Point Source Loadings to Galveston Bay

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Need For Study

Galveston Bay is the most important estuary on the Texas coast. It harbors the largest seaport, houses the largest industrial complex, and produces the largest shellfish catch on the Texas coast at 38 percent of the state's total. Thousands of weekend fishermen and boaters use the bay. However, Galveston Bay also receives the largest total amount of industrial and municipal effluent of all of the Texas estuaries, both directly from the Houston/Texas City areas and indirectly from the Dallas/Ft. Worth area via the Trinity River (EPA, 1980).

Prior to the mid-1970s, the Houston Ship Channel, which empties into Galveston Bay, was listed as one of the 10 most polluted bodies of water in the United States by the U.S. Environmental Protection Agency (EPA). A Ralph Nader Task Force Report (EPA, 1980) stated, "The Houston Ship Channel is the most poisoned and potentially the most explosive body of water in the United States." In 1969, state water quality specialists determined that this water quality degradation caused frequent and massive fish kills in the upper portion of Galveston Bay (EPA, 1980).

In recognition of the magnitude of the threat to Galveston Bay, the Texas Water Quality Board, now the Texas Water Commission (TWC), and the EPA organized a comprehensive study of the bay system. The study spanned the years of 1966 to 1974. Following the study, several corrective measures helped to reduce the impact of municipal and industrial waste on Galveston Bay. These included stricter and more vigorously enforced discharge permits and a monitoring program now operated by the TWC. In 1971, the Texas Water Quality Board ordered all industries discharging to the Houston Ship Channel to conform to excellent (at least secondary) treatment levels. Between 1973 and 1980, millions of dollars were awarded by the EPA to upgrade and expand municipal waste treatment facilities discharging to the Houston Ship Channel and Galveston Bay. In 1976, the EPA said that several Texas waterways were getting cleaner and singled out the Houston Ship Channel as "the most notable improvement, a truly remarkable feat" (EPA, 1980).

Point source loadings of many constituents have been characterized in some detail over at least the last three decades starting with the 1964 study by Gloyna and Malina, the extensive compilations during the Galveston Bay Project (Beal, 1975; Armstrong and

Hinson, 1973a), and now by the TWC in the annual loadings summaries. For toxic materials in particular, two rather detailed loading analyses for permitted dischargers have been performed by Neleigh (1974) and Goodman (1989) (both supervised by the senior author) for point sources and for the Trinity and San Jacinto Rivers by Armstrong et al. (1977) and Goodman (1989).

The focus on these earlier studies was mainly on conventional constituents: dissolved oxygen, fecal coliform, suspended solids, and perhaps pH and ammonia. What about, more specifically, the discharge of toxic materials to Galveston Bay? The effects of toxic discharges to the bay have been documented in Copeland and Fruh (1970), Oppenheimer et al. (1973), Beale (1975), Armstrong et al. (1975), and Armstrong (1980), but these studies dealt primarily with toxic materials in the Bay rather than discharges to it. Until recently, there had been no studies of toxic emissions to Galveston Bay. One study of toxic material mass emission rates to Galveston Bay was done by Neleigh (1974), and it was based on information provided by industries complying with the 1899 Refuse Act as implemented by the EPA and the U.S. Army Corps of Engineers. Following Neleigh's study, significant changes were been made in municipal wastewater treatment and regulatory implementation of industrial discharge permits as mentioned above. The amount of discharger documentation had necessarily increased several-fold, which made the accounting of toxic waste emission to the Bay potentially more realistic in accuracy and detail. Yet, little has been done to update the general picture of toxic emissions to Galveston Bay. Was toxicity at this time still a problem? If it was, to what extent does it exist? Finally, what relationship could be established between toxicity emission rates and the levels of water quality in Galveston Bay? An investigative effort along this line required a close examination of the present waste discharge conditions in the Houston Ship Channel, Trinity River, and other major bay water sources, and that study was conducted by Goodman (1989).

More reporting of toxic materials is being required now than during the period Goodman (1989) used to estimate toxic material loading to the Bay and more dischargers have permits to release materials to the Bay. Thus, there is a need to update all of the loading estimates for constituents reaching Galveston Bay. As the goals of the Galveston Bay National Estuary Program (GBNEP) are to protect and improve water quality and to enhance living resources within the Galveston Bay Estuary, and the approach to achieving these goals includes linking the problems identified in the Bay with the causes, the determination of point source loading is a major step in characterizing one of the causes.

The results of this study have been submitted to the Galveston Bay National Estuary Program in draft form by Armstrong and Ward (1991)

Objectives

The specific objective of this study, as stated in the GBNEP Contract Scope of Services, was to provide an inventory and analysis of pollutant loading data to determine current status and trends of these parameters (i.e., constituents discharged) and their potential effect on water and sediment quality in the Galveston Bay system, and to examine loadings for previous years for this assessment. This study focused on point sources.

The main objective of this study was to calculate and analyze toxic emissions to Galveston Bay. This objective was considered in more detail through the following specific objectives:

1. Examine the literature for historical estimates of specific toxic material loading to Galveston Bay;

2. Compile, from TWC and NPDES permit files for dischargers to Galveston Bay, data on monthly average flows, toxic substance concentrations, and any quality control data available to characterize the variability of the data and from U.S. Geological Survey, as well as other sources, data on tributary flows and toxic material concentrations to estimate loadings from those tributaries;

3. Estimate the loading of toxic substances (in kg/d) and relative toxicity (in toxic units/d) to Galveston Bay from point source discharges and its tributaries; and

4. Relate the loading of toxic materials to concentrations of toxics in Galveston Bay and its tributaries, where such data were available.

Scope

To estimate loadings from point sources (and nonpoint sources), one must have information on both flow and constituent concentration as their product yields load. For permitted point sources into the Galveston Bay System, good estimates of loading could be calculated because of the regularity of sampling of flow and constituent concentration on the same days and consecutive days. These data are available from the self-reporting data in the files of the TWC. Compiling that information and calculating loads as necessary, aggregating the loads by water quality segment, and presenting the information by discharger and by segment accomplished the objective of estimating actual permitted point source loads.

Other point source loads such as major tributaries (including reservoir discharges) were determined again by multiplying flow and concentration. However, while flow data were often available on a daily basis, constituent concentrations were not, and various statistical techniques had to be employed to overcome this irregularity of data collection. These techniques include using concentration vs. flow relationships and load vs. flow relationships developed from flow and constituent concentration data taken on the same day and extrapolating those relationships to days for which flow data were available but concentration data were not.

The project included examination of data reliability (Quality Assurance/Quality Control), identification of data gaps (spatial and temporal), and evaluation of monitoring methodology changes needed, as well as other reviews of the data to discern limitations to the utility of the data. Where possible, per capita (for municipal wastes) and per product or other measure (for industrial wastes) generation rates were calculated so that estimates of future loadings were made as possible.

This study provides an analysis of the present levels of conventional pollutant and toxic material discharge to Galveston Bay and the sources of the important contaminants in an effort to answer these questions.

Summary Of Results

The overall objective of this study was to provide an inventory and analysis of pollutant loading to determine the current status and trends of these parameters (i.e., constituents discharged) and their potential effect on water and sediment quality in the Galveston Bay system, and to examine loadings for previous years for this assessment. This study focused on point sources. The literature was examined for historical estimates of pollutant loading to Galveston Bay.

Data on monthly average flows, toxic substance concentrations, and any quality control data available to characterize the variability of the data was compiled from TWC and NPDES permit files for dischargers to Galveston Bay. Initial estimates of constituent loading were determined from the self-reporting data that were already in a loading format; i.e., the dischargers reported loadings for certain constituents to the Commission whereas for other constituents they only reported concentration. The latter data were not included in initial loading estimates. To be sure that all of the constituents reported by dischargers are accounted for, a table was prepared which showed for each discharger which of the constituents included in the Pacheco et al. (1990) report were reported by that discharger. Of the approximately 730 active permitted discharges being examined, Table 1 shows pollutant levels that dischargers have self-reported for key parameters.

It is clear that beyond flow, BOD, TSS, and oil and grease, the number of permits reporting data for other constituents such as metals and complex organics are extremely small. Even the nitrogen forms reported are mostly ammonia, and there is very little data for other nitrogen forms, which could be used to determine total nitrogen loadings. The loading estimates developed for nutrients, metals, and complex organics will supplement the loading estimates already reported in the draft final report (Armstrong and Ward, 1991).

Recognizing that essentially all municipal dischargers did not report nutrients, metals, and other constituents and some industrial dischargers were not required to report some constituents typically discharged, the procedures outlined in a recent NOAA report on waste loading estimates authored by Pacheco et al. (1990) to calculate loads for those constituents.

Table 1. Pollutant levels.

Constituent	Number of Permittees Required to Report Constituent	Percent of Permittees Required to Report Constituent
Flow	725	99.04%
BOD	509	69.54%
Total Suspended Solids	664	90.71%
Nitrogen Forms	435	59.43%
Phosphorus Forms	17	2.32%
Fecal Coliforms	3	0.41%
Arsenic	9	1.23%
Cadmium	7	0.96%
Chromium	45	6.15%
Copper	35	4.78%
Iron	10	1.37%
Lead	17	2.32%
Mercury	5	0.68%
Zinc	42	5.74%
Oil & Grease	155	21.17%
PCBs	1	0.14%
Chlorinated Hydrocarbons	5	0.68%

Such estimates rely on SIC codes for the discharger and a classification of the discharger as a municipal discharger, an industrial discharger, or a cooling water flow discharger. With the help of TWC staff, SIC information was obtained for each discharger, but also information on the source of the wastewater from within each discharger was obtained. With a single SIC code and single source of wastewater code assigned to each pipe, the source of wastewater codes were matched with categories of typical pollutant concentrations that Pacheco et al. (1990) had developed from EPA effluent limit development documents from the 1970s. For municipal dischargers and cooling water flows, the matches were essentially one to one, but, for process flows of industrial dischargers, the match was made based on the SIC code assigned to the industry. Those typical pollutant concentrations were multiplied by actual discharge flows calculated from the self-reporting data in the database to get loads for each discharger. For each permitted discharger, loading estimates for conventional constituents (e.g., BOD, TSS, nitrogen, phosphorus, oil and grease, and coliforms), metals (arsenic, cadmium, chromium, copper, iron, lead, mercury, and zinc), and two groups of complex organics (PCBs and chlorinated hydrocarbons) were computed.

Other point source loads such as major tributaries (including reservoir discharges) were determined again by multiplying flow and concentration. However, while flow data were often available on a daily basis, constituent concentrations were not, and various statistical techniques had to be employed to overcome this irregularity of data collection. These techniques include using concentration vs. flow relationships and load vs. flow relationships developed from flow and constituent concentration data taken on the same day and extrapolating those relationships to days for which flow data were available but concentration data were not.

Conclusions

Based on the early results of this study (as presented in the Armstrong and Ward, 1991 report), the following conclusions can be drawn:

1. Loading estimates for conventional, nonconventional, and toxic pollutants from waste discharges and major tributaries for the Galveston Bay system have been accomplished;

2. Loading estimates for some pollutants (e.g., BOD and TSS) are considered to be fairly accurate considering that these pollutants are required to be reported by virtually all dischargers, they are analyzed by USGS in all major tributaries, and the precision and accuracy of analysis is good;

3. Loading estimates for other pollutants (particularly nutrients) are incomplete because they are not reported by all dischargers and because the chemical forms analyzed are inconsistent for dischargers required to report and from USGS analyses for tributaries;

4. Loading estimates for metals are incomplete because they are not reported by all dischargers and because the chemical forms (mainly total recoverable versus dissolved forms) analyzed are inconsistent between dischargers and USGS data;

5. Loading estimates for complex organics are the most incomplete of all those reported herein because of the great inconsistency of reporting among dischargers, the variety of chemical forms reported not only among the wastewater dischargers, but also the USGS, and the tendency of the dischargers to report common chemical forms (e.g., toluene, xylene, etc.) and the USGS to report complex forms (e.g., pesticides and herbicides); and

6. While there is consistency in the loadings for primarily toxic substances reported herein with recent estimates by Goodman (1989), there were substantial differences yet to be explained between the results of this study and those of Pacheco et al. (1990), who estimated loadings of pollutants from all dischargers.

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Hazardous Waste Reduction Through Process Change at Oxychem's Pasadena, Texas Plant

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Introduction

In 1987, Occidental Chemical Corporation instituted a program called OxyMin. The objective of this program was the systematic reduction in hazardous waste, toxic air emissions, and water pollutants in each of its chemical manufacturing plants. At OxyChem's Pasadena, Texas, PVC plant, an inventory of these releases from the process revealed that the best opportunity for a major impact under the OxyMin program was the elimination of the toluene used with the reaction initiator in the PVC process, which exited the plant as the major component of a significant hazardous waste stream requiring commercial incineration.

The Toluene Elimination Project

PVC Process Description — The OxyChem Pasadena PVC plant is located on the Houston Ship Channel east of Houston and operates on an around-the-clock basis. The plant produces in excess of one billion pounds of PVC homopolymer resin per year for both rigid and flexible application. The Pasadena plant utilized modern large-reactor suspension process technology that takes place in 12 35,000 gallon batch reactors. Being one of the largest and most efficient PVC resin manufacturing facilities in the country, it uses a full-time process control computer to run the reaction part of the process. Each reactor produces several batches of PVC resin daily. The main ingredients that go into each batch are: (1) water; (2) vinyl chloride monomer (VCM); (4) reaction initiator (organic peroxides); (4) modifiers; and (5) suspending agents.

After each batch is completed, the unreacted VCM is recovered for purification and re-use. The resulting slurry of PVC particles in water (with some organics) is fed to stripping columns which operate on a continuous basis, as does the rest of the process. After stripping to remove residual VCM, the slurry is fed to centrifuges with the separated water being routed to the plant biological waste treatment unit. The separated wet solids are fed to fluidized-bed dryers with the final dry PVC resin being transported by conveying air to large product silos. PVC resin is gravity-fed into rail hopper cars, trucks, or is bagged for shipment.

Role of Toluene — Since the plant started operation in 1975, toluene had been used in two ways in the process: (1) the solvent for the organic peroxide chemicals used as the PVC reaction initiator; and (2) the flush medium for the initiator charge lines to each PVC reactor.

During these years, the suppliers of the reaction initiators supplied the organic peroxides in 70-75% concentration solutions of toluene. The solutions were typically delivered in five gallon (or less) plastic jugs in refrigerated trucks. The jugs were stored on-site in refrigerated vaults equipped with sophisticated temperature control and alarm systems. Earthen blase walls surround these buildings. In the Pasadena plant, the reaction initiator was further diluted to less than a 50% concentration with pure toluene just prior to its computer-controlled introduction to each PVC batch. The transfer of initiator solution is made through insulated and refrigerated piping, which runs from the solution prep building to each PVC reactor. All of these precautions are necessary because these peroxide chemicals are highly reactive and temperature sensitive, and must be handled carefully from a safety standpoint.

Because of the safety considerations with such a potent chemical, it has always been the practice in Pasadena to flush each of these lines from start to finish with pure toluene after each use. This ensures that no residual peroxides are left stagnant in each line when not in use. The toluene used to accomplish this was flushed into each reactor prior to initiating the batch.

As a result of these two operational functions, each batch recipe contained a significant amount of toluene.

Fate of the Toluene — In theory, the toluene did not participate in the polymerization reaction but was simply the carrier for an active ingredient. The toluene was still present in the batch at the end of the reaction, along with unreacted VCM, the newly-formed PVC particles, and the water in which they were suspended.

There are three places that the toluene could end up from here: (1) in the recovered VCM stream, which is purified in a distillation column. Here the toluene is removed as a heavy end and constituted the bulk of the column bottoms stream; (2) as an air emission from the PVC dryers stacks where drying air exits the process; and (3) in the process wastewater leaving the PVC plant that is treated in the Pasadena facility's biological waste treatment unit.

In 1987, the last full calendar year that toluene was used, the distribution of toluene in the process was such that about 1.5 million pounds of the heavy ends stream from the VCM distillation column was generated. As a RCRA hazardous waste, this material was shipped to a nearby commercial facility for incineration.

Steps in the Project — A comprehensive evaluation for potential substitutes for toluene was begun in 1987. This program consisted of: (1) research and development studies in the laboratory; (2) pilot plant studies; (3) negotiations with reaction initiator suppliers; and (4) controlled field tests in the Pasadena PVC plan.

Several consequences of the substitution of toluene with other solvents were of concern: (1) continued safety in the handling of the organic peroxides; (2) the ultimate fate of the substitute chemicals within the process, including the product PVC resin; (3) the impact, if any, on the quality of the various PVC resins produced at the Pasadena plant by having no toluene present; and (4) the effectiveness of the substitute flush medium in the initiator charge lines from a safety standpoint.

In early 1988, these questions were answered to OxyChem's satisfaction and a step-wise substitution for toluene by a chemical as the new solvent/carrier for the organic peroxides was started. During the second quarter, another chemical was substituted for toluene as the new initiator charge line flush medium. In December 1988, the Pasadena PVC plant was totally shut down for a scheduled turn-around. During this outage, any residual toluene still present in the process equipment was removed. After startup, the plant was considered to be completely toluene-free.

In 1989, the first full calendar year that the toluene was not present in the plant, the only heavy end produced from the distillation of recovered VCM turned out to be a water stream. The new substitute chemicals that were recovered from the PVC reactors along with the unreacted VCM from each batch, functioned as light ends in the VCM distillation process. At the end of 1989, no pounds of the heavy ends stream had been generated during the year, compared with the 1.5 million pounds generated in 1987.

Fate of the Substitute Chemicals — Since the new chemicals did not end up as components of the bottoms stream in the VCM distillation column, they had to be distributed elsewhere in the process. A portion of these two chemicals was emitted as VOC air emissions from the PVC dryer stacks. However, on a production-weighted basis, a reduction in total VOC air emissions from the PVC plant of over 40% was realized from 1987 to 1989.

The bulk of these new chemicals exited the PVC progress in the waste water streams going to the facility's biological waste treatment unit. Here, biological treatment is accomplished prior to discharge of the plant effluent to the Houston Ship Channel.

Benefits of This Process Change — The most important benefit of this basic process change is obvious — the dramatic, significant reduction in the volume of hazardous waste and VOC air emissions from the OxyChem Pasadena PVC plant. However, other benefits have also been realized.

Significant cost savings resulted from this process modification: (1) the cost of commercial incineration of the 1.5 million pounds/year of hazardous waste has been eliminated. This savings is in the mid-six figure range; and (2) The cost of the substitute chemicals is less than the cost of the toluene.

Conclusions

By any standard, the Toluene Elimination Project must be considered a major success within the OxyMin Program. This project demonstrates that significant reduction in hazardous waste generation and in toxic air emissions can be accomplished in well-established chemical manufacturing operations through basic process changes.

The key to success is recognizing the opportunity when it is present and then *pursuing it in a determined, organized, and systematic manner.*

When all of the pieces fit together, they can lead to an accomplishment like the one in "pollution prevention" at OxyChem's Pasadena PVC plant.

Characterization of Non-Point Sources and Loadings to Galveston Bay

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Project Goals

Although non-point source (NPS) pollutants have been identified as a key process affecting the water quality of Galveston Bay, only rough estimates of the location and magnitude of non-point sources to the Bay had been developed prior to 1990. To characterize existing NPS loadings to the Bay more accurately, the Galveston Bay National Estuary Program (GBNEP) initiated a detailed water quality and NPS mapping project of the lower 4,238 square mile Galveston Bay watershed in November, 1990.

Non-point sources include a wide array of diffuse pollutant types and sources from major storm water outfalls, land drainage, and human activity. Pollutants include toxics, fecal coliform bacteria, oxygen demand, nutrients, and sediments. Source activities are largely dependent on land use, and include urban development and agricultural activities, septic tanks, and runoff from industrial and residential developments.

Project Design

This project was designed to be a "washoff" study; in other words, a study of non-point source loads originating from different types of land use. Land use has been recognized as one of the major variables in non-point sources of pollution, and has been the focus of most of the non-point source studies performed in the country to date. A unique and original land use/land cover database for Galveston Bay was developed from interpreted satellite imagery that provided a high resolution snapshot of the basin land use as it existed in 1990. In addition, a relatively new technology, Geographical Information Systems (GIS), was used to map the geographic characteristics of the study area, analyze the land use data, complete the NPS calculations, and to graphically present the project results. Other main elements of the project are summarized below.

Watershed Hydrology — The study area (see above) was divided into 21 watersheds and 100 subwatersheds. Three rainfall cases were formulated from raingage data in the basin: an average year, a wet year with a 10-year return period, and an individual storm. The rainfall amounts were transformed into runoff using the Soil Conservation Service curve number method.

Land Use — An original land use database was developed from interpreted satellite imagery to provide a high resolution (approximate mapping resolution: 30 meter by 30 meter) snapshot of the watershed land use as it existed in 1990. Land use in the 4,238 sq. mile project area is divided almost evenly between urban areas, agricultural lands, open/pasture areas, wetlands, and forests, as shown below:

Table 1. Land use.

Classification	Percent	Classification	Percent
High-density urban	10%	Barren	1%
Residential	*9%*	*Wetlands*	*15%*
Open/Pasture	23%	Water	1%
Agricultural	22%	Forest	18%

Relative Non-Point Source Load Estimates by Land Use Category — Eight water quality parameters were identified for the GBNEP non-point source database: total suspended solids, total phosphorus, total nitrogen, biochemical oxygen demand, oil and grease, fecal coliform, dissolved copper, and pesticides.

To calculate non-point source loads from the basin, typical concentrations of each water quality constituent in runoff were estimated from a variety of local and nationwide data sources. These water quality data, defined as event mean concentrations (EMCs), were derived for each land use tvpe defined for the Galveston Bay project (see table above).

The Houston area EMC database indicated that sediments, nutrients, and oxygen-demanding substances in local urban runoff are typical of urban runoff in other parts of the country. Although the rural EMC data were not as extensive as the urban database, they indicated that NPS concentrations from Galveston Bay agricultural areas are lower than many other parts of the country. One possible explanation is the extensive rice cultivation in the watershed; flooded rice fields generate relatively low concentrations of sediments and nutrients compared to typical row crops.

In general, high density urban land use areas, consisting of industrial, commercial, multi-family residential, and transportation land uses, had higher NPS pollutant concentrations than most other non-urban land uses. Forest lands had the lowest concentrations of pollutants in runoff.

Upper Watershed Influence — The Galveston Bay National Estuary Program designed this project to map NPS source loads from the immediate watershed around the bay, and did not include a mapping component for the larger watershed that extends upstream of Lake Houston (to near the Huntsville area) and upstream of Lake Livingston (up to and past the Dallas area). GBNEP identified three reasons for this approach: 1) the lakes provide for some reduction and attenuation of NPS loads, particularly for sediment and sediment-related parameters; 2) implementation of management programs may be more feasible in the watershed immediately adjacent to the bay; and 3) project resources were prioritized to map the watershed immediately adjacent to the bay (approximately 5,000 square miles) compared to the upper watersheds (over 20,000 square miles).

Pollutant loads from Lake Houston and Lake Livingston were calculated for this project, however, in order to provide a total load estimate to the Bay and to identify the contribution of the upper watersheds. The calculation method was different than the spatial mapping calculation performed on the study area (lower watersheds). For both upper watersheds, historical runoff and water quality data were analyzed to arrive at estimates of lake discharges for the three rainfall cases and to obtain average concentrations for lake runoff. Annual load estimates (comprised of point source loads, low-flow loads, and NPS loads) for the three cases were obtained by multiplying the average concentration for most parameters (or best estimate for parameters with limited data) by the total runoff for each rainfall event. Overall, Lake Livingston contributes a greater load to Galveston Bay than Lake Houston for all the parameters except for fecal coliform. Both lakes contribute substantial amounts of pollutants into the bay.

Mapping — A Geographic Information System (GIS) served as the fundamental tool for the entire Galveston Bay Non-Point Source assessment. The GIS permitted the storage, manipulation and processing of the several hundred megabytes of electronic data required for the NPS calculations. Hydrologic and load models were also incorporated into the system to enable flow and water quality calculations for different geographic regions. Finally, the GIS system was used to develop the final NPS maps for the project.

The Galveston Bay GIS database developed for this project consists of six elements:

1. USGS 1:100,000 scale maps of hydrography and transportation networks for the study area;
2. Watershed/subwatershed boundaries;
3. Hydrologic soil type;
4. Land use patterns;
5. Runoff calculation model; and
6. Non-point source load calculation model.

This database was developed using the ARC/INFO GIS software, a standard GIS package, and can be used for future projects requiring manipulation of environmental mapping data.

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This database was developed using the ARC/INFO GIS software, a standard GIS package, and can be used for future projects requiring manipulation of environmental mapping data.

Project Results

1. The precise sources of NPS loads are relatively difficult to determine due to their widespread, diffuse nature. The following table identifies major potential sources of NPS pollutants:

Table 2. Project Results.

Water Quality Parameter	Major Potential Non-Point Sources
Total Suspended Solids	Eroding urban Areas, cultivated fields, and streambanks
Total Nitrogen	Eroding soils, fertilizer application. leaking sanitary sewers, overflows, by-passes, natural organic matter
Total Phosphorus	Eroding soils, fertilizer application. leaking sanitary sewers, overflows, by-passes, natural organic matter
Biochemical Oxygen Demand	Natural decaying organic matter, leaking sanitary sewers, overflows, by-passes, oil and grease, natural organic matter
Oil and Grease	Motor vehicles
Fecal Coliforms	Leaking sanitary sewers, bypasses, overflows, pets, cattle wildlife
Dissolved Copper	Corrosion of copper plumbing, electroplating wastes, algicides, eroding soils
Pesticides	Urban and rural pesticide application

2. Annual loads for Case 1, a year with average rainfall, were estimated to be:

Table 3. Annual loads for Case 1.

	Annual Non-Point Source Loads Average Year (thousands kg/yr, except where noted)	
	Study Area Only	Entire Watershed
Run off	3,010 ac-ft/yr	9,050 ac-ft/yr
Total Suspended Solids	481,000	581,000
Total Nitrogen	6,420	23,128
Total Phosphorus	1,110	3,711
Biochemical Oxygen Demand	26,300	46,500
Oil and Grease	14,300	14,200
Fecal Coliforms	355 x 10^{15} cfu/yr	355 x 10^{15} cfu/yr
Dissolved Copper	10.9	34.0
Pesticides	0.8	1.5

ac-ft: acre-ft cfu: colony forming unit
Entire Watershed includes loadings from study area, Lake Houston, and Lake Livingston.
Lake loadings include contribution from point and low flow sources.

3. To assess the impact of non-point sources under high annual rainfall conditions, Case 2 analyses were conducted assuming annual rainfall that occurs, on the average, once every 10 years. The resulting runoff and loads were 40-60% higher than those found for Case 1, the average year.

4. Case 3 simulated the response of the watershed to an individual storm event that could be expected to occur, on the average, once per year. This individual storm load was approximately 15 to 20% of the total annual non-point source load to the bay. These data indicate that a significant portion of the annual loads occur during the largest rainfall events during the year.

5. High density urban land use areas were the main contributor of NPS loads from the study area for all the parameters. For example, high density urban land uses contributed approximately 87% of the annual oil and grease loading, 59% of the annual fecal coliform loading, and 50% of the annual pesticides loadings from the study.

6. The pollutant load from the upper watersheds, which originates as discharge from Lake Houston and Lake Livingston, varied considerably among parameters. Over 70% of the annual nitrogen load, for example, originates from the upper watersheds and overwhelms the contribution from the local watersheds. For oil and grease and bacteria, however, the contribution of the upper watersheds was minor compared to that of the local watersheds in the study area.

7. The load maps produced for this project identified the locations of highly concentrated non-point source loads generation. In general, the highly urbanized areas in the Houston metropolitan area, Baytown, Texas City, and Galveston show the highest loads per unit area for all of the water quality constituents. As would be expected, fecal coliform and oil and grease NPS loads are almost entirely derived from the urban areas. Urban areas were also shown to be high source zones for pesticides as well.

   The non-point source maps indicate that the highest erosion rates and, consequently, the greatest sources of sediment, occur in a wedge-shaped area, having a point at the mouth of the Ship Channel and reaching through Houston to the watersheds upstream of Barker/Addicks reservoirs. The high sediment loads were attributed to eroding urban land areas in the Houston area and barren land in the rural western watersheds.

8. The 100 different subwatersheds were ranked by NPS loading to:

   - Identify areas with high sediment loads for the purpose of implementing special erosion control or sedimentation measures;

- *Determine which cities have jurisdiction over high NPS areas;*
- Compare the relative differences in NPS loads between high NPS source areas and low NPS areas;
- Locate areas with high NPS loadings within individual watersheds; and
- Identify NPS "hot spots" on a subwatershed basis using the priority ranking.

These activities are examples of management information that can be derived *directly from the priority ranking and the NPS maps provided in this report.*

9. Actual impacts of local NPS pollutants on the Bay are difficult to assess without analyzing the change in pollutant concentrations in Galveston Bay itself. NPS loads are relatively brief slugs of pollutants that enter the bay intermittently from numerous entry points in the presence of large volumes of runoff. The amount, timing, and duration of these NPS events are determined by rainfall conditions. Discharge from Lake Livingston and Lake Houston complicates this assessment, as the reservoirs change the timing and water quality of the discharge from the Trinity and San Jacinto rivers to the bay.

   While the loading data from this study cannot be used directly to quantify the effect on the bay or evaluate the denial of beneficial uses to users of the bay, it can serve as a foundation for future projects evaluating the actual impact of NPS loads to Galveston Bay. The three loading cases can be applied to answer different management questions regarding the water quality of the bay.

Summary

The non-point source load data generated for this project can be used to develop strategies for managing water quality in Galveston Bay. All of the water quality and GIS databases are available on electronic media so that the information can be used ir future environmental studies or for development of the bay management plan. It is expected that the GIS mapping data developed for this project would serve as the foundation for future Galveston Bay projects that require an intensive mapping effort

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Impact of Confined Animal Operations on Non-point Source Pollution Loadings to Galveston Bay.

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Introduction

Many activities in urban areas are a major source of environmental degradation. For example, chemical industries are producing new products which create new types of pollutants. At the same time, agricultural activities near urban areas are also charging storm waters with constant loads of sediments and organic nutrients. Galveston Bay is receiving much of the runoff generated from urban, and agricultural activities from many upland watersheds. The origins of these "non-point" pollutant sources are difficult to locate. This must be accomplished if the water quality of Galveston Bay is to be preserved.

Implication of Urban Animal Confines

Much interest and activity has recently been centered around non-point source pollution. Non-point pollution cannot be traced to a specific source: it is diverse and complex. As many cities in Texas begin to see non-point source pollution as a challenge, it is important to examine activities that potentially are contributing to pollution loads. Animal waste problems in the greater Houston area (and other cities that drain into Galveston Bay) require greater attention. In particular, dairies constitute a major problem because of the large amounts of wastes they generate. The Texas Water Commission non-point source pollution assessment shows that 37 surface water bodies are known to be impacted by non-point sources of pollution (TWC, 1990), including animal wastes and other pollutants.

A recent study carried out at Texas Southern University (Agbanobi, 1992) confirmed the existence of 52 confined animal facilities in parts of Harris County. The confined animals generate about 60,000 lbs. of fecal wastes per week. It is probable that there may be over 100 dairies and private animal confines within Harris County. Figures 1 and 2 show the rate of waste generation per day in some parts of Harris County by zones.

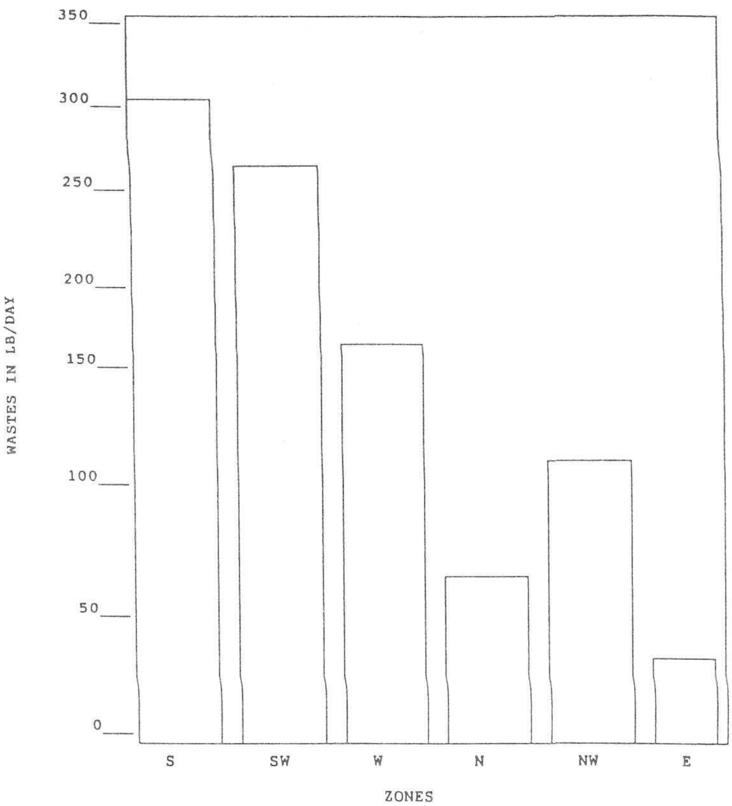

Figure 1. Waste generated per day by horses (by zones).

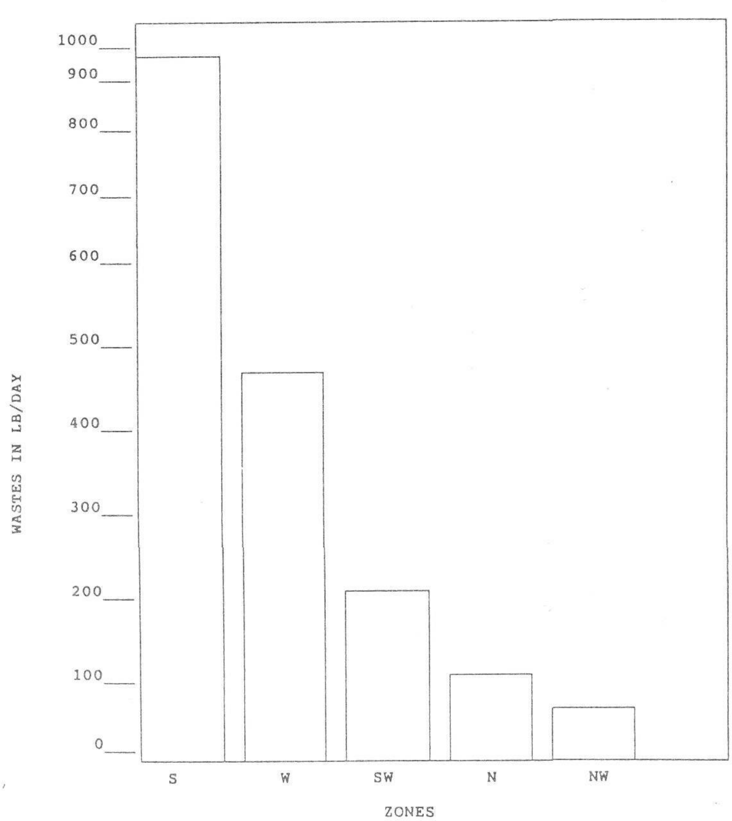

Figure 2. Waste generated per day by cows (by zones).

Confined Animal Wastes

Methods used to handle and dispose of wastes in urban animal confines are a major concern. A study of waste management practices showed that many methods used today by dairy operators in Harris County are archaic and pose serious pollution threats. Many farmers spread the animal wastes on land surfaces and cover them with straw, dirt and wood shavings. Others produce compost by mixing animal wastes with wood dusts and sell the compost to the public for use on lawns and gardens. Very few bag the wastes for collection by City sanitation units. For some small confines, operators simply allow the wastes to undergo biodegradation on the land surface. These crude landfilling and open dumping systems are carried out repeatedly on the same sites.

Landfilling raw animal wastes and conditioning soil with composts produced by a mixture of wood dusts and animal wastes essentially produce the same conditions that could be found in a sanitary landfill. No provisions are made for collecting leachates, to control erosion, or to prevent organic pollutants from reaching drainage systems. It is obvious that many urban animal confines cannot meet both the economics and the technology now required to operate an approved landfill systems. There is a need for alternative technologies. For example, wood dusts absorb moisture from animal wastes and do not enhance manure degradation.

Urban Runoff in Galveston Bay Waters

The primary urban non-point pollution sources include fertilizers, animal wastes, oil and gas products, liter and debris, vegetation, and erosion. The magnitude of pollution transported by stormwater runoff to receiving waters is comparable to partially treated sewage in some cases. The map of Galveston Bay shows how it serves as terminal and reservoir of contaminants that are transported by urban storm runoff through many streams and bayous (Figure 3).

Wastes from urban runoff contain high levels of nitrates, phosphorus, and sediments. In surface waters the nitrates are quickly converted to organic nitrogen by photosynthesis of aquatic plants, phytoplankton and algae, and rooted plants.

Control

Land-filling animal wastes in urban areas is not waste disposal. It is merely changing the wastes from one phase to another, without eliminating the pollution threat. Nitrate levels ranged from 5 to 35 mg/l and total suspended solids ranged from 55 to 985 mg/l. This shows that urban animal confines are contributing to the non-point sources pollution.

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These nutrients may be increasing microscopic plant production in Galveston Bay waters and may increase the amount of organic matter deposited on Bay sediments (Thurman, 1989). One major control must be to treat the animal wastes generated from animal confines in urban areas so that non-point pollution can be lessened. Studies on the handling and treatment of animal wastes have been carried out by Agnew and Loehn (1986) and many others. In Texas, Sweeten and Melvin (1985) have been focusing on the effectiveness of lagoons, land application of manure, irrigation with wastewater effluents, and other treatments.

Conclusion

The effect of urban animal confines on water resources in some areas in Harris County has yet to be fully determined. However, this study has suggests that dairies and other confined animal operations in Harris County and near other urban areas could potentially comprise up to 30% of the organic pollutants in non-point source pollution. In addition, many composting processes that utilize animal wastes and wood dusts are, in effect, functioning in much the same way as sanitary landfills. This could also increase sediment transport into the receiving waters.

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Sources and Distribution of Bay Debris

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One of the Priority Problems identified by the Galveston Bay National Estuary Program is that of floating, submerged, and shoreline debris. While studies have been done in the Gulf of Mexico, little is understood about the extent of the problem in Galveston Bay. The objective of this study is to analyze the occurrence, magnitude, distribution, and effects of debris in the Galveston estuary.

Data has been collected by volunteer citizens and the Texas Parks and Wildlife Department (TPWD). Data collection occurred between June 1, 1992, and September 30, 1992. Thirty-seven samples were collected along the shoreline by volunteer citizens. Eighty bag seine and 104 trawl samples were collected by TPWD. Trawl samples indicate submerged debris in open water areas of the bay while bag seine samples characterize the near-shore environment. In addition, six transects were done across the bay to sample floating debris. Data was recorded on beach cleanup data sheets.

Major categories of debris are currently being analyzed (i.e., plastics, styrofoam, glass, rubber, metal, paper, wood, cloth, and construction/industrial). The construction/industrial category, which was not contained on the beach cleanup sheets, was added during compilation because items such as shingles, tar, bricks, etc. were fairly commonly found and were listed on river cleanup sheets.

Preliminary results show that plastic was a major component in all collection areas, making up over 50% of the debris items collected in trawl and by the citizens. It was less prevalent in the near-shore areas sampled by bag seine, where construction debris also constituted an important component (Figure 1). While the number of samples done by the citizens group was much smaller than those done by bag seine and trawl, the majority of debris was collected from the shoreline environment (Figures 2-4).

The magnitude of the debris problem shall be evaluated for all environments. Preliminary geographic distribution maps of debris are being generated using ATLAS/GIS to see if there are aggregations in certain areas of the bay (Figure 2-4). If aggregations occur, the debris distribution will be stratified accordingly.

Separate estimates for major categories will be made when sufficient data are present. Some minor categories (plastic straws, plastic grocery bags, metal aerosol cans, etc.) may also be analyzed separately when sufficient data are present.

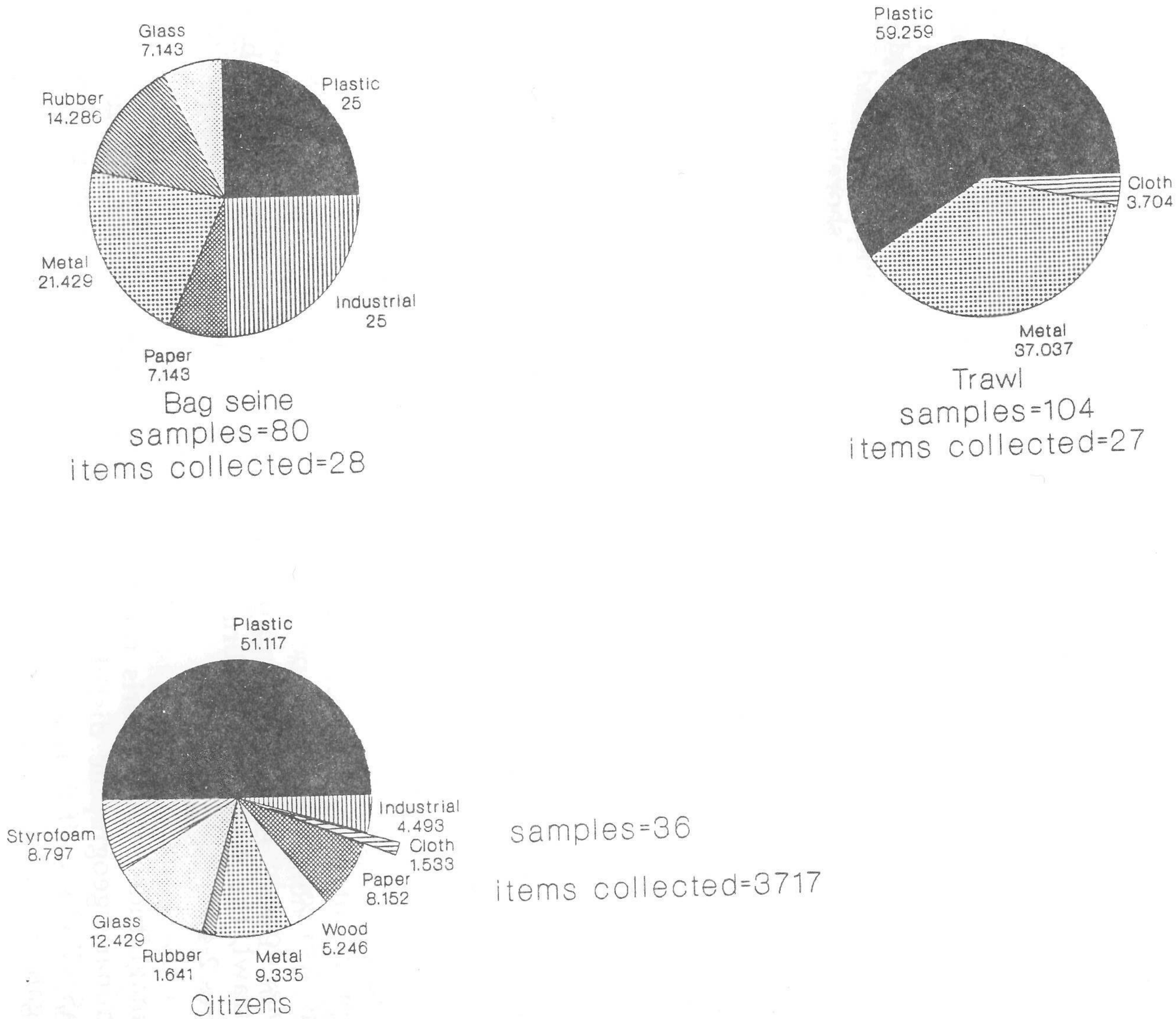

Figure 1. Percentage composition of marine debris collected in Galveston Bay.

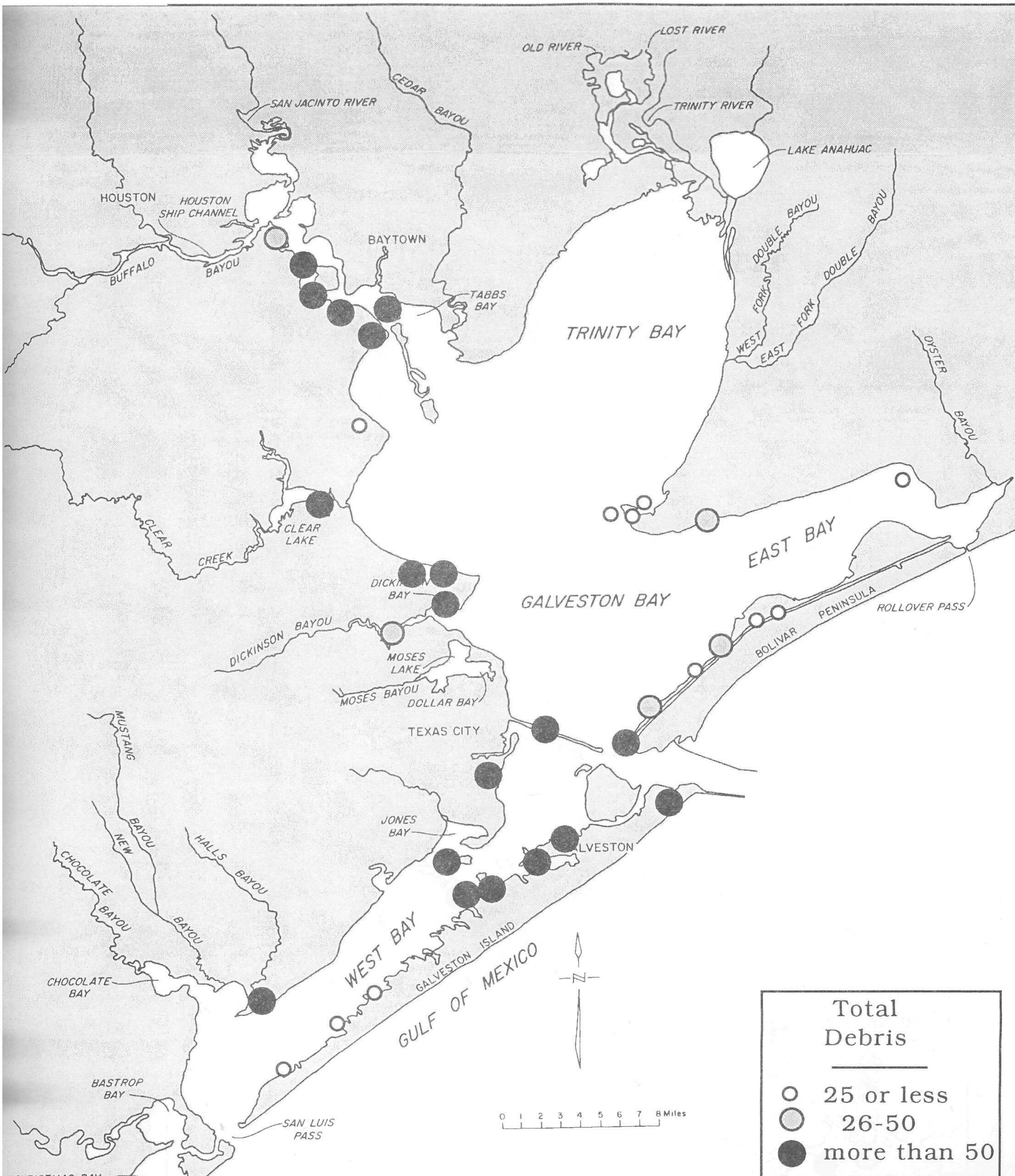

Figure 2. Spatial distribution of debris data collected by citizens.

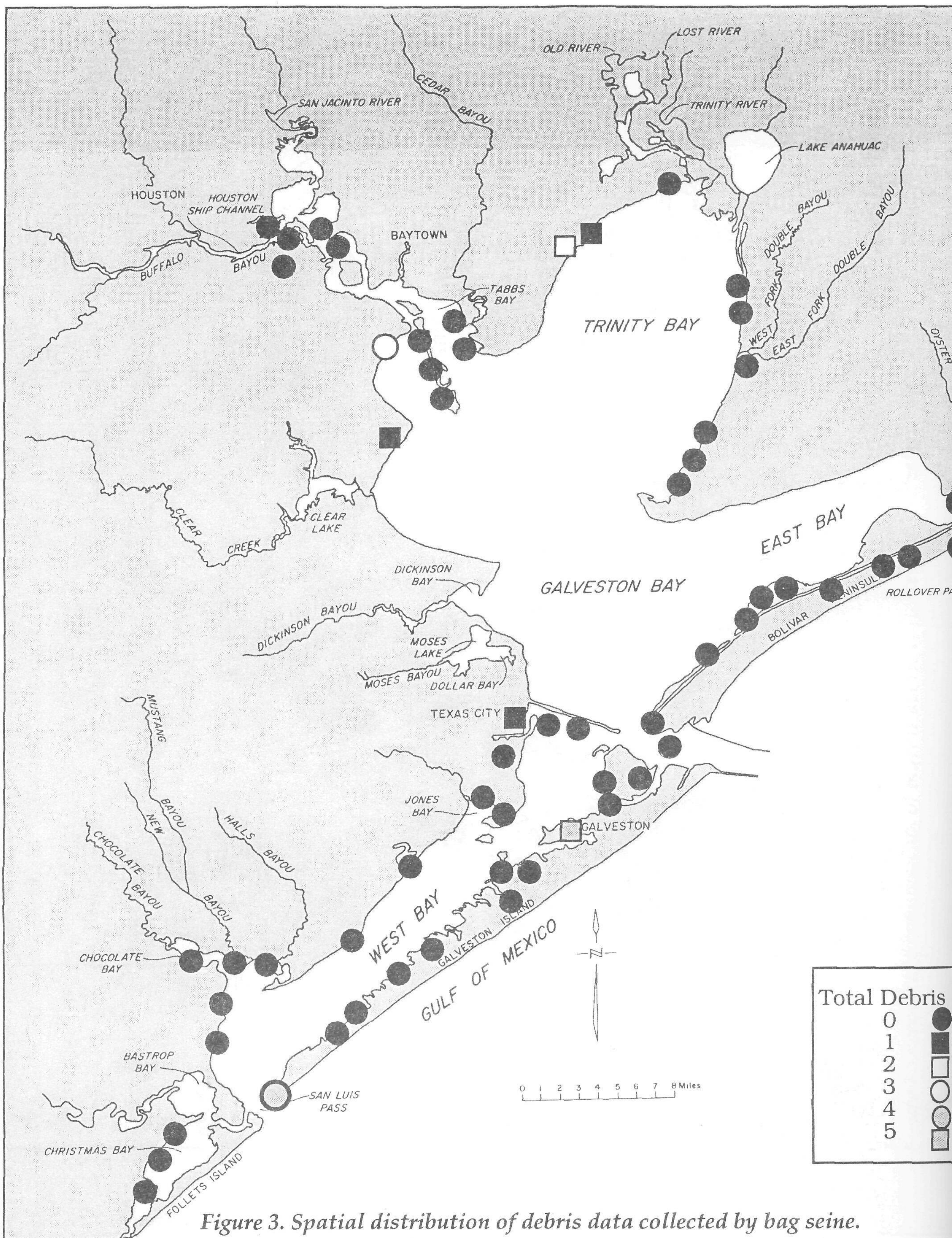

Figure 3. Spatial distribution of debris data collected by bag seine.

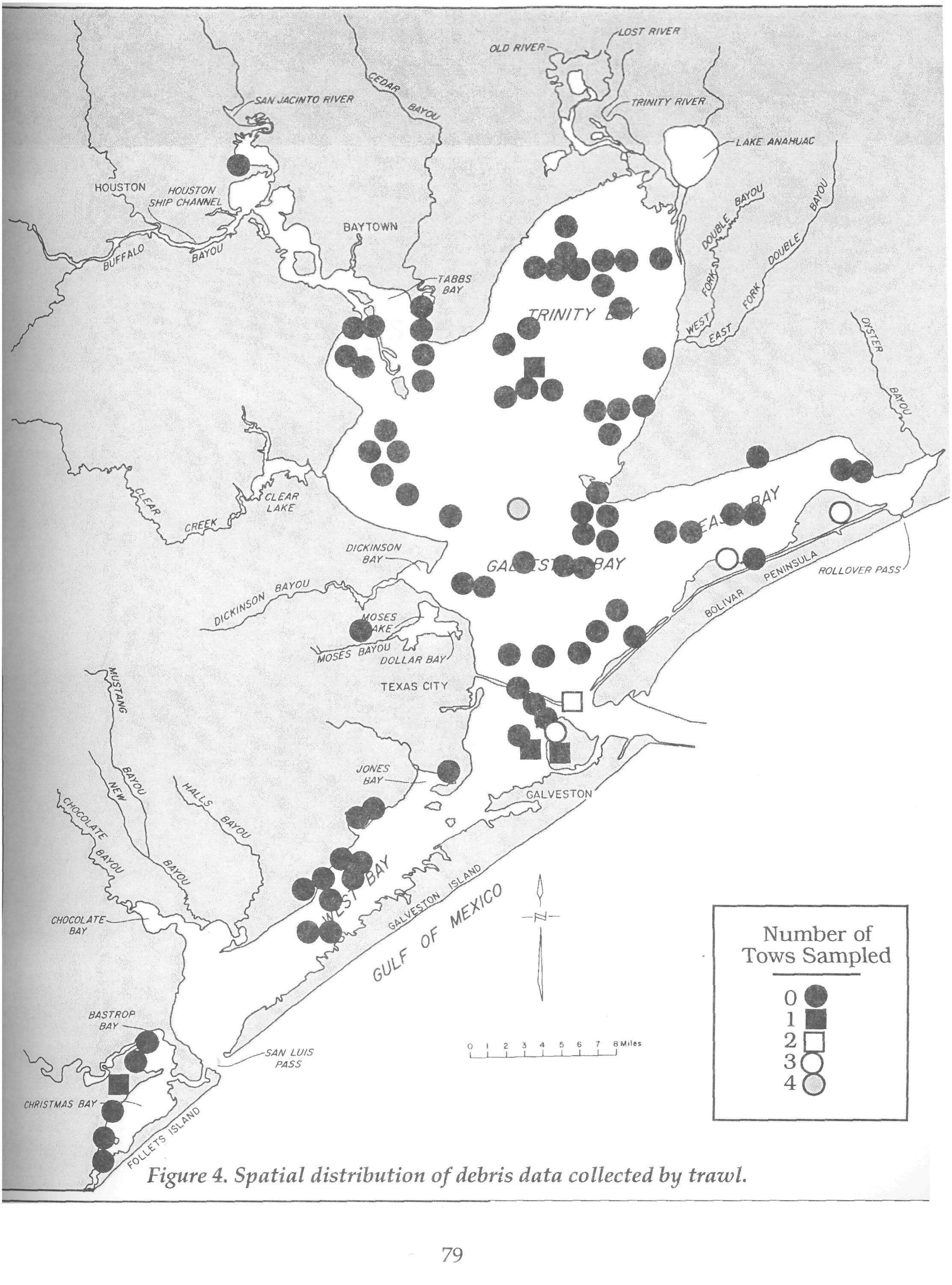

Figure 4. Spatial distribution of debris data collected by trawl.