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In cooperation with the Texas Agricultural Experiment Station,
Caesar Kleberg Wildlife Research Institute, and
Coastal Bend Bays and Estuary Program

Hydrologic Conditions and Water Quality in an Agricultural Area in Kleberg and Nueces Counties, Texas, 1996–98

Water-Resources Investigations Report 01–4101

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By Darwin J. Ockerman and Brian L. Petri

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Austin, Texas
2001

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By Darwin J. Ockerman *and* Brian L. Petri

Abstract

During 1996–98, rainfall and runoff were monitored on a 49,680-acre agricultural watershed in Kleberg and Nueces Counties in South Texas. Nineteen rainfall samples were analyzed for selected nutrients, and runoff samples from 29 storms were analyzed for major ions, nutrients, and pesticides. Loads of nutrients in rainfall and loads of nutrients and pesticides in runoff were computed. For a 40,540-acre part of the watershed (lower study area), constituent loads entering the watershed in rainfall, in runoff from the upper study area, and from agricultural chemical applications to the lower study area were compared with runoff loads exiting the lower study area.

Total rainfall for 1996–98 averaged 25.86 inches per year, which is less than the long-term annual average rainfall of 29.80 inches for the area. Rainfall and runoff during 1996–98 were typical of historical patterns, with periods of below average rainfall and runoff interspersed with extreme events. Five individual storms accounted for about 38 percent of the total rainfall and 94 percent of the total runoff.

During the 3-year study, the total nitrogen runoff yield from the lower study area was 1.3 pounds per acre per year, compared with 49 pounds per acre per year applied as fertilizer and 3.1 pounds per acre per year from rainfall. While almost all of the fertilizer and rainfall nitrogen was ammonia and nitrate, most of the nitrogen in runoff was particulate organic nitrogen, associated with crop residue. Total nitrogen exiting the lower study area in surface-water runoff was about 2.5 percent of the nitrogen inputs (fertilizer and rainfall nitrogen). Annual deposition of total nitrogen entering the lower study area in rainfall exceeded net yields of total nitrogen exiting the watershed in runoff because most of the rainfall does not contribute to runoff.

During the study, the total phosphorus runoff yield from the lower study area was 0.48 pound per acre per year compared with 4.2 pounds per acre per year applied as fertilizer and 0.03 pound per acre per year from rainfall.

Twenty-one pesticides were detected in runoff with varying degrees of frequency during the study. The herbicide atrazine was detected in all runoff samples. All of the most frequently detected pesticides (atrazine, trifluralin, simazine, pendimethalin, and diuron) exhibited higher concentrations during the pre-harvest period (March–May) than during the post-harvest period (August–October).

During 1996–98, an average of 0.37 pound per acre per year of atrazine was applied to the lower study area. During the same period, 0.0027 pound per acre per year of atrazine and its breakdown product deethylatrazine exited the lower study area in runoff (about 0.7 percent of the total atrazine applied to the cropland). During 1997, when heavy rainfall occurred during the months of April and May, the atrazine plus deethylatrazine exiting the lower study area was 1.8 percent of the applied atrazine.

The 1996–98 average sediment yield was 610 pounds per acre per year. Sediment loads from the study area are associated with large storm events. Of the 45,300 tons of sediment transported from the study area during 1996–98 about 87 percent was transported during the three largest runoff

events (April 1997, October 1997, and October 1998).

Runoff-weighted average concentrations were computed for selected nutrients and pesticides. The 1996–98 runoff-weighted concentrations for total nitrogen and total phosphorus were 1.3 and 0.50 milligrams per liter, respectively. The 1996–98 runoff-weighted concentration for atrazine plus deethylatrazine was 2.7 micrograms per liter.

INTRODUCTION

Baffin Bay and Laguna Madre south of Corpus Christi, Texas (fig. 1), are shallow, poorly circulated estuaries that are potentially sensitive to point and non-point source contributions of water-quality constituents. These estuary systems experienced a persistent brown-tide algae bloom beginning in spring 1990 that threatened their biological productivity. Non-point source nutrient inputs are a possible concern, although the causes of the blooms are not well understood (Coastal Bend Bays and Estuaries Program, 1998). The brown tide bloom subsided in fall 1997, coincident with heavy rains in the area.

The U.S. Geological Survey (USGS) studied the hydrology and water quality of a 49,680-acre agricultural area adjacent to Baffin Bay during January 1996–December 1998 to provide a better understanding of contributions of freshwater and runoff constituent loads from the agricultural area to Baffin Bay. The study was done in cooperation with the Texas Agricultural Experiment Station (TAES), Texas A&M University-Corpus Christi; Caesar Kleberg Wildlife Research Institute, Texas A&M University-Kingsville; and Coastal Bend Bays and Estuary Program.

Purpose and Scope

This report describes the quantity and quality of rainfall and runoff in an agricultural watershed in Kleberg and Nueces Counties and presents constituent loads and yields associated with the runoff. Data were collected at five streamflow-gaging stations and one weather station in an agricultural watershed in the Baffin Bay drainage area. Nineteen rainfall event samples were collected at the weather station and analyzed for nutrient concentrations. Twenty-nine event-composite runoff samples were collected at the five streamflow stations and analyzed for major ions, nutrients, and pesticides. Event-mean concentrations and constituent loads and yields were determined from these data. Loads and yields of selected constituents in rainfall and runoff were compared with applications of fertilizers and pesticides for that part of the study area where the application data were available.

Description of Study Area

Alice and Kingsville (1997 populations of 20,301 and 26,646, respectively) (Texas State Data Center, 1998) are the primary urban centers in the region (fig. 1). Land use in the Baffin Bay watershed is about 33 percent cropland and about 64 percent rangeland. The study area (fig. 2) within the Baffin Bay watershed consists of 49,680 acres of agricultural land located in Nueces and Kleberg Counties. The study area is primarily cropland except for 3,392 acres of rangeland and about 500 acres of canals, ditches, and roads in the lower study area.

The climate of the area is classified as subtropical, with warm tropical air from the Gulf of Mexico contributing to mild winter temperatures and hot, humid summer weather (Baird and others, 1996). Prevailing winds are southeasterly throughout the year.

Streams in the study area are ephemeral and have runoff only after heavy rains. Most of the runoff from the study area enters Petronila Creek, Alazan Bay, and Baffin Bay (from Tunas Creek). Some of the runoff from the lower study area enters rangeland and ephemeral wetlands, and by overland flow, moves toward Baffin Bay through Cayo del Grullo (fig. 2).

Besides climate and rainfall, the type and nature of the soils and, to a lesser degree, the agricultural practices are crucial in the rainfall-runoff process. Victoria-Claireville Association clays are the dominant soil in the watershed (R. Schmidt, Natural Resource Conservation Commission, Kingsville, Texas, oral commun., 1996). These soils are dark, calcareous, and crumbly. Because Victoria soils dry and crack almost every summer, their subsoil can take in and store much water in a short time during heavy rains in the fall. However, after the soils are saturated, they take in water very slowly, resulting in substantial runoff during heavy rains (Soil Conservation Service, 1992). Slopes in the study area are nearly flat, ranging from 0 to 3 percent.

The primary crops in the study area are cotton and grain sorghum, which are rotated annually. The following table shows the acreage of each crop planted in the lower study area during 1996–98. Crop acreage was not

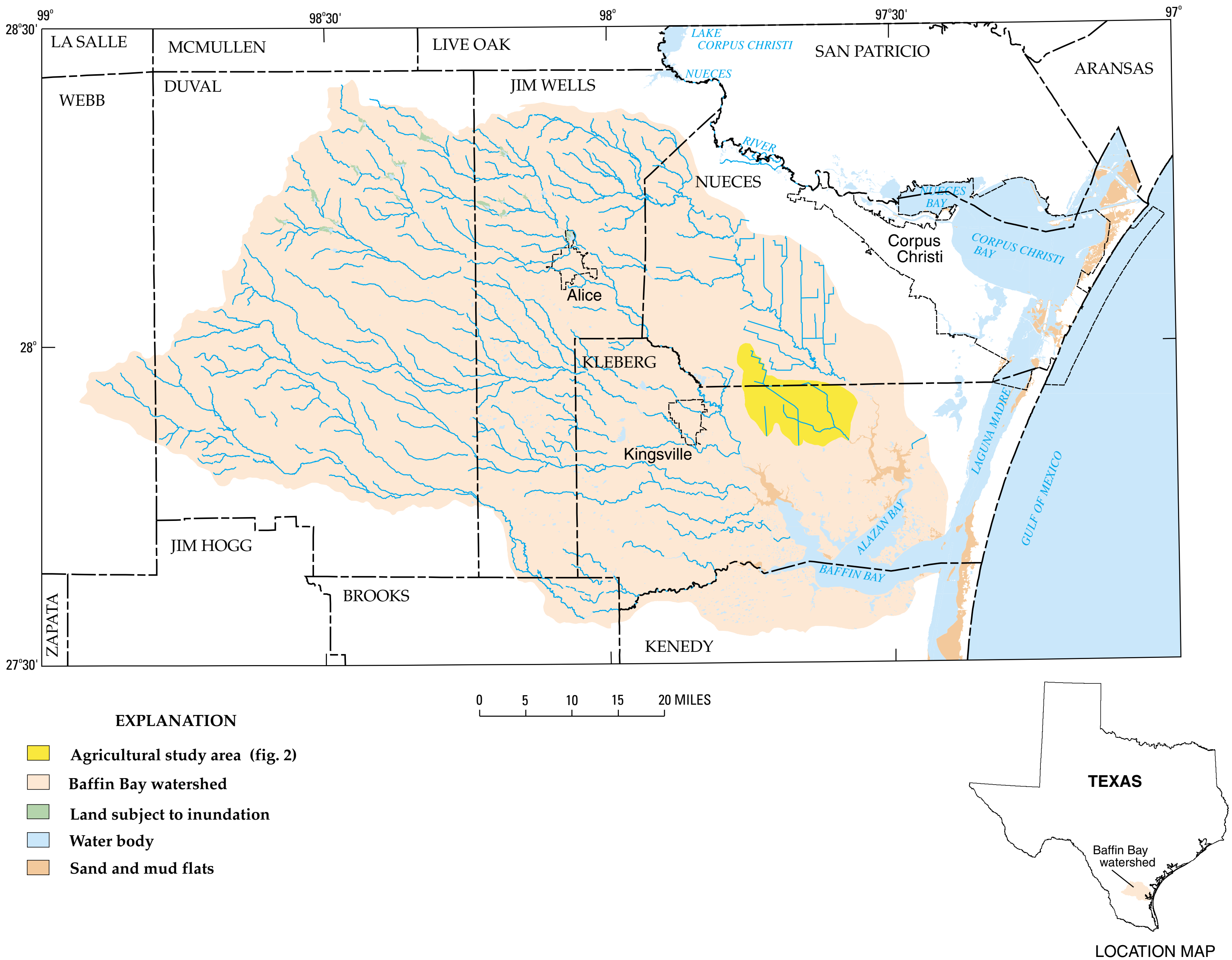


Figure 1. Location of agricultural study area in Kleberg and Nueces Counties, Texas.

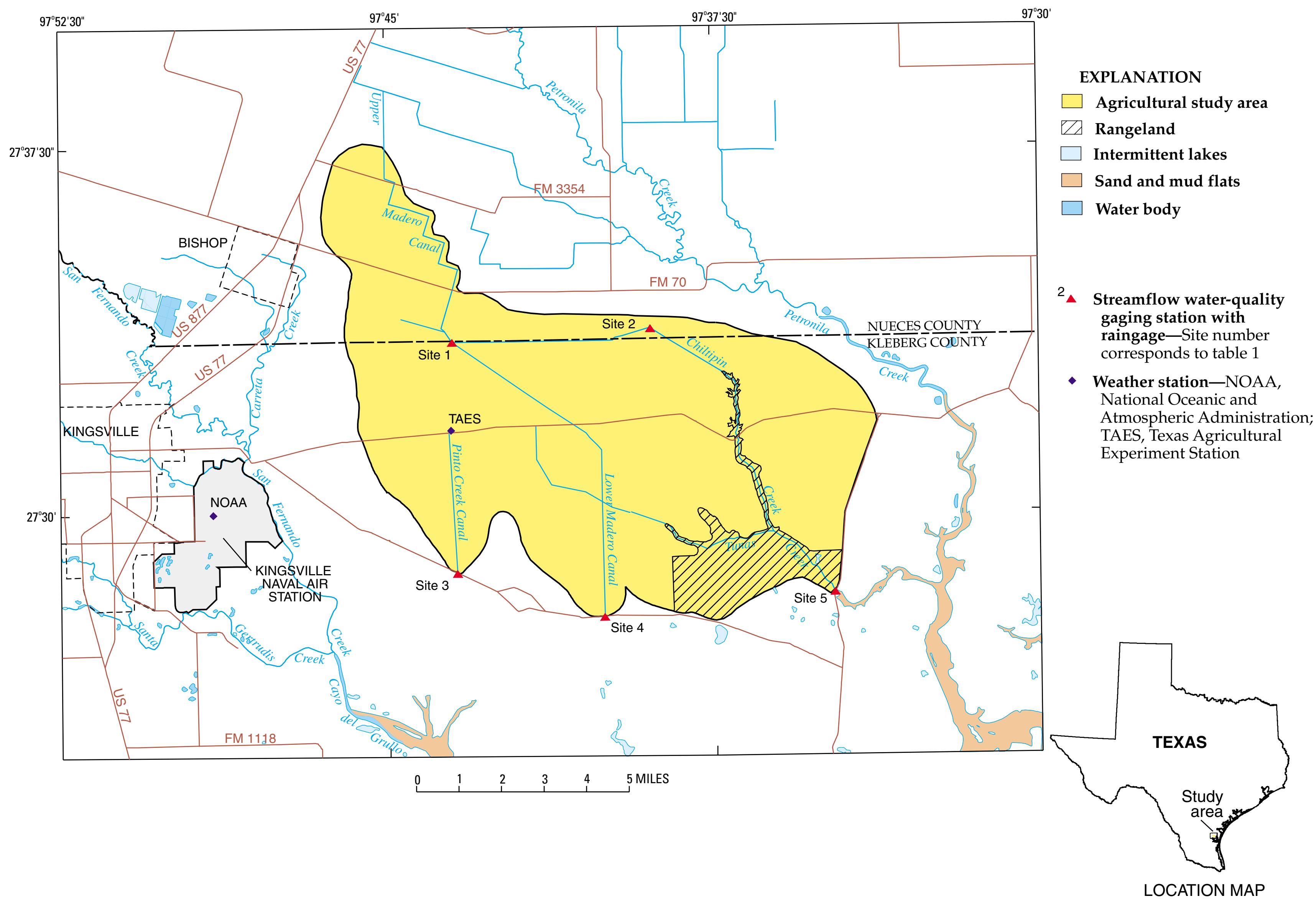


Figure 2. Location of data-collection sites in agricultural study area.

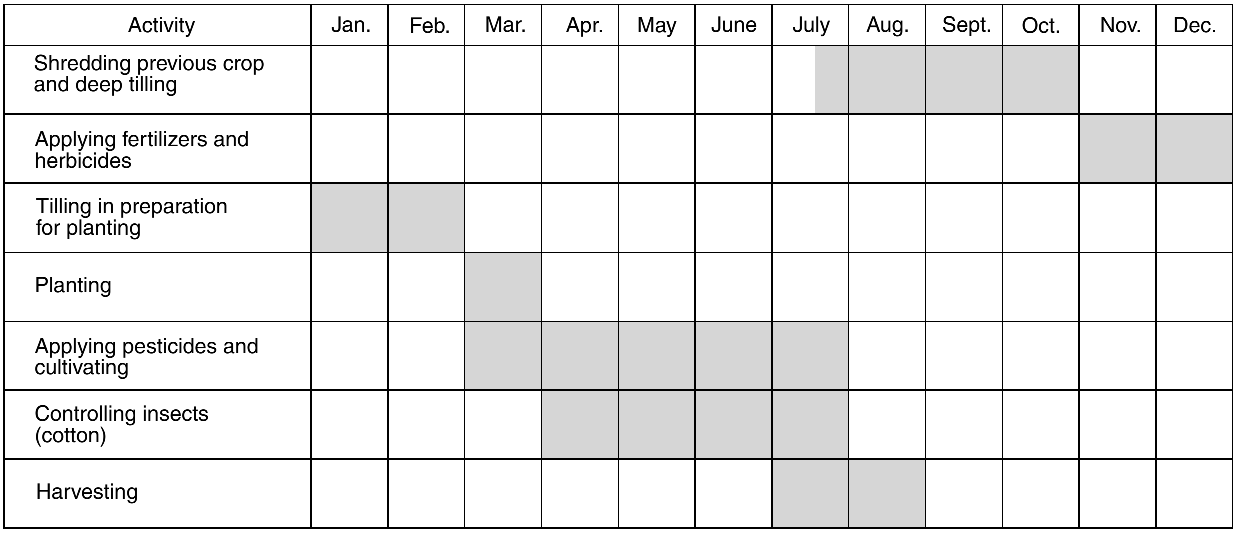


Figure 3. Typical timing of agricultural activities in Nueces and Kleberg Counties, Texas.

available for the upper study area; however, farming practices and crop ratios are similar to those in the lower study area.

Crop acreage within the lower 40,540-acre study area, 1996–98

[About 3,932 acres are rangeland; about 500 acres are canals, ditches, and roads]

Year	Cotton	Grain sorghum	Total
1996	21,814	14,354	36,168
1997	19,100	17,028	36,128
1998	16,770	19,358	36,128

Crop production begins during mid-July to late-August with shredding of crop residue from the previous crop and deep tilling (fig. 3) to plow out stubble and prepare the ground to absorb fall and winter rains. The soil is retilled during September and October to destroy winter weeds and to prepare the seedbed for the succeeding crop. Pre-plant fertilizers and broadcast pre-emergence herbicides are usually applied during the low rainfall months of November and December. During January to mid-February, additional tilling is done. Planting begins in early- to late-March, depending on the available soil moisture, soil temperature, and type of crop. After the crops have emerged from the soil, production practices throughout the growing season consist of pesticide application and row cultivation. From mid- to late-April to early-July, few field operations are required for grain sorghum. However, for cotton, this is a period of heavy activity involving insect control. Grain sorghum usually is harvested in early- to mid-July. Cotton harvest usually begins with application of harvest aids (defoliants) around mid-July and ends around mid-August (Dr. Bobby Eddleman, Texas Agricultural Experiment Station, Texas A&M University-Corpus Christi, written commun., 1998)

Texas Water-Quality Standards

The Texas Natural Resource Conservation Commission (TNRCC) has designated water-quality standards and appropriate uses (such as aquatic life, contact or non-contact recreation, drinking water) for specific stream, estuary, and bay segments (Texas Natural Resource Conservation Commission, 1999). To support the designated use of the water-body segments, standards for common water-quality indicators such as dissolved oxygen, temperature, pH, dissolved minerals, and fecal bacteria have been established for some stream and bay segments. The TNRCC has not developed segment-specific standards for any of the canals or creeks monitored during this study. However, some segment-specific standards have been established for nearby Petronila Creek and Baffin Bay, which eventually receive runoff from the study area. The water-body segment that includes Baffin Bay is designated for contact recreation, high aquatic life, and oyster waters

(State of Texas, 1997). Similarly, the tidal segment of Petronila Creek is designated for contact recreation.

Acknowledgments

Special thanks are extended to Dr. Bobby Eddleman and Clinton Livingston with the Texas Agricultural Experiment Station, Texas A&M University-Corpus Christi, for their substantial support to this project. Dr. Eddleman provided valuable project oversight and technical assistance, while Clinton Livingston assisted with site and equipment maintenance and sample collection.

DATA-COLLECTION METHODS

The study area is defined by the location of five streamflow-gaging and water-quality sampling stations with raingages (fig. 2) that were installed in January 1996 and operated through December 1998. A weather station with rainfall sample collector (operated by TAES) also is located in the study area. A long-term, National Oceanic and Atmospheric Administration (NOAA) operated raingage is located near Kingsville. Table 1 (at end of report) lists selected characteristics of the data-collection sites.

The watershed of the upper study area is defined by the drainage area for sites 1 and 2 (fig. 2). Site 1 is located on Upper Madero Canal just inside Kleberg County. Site 2 is located on Chiltipin Creek just inside Nueces County. The combined drainage area of the upper study area is 9,140 acres, although the specific drainage areas gaged by each station are indeterminate, primarily because of the interconnecting canal between the two gaging stations.

Sites 3, 4, and 5 are located at the outlets of the study area (fig. 2). Site 3 is located on Pinto Creek Canal and site 4 on Lower Madero Canal. Runoff exiting the study area through sites 3 and 4 makes its way toward Cayo del Grullo (an arm of Baffin Bay) via overland flow through rangeland and ephemeral wetlands. Site 5 is located on Tunas Creek 3 miles (mi) upstream from the confluence with Petronila Creek and Alazan Bay (another arm of Baffin Bay). The combined drainage of the lower study area is 40,540 acres. The individual drainage areas gaged by each of the lower stations are not well defined (again, because of interconnecting canals between gaging stations). However, most of the upper and lower study area ultimately drains to site 5. During the study, about 93 percent of all runoff leaving the study area exited through site 5.

Rainfall

Five tipping bucket raingages at sites 1–5 and one at the TAES weather station recorded hourly rainfall for the study area. The raingages at sites 1–5 have recorded data since January 1996, and the TAES raingage has recorded data since 1988. The average rainfall volumes on the study area were determined from a Theissen-weighted average (Wanielista, 1990, p. 51) of the six raingage measurements.

Runoff

Gage height was continuously recorded at all sites using a gas-bubbler and pressure transducer system. A relation between gage height and discharge was developed by making independent discharge measurements during runoff events. At site 5, the relation between gage height and discharge was variable and not well defined because of tidal influence. Therefore, an acoustic velocity meter (AVM) also was installed to measure stream velocity along with gage height. Independent stream discharge measurements at site 5 were used to develop a relation between gage height, stream velocity, and stream discharge (Patino and Ockerman, 1997).

Water Quality

Rainfall samples were collected at the TAES weather station by an automatic rainfall sample collector. The collector is equipped with an empty polyethylene bucket that is covered prior to rainfall. A moisture sensor activates a mechanism to uncover the collection bucket when rainfall begins and cover the bucket when rainfall ends to prevent evaporation and contamination of the sample. About 0.2 inch (in.) of rain is required to provide sufficient sample volume for analysis. Rainfall samples were collected as single-event composite samples during rainfall events and therefore represent rainfall event-mean concentrations (EMCs). The samples were retrieved as soon as possible after a rainfall event, chilled, and shipped overnight to the USGS National Water Quality Laboratory (NWQL) in Denver, Colorado, for analysis.

Rainfall samples were analyzed for the following forms of nitrogen: ammonia, nitrite plus nitrate, dissolved organic, and total organic. Total nitrogen concentrations were computed for each sample as the sum of ammonia, nitrite plus nitrate, and total organic nitrogen. The samples also were analyzed for total phosphorus, dissolved phosphorus, and dissolved orthophosphate phosphorus. Field measurements of pH and alkalinity also were made for selected samples.

Automatic water samplers at sites 1–5 collected runoff samples during storm events. When the streamflow-gaging instrumentation detected runoff, automatic samplers were activated to collect runoff samples. Discrete aliquots (subsamples) were collected by the automatic samplers at a frequency proportional to stream discharge. As the flow at a particular site increased, the sampler collected subsamples more frequently; thus, the samples were automatically flow-weighted during the collection process. At the end of the event, the subsamples from each site were combined into a single discharge-weighted composite sample (one sample from each site). Analysis of the composite samples yielded EMCs, which represent the discharge-weighted average concentrations during the runoff event. Figure 4 shows a rainfall-discharge hydrograph of a runoff event at site 4 during Sept. 22–24, 1998, and also shows the subsample-collection timing during the event.

During several of the longer duration runoff events, multiple composite samples were collected at some sites. For example, after 24 hours of sampling, the subsamples already collected would be composited, processed, and shipped to the laboratory for analysis while automatic sampling continued at the site. In this way, subsamples collected during the early phase of a runoff event would not be degraded if the runoff event lasted several days[1]. When multiple composite samples were collected and analyzed at a particular site during an event, EMCs for the entire event were calculated by discharge-weight averaging of the concentrations from the separate composites. Runoff samples were analyzed by the NWQL for major inorganic ions, nutrients, and dissolved pesticides.

Total suspended solids concentrations were determined by analysis of the samples collected with automatic samplers. In addition, five suspended sediment samples were collected manually at site 5 using the equal-discharge-increment (EDI) method (Wells and others, 1990). The EDI method involves collection of a sample at a specific time and discharge that is integrated horizontally and vertically through the channel cross section. Because sediment concentrations vary with location in the channel cross section, the EDI method is more accurate for determining sediment concentrations than using automatic samplers, which collect samples from a single fixed point in the channel.

Sand-break analysis was performed on several of the EDI sediment samples to determine the sand-clay composition of the sediment. Sand-break analysis gives the percentage of sediment, by weight, that is finer than 0.062 millimeter.

[1] During the October 1997 event, 5 days of sampling at site 5 resulted in 104 subsamples, representing three composite samples that were analyzed and aggregated by discharge to determine the EMCs.

Fertilizer and Pesticide Application

Detailed fertilizer and pesticide application data for the 40,540-acre lower study area (excluding area gaged by sites 1 and 2) were provided by the agricultural producer and TAES. Runoff data collected at sites 1 and 2 provide information on runoff and constituents entering the lower study area. Runoff data for sites 3, 4, and 5 provide information on runoff exiting the entire study area. The chemical application data can be used, along with runoff data, to compare loads and yields of nitrogen, phosphorus, and pesticides entering (through rainfall and chemical applications) and exiting (through surface runoff) the lower study area. Annual applications of nitrogen and phosphorus fertilizers and selected pesticides are listed in table 2 (at end of report).

HYDROLOGIC CONDITIONS

Rainfall

Long-term rainfall data from the NOAA weather station at Kingsville Naval Air Station (fig. 2) were compared with study area rainfall data during 1996–98. The NOAA station annual rainfall for 1969–98 is shown in figure 5. The 30-year mean annual rainfall is 29.80 in. with a minimum of 17.14 in. during 1988 and a maximum of 46.01 in. during 1981.

During January 1996–December 1998, the study area received 77.59 in., as determined by a Theissen average (Wanielista, 1990) based on the six study area raingages. Annual distribution of the rainfall is listed in the table below.

Annual and mean annual rainfall for study area (1996–98) and mean annual rainfall for NOAA station, 1969–98

Study area rainfall (inches)				1969–98 mean annual NOAA station rainfall (inches)
1996	1997	1998	1996–98 mean annual	
12.86	38.08	26.65	25.86	29.80

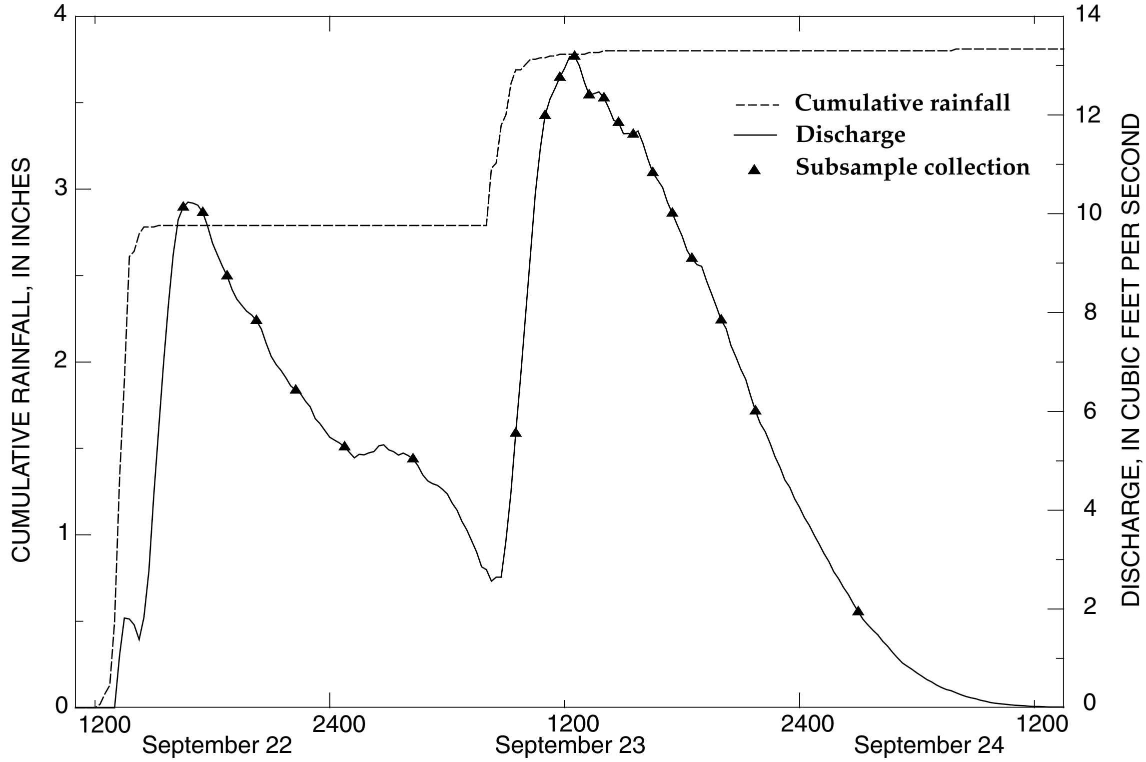


Figure 4. Hydrograph showing rainfall, discharge, and subsample-collection timing at site 4 during storm event of September 22–24, 1998.

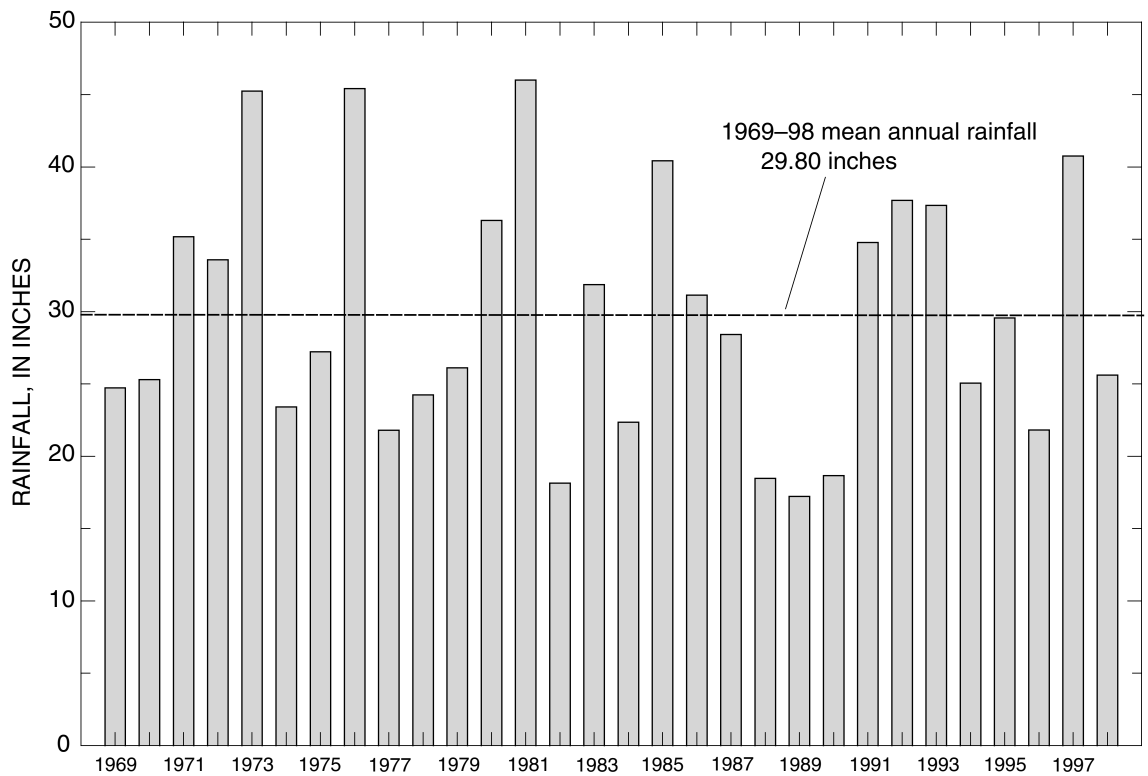


Figure 5. Annual rainfall at National Oceanic and Atmospheric Administration Kingsville weather station, 1969–98.

The study area rainfall of 12.86 in. during 1996 was less than any individual annual rainfall during 1969–98 at the NOAA station (fig. 5). The 1997 study area rainfall exceeded the NOAA station mean annual rainfall because of heavy April and October rains. However, the study area received only 0.84 in. of rain during June–August (8.75 in. less than the NOAA mean monthly rainfall for June–August 1969–98, shown in fig. 6). In 1998, study area rainfall was less than the NOAA mean annual rainfall, despite heavy September and October rains.

The NOAA station mean monthly rainfall (1969–98) indicates a bimodal rainfall pattern, with May–June and August–October generally receiving the greatest rainfall (fig. 6). Heavy rainfall during August–October often is associated with tropical disturbances originating from the Gulf of Mexico.

A graph of the deviation of monthly study area rainfall during 1996–98 from the NOAA station mean monthly rainfall during 1969–98 shows that the study area rainfall was below the NOAA mean monthly during 24 months (fig. 7). Even during 1997, when the study area received above-average rainfall, rainfall was below average during 6 months. This pattern of periods of below-average rainfall punctuated by extreme rainfall events is typical of historical patterns (Ward, 1997).

Runoff

Runoff conditions during the study period generally corresponded to the rainfall pattern, with runoff events interspersed between long periods of no runoff. During 1996–98, 77.59 in. of rain fell on the study area resulting in 12.05 in. (fig. 8) or 50,300 acre-feet (acre-ft) of runoff. The runoff coefficient (ratio of runoff volume to rainfall volume) for the entire study period is 0.16. Annual coefficients were less than 0.01 in 1996, 0.21 in 1997, and 0.15 in 1998.

During the study, 18 separate runoff events (runoff at one or more of the five sites) were recorded. Table 3 (at end of report) lists the dates of the runoff events at each of the five monitoring sites; study area rainfall for each event (Theissen average); runoff volume at each site; total runoff exiting the study area; and runoff coefficients for individual events. Runoff coefficients for individual events ranged from less than 0.001 (Aug. 23–25, 1996, and Aug. 31–Sept. 1, 1996) to 0.488 (Oct. 18–31, 1998).

In the study area, runoff largely depends on rainfall, rainfall intensity, and antecedent soil moisture conditions. The combination of climate, soil type, and agricultural practices typically results in runoff only after rainfall of 2 in. or more, depending on antecedent conditions. Daily rainfalls of 2.71 and 1.96 in. (Sept. 21, 1997, and Aug. 14, 1998, respectively) resulted in no runoff because of dry antecedent soil conditions. In contrast, rainfall of 0.37 in. (Feb. 21–22, 1998) produced runoff (at only one site) during wet antecedent soil conditions (runoff had occurred 7 days previously). Most of the total volume of runoff during the study period resulted from relatively extreme storm events (greater than 5.0 in. of rainfall). The table below shows the percentage of runoff that resulted from specific amounts of event rainfall.

Distribution of 18 runoff events by rainfall amount, 1996–98

[>, greater than]

Event rainfall (inches):	0 to 0.99	1.00 to 1.99	2.00 to 2.99	3.00 to 3.99	4.00 to 4.99	>5.00
Number of events	3	9	2	0	1	3
Runoff (acre-feet)	140	2,040	3,510	0	3,980	40,600
Percent of total study area runoff	.28	4.1	7.0	0	7.9	81

During the study, the five largest storm events contributed about 38 percent of the total rainfall for the study area and 94 percent of the total runoff (table 3). During 1996, the study area received only about 13 in. of rain; furthermore, no daily rainfall was greater than 1.5 in., resulting in very little runoff. During 1997, rainfall of 5.50 in. on Apr. 2–13, 2.54 in. on May 15–19, and 11.16 in. on Oct. 10–24, accounted for about 97 percent of the annual runoff. During 1998, rainfall of 4.62 in. on Sept. 17–Oct. 4 and 5.45 in. on Oct. 18–31, accounted for about 90 percent of the annual runoff. During 1996–98, there were no runoff events during June, historically one of the months with the greatest rainfall.

Most of the runoff from the study area exited through site 5. The total runoff from the study area during 1996–98 was 50,300 acre-ft (table 3). The runoff exiting the study area through site 5 (46,900 acre-ft) was 93 percent of the total study area runoff.

WATER QUALITY

Rainfall and runoff quality were investigated by statistical analysis of EMCs; computation of constituent

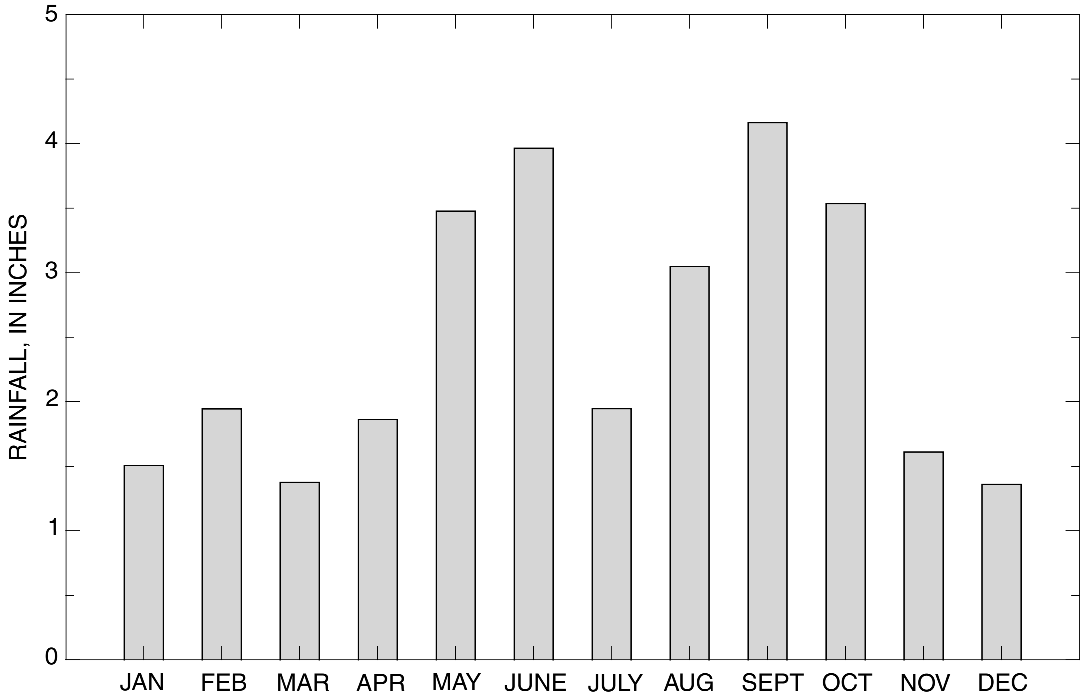


Figure 6. Mean monthly rainfall at National Oceanic and Atmospheric Administration Kingsville weather station, 1969–98.

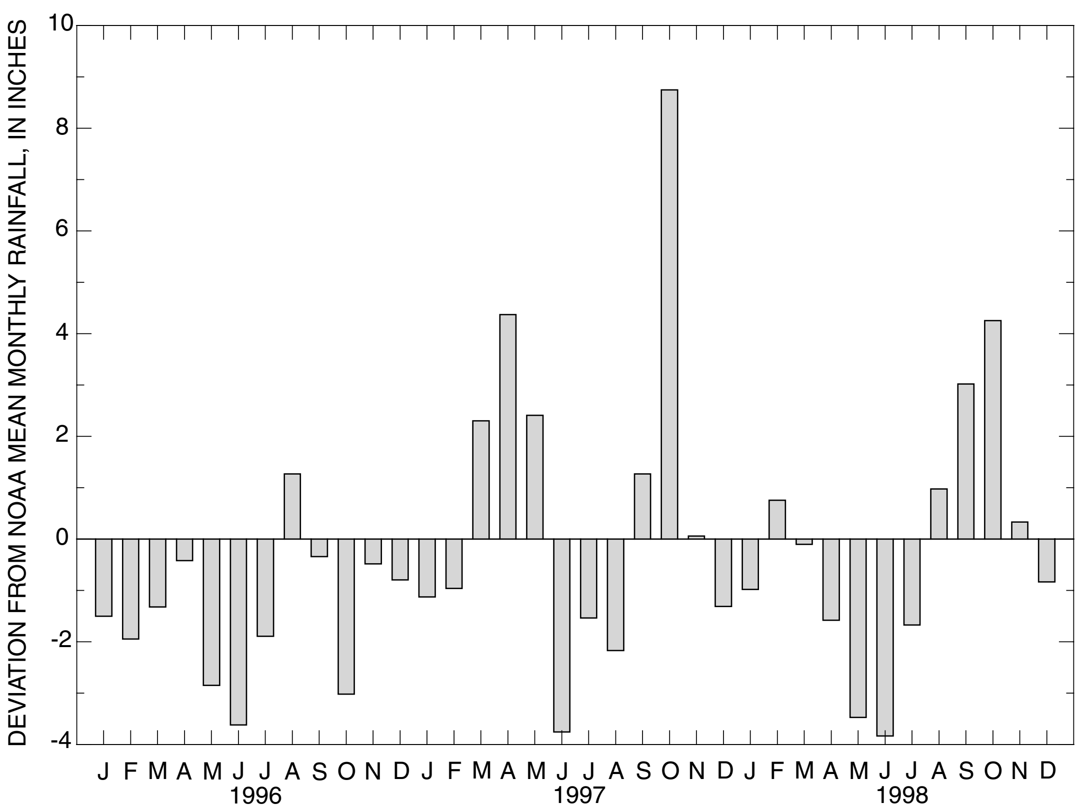


Figure 7. Deviation of monthly study area rainfall from mean monthly rainfall at National Oceanic and Atmospheric Administration Kingsville weather station, 1969–98.

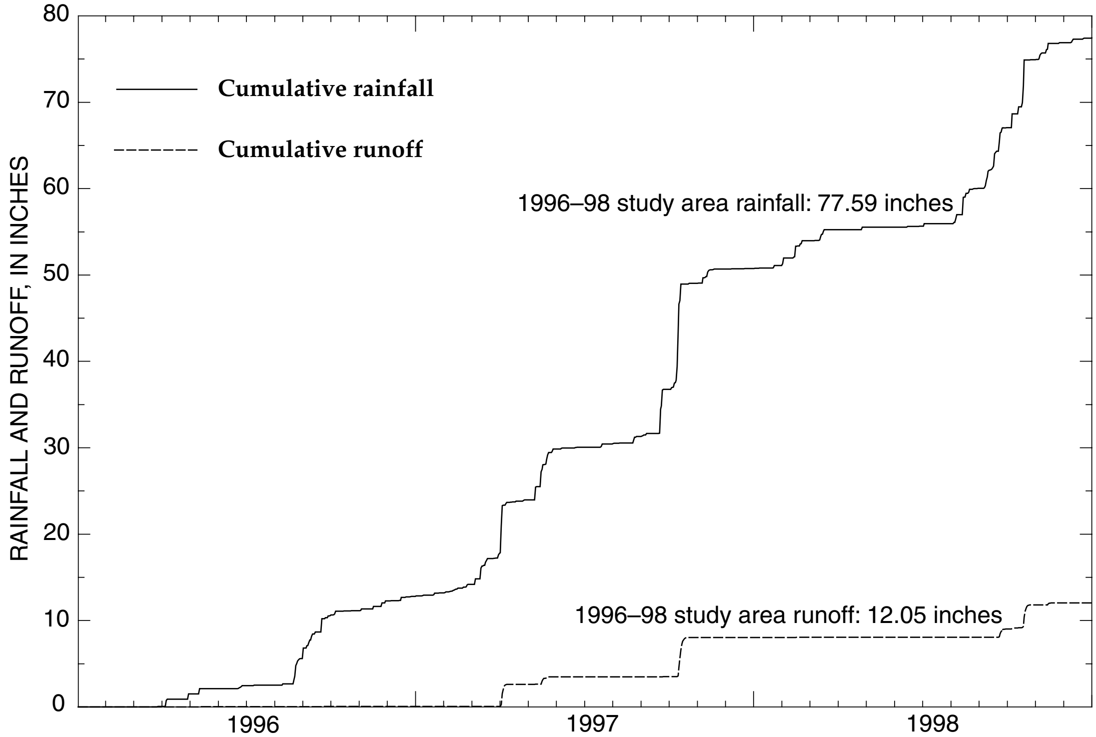


Figure 8. Hydrograph showing cumulative rainfall and runoff in study area, 1996–98.

deposition, loads, and yields; and determination of average study area constituent concentrations. Also, amounts of fertilizer and pesticide applications were compared with amounts of chemicals present in rainfall and runoff.

Rainfall

During 1996–98, 19 rainfall samples were collected at the TAES weather station and analyzed (appendix 1); 13 rainfall events that produced runoff were sampled and 6 other selected rainfall events that did not produce runoff were sampled. During the study period, 75.74 in. of rainfall were recorded at the TAES station. The 19 samples represent 28.84 in. of rainfall, or about 38 percent of the total rainfall (recorded at the TAES station) during the study period.

Event-Mean Nutrient Concentrations

Descriptive statistics computed from EMCs of selected nutrients in the rainfall samples are shown in table 4 (at end of report). Most of the nitrogen is in the form of dissolved ammonia (NH_4) and dissolved nitrate (NO_3), which were detected in all samples. The median ammonia and nitrate concentrations were 0.15 and 0.10 milligram per liter (mg/L), respectively. Dissolved nitrite (NO_2) and dissolved and total forms of organic nitrogen were detected in about one-half of the samples. Nitrite concentrations were less than the laboratory minimum reporting level (0.001 mg/L) in eight samples; the median concentration was 0.001 mg/L. The median total organic nitrogen concentration was 0.02 mg/L.

Total phosphorus was detected in all of the rainfall samples; the median concentration was 0.005 mg/L. Most of the phosphorus was dissolved phosphorus (median concentration 0.004 mg/L). Orthophosphate phosphorus was detected above the minimum reporting level (0.001 mg/L) in nine samples; the maximum concentration was 0.02 mg/L.

Rainfall Deposition

The deposition of rainfall constituents (in pounds per acre) can be defined as the product of the event constituent concentration and the rainfall volume. Daily rainfall deposition on the lower study area was computed for total nitrogen, dissolved ammonia, dissolved nitrate, and total phosphorus. For rainfall events during which rainfall samples were collected and analyzed, thus providing EMCs, daily deposition was computed as:

$$D = EMC \times R \times Cf, \qquad (1)$$

where

D = daily deposition, in pounds per acre;

EMC = nutrient concentration in rainfall, in milligrams per liter;

R = study area daily rainfall, in inches; and

Cf = conversion factor of 0.2266.

For unsampled events, in which rainfall constituent concentration data were not available, daily deposition of total nitrogen, ammonia, and nitrate was computed by regression equations that relate daily rainfall and daily nutrient deposition. The regression equations were developed from a larger database that includes data from this study along with rainfall nitrogen data collected from another location in the region (Ockerman and Livingston, 1999). Daily rainfall deposition of total phosphorus for unsampled events was computed using the median total phosphorus concentration in the rainfall samples (table 4). The daily rainfall depositions of nitrogen and phosphorus were aggregated to produce monthly and annual rainfall depositions of nitrogen and phosphorus to the study area as shown in table 5 (at end of report).

Applying the deposition rates (table 5), 465,000 pounds (lb) of total nitrogen were delivered to the 49,680-acre study area during 1996–98. Ammonia and nitrate accounted for 88 percent of the total nitrogen rainfall deposition. Compared to total nitrogen, total phosphorus deposition from rainfall was small, 4,870 lb delivered to the study area during 1996–98.

Runoff

Event-Mean Concentrations

During August 1996–October 1998, 29 runoff event samples were collected at sites 1–5 and analyzed to characterize the quality of runoff from the study area. Runoff EMCs, by site and event, are listed in appendix 2.

Nutrients and Major Inorganic Ions

The first step in analyzing nutrient and major inorganic ion concentrations in runoff was to test for statistically significant differences in concentrations among sampling sites. The Kruskall-Wallis test (Helsel and Hirsch, 1992, p. 159), a nonparametric test, compares the medians of groups differentiated by one explanatory variable (in this case, sampling site) to determine whether all groups have the same median (null hypothesis), or whether at least one median is different (alternative hypothesis). The p-values[2] of each test are shown in the table below. A statistical difference in concentrations among sites was deemed to exist when p-values were less than 0.05.

Results of Kruskal-Wallis test for statistical differences in nutrient and major inorganic ion concentrations in runoff samples among sites 1–5

Constituent	p-value	Is there a difference in concentrations among sites?
Nitrogen, total	0.22	No
Ammonia nitrogen, dissolved (as N)	.02	Yes
Nitrate + nitrite nitrogen, dissolved (as N)	.75	No
Ammonia + organic nitrogen, total (as N)	.28	No
Phosphorus, total	.72	No
Calcium, dissolved	.02	Yes
Magnesium, dissolved	.003	Yes
Potassium, dissolved	.01	Yes
Chloride, dissolved	.001	Yes
Sulfate, dissolved	.001	Yes

The results of the Kruskall-Wallis tests indicate a significant difference in all major inorganic ion concentrations and ammonia nitrogen concentrations among sites but no significant difference in other nutrient concentrations. Because the major inorganic ion EMCs at site 5 were greater than major inorganic ion EMCs at all other sites (appendix 2), the Mann-Whitney test (Helsel and Hirsch, 1992, p. 118) was used for further comparison of the major inorganic ion data from site 5 with the data from sites 1–4. The Mann-Whitney test, also a nonparametric test similar to the Kruskal-Wallis test, is intended to compare only two datasets. Results of this test indicated major inorganic ion concentrations were

[2] The p-value is the "attained level of significance" (the significance level attained by the data), which is the probability of obtaining the computed test statistic, or one even less likely, when the null hypothesis is true (Helsel and Hirsch, 1992, p. 108).

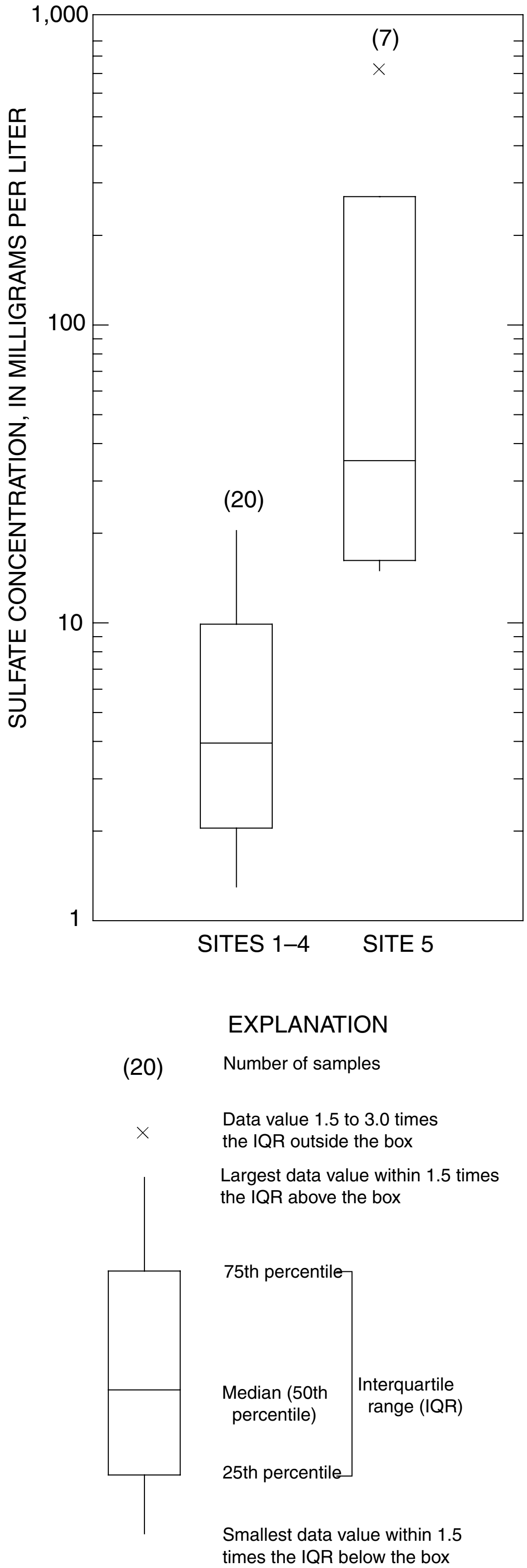


Figure 9. Distribution of sulfate concentrations in runoff samples from sites 1–4 and site 5, 1996–98.

significantly greater at site 5 compared with sites 1–4, as shown in the table below.

Results of Mann-Whitney test for statistical differences in major inorganic ion concentrations in runoff samples between sampling sites 1–4 and site 5

Constituent	p-value	Are concentrations greater at site 5 than at sites 1–4?
Calcium, dissolved	0.004	Yes
Magnesium, dissolved	.0001	Yes
Potassium, dissolved	.022	Yes
Chloride, dissolved	.0002	Yes
Sulfate, dissolved	.0008	Yes

A likely cause of greater major inorganic ion concentrations at site 5, compared to those at sites 1–4, is the proximity of site 5 to Baffin Bay. Sites 1–4 are located on canals that carry only freshwater runoff. However, the channel at site 5 is close enough to Baffin Bay that the channel occasionally is inundated by bay water (with greater major inorganic ion concentrations; Hem, 1985, p. 7)[3]. Deposits of major ions in bed sediment of Tunas Creek could be washed out during runoff events and contribute to the greater concentrations in the runoff.

Discharges of oil-field brines also have occurred previously in Tunas Creek[4] and nearby Petronilla Creek (the confluence of Tunas and Petronilla Creeks is about 3 mi downstream of site 5). Brine discharges (with chloride concentrations exceeding 50,000 mg/L, Armstrong and Ward, 1998) over the years could have saturated channel sediments and might continue to be flushed out during runoff events[5].

Concentrations of major inorganic ions at site 5 are not considered representative of cropland runoff. The difference between distribution of sulfate concentrations at sites 1–4 and site 5 are shown by boxplots in figure 9.

[3] During August 1998, salt deposits on the channel bed and banks were observed along the reach of Tunas Creek where site 5 is located, likely caused by evaporation of bay water, which had inundated the creek during high tides.

[4] Until 1987, 24 permitted brine discharge points into Tunas Creek combined for a permitted discharge of 1.47 acre-ft per day (Armstrong and Ward, 1998).

[5] Fifty years of continual brine discharges to Petronilla Creek ended in 1987. Instream salinity values near discharge sites did not recover quickly, suggesting brine constituents are recalcitrant and reside in sediment after discharge (Texas Natural Resource Conservation Commission, 1996).

The difference in ammonia concentrations among sites also was further examined. Concentrations at the upper study area sites 1 and 2 were significantly less than concentrations at the lower study area sites 3, 4, and 5 (Mann-Whitney test, p-value 0.0007). However, the cause of the difference was not apparent.

The next step in analyzing major ion and nutrient concentrations was to perform statistical tests to identify seasonal trends in concentrations. Major ion (except for site 5) and nutrient concentrations from runoff samples were grouped into two seasonal categories—pre-harvest and post-harvest. The pre-harvest season includes February–May, and the post-harvest season includes August–November. All runoff events during the study period were in these two seasonal categories—13 runoff samples were collected during the pre-harvest season and 16 runoff samples were collected during the post-harvest season. The Mann-Whitney test was used to determine whether one season tends to produce greater concentrations than the other season. Test results of median concentrations did not indicate statistically significant seasonal differences for any of the major ion or nutrient concentrations, although the p-value for ammonia, 0.07, indicates a possible seasonal difference.

Results of Wilcoxon rank-sum test for statistical seasonal differences in nutrient and major inorganic ion concentrations in runoff samples

Constituent	p-value	Is there a seasonal difference?
Nitrogen, total	0.29	No
Ammonia nitrogen, dissolved (as N)	.07	Maybe
Nitrite + nitrate nitrogen, dissolved (as N)	.77	No
Phosphorus, total	.52	No
Phosphorus, dissolved	.29	No
Orthophosphate phosphorus, dissolved (as P)	.40	No
Calcium, dissolved	.34	No
Magnesium, dissolved	.17	No
Potassium, dissolved	.30	No
Chloride, dissolved	.12	No
Sulfate, dissolved	.24	No

The final step in analyzing concentrations was to produce summary statistics of the data to characterize cropland runoff-event concentrations. Data from all sites, except major inorganic ion concentrations from site 5, were combined, and summary statistics were generated (table 6 at end of report). Table 6 also lists, for comparative purposes, TNRCC Texas Surface Water Quality Standards (TSWQS) for aquatic life protection or human health protection for nitrite plus nitrate nitrogen and total phosphorus.

Pesticides

The runoff samples were analyzed for a suite of 88 pesticides, some of which are not used in the study area (appendix 2). The pesticides that were applied on the lower study area during 1996–98 are listed in table 7 (at end of report). The table also indicates which pesticides were analyzed in the runoff samples.

One measure of pesticide occurrence is the frequency of detection among all samples. The bar graphs in figure 10 show the percentage of samples with herbicide and insecticide detections. The runoff samples had detections of 21 pesticides (15 herbicides and 6 insecticides). The herbicide atrazine and its breakdown product deethylatrazine were detected in all samples. Other pesticides detected in at least 25 percent of the samples were the herbicides trifluralin, simazine, pendimethalin, diuron, and metolachlor and the insecticide malathion. A statistical summary of concentrations of pesticides detected in the runoff samples and selected water-quality standards are listed in table 8 (at end of report).

Certain pesticide concentrations exhibited significant seasonal differences, probably because of the timing of pesticide application. The boxplots in figure 11 show the distribution of atrazine concentrations in runoff samples grouped by the two seasonal categories. The median pre-harvest, median post-harvest, and median of all samples for selected pesticides are listed in table 9 (at end of report).

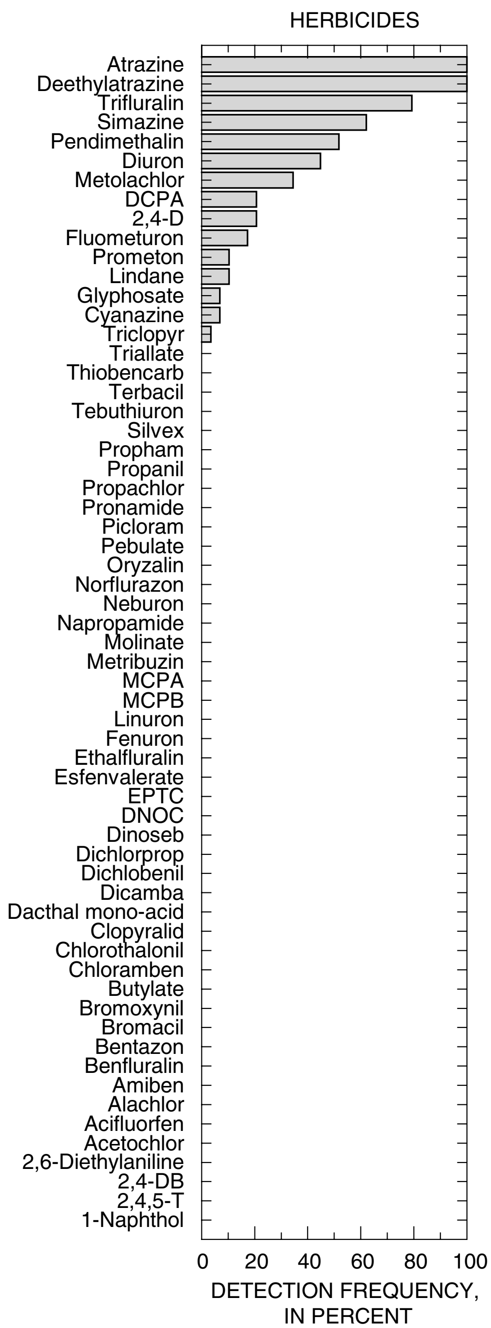
Suspended Sediment

Five suspended sediment samples were collected during two runoff events at site 5 as shown in the table below. Sand-break analysis was performed on three of the five sediment samples. Sediment composition, by weight, ranged from 98.4 to 99.7 percent silt and clay.

Suspended sediment concentrations in runoff samples collected at site 5

[--, not determined]

Date	Discharge (cubic feet per second)	Concentration (milligrams per liter)	Percent silt and clay (by weight)
04/03/97	3,230	812	98.4
04/03/97	2,380	839	99.4
04/04/97	990	841	99.7
05/16/97	750	570	--
05/17/97	225	327	--



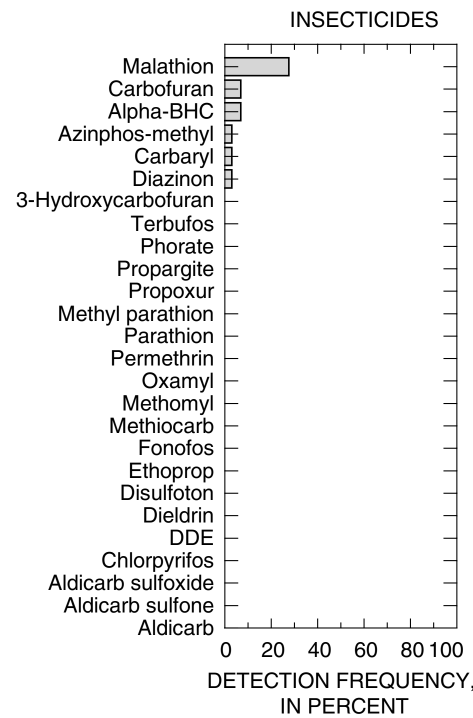


Figure 10. Herbicide and insecticide detection frequency in 29 runoff samples, 1996–98.

The sediment concentrations from these samples (shown above) are not EMCs but represent sediment concentrations at the time of sample collection. Sediment concentrations are a function of stream discharge and other factors, including rainfall duration and intensity and tillage practices. The relation between suspended sediment concentration and discharge for runoff samples collected at site 5 is shown in figure 12. The equation describing this relation is:

$$C = 0.0925 \times Q^{1.25}, \qquad (2)$$

where

C = sediment concentration in milligrams per liter, and

Q = stream discharge in cubic feet per second.

Equation 2 was used to compute discharge-weighted EMCs for sediment at site 5 for the seven events for which runoff samples were collected for water-quality analysis. The sediment EMCs are shown below:

Calculated EMCs of suspended sediment in selected runoff samples collected at site 5

Date	Runoff (acre-feet)	EMC (milligrams per liter)
09/96	82	199
03/97	38	172
04/97	10,100	727
05/97	2,700	543
10/97	18,000	759
09/98	3,420	509
10/98	10,300	688

Constituent Loads and Yields

The load of a constituent in runoff is the mass of a given constituent transported past a site during a

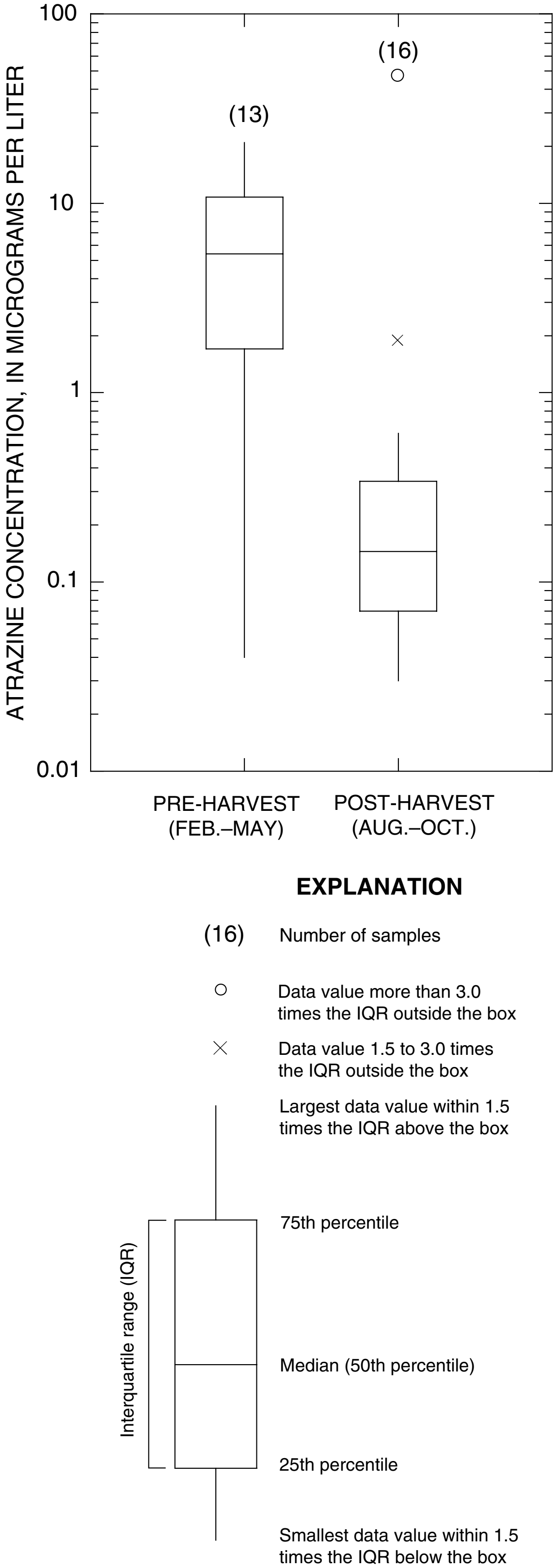


Figure 11. Seasonal distribution of atrazine concentrations in runoff samples, 1996–98.

specified time. Daily nutrient and pesticide loads in runoff were computed at each site from runoff and concentration data. For runoff events that were sampled and for which EMCs were determined, the daily constituent load at a particular site is (Ockerman and others, 1999):

$$L_n = EMC \times V \times Cf, \qquad (3)$$

where

L_n = constituent load, in pounds per day at site $_n$;
EMC = event-mean concentration during runoff event, in milligrams per liter or micrograms per liter;
V = daily runoff, in acre-feet; and
Cf = conversion factor, 2.719 for concentrations in milligrams per liter or 0.00272 for concentrations in micrograms per liter.

For unsampled events, median EMCs for samples collected during the study were used in equation 3 to compute daily loads. Runoff loads from the total study area are the sum of loads from sites 3, 4, and 5. Net runoff loads from the lower study area are total study area loads (sites 3, 4, and 5) minus loads from the upper study area (sites 1 and 2). Daily loads were summed to compute monthly and annual loads.

Constituent yield, a measure of the load-producing characteristics of a watershed, is computed by dividing the load by the drainage area of the watershed:

$$Y = L / DA, \qquad (4)$$

where

Y = constituent yield, in pounds per acre per month (or year);
L = constituent load exiting the watershed, in pounds per month (or year); and
DA = contributing area of the watershed, in acres.

Sediment loads for the entire study area were computed from regression equations based on sediment concentration and load data collected at site 5. Sediment yields were computed from the estimated loads using equation 4.

Nutrients

Nutrient concentrations estimated from median EMCs (table 6) were used in equation 3 to compute daily loads for runoff events in which water-quality samples were not collected. Unsampled events account for about 5 percent (513 acre-ft of the total of

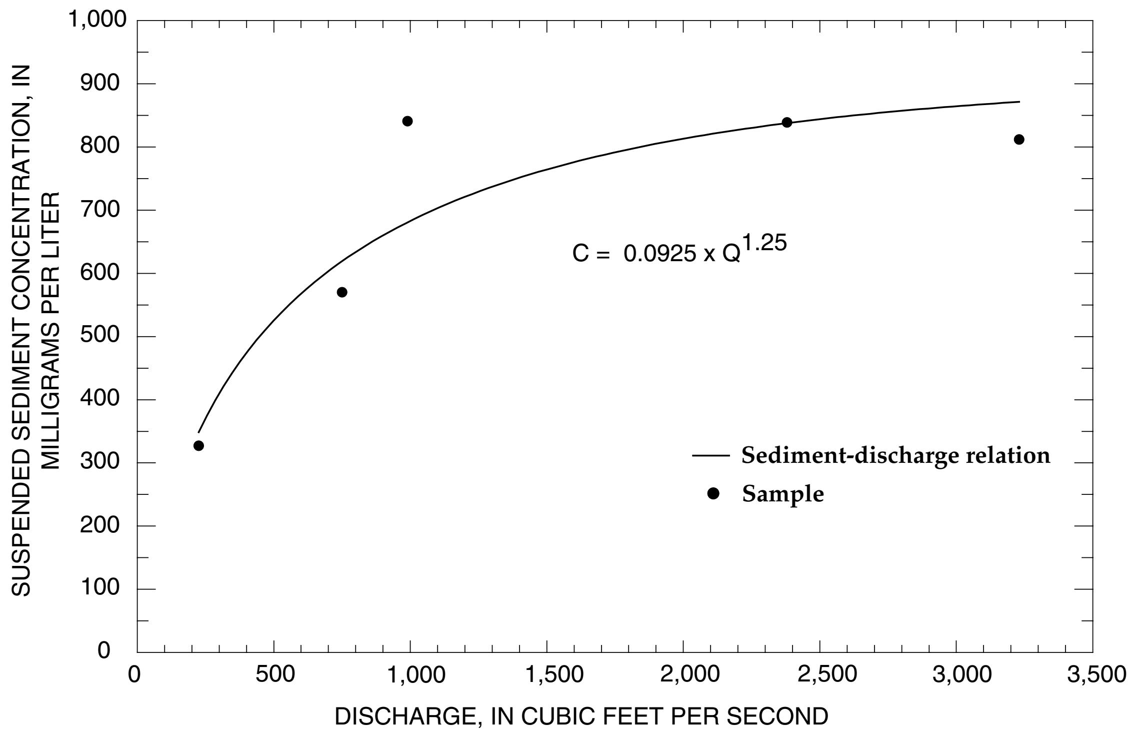


Figure 12. Relation between suspended sediment concentration (C) and discharge (Q) in runoff samples collected at site 5.

9,920 acre-ft) of the runoff in the upper study area and about 7 percent (3,480 acre-ft of the total of 50,300 acre-ft) of the runoff exiting the study area during 1996–98. The monthly and annual loads of selected nutrients in runoff are listed in table 10 (at end of report), and the corresponding annual yields are listed in table 11 (at end of report). The tables list loads and yields for the upper and lower study area as well as for the entire study area.

Annual runoff loads and yields of nutrients were highly variable, corresponding to the highly variable annual runoff. The total nitrogen load exiting the study area in 1996 was 800 lb compared to 102,000 lb in 1997 and 81,500 lb in 1998. The average annual load of total nitrogen for 1996–98 was 61,400 lb. The annual total phosphorus loads were 180 lb in 1996, 46,600 lb in 1997, and 21,400 lb in 1998, for an average annual load for 1996–98 of 22,700 lb.

The total nitrogen yields for the study area were 0.02, 2.1, and 1.6 pounds per acre per year (lb/acre-yr) in 1996, 1997, and 1998, respectively. The average annual yield for 1996–98 was 1.2 pounds per acre (lb/acre). The total phosphorus yields were <0.01, 0.94, and 0.43 lb/acre-yr in 1996, 1997, and 1998, respectively, for an average annual yield for 1996–98 of 0.46 lb/acre.

Net runoff yields of total nitrogen and total phosphorus for the lower study area were compared to nutrient inputs from fertilizer applications and rainfall deposition, as shown in the table below:

Comparison of fertilizer applications, rainfall deposition, and runoff yields of nitrogen and phosphorus for the 40,540-acre lower study area

[In pounds per acre per year; <, less than]

Year or period	Nitrogen fertilizer application	Rainfall deposition of nitrogen	Runoff yield of nitrogen
Total nitrogen			
1996	45	2.1	0.02
1997	73	3.9	2.1
1998	28	3.3	1.7
1996–98 average	49	3.1	1.3

Year or period	Phosphorus fertilizer application	Rainfall deposition of phosphorus	Runoff yield of phosphorus
Total phosphorus			
1996	0	0.02	<0.01
1997	7.1	.04	1.0
1998	5.4	.03	.45
1996–98 average	4.2	.03	.48

Nitrogen input from fertilizer is much larger than all other inputs or outputs of nitrogen in the study area. Average annual application of fertilizer-based nitrogen in the lower study area was 49 lb/acre[6] compared to 3.1 lb/acre from rainfall deposition and 1.3 lb/acre in net runoff. Annual rainfall deposition of nitrogen on the lower study area exceeds runoff yields of nitrogen exiting the study area because most of the rainfall does not contribute to runoff. The average annual net runoff yield of nitrogen exiting the lower study area represents about 2.5 percent of the nitrogen entering the lower study area as fertilizer and in rainfall deposition. However, the forms of nitrogen entering the lower study area are different from the forms exiting the area in runoff. Most of the nitrogen applied as fertilizer is in the form of ammonia and nitrate, and rainfall nitrogen also consists mainly of ammonia and nitrate (table 5). Annual net runoff loads of total nitrogen exiting the lower study area are primarily (about 77 percent) organic nitrogen (table 10). Also, the organic nitrogen is mostly in particulate form[7] (crop residue), rather than dissolved organic nitrogen.

As with nitrogen, the average annual application of fertilizer-based phosphorus exceeds other sources of phosphorus entering or exiting the lower study area. Average annual application of fertilizer-based phosphorus in the lower study area was 4.2 lb/acre. The fertilizer is applied as soluble orthophosphate phosphorus. The average annual net runoff yield of phosphorus exiting the lower study area was 0.48 lb/acre (or about 11 percent of phosphorus entering as fertilizer and in rainfall deposition). About 21 percent (0.10 lb/acre) of the phosphorus exiting the study area is orthophosphate. Most of the phosphorus in runoff was particulate in nature, associated with crop debris and eroded soils that contain phosphorus (Hem, 1985, p. 126). Phosphorus inputs from rainfall during 1996–98 were relatively small, with an average annual deposition of 0.03 lb/acre.

Comparisons of sources of nitrogen and phosphorus also were made for an individual runoff event (April 1997). Various forms of nitrogen in rainfall deposition and runoff yields for the lower study area are shown in figure 13. Rainfall deposition of total nitrogen was 0.15 lb/acre compared to runoff yield of 1.18 lb/acre. Similar to annual trends, most of the rainfall nitrogen was ammonia and nitrate while most of the runoff nitrogen was particulate organic nitrogen. The ammonia nitrogen was greater in rainfall deposition than in runoff yield, possibly indicating that some of the rainfall ammonia might undergo a transformation to other forms of nitrogen, such as nitrate, during the runoff process.

During the April 1997 event, the net runoff yield of total phosphorus exiting the lower study area was 0.41 lb/acre, including 0.08 lb/acre of dissolved orthophosphate. Rainfall deposition of total phosphorus was 0.004 lb/acre, including 0.003 lb/acre of orthophosphate. The ratio of orthophosphate to total phosphorus in runoff during this event is similar to that observed in runoff during the 1996–98 study.

Pesticides

Runoff loads of three pesticides (atrazine plus deethylatrazine, diuron, and trifluralin) were computed similarly to loads of nutrients. Loads for unsampled events were computed using the seasonal median concentrations (table 9). Monthly and annual loads of the three pesticides are listed in table 12 (at end of report), and the corresponding annual yields are listed in table 13 (at end of report). The tables list loads and yields for the upper and lower study area as well as for the entire study area.

The net runoff yield of dissolved atrazine plus deethylatrazine exiting the lower study area was computed (table 13) and compared to applications of atrazine in the lower study area (table 2). During the study period, atrazine applications in the lower study area ranged from 0.26 to 0.43 lb/acre-yr as shown in the table below:

Comparison of applications and runoff yields of atrazine for the 40,540-acre lower study area

[In pounds per acre]

Year or period	Atrazine application	Net runoff yield of atrazine plus deethylatrazine
1996	0.26	0.0003
1997	.42	.00876
1998	.43	.0003
1996–98 average	.37	.0027

[6] Fertilizer application is computed as the total mass (pounds) of active ingredients divided by the total acreage of the lower study area, including 3,932 acres of rangeland, which do not actually receive any nitrogen applications.

[7] The EMCs of dissolved organic nitrogen at all five sites during the April 1997 runoff event were below the minimum reporting level of 0.2 mg/L; however, total (dissolved and particulate) organic nitrogen concentrations at the five sites ranged from 0.77 to 2.83 mg/L.

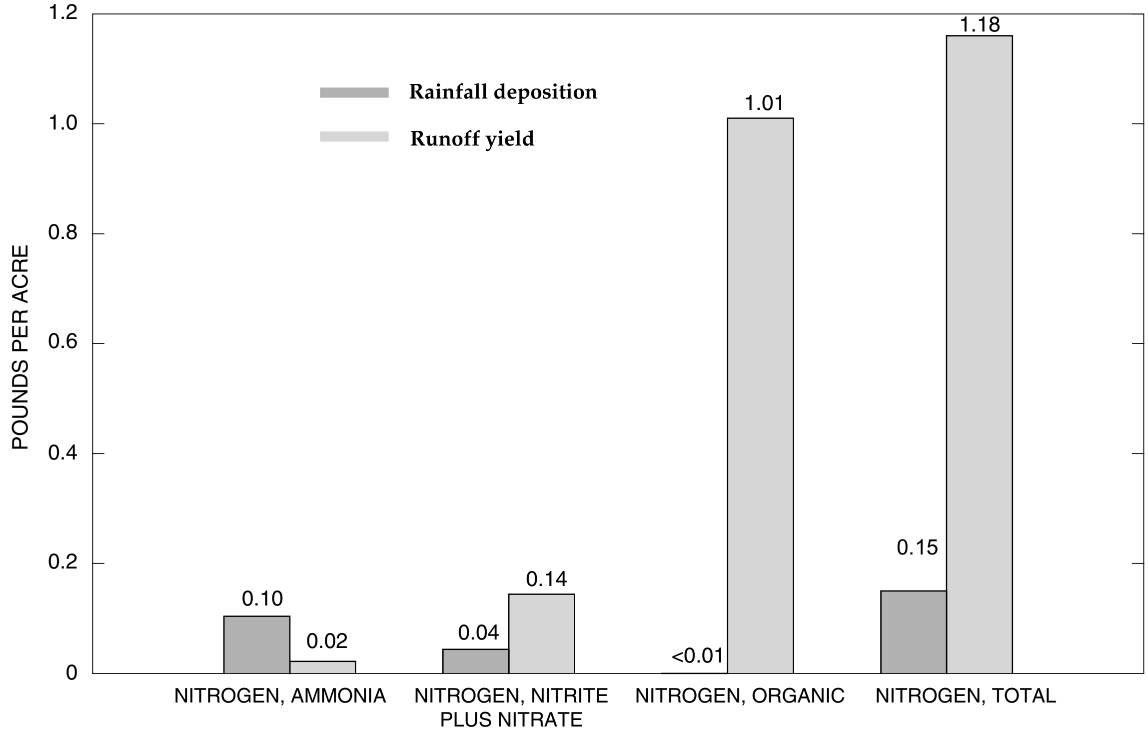


Figure 13. Comparison of rainfall deposition and runoff yield of nitrogen during April 2–13, 1997, lower study area.

Overall, during 1996–98, 45,500 lb of atrazine were applied (0.37 lb/acre-yr), and about 330 lb of dissolved atrazine plus deethylatrazine exited the lower study area in net runoff (about 0.0027 lb/acre-yr). The 1996–98 net runoff yield was about 0.7 percent of the total atrazine applied to the cropland during that period. Most of the atrazine runoff loads occurred during April and May 1997. As a result, the 1997 runoff yield of atrazine was about 1.8 percent of the atrazine applied that year.

Sediment

The sediment loads for all runoff events at site 5 were computed using equation 3 and the EMCs determined earlier. The event sediment loads are compared with event runoff in figure 14. The equation expressing the relation between sediment load and runoff is:

$$Ls = 56.1 \times R^{0.35}, \qquad (5)$$

where

Ls = sediment load in tons, and

R = event runoff in acre-feet.

Equation 5 was used to estimate sediment loads for runoff events at sites 3 and 4. The total (sites 3, 4, and 5) monthly and annual loads of sediment in runoff exiting the study area are listed in table 14 (at end of report), and the corresponding annual yields are listed in table 15 (at end of report).

Sediment loads exiting the study area during runoff events varied widely, ranging from 0.90 ton in August 1996 to 19,000 tons in October 1997. Sediment loads from the study area are dominated by storm events—87 percent of the 45,300 tons of sediment transported from the study area during 1996–98 occurred during three events (April 1997, October 1997, and October 1998). The annual sediment yield was 2.2 lb/acre in 1996 compared to 1,270 lb/acre in 1997 with a 1996–98 average yield of 610 lb/acre-yr.

Runoff-Weighted Average Concentrations

The runoff-weighted average concentration is computed by dividing the load of a constituent exiting the study area by the study area runoff to take into account the runoff at each site. Runoff-weighted average concentrations are considered a way to express

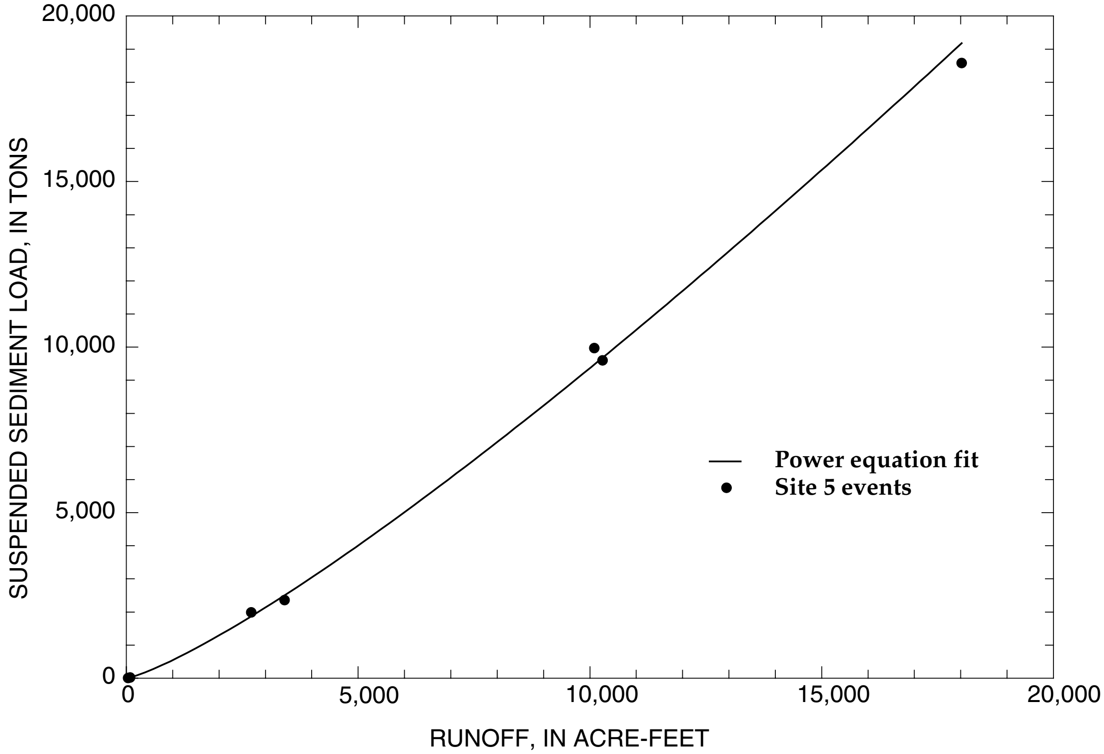


Figure 14. Relation between suspended sediment load and storm event runoff at site 5, 1996–98.

the total watershed load in terms of a concentration value. The runoff-weighted average concentration can be determined for a single runoff event or for a longer period, such as a month or year. For example, because the runoff at site 5 was always much greater than the runoff from sites 3 and 4, the corresponding event concentrations at site 5 will be weighted more heavily in computing the average concentrations of constituents in runoff exiting the study area. Computation of annual (or longer) runoff-weighted average concentrations will be influenced more by concentration data from larger runoff events than by concentration data from smaller runoff events.

Nutrients

Study area runoff-weighted nutrient concentrations computed by month, year, and entire study period are listed in table 16 (at end of report). The monthly runoff-weighted concentrations generally correspond to single events. The annual and entire study period concentrations represent long-term runoff water quality.

The 1996–98 average runoff-weighted concentration for total nitrogen (1.3 mg/L) is smaller than either the mean (1.6 mg/L) or the median (1.4 mg/L) EMC because of the influence of large runoff events with smaller concentrations. Similarly, the 1996–98 nitrite plus nitrate runoff-weighted concentration (0.22 mg/L) is smaller than either the mean (0.36 mg/L) or the median (0.27 mg/L) EMC. However, the total phosphorus runoff-weighted concentration (0.50 mg/L) is slightly larger than either the mean (0.48 mg/L) or the median (0.46 mg/L) EMC because much of the total phosphorus is associated with sediment, and larger sediment concentrations associated with greater runoff events result in the larger runoff-weighted average concentrations.

Pesticides

Runoff-weighted concentrations computed for three pesticides are listed in table 17 (at end of report). For EMCs less than the minimum reporting level, the minimum reporting level was used to compute the event runoff loads that then were used to compute runoff-weighted average concentrations.

Although atrazine was the most frequently detected pesticide, the herbicide diuron had the largest runoff-weighted concentration, 2.9 micrograms per liter (µg/L) for 1996–98. Nearly all (99 percent) of the diuron runoff occurred during pre-harvest events in 1997. The April and May 1997 runoff-weighted diuron concentrations were 12 and 4.9 µg/L, respectively. The 1996–98 runoff-weighted atrazine plus deethylatrazine concentration was 2.7 µg/L. Most of the atrazine runoff also occurred during the pre-harvest season in 1997, resulting in April and May 1997 runoff-weighted concentrations of 7.6 and 11 µg/L, respectively.

SUMMARY

From January 1996 to December 1998, rainfall and runoff were monitored at five streamflow-gaging stations and one weather station in a 49,680-acre agricultural area in Kleberg and Nueces Counties in the Baffin Bay watershed of South Texas. Nineteen rainfall samples were collected at the weather station and analyzed for nutrients, and 29 event-composite runoff samples were collected at the streamflow stations and analyzed for major ions, nutrients, and pesticides.

Total rainfall for 1996–98 averaged 25.86 in. per year, which is less than the long-term annual average rainfall of 29.80 in. for the area. Historically, rainfall in the region can be characterized by long periods of below-average rainfall punctuated by extreme rainfall events, with the heaviest rainfall generally occurring during May–June and August–October. Study area rainfall during 1996–98 was typical of this pattern. Rainfall was below average for 1996 (12.86 in.), but extreme rainfall events during 1997 and 1998 resulted in above-average rainfall for 1997 and near-average rainfall for 1998.

The combination of climate, soil type, and agricultural practices typically results in runoff only after rainfall of 2 in. or more, depending on antecedent conditions. Extreme rainfall events are the most important factor affecting the amount and timing of runoff and associated constituent loads. During 1996, the below-average rainfall coupled with no daily rainfall greater than 1.5 in. resulted in very little runoff. During 1997, rainfall of 5.50 in. on Apr. 2–13, 2.54 in. on May 15–19, and 11.16 in. on Oct. 10–24 accounted for about 97 percent of the annual runoff. Similarly, during 1998, rainfall of 4.62 in. on Sept. 17–Oct. 4 and 5.45 in. on Oct. 18–31 accounted for about 90 percent of the annual runoff. Overall, five rainfall events during the study period accounted for about 38 percent of the total rainfall and 94 percent of the total runoff. Annual runoff coefficients (ratio of runoff volume to rainfall volume) were less than 0.01 in 1996, 0.21 in 1997, and 0.15 in 1998.

Rainfall on the 40,540-acre lower study area during 1996–98 deposited an average of about 3.1 lb/acre-yr of total nitrogen compared to 49 lb/acre-yr from fertilizer. Rainfall on the lower study area during 1996–98 deposited an average of about 0.03 lb/acre-yr of total phosphorus compared to 4.2 lb/acre-yr applied as fertilizer.

Annual net runoff yields computed for total nitrogen and total phosphorus exiting the lower study area were slightly greater than yields computed for the entire 49,680-acre study area. Net runoff yields of nitrogen exiting the lower study area, ranging from 0.02 lb/acre in 1996 to 2.1 lb/acre in 1997 with an average of 1.3 lb/acre-yr, are less than that entering through rainfall. Total nitrogen in runoff from the lower study area is about 2.5 percent of the combined fertilizer and rainfall nitrogen entering the lower study area during 1996–98. While most of the nitrogen entering the study area through rainfall or fertilizer is ammonia and nitrate, most of the nitrogen in runoff exiting the study area is particulate organic nitrogen. The major source of the organic nitrogen likely is crop residue. Net runoff yields of phosphorus exiting the lower study area ranged from <0.01 lb/acre in 1996 to 1.0 lb/acre in 1997 with an average of 0.48 lb/acre-yr. Total phosphorus in runoff from the lower study area is about 11 percent of the combined fertilizer and rainfall (mostly fertilizer) phosphorus entering the lower study area during 1996–98. Phosphorus fertilizer is applied as soluble orthophosphate; however, most of the total phosphorus in runoff is particulate, associated with crop debris and eroded soils.

Twenty-one pesticides were detected in runoff with varying degrees of frequency during the study. The herbicide atrazine and its breakdown product deethylatrazine were detected in all runoff event samples. Other frequently detected pesticides included trifluralin, simazine, pendimethalin, and diuron. Concentrations of these most frequently detected pesticides were greater during the pre-harvest period (March–May) than during the post-harvest period (August–October).

Atrazine plus deethylatrazine and diuron contributed the greatest loads of pesticides in runoff. Larger concentrations are detected in spring; thus, spring runoff events have the potential to deliver considerably larger pesticide loads than fall events. Most of the atrazine runoff loads were during April and May 1997.

About 1.8 percent of the atrazine applied to the lower cropland study area during 1997 exited the cropland in runoff. The 1996–98 runoff yield of atrazine plus deethylatrazine exiting the lower study area was about 0.7 percent of the total atrazine application.

Sediment loads exiting the study area during runoff events varied widely, ranging from 0.90 ton in August 1996 to 19,000 tons in October 1997. Sediment loads from the study area are dominated by storm events—of the 45,300 tons of sediment transported from the study area during 1996–98, 87 percent was transported during three events (April 1997, October 1997, and October 1998). The annual sediment yield was 2.2 lb/acre in 1996 compared to 1,270 lb/acre in 1997 with a 1996–98 average yield of 610 lb/acre-yr.

Runoff-weighted average concentrations (constituent load exiting study area divided by study area runoff) for the entire study area were computed for selected nutrients and pesticides for month, year, and entire study period. Because runoff-weighted average concentrations assign more weight to the sample concentrations at sites or during events where greater runoff occurred, they might best characterize water quality from the study area. The study area runoff-weighted concentrations of total nitrogen and total phosphorus for 1996–98 were 1.3 and 0.50 mg/L, respectively. Runoff-weighted concentrations of total nitrogen were less than either the mean or the median EMC. Runoff-weighted concentrations of total phosphorus were slightly greater than either the mean or the median EMC. The runoff-weighted atrazine plus deethylatrazine concentration for 1996–98 was 2.7 μg/L.

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Table 1. Selected characteristics of data-collection sites

[USGS, U.S. Geological Survey; TAES, Texas Agricultural Experiment Station; --, not applicable; NOAA, National Oceanic and Atmospheric Administration]

Site no. (fig. 1)	Responsible agency	USGS station no.	Station name	Type of data collected	Period of operation
1	TAES, USGS	08212500	Upper Madero Canal near Kingsville, Tex.	Rainfall, streamflow, water quality	1996–98
2	TAES, USGS	08212600	Chiltipin Creek near Kingsville, Tex.	Rainfall, streamflow, water quality	1996–98
3	TAES, USGS	08212700	Pinto Creek Canal near Kingsville, Tex.	Rainfall, streamflow, water quality	1996–98
4	TAES, USGS	08212800	Lower Madero Canal near Kingsville, Tex.	Rainfall, streamflow, water quality	1996–98
5	TAES, USGS	08212900	Tunas Creek near Kingsville, Tex.	Rainfall, streamflow, water quality	1996–98
--	TAES	--	Kleberg County–2	Rainfall Rainfall quality	1988–present 1996–98
--	NOAA	--	Kingsville	Rainfall	1949–present

Table 2. Applications of fertilizers and selected pesticides on 40,540-acre lower study area, 1996–98

[Actual planted area ranged from 36,128 to 36,168 acres]

Chemical	Application (pounds)			
	1996	1997	1998	Average
Fertilizer				
Nitrogen	1,800,000	2,950,000	1,130,000	1,960,000
Phosphorus	0	289,000	220,000	170,000
Pesticide				
Acephate	614	10,900	998	4,170
Atrazine	10,700	17,200	17,600	15,200
Azinphos-methyl	3,040	1,080	0	1,370
Carbofuran	1,130	0	4,140	1,760
2,4-D	1,060	13,600	18,100	10,900
Dimate	2,750	4,190	1,410	2,780
Diuron	760	21,800	19,600	14,100
Ethephon	11,900	13,600	5,050	10,200
Glyphosate	17,900	30,100	48,100	32,000
Malathion	63,300	87,100	70,700	73,700
MSMA	2,890	174	900	1,320
Paraquat	0	1,430	401	611
Thidiazuron	16,800	16,400	4,560	12,600
Trifluralin	16,900	18,200	0	11,700

Table 3. Rainfall, runoff volumes, and runoff coefficients for runoff events, 1996–98

[Total study area runoff is sum of runoff from sites 3, 4, and 5; --, no runoff; <, less than]

Event date	Study area rainfall (inches)	Runoff (acre-feet)						Runoff coefficient
		Site 1	Site 2	Site 3	Site 4	Site 5	Total study area	
05/11–12/96	0.62	--	14	--	--	110	110	0.042
08/23–25/96	1.74	--	--	4.7	--	--	4.7	<.001
08/31–09/01/96	1.20	--	1.0	.5	--	--	.5	<.001
09/20–21/96	1.55	2.1	4.2	.7	--	82	83	.013
03/12–13/97	1.47	--	--	--	--	38	38	.006
04/02–13/97	5.50	820	590	410	130	10,100	10,600	.467
05/09–11/97	1.53	--	24	--	--	180	180	.029
05/15–19/97	2.54	71	110	82	34	2,700	2,820	.267
05/21–26/97	1.34	--	67	80	10	610	700	.126
05/28–30/97	.40	--	--	10	3.0	--	13	.008
09/24–27/97	1.91	--	--	15	--	11	26	.003
10/10–24/97	11.16	3,620	1,570	620	320	18,000	18,900	.410
02/14–15/98	1.23	--	4.0	1.0	--	63	64	.012
02/21–22/98	.37	--	--	18	--	--	18	.012
09/17–10/04/98	4.62	43	222	540	23	3,420	3,980	.208
10/06–17/98	2.41	23	30	160	6.8	540	710	.070
10/18–31/98	5.45	1,550	1,050	640	100	10,300	11,000	.488
11/08–22/98	1.19	73	36	150	21	780	950	.192
Total of 18 events	46.23	6,200	3,720	2,730	650	46,900	50,300	.263

Table 4. Summary statistics of selected nutrient concentrations for 19 rainfall samples, 1996–98

[In milligrams per liter; --, not determined; <, less than]

Nutrient	Mean	Median	Minimum	Maximum
Nitrogen, total	0.36	0.37	0.03	0.91
Ammonia nitrogen, dissolved (as N)	.18	.15	.01	.41
Nitrate nitrogen, dissolved (as N)	.12	.10	.03	.45
Nitrite nitrogen, dissolved (as N)	--	.001	<.001	.01
Organic nitrogen, total (as N)	.05	.02	<.1	.36
Phosphorus, total	.01	.005	.001	.06
Phosphorus, dissolved	--	.004	<.001	.02
Orthophosphate phosphorus, dissolved (as P)	--	<.002	<.001	.02

Table 5. Monthly and annual rainfall deposition of nitrogen and phosphorus,1996-98

[In pounds per acre; <, less than]

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
Nitrogen, total													
1996	0	0	0.02	0.19	0.10	0.12	0.03	0.53	0.54	0.16	0.21	0.18	2.08
1997	.18	.37	.54	.39	.60	.09	.09	.20	.37	.73	.32	.06	3.94
1998	.15	.40	.25	.05	.01	.06	.06	.49	.86	.49	.36	.16	3.34
Ammonia nitrogen													
1996	0	0	.01	.10	.06	.08	.02	.26	.32	.10	.12	.11	1.18
1997	.12	.22	.27	.24	.31	.06	.05	.09	.29	.21	.18	.04	2.08
1998	.09	.23	.14	.02	.01	.04	.03	.26	.44	.23	.20	.10	1.79
Nitrate nitrogen													
1996	0	0	.01	.07	.03	.04	.01	.17	.18	.06	.07	.06	.70
1997	.07	.13	.18	.13	.19	.03	.03	.08	.14	.20	.12	.02	1.32
1998	.05	.13	.09	.02	<.01	.02	.02	.17	.31	.17	.13	.06	1.17
Phosphorus, total													
1996	0	0	<.001	.002	.003	<.001	<.001	.008	.006	.001	.002	.001	.023
1997	<.001	.001	.008	.004	.007	<.001	.001	.005	.006	.011	.002	<.001	.045
1998	.001	.004	.001	<.001	0	<.001	<.001	.005	.007	.009	.002	.001	.030

Table 6. Summary statistics of selected major ion and nutrient concentrations in runoff samples, 1996–98, and selected regulatory water-quality criteria

[In milligrams per liter; does not include major ion data from site 5 (sub-tidal site). TSWQS, Texas Surface Water Quality Standard; --, not applicable; <, less than]

Major ion or nutrient	No. of samples	Mean	Median	Maximum	Minimum	TSWQS aquatic life protection[1]	TSWQS human health protection[1]
Calcium, dissolved	20	17.1	16.2	30.0	10.0	--	--
Magnesium, dissolved	20	1.46	1.25	2.7	.90	--	--
Potassium, dissolved	20	3.4	2.9	7.1	1.4	--	--
Sulfate, dissolved	20	6.7	3.9	20	1.3	--	--
Chloride, dissolved	20	7.0	3.8	32	.90	--	--
Nitrogen, total	29	1.6	1.4	5.3	.49	--	--
Ammonia nitrogen, dissolved (as N)	29	.06	.03	.26	<.015	--	--
Nitrite + nitrate nitrogen, dissolved (as N)	29	.36	.27	1.5	.12	10	--
Ammonia + organic nitrogen, total (as N)	29	1.2	1.0	3.8	.34	--	--
Phosphorus, total	29	.48	.46	1.2	.03	--	100
Phosphorus, dissolved	29	.13	.12	.36	.02	--	--
Orthophosphate phosphorus, dissolved (as P)	29	.13	.11	.37	.02	--	--

[1] Texas Natural Resource Conservation Commission (1999).

Table 7. Pesticides applied on lower study area, 1996–98

[X, application; --, no application

Pesticide	1996	1997	1998	Included in sample analysis	Pesticide	1996	1997	1998	Included in sample analysis
Herbicides					**Insecticides**				
Atrazine	X	X	X	Yes	Acephate	X	X	X	No
Bromoxynil	X	X	X	No	Azinphos-methyl	X	X	X	Yes
Clethodin	X	X	X	No	Carbofuran	X	X	X	Yes
Cyanazine	X	X	X	Yes	Dimethoate	X	X	X	Yes
2,4-D	X	X	X	Yes	Endosulfan	X	X	X	Yes
Dicamba	X	X	X	Yes	Esfenvalerate	X	X	X	Yes
Dimate	X	X	X	No	Imidacloprid	X	X	X	No
Diuron	X	X	X	Yes	Lambda cyhalothrin	--	X	--	No
Fenoxaprop-P-ethyl	--	X	--	No	Malathion	X	X	X	Yes
Glyphosate	X	X	X	Yes	Oxamyl	--	X	--	Yes
Halosulfuron-methyl	--	X	X	No	Tralomethrin	X	X	X	No
MSMA	X	X	X	No	zeta-Cypermethrin	X	X	X	No
Paraquat	--	X	X	No	**Defoliants, growth regulators**				
Pendimethalin	X	X	X	Yes	Ethephon	X	X	X	No
Pyrithiobac-sodium	X	X	X	No	Mepiquat chloride	--	X	--	No
Quizalofop-P-ethyl	X	--	X	No	Thidiazuron	X	X	X	No
Triclopyr	X	X	X	Yes					
Trifluralin	X	X	X	Yes					

Table 8. Summary statistics of selected pesticide concentrations in runoff samples, 1996–98, and selected regulatory water-quality criteria

[In micrograms per liter; TSWQS, Texas Surface Water Quality Standard; --, not determined; <, less than]

Pesticide	No. of detections in 29 samples	Mean	Median	Maximum	Minimum	TSWQS aquatic life protection[1]	TSWQS human health protection[1]
Herbicides							
Atrazine, dissolved	29	4.76	0.61	47	0.03	--	--
Deethylatrazine, dissolved	29	.24	.12	2.4	.007	--	--
Cyanazine, dissolved	5	--	<.004	.05	<.004	--	--
2,4-D, dissolved	6	--	<.035	.87	<.035	--	[2]70
DCPA, dissolved	6	--	<.002	.004	<.002	--	--
Diuron, dissolved	13	--	<.02	16.7	<.02	[3]70	--
Fluometuron, dissolved	5	--	<.035	1.0	<.035	--	--
Glyphosate, dissolved	2	--	<5.0	20.4	<5.0	--	--
Lindane, dissolved	3	--	<.004	.014	<.004	[4].16	[2].20
Metolachlor, dissolved	10	--	<.002	.07	<.002	--	--
Pendimethalin, dissolved	15	--	<.004	.26	<.004	--	--
Prometon, dissolved	3	--	<.018	.05	<.018	--	--
Simazine, dissolved	18	--	.005	.24	<.005	--	--
Triclopyr, dissolved	1	--	<.05	.14	<.05	--	--
Trifluralin, dissolved	23	--	.008	.21	<.02	--	--
Insecticides							--
Azinphos-methyl, dissolved	1	--	<.001	.08	<.001	--	--
alpha-BHC, dissolved	2	--	<.002	.015	<.002	--	--
Carbaryl, dissolved	1	--	<.003	.011	<.003	[4]613	--
Carbofuran, dissolved	2	--	<.003	.02	<.003	--	--
Diazinon, dissolved	1	--	<.002	<.02	<.002	--	--
Malathion, dissolved	8	--	<.005	.035	<.005	[3].01	--

[1] Texas Natural Resource Conservation Commission (1999).
[2] Water and fish.
[3] Freshwater chronic criteria.
[4] Saltwater acute criteria.

Table 9. Median concentrations of selected pesticides in runoff samples grouped by seasonal category

[In micrograms per liter; <, less than]

Pesticide	Pre-harvest (Feb.–May)	Post-harvest (Aug.–Oct.)	Median, all samples
Atrazine, dissolved	5.4	0.14	0.61
Deethylatrazine, dissolved	.21	.03	.12
Diuron, dissolved	2.3	<.02	<.02
Pendimethalin, dissolved	.04	<.004	<.004
Simazine, dissolved	.04	<.005	.003
Trifluralin, dissolved	.080	.005	.008

Table 10. Monthly and annual loads of selected nutrients in runoff, 1996–98[1]

Nutrient	Runoff loads, in pounds, exiting 49,680-acre study area												
	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
1996													
Nitrogen, total	0	0	0	0	420	0	0	30	350	0	0	0	800
Ammonia nitrogen, dissolved (as N)	0	0	0	0	9.0	0	0	1.0	30	0	0	0	40
Nitrite + nitrate nitrogen, dissolved (as N)	0	0	0	0	78	0	0	3.0	160	0	0	0	240
Ammonia + organic nitrogen, total (as N)	0	0	0	0	290	0	0	27	190	0	0	0	510
Phosphorus, total	0	0	0	0	130	0	0	7.0	40	0	0	0	180
Orthophosphate phosphorus, dissolved (as P)	0	0	0	0	32	0	0	1.0	27	0	0	0	60
1997													
Nitrogen, total	0	0	50	53,400	12,100	0	0	0	150	36,000	0	0	102,000
Ammonia nitrogen, dissolved (as N)	0	0	4.0	1,310	300	0	0	0	3.0	6,350	0	0	7,970
Nitrite + nitrate nitrogen, dissolved (as N)	0	0	16	6,700	2,870	0	0	0	13	7,250	0	0	16,800
Ammonia + organic nitrogen, total (as N)	0	0	35	46,700	8,860	0	0	0	140	28,900	0	0	84,600
Phosphorus, total	0	0	4.0	19,000	3,910	0	0	0	50	23,600	0	0	46,600
Orthophosphate phosphorus, dissolved (as P)	0	0	2.0	4,150	1,260	0	0	0	7.0	5,650	0	0	11,100
1998													
Nitrogen, total	0	320	0	0	0	0	0	0	22,500	55,000	3,680	0	81,500
Ammonia nitrogen, dissolved (as N)	0	7.0	0	0	0	0	0	0	1,480	1,240	77	0	2,800
Nitrite + nitrate nitrogen, dissolved (as N)	0	62	0	0	0	0	0	0	3,390	8,590	690	0	12,700
Ammonia + organic nitrogen, total (as N)	0	220	0	0	0	0	0	0	16,800	45,600	2,530	0	65,200
Phosphorus, total	0	100	0	0	0	0	0	0	5,870	14,700	780	0	21,400
Orthophosphate phosphorus, dissolved (as P)	0	24	0	0	0	0	0	0	1,310	2,400	300	0	4,030

[1] Sums of monthly loads might not equal annual loads because of rounding.

Table 10. Monthly and annual loads of selected nutrients in runoff, 1996–98[1]—Continued

Nutrient	Runoff loads, in pounds, from 9,140-acre upper study area												
	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
1996													
Nitrogen, total	0	0	0	0	54	0	0	4.0	28	0	0	0	86
Ammonia nitrogen, dissolved (as N)	0	0	0	0	1.1	0	0	.10	.30	0	0	0	1.5
Nitrite + nitrate nitrogen, dissolved (as N)	0	0	0	0	10	0	0	.70	9.3	0	0	0	20
Ammonia + organic nitrogen, total (as N)	0	0	0	0	38	0	0	4.0	19	0	0	0	61
Phosphorus, total	0	0	0	0	17	0	0	1.0	7.8	0	0	0	26
Orthophosphate phosphorus, dissolved (as P)	0	0	0	0	4.1	0	0	.40	3.8	0	0	0	8.3
1997													
Nitrogen, total	0	0	0	5,910	800	0	0	0	0	9,240	60	0	16,000
Ammonia nitrogen, dissolved (as N)	0	0	0	110	17	0	0	0	0	290	1.0	0	420
Nitrite + nitrate nitrogen, dissolved (as N)	0	0	0	830	150	0	0	0	0	2,080	10	0	3,070
Ammonia + organic nitrogen, total (as N)	0	0	0	4,320	590	0	0	0	0	7,170	26	0	12,100
Phosphorus, total	0	0	0	2,150	310	0	0	0	0	2,900	18	0	5,380
Orthophosphate phosphorus, dissolved (as P)	0	0	0	720	130	0	0	0	0	1,580	4.0	0	2,430
1998													
Nitrogen, total	0	16	0	0	0	0	0	0	1,020	10,400	420	0	11,900
Ammonia nitrogen, dissolved (as N)	0	.30	0	0	0	0	0	0	15	220	9.0	0	240
Nitrite + nitrate nitrogen, dissolved (as N)	0	3.0	0	0	0	0	0	0	310	1,940	80	0	2,330
Ammonia + organic nitrogen, total (as N)	0	11	0	0	0	0	0	0	690	7,190	300	0	8,190
Phosphorus, total	0	3.0	0	0	0	0	0	0	270	2,750	120	0	3,140
Orthophosphate phosphorus, dissolved (as P)	0	1.0	0	0	0	0	0	0	73	790	33	0	900

[1] Sums of monthly loads might not equal annual loads because of rounding.

Table 10. Monthly and annual loads of selected nutrients in runoff, 1996–98[1]—Continued

Nutrient	Net runoff loads, in pounds, from 40,540-acre lower study area												
	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
1996													
Nitrogen, total	0	0	0	0	360	0	0	26	320	0	0	0	710
Ammonia nitrogen, dissolved (as N)	0	0	0	0	7.9	0	0	.90	30	0	0	0	39
Nitrite + nitrate nitrogen, dissolved (as N)	0	0	0	0	68	0	0	2.3	150	0	0	0	220
Ammonia + organic nitrogen, total (as N)	0	0	0	0	250	0	0	23	170	0	0	0	440
Phosphorus, total	0	0	0	0	120	0	0	6.0	32	0	0	0	160
Orthophosphate phosphorus, dissolved (as P)	0	0	0	0	28	0	0	.60	23	0	0	0	52
1997													
Nitrogen, total	0	0	50	47,500	11,300	0	0	0	150	26,800	-60	0	85,700
Ammonia nitrogen, dissolved (as N)	0	0	4.0	1,200	280	0	0	0	3.0	6,070	-1.0	0	7,550
Nitrite + nitrate nitrogen, dissolved (as N)	0	0	16	5,870	2,720	0	0	0	13	5,160	-10	0	13,800
Ammonia + organic nitrogen, total (as N)	0	0	35	42,400	8,260	0	0	0	140	21,800	-26	0	72,600
Phosphorus, total	0	0	4.0	16,900	3,600	0	0	0	50	20,700	-18	0	41,200
Orthophosphate phosphorus, dissolved (as P)	0	0	2.0	3,430	1,140	0	0	0	7.0	4,100	-4.0	0	8,680
1998													
Nitrogen, total	0	310	0	0	0	0	0	0	21,500	44,600	3,250	0	69,700
Ammonia nitrogen, dissolved (as N)	0	6.7	0	0	0	0	0	0	1,470	1,020	68	0	2,560
Nitrite + nitrate nitrogen, dissolved (as N)	0	59	0	0	0	0	0	0	3,080	6,650	610	0	10,400
Ammonia + organic nitrogen, total (as N)	0	210	0	0	0	0	0	0	16,100	38,400	2,230	0	56,900
Phosphorus, total	0	99	0	0	0	0	0	0	5,600	11,900	660	0	18,300
Orthophosphate phosphorus, dissolved (as P)	0	23	0	0	0	0	0	0	1,240	1,610	270	0	3,140

[1] Sums of monthly loads might not equal annual loads because of rounding.

Table 11. Annual and average annual yields of selected nutrients in runoff,1996–98

[In pounds per acre per year; <, less than]

Nutrient	1996	1997	1998	1996–98 average
Runoff yields from 49,680-acre study area				
Nitrogen, total	0.02	2.1	1.6	1.2
Ammonia nitrogen, dissolved (as N)	<.01	.16	.06	.07
Nitrite + nitrate nitrogen, dissolved (as N)	<.01	.34	.26	.20
Ammonia + organic nitrogen, total (as N)	.01	1.7	1.3	1.0
Phosphorus, total	<.01	.94	.43	.46
Orthophosphate phosphorus, dissolved (as P)	<.01	.22	.08	.10
Runoff yields from 9,140-acre upper study area				
Nitrogen, total	.01	1.8	1.3	1.0
Ammonia nitrogen, dissolved (as N)	<.01	.05	.03	.03
Nitrite + nitrate nitrogen, dissolved (as N)	<.01	.34	.25	.20
Ammonia + organic nitrogen, total (as N)	.01	1.3	.90	.74
Phosphorus, total	<.01	.59	.34	.31
Orthophosphate phosphorus, dissolved (as P)	<.01	.27	.10	.12
Net runoff yields from 40,540-acre lower study area				
Nitrogen, total	.02	2.1	1.7	1.3
Ammonia nitrogen, dissolved (as N)	<.01	.19	.06	.08
Nitrite + nitrate nitrogen, dissolved (as N)	.01	.34	.26	.20
Ammonia + organic nitrogen, total (as N)	.01	1.8	1.4	1.1
Phosphorus, total	<.01	1.0	.45	.48
Orthophosphate phosphorus, dissolved (as P)	<.01	.21	.08	.10

Table 12. Monthly and annual loads of selected pesticides in runoff, 1996–98[1]

Pesticide	Runoff loads, in pounds, exiting 49,680-acre study area												
	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
1996													
Atrazine + deethylatrazine, dissolved	0	0	0	0	1.6	0	0	0.01	10.7	0	0	0	12.3
Diuron, dissolved	0	0	0	0	.70	0	0	0	.05	0	0	0	.75
Trifluralin, dissolved	0	0	0	0	.023	0	0	0	.004	0	0	0	.027
1997													
Atrazine + deethylatrazine, dissolved	0	0	.10	220	110	0	0	0	.01	8.4	0	0	340
Diuron, dissolved	0	0	.50	340	49	0	0	0	0	1.0	0	0	390
Trifluralin, dissolved	0	0	0	3.7	.90	0	0	0	0	.33	0	0	4.9
1998													
Atrazine + deethylatrazine, dissolved	0	1.2	0	0	0	0	0	0	4.7	7.5	.4	0	13.8
Diuron, dissolved	0	.53	0	0	0	0	0	0	.25	.91	.37	0	2.1
Trifluralin, dissolved	0	.06	0	0	0	0	0	0	.06	.14	.05	0	.31

Pesticide	Runoff loads, in pounds, from 9,140-acre upper study area												
	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
1996													
Atrazine + deethylatrazine, dissolved	0	0	0	0	0.21	0	0	<0.01	0.02	0	0	0	0.23
Diuron, dissolved	0	0	0	0	.09	0	0	0	.01	0	0	0	.10
Trifluralin, dissolved	0	0	0	0	.003	0	0	0	.001	0	0	0	.004
1997													
Atrazine + deethylatrazine, dissolved	0	0	0	17	7.4	0	0	0	0	2.8	0	0	27
Diuron, dissolved	0	0	0	5.0	1.0	0	0	0	0	.30	0	0	6.3
Trifluralin, dissolved	0	0	0	.15	.05	0	0	0	0	.15	0	0	.35
1998													
Atrazine + deethylatrazine, dissolved	0	.06	0	0	0	0	0	0	.08	1.2	.04	0	1.4
Diuron, dissolved	0	.03	0	0	0	0	0	0	.01	.23	.01	0	.28
Trifluralin, dissolved	0	.001	0	0	0	0	0	0	.001	.13	.001	0	.13

[1] Sums of monthly loads might not equal annual loads because of rounding.

Table 12. Monthly and annual loads of selected pesticides in runoff, 1996–98[1]—Continued

Pesticide	Net runoff loads, in pounds, from 40,540-acre lower study area												
	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
1996													
Atrazine + deethylatrazine, dissolved	0	0	0	0	1.4	0	0	0	10.7	0	0	0	12.1
Diuron, dissolved	0	0	0	0	.61	0	0	0	.04	0	0	0	.65
Trifluralin, dissolved	0	0	0	0	.02	0	0	0	.003	0	0	0	.023
1997													
Atrazine + deethylatrazine, dissolved	0	0	.10	200	100	0	0	0	.01	5.6	0	0	310
Diuron, dissolved	0	0	.50	330	47.9	0	0	0	0	.74	0	0	380
Trifluralin, dissolved	0	0	0	3.6	.95	0	0	0	0	.18	0	0	4.6
1998													
Atrazine + deethylatrazine, dissolved	0	1.1	0	0	0	0	0	0	4.6	6.3	.36	0	12.4
Diuron, dissolved	0	.50	0	0	0	0	0	0	.24	.68	.36	0	1.8
Trifluralin, dissolved	0	.06	0	0	0	0	0	0	.06	.01	.05	0	.18

[1] Sums of monthly loads might not equal annual loads because of rounding.

Table 13. Annual and average annual yields of selected pesticides in runoff, 1996–98

[In pounds per acre per year; <, less than]

Pesticide	1996	1997	1998	1996–98 average
Runoff yields from 49,680-acre study area				
Atrazine + deethylatrazine, dissolved	0.0002	0.0068	0.0003	0.0024
Diuron, dissolved	<.0001	.0078	<.0001	.0026
Trifluralin, dissolved	<.0001	.0001	<.0001	<.0001
Runoff yields from 9,140-acre upper study area				
Atrazine + deethylatrazine, dissolved	<.0001	.0030	.0002	.0011
Diuron, dissolved	<.0001	.0007	<.0001	.0002
Trifluralin, dissolved	<.0001	<.0001	<.0001	<.0001
Net runoff yields from 40,540-acre lower study area				
Atrazine + deethylatrazine, dissolved	.0003	.0076	.0003	.0027
Diuron, dissolved	<.0001	.0094	<.0001	.0031
Trifluralin, dissolved	<.0001	.0001	<.0001	<.0001

Table 14. Monthly and annual loads of sediment in runoff, study area, 1996–98

[In tons]

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
1996	0	0	0	0	32	0	0	0.90	22	0	0	0	55
1997	0	0	8.9	10,200	2,390	0	0	0	4.6	19,000	0	0	31,600
1998	0	20	0	0	0	0	0	0	2,700	10,400	440	0	13,600

Table 15. Annual and average annual yields of sediment in runoff, study area, 1996–98

[In pounds per acre per year]

1996	1997	1998	1996–98 average
2.2	1,270	550	610

Table 16. Study area runoff-weighted concentrations of selected nutrients, 1996–98

[In milligrams per liter]

Nutrient	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
1996													
Nitrogen, total	0	0	0	0	1.4	0	0	2.1	1.5	0	0	0	1.5
Ammonia nitrogen, dissolved (as N)	0	0	0	0	.03	0	0	.07	.13	0	0	0	.08
Nitrite + nitrate nitrogen, dissolved (as N)	0	0	0	0	.27	0	0	.21	.71	0	0	0	.45
Ammonia + organic nitrogen, total (as N)	0	0	0	0	1.0	0	0	1.9	.84	0	0	0	.95
Phosphorus, total	0	0	0	0	.46	0	0	.50	.18	0	0	0	.34
Orthophosphate phosphorus, dissolved (as P)	0	0	0	0	.11	0	0	.07	.12	0	0	0	.11
1997													
Nitrogen, total	0	0	.48	1.8	1.2	0	0	0	2.2	.70	0	0	1.1
Ammonia nitrogen, dissolved (as N)	0	0	.04	.05	.03	0	0	0	.04	.12	0	0	.09
Nitrite + nitrate nitrogen, dissolved (as N)	0	0	.15	.23	.28	0	0	0	.18	.14	0	0	.19
Ammonia + organic nitrogen, total (as N)	0	0	.34	1.6	.88	0	0	0	1.9	.56	0	0	.93
Phosphorus, total	0	0	.04	.66	.39	0	0	0	.71	.46	0	0	.51
Orthophosphate phosphorus, dissolved (as P)	0	0	.02	.14	.13	0	0	0	.10	.11	0	0	.12
1998													
Nitrogen, total	0	1.9	0	0	0	0	0	0	2.1	1.7	1.4	0	1.8
Ammonia nitrogen, dissolved (as N)	0	.04	0	0	0	0	0	0	.14	.04	.03	0	.06
Nitrite + nitrate nitrogen, dissolved (as N)	0	.36	0	0	0	0	0	0	.31	.27	.27	0	.28
Ammonia + organic nitrogen, total (as N)	0	1.3	0	0	0	0	0	0	1.6	1.4	.98	0	1.4
Phosphorus, total	0	.59	0	0	0	0	0	0	.54	.46	.30	0	.47
Orthophosphate phosphorus, dissolved (as P)	0	.14	0	0	0	0	0	0	.12	.08	.12	0	.09

Nutrient	1996–98 average
Nitrogen, total	1.3
Ammonia nitrogen, dissolved (as N)	.08
Nitrite + nitrate nitrogen, dissolved (as N)	.22
Ammonia + organic nitrogen, total (as N)	1.1
Phosphorus, total	.50
Orthophosphate phosphorus, dissolved (as P)	.11

Table 17. Study area runoff-weighted concentrations of selected pesticides, 1996–98

[In micrograms per liter; <, less than]

Pesticide	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
1996													
Atrazine + deethylatrazine, dissolved	0	0	0	0	5.6	0	0	0.57	48	0	0	0	23
Diuron, dissolved	0	0	0	0	2.3	0	0	<.02	<.001	0	0	0	1.3
Trifluralin, dissolved	0	0	0	0	.08	0	0	.007	0	0	0	0	.057
1997													
Atrazine + deethylatrazine, dissolved	0	0	.1	7.6	11	0	0	0	.17	.16	0	0	3.7
Diuron, dissolved	0	0	.5	12	4.9	0	0	0	<.02	.019	0	0	4.3
Trifluralin, dissolved	0	0	0	.13	.10	0	0	0	<.005	.006	0	0	.055
1998													
Atrazine + deethylatrazine, dissolved	0	5.2	0	0	0	0	0	0	.45	.23	.17	0	.30
Diuron, dissolved	0	1.8	0	0	0	0	0	0	.08	<.02	<.02	0	.03
Trifluralin, dissolved	0	.06	0	0	0	0	0	0	.009	.002	.005	0	.004

Pesticide	1996–98 average
Atrazine + deethylatrazine, dissolved	2.7
Diuron, dissolved	2.9
Trifluralin, dissolved	.4

Appendix I—
Rainfall Sample Analyses

Texas Agricultural Experiment Station samples

[in., inches; mg/L, milligrams per liter; <, less than; --, not measured]

Date	Rain-fall (in.)	Nitrogen, total (mg/L as N)	Nitrogen, nitrate, dissolved (mg/L as N)	Nitrogen, nitrite, dissolved (mg/L as N)	Nitrogen, ammonia, dissolved (mg/L as N)	Nitrogen, ammonia + organic, dissolved (mg/L as N)	Nitrogen, ammonia + organic, total (mg/L as N)	Nitrogen, nitrite + nitrate, dissolved (mg/L as N)	Phosphorus, total (mg/L)	Phosphorus, dissolved (mg/L)	Phosphorus, ortho-phosphate (mg/L as P)	Field pH (standard units)
05/11/96	0.47	0.67	0.17	<0.01	0.41	0.4	0.5	0.17	0.02	<0.01	<0.01	--
08/09/96	.19	.52	.22	<.001	.245	.3	.3	.22	.003	.01	<.001	--
08/21/96	.61	.35	.20	.002	.141	<.2	<.2	.2	.004	.003	<.001	6.24
08/23/96	.90	.47	.064	.002	.20	<.2	.4	.066	.017	.007	<.001	--
09/20/96	1.63	.27	.069	<.001	.20	.3	.2	.069	.009	.003	<.001	--
11/24/96	.28	.61	.11	<.001	.324	.5	.5	.11	.017	.001	<.001	--
12/15/96	.31	.54	.14	<.001	.301	.3	.4	.14	.005	.004	<.001	--
03/11/97	.65	.41	.1	.01	.14	.3	.3	.11	.02	.02	.02	7.82
04/02/97	1.73	.03	.033	<.001	.057	<.2	<.2	.033	.003	.001	.002	--
04/03/97	3.51	.04	.026	<.001	.089	<.2	<.2	.026	.002	<.001	<.001	--
05/09/97	1.03	.31	.169	<.001	.182	<.2	<.2	.169	.006	.005	.006	4.96
05/16/97	2.02	.20	.117	.002	.146	<.2	<.2	.119	.003	.002	.002	--
08/23/97	.40	.91	.45	.01	.09	.21	.45	.46	.062	.025	.015	--
09/22/97	2.74	.19	.06	.002	.109	<.2	<.2	.063	.001	.001	<.001	--
09/24/97	1.96	.38	.10	.001	.276	.26	.28	.105	.004	.004	.002	--
10/11/97	5.52	.18	.04	<.001	.01	<.2	<.2	.04	.001	.001	<.001	--
02/14/98	1.18	.52	.14	.002	.302	.34	.38	.145	.008	.007	.006	--
09/23/98	1.50	.12	.066	.001	.051	<.1	<.1	.067	.001	<0.001	.002	5.20
10/18/98	2.21	.11	.062	.001	.053	<.1	<.1	.063	.006	.006	.003	6.03

Appendix II—
Runoff Event-Mean Concentrations

Site 1 (08212500) Upper Madero Canal near Kingsville, Tex.

[mg/L, milligrams per liter, <, less than; µg/L, micrograms per liter; µS/cm, microsiemens per centimeter at 25 degrees Celsius; --, not measured]

Constituent	Units	Event date			
		09/21/96	04/02–13/97	05/17/97	10/10–23/97
Nitrogen, ammonia	mg/L as N	0.02	0.03	0.03	0.02
Nitrogen, nitrite	mg/L as N	.02	.02	<.01	.01
Nitrogen, nitrite + nitrate	mg/L as N	.14	.44	.20	.16
Nitrogen, ammonia + organic, dissolved	mg/L as N	.4	<.2	<.2	.26
Nitrogen, ammonia + organic, total	mg/L as N	1.1	1.38	.88	.51
Phosphorus, total	mg/L as P	.4	.64	.48	.20
Phosphorus, dissolved	mg/L as P	.24	.21	.18	.12
Phosphorus, orthophosphate, dissolved	mg/L as P	.28	.20	.17	.09
Calcium, dissolved	mg/L as Ca	26	16.2	16.3	25.2
Magnesium, dissolved	mg/L as Mg	2	1.2	1.2	2.7
Sodium, dissolved	mg/L as Na	6.6	4.7	4.9	11.8
Potassium, dissolved	mg/L as K	7	3.8	3.8	7.1
Chloride, dissolved	mg/L as Cl	6.3	1.0	1.3	13.2
Sulfate, dissolved	mg/L as SO^4	9.4	1.7	2.3	5.7
Fluoride, dissolved	mg/L as F	.2	.3	.2	.2
Silica, dissolved	mg/L as SiO^2	17	11.6	11.0	16.7
Boron, dissolved	µg/L as B	81	49.8	57	91
Iron, dissolved	µg/L as Fe	10	<3	5.2	<3.0
Dissolved solids	mg/L	152	89	84	149.00
Suspended solids	mg/L	192	581	615	123
Specific conductance	µS/cm	206	139	125	163
Alkalinity	mg/L as $CaCO_3$	80	76	70	94
pH	standard units	7.3	--	7.9	--
2,4-DB	µg/L	<.035	<.035	<.035	<.035
2,4-D	µg/L	<.035	<.035	<.035	<.035
2,4,5-T	µg/L	<.035	<.035	<.035	<.035
3-Hydroxycarbofuran	µg/L	<.014	<.014	<.014	<.014
Acetochlor	µg/L	<.002	<.002	<.002	<.002
Amiben	µg/L	<.011	<.011	<.011	<.011
Aldicarb	µg/L	<.016	<.016	<.016	<.016
Aldicarb sulfone	µg/L	<.016	<.016	<.016	<.016
Aldicarb sulfoxide	µg/L	<.021	<.021	<.021	<.021
Acifluorfen	µg/L	<.035	<.035	<.035	<.035
Atrazine	µg/L	.06	5.8	10.8	.18
Deethylatrazine	µg/L	.008	.06	.73	.03
Alachlor	µg/L	<.002	<.002	<.002	<.002
Azinphos-methyl	µg/L	<.001	<.001	<.001	<.001
Bentazon	µg/L	<.014	<.014	<.014	<.014
Bromacil	µg/L	<.035	<.035	<.035	<.035
Benfluralin	µg/L	<.002	<.002	<.002	<.002
Bromoxynil	µg/L	<.035	<.035	<.035	<.035
Butylate	µg/L	<.002	<.002	<.002	<.002
Carbofuran	µg/L	<.028	<.028	<.028	<.028
Carbaryl	µg/L	<.003	<.003	<.003	<.003
Carbofuran	µg/L	<.003	<.003	<.003	<.003
Chloramben	µg/L	<.011	<.011	<.011	<.011
Chlorpyrifos	µg/L	<.004	<.004	<.004	<.004
Cyanazine	µg/L	<.004	<.004	<.004	<.004
Clopyralid	µg/L	<.05	<.05	<.05	<.05
Chlorothalonil	µg/L	<.035	<.035	<.035	<.035
Dacthal mono-acid	µg/L	<.017	<.017	<.017	<.017
Dicamba	µg/L	<.035	<.035	<.035	<.035
2,6-Diethylaniline	µg/L	<.003	<.003	<.003	<.003
Diuron	µg/L	<.02	.58	.06	<.02

Site 1 (08212500) Upper Madero Canal near Kingsville, Tex.—Continued

Constituent	Units	Event date			
		09/21/96	04/02–13/97	05/17/97	10/10–23/97
Dinoseb	µg/L	<0.035	<0.035	<0.035	<0.035
Dichlorprop	µg/L	<.032	<.032	<.032	<.032
Dichlobenil	µg/L	<.02	<.02	<.02	<.02
DCPA	µg/L	.003	<.002	<.002	<.002
DDE	µg/L	<.006	<.006	<.006	<.006
Diazinon	µg/L	<.002	<.002	<.002	<.02
Dieldrin	µg/L	<.001	<.001	<.001	<.001
Disulfoton	µg/L	<.017	<.017	<.017	<.017
DNOC	µg/L	<.035	<.035	<.035	<.035
EPTC	µg/L	<.002	<.002	<.002	<.002
Esfenvalerate	µg/L	<.019	<.019	<.019	<.019
Ethalfluralin	µg/L	<.004	<.004	<.004	<.004
Ethoprop	µg/L	<.003	<.003	<.003	<.003
Fluometuron	µg/L	<.035	.91	.57	<.035
Fenuron	µg/L	<.013	<.013	<.013	<.013
Fonofox	µg/L	<.003	<.003	<.003	<.003
BHC alpha	µg/L	<.002	.015	.003	<.002
Lindane	µg/L	<.004	.014	<.004	<.004
Linuron	µg/L	<.002	<.002	<.002	<.002
MCPA	µg/L	<.05	<.05	<.05	<.05
MCPB	µg/L	<.035	<.035	<.035	<.035
Malathion	µg/L	.035	<.005	<.005	<.005
Methyl parathion	µg/L	<.006	<.006	<.006	<.006
Metolachlor	µg/L	<.002	.007	.070	.003
Metribuzin	µg/L	<.004	<.004	<.004	<.004
Molinate	µg/L	<.004	<.004	<.004	<.004
Methomyl	µg/L	<.017	<.017	<.017	<.017
Methiocarb	µg/L	<.026	<.026	<.026	<.026
Napropamide	µg/L	<.003	<.003	<.003	<.003
Norflurazon	µg/L	<.024	<.024	<.024	<.024
Neburon	µg/L	<.015	<.015	<.015	<.015
1-Naphthol	µg/L	<.007	<.007	<.007	<.007
Oryzalin	µg/L	<.019	<.019	<.019	<.019
Oxamyl	µg/L	<.018	<.018	<.018	<.018
Parathion	µg/L	<.004	<.004	<.004	<.004
Pebulate	µg/L	<.004	<.004	<.004	<.004
Pendimethalin	µg/L	<.004	<.004	<.004	<.004
Permethrin	µg/L	<.005	<.005	<.005	<.005
Phorate	µg/L	<.002	<.002	<.002	<.002
Prometon	µg/L	<.018	<.018	.05	<.018
Pronamide	µg/L	<.003	<.003	<.003	<.003
Propanil	µg/L	<.004	<.004	<.004	<.004
Propachlor	µg/L	<.007	<.007	<.007	<.007
Propargite	µg/L	<.013	<.013	<.013	<.013
Propoxur	µg/L	<.035	<.035	<.035	<.035
Propham	µg/L	<.035	<.035	<.035	<.035
Picloram	µg/L	<.035	<.035	<.035	<.035
Silvex	µg/L	<.021	<.021	<.021	<.021
Simazine	µg/L	<.005	.039	.07	.004
Thiobencarb	µg/L	<.002	<.002	<.002	<.002
Tebuthiuron	µg/L	<.01	<.01	<.01	<.01
Terbacil	µg/L	<.007	<.007	<.007	<.007
Terbufos	µg/L	<.013	<.013	<.013	<.013
Triallate	µg/L	<.001	<.001	<.001	<.001
Trifluralin	µg/L	<.002	<.002	<.002	.01
Triclopyr	µg/L	<.05	<.05	<.05	<.05
Glyphosate	µg/L	<5	<10	<5	<5

Site 2 (08212600) Chiltipin Creek near Kingsville, Tex.

Constituent	Units	Event date					
		09/21/96	04/02–09/97	05/10/97	05/17/97	10/10–23/97	09/23/98
Nitrogen, ammonia	mg/L as N	0.02	0.03	<0.015	0.02	0.02	<0.02
Nitrogen, nitrite	mg/L as N	.03	.01	.035	<.01	.01	.015
Nitrogen, nitrite + nitrate	mg/L as N	.73	.31	.40	.21	.12	.46
Nitrogen, ammonia + organic, dissolved	mg/L as N	.3	<.2	.33	<.2	.21	.16
Nitrogen, ammonia + organic, total	mg/L as N	1.1	.81	.97	.60	.50	.95
Phosphorus, total	mg/L as P	.48	.47	.59	.33	.22	.36
Phosphorus, dissolved	mg/L as P	.11	.20	.36	.17	.12	.08
Phosphorus, orthophosphate, dissolved	mg/L as P	.13	.18	.37	.17	.09	.1
Calcium, dissolved	mg/L as Ca	24	16.4	30	14.2	18.0	10.7
Magnesium, dissolved	mg/L as Mg	2.3	1.2	2.5	1.0	1.3	.9
Sodium, dissolved	mg/L as Na	20	4.2	10.7	3.6	8.1	5.9
Potassium, dissolved	mg/L as K	3	3.4	4.9	2.8	4.5	2.5
Chloride, dissolved	mg/L as Cl	23	2.8	32	3.2	3.2	11.5
Sulfate, dissolved	mg/L as SO^4	12	2.2	5.7	1.9	1.6	4.1
Fluoride, dissolved	mg/L as F	.6	.2	.2	.2	.3	.29
Silica, dissolved	mg/L as SiO^2	12	10.0	10.8	8.4	12.8	9.7
Boron, dissolved	µg/L as B	139	42.5	51	40	76	55
Iron, dissolved	µg/L as Fe	<3	<3	<3	3.5	<3.0	<10
Dissolved solids	mg/L	148	80	139	73	94	234
Suspended solids	mg/L	764	442	360	610	222	524
Specific conductance	µS/cm	265	123	251	108	152	99
Alkalinity	mg/L as $CaCO_3$	85	62	66	60	71	77
pH	standard units	7.8	--	7.8	8.0	--	8.3
2,4-DB	µg/L	<.035	<.035	<.035	<.035	<.035	<.24
2,4-D	µg/L	<.035	<.035	<.035	<.035	<.035	<.15
2,4,5-T	µg/L	<.035	<.035	<.035	<.035	<.035	<.035
3-Hydroxycarbofuran	µg/L	<.014	<.014	<.014	<.014	<.014	<.014
Acetochlor	µg/L	<.002	<.002	<.002	<.002	<.002	<.002
Amiben	µg/L	<.011	<.011	<.011	<.011	<.011	<.011
Aldicarb	µg/L	<.016	<.016	<.016	<.016	<.016	<.55
Aldicarb sulfone	µg/L	<.016	<.016	<.016	<.016	<.016	<.10
Aldicarb sulfoxide	µg/L	<.021	<.021	<.021	<.021	<.021	<.021
Acifluorfen	µg/L	<.035	<.035	<.035	<.035	<.035	<.035
Atrazine	µg/L	1.93	2.41	4.80	12.6	.14	.07
Deethylatrazine	µg/L	.12	.13	2.40	.30	.02	.07
Alachlor	µg/L	<.002	<.002	<.002	<.002	<.002	<.002
Azinphos-methyl	µg/L	<.001	<.001	.04	<.001	<.001	<.001
Bentazon	µg/L	<.014	<.014	<.014	<.014	<.014	<.014
Bromacil	µg/L	<.035	<.035	<.035	<.035	<.035	<.035
Benfluralin	µg/L	<.002	<.002	<.002	<.002	<.002	<.002
Bromoxynil	µg/L	<.035	<.035	<.035	<.035	<.035	<.035
Butylate	µg/L	<.002	<.002	<.002	<.002	<.002	<.002
Carbofuran	µg/L	<.028	<.028	<.028	<.028	<.028	<.028
Carbaryl	µg/L	<.003	<.003	<.003	<.003	<.003	<.003
Carbofuran	µg/L	<.003	<.003	<.003	<.003	<.003	<.003
Chloramben	µg/L	<.011	<.011	<.011	<.011	<.011	<.42
Chlorpyrifos	µg/L	<.004	<.004	<.004	<.004	<.004	<.004
Cyanazine	µg/L	<.004	.05	<.004	<.004	<.004	<.004
Clopyralid	µg/L	<.05	<.05	<.05	<.05	<.05	<.23
Chlorothalonil	µg/L	<.035	<.035	<.035	<.035	<.035	<.48
Dacthal mono-acid	µg/L	<.017	<.017	<.017	<.017	<.017	<.017
Dicamba	µg/L	<.035	<.035	<.035	<.035	<.035	<.035
2,6-Diethylaniline	µg/L	<.003	<.003	<.003	<.003	<.003	<.003
Diuron	µg/L	.46	2.3	2.8	1.3	<.02	<.02
Dinoseb	µg/L	<.035	<.035	<.035	<.035	<.035	<.035

Site 2 (08212600) Chiltipin Creek near Kingsville, Tex.—Continued

Constituent	Units	Event date					
		09/21/96	04/02–09/97	05/10/97	05/17/97	10/10–23/97	09/23/98
Dichlorprop	µg/L	<0.032	<0.032	<0.032	<0.032	<0.032	<0.032
Dichlobenil	µg/L	<.02	<.02	<.02	<.02	<.02	<1.2
DCPA	µg/L	.003	<.002	.001	<.002	<.002	<.002
DDE	µg/L	<.006	<.006	<.006	<.006	<.006	<.006
Diazinon	µg/L	<.002	<.002	<.002	<.002	<.002	<.002
Dieldrin	µg/L	<.001	<.001	<.001	<.001	<.001	<.001
Disulfoton	µg/L	<.017	<.017	<.017	<.017	<.017	<.017
DNOC	µg/L	<.035	<.035	<.035	<.035	<.035	<.42
EPTC	µg/L	<.002	<.002	<.002	<.002	<.002	<.002
Esfenvalerate	µg/L	<.019	<.019	<.019	<.019	<.019	<.019
Ethalfluralin	µg/L	<.004	<.004	<.004	<.004	<.004	<.004
Ethoprop	µg/L	<.003	<.003	<.003	<.003	<.003	<.003
Fluometuron	µg/L	<.035	1.0	.18	.65	<.035	<.035
Fenuron	µg/L	<.013	<.013	<.013	<.013	<.013	<.013
Fonofox	µg/L	<.003	<.003	<.003	<.003	<.003	<.003
BHC alpha	µg/L	<.002	<.002	<.002	<.002	<.002	<.002
Lindane	µg/L	<.004	.01	<.004	<.004	<.004	<.004
Linuron	µg/L	<.002	<.002	<.002	<.002	<.002	<.002
MCPA	µg/L	<.05	<.05	<.05	<.05	<.05	<.17
MCPB	µg/L	<.035	<.035	<.035	<.035	<.035	<.14
Malathion	µg/L	<.005	<.005	<.005	<.005	<.005	.005
Methyl parathion	µg/L	<.006	<.006	<.006	<.006	<.006	<.006
Metolachlor	µg/L	<.002	<.002	.006	.005	<.005	<.005
Metribuzin	µg/L	<.004	<.004	<.004	<.004	<.004	<.004
Molinate	µg/L	<.004	<.004	<.004	<.004	<.004	<.004
Methomyl	µg/L	<.017	<.017	<.017	<.017	<.017	<.017
Methiocarb	µg/L	<.026	<.026	<.026	<.026	<.026	<.026
Napropamide	µg/L	<.003	<.003	<.003	<.003	<.003	<.003
Norflurazon	µg/L	<.024	<.024	<.024	<.024	<.024	<.024
Neburon	µg/L	<.015	<.015	<.015	<.015	<.015	<.015
1-Naphthol	µg/L	<.007	<.007	<.007	<.007	<.007	<.007
Oryzalin	µg/L	<.019	<.019	<.019	<.019	<.019	<.31
Oxamyl	µg/L	<.018	<.018	<.018	<.018	<.018	<.018
Parathion	µg/L	<.004	<.004	<.004	<.004	<.004	<.004
Pebulate	µg/L	<.004	<.004	<.004	<.004	<.004	<.004
Pendimethalin	µg/L	<.004	.26	.09	.19	<.004	.03
Permethrin	µg/L	<.005	<.005	<.005	<.005	<.005	<.005
Phorate	µg/L	<.002	<.002	<.002	<.002	<.002	<.002
Prometon	µg/L	<.018	<.018	<.018	<.018	<.018	<.018
Pronamide	µg/L	<.003	<.003	<.003	<.003	<.003	<.003
Propanil	µg/L	<.004	<.004	<.004	<.004	<.004	<.004
Propachlor	µg/L	<.007	<.007	<.007	<.007	<.007	<.007
Propargite	µg/L	<.013	<.013	<.013	<.013	<.013	<.013
Propoxur	µg/L	<.035	<.035	<.035	<.035	<.035	<.035
Propham	µg/L	<.035	<.035	<.035	<.035	<.035	<.035
Picloram	µg/L	<.035	<.035	<.035	<.035	<.035	<.035
Silvex	µg/L	<.021	<.021	<.021	<.021	<.021	<.021
Simazine	µg/L	.007	.03	.06	.17	<.005	<.005
Thiobencarb	µg/L	<.002	<.002	<.002	<.002	<.002	<.002
Tebuthiuron	µg/L	<.01	<.01	<.01	<.01	<.01	<.01
Terbacil	µg/L	<.007	<.007	<.007	<.007	<.007	<.007
Terbufos	µg/L	<.013	<.013	<.013	<.013	<.013	<.013
Triallate	µg/L	<.001	<.001	<.001	<.001	<.001	<.001
Trifluralin	µg/L	.11	.09	.09	.09	.01	.002
Triclopyr	µg/L	<.05	<.05	<.05	<.05	<.05	<.25
Glyphosate	µg/L	<5	<10	<5	<5	<5	<5

Site 3 (08212700) Pinto Creek Canal near Kingsville, Tex.

Constituent	Units	Event date							
		08/23/96	09/21/96	04/02–09/97	05/17/97	09/24/97	10/10–14/97	02/15/98	09/23/98
Nitrogen, ammonia	mg/L as N	0.07	0.25	0.03	0.02	0.04	0.06	0.09	0.05
Nitrogen, nitrite	mg/L as N	.02	.26	.02	<.01	.03	<.01	.03	.03
Nitrogen, nitrite + nitrate	mg/L as N	.17	1.5	.20	.28	.12	.14	1.04	.46
Nitrogen, ammonia + organic, dissolved	mg/L as N	<.2	.9	<.2	<.2	<.2	.24	.46	.23
Nitrogen, ammonia + organic, total	mg/L as N	1.7	3.8	2.85	.58	2.62	1.02	.67	1.32
Phosphorus, total	mg/L as P	.42	1.2	.93	.27	.92	.38	.15	.45
Phosphorus, dissolved	mg/L as P	.08	.19	.12	.13	.06	.13	.06	.12
Phosphorus, orthophosphate, dissolved	mg/L as P	.08	.29	.11	.14	.06	.12	.04	.13
Calcium, dissolved	mg/L as Ca	24	--	15.8	12.0	12.0	18.73	--	11.3
Magnesium, dissolved	mg/L as Mg	1.3	--	1.3	1.0	1.4	1.62	--	1.1
Sodium, dissolved	mg/L as Na	23	--	5.0	6.0	13	6.89	--	8
Potassium, dissolved	mg/L as K	2.2	--	2.5	2.0	2.2	4.63	--	2.7
Chloride, dissolved	mg/L as Cl	7.8	--	1.1	.9	1.6	2.27	--	1.2
Sulfate, dissolved	mg/L as SO^4	4.2	--	2.6	1.3	2.6	1.67	--	3.8
Fluoride, dissolved	mg/L as F	.5	--	.2	.2	.4	.20	--	.29
Silica, dissolved	mg/L as SiO^2	4.5	--	7.0	7.2	9.7	11.60	--	8.1
Boron, dissolved	µg/L as B	169	--	46.9	58	124	70.13	--	78
Iron, dissolved	µg/L as Fe	<3	--	<3	4.2	11	<3	--	<10
Dissolved solids	mg/L	152	--	81	70	--	.00	--	120
Suspended solids	mg/L	1,150	--	743	565	1,140	531.84	--	1,980
Specific conductance	µS/cm	258	--	122	104	124	150.79	--	115
Alkalinity	mg/L as $CaCO_3$	75	--	73	62	75	87.47	--	135
pH	standard units	7.8	--	--	8.0	8.1	7.99	--	8.3
2,4-DB	µg/L	<.035	<.035	<.035	<.035	<.035	<.035	<.035	<.24
2,4-D	µg/L	<.035	.25	<.035	<.035	<.035	<.035	.19	<.15
2,4,5-T	µg/L	<.035	<.035	<.035	<.035	<.035	<.035	<.035	<.035
3-Hydroxycarbofuran	µg/L	<.014	<.014	<.014	<.014	<.014	<.014	<.014	<.014
Acetochlor	µg/L	<.002	<.002	<.002	<.002	<.002	<.002	<.002	<.002
Amiben	µg/L	<.011	<.011	<.011	<.011	<.011	<.011	<.011	<.011
Aldicarb	µg/L	<.016	<.016	<.016	<.016	<.016	<.016	<.016	<.55
Aldicarb sulfone	µg/L	<.016	<.016	<.016	<.016	<.016	<.016	<.016	<.10
Aldicarb sulfoxide	µg/L	<.021	<.021	<.021	<.021	<.021	<.021	<.021	<.021
Acifluorfen	µg/L	<.035	<.035	<.035	<.035	<.035	<.035	<.035	<.035
Atrazine	µg/L	.61	.05	5.4	1.5	.15	.07	.04	.44
Deethylatrazine	µg/L	.009	.007	.05	.15	.018	.01	.01	.2
Alachlor	µg/L	<.002	<.002	<.002	<.002	<.002	<.002	<.002	<.002
Azinphos-methyl	µg/L	<.001	<.001	<.001	.08	<.001	<.001	<.001	<.001
Bentazon	µg/L	<.014	<.014	<.014	<.014	<.014	<.014	<.014	<.014
Bromacil	µg/L	.06	<.035	<.035	<.035	<.035	<.035	<.035	<.035
Benfluralin	µg/L	<.002	<.002	<.002	<.002	<.002	<.002	<.002	<.002
Bromoxynil	µg/L	<.035	<.035	<.035	<.035	<.035	<.035	<.035	<.035
Butylate	µg/L	<.002	<.002	<.002	<.002	<.002	<.002	<.002	<.002
Carbaryl	µg/L	<.003	<.003	<.003	<.003	<.003	<.003	<.003	<.008
Carbofuran	µg/L	<.003	<.003	<.003	<.003	<.003	<.003	<.003	<.12
Chloramben	µg/L	<.011	<.011	<.011	<.011	<.011	<.011	<.011	<.42
Chlorpyrifos	µg/L	<.004	<.004	<.004	<.004	<.004	<.004	<.004	<.004
Cyanazine	µg/L	.023	<.004	<.004	<.004	<.004	<.004	<.004	<.004
Clopyralid	µg/L	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.23
Chlorothalonil	µg/L	<.035	<.035	<.035	<.035	<.035	<.035	<.035	<.48
Dacthal mono-acid	µg/L	<.017	<.017	<.017	<.017	<.017	<.017	<.017	<.017
Dicamba	µg/L	<.035	<.035	<.035	<.035	<.035	<.035	<.035	<.035
2,6-Diethylaniline	µg/L	<.003	<.003	<.003	<.003	<.003	<.003	<.003	<.003
Diuron	µg/L	<.02	<.02	16.7	4.1	<.02	<.02	<.02	<.02
Dinoseb	µg/L	<.035	<.035	<.035	<.035	<.035	<.035	<.035	<.035
Dichlorprop	µg/L	<.032	<.032	<.032	<.032	<.032	<.032	<.032	<.032

Site 3 (08212700) Pinto Creek Canal near Kingsville, Tex.—Continued

Constituent	Units	Event date							
		08/23/96	09/21/96	04/02–09/97	05/17/97	09/24/97	10/10–14/97	02/15/98	09/23/98
Dichlobenil	µg/L	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<1.2
DCPA	µg/L	<.002	<.002	<.002	<.002	<.002	<.002	<.002	<.002
DDE	µg/L	<.006	<.006	<.006	<.006	<.006	<.006	<.006	<.006
Diazinon	µg/L	<.002	<.002	<.002	<.002	<.002	<.002	<.002	<.002
Dieldrin	µg/L	<.001	<.001	<.001	<.001	<.001	<.001	<.001	<.001
Disulfoton	µg/L	<.017	<.017	<.017	<.017	<.017	<.017	<.017	<.017
DNOC	µg/L	<.035	<.035	<.035	<.035	<.035	<.035	<.035	<.42
EPTC	µg/L	<.002	<.002	<.002	<.002	<.002	<.002	<.002	<.002
Esfenvalerate	µg/L	<.019	<.019	<.019	<.019	<.019	<.019	<.019	<.019
Ethalfluralin	µg/L	<.004	<.004	<.004	<.004	<.004	<.004	<.004	<.004
Ethoprop	µg/L	<.003	<.003	<.003	<.003	<.003	<.003	<.003	<.003
Fluometuron	µg/L	<.035	<.035	<.035	<.035	<.035	<.035	<.035	<.035
Fenuron	µg/L	<.013	<.013	<.013	<.013	<.013	<.013	<.013	<.013
Fonofox	µg/L	<.003	<.003	<.003	<.003	<.003	<.003	<.003	<.003
BHC alpha	µg/L	<.002	<.002	<.002	<.002	<.002	<.002	<.002	<.002
Lindane	µg/L	<.004	<.004	<.004	<.004	<.004	<.004	<.004	<.004
Linuron	µg/L	<.002	<.002	<.002	<.002	<.002	<.002	<.002	<.018
MCPA	µg/L	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.17
MCPB	µg/L	<.035	<.035	<.035	<.035	<.035	<.035	<.035	<.14
Malathion	µg/L	.032	<.004	<.005	<.005	<.005	<.005	<.005	.007
Methyl parathion	µg/L	<.006	<.006	<.006	<.006	<.006	<.006	<.006	<.006
Metolachlor	µg/L	<.002	<.002	.004	<.002	<.002	<.002	.003	<.002
Metribuzin	µg/L	<.004	<.004	<.004	<.004	<.004	<.004	<.004	<.004
Molinate	µg/L	<.004	<.004	<.004	<.004	<.004	<.004	<.004	<.004
Methomyl	µg/L	<.017	<.017	<.017	<.017	<.017	<.017	<.017	<.017
Methiocarb	µg/L	<.026	<.026	<.026	<.026	<.026	<.026	<.026	<.026
Napropamide	µg/L	<.003	<.003	<.003	<.003	<.003	<.003	<.003	<.003
Norflurazon	µg/L	<.024	<.024	<.024	<.024	<.024	<.024	<.024	<.024
Neburon	µg/L	<.015	<.015	<.015	<.015	<.015	<.015	<.015	<.015
1-Naphthol	µg/L	<.007	<.007	<.007	<.007	<.007	<.007	<.007	<.007
Oryzalin	µg/L	<.019	<.019	<.019	<.019	<.019	<.019	<.019	<.31
Oxamyl	µg/L	<.018	<.018	<.018	<.018	<.018	<.018	<.018	<.018
Parathion	µg/L	<.004	<.004	<.004	<.004	<.004	<.004	<.004	<.004
Pebulate	µg/L	<.004	<.004	<.004	<.004	<.004	<.004	<.004	<.004
Pendimethalin	µg/L	<.004	<.004	.02	.01	<.004	<.004	.04	.01
Permethrin	µg/L	<.005	<.005	<.005	<.005	<.005	<.005	<.005	<.005
Phorate	µg/L	<.002	<.002	<.002	<.002	<.002	<.002	<.002	<.002
Prometon	µg/L	<.018	<.018	<.018	<.018	<.018	<.018	<.018	<.018
Pronamide	µg/L	<.003	<.003	<.003	<.003	<.003	<.003	<.003	<.003
Propanil	µg/L	<.004	<.004	<.004	<.004	<.004	<.004	<.004	<.004
Propachlor	µg/L	<.007	<.007	<.007	<.007	<.007	<.007	<.007	<.007
Propargite	µg/L	<.013	<.013	<.013	<.013	<.013	<.013	<.013	<.013
Propoxur	µg/L	<.035	<.035	<.035	<.035	<.035	<.035	<.035	<.035
Propham	µg/L	<.035	<.035	<.035	<.035	<.035	<.035	<.035	<.035
Picloram	µg/L	<.035	<.035	<.035	<.035	<.035	<.035	<.035	<.05
Silvex	µg/L	<.021	<.021	<.021	<.021	<.021	<.021	<.021	<.021
Simazine	µg/L	<.005	<.005	.011	.03	<.005	.003	.003	<.005
Thiobencarb	µg/L	<.002	<.002	<.002	<.002	<.002	<.002	<.002	<.002
Tebuthiuron	µg/L	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01
Terbacil	µg/L	<.007	<.007	<.007	<.007	<.007	<.007	<.007	<.007
Terbufos	µg/L	<.013	<.013	<.013	<.013	<.013	<.013	<.013	<.013
Triallate	µg/L	<.001	<.001	<.001	<.001	<.001	<.001	<.001	<.001
Trifluralin	µg/L	.008	<.002	.21	.11	<.002	.008	.008	.002
Triclopyr	µg/L	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.25
Glyphosate	µg/L	<5	20.4	<10	<10	<5	<5	18	<5

Site 4 (08212800) Lower Madero Canal near Kingsville, Tex.

Constituent	Units	Event date			
		04/02–04/97	05/17/97	10/10–16/97	09/23/98
Nitrogen, ammonia	mg/L as N	0.02	<0.015	0.08	0.26
Nitrogen, nitrite	mg/L as N	.02	<.01	<.01	.14
Nitrogen, nitrite + nitrate	mg/L as N	.25	.25	.35	.44
Nitrogen, ammonia + organic, dissolved	mg/L as N	<.2	<.2	.46	.46
Nitrogen, ammonia + organic, total	mg/L as N	1.4	1.9	.86	1.0
Phosphorus, total	mg/L as P	.65	.69	.55	.33
Phosphorus, dissolved	mg/L as P	.07	.08	.10	.08
Phosphorus, orthophosphate, dissolved	mg/L as P	.05	.08	.09	.09
Calcium, dissolved	mg/L as Ca	10.2	10.4	20	10
Magnesium, dissolved	mg/L as Mg	1.1	1.1	2.12	1
Sodium, dissolved	mg/L as Na	13.3	18.2	25	22
Potassium, dissolved	mg/L as K	1.5	1.4	5.0	1.7
Chloride, dissolved	mg/L as Cl	4.8	5.3	12.2	4.3
Sulfate, dissolved	mg/L as SO^4	10.4	19.9	20.4	20
Fluoride, dissolved	mg/L as F	.3	.3	.4	.52
Silica, dissolved	mg/L as SiO^2	5.9	6.6	15.7	8.2
Boron, dissolved	µg/L as B	112	153	218	240
Iron, dissolved	µg/L as Fe	<3	<3	<3.0	<10
Dissolved solids	mg/L	81	100	155	167
Suspended solids	mg/L	992	1,190	867	1,220
Specific conductance	µS/cm	131	164	248	208
Alkalinity	mg/L as $CaCO_3$	54	58	87	160
pH	standard units	8.2	8.2	--	8.4
2,4-DB	µg/L	<.035	<.035	<.035	<.24
2,4-D	µg/L	<.035	<.035	<.035	.12
2,4,5-T	µg/L	<.035	<.035	<.035	<.035
3-Hydroxycarbofuran	µg/L	<.014	<.014	<.014	<.014
Acetochlor	µg/L	<.002	<.002	<.002	<.002
Amiben	µg/L	<.011	<.011	<.011	<.011
Aldicarb	µg/L	<.016	<.016	<.016	<.55
Aldicarb sulfone	µg/L	<.016	<.016	<.016	<.10
Aldicarb sulfoxide	µg/L	<.021	<.021	<.021	<.021
Acifluorfen	µg/L	<.035	<.035	<.035	<.05
Atrazine	µg/L	20.9	1.70	.17	.03
Deethylatrazine	µg/L	.39	.60	.06	.016
Alachlor	µg/L	<.002	<.002	<.002	<.002
Azinphos-methyl	µg/L	<.001	<.001	<.001	<.001
Bentazon	µg/L	<.014	<.014	<.014	<.014
Bromacil	µg/L	<.035	<.035	<.035	<.035
Benfluralin	µg/L	<.002	<.002	<.002	<.002
Bromoxynil	µg/L	<.035	<.035	<.035	<.035
Butylate	µg/L	<.002	<.002	<.002	<.002
Carbofuran	µg/L	<.028	<.028	<.028	<.028
Carbaryl	µg/L	<.003	<.003	<.003	<.003
Carbofuran	µg/L	<.003	<.003	<.003	<.003
Chloramben	µg/L	<.011	<.011	<.011	<.42
Chlorpyrifos	µg/L	<.004	<.004	<.004	<.004
Cyanazine	µg/L	<.004	<.004	<.004	<.004
Clopyralid	µg/L	<.05	<.05	<.05	<.05
Chlorothalonil	µg/L	<.035	<.035	<.035	<.48
Dacthal mono-acid	µg/L	<.017	<.017	<.017	<.017
Dicamba	µg/L	<.035	<.035	<.035	<.035
2,6-Diethylaniline	µg/L	<.003	<.003	<.003	<.003
Diuron	µg/L	.67	.3	<.02	<.23
Dinoseb	µg/L	<.035	<.035	<.035	<.035

Site 4 (08212800) Lower Madero Canal near Kingsville, Tex.—Continued

Constituent	Units	Event date			
		04/02–04/97	05/17/97	10/10–16/97	09/23/98
Dichlorprop	µg/L	<0.032	<0.032	<0.032	<0.032
Dichlobenil	µg/L	<.02	<.02	<.02	<.02
DCPA	µg/L	<.002	<.002	<.002	<.002
DDE	µg/L	<.006	<.006	<.006	<.006
Diazinon	µg/L	<.002	<.002	<.002	<.002
Dieldrin	µg/L	<.001	<.001	<.001	<.001
Disulfoton	µg/L	<.017	<.017	<.017	<.017
DNOC	µg/L	<.035	<.035	<.035	<.42
EPTC	µg/L	<.002	<.002	<.002	<.002
Esfenvalerate	µg/L	<.019	<.019	<.019	<.019
Ethalfluralin	µg/L	<.004	<.004	<.004	<.004
Ethoprop	µg/L	<.003	<.003	<.003	<.003
Fluometuron	µg/L	<.035	<.035	<.035	<.24
Fenuron	µg/L	<.013	<.013	<.013	<.013
Fonofox	µg/L	<.003	<.003	<.003	<.003
BHC alpha	µg/L	<.002	<.002	<.002	<.002
Lindane	µg/L	<.004	<.004	<.004	<.004
Linuron	µg/L	<.002	<.002	<.002	<.002
MCPA	µg/L	<.05	<.05	<.05	<.17
MCPB	µg/L	<.035	<.035	<.035	<.14
Malathion	µg/L	<.005	<.005	<.005	.012
Methyl parathion	µg/L	<.006	<.006	<.006	<.006
Metolachlor	µg/L	<.002	<.002	<.002	<.002
Metribuzin	µg/L	<.004	<.004	<.004	<.004
Molinate	µg/L	<.004	<.004	<.004	<.004
Methomyl	µg/L	<.017	<.017	<.017	<.017
Methiocarb	µg/L	<.026	<.026	<.026	<.026
Napropamide	µg/L	<.003	<.003	<.003	<.003
Norflurazon	µg/L	<.024	<.024	<.024	<.024
Neburon	µg/L	<.015	<.015	<.015	<.015
1-Naphthol	µg/L	<.007	<.007	<.007	<.007
Oryzalin	µg/L	<.019	<.019	<.019	<.31
Oxamyl	µg/L	<.018	<.018	<.018	<.018
Parathion	µg/L	<.004	<.004	<.004	<.004
Pebulate	µg/L	<.004	<.004	<.004	<.004
Pendimethalin	µg/L	.01	<.004	<.004	.013
Permethrin	µg/L	<.005	<.005	<.005	<.005
Phorate	µg/L	<.002	<.002	<.002	<.002
Prometon	µg/L	<.018	<.018	<.018	<.018
Pronamide	µg/L	<.003	<.003	<.003	<.003
Propanil	µg/L	<.004	<.004	<.004	<.004
Propachlor	µg/L	<.007	<.007	<.007	<.007
Propargite	µg/L	<.013	<.013	<.013	<.013
Propoxur	µg/L	<.035	<.035	<.035	<.035
Propham	µg/L	<.035	<.035	<.035	<.035
Picloram	µg/L	<.035	<.035	<.035	<.035
Silvex	µg/L	<.021	<.021	<.021	<.021
Simazine	µg/L	.24	.04	.005	<.005
Thiobencarb	µg/L	<.002	<.002	<.002	<.002
Tebuthiuron	µg/L	<.01	<.01	<.01	<.01
Terbacil	µg/L	<.007	<.007	<.007	<.007
Terbufos	µg/L	<.013	<.013	<.013	<.013
Triallate	µg/L	<.001	<.001	<.001	<.001
Trifluralin	µg/L	.01	.03	.005	.005
Triclopyr	µg/L	<.05	<.05	<.05	.14
Glyphosate	µg/L	--	--	<5	<5

Site 5 (08212500) Tunas Creek near Kingsville, Tex.

Constituent	Units	Event date						
		09/21/96	03/12–13/97	04/02–07/97	05/16–17/97	10/10–15/97	09/22–24/98	10/18–19/98
Nitrogen, ammonia	mg/L as N	0.13	0.04	0.05	0.03	0.13	0.15	0.04
Nitrogen, nitrite	mg/L as N	.02	.01	.02	.016	<.01	.02	<.01
Nitrogen, nitrite + nitrate	mg/L as N	.69	.15	.23	.29	.14	.29	.27
Nitrogen, ammonia + organic, dissolved	mg/L as N	.5	.24	<.2	<.2	.42	.36	.33
Nitrogen, ammonia + organic, total	mg/L as N	.8	.34	1.57	.85	.54	1.7	1.5
Phosphorus, total	mg/L as P	.16	.03	.65	.37	.47	.56	.46
Phosphorus, dissolved	mg/L as P	.11	.02	.16	.13	.12	.12	.07
Phosphorus, orthophosphate, dissolved	mg/L as P	.11	.02	.15	.13	.11	.12	.07
Calcium, dissolved	mg/L as Ca	150	465	19.5	22	33.2	30	19
Magnesium, dissolved	mg/L as Mg	88	264	3.0	5.4	10.5	7.2	3.7
Sodium, dissolved	mg/L as Na	890	2,159	25.5	44	92.8	68	25
Potassium, dissolved	mg/L as K	11	34	3.4	3.0	6.3	4.6	4.9
Chloride, dissolved	mg/L as Cl	1,700	5,288	39.3	82	176	110	30
Sulfate, dissolved	mg/L as SO^4	270	724	16.2	18	35.1	42	15
Fluoride, dissolved	mg/L as F	.3	.2	.2	.2	.2	.3	.2
Silica, dissolved	mg/L as SiO^2	5.2	2.6	8.5	7.6	13.1	9.7	10
Boron, dissolved	µg/L as B	1,100	2,454	90.5	105	229	201	125
Iron, dissolved	µg/L as Fe	23	40	4.7	<3	5.6	<10	5.4
Dissolved solids	mg/L	3,140	9,410	153	217	417	323	188
Suspended solids	mg/L	668	7.5	626	583	529	1,170	1,050
Specific conductance	µS/cm	5,770	15,937	276	410	775	591	270
Alkalinity	mg/L as $CaCO_3$	48	51	59	53.7	79	76	130
pH	standard units	7.5	8.0	--	7.7	--	7.9	7.9
2,4-DB	µg/L	<.035	<.035	<.035	<.035	<.035	<.24	<.24
2,4-D	µg/L	.69	<.035	<.035	<.035	<.035	.6	.87
2,4,5-T	µg/L	<.035	<.035	<.035	<.035	<.035	<.035	<.035
3-Hydroxycarbofuran	µg/L	<.014	<.014	<.014	<.014	<.014	<.014	<.014
Acetochlor	µg/L	<.002	<.002	<.002	<.002	<.002	<.002	<.002
Amiben	µg/L	<.011	<.011	<.011	<.011	<.011	--	--
Aldicarb	µg/L	<.016	<.016	<.016	<.016	<.016	<.55	<.55
Aldicarb sulfone	µg/L	<.016	<.016	<.016	<.016	<.016	<.10	<.10
Aldicarb sulfoxide	µg/L	<.021	<.021	<.021	<.021	<.021	<.021	<.021
Acifluorfen	µg/L	<.035	<.035	<.035	<.035	<.035	<.035	<.035
Atrazine	µg/L	47.0	.72	7.31	12.6	.14	.24	.12
Deethylatrazine	µg/L	.75	.18	.21	.28	.024	.17	.12
Alachlor	µg/L	<.002	<.002	<.002	<.002	<.002	<.002	<.002
Azinphos-methyl	µg/L	<.001	<.001	<.001	<.001	<.001	<.001	<.001
Bentazon	µg/L	<.014	<.014	<.014	<.014	<.014	<.014	<.014
Bromacil	µg/L	<.035	<.035	<.035	<.035	<.035	<.035	<.035
Benfluralin	µg/L	<.002	<.002	<.002	<.002	<.002	<.002	<.002
Bromoxynil	µg/L	<.035	<.035	<.035	<.035	<.035	<.035	<.035
Butylate	µg/L	<.002	<.002	<.002	<.002	<.002	<.002	<.002
Carbaryl	µg/L	<.003	<.003	<.003	<.003	<.003	<.008	.011
Carbofuran	µg/L	<.003	.02	.005	<.003	<.003	<.003	<.003
Chloramben	µg/L	<.011	<.011	<.011	<.011	<.011	<.42	<.42
Chlorpyrifos	µg/L	<.004	<.004	<.004	<.004	<.004	<.004	<.004
Cyanazine	µg/L	<.004	<.004	.015	<.004	.008	<.004	<.004
Clopyralid	µg/L	<.05	<.05	<.05	<.05	<.05	<.23	<.23
Chlorothalonil	µg/L	<.035	<.035	<.035	<.035	<.035	<.48	<.48
Dacthal mono-acid	µg/L	<.017	<.017	<.017	<.017	<.017	<.017	<.017
Dicamba	µg/L	<.035	<.035	<.035	<.035	<.035	<.035	<.035
2,6-Diethylaniline	µg/L	<.003	<.003	<.003	<.003	<.003	<.003	<.003
Diuron	µg/L	.21	4.88	11.57	5.74	<.02	<.02	<.02
Dinoseb	µg/L	<.035	<.035	<.035	<.035	<.035	<.035	<.035

Site 5 (08212500) Tunas Creek near Kingsville, Tex.—Continued

Constituent	Units	Event date						
		09/21/96	03/12–13/97	04/02–07/97	05/16–17/97	10/10–15/97	09/22–24/98	10/18–19/98
Dichlorprop	µg/L	<0.032	<0.032	<0.032	<0.032	<0.032	<0.032	<0.032
Dichlobenil	µg/L	<.02	<.02	<.02	<.02	<.02	<1.2	<1.2
DCPA	µg/L	.004	.001	<.002	<.002	<.002	<.002	<.002
DDE	µg/L	<.006	<.006	<.006	<.006	<.006	<.006	<.006
Diazinon	µg/L	<.002	<.002	<.002	<.002	<.002	<.002	<.002
Dieldrin	µg/L	<.001	<.001	<.001	<.001	<.001	<.001	<.001
Disulfoton	µg/L	<.017	<.017	<.017	<.017	<.017	<.017	<.017
DNOC	µg/L	<.035	<.035	<.035	<.035	<.035	<.42	<.42
EPTC	µg/L	<.002	<.002	<.002	<.002	<.002	<.002	<.002
Esfenvalerate	µg/L	<.019	<.019	<.019	<.019	<.019	<.019	<.019
Ethalfluralin	µg/L	<.004	<.004	<.004	<.004	<.004	<.004	<.004
Ethoprop	µg/L	<.003	<.003	<.003	<.003	<.003	<.003	<.003
Fluometuron	µg/L	<.035	<.035	<.035	<.035	<.035	<.035	<.035
Fenuron	µg/L	<.013	<.013	<.013	<.013	<.013	<.013	<.013
Fonofox	µg/L	<.003	<.003	<.003	<.003	<.003	<.003	<.003
BHC alpha	µg/L	<.002	<.002	<.002	<.002	<.002	<.002	<.002
Lindane	µg/L	<.004	<.004	<.004	<.004	<.004	<.004	<.004
Linuron	µg/L	<.002	<.002	<.002	<.002	<.002	<.018	<.018
MCPA	µg/L	<.05	<.05	<.05	<.05	<.05	<.17	<.17
MCPB	µg/L	<.035	<.035	<.035	<.035	<.035	<.14	<.14
Malathion	µg/L	.03	<.005	<.005	<.005	<.005	.032	<.005
Methyl parathion	µg/L	<.006	<.006	<.006	<.006	<.006	<.006	<.006
Metolachlor	µg/L	<.002	.01	.003	<.002	<.002	<.002	<.002
Metribuzin	µg/L	<.004	<.004	<.004	<.004	<.004	<.004	<.004
Molinate	µg/L	<.004	<.004	<.004	<.004	<.004	<.004	<.004
Methomyl	µg/L	<.017	<.017	<.017	<.017	<.017	<.017	<.017
Methiocarb	µg/L	<.026	<.026	<.026	<.026	<.026	<.026	<.026
Napropamide	µg/L	<.003	<.003	<.003	<.003	<.003	<.003	<.003
Norflurazon	µg/L	<.024	<.024	<.024	<.024	<.024	<.024	<.024
Neburon	µg/L	<.015	<.015	<.015	<.015	<.015	<.015	<.015
1-Naphthol	µg/L	<.007	<.007	<.007	<.007	<.007	--	--
Oryzalin	µg/L	<.019	<.019	<.019	<.019	<.019	<.31	<.31
Oxamyl	µg/L	<.018	<.018	<.018	<.018	<.018	<.018	<.018
Parathion	µg/L	<.004	<.004	<.004	<.004	<.004	<.004	<.004
Pebulate	µg/L	<.004	<.004	<.004	<.004	<.004	<.004	<.004
Pendimethalin	µg/L	<.004	.01	.028	.02	<.004	.014	<.004
Permethrin	µg/L	<.005	<.005	<.005	<.005	<.005	<.005	<.005
Phorate	µg/L	<.002	<.002	<.002	<.002	<.002	<.002	<.002
Prometon	µg/L	<.018	<.018	<.018	<.018	<.018	<.018	<.018
Pronamide	µg/L	<.003	<.003	<.003	<.003	<.003	<.003	<.003
Propanil	µg/L	<.004	<.004	<.004	<.004	<.004	<.004	<.004
Propachlor	µg/L	<.007	<.007	<.007	<.007	<.007	<.007	<.007
Propargite	µg/L	<.013	<.013	<.013	<.013	<.013	<.013	<.013
Propoxur	µg/L	<.035	<.035	<.035	<.035	<.035	<.035	<.035
Propham	µg/L	<.035	<.035	<.035	<.035	<.035	<.035	<.035
Picloram	µg/L	<.035	<.035	<.035	<.035	<.035	<.05	<.05
Silvex	µg/L	<.021	<.021	<.021	<.021	<.021	<.021	<.021
Simazine	µg/L	<.005	<.005	.09	.23	.003	<.005	<.005
Thiobencarb	µg/L	<.002	<.002	<.002	<.002	<.002	<.002	<.002
Tebuthiuron	µg/L	<.01	<.01	<.01	<.01	<.01	<.01	<.01
Terbacil	µg/L	<.007	<.007	<.007	<.007	<.007	<.007	<.007
Terbufos	µg/L	<.013	<.013	<.013	<.013	<.013	<.013	<.013
Triallate	µg/L	<.001	<.001	<.001	<.001	<.001	<.001	<.001
Trifluralin	µg/L	.02	.013	.12	.08	.006	.001	<.002
Triclopyr	µg/L	<.05	<.05	<.05	<.05	<.05	<.25	<.25
Glyphosate	µg/L	<5	<5	<10	<5	<5	<5	<5

Ockerman and Petri— Hydrologic Conditions and Water Quality in an Agricultural Area in— Kleberg and Nueces Counties, Texas, 1996–98 USGS WRIR 01–4101

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