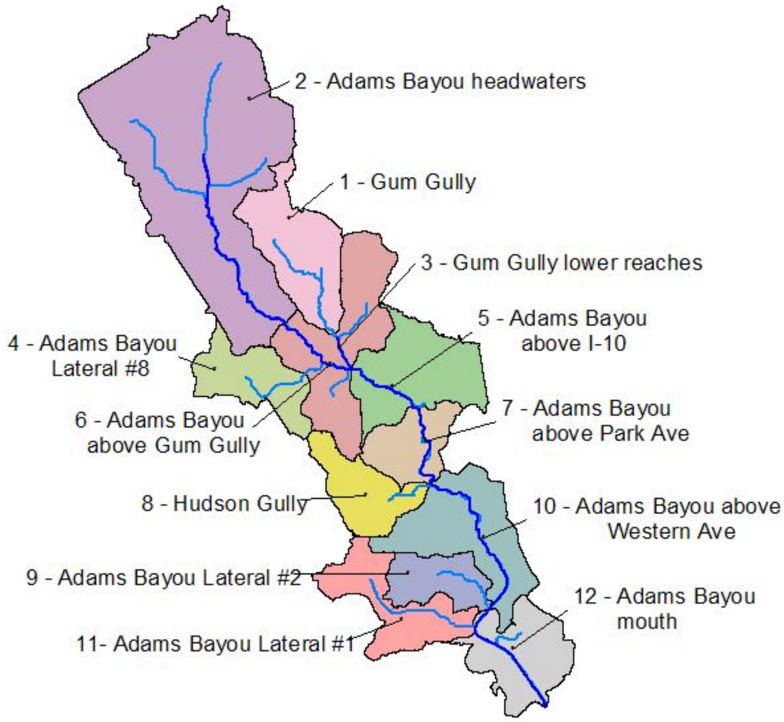

Figure 4. Adams Bayou model reaches and sub-watersheds

The model is based on English units. Active modules for pervious land use categories include:

- ATEMP (air temperature elevation difference),
- PWATER (water budget pervious),
- SEDMNT (production and removal of sediment),
- PSTEMP (soil temperature),
- PWTGAS (water temperature and dissolved gas concentrations), and
- PQUAL (quality constituents using simple relationships).

Active modules for impervious land use categories included:

- ATMP (air temperature elevation difference),
- IWATER (water budget impervious),

- SOLIDS (accumulation and removal of solids),
- IWG (water temperature and dissolved gas concentrations), and
- IQUAL (washoff of quality constituents using simple relationships).

Active modules for the RCHRES (stream) sections include:

- SINK (sinking of suspended material)
- HYDR (hydraulic behavior),
- ADCALC (advection of fully entrained constituents),
- CONS (conservative constituents)
- HTRCH (heat exchange and water temperature)
- SEDTRN (behavior of inorganic sediment)
- GQUAL (generalized water quality constituent)
- OXRX (primary BOD and dissolved oxygen balances)
- NUTRX (primary inorganic nitrogen and phosphorus balances)
- PLANK (plankton populations and associated reactions)
- PHCARB (pH, carbon dioxide, total inorganic carbon, and alkalinity)

Key water quality constituents simulated in the model include E. coli bacteria, dissolved oxygen, pH, BOD, nitrate nitrogen, ammonia nitrogen, orthophosphate phosphorus, alkalinity, and total suspended solids. Chlorophyll A and organic nitrogen and phosphorus were also simulated, but were not calibrated due to a lack of data. The BOD parameter simulated is ultimate BOD, rather than the more commonly measured 5-day BOD.

The new high water table, low gradient algorithms incorporated into version 12 of HSPF were applied to the Adams and Cow Bayou models after preliminary simulations indicated a failure to calibrate with the conventional HSPF algorithms. These algorithms were developed for wetland environments. Wetlands appear to exert a controlling influence on the hydrology of Cow Bayou. Basically, the wetlands act like a sponge, absorbing rainfall with little or no runoff until the sponge is saturated. For this reason, there is often very little flow in Cow Bayou in the summer, when evaporation and evapotranspiration by plants speeds the drying of the wetlands. To represent the pervious soil environment, the new HSPF algorithms keep track of the groundwater levels (top of saturated zone) and the interaction between the saturated and unsaturated zone. Also, surface flow is simulated as a power function of the water storage on the land surface, rather than the traditional approach based on the length, slope, and roughness of the overland flow plane.

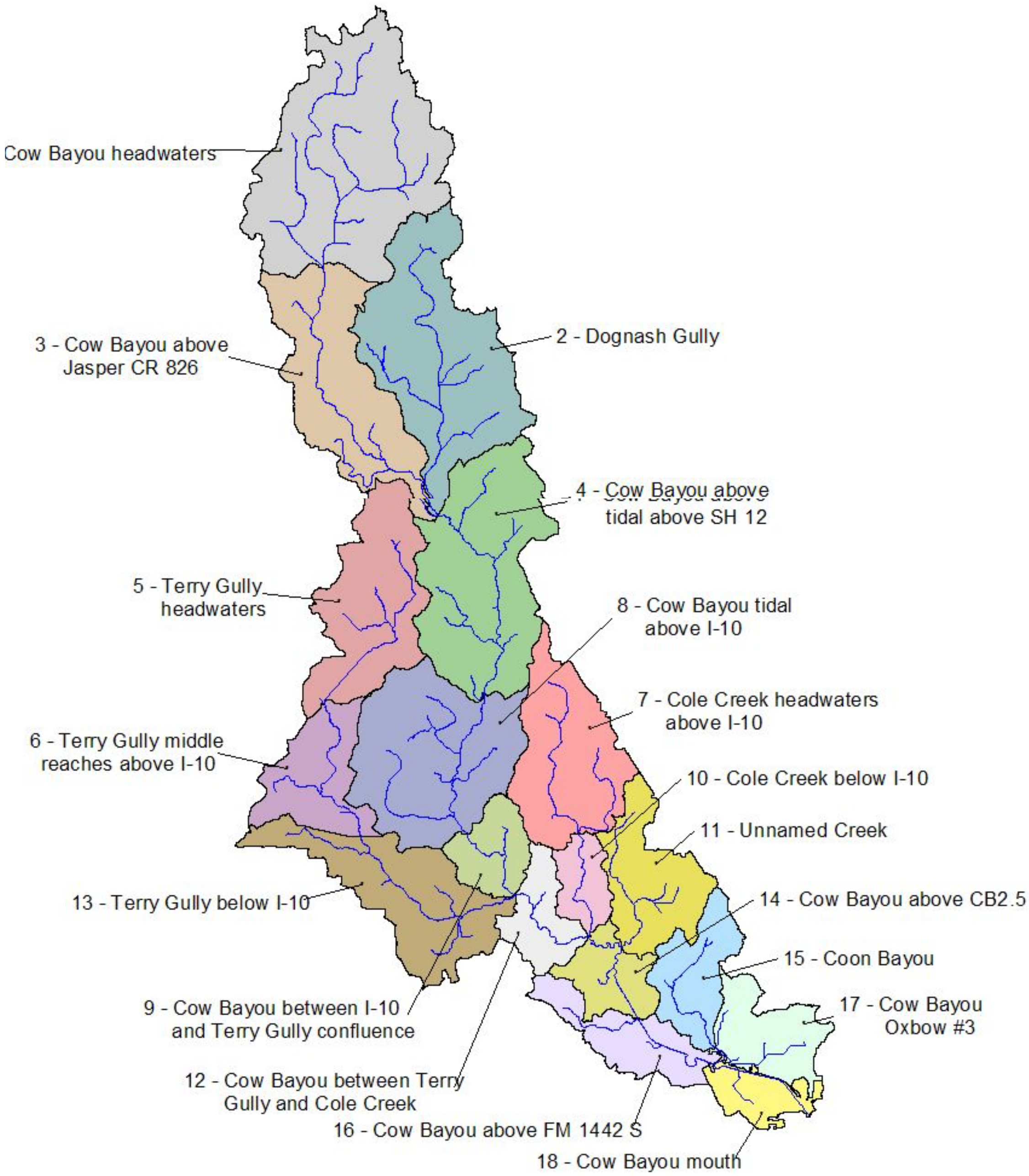

Figure 5. Cow Bayou model reaches and sub-watersheds

Data for Model Development

Meteorological, flow, and water quality data were required to develop the watershed model.

Meteorology

Nonpoint source pollution is a weather-driven process. Required meteorological data elements included precipitation, air temperature, potential evapotranspiration, wind speed, solar radiation, dew point temperature, and cloud cover. Precipitation is the primary input for simulating soil moisture, surface runoff, and soil erosion, and pollutant transport. Air temperature is used in the calculation of heat balance and transfer in soil and water bodies. Evapotranspiration comprises evaporation directly from water, soils and vegetation surfaces, and transpiration through plants. Evapotranspiration is used in simulating soil moisture, which affects runoff, as well as direct evaporation from water bodies. Wind speed is used to calculate the oxygen re-aeration rate of water bodies from the atmosphere, chemical volatilization rates, and heat transfer. Solar radiation is used in the calculation of the heat balance and algae growth rates in water bodies. The dew point temperature and cloud cover are also used in calculating the heat balance in water bodies.

The HSPF model runs on a one hour time step, hence hourly meteorological data are required. The nearest weather station with available hourly meteorological data was at the Beaumont/Port Arthur Southeast Texas Regional Airport in neighboring Jefferson County. In terms of temperature and most other meteorological parameters, this station is fairly representative of conditions in the modeled watersheds. However, rainfall can be quite variable on a local scale, and it is also the most important driver of the HSPF model. For this reason, we identified additional weather stations with daily precipitation totals nearer to the watershed. The Evadale National Weather Service cooperative weather station in Evadale was the rain gage closest to the non-tidal portions of Cow Bayou where the HSPF model hydrology was being calibrated. Thus the model used daily rainfall totals from the Evadale station, which were converted to hourly values based on the hourly distribution of daily rainfall at Beaumont.

Flow

There is one flow gage in the project area with long-term flow records useful for calibration of the HSPF model. This gage is located on Cow Bayou at SH 12 east of Vidor. Flow measurements at this site were collected from 1949 to 1986, then again starting in October 2002 until the present. Daily flow totals were retrieved from the USGS web site at http://nwis.waterdata.usgs.gov/tx/nwis/discharge.

Water Quality Monitoring of Runoff

Water quality was monitored during runoff events to quantify nonpoint source pollutant loads, to assist in calibration of the HSPF watershed model. Six sampling locations, three in each bayou, were sampled during two runoff events each. The land use and size of the contributing watersheds was varied (Table 6). It may be noted that the highest fraction of developed land was only 9% for the contributing watersheds monitored. This was necessary because portions of the bayous with more urbanized watersheds were tidally influenced, meaning that there would be non-flowing water there at all times, which would confound the sampling of runoff.

Table 6. Runoff water quality monitoring stations and watershed properties

Station ID	Site Description	Area (mi^2)	Land Use
16058	Cow Bayou at Jasper CR 826	43.5	69% forest, 12% pasture, 10% wetlands, 6% transitional, 3% developed
16060	Cole Creek at IH-10	13.0	65% forest, 22% pasture, 8% developed, 5% wetlands
16040	Terry Gully at IH-10	21.3	80% forest, 9% developed, 8% pasture, 4% wetlands
16049	Gum Gully at Halliburton Rd. (GG)	2.9	52% pasture/hay, 34% forest, 12% wetlands, 2% developed
14964	Adams Bayou at FM 1078 (AB8)	12.2	47% forest, 28% pasture, 23% wetlands, 2% developed
16053	Adams Bayou Lateral #8 at Bancroft Road (AL8)	2.0	49% pasture, 29% forest, 12% wetlands, 7% developed

Runoff water quality monitoring was performed by the SRA in accordance with a TCEQ- and USEPA-approved quality assurance project plan (QAPP) (Parsons 2003c). The runoff events sampled included two storms in January 2004, one in May 2004, and one in November 2004. For each event, flow was measured and water quality samples were collected shortly after rain began and every few hours thereafter for one to several days, as stream flow rose and subsequently fell. Some of the key parameters measured are listed in Table 7.

Table 7. Water quality parameters measured during runoff sampling

total and phenolphthalein alkalinity	stream flow
pH	nitrate+ nitrite nitrogen
dissolved oxygen	ammonia nitrogen
5-day carbonaceous biochemical oxygen demand	total Kjeldahl nitrogen
total suspended solids	dissolved orthophosphorus
volatile suspended solids	total dissolved solids
E. coli	specific conductivity
water temperature	salinity

Pollutant Source Assessment

Nonpoint Sources of Pollutants

A nonpoint pollutant source inventory was developed for each watershed and sub-watershed using a system of linked Microsoft Excel spreadsheets. This tool was adapted from the Bacterial Indicator Tool developed by the USEPA (2000). The tool provides monthly and annual loading estimates of indicator bacteria for the HSPF model based on land use, livestock and wildlife populations, the number and failure rate of septic systems, and other watershed properties. Assumptions are easily modified to generate revised loading estimates for HSPF. This tool was modified to address watershed-specific conditions and sources, as well as the nitrate and ammonia nitrogen, orthophosphorus, and biochemical oxygen demand.

On-Site Sewage Facilities

On-site sewage facilities (OSSFs), such as septic tanks, can serve as nonpoint sources of pollutants. Malfunctioning septic tanks are those that have been improperly engineered or installed, poorly maintained, or where soils do not permit the sanitary absorption of septic effluent. In rural and some suburban areas of Adams and Cow Bayou, conventional septic tanks serve as the primary mechanism for sewage disposal. The most recent available data on the abundance of septic tanks in the watersheds comes from the 1990 decennial federal census. In the long questionnaire given to roughly 1 in 6 households, respondents were asked to identify the sewage disposal method of their housing unit as either “public sewer”, “septic tank or cesspool”, or “other means”. In the Adams Bayou watershed, 6,754 housing units (88%) were connected to a public sewer, 888 units (12%) used septic tanks or cesspools for sewage disposal, and 20 units reported an “other” sewage disposal method. In the Cow Bayou watershed, 2,205 housing units (28%) were connected to a public sewer, 5,582 units (71%) used septic tanks or cesspools, and 108 units (1%) reported an “other” sewage disposal method.

In the 2000 census, the questionnaire did not include a question on sewage disposal. Since 1991, when Orange County adopted its OSSF program, it has been a requirement that a soil survey must be performed before installation of an OSSF. Given that almost all soils in the watersheds are unsuitable for conventional septic systems, in most cases an aerobic OSSF must be installed. Thus, since 1991 new housing in areas not served by public sewers has generally required aerobic OSSF systems, and the number of housing units utilizing conventional septic systems has likely remained steady.

Figure 6 displays the density of septic tanks in the Cow and Adams Bayou watersheds, based on the 1990 federal census. The absolute highest densities of septic tanks at that time appear to have occurred near Vidor and between Bridge City and West Orange. A previous report (Hydroscience 1978) cited the Maple Crest neighborhood near Vidor, the Westlawn area near I-10, Orangefield, the Bridge City area along Cow Bayou, and Mauriceville as areas with dense concentrations of conventional septic systems.

Conventional septic tank systems rely on absorption fields to disperse liquid components of sewage into the soil, after solids have settled into the tank. Several factors affect the suitability of soils for septic tank absorption fields (NRCS 2004).

1) frequency and duration of flooding

   Flooding here indicates the temporary inundation of an area caused by overflowing streams, tides, or runoff from adjacent slopes. Flooding may allow the widespread contamination of surface waters with septic tank effluent.

2) frequency and duration of ponding

   Ponding is standing water in a closed depression. Ponding may allow the localized contamination of surface waters with septic tank effluent.

3) soil water permeability

   Limited soil water permeability limits the rate at which the septic field can absorb and transmit septic effluent. The soil hydrologic group indicates the soil water permeability.

4) depth to the saturated zone

   The saturated zone refers to the depth from the land surface down to where the soil is saturated with ground water. Shallow saturated zones may lead to contamination of ground water. Most of the soils in the Adams and Cow Bayou tend to be saturated near the surface at least part of the year, which makes them inappropriate for septic fields.

5) Tendency for subsidence

   Soil subsidence may cause leaks or other malfunctions in the septic tank. Subsidence is not a major problem for many of the soils in these watersheds

Based on one or more of these factors, almost all of the soils in the Adams and Cow Bayou watersheds are very limited in their utility for septic tank absorption fields (Figure 7), according to the Soil Survey Geographic Database (SSURGO) developed by the Natural Resource Conservation Service (NRCS) of the USDA. Extensive site engineering may minimize the effects of some of these factors. A survey of septic tank failure in Texas (Reed Stowe and Yanke 2001) estimated that the overall chronic malfunction rate of OSSF systems in east Texas was 19%, more than any other region in the state. The estimated chronic malfunction rate rose to 54% for systems installed in the fine-textured, clayey soils common in the Adams and Cow Bayou watersheds. In this region, the factor reported to have the highest impact on malfunction was unsuitable soils, followed by the high water table, then system age. Project stakeholders with knowledge of the watersheds, including septic system inspectors, believe that the actual rate of malfunction of conventional septic systems in these watersheds is close to 100%. They cited observations that almost all conventional systems had the cap removed from the septic field drain line, essentially conveying the septage directly from the tank to the ditch. In accordance with these estimates, it was assumed in the model that 95% of the conventional septic systems in these watersheds are malfunctioning.

Properly functioning conventional septic tank systems and aerobic systems were assumed to produce no pollutant loads to the bayous, while loads from malfunctioning septic tank systems were included in the model as point sources to the bayous. Flows from septic systems were estimated based on an average of 2.5 persons per household and 70 gallons of wastewater produced per person per day (Horsely and Whitten 1996). Pollutant concentrations in septic tank effluent (Table 8) were estimated as the approximate average concentrations from a number of published reports (Anderson et al. 1988, Metcalf and Eddy 1991, Canter and Knox 1985, Cogger and Carlile 1984, Brown et al 1984).

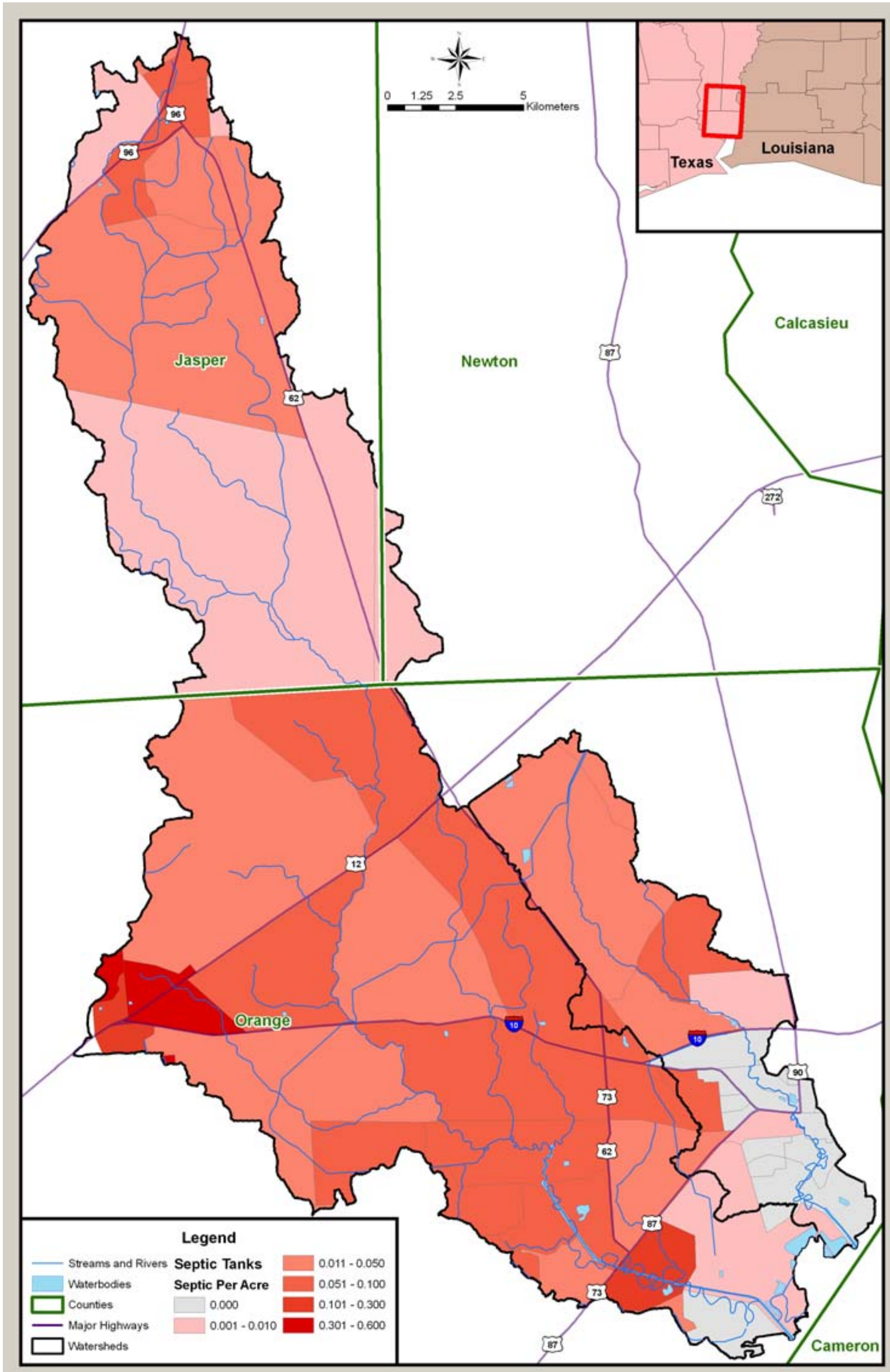

Figure 6. Septic tank density based on 1990 federal census data

Table 8. Assumed pollutant concentrations in malfunctioning septic tank effluent

Parameter	Concentration
E. coli	100,000 cfu/100 ml†
BOD	170 mg/L
Total Suspended Solids	70 mg/L
Ammonia nitrogen	35 mg/L as N
Phosphate phosphorus	15 mg/L as P

cfu = colony forming unit

† includes 10x attenuation factor to account for E. coli death between end of pipe and stream

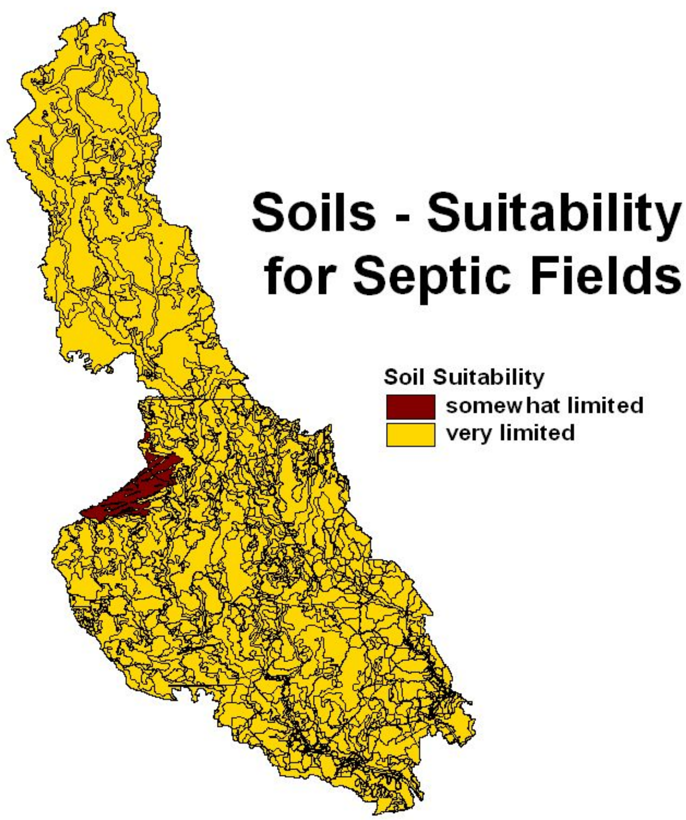

Figure 7. Soil suitability for conventional septic systems in the Adams and Cow Bayou watersheds

Livestock and Manure

Livestock fecal waste may serve as a major nonpoint source pollutant, either by runoff of fecal matter directly deposited on land by grazing animals on pasture, rangeland, or in water, or by application of manure from confined animals to fields as fertilizer. Manure production by livestock was estimated based on the animal population estimate from the 2002 USDA Census of Agriculture multiplied by the estimated average daily manure production rate from the American Society of Agricultural Engineers (ASAE 1998). The E. coli, ammonia nitrogen, and phosphorus production estimates were also derived from published ASAE estimates.

Manure from cattle, horses, sheep, and goats was assumed to be directly deposited to pastureland. A portion of the manure from grazing cattle was assumed to be deposited directly in water as the animals drank from streams. It was assumed for modeling purposes, based on the best estimates of watershed stakeholders, that only 5% of cattle in Adams Bayou watersheds above I-10 drink from the bayous, and 1% of cattle in watersheds below I-10 drink from the bayous. The lower estimate for below I-10 was partly attributable to the more saline and thus less desirable water in the tidal reaches. In the Cow Bayou watershed, it was assumed that 5% of cattle below I-10 and 10% of cattle above I-10 drink from Cow Bayou or its tributaries. It was also assumed that, on average, the cattle getting drinking water from the bayous spend 10 minutes per day in the stream while drinking in June, July, August, or September, 5 minutes per day in March, April, May, October, and November, and do not stand in the bayous to drink from December through February. The fecal deposition to the stream was assumed to be directly proportional to the time spent in the streams. On average, only 0.01% of the total fecal load from grazing cattle in the Adams Bayou watershed was assumed to be deposited directly into Adams Bayou or its tributaries, and 0.03% of the total fecal load from grazing cattle in the Cow Bayou watersheds was deposited to the bayous.

Because there are few if any dairy cattle in the watersheds, and other cattle are not confined, it was assumed that no cattle manure was collected and spread on cropland as fertilizer. However, manure from swine and poultry within the watershed was assumed to be collected and applied to cropland as fertilizer.

Table 9. Pollutant production rates of livestock in manure
(all values from ASAE (1998) except where otherwise noted)

Animal	E. Coli production cfu/animal/day	BOD Production lb/animal/day	Ammonia Nitrogen Production lb/animal/day	Phosphate Phosphorus Production lb/animal/day	Solids Production lb/animal/day
Beef cow	1.04E+11	1.28	0.069	0.074	6.8
Hog	1.08E+10	0.42	0.039	0.024	1.5
Sheep	1.20E+10	0.07	0.005	0.005	0.66
Horse	4.20E+08	1.70	0.079	0.071	15

Goat	1.00E+10#	0.07#	0.005#	0.005#	0.66#
Chicken	1.36E+08	0.02	0.001	0.001	0.06
Turkey	9.30E+07	0.03	0.001	0.004	0.18

best professional judgment – no data exist

Wildlife

Very few data exist on the population size of wildlife species in the watersheds. The whitetail deer population in Jasper County has hovered around 50 per 1,000 acres over the last few years, and that in Newton County has stayed closer to 30 per 1,000 acres, according to information on the Texas Parks and Wildlife Department web site (http://www.tpwd.state.tx.us/ conserve/wildlife_management/pineywood/regulatory/). No deer population estimates were found for Orange County, which has a greater urban influence, and less forest.

Wildlife are assumed to contribute pollutants to all land use categories and subwatersheds. The assumed populations of wildlife are shown in Table 10. Pollutant production rates of wildlife (Table 11) were estimated based on Schueler (2001) and other references in the Bacterial Indicator Tool (USEPA 2000). In cases where pollutant production rates from wildlife species were not available, they were estimated by multiplying the manure production rate estimate for the animal by the average pollutant concentration in manure for other animal species. While the levels of uncertainty in the wildlife populations and pollutant production rates are very large, sensitivity analyses showed that varying these numbers had little effect on the model outcome as wildlife were a relatively minor source.

Table 10. Assumed wildlife population densities for various land use categories

Species	Population Density (animals/ square mile)					
	Cropland	Wetlands	Pasture	Forest	Grassland	Residential
Deer	20	50	20	50	10	40
Waterfowl	10	128	10	0	0	0
Other birds	100	1,500	1,000	1,500	1,500	1,500
Opossum	20	100	50	100	20	50
Raccoon	4	100	4	100	20	50
Rodents	2,000	2,000	2,000	2,000	2,000	2,000

Table 11. Pollutant production rates of wildlife in manure

Animal	E. Coli production (cfu/animal/day)	BOD Production (lb/animal/day)	Ammonia Nitrogen Production (lb/animal/day)	Phosphate Phosphorus Production (lb/animal/day)
Deer	5.00E+08	0.050	3.3E-3	3.2E-3
Waterfowl	2.43E+09	0.011	7.4E-4	7.1E-4
Other birds	1.22E+08	0.0006	3.7E-5	3.5E-5
Opossum	1.25E+08	0.028	1.8E-3	1.8E-3
Raccoon	1.25E+08	0.10	6.5E-3	6.3E-3
Rodents	5.81E+06	0.0027	1.8E-4	1.7E-4

Atmospheric Deposition

Atmospheric deposition was assumed to contribute ammonia nitrogen and nitrate nitrogen to all land uses via wet (precipitation) and dry (particle) deposition. Annual wet and dry deposition rates of ammonia and nitrate nitrogen for the project watersheds were estimated from isopleth maps prepared by the National Atmospheric Deposition Program (NADP 2005). BOD loadings from atmospheric deposition were assumed to equal five times the ammonia nitrogen content to approximate the oxygen demand for conversion of ammonia to nitrate.

Table 12. Daily average atmospheric loadings of pollutants

Pollutant	Wet Deposition (Rain) (lb/acre/day)	Dry Deposition (lb/acre/day)
Ammonia Nitrogen	0.0040	0.0006
Nitrate Nitrogen	0.0048	0.0024
BOD	0.02	0.003

Forest Leaf Litter

Forest leaf litter deposition can be a nonpoint source of nitrogen, phosphorus, and BOD to waters. An estimated 30 pounds of nitrogen and 2 pounds of phosphorus are deposited in leaf litter per acre of forest per year, based on the measurements of Finzi et al. (2001) for a mature loblolly pine/hardwood forest, similar to the dominant type in the Adams and Cow Bayou watersheds. The nitrogen was assumed to be ammonia nitrogen, phosphorus assumed to be phosphate, and a BOD/nitrogen ratio of 5 was used to estimate the BOD content. Evergreen forests were assumed to deposit leaf litter evenly throughout the year, while litter fall from deciduous forests was assumed to occur primarily in October and November, and mixed forests were intermediate.

Residential Area Nonpoint Sources

Potential pollutant sources in residential areas that were considered in the model include malfunctioning septic systems, dog and cat fecal waste, wildlife fecal waste, and lawn fertilizer. Malfunctioning septic systems were described previously and incorporated in the model independently. The populations of dogs and cats were estimated based on the number of households in each subwatershed, along with the national average numbers of 0.58 dogs and 0.66 cats per household, from the American Veterinary Medicine Association (AVMA, 2002). Estimates of pollutant loadings to residential land in pet fecal waste are summarized in Table 13. It was assumed that 100% of dog feces and 50% of cat feces was applied outdoors, and that 20% of dog waste was collected and removed to a landfill. Fecal production and pollutant concentrations were estimated from the Bacterial Indicator Tool (USEPA 2000) and from Baker et al (2001).

Table 13. Pollutant production rates of dogs and cats

Animal	E. Coli production (cfu/animal/day)	BOD Production (lb/animal/day)	Ammonia Nitrogen Production (lb/animal/day)	Phosphate Phosphorus Production (lb/animal/day)
Dog	4.1E+09	0.10	6.5E-3	6.3E-3
Cat	5.4E+08	0.028	1.8E-3	1.8E-3

To estimate the amount of commercial fertilizer applied to lawns, it was assumed that 50% of the residential land was covered by turf grasses, nitrogen was applied to turf at the rate of 4 pounds of ammonia nitrogen per 1,000 square feet per year, and phosphate phosphorus at a rate of 2 pounds per 1,000 square feet per year, in line with the low end of Texas Agricultural Extension recommendations for St. Augustine and Bermuda grass lawns in East Texas. It was assumed that the BOD content of fertilizer was 5 times the ammonia nitrogen content to account for the oxidation of ammonia. It was also assumed that 49% of the applied nutrients were collected and removed to the landfill each year as grass clippings and other yard waste (Baker et al., 2001).

Unauthorized Discharges

Some common types of unauthorized discharges are leaks and overflows from the sanitary sewer system, and cross-connections between the sanitary and storm sewer systems. Unlawful discharges by septic tank and grease trap cleaners and haulers are also possible. These discharges are episodic and may impact the bayous in the vicinity of the discharge a great deal for a short period of time until the pollutants are dispersed. It is difficult to gage the magnitude of unauthorized discharges, as very few data exist. Inspection of permit files revealed only a few instances where unauthorized discharges were reported to state authorities, and these reports were only made since 2004, from two facilities where TCEQ inspectors noted that they had not been reporting sewage leaks. There is no reason to expect that problems with sewer systems are limited to these two facilities, so the magnitude of the problem is likely underestimated. The reported unauthorized discharges are noted in Table 14. Since only an estimate of the volume of the unauthorized discharge was reported, the concentrations of pollutants were estimated as the reported typical domestic sewage of medium concentration (Metcalf and Eddy 1991). It was also assumed that all of the nutrients and BOD discharged ultimately made it into the bayou, but that the loads of E. coli bacteria were diminished by one order of magnitude due to dieoff before they entered the bayou. To estimate annual loadings, the reported discharges from the years in which discharges were reported were assumed to be representative of other years.

Point Sources of Pollutants

Point source loadings were estimated based on a combination of self-reported effluent data (from January 2000 through March 2005) and effluent measurements made during the intensive surveys of the summer of 2004. Most facilities with permitted discharges to the bayous are required to report each month the average measured flow rate of their discharge. Most facilities are also required to report on a monthly basis either the monthly total loads or average concentrations of one or more specific pollutants or other parameters in their wastewater discharge to the bayous. In cases where the facility did not self-report a pollutant concentration or load, that load was estimated using the self-reported monthly average flow and the average concentration measured during the intensive surveys. Point source loads to Adams and Cow Bayou are summarized in Tables 15 and 16.

In some cases, sewage treatment facilities receive more flow than they are able to treat during storm events. This is typically caused by inflow and infiltration into the sewers, as well as storm drains connected to the sanitary sewers. Facilities will typically disinfect but not otherwise treat these sewage flows exceeding capacity before discharging them to the bayou. Many sewerage facilities have made extensive efforts to reduce inflow and infiltration to sanitary sewers to minimize these untreated storm discharges. The extent of the remaining problem is not known. However, the City of Bridge City has reported to the TCEQ the volume and BOD and TSS content of their excess storm flows, and that data is summarized in Table 16.

Table 14. Estimated pollutant loads from reported unauthorized discharges

Facility Name	Date	Volume gallons	Fecal coliform orgs	BOD_5 lb	NH3-N lb	PO4-P lb	TKN lb	TSS lb
Orange County WCID #2	2/11/2004	200,000	2.4E+12	366	42	8	25	366
	5/13/2004	180,000	2.2E+12	330	37	7	22	330
	6/24/2004	100,000	1.2E+12	183	21	4	12	183
	6/25/2004	200,000	2.4E+12	366	42	8	25	366
	7/17/2005	2,000	2.4E+10	4	0.4	0.1	0.2	4
City of Bridge City	1/31/2005	~0	0	0	0	0	0	0
	5/16/2005	150	1.8E+9	0.3	0.03	0.01	0.02	0.3
	7/19/2005	8,000	9.6E+10	15	2	0.3	1	15

Table 15. NPDES point sources to Adams Bayou: estimated/reported average pollutant loads, 2000 - 2005

Facility Name	Permit Number	Flow MGD	Fecal coliform cfu/day	BOD_5 lb/day	NH3-N lb/day	NO3-N lb/day	PO4-P lb/day	TKN lb/day	TSS lb/day	VSS lb/day
A. Schulman‡	WQ0000337	0.028	0	0.38	NA	NA	0.12	NA	0.30	NA
Orange County WCID #2	WQ0010240	0.65	2.5E+9	17	21	12	30	18	33	27
City of Pinehurst	WQ0010597	0.35	1.0E+9	14	14	5.9	14	27	36	30
City of Orange Jackson St. Plant Outfall 002 (stormwater)	WQ0010626	0.29	3.0E+9	5.7	5.3	NA	NA	NA	15	NA

‡ includes multiple outfalls: storm water and process/utility/domestic flows

Table 16. NPDES point sources to Cow Bayou: estimated/reported average pollutant loads, 2000 - 2005

Facility Name	Permit Number	Flow MGD	Fecal coliform cfu/day	BOD_5 lb/day	NH3-N lb/day	NO3-N lb/day	PO4-P lb/day	TKN lb/day	TSS lb/day	VSS lb/day
Jasper Co. WCID #1	WQ0010808	0.15	2.2E+9	20.0	2.1	0.12	4.5	8.9	28.7	27.7
Bayou Pines Park (Edward N. Smith, Jr.)	WQ0011315	0.0013	6.3E+8	0.15	0.054	0.0012	0.010	0.071	0.38	0.30
Blacksher Development Corp. (Waterwood Estates)	WQ0013691	0.0076	2.2E+7	0.58	0.047	0.41	0.15	NA	0.95	NA
City of Bridge City	WQ0010051	0.94	5.0E+8	28	8.6	33	33	16	49	40
City of Bridge City excess storm flow †	WQ0010051	0.11	NA	29	NA	NA	NA	NA	13	NA
Chevron Phillips Chemical Orange Plant	WQ0000359	1.1	1.6E+9	26	4.3	1.1	18	9.6	173	42
Firestone Polymers Orange Plant	WQ0000454	0.76	3.6E+7	35	3.1	0.25	3.9	13	117	88
Honeywell International Inc. ‡	WQ0000670	1.0	8.6E+8	21	0.6	0.0	0.1	3.3	13	11
Lanxess Corp.	WQ0001167	3.7	3.6E+9	68	3.7		13	17	176	
Orangefield ISD	WQ0011607	0.016	1.8E+6	0.34	0.018	1.1	0.62	0.18	0.56	0.56
PCS Development	WQ0011916	0.010	1.0E+8	0.14	0.011	0.99	0.33	0.17	0.75	0.28
Printpak, Inc.	WQ0002858	0.02	4.3E+7	0.41	0.0059	0.26	0.058		0.34	
Sabine River Authority	WQ0012134	0.0008	1.1E+5	0.018	0.012		0.052		0.030	
Sunrise East Apartments (Gulflander Partners Group)	WQ0013488	0.0072	1.4E+6	0.43	0.20	0.52	0.24		0.83	
Texas Polymer Services, Inc. ‡	WQ0002835	0.42	4.1E+7	16	0.064	3.6	0.64		40	
Texas Department of Transportation	WQ0011457	0.0040	1.2E+6	0.20	1.2	0.89	0.73	1.4	0.46	0.44

† excess storm flows exceeded treatment capacity, bypassed treatment process except disinfection, then were blended with treated wastewater before discharge to bayou

‡ includes multiple outfalls: storm water and process/utility/domestic flows

Model Calibration

The HSPF model of Cow Bayou was calibrated to USGS daily measured flows from Cow Bayou at SH 12 for the period from October 1, 2002 through March 28, 2005. The calibration was performed manually as semi-automated calibration software did not work with the high water table, low topography algorithms used. The primary calibration targets included annual, seasonal, and monthly water balances, and the flow duration curve. Additionally, storm event runoff volumes were used as a calibration target. Figure 8 compares the simulated and observed flow duration curves for Cow Bayou at SH 12. A flow duration curve depicts the percentage of the time that a given flow is exceeded. It can be seen that the maximum flow observed at this site was approximately 3,000 cfs for the calibration period, the median flow was approximately 30 cfs, and there is less than 1 cfs of flow on about 74% of the days. The model simulation agrees well with the observed flow duration curve across all flow conditions.

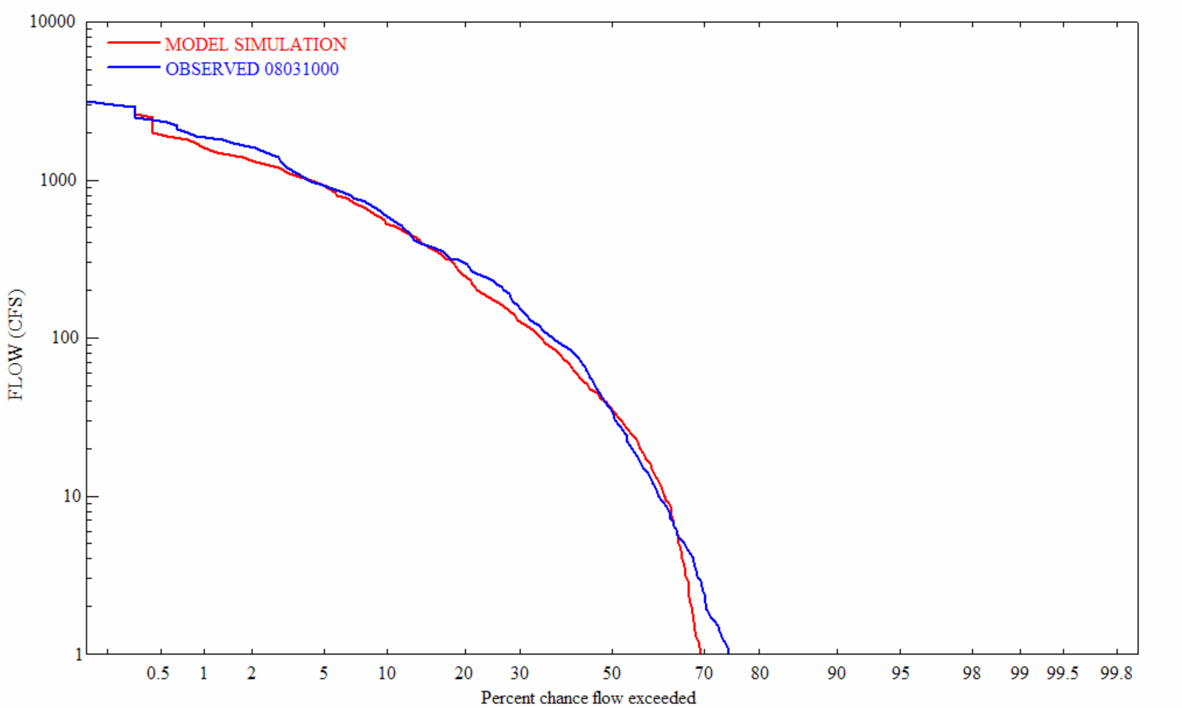

Figure 8. Observed and simulated flow duration curves for Cow Bayou at SH 12

Figure 9 displays a time series of observed vs predicted daily flows in Cow Bayou at SH 12. While there is some deviation between observed and modeled peak storm flows, the deviations occur in both positive and negative directions to a roughly equal extent. Some differences are expected due to the spatial and temporal heterogeneity of rainfall, and the distance from the rain gage to various points in the watershed. The overall correlation coefficient between observed and modeled flows was 0.85.

Figures 10 and 11 display seasonal and monthly flow calibration results. Table 17 compares measured and modeled flow summaries for annual and seasonal periods. The model underpredicted flows in 2002 and 2003, and overpredicted flows in 2004. The model also underpredicted winter flows and overpredicted summer flows. This was believed to be largely due to the influence of a few large storms, which in turn is very sensitive to rainfall estimates. It may also be due to the extent of saturation of the water holding capacity of wetlands, which is primarily adjusted in the model with the upper and lower zone normal water storage parameters. Extensive efforts did not improve the overall calibration.

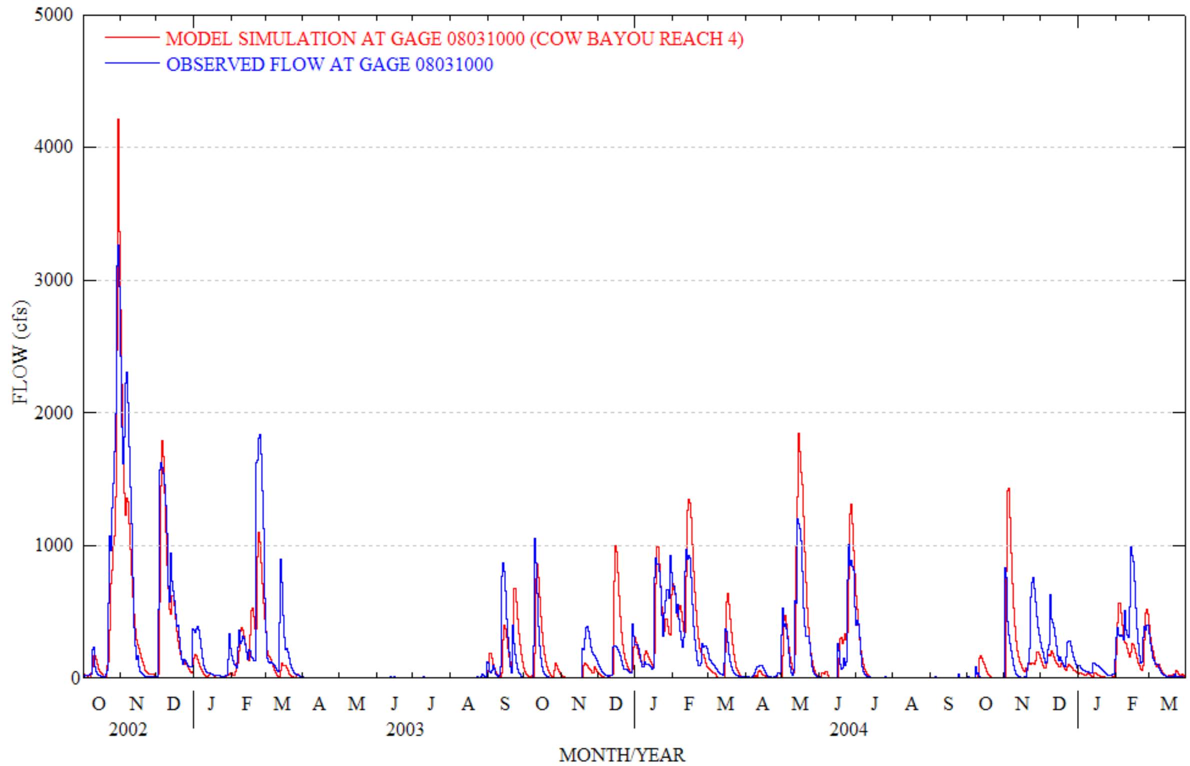

Figure 9. Observed and simulated flows in Cow Bayou at SH 12

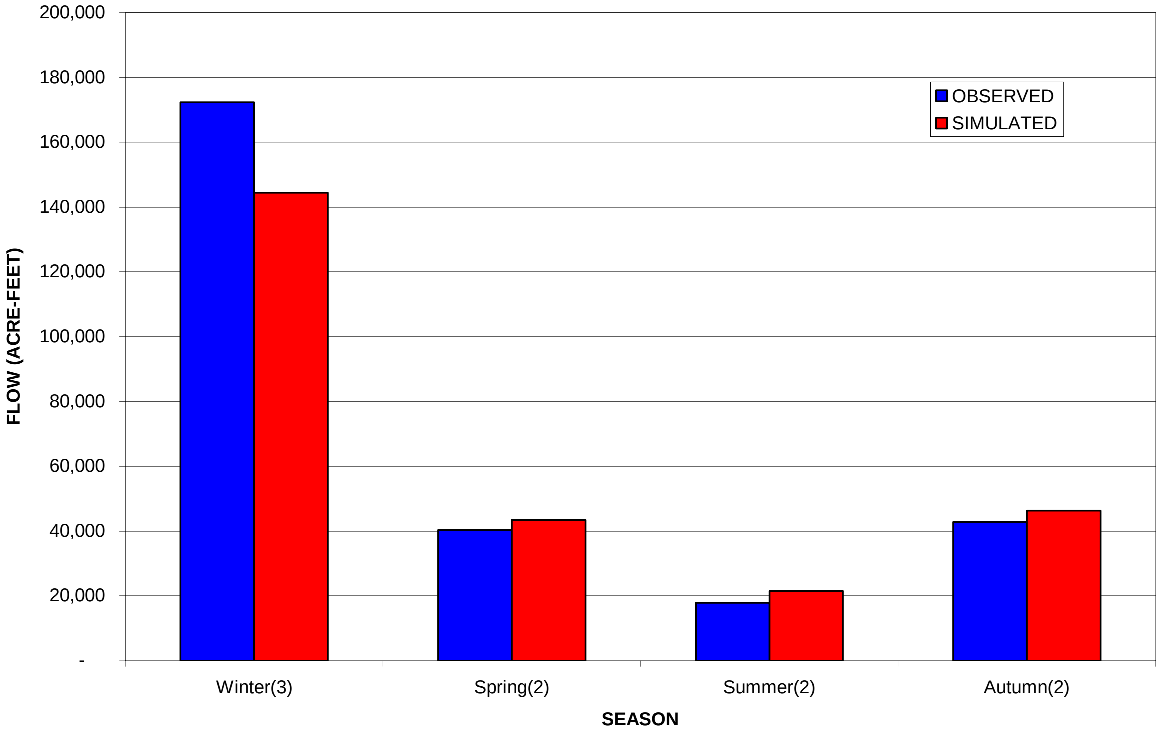

Figure 10. Observed and simulated seasonal flows in Cow Bayou at SH 12*

*for the period 10/1/2002 – 3/28/2005. The number in parenthesis indicates the number of seasons included

Table 17. Flow comparisons for Cow Bayou at SH 12

Period	Observed Flow acre-feet	Simulated Flow acre-feet	% Difference
2003 annual	82,516	66,851	-19%
2004 annual	127,456	142,349	12%
Winter (2002-3, 2003-4, and 2004-5)	172,360	144,485	-16%
Spring (2003 and 2004)	40,365	43,463	8%
Summer (2003 and 2004)	17,933	21,504	20%
Fall (2003 and 2004)	42,770	46,362	8%

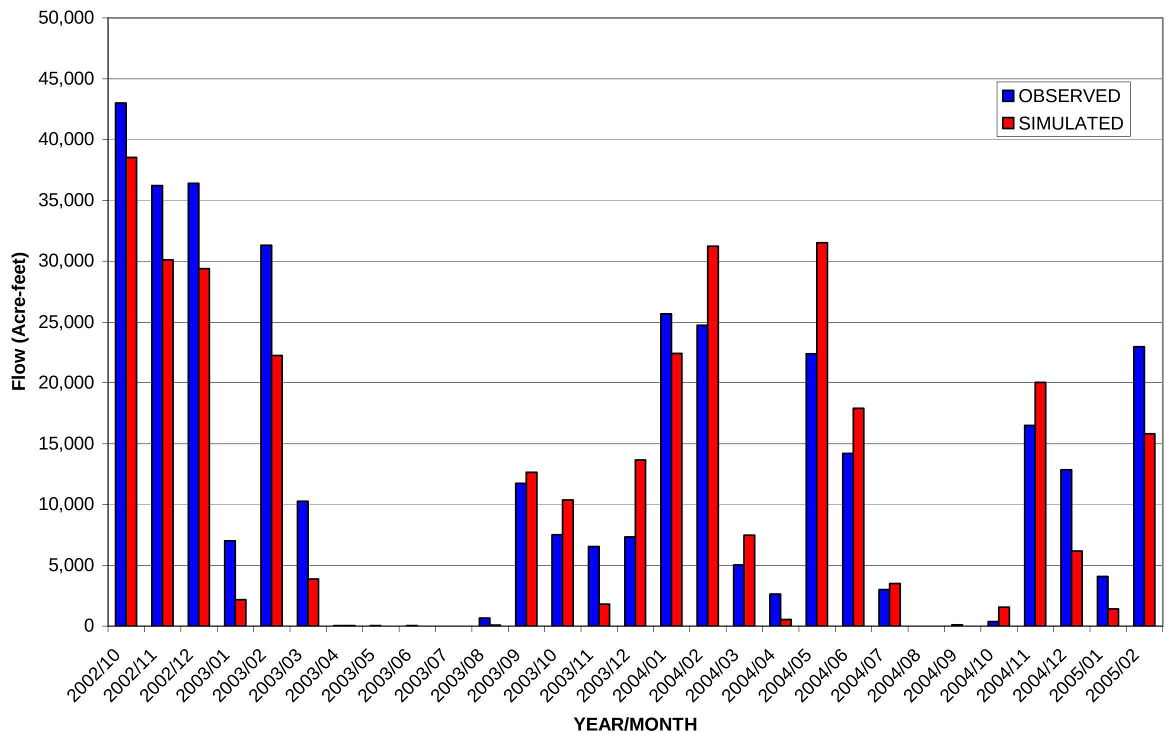

Figure 11. Observed and simulated flows by month in Cow Bayou at SH 12*

* for the calibration period 10/1/2002 – 3/28/2002

Sediment Erosion Calibration

Sediments are an important transport mechanism for pollutants to the bayous, and also exert significant control over the transport and availability of pollutants within the bayous. Annual sediment loads at the edge of fields were estimated from soil texture, soil erodability factor, topography, rainfall, land cover and management practices using the Uniform Soil Loss Equation (USLE) of the NRCS. Figure 12 presents the edge of stream soil loss rates for various land use categories in Cow Bayou. The calculations for each watershed land use are presented in Appendix A. The annual sediment loads calculated in HSPF for each land use were calibrated to match the USLE estimates.

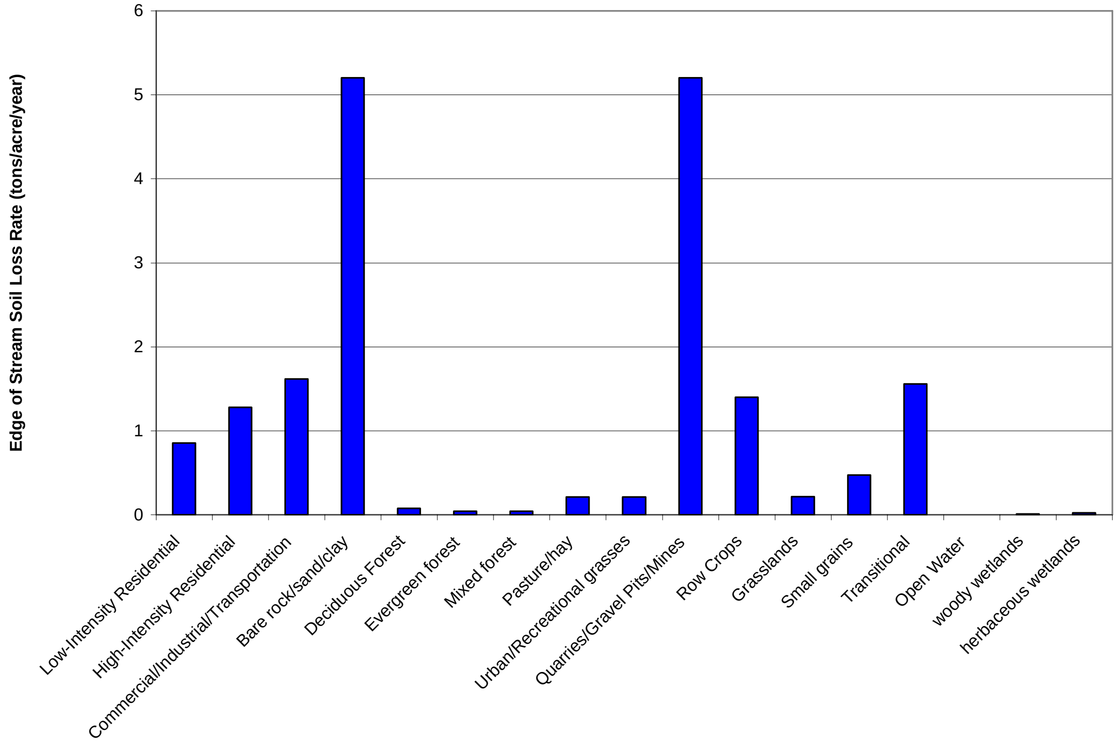

Figure 12. Edge of stream sediment loading rates for Cow Bayou land uses

Water Quality Calibration

With only two storm events at each of three monitoring stations, and considering the spatial and temporal variation in rainfall, water quality calibrations were somewhat less rigorous than flow calibrations. Observed water quality parameter measurements were compared to model concentration time series data. Model parameters were adjusted within physically realistic ranges used in prior modeling studies to ensure that the average model concentrations were similar to the average of measured concentrations, and that the range of model concentrations encompassed the measured concentrations. However, given the uncertainties in the rain and other model input data, the HSPF model is not designed to reliably simulate pollutant concentration time series for individual storm events, but rather to simulate pollutant loadings over a longer period of time. The concentration time series comparisons indicate that the model captures the general trends of water quality, and the differences between watersheds, but does not precisely match every storm event at every station.

Loading Summary and Source Assessment

The estimated pollutant loading from point and nonpoint sources to the bayous are summarized in Figures 13 to 36. Detailed tables describing loading from individual sub-watersheds are included in the appendix. Malfunctioning septic tanks are calculated to be a major source of many key pollutants based on the modeling assumptions. It is important to note that a large pollutant source to the bayou may not necessarily be an important cause of the pollution problem, for two reasons. First, large pollutant loads may be associated with large flows, representing a low concentration that actually dilutes the instream concentration of the pollutant. Second, the pollutant assimilation capacity of the bayous varies from location to location. Lower reaches of the bayou hold much more water and are frequently flushed by tidal mixing with the Sabine River. Thus, lower reaches of the bayous have much greater assimilative capacity than the upper reaches. Therefore, the WASP model will be required to quantify the importance of a pollutant source in terms of the water quality impairments.

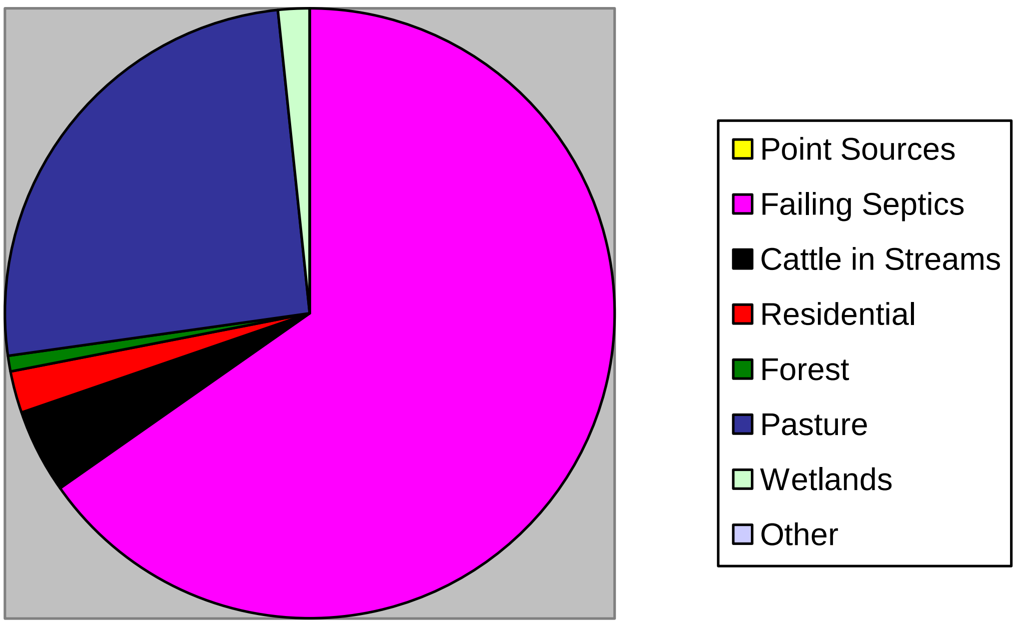

Figure 13. Sources of *E. coli* loading to Adams Bayou above I-10

Total annual load ~ 2.1x 10^{14} cfu

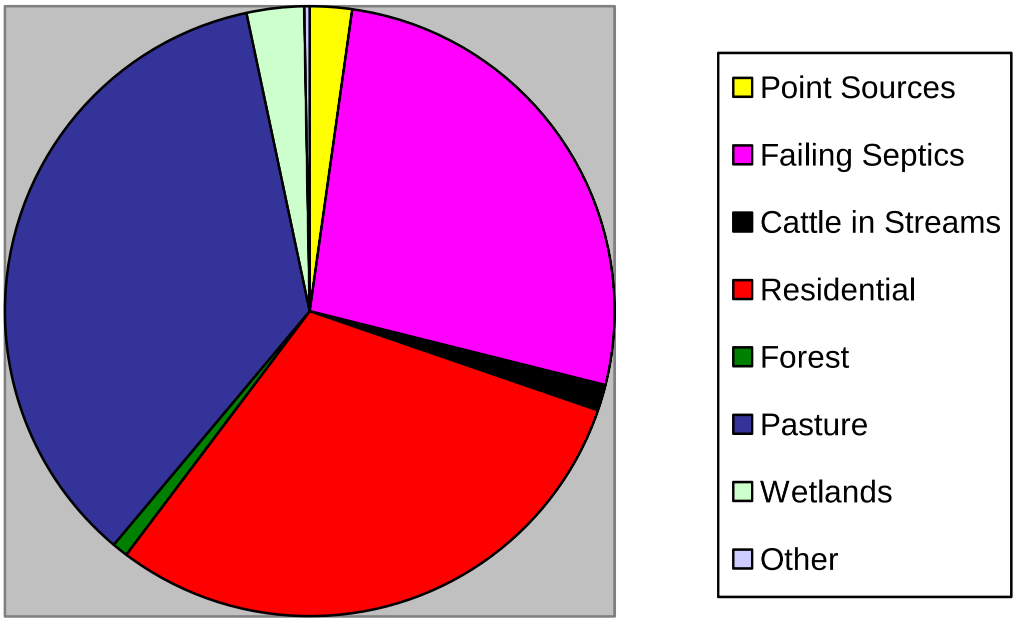

Figure 14. Sources of *E. coli* loading to Adams Bayou below I-10

Total annual load ~ 5.6 x 10^{13} cfu

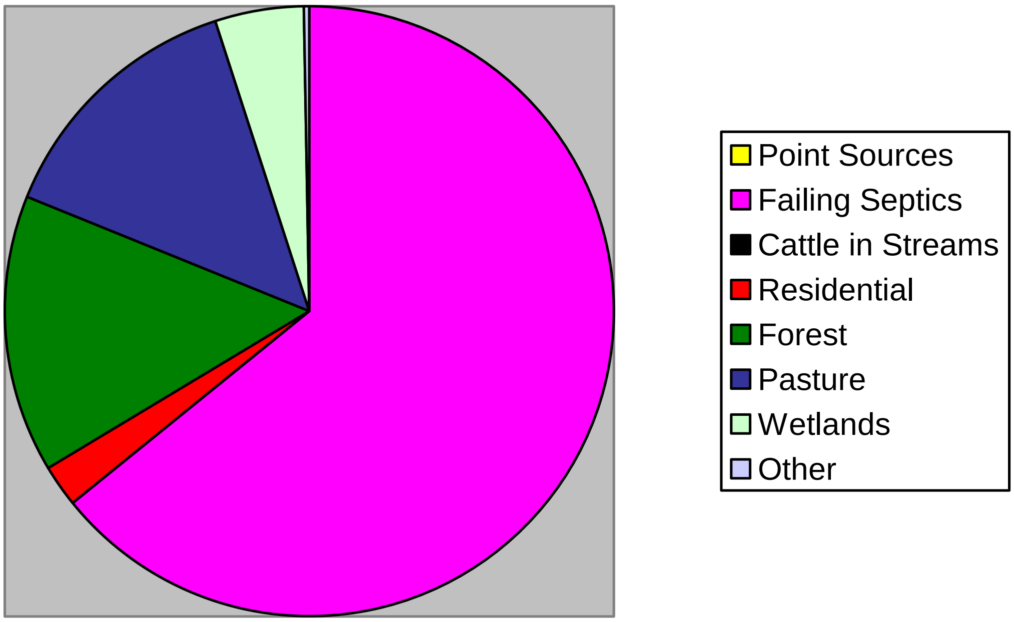

Figure 15. Sources of BOD loading to Adams Bayou above I-10

Total annual load ~ 80,600 pounds

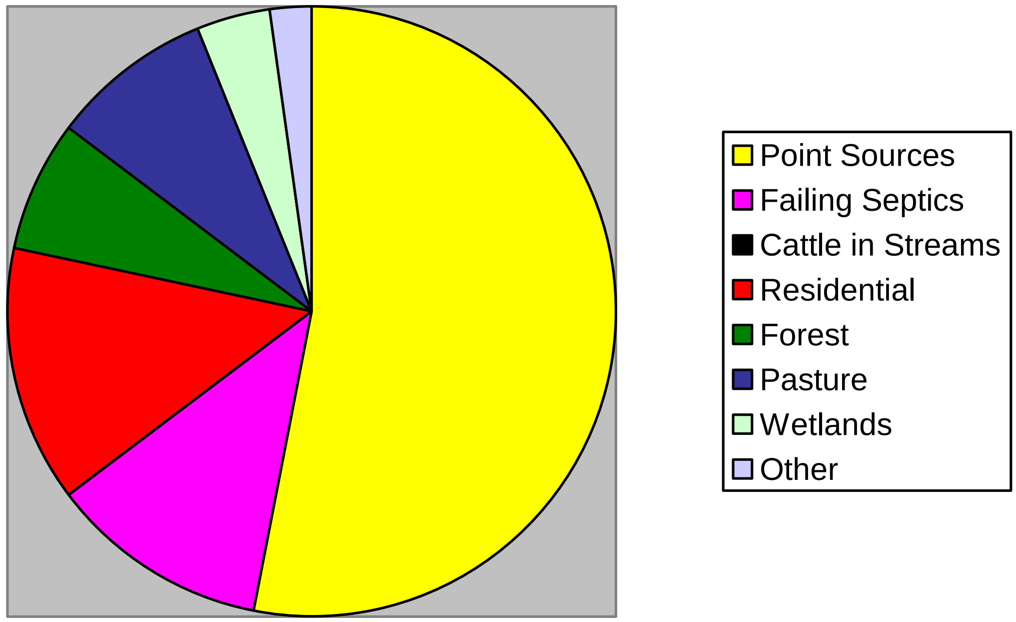

Figure 16. Sources of BOD loading to Adams Bayou below I-10

Total annual load ~ 47,100 pounds

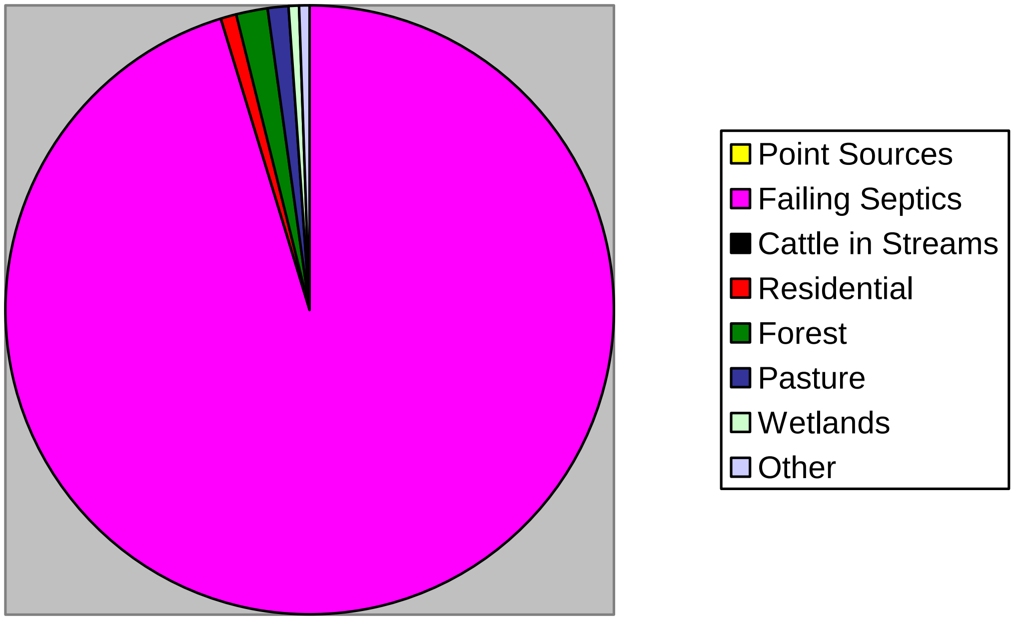

Figure 17. Sources of ammonia nitrogen loading to Adams Bayou above I-10

Total annual load ~ 11,300 pounds

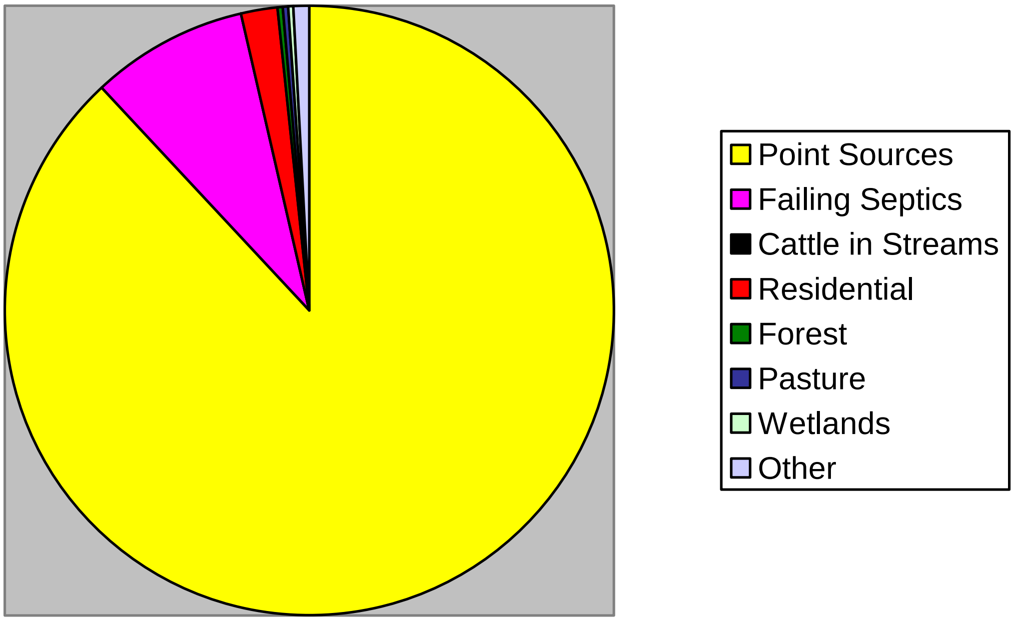

Figure 18. Sources of ammonia nitrogen loading to Adams Bayou below I-10

Total annual load ~ 14,400 pounds

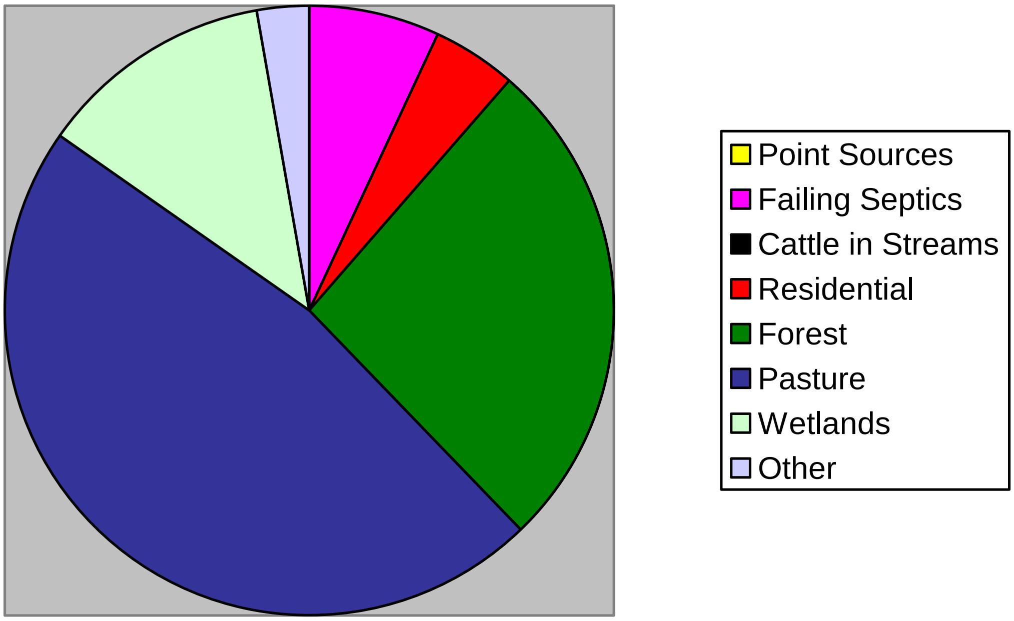

Figure 19. Sources of nitrate nitrogen loading to Adams Bayou above I-10

Total annual load ~ 400 pounds

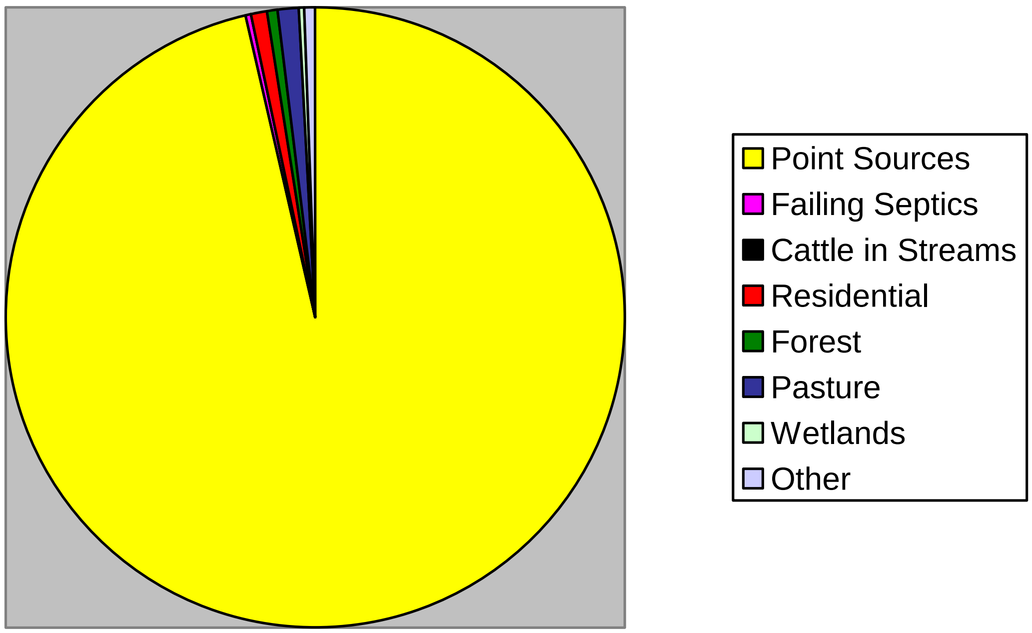

Figure 20. Sources of nitrate nitrogen loading to Adams Bayou below I-10

Total annual load ~ 6,600 pounds

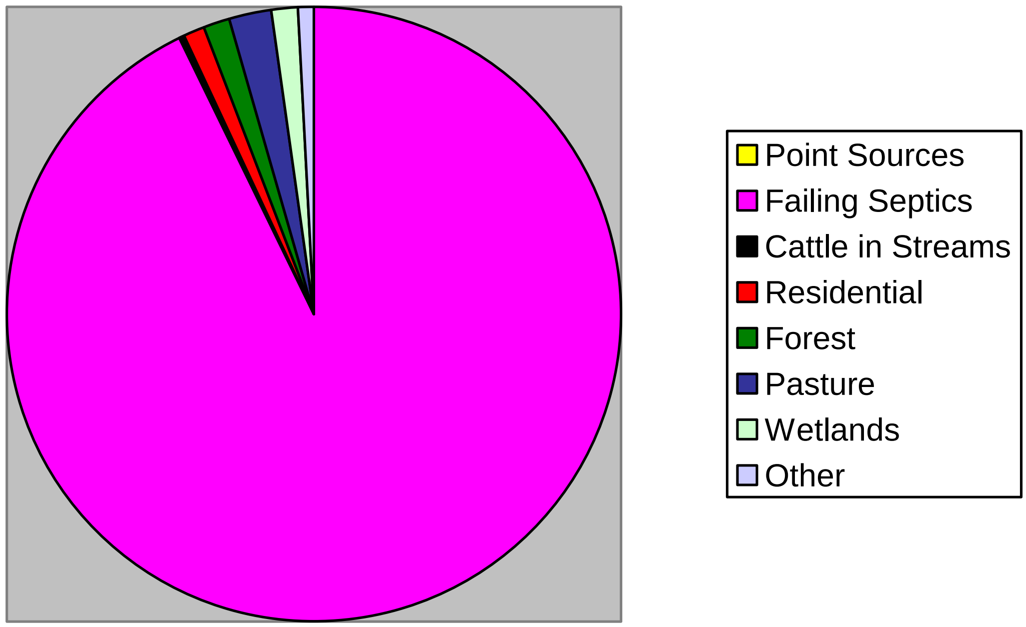

Figure 21. Sources of phosphate phosphorus loading to Adams Bayou above I-10

Total annual load ~ 4,950 pounds

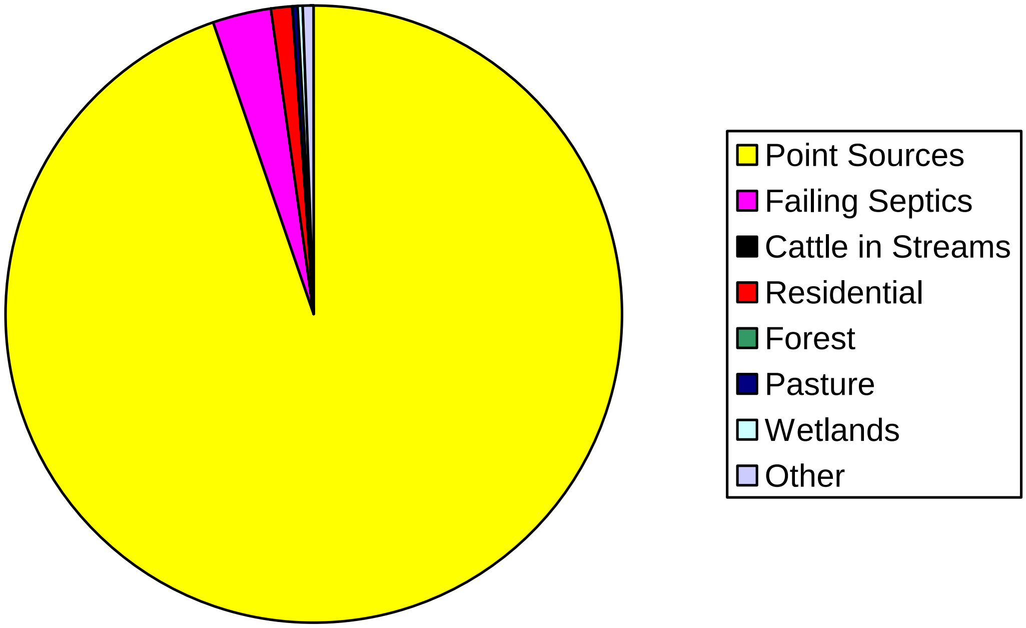

Figure 22. Sources of phosphate phosphorus loading to Adams Bayou below I-10

Total annual load ~ 17,100 pounds

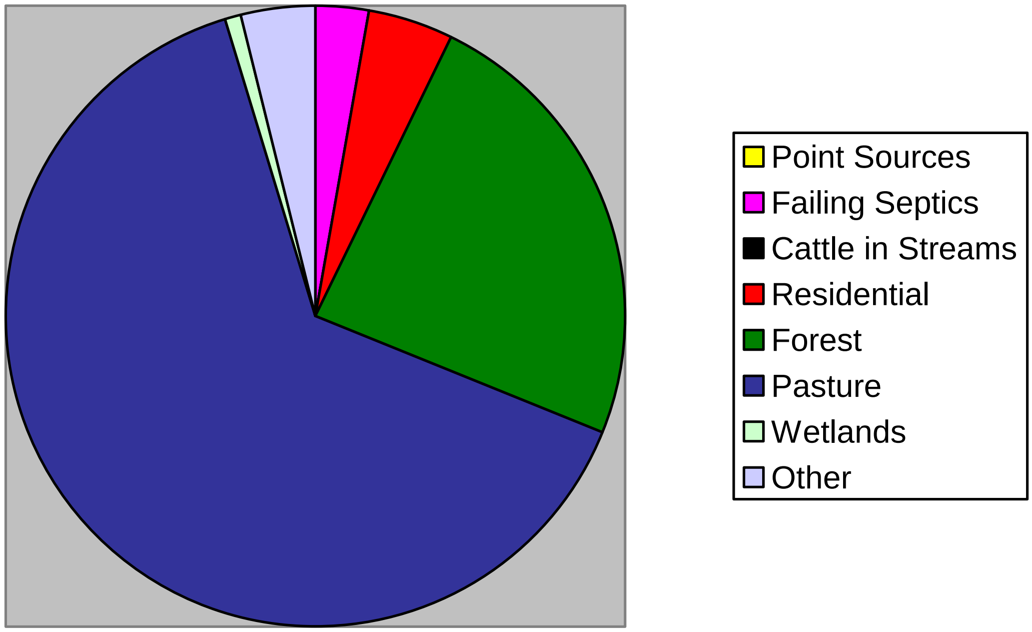

Figure 23. Sources of sediment loading to Adams Bayou above I-10

Total annual load ~ 442 tons

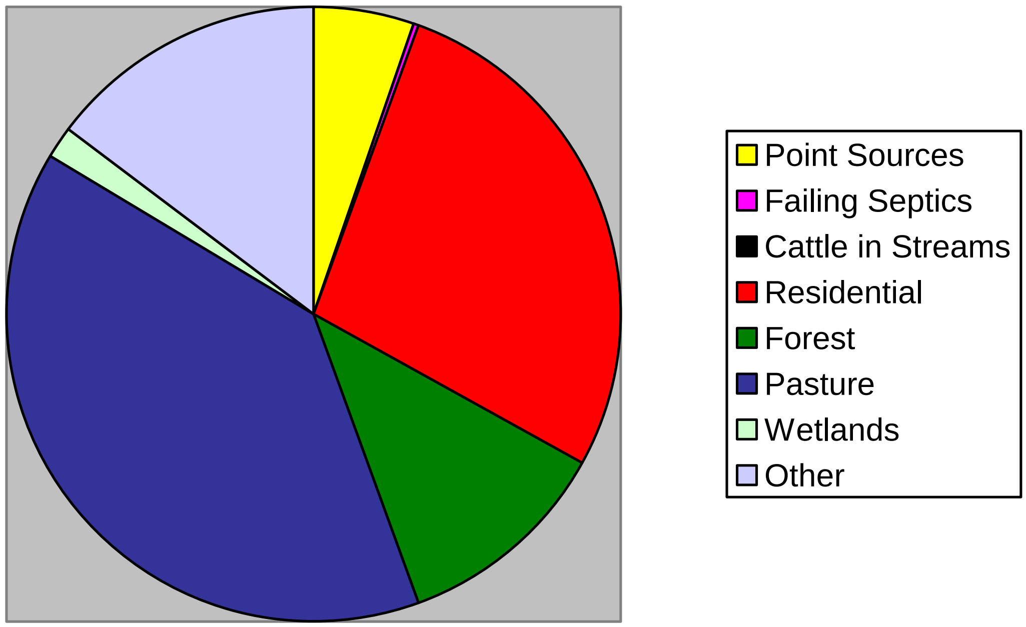

Figure 24. Sources of sediment loading to Adams Bayou below I-10

Total annual load ~ 250 tons

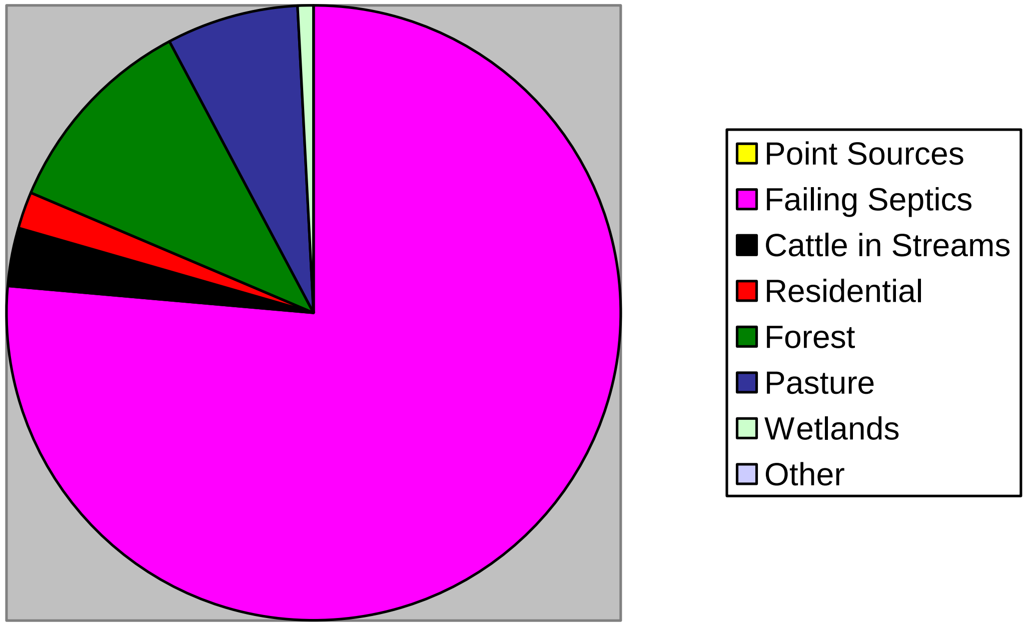

Figure 25. Sources of *E. coli* loading to Cow Bayou above I-10

Total annual load ~ 1.1 x 10^{15} cfu

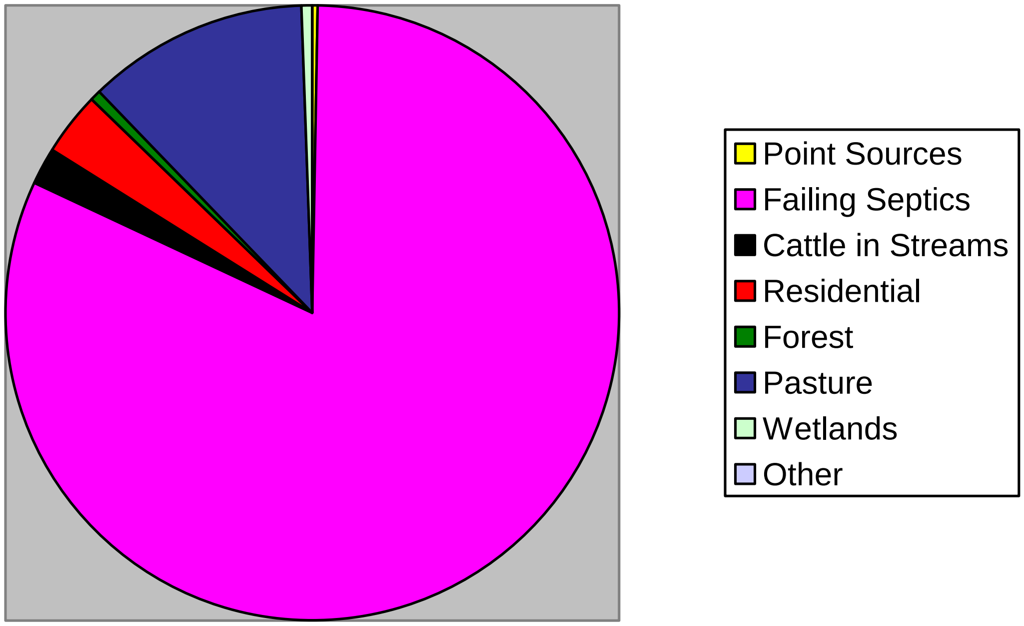

Figure 26. Sources of *E. coli* loading to Cow Bayou below I-10

Total annual load ~ 7.8 x 10^{14} cfu

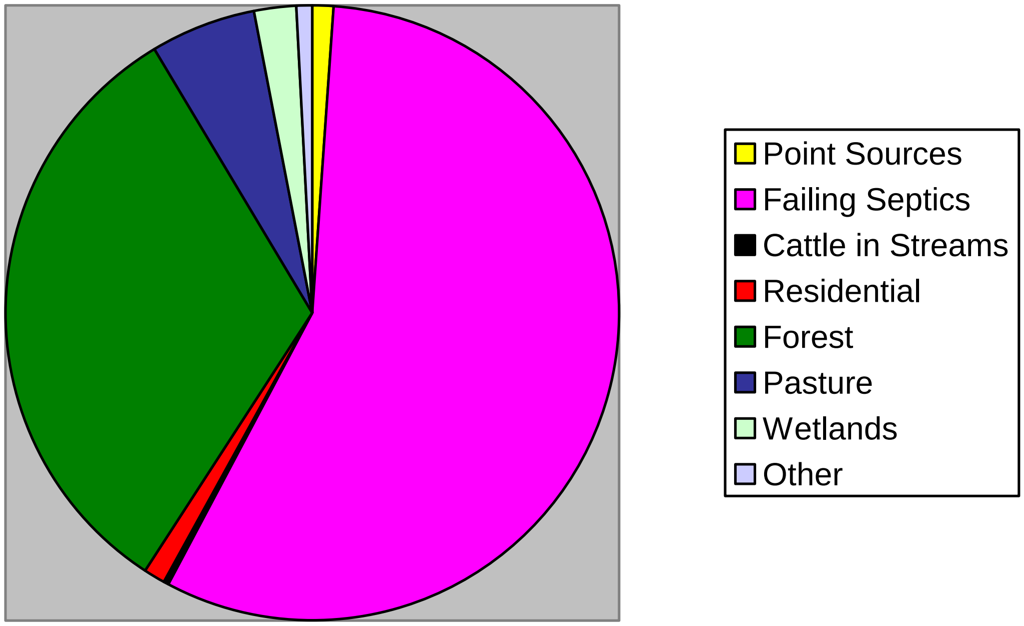

Figure 27. Sources of BOD loading to Cow Bayou above I-10

Total annual load ~ 601,000 pounds

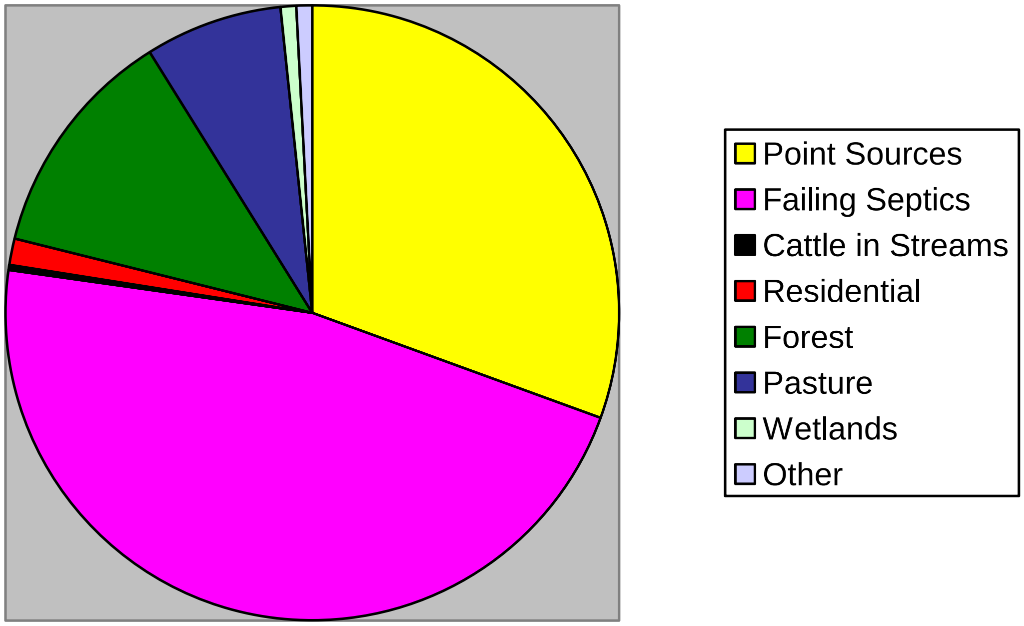

Figure 28. Sources of BOD loading to Cow Bayou below I-10

Total annual load ~ 504,000 pounds

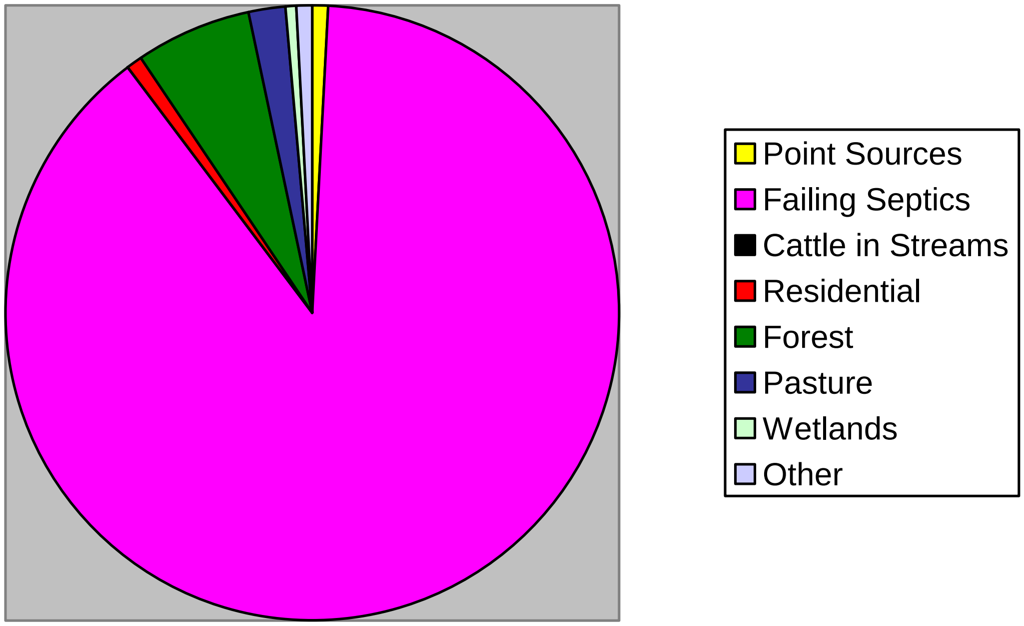

Figure 29. Sources of ammonia nitrogen loading to Cow Bayou above I-10

Total annual load ~ 78,000 pounds

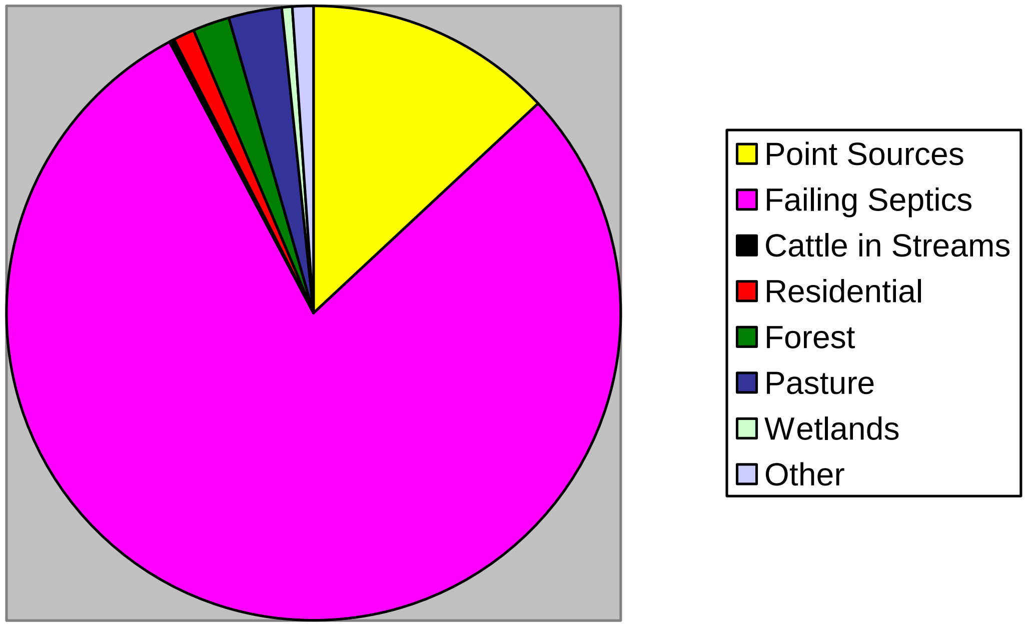

Figure 30. Sources of ammonia nitrogen loading to Cow Bayou below I-10

Total annual load ~ 61,100 pounds

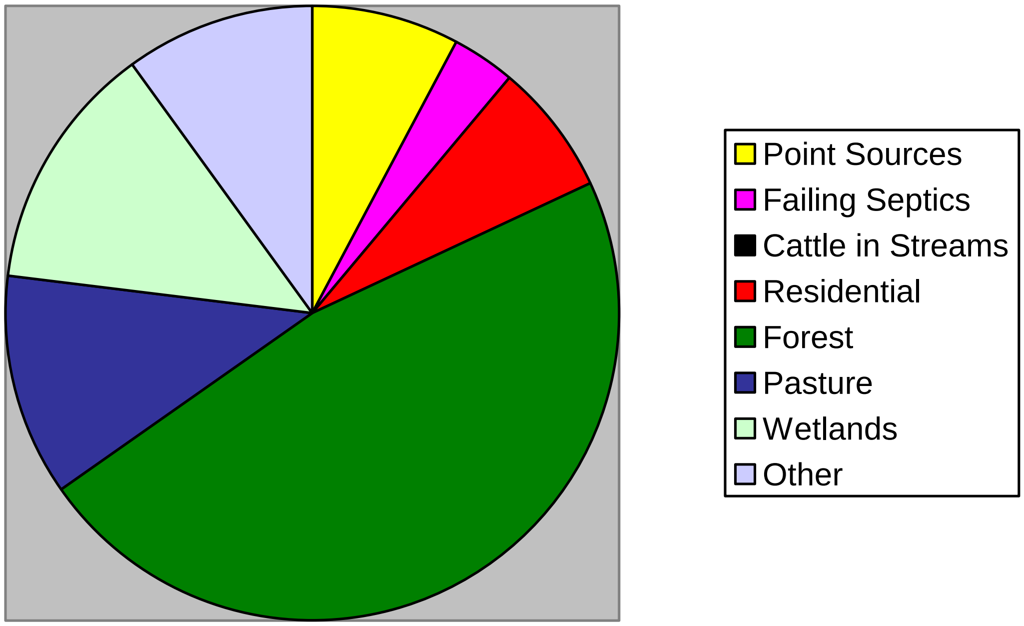

Figure 31. Sources of nitrate nitrogen loading to Cow Bayou above I-10

Total annual load ~ 5,300 pounds

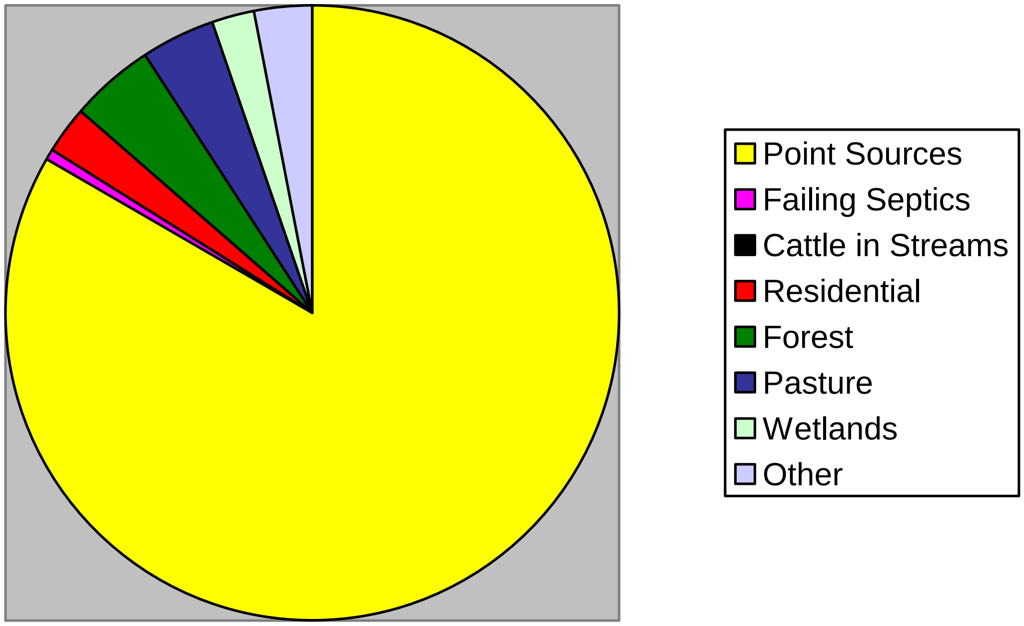

Figure 32. Sources of nitrate nitrogen loading to Cow Bayou below I-10

Total annual load ~ 17,800 pounds

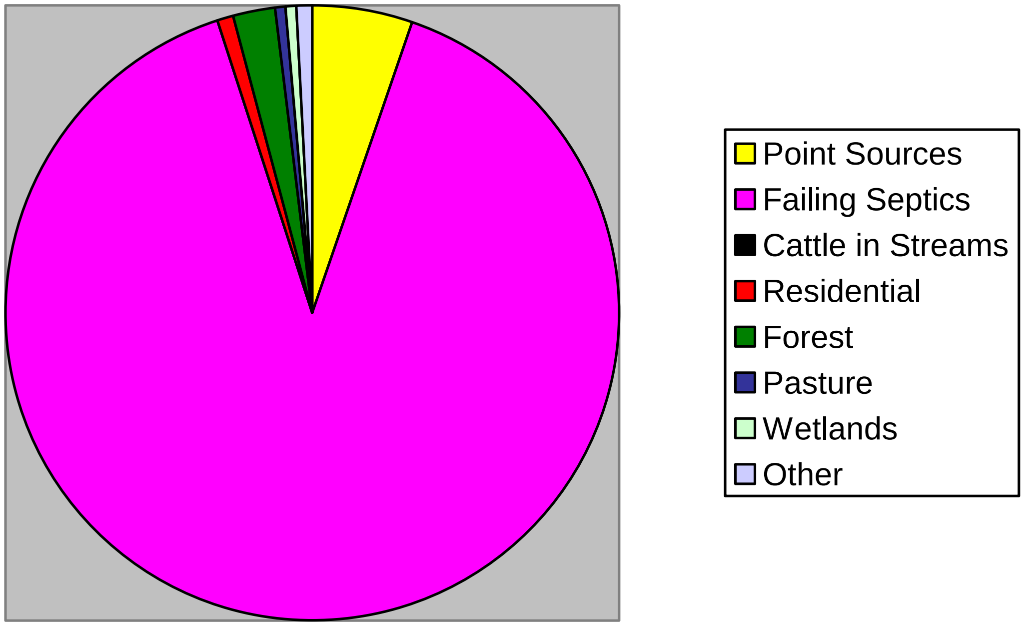

Figure 33. Sources of phosphate phosphorus loading to Cow Bayou above I-10

Total annual load ~ 33,500 pounds

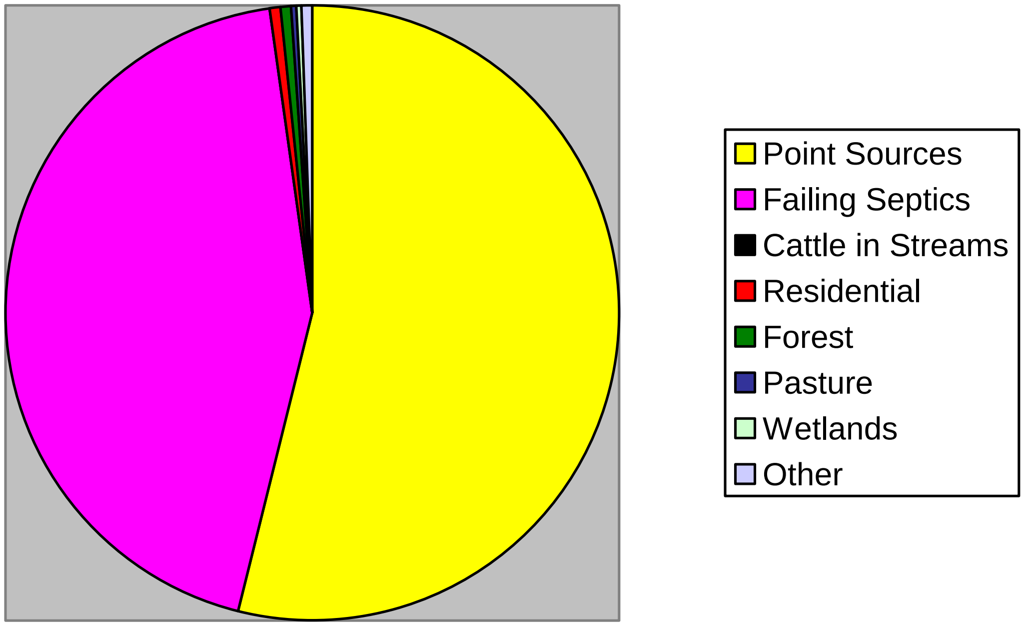

Figure 34. Sources of phosphate phosphorus loading to Cow Bayou below I-10

Total annual load ~ 47,600 pounds

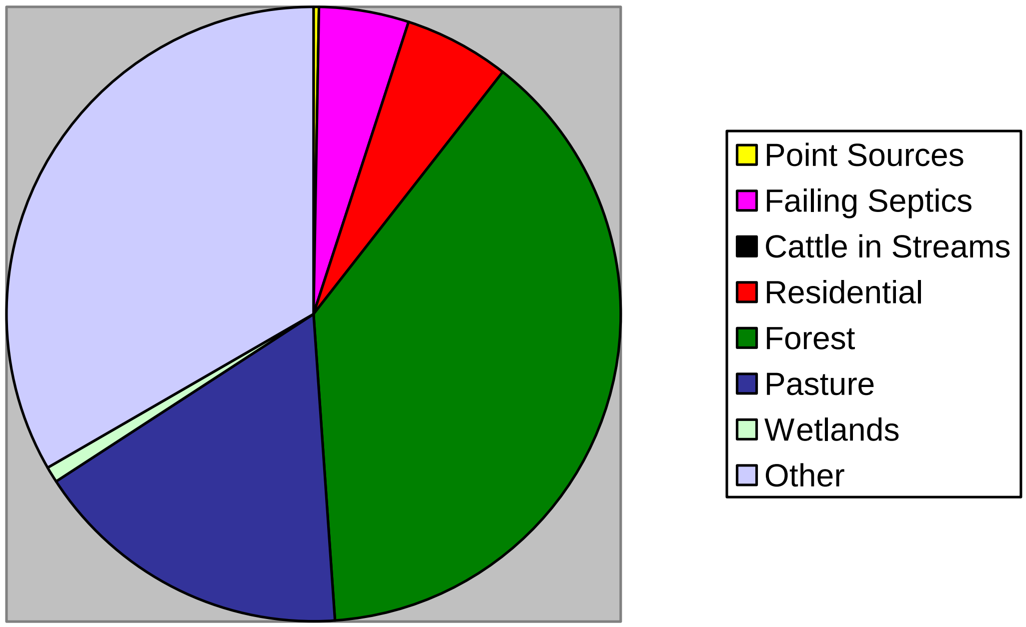

Figure 35. Sources of suspended solids loading to Cow Bayou above I-10
Total annual load ~ 1,550 tons

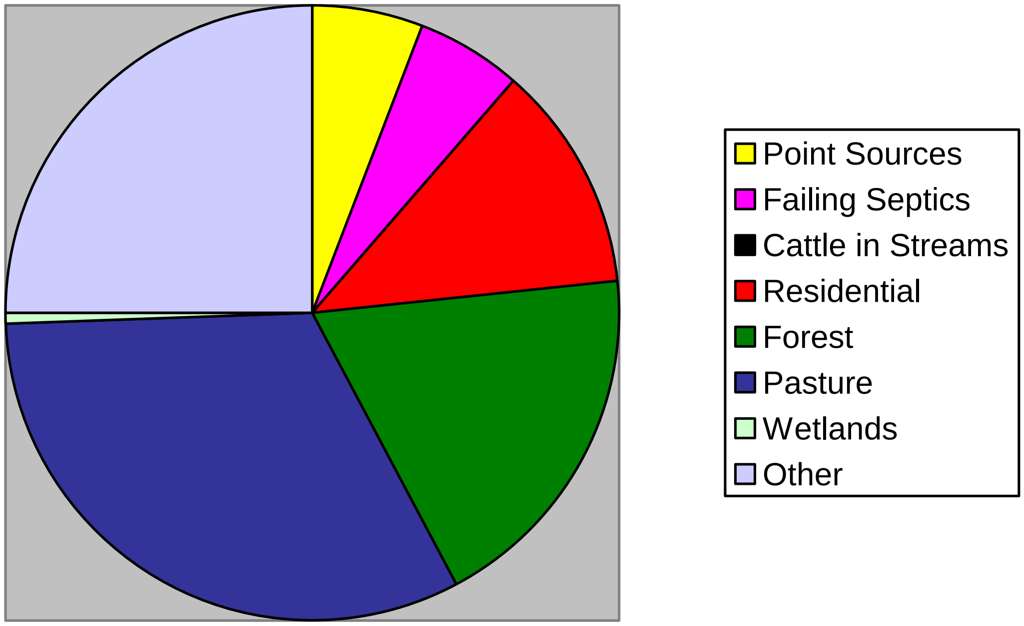

Figure 36. Sources of suspended solids loading to Cow Bayou below I-10

Total annual load ~ 911 tons

References

ASAE (American Society of Agricultural Engineers). 1998. ASAE standards, 45th edition: standards, engineering practices, data. St. Joseph, MI.

AVMA (American Veterinary Medical Association). 2002. U.S. Pet Ownership and Demographics Sourcebook (2002 Edition). Schaumberg, IL.

Baker, LA, D Hope, Y Xu, J Edmonds, and L. Lauver. 2001. Nitrogen Balance for the Central Arizona – Phoenix (CAP) Ecosystem. *Ecosystems* 4: 582-602.

Brown, KW, KC Donnelly, JC Thomas, and JF Slowey. 1984. The movement of nitrogen species through three soils below septic fields. *J. Environ. Qual*. 13 (3).

Canter, LW and RC Knox. 1985. Septic tank system effects on ground water quality. Lewis Publishers, Boca Raton, FL.

Cogger, CG and BL Carlile. 1984. Field performance of conventional and alternative septic systems in wet soils. *J. Environ. Qual*. 13 (1).

Finzi, AC, AS Allen, EH DeLucia, DS Ellsworth, and WH Schlesinger. 2001. Forest Litter Production, Chemistry, and Decomposition Following Two Years of Free-Air CO2 Enrichment. *Ecology* 82(2): 470-484.

Horsely and Whitten. 1996. Identification and Evaluation of Nutrient and Bacteriological Loadings to Maquoit Bay, Brunswick, and Freeport, Maine. Final Report. Casco Bay Estuary Project, Portland, ME.

Hydroscience. 1978. An Assessment of Non-Point Sources of Pollution in the Southeast Texas Designated 208 Planning Area. Prepared for the South East Texas Regional Planning Commission. July 1978.

LIRPB (Long Island Regional Planning Board). 1978. Long Island comprehensive waste treatment management plan. Volume II: summary documentation. Nassau-Suffolk regional planning board. Hauppauge, NY.

Metcalf & Eddy. 1991. Wastewater Engineering: Treatment, Disposal, and Reuse (3rd edition). McGraw-Hill, New York.

NADP (National Atmospheric Deposition Program). 2005. National Atmospheric Deposition Program 2004 Annual Summary. NADP Data Report 2005-01. Illinois State Water Survey, Champaign, IL. Available at http://nadp.sws.uiuc.edu.

NRCS (Natural Resources Conservation Service). 1986. Technical Release 55 – Urban Hydrology for Small Watersheds. Second Edition. 210-VI-TR-55. U.S. Department of Agriculture. Washington, DC. June 1986.

NRCS (Natural Resource Conservation Service). 2004. Soil Survey Geographic (SSURGO) database for Jefferson and Orange Counties, Texas. U.S. Department of Agriculture. Fort Worth, Texas.

Parsons. 2002. Assessment of water quality impairments in Adams Bayou Tidal (segment 0508), Cow Bayou Tidal (segment 0511) and their tributaries. Austin, Texas. October 2002.

Parsons. 2003a. Model evaluation and selection for TMDL development in Adams Bayou Tidal (segment 0508), Cow Bayou Tidal (segment 0511) and their tributaries. Austin, Texas. January 2003.

Parsons. 2003b. Sampling plan for modeling to support TMDL development in Adams Bayou Tidal (segment 0508), Cow Bayou Tidal (segment 0511) and their tributaries. Austin, Texas. June 2003.

Parsons. 2003c. Orange County TMDL Project Quality Assurance Project Plan. Austin, Texas. August 2003.

Reed Stowe and Yanke. 2001. Study to determine the magnitude of, and reasons for, chronically malfunctioning on-site sewage facility systems in Texas. Austin, Texas, September 2001.

Schueler, TR. 2000. Microbes and Urban Watersheds: Concentrations, Sources, and Pathways. In *The Practice of Watershed Protection*, TR Schueler and HK Holland, eds. Center for Watershed Protection, Ellicott City, MD.

TCEQ (Texas Commission on Environmental Quality). 2002. Texas 2000 Clean Water Act Section 303(d) List. Austin, Texas, December 19, 2002. 40pp.

TWC (Texas Water Commission). 1986. Waste load evaluation for Adams Bayou Tidal in the Sabine River Basin, Segment 0508. Austin, TX.

USEPA (U.S. Environmental Protection Agency). 2000. Bacterial Indicator Tool; User Guide. EPA-823-B-01-003. Office of Water. Washiington, DC. March 2000.

USGS (U.S. Geological Survey). 1999a. National Land Cover Dataset. Reston, VA. Available via http://landcover.usgs.gov/natllandcover.asp.

USGS (U.S. Geological Survey). 1999b. National Elevation Dataset. Reston, VA. Available via http://gisdata.usgs.net/ned.

USGS (U.S. Geological Survey). 2002. National Hydrography Dataset. Reston, VA. Available via http://nhd.usgs.gov/data.html.

Appendix A. Detailed Sub-Watershed Property Tables

Table A1. Major (>5%) soil map units of Cow Bayou sub-watersheds

Soil Map Unit	Acres	% Area
Sub-basin 1		
MKB	3,871	33%
EgB	3,105	26%
EaA	1,832	15%
MaB	1,291	11%
KWB	1,254	11%
Sub-basin 2		
EgB	6,171	69%
EaA	1,725	19%
WAA	831	9%
Sub-basin 3		
EgB	2,520	30%
TeB	1,828	22%
EaA	641	8%
TaA	563	7%
TgA	544	7%
CrA	537	6%
EvA	508	6%
BwA	450	5%
Sub-basin 4		
EgB	1,143	20%
TeB	835	15%
MoA	720	13%
EvA	704	12%
CrA	670	12%
TaA	562	10%
MmA	511	9%
Sub-basin 5		
TeB	1,298	38%
OuA	696	21%
MoA	631	19%
CrA	277	8%
TaA	221	7%
Sub-basin 6		
TeB	1,298	38%
OuA	696	21%
MoA	631	19%
CrA	277	8%
TaA	221	7%

Soil Map Unit	Acres	% Area
Sub-basin 7		
TeB	1,377	25%
TgA	1,180	21%
OsA	947	17%
TaA	785	14%
OcA	409	7%
CaA	349	6%
Sub-basin 8		
TeB	3,880	49%
EvA	967	12%
CrA	950	12%
LaA	596	8%
Sub-basin 9		
TeB	886	45%
OcA	433	22%
BwA	194	10%
OsA	157	8%
OaB	128	7%
Sub-basin 10		
OcA	491	34%
OsA	461	32%
OaB	161	11%
BwA	148	10%
Sub-basin 11		
OsA	1,376	36%
OcA	1,343	36%
TgA	336	9%
TaA	303	8%
Sub-basin 12		
OcA	473	24%
OsA	451	23%
TgA	270	13%
BwA	252	13%
TeB	251	13%
OaB	173	9%
Sub-basin 13		
TeB	1,442	25%
LaA	667	12%
MrA	634	11%
OsA	617	11%
OuA	592	10%
TgA	460	8%
LdA	434	8%

Soil Map Unit	Acres	% Area
Sub-basin 14		
OaB	719	36%
OuA	326	16%
OsA	289	14%
OcA	248	12%
BwA	195	10%
Sub-basin 15		
OsA	889	33%
OcA	647	24%
AsA	273	10%
AnA	259	9%
LbA	217	8%
OuA	174	6%
Sub-basin 16		
OuA	521	19%
AnA	432	16%
OcA	402	15%
LdA	309	12%
BwA	176	7%
AuA	172	6%
ImA	162	6%
OaB	148	5%
Sub-basin 17		
OuA	517	19%
OcA	386	14%
ImA	320	12%
OsA	280	10%
CeA	245	9%
AsA	243	9%
NuC	166	6%
OaB	159	6%
Sub-basin 18		
CeA	470	31%
ImA	274	18%
OaB	237	15%
OsA	198	13%
OcA	82	5%

See Table 4 for soil map unit full names and properties

Table A2. Major (>5%) soil map units of Adams Bayou sub-watersheds

Soil Map Unit	Acres	% Area
Sub-basin 1		
LaA	680	36%
OcA	633	34%
LdA	424	23%
Sub-basin 2		
TaA	3,525	45%
TgA	1,496	19%
CaA	669	9%
OcA	545	7%
Sub-basin 3		
OcA	579	24%
LaA	576	23%
OsA	539	22%
LdA	313	13%
EvA	205	8%
Sub-basin 4		
OcA	621	49%
OsA	352	28%
LaA	171	13%
TgA	83	7%
Sub-basin 5		
OcA	765	38%
OuA	626	31%
LaA	267	13%
EvA	105	5%
FaA	101	5%
Sub-basin 6		
OuA	708	68%
OcA	201	19%
FaA	93	9%
Sub-basin 7		
OcA	544	46%
OuA	355	30%
OsA	178	15%
OaB	101	9%
Sub-basin 8		
OuA	511	55%
OaB	124	13%
LdA	115	12%
LaA	100	11%
LvA	60	6%
Sub-basin 9		
OuA	1,635	74%
FaA	299	13%
OcA	167	8%
Sub-basin 10		
LaA	320	21%
OsA	286	19%
AsA	249	17%
OuA	235	16%
OaB	154	10%
LdA	86	6%
OcA	81	5%
Sub-basin 11		
LvA	759	48%
W	265	17%
OuA	230	14%
NuC	169	11%
ImA	158	10%

See Table 4 for soil map unit full names and properties

Table A3. Land use in Cow Bayou sub-watersheds. All Values in Acres

Land Use Category	Sub-watershed and Reach ID																	
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Low Density Residential	353	16	0	219	167	444	190	256	21	0	381	110	289	143	394	387	133	0
High Density Residential	181	3	0	87	128	227	159	129	13	0	252	80	183	118	183	158	125	2
Commercial/Industrial/Transportation	256	137	12	186	65	106	225	142	13	6	204	8	145	81	183	62	700	2
Bare rock/sand/clay	21	2	0	45	2	8	12	10	2	2	2	1	19	8	9	4	4	6
Quarries/strip mines/gravel pits	0	0	0	0	0	0	0	0	51	0	0	154	0	0	0	0	0	0
Transitional	1037	170	543	163	0	0	0	266	0	49	0	63	0	0	0	0	0	0
Deciduous forest	1205	1147	1236	1664	983	412	1023	1303	315	358	744	232	988	370	295	393	515	277
Evergreen forest	4028	2379	2020	2392	1835	1056	2501	3256	793	748	1221	774	2279	785	344	433	123	90
Mixed forest	6672	5224	4085	5208	4487	2123	1859	4927	1153	887	776	861	2733	488	272	310	116	42
Grasslands/herbaceous	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	85	59
Pasture/hay	2876	978	433	937	487	546	1858	1238	427	99	1652	347	1374	550	2115	1563	1252	821
Row crops	2	2	0	1	0	0	0	0	0	0	0	0	14	0	1	0	0	0
Small grains	0	0	0	0	0	0	0	0	0	0	0	0	361	0	0	0	119	0
Urban/recreational grasses	74	1	0	30	10	66	56	65	9	0	119	41	38	49	186	173	87	0
Woody wetlands	845	2989	1422	1311	309	0	240	0	91	1	179	244	3	66	14	182	45	45
Herbaceous wetlands	224	322	268	196	123	54	133	61	22	8	48	49	153	137	49	140	569	698
Open water	20	25	17	45	1	17	32	81	2	0	61	30	26	212	32	211	177	253
Total Acres	17795	13397	10039	12488	8602	5065	8295	11742	2921	2168	5650	3006	8618	3021	4092	4032	4067	2313

Table A4. Land use in Adams Bayou sub-watersheds. All Values in Acres

Land Use Category	Sub-watershed/Reach ID										
	1/1	2/2	3/(3+6)	4/4	5/5	6/7	7/8	8/9	9/10	10/11	11/12
Low Density Residential	7	31	126	31	194	175	310	195	567	126	90
High Density Residential	4	14	51	25	83	78	62	52	292	35	10
Commercial/Industrial/Transportation	24	95	68	35	50	29	23	30	199	87	216
Bare rock/sand/clay	4	8	0	2	1	0	1	3	0	6	0
Transitional	0	0	0	0	0	0	0	0	7	0	0
Deciduous forest	233	806	223	144	182	61	69	108	142	224	27
Evergreen forest	276	1553	512	79	279	190	180	80	158	140	11
Mixed forest	119	1338	207	145	142	83	67	50	95	109	0
Grasslands/herbaceous	0	0	0	0	0	0	0	16	28	30	40
Pasture/hay	964	2153	536	619	465	165	372	303	286	601	4
Row crops	1	0	0	0	0	0	0	0	0	0	2
Small grains	0	0	0	0	0	0	0	3	7	31	61
Urban/recreational grasses	0	4	25	38	30	75	59	57	129	33	30
Woody wetlands	165	1122	584	24	487	157	22	13	137	35	0
Herbaceous wetlands	51	252	91	11	63	21	10	22	99	34	891
Open water	17	439	28	114	45	15	2	2	73	2	213
Total Acres	1866	7817	2455	1270	2025	1055	1184	940	2229	1503	1607

Table A5. Soil loss calculations from the uniform soil loss equation for Adams Bayou

Land Use	Representative Soil Series Name	Soil Texture	Soil Erodibility Factor	Rainfall & Runoff	Topography	Cover & Mngmnt.	Support Practice	Edge of Field Rate	Segment Area	Edge of Field Load	Delivery Ratio	Edge of stream load	Edge of Stream Rate
			(K)	(R)	(LS)	(C)	(P)	(ton/ac/yr)	(acres)	(ton/yr)		(ton/yr)	(ton/ac/yr)
Low-Intensity Residential	Orcadia-Urban Land Complex	SIL	0.43	550	0.18	0.10	1	4.26	1853	7894	0.24	1895	1.02
High-Intensity Residential	Orcadia-Urban Land Complex	SIL	0.43	550	0.18	0.15	1	6.39	706	4511	0.24	1083	1.53
Commercial/Industrial/Transportation		SIL	0.43	550	0.18	0.20	1	8.52	856	7293	0.24	1750	2.04
Bare rock/sand/clay		SIL	0.43	550	0.11	1.00	1	26.02	24	624	0.24	150	6.24
Deciduous Forest	Evadale-Gist Complex	SIL	0.43	550	0.16	0.01	1	0.38	2219	843	0.24	202	0.091
Evergreen forest	Texla-Evadale Complex	SIL	0.43	550	0.09	0.01	1	0.21	3458	726	0.24	174	0.050
Mixed forest		SIL	0.43	550	0.09	0.01	1	0.21	2356	495	0.24	119	0.050
Pasture/hay	Orcadia-Anahuac Complex	SIL	0.43	550	0.09	0.05	1	1.06	6468	6856	0.24	1645	0.25
Urban/Recreational grasses		SIL	0.43	550	0.09	0.05	1	1.06	480	509	0.24	122	0.25
Row Crops	Orcadia-Anahuac Complex	SIL	0.43	550	0.10	0.30	1	7.1	3	21	0.24	5	1.70
Grasslands	Orcadia-Anahuac Complex	SIL	0.43	550	0.09	0.05	1	1.06	114	121	0.24	29	0.25
Small grains	Labelle Silt Loam	SIL	0.43	550	0.10	0.10	1	2.37	102	242	0.24	58	0.57
Transitional		SIL	0.43	550	0.11	0.30	1	7.8	7	55	0.24	13	1.87
Open Water						0.00			951	0	0	0	0.000
woody wetlands	Mollco fine sandy loam	SL	0.28	550	0.04	0.01	1	0.06	2745	165	0.24	40	0.014
herbaceous wetlands	Caplen Mucky peat	SLC	0.49	550	0.04	0.01	1	0.11	1545	170	0.24	41	0.026

Table A6. Soil loss calculations from the uniform soil loss equation for Cow Bayou

Land Use	Representative Soil Series Name	Soil Texture	Soil Erodibility Factor	Rainfall & Runoff	Topography	Cover & Mngmnt.	Support Practice	Edge of Field Rate	Segment Area	Edge of Field Load	Delivery Ratio	Edge of stream load	Edge of Stream Rate
			(K)	(R)	(LS)	(C)	(P)	(ton/ac/yr)	(acres)	(ton/yr)		(ton/yr)	(ton/ac/yr)
Low-Intensity Residential	Orcadia-Urban Land Complex	SIL	0.43	550	0.18	0.10	1	4.26	3503	14923	0.19	2985	0.85
High-Intensity Residential	Orcadia-Urban Land Complex	SIL	0.43	550	0.18	0.15	1	6.39	2028	12959	0.19	2592	1.28
Commercial/Industrial/Transportation		SIL	0.43	550	0.18	0.20	1	8.52	2533	21581	0.19	4100	1.62
Bare rock/sand/clay		SIL	0.43	550	0.11	1.00	1	26.02	157	4085	0.19	817	5.20
Deciduous Forest	Evadale-Gist Complex	SIL	0.43	550	0.16	0.01	1	0.38	13460	5115	0.19	1023	0.08
Evergreen forest	Texla-Evadale Complex	SIL	0.43	550	0.09	0.01	1	0.21	27057	5682	0.19	1136	0.04
Mixed forest		SIL	0.43	550	0.09	0.01	1	0.21	42223	8867	0.19	1773	0.04
Pasture/hay	Orcadia-Anahuac Complex	SIL	0.43	550	0.09	0.05	1	1.06	19553	20726	0.19	4145	0.21
Urban/Recreational grasses		SIL	0.43	550	0.09	0.05	1	1.06	1004	1064	0.19	213	0.21
Quarries/Gravel Pits/Mines		SIL	0.43	550	0.11	1.00	1	26.02	205	5334	0.19	1067	5.20
Row Crops	Orcadia-Anahuac Complex	SIL	0.43	550	0.10	0.30	1	7.1	20	142	0.19	28	1.40
Grasslands	Orcadia-Anahuac Complex	SIL	0.43	550	0.09	0.05	1	1.06	144	153	0.19	31	0.22
Small grains	Labelle Silt Loam	SIL	0.43	550	0.10	0.10	1	2.37	480	1138	0.19	228	0.48
Transitional		SIL	0.43	550	0.11	0.30	1	7.8	2291	17870	0.19	3574	1.56
Open Water						0.00	0	0	1242	0	0	0	0.00
woody wetlands	Mollco fine sandy loam	SL	0.28	550	0.04	0.01	1	0.06	7986	479	0.19	96	0.012
herbaceous wetlands	Caplen Mucky peat	SLC	0.49	550	0.04	0.01	1	0.11	3254	358	0.19	72	0.022

Table A7. Estimated average pollutant loads to land surfaces in the Adams Bayou watershed

Land Use Category	Nonpoint Source	E. coli cfu/acre/yr	Ammonia Nitrogen lbs/acre/yr	Nitrate Nitrogen lbs/acre/yr	Phosphate Phosphorus lbs/acre/yr	BOD lbs/acre/yr
Cropland	Wildlife	3.20E+10	0.26		0.25	4.06
Cropland	Hog Manure Application	4.27E+11	1.55		0.96	16.54
Cropland	Poultry Litter Application	2.87E+10	0.18		0.25	3.21
Cropland	Atmospheric Deposition		1.69	2.66		6.75
Forest	Wildlife	1.39E+11	0.80		0.77	12.35
Forest	Leaf Litter		29.76		2.02	136.02
Forest	Atmospheric Deposition		1.69	2.66		6.75
Commercial, Industrial, And Transportation	Mixed	2.27E+09				
	Atmospheric Deposition		1.69	2.66		6.75
High-Density Residential	Dogs And Cats	2.03E+12	3.01		3.13	50.01
High-Density Residential	Wildlife	1.28E+11	0.55		0.53	8.41
High-Density Residential	Lawn Fertilizer		52.27		26.14	209.09
High-Density Residential	Lawn Waste Removal	-3.79E+11	-26.23		-13.39	-111.77
High-Density Residential	Atmospheric Deposition		1.69	2.66		6.75
Low Density Residential	Dogs And Cats	1.27E+12	1.88		1.95	31.24
Low Density Residential	Wildlife	1.28E+11	0.55		0.53	8.41
Low Density Residential	Lawn Fertilizer		52.27		26.14	209.09
Low Density Residential	Lawn Waste Removal	-2.41E+11	-26.01		-13.18	-108.39
Low Density Residential	Atmospheric Deposition		1.69	2.66		6.75
Pasture	Wildlife	9.93E+10	0.33		0.32	5.12
Pasture	Horse Manure Application	1.14E+09	0.22		0.19	4.63
Pasture	Cattle Grazing	1.14E+13	7.53		8.05	140.04
Pasture	Horse Grazing	3.19E+09	0.60		0.54	12.92
Pasture	Sheep Grazing	1.50E+10	0.01		0.01	0.09
Pasture	Goat Grazing	3.04E+09	0.01		0.02	0.22
Pasture	Atmospheric Deposition		1.69	2.66		6.75
Wetlands	Wildlife	3.15E+11	0.86		0.82	13.17
Wetlands	Atmospheric Deposition		1.69	2.66		6.75
Grasslands	Wildlife	1.16E+11	0.35		0.33	5.36
Grasslands	Atmospheric Deposition		1.69	2.66		6.75

Table A8. Estimated average pollutant loads to land surfaces in the Cow Bayou watershed

Land Use Category	Nonpoint Source	E. coli col/acre/yr	Ammonia Nitrogen lbs/acre/yr	Nitrate Nitrogen lbs/acre/yr	Phosphate Phosphorus lbs/acre/yr	BOD lbs/acre/yr
Cropland	Wildlife	3.20E+10	0.26		0.25	4.06
Cropland	Hog Manure Application	1.85E+11	0.67		0.42	7.18
Cropland	Poultry Litter Application	6.95E+09	0.04		0.06	0.78
Cropland	Atmospheric Deposition		1.69	2.66		6.75
Forest	Wildlife	1.39E+11	0.80		0.77	12.35
Forest	Leaf Litter		29.74		2.02	148.70
Forest	Atmospheric Deposition		1.69	2.66		6.75
Commercial, Industrial, And Transportation	Mixed	1.51E+09				
	Atmospheric Deposition		1.69	2.66		6.75
High-Density Residential	Dogs And Cats	1.51E+12	2.41		2.32	37.07
High-Density Residential	Wildlife	1.28E+11	0.55		0.53	8.41
High-Density Residential	Lawn Fertilizer		52.27		26.14	209.09
High-Density Residential	Lawn Waste Removal	-2.83E+11	-26.07		-13.24	-109.41
High-Density Residential	Atmospheric Deposition		1.69	2.66		6.75
Low Density Residential	Dogs And Cats	7.45E+11	1.19		1.14	18.31
Low Density Residential	Wildlife	1.28E+11	0.55		0.53	8.41
Low Density Residential	Lawn Fertilizer		52.27		26.14	209.09
Low Density Residential	Lawn Waste Removal	-1.39E+11	-25.85		-13.03	-105.91
Low Density Residential	Atmospheric Deposition		1.69	2.66		6.75
Pasture	Wildlife	9.93E+10	0.33		0.32	5.12
Pasture	Horse Manure Application	1.05E+09	0.20		0.18	4.23
Pasture	Cattle Grazing	1.10E+13	7.26		7.77	135.10
Pasture	Horse Grazing	2.92E+09	0.55		0.49	11.81
Pasture	Sheep Grazing	1.21E+10	0.00		0.00	0.04
Pasture	Goat Grazing	2.80E+09	0.01		0.01	0.20
Pasture	Atmospheric Deposition		1.69	2.66		6.75
Wetlands	Wildlife	3.15E+11	0.86		0.82	13.17
Wetlands	Atmospheric Deposition		1.69	2.66		6.75
Grasslands	Wildlife	1.16E+11	0.35		0.33	5.36
Grasslands	Atmospheric Deposition		1.69	2.66		6.75

Table A9. Annual average E. coli loads (in cfu/year) to Adams Bayou and tributaries by reach

Sub-watershed ID	1	2	3	4	5	6	7	8	9	10	11	12	Sum	Above I-10	Below I-10
Low-density residential	3.8E+10	1.7E+11	3.5E+11	1.7E+11	1.1E+12	3.5E+11	9.8E+11	1.7E+12	1.1E+12	3.1E+12	7.0E+11	5.0E+11	1.0E+13	2.2E+12	8.1E+12
High-density residential	6.0E+10	2.2E+11	4.3E+11	4.1E+11	1.4E+12	4.3E+11	1.3E+12	1.0E+12	8.5E+11	4.8E+12	5.7E+11	1.6E+11	1.2E+13	2.9E+12	8.7E+12
Commercial-Industrial-transportation	5.0E+08	1.9E+09	6.6E+08	6.7E+08	1.0E+09	6.6E+08	5.5E+08	4.2E+08	6.4E+08	3.9E+09	1.7E+09	4.2E+09	1.7E+10	5.4E+09	1.2E+10
Bare rock/sand/clay	3.6E+08	7.1E+08	0	1.8E+08	8.9E+07	0	0	8.9E+07	2.7E+08	0	5.3E+08	0	2.2E+09	1.3E+09	8.9E+08
Deciduous forest	4.6E+10	1.6E+11	2.2E+10	2.9E+10	3.6E+10	2.2E+10	1.2E+10	1.4E+10	2.1E+10	2.8E+10	4.5E+10	5.4E+09	4.4E+11	3.2E+11	1.3E+11
Evergreen forest	6.6E+10	3.7E+11	6.1E+10	1.9E+10	6.7E+10	6.1E+10	4.6E+10	4.3E+10	1.9E+10	3.8E+10	3.4E+10	2.6E+09	8.3E+11	6.5E+11	1.8E+11
Mixed forest	2.6E+10	3.0E+11	2.3E+10	3.2E+10	3.1E+10	2.3E+10	1.8E+10	1.5E+10	1.1E+10	2.1E+10	2.4E+10	-	5.2E+11	4.3E+11	8.9E+10
Pasture/hay	1.1E+13	2.5E+13	3.1E+12	7.1E+12	5.4E+12	3.1E+12	1.9E+12	4.3E+12	3.5E+12	3.3E+12	6.9E+12	4.6E+10	7.4E+13	5.5E+13	2.0E+13
Urban/recreational grasses	0	1.4E+09	4.7E+09	1.4E+10	1.1E+10	4.7E+09	2.7E+10	2.1E+10	2.1E+10	4.6E+10	1.2E+10	1.1E+10	1.7E+11	3.5E+10	1.4E+11
Row Crops	2.6E+09	0	0	0	0	0	0	0	0	0	0	5.3E+09	7.9E+09	2.6E+09	5.3E+09
Grassland	0	0	0	0	0	0	0	0	5.0E+09	8.8E+09	9.5E+09	1.3E+10	3.6E+10	0	3.6E+10
Small grains	0	0	0	0	0	0	0	0	5.7E+09	1.3E+10	5.9E+10	1.2E+11	1.9E+11	0	1.9E+11
Transitional	0	0	0	0	0	0	0	0	0	7.2E+08	0	0	7.2E+08	0	7.2E+08
Open Water	5.4E+08	1.4E+10	4.5E+08	3.7E+09	1.4E+09	4.5E+08	4.8E+08	6.4E+07	6.4E+07	2.3E+09	6.4E+07	6.8E+09	3.0E+10	2.1E+10	9.8E+09
Woody Wetlands	2.0E+11	1.4E+12	3.6E+11	2.9E+10	6.0E+11	3.6E+11	1.9E+11	2.7E+10	1.6E+10	1.7E+11	4.3E+10	0	3.4E+12	2.9E+12	4.4E+11
Herbaceous Wetlands	6.6E+10	3.2E+11	5.9E+10	1.4E+10	8.1E+10	5.9E+10	2.7E+10	1.3E+10	2.8E+10	1.3E+11	4.4E+10	1.1E+12	2.0E+12	6.0E+11	1.4E+12
Total Runoff Load	1.2E+13	2.8E+13	4.4E+12	7.8E+12	8.6E+12	4.4E+12	4.5E+12	7.1E+12	5.6E+12	1.2E+13	8.5E+12	2.0E+12	1.0E+14	6.5E+13	3.9E+13
Malfunctioning Septic Tanks	1.2E+13	7.1E+13	1.1E+13	1.8E+13	1.2E+13	1.1E+13	0	7.4E+12	0	0	8.0E+12	0	1.5E+14	1.4E+14	1.5E+13
Cattle in Streams	2.0E+12	4.4E+12	5.5E+11	1.3E+12	9.5E+11	5.5E+11	6.7E+10	1.5E+11	1.2E+11	1.2E+11	2.4E+11	0	1.0E+13	9.6E+12	7.7E+11
NPDES Permitted Facilities	0	0	0	0	0	0	0	0	0	1.3E+12	0	0	1.3E+12	0	1.3E+12
Unauthorized Discharges	0	0	0	0	0	0	0	0	6.9E+10	0	0	0	6.9E+10	0	6.9E+10
Total Load	2.6E+13	1.0E+14	1.6E+13	2.7E+13	2.2E+13	1.6E+13	4.6E+12	1.5E+13	5.8E+12	1.3E+13	1.7E+13	2.0E+12	2.6E+14	2.1E+14	5.6E+13

Table A10. Annual average ultimate BOD loads (in pounds/year) to Adams Bayou and tributaries by reach

Sub-watershed ID	1	2	3	4	5	6	7	8	9	10	11	12	Sum	Above I-10	Below I-10
Low-density residential	16	72	146	72	449	146	407	718	453	1,313	291	208	4,292	1,484	5,587
High-density residential	9	30	52	51	170	52	160	128	108	601	72	21	1,455	366	1,089
Commercial-Industrial-transportation	10	35	13	13	20	13	10	8	12	75	33	81	323	103	219
Bare rock/sand/clay	5	10	0	2	1	0	0	1	4	0	7	0	31	18	12
Deciduous forest	415	1,434	199	256	324	199	109	123	192	253	399	48	3,950	2,827	1,123
Evergreen forest	551	3,100	511	158	557	511	379	359	160	315	279	22	6,902	5,387	1,515
Mixed forest	225	2,530	197	274	269	197	157	127	95	180	206	0	4,455	3,691	764
Pasture/hay	2,308	5,156	642	1,482	1,113	642	395	891	726	685	1,439	10	15,488	11,343	4,145
Urban/recreational grasses	0	6	21	60	47	21	119	93	90	204	52	47	760	155	606
Row Crops	3	0	0	0	0	0	0	0	0	0	0	6	9	3	6
Grassland	0	0	0	0	0	0	0	0	20	36	38	51	145	0	145
Small grains	0	0	0	0	0	0	0	0	8	19	84	165	276	0	276
Transitional	0	0	0	0	0	0	0	0	0	11	0	0	11	0	11
Open Water	2	54	2	14	6	2	2	0	0	9	0	26	117	79	38
Woody Wetlands	204	1,388	361	30	602	361	194	27	16	169	43	0	3,397	2,947	450
Herbaceous Wetlands	69	340	62	15	85	62	28	14	30	134	46	1,203	2,087	633	1,454
Total Runoff Load	3,817	14,156	2,205	2,428	3,644	2,205	1,960	2,488	1,913	4,003	2,990	1,888	43,698	28,455	15,243
Malfunctioning Septic Tanks	4,362	26,667	4,955	6,610	4,504	4,955	0	2,785	0	0	2,986	0	57,824	52,053	5,771
Cattle in Streams	24	54	7	16	12	7	1	2	2	1	3	0	127	119	8
NPDES Permitted Facilities	0	0	0	0	0	0	0	0	0	25802	321	0	26,123	0	26,123
Unauthorized Discharges	0	0	0	0	0	0	0	0	1	0	0	0	1	0	1
Total Load	8,203	40,877	7,167	9,054	8,160	7,167	1,961	5,275	1,916	29,806	6,300	1,888	127,773	80,627	47,146

Table A11. Annual average ammonia nitrogen loads (in pounds/year) to Adams Bayou and tributaries by reach

Sub-watershed ID	1	2	3	4	5	6	7	8	9	10	11	12	Sum	Above I-10	Below I-10
Low-density residential	1	4	8	4	25	8	23	40	25	73	16	12	239	50	189
High-density residential	1	2	4	4	14	4	13	10	9	49	6	2	119	30	89
Commercial-Industrial-transportation	4	16	6	6	8	6	5	4	5	33	14	36	142	45	97
Bare rock/sand/clay	0.1	0.3	0	0.1	0	0	0	0	0.1	0	0.2	0	0.8	0.5	0.3
Deciduous forest	7	24	3	4	6	3	2	2	3	4	7	0.8	67	48	19
Evergreen forest	9	53	9	3	10	9	7	6	3	5	5	0.4	119	92	26
Mixed forest	4	42	3	5	4	3	3	2	2	3	3	0	75	62	13
Pasture/hay	28	62	8	18	13	8	5	11	9	8	17	0.1	187	137	50
Urban/recreational grasses	0	0.1	0.3	1	0.8	0.3	2	2	1	3	0.9	0.8	13	3	10
Row Crops	0.	0	0	0	0	0	0	0	0	0	0	0.1	0.1	0	0.1
Grassland	0	0	0	0	0	0	0	0	0.3	0.5	0.5	0.7	2	0	2
Small grains	0	0	0	0	0	0	0	0	0.1	0.2	1	2	3	0	3
Transitional	0	0	0	0	0	0	0	0	0	0.2	0	0	0.2	0	0.2
Open Water	0.8	21	0.7	5	2	0.7	0.7	0.1	0.1	3	0	10	45	30	15
Woody Wetlands	2	14	4	0.3	6	4	2	0.3	0.2	2	0	0	33	29	4
Herbaceous Wetlands	0.7	3	0.6	0.1	0.8	0.6	0.3	0.1	0.3	1	0	12	20	6	14
Total Runoff Load	57	242	46	50	90	46	61	77	58	187	73	76	1,064	533	532
Malfunctioning Septic Tanks	898	5,490	1,020	1,361	927	1,020	0	573	0	0	615	0	11,904	10,716	1,188
Cattle in Streams	1	3	0	1	1	0	0	0	0	0	0	0	7	7	0
NPDES Permitted Facilities	0	0	0	0	0	0	0	0	0	12,702	0	0	12,702	0	12,702
Unauthorized Discharges	0	0	0	0	0	0	0	0	0.1	0	0	0	0.1	0	0.1
Total Load	956	5,735	1,066	1,412	1,018	1,066	61	650	58	12,889	688	76	25,675	11,254	14,421

Table A12. Annual average nitrate-nitrogen loads (in pounds/year) to Adams Bayou and tributaries by reach

Sub-watershed ID	1	2	3	4	5	6	7	8	9	10	11	12	Sum	Above I-10	Below I-10
Low-density residential	0.2	0.9	2	0.9	5	2	5	9	6	16	4	3	53	11	42
High-density residential	0.1	0.5	0.9	0.9	3	0.9	3	2	2	11	1	0.4	25	6	19
Commercial-Industrial-transportation	0.8	3	1	1	2	1	1	0.8	1	7	3	7	29	9	20
Bare rock/sand/clay	0.1	0.2	0	0	0	0	0	0	0.1	0	0.1	0	0.6	0.3	0.2
Deciduous forest	4	13	2	2	3	2	1	1	2	2	4	0.4	36	25	10
Evergreen forest	5	26	4	1	5	4	3	3	1	3	2	0.2	59	46	13
Mixed forest	2	22	2	2	2	2	1	1	1	2	2	0	38	32	6
Pasture/hay	37	83	10	24	18	10	6	14	12	11	23	0.2	250	183	67
Urban/recreational grasses	0	0.1	0.3	0.8	0.6	0.3	2	1	1	3	0.7	0.6	10	2	8
Row Crops	0.1	0	0	0	0	0	0	0	0	0	0	0.1	0.2	0.1	0.1
Grassland	0	0	0	0	0	0	0	0	0.2	0.4	0.5	0.6	2	0	2
Small grains	0	0	0	0	0	0	0	0	0.2	0.4	2	3	6	0	6
Transitional	0	0	0	0	0	0	0	0	0	0.1	0	0	0.1	0	0.1
Open Water	0.5	13	0.4	4	1	0.4	0.5	0.1	0.1	2	0.1	6	29	20	9
Woody Wetlands	2	13	3	0.3	6	3	2	0.3	0.2	2	0.4	0	32	28	4
Herbaceous Wetlands	0.6	3	0.6	0.1	0.8	0.6	0.3	0.1	0.3	1	0.4	11	20	6	14
Total Runoff Load	52	179	27	38	47	27	25	33	26	60	43	33	588	368	220
Malfunctioning Septic Tanks	2	14	3	4	2	3	0	1	0	0	2	0	31	27	4
Cattle in Streams	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
NPDES Permitted Facilities	0	0	0	0	0	0	0	0	0	6,351	0	0	6,351	0	6,351
Unauthorized Discharges	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total Load	54	193	30	42	49	30	25	34	26	6,411	45	33	6,970	395	6,575

Table A13. Annual average orthophosphate phosphorus loads (in pounds/year) to Adams Bayou and tributaries by reach

Sub-watershed ID	1	2	3	4	5	6	7	8	9	10	11	12	Sum	Above I-10	Below I-10
Low-density residential	0.6	3	5	3	17	5	15	27	17	49	11	8	159	33	126
High-density residential	0.5	2	4	3	11	4	10	8	7	39	5	1	95	24	71
Commercial-Industrial-transportation	4	16	6	6	8	6	5	4	5	33	15	36	143	46	98
Bare rock/sand/clay	0.1	0.2	0	0	0	0	0	0	0.1	0	0.1	0	0.6	0.3	0.2
Deciduous forest	3	9	1	2	2	1	0.7	0.8	1	2	3	0.3	26	18	7
Evergreen forest	4	21	3	1	4	3	3	2	1	2	2	0.1	46	36	10
Mixed forest	2	17	1	2	2	1	1	0.8	0.6	1	1	0	29	24	5
Pasture/hay	20	45	6	13	10	6	4	8	6	6	13	0.1	135	99	36
Urban/recreational grasses	0	0.1	0.3	0.7	0.6	0.3	2	1	1	2	0.6	0.6	9	2	8
Row Crops	0	0	0	0	0	0	0	0	0	0	0	0	0.1	0	0
Grassland	0	0	0	0	0	0	0	0	0.4	0.7	0.8	1	3	0	3
Small grains	0	0	0	0	0	0	0	0	0.1	0.1	0.5	1	2	0	2
Transitional	0	0	0	0	0	0	0	0	0	0.2	0	0	0.2	0	0.2
Open Water	0.2	6	0.2	2	0.6	0.2	0.2	0	0	1	0	3	14	9	4
Woody Wetlands	3	23	6	0.5	10	6	3	0.4	0.3	3	0.7	0	56	48	7
Herbaceous Wetlands	1	5	1	0.2	1	1	0.5	0.2	0.5	2	0.7	19	33	10	23
Total Runoff Load	38	147	34	32	66	34	44	52	41	141	52	71	751	350	400
Malfunctioning Septic Tanks	385	2,353	437	583	397	437	0	246	0	0	263	0	5,102	4,593	509
Cattle in Streams	1	3	0	1	1	0	0	0	0	0	0	0	7	7	0
NPDES Permitted Facilities	0	0	0	0	0	0	0	0	16,140	44	0	0	16,184	0	16,184
Unauthorized Discharges	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total Load	424	2,503	471	616	464	471	44	298	16,181	185	315	71	22,044	4,950	17,093

Table A14. Annual average sediment load (in tons/year) to Adams Bayou and tributaries by reach

Sub-watershed ID	1	2	3	4	5	6	7	8	9	10	11	12	Sum	Above I-10	Below I-10
Low-density residential	0.2	1	2	1	6	2	6	10	6	19	4	3	62	13	49
High-density residential	0.2	0.5	0.9	0.9	3	0.9	3	2	2	11	1	0.4	26	6	19
Commercial-Industrial-transportation	0.6	2	0.8	0.8	1	0.8	0.7	0.5	0.8	5	2	5	21	7	15
Bare rock/sand/clay	2	4	0	0.9	0.5	0	0	0.5	1	0	3	0	12	7	5
Deciduous forest	6	19	3	3	4	3	1	2	3	3	5	0.6	53	38	15
Evergreen forest	4	21	4	1	4	4	3	2	1	2	2	0.1	47	36	10
Mixed forest	1	15	1	2	2	1	0.9	0.8	0.6	1	1	0	26	22	4
Pasture/hay	54	120	15	35	26	15	9	21	17	16	34	0.2	362	265	97
Urban/recreational grasses	0	0.1	0.3	0.8	0.6	0.3	2	1	1	3	0.7	0.6	10	2	8
Row Crops	0.1	0	0	0	0	0	0	0	0	0	0	0.3	0.4	0.1	0.3
Grassland	0	0	0	0	0	0	0	0	0.4	0.7	0.8	1	3	0	3
Small grains	0	0	0	0	0	0	0	0	0.1	0.3	2	3	5	0	5
Transitional	0	0	0	0	0	0	0	0	0	1	0	0	1	0	1
Open Water	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Woody Wetlands	0.2	2	0.4	0	0.6	0.4	0.2	0	0	0.2	0	0	4	3	1
Herbaceous Wetlands	0.2	0.8	0.1	0	0.2	0.1	0.1	0	0.1	0.3	0.1	3	5	1	3
Total Runoff Load	68	186	27	45	48	27	25	40	34	63	56	17	636	401	235
Malfunctioning Septic Tanks	0.9	5	1	1	0.9	1	0	0.3	0	0	0.6	0	12	11	1
Cattle in Streams	0.1	0.1	0	0	0	0	0	0	0	0	0	0	0.3	0.3	0
NPDES Permitted Facilities	0	0	0	0	0	0	0	0	0	13	0.1	0	13	0	13
Unauthorized Discharges	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total Load	69	191	28	46	49	28	25	40	34	76	57	17	662	412	249

Table A15. Annual average E. coli loads (in cfu/year) to Cow Bayou and tributaries by reach

Sub-watershed ID	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	Sum	Above I-10	Below I-10
Low-density residential	1.7E+12	7.7E+10	0	1.0E+12	8.0E+11	2.1E+12	9.1E+11	1.2E+12	9.8E+10	0	1.8E+12	5.3E+11	1.4E+12	6.9E+11	1.9E+12	1.9E+12	6.4E+11	0	1.7E+13	7.9E+12	8.9E+12
High-density residential	2.9E+12	5.2E+10	0	1.4E+12	2.1E+12	3.7E+12	2.6E+12	2.1E+12	2.1E+11	0	4.1E+12	1.3E+12	3.0E+12	1.9E+12	3.0E+12	2.6E+12	2.0E+12	3.0E+10	3.3E+13	1.5E+13	1.8E+13
Commercial-Industrial-transportation	5.0E+09	2.7E+09	2.5E+08	3.7E+09	1.3E+09	2.1E+09	4.4E+09	2.8E+09	2.6E+08	1.2E+08	4.0E+09	1.4E+08	2.9E+09	1.6E+09	3.6E+09	1.2E+09	1.4E+10	1.8E+07	5.0E+10	2.2E+10	2.7E+10
Bare rock/sand/clay	1.8E+09	1.7E+08	0	3.9E+09	1.7E+08	7.0E+08	1.0E+09	8.7E+08	1.7E+08	1.7E+08	1.7E+08	8.7E+07	1.7E+09	7.0E+08	7.8E+08	3.5E+08	3.5E+08	5.2E+08	1.4E+10	8.7E+09	5.0E+09
Deciduous forest	2.2E+11	2.1E+11	2.2E+11	3.0E+11	1.8E+11	7.4E+10	1.8E+11	2.4E+11	5.7E+10	6.5E+10	1.3E+11	4.2E+10	1.8E+11	6.7E+10	5.3E+10	7.1E+10	9.3E+10	5.0E+10	2.4E+12	1.6E+12	8.1E+11
Evergreen forest	8.9E+11	5.3E+11	4.5E+11	5.3E+11	4.1E+11	2.3E+11	5.5E+11	7.2E+11	1.8E+11	1.7E+11	2.7E+11	1.7E+11	5.0E+11	1.7E+11	7.6E+10	9.6E+10	2.7E+10	2.0E+10	6.0E+12	4.3E+12	1.7E+12
Mixed forest	1.4E+12	1.1E+12	8.3E+11	1.1E+12	9.1E+11	4.3E+11	3.8E+11	1.0E+12	2.3E+11	1.8E+11	1.6E+11	1.7E+11	5.5E+11	9.9E+10	5.5E+10	6.3E+10	2.4E+10	8.5E+09	8.6E+12	7.0E+12	1.5E+12
Pasture/hay	2.5E+13	8.7E+12	3.8E+12	8.3E+12	4.3E+12	4.8E+12	1.6E+13	1.1E+13	3.8E+12	8.8E+11	1.5E+13	3.1E+12	1.2E+13	4.9E+12	1.9E+13	1.4E+13	1.1E+13	7.3E+12	1.7E+14	8.3E+13	9.0E+13
Urban/recreational grasses	7.6E+10	1.0E+09	0	3.1E+10	1.0E+10	6.8E+10	5.7E+10	6.7E+10	9.2E+09	0	1.2E+11	4.2E+10	3.9E+10	5.0E+10	1.9E+11	1.8E+11	8.9E+10	0	1.0E+12	3.1E+11	7.2E+11
Quarries/gravel pits	0	0	0	0	0	0	0	0	4.8E+09	0	0	1.4E+10	0	0	0	0	0	0	1.9E+10	0	1.9E+10
Row Crops	4.5E+09	4.5E+09	0	2.2E+09	0	0	0	0	0	0	0	0	3.1E+10	0	2.2E+09	0	0	0	4.5E+10	1.1E+10	3.4E+10
Grassland	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5.5E+09	3.8E+09	9.4E+09	0	9.1E+09
Small grains	0	0	0	0	0	0	0	0	0	0	0	0	6.1E+11	0	0	0	2.0E+11	0	8.2E+11	0	8.2E+11
Transitional	7.8E+10	1.3E+10	4.1E+10	1.2E+10	0	0	0	2.0E+10	0	3.7E+09	0	4.7E+09	0	0	0	0	0	0	1.7E+11	1.6E+11	8.4E+09
Open Water	2.8E+08	3.5E+08	2.4E+08	6.4E+08	1.4E+07	2.4E+08	4.5E+08	1.1E+09	2.8E+07	0	8.6E+08	4.2E+08	3.7E+08	3.0E+09	4.5E+08	3.0E+09	2.5E+09	3.6E+09	1.8E+10	3.4E+09	1.4E+10
Woody Wetlands	1.0E+12	3.7E+12	1.7E+12	1.6E+12	3.8E+11	0	2.9E+11	0	1.1E+11	1.2E+09	2.2E+11	3.0E+11	3.7E+09	8.1E+10	1.7E+10	2.2E+11	5.5E+10	5.5E+10	9.8E+12	8.7E+12	1.1E+12
Herbaceous Wetlands	2.9E+11	4.1E+11	3.4E+11	2.5E+11	1.6E+11	6.9E+10	1.7E+11	7.8E+10	2.8E+10	1.0E+10	6.2E+10	6.3E+10	2.0E+11	1.8E+11	6.3E+10	1.8E+11	7.3E+11	8.9E+11	4.2E+12	1.8E+12	2.4E+12
Total Runoff Load	3.4+13	1.5E+13	7.5+12	1.5E+13	9.2E+12	1.2E+13	2.2E+13	1.6E+13	4.7E+12	1.3E+12	2.2E+13	5.7E+12	1.9E+13	8.1E+12	2.4E+13	1.9E+13	1.5E+13	8.3E+12	2.6E+14	1.3E+14	1.3E+14
Malfunctioning Septic Tanks	1.3E+14	2.3E+13	6.6E+12	1.4E+14	5.1E+13	2.7E+14	1.1E+14	1.8E+14	2.6E+13	1.5E+13	1.6E+14	4.7E+13	1.4E+14	6.4E+13	7.8E+13	9.3E+13	6.4E+12	1.4E+12	1.5E+15	9.1E+14	6.3E+14
Cattle in Streams	1.0E+13	4.2E+12	1.5E+12	3.7E+12	2.0E+12	2.3E+12	8.0E+12	5.3E+12	1.8E+12	2.1E+11	3.5E+12	7.4E+11	2.9E+12	0	4.5E+12	0	0	0	5.1E+13	3.7E+13	1.4E+13
NPDES Permitted Facilities	8.0E+11	0	0	0	0	0	0	3.7E+10	4.4E+08	0	1.5E+10	0	0	6.6E+08	2.4E+11	1.8E+11	0	2.2E+12	3.5E+12	8.4E+11	2.7E+12
Unauthorized Discharges	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	9.8E+11	0	0	9.8E+11	0	9.8E+11
Total Load	1.7E+14	4.2E+13	1.5E+13	1.6E+14	6.2E+13	2.8E+14	1.4E+14	2.0E+14	3.3E+13	1.7E+13	1.8E+14	5.3E+13	1.6E+14	7.2E+13	1.1E+14	1.1E+14	2.1E+13	1.2E+13	1.9E+15	1.1E+15	7.8E+14

Table A16. Annual average ultimate BOD loads (in pounds/year) to Cow Bayou and tributaries by reach

Sub-watershed ID	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	Sum	Above I-10	Below I-10
Low-density residential	1,031	46	0	635	488	1,298	555	748	62	0	1,114	321	844	418	1,152	1,131	388	0	10,233	4,802	5,431
High-density residential	432	6	0	209	306	544	382	311	30	0	604	192	437	282	437	378	299	6	4,855	2,190	2,665
Commercial-Industrial-transportation	91	50	5	67	24	38	81	50	5	2	74	2	53	29	65	22	251	0	909	406	503
Bare rock/sand/clay	27	3	0	59	3	10	16	13	3	3	3	1	25	10	12	5	5	8	206	131	75
Deciduous forest	3,425	3,260	3,513	4,730	2,794	1,171	2,908	3,704	895	1,018	2,115	659	2,808	1,052	839	1,117	1,464	787	38,259	25,505	12,754
Evergreen forest	12,891	7,614	6,465	7,655	5,873	3,380	8,004	10,420	2,538	2,394	3,908	2,477	7,294	2,512	1,101	1,386	394	288	86,594	62,302	24,292
Mixed forest	20,486	16,040	12,543	15,991	13,777	6,518	5,708	15,128	3,540	2,723	2,383	2,644	8,391	1,498	835	952	356	129	129,642	106,191	23,451
Pasture/hay	10,279	3,495	1,548	3,349	1,741	1,951	6,641	4,425	1,526	354	5,904	1,240	4,911	1,966	7,559	5,586	4,475	2,934	69,884	33,429	36,455
Urban/recreational grasses	172	2	0	70	23	153	130	151	21	0	277	95	88	114	443	402	202	0	2,343	701	1,642
Quarries/gravel pits	0	0	0	0	0	0	0	0	54	0	0	163	0	0	0	0	0	0	217	0	217
Row Crops	6	6	0	3	0	0	0	0	0	0	0	0	41	0	3	0	0	0	59	15	44
Grassland	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	120	83	203	0	203
Small grains	0	0	0	0	0	0	0	0	0	0	0	0	1,019	0	0	0	336	0	1,355	0	1,355
Transitional	1,714	281	897	269	0	0	0	440	0	81	0	104	0	0	0	0	0	0	3,786	3,601	185
Open Water	4	4	3	8	0	3	6	15	0	0	11	5	5	38	6	38	32	45	223	43	180
Woody Wetlands	1,317	4,660	2,217	2,044	482	0	374	0	142	2	279	380	5	103	22	284	70	70	12,451	11,094	1,357
Herbaceous Wetlands	399	574	478	349	219	96	237	109	39	14	86	87	273	244	87	249	1,014	1,244	5,798	2,461	3,337
Total Runoff Load	52,275	36,042	27,668	35,438	25,729	15,165	25,042	35,512	8,856	6,591	16,757	8,373	26,193	8,266	12,550	11,550	9,407	5,595	367,009	252,871	114,137
Malfunctioning Septic Tanks	49,823	8,669	2,478	51,100	18,933	101,569	42,008	65,868	9,607	5,643	58,342	17,684	53,392	23,860	29,098	34,952	2,391	522	575,939	340,448	235,491
Cattle in Streams	119	49	19	42	23	27	94	61	21	3	41	9	34	0	53	0	0	0	595	434	161
NPDES Permitted Facilities	7,191	0	0	0	0	0	0	121	165	0	13,447	0	0	287	965	34,712	0	104,518	161,406	7,312	154,094
Unauthorized Discharges	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	15	0	0	15	0	15
Total Load	109,408	44,759	30,166	86,580	44,686	116,758	67,144	101,562	18,649	12,237	88,587	26,063	79,620	32,413	42,666	81,229	11,797	60,896	1,104,964	601,065	503,898

Table A17. Annual average ammonia nitrogen loads (in pounds/year) to Cow Bayou and tributaries by reach

Sub-watershed ID	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	Sum	Above I-10	Below I-10
Low-density residential	89	4	0	55	42	112	48	64	5	0	96	28	73	36	99	97	33	0	881	414	467
High-density residential	61	1	0	29	43	76	53	43	4	0	84	27	61	40	61	53	42	1	680	306	373
Commercial-Industrial-transportation	93	49	4	67	23	38	81	51	5	2	74	3	52	29	66	22	253	1	915	407	507
Bare rock/sand/clay	2	0	0	5	0	1	1	1	0	0	0	0	2	1	1	0	0	1	18	12	7
Deciduous forest	66	63	68	91	54	23	56	71	17	20	41	13	54	20	16	22	28	15	738	492	246
Evergreen forest	244	144	123	145	111	64	152	198	48	45	74	47	138	48	21	26	7	5	1,642	1,182	461
Mixed forest	395	309	242	308	265	126	110	291	68	52	46	51	162	29	16	18	7	2	2,498	2,046	452
Pasture/hay	478	163	72	156	81	91	309	206	71	16	275	58	228	91	352	260	208	137	3,251	1,555	1,696
Urban/recreational grasses	8	0	0	3	1	7	6	7	1	0	13	5	4	5	20	19	10	0	110	33	77
Quarries/gravel pits	0	0	0	0	0	0	0	0	6	0	0	18	0	0	0	0	0	0	24	0	24
Row Crops	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	4	1	3
Grassland	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6	4	10	0	10
Small grains	0	0	0	0	0	0	0	0	0	0	0	0	60	0	0	0	20	0	80	0	80
Transitional	113	19	59	18	0	0	0	29	0	5	0	7	0	0	0	0	0	0	249	237	12
Open Water	2	3	2	6	0	2	4	10	0	0	8	4	3	26	4	26	22	31	154	29	124
Woody Wetlands	40	142	67	62	15	0	11	0	4	0	8	12	0	3	1	9	2	2	379	337	41
Herbaceous Wetlands	12	17	14	10	6	3	7	3	1	0	3	3	8	7	3	7	30	37	172	73	99
Total Runoff Load	1,604	914	651	956	643	542	839	976	232	142	721	273	850	336	660	560	668	236	11,804	7,125	4,679
Malfunctioning Septic Tanks	10,256	1,785	511	10,519	3,898	20,911	8,651	13,560	1,978	1,161	12,012	3,643	10,994	4,913	5,990	7,198	493	110	118,583	70,091	48,492
Cattle in Streams	6	3	1	2	1	1	5	3	1	0.1	2	0.5	2	0	3	0	0	0	31	22	9
NPDES Permitted Facilities	762	0	0	0	0	0	0	4	426	0	27	0	0	7	112	3,135	0	4,262	8,735	766	7,969
Unauthorized Discharges	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	2	0	2
Total Load	12,629	2,702	1,163	11,477	4,542	21,454	9,495	14,543	2,638	1,303	12,763	3,916	11,845	5,256	6,764	10,894	1,161	4,608	139,155	78,004	61,151

Table A18. Annual average nitrate nitrogen loads (in pounds/year) to Cow Bayou and tributaries by reach

Sub-watershed ID	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	Sum	Above I-10	Below I-10
Low-density residential	46	2	0	29	22	58	25	34	3	0	50	14	38	19	52	51	17	0	460	216	244
High-density residential	33	1	0	16	23	42	29	24	2	0	46	15	34	22	34	29	23	0	372	167	204
Commercial-Industrial-transportation	55	29	3	40	14	23	48	31	3	1	44	2	31	17	39	13	150	0	544	243	302
Bare rock/sand/clay	3	0.3	0	6	0.3	1	2	1	0.3	0.3	0.3	0.1	3	1	1	1	1	1	22	14	8
Deciduous forest	41	39	43	57	34	14	35	45	11	12	26	8	34	13	10	14	18	10	463	309	154
Evergreen forest	170	101	85	101	78	45	106	138	34	32	52	33	96	33	15	18	5	4	1,144	823	321
Mixed forest	265	208	162	207	178	84	74	196	46	35	31	34	109	19	11	12	5	2	1,678	1,375	304
Pasture/hay	192	65	29	63	33	37	124	83	29	7	111	23	92	37	142	105	84	55	1,309	626	683
Urban/recreational grasses	8	0.1	0	3	1	7	6	7	1	0	12	4	4	5	19	18	9	0	104	31	72
Quarries/gravel pits	0	0	0	0	0	0	0	0	7	0	0	22	0	0	0	0	0	0	29	0	29
Row Crops	0.1	0.1	0	0.1	0	0	0	0	0	0	0	0	1	0	0.1	0	0	0	1	0.3	1
Grassland	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7	5	13	0	13
Small grains	0	0	0	0	0	0	0	0	0	0	0	0	22	0	0	0	7	0	30	0	30
Transitional	117	19	61	18	0	0	0	30	0	6	0	7	0	0	0	0	0	0	258	246	13
Open Water	4	5	4	9	0.2	4	7	17	0.4	0	13	6	5	44	7	44	37	52	257	49	208
Woody Wetlands	64	225	107	99	23	0	18	0	7	0.1	13	18	0.2	5	1	14	3	3	602	536	66
Herbaceous Wetlands	18	26	21	16	10	4	11	5	2	1	4	4	12	11	4	11	46	56	260	110	150
Total Runoff Load	1,017	721	515	664	416	318	484	609	144	94	401	191	481	226	334	329	412	188	7,546	4,746	2,800
Malfunctioning Septic Tanks	26	4	0	26	11	55	22	36	4	4	29	11	29	11	15	18	0	0	301	180	121
Cattle in Streams	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
NPDES Permitted Facilities	45	0	0	0	0	0	0	363	324	0	1,301	0	0	396	339	11,903	0	572	15,243	408	14,835
Unauthorized Discharges	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	2	0	2
Total Load	1,087	725	515	690	428	374	507	1,010	474	98	1,732	201	510	633	689	12,253	412	760	23,098	5,335	17,763

Table A19. Annual average orthophosphate phosphorus loads (in pounds/year) to Cow Bayou and tributaries by reach

Sub-watershed ID	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	Sum	Above I-10	Below I-10
Low-density residential	30	1	0	19	14	38	16	22	2	0	32	9	25	12	34	33	11	0	299	141	159
High-density residential	24	0.4	0	12	17	30	21	17	2	0	34	11	25	16	25	21	17	0.3	271	122	149
Commercial-Industrial-transportation	43	23	2	32	11	18	38	24	2	1	35	1	25	14	31	11	119	0.3	429	191	238
Bare rock/sand/clay	0.5	0	0	1	0	0.2	0.3	0.2	0	0	0	0	0.4	0.2	0.2	0.1	0.1	0.1	4	2	1
Deciduous forest	14	13	14	19	11	5	12	15	4	4	9	3	12	4	3	5	6	3	157	105	52
Evergreen forest	56	33	28	33	26	15	35	45	11	10	17	11	32	11	5	6	2	1	378	272	106
Mixed forest	86	68	53	67	58	27	24	64	15	11	10	11	35	6	4	4	2	1	547	448	99
Pasture/hay	54	18	8	18	9	10	35	23	8	2	31	7	26	10	40	29	24	15	368	176	192
Urban/recreational grasses	3	0	0	1	0.4	2	2	2	0.3	0	4	2	1	2	7	6	3	0	36	11	25
Quarries/gravel pits	0	0	0	0	0	0	0	0	1	0	0	4	0	0	0	0	0	0	5	0	5
Row Crops	0.04	0.04	0	0.02	0	0	0	0	0	0	0	0	0.3	0	0.02	0	0	0	0.4	0.1	0.3
Grassland	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	1	3	0	3
Small grains	0	0	0	0	0	0	0	0	0	0	0	0	6	0	0	0	2	0	8	0	8
Transitional	21	4	11	3	0	0	0	5	0	1	0	1	0	0	0	0	0	0	47	45	2
Open Water	0.3	0.4	0.2	1	0	0.2	0.5	1	0	0	1	0.4	0.4	3	0.5	3	2	4	18	3	14
Woody Wetlands	17	61	29	27	6	0	5	0	2	0	4	5	0.1	1	0.3	4	1	1	162	145	18
Herbaceous Wetlands	5	7	6	4	3	1	3	1	0.5	0.2	1	1	3	3	1	3	13	15	71	30	41
Total Runoff Load	356	230	152	237	156	148	192	222	47	30	178	66	190	83	150	125	202	42	2,804	1,691	1,113
Malfunctioning Septic Tanks	4,396	765	219	4,509	1,671	8,962	3,707	5,812	848	498	5,148	1,560	4,711	2,105	2,568	3,084	211	46	50,819	30,039	20,779
Cattle in Streams	7	3	1	3	1	2	6	4	1	0.1	3	1	2	0	3	0	0	0	36	26	10
NPDES Permitted Facilities	1,643	0	0	0	0	0	0	120	266	0	253	0	0	226	146	12,045	0	12,796	27,495	1,763	25,732
Unauthorized Discharges	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total Load	6,410	1,004	376	4,754	1,832	9,113	3,908	6,163	1,164	529	5,583	1,628	4,907	2,416	2,868	15,256	413	12,886	81,153	33,515	47,638

Table A20. Annual average sediment loads (in tons/year) to Cow Bayou and tributaries by reach

Sub-watershed ID	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	Sum	Above I-10	Below I-10
Low-density residential	12	1	0	7	6	15	6	9	1	0	13	4	10	5	13	13	4	0	117	55	62
High-density residential	7	0.1	0	3	5	8	6	5	0.5	0	9	3	7	4	7	6	5	0.1	74	33	41
Commercial-Industrial-transportation	6	3	0.3	5	2	3	6	4	0.3	0.2	5	0.2	4	2	5	2	17	0	63	28	35
Bare rock/sand/clay	10	1	0	21	1	4	6	5	1	1	1	0.4	9	4	4	2	2	3	72	46	26
Deciduous forest	19	18	19	26	15	6	16	20	5	6	11	4	15	6	5	6	8	4	207	138	69
Evergreen forest	37	22	18	22	17	10	23	30	7	7	11	7	21	7	3	4	1	1	246	177	69
Mixed forest	53	41	32	41	35	17	15	39	9	7	6	7	22	4	2	2	1	0.3	333	273	60
Pasture/hay	79	27	12	26	13	15	51	34	12	3	45	10	38	15	58	43	34	23	537	257	280
Urban/recreational grasses	1	0	0	0.6	0.2	1	1	1	0.2	0	2	0.8	0.8	1	4	3	2	0	20	6	14
Quarries/gravel pits	0	0	0	0	0	0	0	0	23	0	0	68	0	0	0	0	0	0	91	0	91
Row Crops	0.3	0.3	0	0.1	0	0	0	0	0	0	0	0	2	0	0.1	0	0	0	3	1	2
Grassland	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	1	4	0	4
Small grains	0	0	0	0	0	0	0	0	0	0	0	0	17	0	0	0	6	0	23	0	23
Transitional	209	34	109	33	0	0	0	54	0	10	0	13	0	0	0	0	0	0	461	439	23
Open Water	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Woody Wetlands	1	4	2	2	0.4	0	0.3	0	0.1	0.00	0.2	0.3	0	0.1	0	0.2	0.1	0.1	10	9	1
Herbaceous Wetlands	0.7	0.9	0.8	0.6	0.4	0.2	0.4	0.2	0.1	0	0.1	0.1	0.4	0.4	0.1	0.4	2	2	9	4	5
Total Runoff Load	433	152	194	186	94	79	129	199	58	33	105	116	144	48	100	81	84	34	2,270	1,466	805
Malfunctioning Septic Tanks	10	2	0.5	10	4	21	9	14	2	1	12	4	11	5	6	7	0.5	0.1	119	70	48
Cattle in Streams	0.3	0.1	0.0	0.1	0.1	0.1	0.3	0.2	0.1	0.0	0.1	0.0	0.1	0	0.1	0	0	0	2	1	0.5
NPDES Permitted Facilities	5	0	0	0	0	0	0	0.1	0.1	0	7	0	0	0.1	0.3	11	0	32	57	5	51
Unauthorized Discharges	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total Load	451	154	194	198	99	100	140	215	61	35	123	121	157	54	108	100	85	67	2,461	1,550	911