FINAL REPORT
POINT SOURCE LOADING CHARACTERIZATION
OF CORPUS CHRISTI BAY

EXECUTIVE SUMMARY

By

Neal E. Armstrong
Department of Civil Engineering and
Center for Research in Water Resources

George H. Ward, Jr.
Center for Research in Water Resources

The University of Texas at Austin
Austin, Texas 78712

NEED FOR PROJECT

The Corpus Christi region can be characterized as geographically and culturally transitional, lying between the chaparral brush country to the south and the coastal-plain grassland prairies to the north, and influenced by the vast coastal-plain ranches of south Texas, the planters from the east, and Spanish traditions from the south. The region is also transitional from a perspective of hydroclimatology, being tropical much of the time, but still far enough north to be influenced by the midlatitude westerlies. It is also usually arid, but the exceptions are extreme: freshets on the Nueces and diluvial tropical storms, either of which can result in flooding and render much of the bay fresh. These extremes in hydroclimatology are also the primary external forcings of Corpus Christi bay that ultimately govern its quality.

Urbanization and industry are relative latecomers to the area. The boom of prosperity in Texas in the last quarter of the Nineteenth Century expressed itself in the Corpus Christi area as expansions in ranching, agriculture, and commercial fishing, in synergism with incursions of railroads and shipping, and, of course, tourism. But the population increase attending this expansion was modest in comparison to that of the upper coast. By 1900, Houston and its port had become a major industrial center, while Corpus Christi was regarded as primarily a tourist resort. Only in the 1930's did heavy industry begin to develop with construction of the Southern Alkali Corporation plant (which used oyster shell from Nueces Bay) situated on the industrial canal. Oil production began in this same decade of the 1930's near White Point and in the Saxet Field which stimulated shipping and later refining, and was the major impetus for growth in the area.

For Corpus Christi Bay and the adjacent systems of Aransas-Copano Bay and Laguna Madre, concerns about the quality of the system have arisen rather more recently than for the urbanized and industrialized bays on the upper Texas coast. Up to World War II, there appear few reports or indications of perceived pollution problems in the Corpus Christi area, in contrast to the upper coast. Far more fish kills had occurred in the Corpus Christi Bay system due to freshets and freezes than to contamination. In the last two decades public attention and concern for the Corpus Christi Bay system has changed. With accelerating urban development, awareness of the potential impacts on the bay has increased, and maintenance of the health of the system – and its reconciliation with goals of municipal growth and industrial development – has become a major issue. With this concern is the recognition that the quality of Corpus Christi Bay must be managed.

The cornerstone of management of a natural system like Corpus Christi Bay is the ability to determine responses of the system to changes in external or controlling factors, i.e. its "controls," in the form of cause-and-effect relations. Two elements are needed in order to appraise variation in water quality, "the effect", and to identify its cause, "loadings". First is a quantitative measure, i.e. identification and analysis of a parameter (or parameters) indicative of water quality. Complaints of declines in a fishery, for example, are dramatic evidence of something, but offer little basis for scientific evaluation. Instead, a physical or chemical parameter (or several, or many) is needed upon which the viability of that fishery depends, and which represents the impacts of some natural or human process on waters of the bay. The second element needed is an extensive database on the parameter. The database must have sufficient spatial and temporal resolution to establish the variation of the parameter, and must also encompass a considerable period of time.

The "cause consists of point and non-point source loadings of constituents to the Bay. Determining the magnitude of these loading, their spatial locations of entry into the Bay, and their temporal variations provides the initial information in understanding the variations in water quality that may be found.

As the goals of the Corpus Christi Bay National Estuary Program (CCBNEP) are to protect and improve the environmental and ecological quality of the estuarine waters and living resources of CCBNEP and the approach to achieving these goals includes linking the problems identified in the Bay with the causes, the analysis of point source discharges is a major step in characterizing one of the causes. The CCBNEP Contract Scope of Services, Article 7, for this study gives the specific objectives of this study as characterizing "the current status and temporal trends in permitted point source loadings and accidental releases of pollutants into the Corpus Christi Bay system", compiling "relevant data from long-term data sets maintained by various agencies", conducting "statistical and time series analysis ... where feasible for selected parameters", and making "suggestions for modifications as appropriate". These overall objectives as given in the Contract Scope of Services comprise then the need for this study.

PROJECT OBJECTIVES AND SCOPE

The overall objective of this study 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 Corpus Christi Bay system, and to examine loadings for previous years for this assessment. The main objective of this study was to characterize the current status and spatial and temporal trends in permitted point source loadings of constituents into the Corpus Christi Bay system.

The overall and main objectives were accomplished through the following specific objectives: (1) research and compile long-term point source loadings data for as far back as the data allow; (2) document data and information gaps and assess historical and existing quality control systems or procedures; (3) describe existing permitted point source loading and historical trends in the CCBNEP study area; (4) compare existing loading to waste load allocations and Total Maximum Daily Loadings ("TMDL") (where they exist) for each Texas Water Quality Segment in the CCBNEP study area, determine cumulative loading for pollutants being discharged on a segment by segment basis for the study area, and identify potential problem areas and rank water quality segments within the CCBNEP study area; and (5) make recommendations concerning management of segments and parameters of potential concern and for future monitoring programs in the CCBNEP study area.

PROJECT RESULTS

Estimation of point source loads of conventional, non-conventional, and priority pollutants to the Corpus Christi Bay system has required analysis and examination of an immense amount of data, the use of estimating procedures that incorporate uncertainty into load estimates, and assumptions that cannot be tested without a more extensive analysis of existing data and gathering of even more extensive new data. The point source constituent loads derived in this study represent best estimates as of the 1980, 1986, 1990, and 1995 calendar years, and it should be recognized that the 1995 loads have already changed and will continue to change as populations and industrial activities change in the Corpus Christi Bay drainage area and as regulatory limits on what can be discharged become more stringent.

Based on the results of this study, the following conclusions were drawn:

1. Loading estimates for conventional, nonconventional, and toxic pollutants from municipal and industrial point source wastewater discharges for the Corpus Christi Bay system were compiled and are given in Table 6.1. The reader is cautioned to note that these load estimates are based on self-reporting and Typical Pollutant Concentrations; where no self-reporting data exist for particular constituent and no TPCs exist for either municipal or industrial dischargers, the load may be reported as zero as in the case of phosphorus loads from industry. This does not necessarily mean that those dischargers did not in fact discharge that constituent; it only means that there were no means available to estimate the load. Also, the fact that constituents are not self-reported by dischargers means that the constituent is either essentially absent or low enough in concentration so as not to be of concern to the Texas Natural Resource Conservation Commission or the U.S. Environmental Protection Agency. With these caveats in mind, the following results are given:

    a. Flows of wastewater for 1995 totaled 322.8 billion gallons per year, and of that some 6.63 billion gallons per year was industrial wastewater discharges, 302.5

billion gallons per year was electrical utility cooling water, and 13.7 billion gallons per year of municipal wastewater discharger flows.

b. BOD_5 loads to the Bay system amounted to 0.988 million lbs/yr with 26.2 percent originated from industrial sources and 73.8 percent from municipal sources.

c. Total suspended solids loads to the Bay system equaled 1.779 million lbs/yr with 46.4 percent coming from industries and 53.6 percent from municipalities.

d. Some 1.582 million lbs/yr of total nitrogen reached the Bay of which 5.0 percent originated with industrial discharges and 95.0 percent from municipalities.

e. Total phosphorus loads totaled 0.799 million lbs/yr with 6.8 percent coming from industries and 93.2 percent from municipalities.

f. Oil and grease loads totaled 1.373 million lbs/yr with zero percent from industries and 100.0 percent from municipalities.

g. For all of the metals except copper, the major sources were the municipalities. Of the amount originating with the wastewater discharges, usually over 70 percent came from municipal discharges. It should be noted, however, that most of the municipal industrial load estimates were based on Typical Pollutant Concentrations.

h. No PCBs were estimated to be reaching the Bay, and just over 68 lbs/yr of chlorinated hydrocarbon pesticides were estimated via TPCs to be coming from municipalities.

2. A substantial portion of the estimated municipal and industrial wastewater constituent loading is based on Typical Pollutant Concentrations (TPCs), and the greater the proportion of the load estimated the greater the uncertainty of the estimates; the proportions of the constituent loadings estimated from measured (self-reporting) data and estimated (TPCs) are given below:

   a. Loading estimates for two of the conventional pollutants (BOD_5 and TSS) were considered to be the most accurate considering they were required to be reported by most dischargers while loading estimates of fecal coliform bacteria are essentially all by Typical Pollutant Concentrations and are to be used with caution.

   b. Loading estimates for other pollutants (particularly nonconventional pollutants like nutrients) were less accurate because they were not reported by all dischargers, the chemical forms analyzed in effluents generally did not represent the total nutrient concentration (particularly for nitrogen) that may be present, and because Typical Pollutant Concentrations had to be employed to estimate loadings.

c. Loading estimates for toxic substances like metals are the least reliable for effluents because they are reported by very few dischargers (and, thus, Typical Pollutant Concentrations had to be employed again) and because of concern about the reliability of historical metals data due to possible sample contamination.

d. Loading estimates for complex organics are the most incomplete because very few dischargers report them and the lack of any Typical Pollutant Concentrations to use for estimation purposes.

3. Loading comparisons with Pacheco et al. (1990) reveal close similarities for 1990 loads into the Corpus Christi Bay system as expected because they estimated loadings of constituents from all discharges based on monitoring data, permitted discharges, TPCs in effluents, and other information much as was done in this study.

   a. This study calculated higher total flow (industrial process wastewater, cooling water, and municipal wastewater) than was estimated by Pacheco et al. (1990), and this increase might be expected given the circa 1987 timing of their estimates; however, process and municipal wastewater flows were lower than Pacheco, et. al., and this reduction in wastewater flows is reflected in part in the loadings of other constituents which were estimated as the product of constituent concentration and flow.

   b. BOD_5 and TSS loading estimates were 75 and 58 percent, respectively, of the loads estimated by Pacheco et al. (1990) due to Pacheco et al.'s TPC for these two constituents being substantially higher than the concentrations actually measured in municipal effluents in the Corpus Christi Bay area.

   c. Total nitrogen loads were very close to those given by Pacheco et al.; however, those for total phosphorus were considerably higher.

   d. All of the metals loadings were between 30 and 80 percent of those of Pacheco et al. (1990) again reflecting the lower TPCs used in this study.

4. Comparison of aggregated constituent loadings by water quality segment with the concentrations of those constituents in Corpus Christi Bay showed the following:

   a. Relating loads to water quality can be done to some extent by simple comparisons of load to water quality, but more confident comparisons require mass balance relationships between total constituent loads (point source, tributary, and non-point source) and receiving body water and sediment quality.

   b. Without knowing the magnitudes of the tributary and non-point source loads in relation to the point source loads, it is not possible to know whether the point source loads dominate the total loading enough to be the primary determinant of water quality, and these correlations must be done with care, knowing that regardless of the magnitude of the point source loads, the other loads may be more important.

c. Oso Bay (Segment 2485) and the Inner Harbor (Segment 2484) consistently received the greatest loads of constituents, and water quality levels in Oso Bay and the Inner Harbor generally show the effects of loadings.

d. The central portion of the Corpus Christi Bay system received the majority of loads of almost all constituents while the lower portion (Baffin Bay and Laguna Madre) was next followed by the upper portion (Redfish Bay and north). If point source loads alone were influencing water quality, then the impacts in Oso Bay and the Inner Harbor could be explained, and the trend of increasing concentrations of some constituents from north to south as documented by Ward and Armstrong (1996) would also be explained.

5. The 1995 reported brine discharge flow by the TRC was 32.81 MG/yr with less than 1 percent of it being discharged to the Aransas Bay/Redfish Bay area, some 24.3 percent to Nueces Bay/Corpus Christi Bay, and 75.2 to the Baffin Bay/Laguna Madre area.

6. Temporal analysis of flows and loadings revealed the following:

a. Total wastewater flows (including cooling water flows) have increased almost 14 percent from 1980 to 1995 while industrial process wastewater and municipal wastewater flows have increased by 42 percent (percent increases in each were about the same).

b. Despite the increase in wastewater flows, from 1980 to 1995 there has been a 59 percent decrease in BOD_5 loads and a 45 percent decrease in TSS loads; since 1970 the BOD_5 load decrease has been 97 percent and the TSS load decrease 95 percent representing very significant improvements in effluent quality for both industrial and municipal wastewater discharges.

c. Temporal changes in the rest of the constituents are so based on Typical Pollutant Concentrations and thus linked strongly to flows that loads are shown to increase, and these trends should be used with caution.

7. The database to estimate point source loads of pollutants to Corpus Christi Bay is overall relatively incomplete. While flow measurements in effluents are the most complete sets of data available, the database for chemical constituents in general is rather sparse. For conventional pollutants like BOD_5 and TSS, a much more dense set of data exists. For non-conventional pollutants like total nitrogen, total phosphorus, and oil and grease, the self-reporting data available is essentially zero for the first two and very limited for the latter. Because of the paucity of permits with self-reporting requirements for metals and complex organics, all of the point source effluent loading estimates for these substances are almost totally based on TPCs with the exception of one metal - copper.

RECOMMENDATIONS

Based on the results of this study and the accompanying analysis of data availability and data quality, the following recommendations are made:

1. To put point source loads of water quality constituents into perspective, it is essential to estimate loadings of constituents from tributaries and non-point sources. In Galveston Bay, for example, Armstrong and Ward (1994) found that point sources contributed less than one-third generally of the same constituents as investigated in this study, tributaries contributed between one-half to two-thirds, and non-point sources the balance. With lower freshwater inflows into the Corpus Christi Bay system compared to Galveston Bay, it is anticipated that tributaries will contribute proportionately less than in Galveston Bay, but any actions that might be taken to manage constituent loadings must account for sources other than point sources.

2. Because the central and southern portions of the Corpus Christi Bay system are receiving the highest loads of essentially all the constituents, the following recommendations are made:

    a. Special studies of Oso Bay, the Inner Harbor, Nueces Bay, and Baffin Bay should be performed to ascertain more clearly the impact of waste discharges to these systems, to understand the role of point sources discharges in the spatial and temporal trends in water quality found by Ward and Armstrong (1998) in these bays, and to determine if additional treatment is needed.

    b. Mathematical modeling of water quality is particularly needed to link constituent loadings to receiving water quality.

3. For improving effluent loading estimates for point source discharges:

    a. Loading estimates for nutrients, metals, and complex organics from permitted wastewater discharges to Corpus Christi Bay can be enhanced through:

        (i) a one-time special sampling program in which conventional, non-conventional, and toxic substances are monitored over a one year period in each permitted discharge with samples being taken bimonthly, analyzed for those constituents not already being monitored by each discharger to satisfy discharge permit requirements, and analyzed with analytical methods appropriate to the concentrations anticipated and with clean methods for metals.

        (ii) TNRCC and EPA adding to their permit application forms (in which every major industrial discharger is required to complete EPA Form 2C and to list priority pollutants in their effluent and concentrations for them) conventional and non-conventional constituents so that information on these and toxic substances will be acquired on a regular basis.

b. The Typical Pollutant Concentrations developed by Pacheco et al. (1990) need to be updated to bring them current with wastewater treatment technology now being used by industry and municipalities.

c. Typical Pollutant Concentrations need to be developed for non-conventional constituents, particularly nitrogen (including ammonia-N) and phosphorus, for industrial discharges and for municipal discharges with nitrogen and/or phosphorus removal.

c. Typical Pollutant Concentrations need to be developed for those metals for which TPCs are not already available, for complex organics, and for non-conventional constituents.

4. Constituent load estimates from brine water discharges could be enhanced by expanded sampling of minerals, metals, and organics; indeed, with produced water discharges to Texas coastal waters being phased out by the end of 1998, it would be helpful to have expanded sampling of these discharges before they cease to understand better the constituent concentrations that will remain in the receiving waters after their cessation.

5. Load estimates for constituents from spills can be improved if there are better estimates of quantities of spilled materials reaching surface waters and chemical analysis of those materials; naturally, this is made difficult by the conditions surrounding spills and the assessment and cleanup priorities for it.

Table E.1 - Summary of Effluent Loads to the Corpus Christi Bay System in 1995

Point Source Load Characterization Project
Corpus Christi Bay National Estuary Program

Constituent	Units	Industrial Load	Municipal Load	Total Load
Tot. Flow	(MG/yr)	309,160.3	13,688.1	322,848.2
	% of Total	95.8	4.2	
Cooling Water	(MG/yr)	302,531.1	0.0	302,531.1
	% of Total	100.0	0.0	
Process Flow	(MG/yr)	6,629.2	13,688.1	20,317.3
	% of Total	32.6	67.4	
BOD_5	(lbs/yr)	255,312.9	701,379.3	956,692.3
	% of Total	26.7	73.3	
TSS	(lbs/yr)	763,296.5	954,002.2	1,717,298.7
	% of Total	44.4	55.6	
Oil & Grease	(lbs/yr)	93,172.8	1,278,578.1	1,371,750.9
	% of Total	6.8	93.2	
Total N	(lbs/yr)	0.0	1,598,222.7	1,598,222.7
	% of Total	0.0	100.0	
Total P	(lbs/yr)	0.0	799,111.3	799,111.3
	% of Total	0.0	100.0	
Fecal Coliforms	(10^6 col./yr)	2,293	103,482,042	103,484,335
	% of Total	0.0	100.0	
Total As	(lbs/yr)	451.2	3,653.1	4,104.3
	% of Total	11.0	89.0	
Total Cd	(lbs/yr)	236.9	1,255.7	1,492.6
	% of Total	15.9	84.1	
Total Cr	(lbs/yr)	1,508.6	4,908.8	6,417.4
	% of Total	23.5	76.5	
Total Cu	(lbs/yr)	7,103.6	2,105.5	9,209.1
	% of Total	77.1	22.9	
Total Fe	(lbs/yr)	0.0	79,911.1	79,911.1
	% of Total	0.0	100.0	
Total Pb	(lbs/yr)	346.6	5,137.1	5,483.8
	% of Total	6.3	93.7	
Total Hg	(lbs/yr)	38.2	95.8	134.0
	% of Total	28.5	71.5	
Total Zn	(lbs/yr)	4,629.6	18,836.2	23,465.7
	% of Total	19.7	80.3	
PCB	(lbs/yr)	0.0	0.0	0.0
	% of Total	0.0	0.0	
CHP	(lbs/yr)	0.0	68.5	68.5
	% of Total	0.0	100.0	

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CHAPTER 1

INTRODUCTION

1.1 NEED FOR STUDY

The Corpus Christi region could be characterized as geographically and culturally transitional, lying between the chaparral brush country to the south and the coastal-plain grassland prairies to the north, and influenced by the vast coastal-plain ranches of south Texas, the planters from the east, and Spanish traditions from the south. The region is also transitional from a perspective of hydroclimatology, being tropical much of the time, but still far enough north to be influenced by the midlatitude westerlies. It is also usually arid, but the exceptions are extreme: freshets on the Nueces and diluvial tropical storms, either of which can result in flooding and render much of the bay fresh. These extremes in hydroclimatology are also the primary external forcings of Corpus Christi bay that ultimately govern its quality.

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The cornerstone of management of a natural system like Corpus Christi Bay is the ability to determine responses of the system to changes in external or controlling factors, i.e. its "controls," in the form of cause-and-effect relations. Two elements are needed in order to appraise variation in water quality, "the effect", and to identify its cause, "loadings". First is a quantitative measure, i.e. identification and analysis of a parameter (or parameters) indicative of water quality. Complaints of declines in a fishery, for example, are dramatic evidence of something, but offer little basis for scientific evaluation. Instead, a physical or chemical parameter (or several, or many) is needed upon which the viability of that fishery depends, and which represents the impacts of some natural or human process on waters of the bay. The second element needed is an extensive database on the parameter. The database must have sufficient spatial and temporal resolution to establish the variation of the parameter, and must also encompass a considerable period of time.

The "cause" consists of point and non-point source loadings of constituents to the Bay. Determining the magnitude of these loading, their spatial locations of entry into the Bay, and their temporal variations provides the initial information in understanding the variations in water quality that may be found.

As the goals of the Corpus Christi Bay National Estuary Program (CCBNEP) are to protect and improve the environmental and ecological quality of the estuarine waters and living resources of CCBNEP and the approach to achieving these goals includes linking the problems identified in the Bay with the causes, the analysis of point source discharges is a major step in characterizing one of the causes. The CCBNEP Contract Scope of Services, Article 7, for this study gives the specific objectives of this study as characterizing "the current status and temporal trends in permitted point source loadings and accidental releases of pollutants into the Corpus Christi Bay system", compiling "relevant data from long-term data sets maintained by various agencies", conducting "statistical and time series analysis ... where feasible for selected parameters", and making "suggestions for modifications as appropriate". These overall objectives are given in the Contract Scope of Services as the following five major objectives:

a. Research and compile long-term point source loadings data for as far back as the data allows (for the purposes of time series analysis, long-term data sets generally refer to data that has been collected for at least 5 years);

b. Document data and information gaps and assess historical and existing quality control systems or procedures;

c. Describe existing permitted point source loading and historical trends in the CCBNEP study area;

d. Compare existing loading to waste load allocations and Total Maximum Daily Loadings ("TMDL") (where they exist) for each Texas Water Quality Segment in the CCBNEP study area, determine cumulative loading for pollutants being discharged on a segment by segment basis for the study area, and identify potential problem areas and rank water quality segments within the CCBNEP study area; and

e. Make recommendations concerning management of segments and parameters of potential concern and for future monitoring programs in the CCBNEP study area.

Clearly the major focus of this project was to determine loadings of waste constituents from point sources (including oil field brine discharges) to the CCBNEP study area, and this focus pointed to one of the identified Priority Problems, namely degradation of water quality which may be caused by loadings of constituents from some sources. Loadings were estimated as the mathematical product of flow and constituent concentration; thus, it was essential to have numerical values for both to perform the estimate. For permitted point sources into the CCBNEP study area, estimates of loading were obtained directly from the monthly self-reporting data for those constituents for which values are reported in daily loading units while for others the estimate were made by multiplying average daily flow and average daily constituent concentration for the month. These data were available from the self-reporting data files of the Texas Natural Resource Conservation Commission (TNRCC).

Oil field brine discharge information was available from the Texas Railroad Commission (TRC), and information on the location of oil wells in the CCBNEP study area and the brine discharge flow and constituent composition from each was sought from that agency. To the extent possible, spatial and temporal trends in those constituent loadings from those discharges were examined. Likewise, spill data was sought for both oil and other substances from the Texas General Land Office and the U.S. Coast Guard, and to the extent possible estimates of quantities spilled and the spill composition were used to estimate constituent loads spilled.

The study area for this project encompassed the estuarine and coastal nearshore areas of the Coastal Bend area, extending from the mud flats (a.k.a. middle ground, a.k.a. landbridge, a.k.a. landcut) of the Laguna Madre to the southern limit of San Antonio Bay, and included Baffin Bay, Corpus Christi Bay proper and its secondary embayments, the Aransas-Copano system, and Mesquite/Ayres Bay. Aransas, Copano and their secondary systems (including Mesquite) are referred to as the upper bays and Baffin Bay and the Upper Laguna Madre as the lower bays. Differentiation between the Corpus Christi Bay "system," i.e. the CCBNEP study area, and the subregion of Corpus Christi Bay proper is made by appropriate qualifiers when necessary, but generally the context of use clarifies which is meant.

1.2 OBJECTIVES

The major objective of this project was to determine loadings of waste constituents from point sources (including oil field brine discharges) to the CCBNEP study area. The specific objectives of this study were to characterize "the current status and temporal trends in permitted point source loadings and accidental releases of pollutants into the Corpus Christi Bay system", compiling "relevant data from long-term data sets maintained by various agencies", conducting "statistical and time series analysis ... where feasible for selected parameters", and making "suggestions for modifications as appropriate". These specific objectives were to be accomplished by five tasks presented in Article 8 of the Proposed Work Plan document.

1.3 SCOPE OF WORK

These specific objectives were accomplished by the following five tasks:

Task 1 - Data Acquisition And Compilation − research and compile long-term point source loading data from a variety of sources, describe existing permitted point source loading and historical trends in the CCBNEP study area using various graphical and statistical methods, aggregate the loadings by water quality segment, and present the loadings data in a GIS-based system.

Task 2 - Segment Comparisons − compare constituent loadings among the Texas Water Quality segments and the derived segments to determine spatial trends, to rank these segments by the loadings, and to prepare written descriptions of the comparisons.

Task 3 - Data Analysis − conduct statistical and time series analyses using accepted statistical methods and graphical displays to show the temporal trends in the loadings of those constituents listed in Task 1.

Task 4 - Identification Of Data And Information Gaps And Methodology Problems − (1) assess historical and existing quality control systems or procedures including sampling methodology and make determinations regarding the reliability of data sets based on these assessments; (2) determine gaps in existing data which impede adequate appraisal of water/sediment (or, in this case, wastewater) quality; and (3) document problems with existing monitoring methodology (both in the laboratory and the field) which impede the use of monitoring data for trend analysis.

Task 5 - Final Report Preparation − develop a final comprehensive report describing the current status and historical trends in point source loadings in the CCBNEP study area.

1.4 ACKNOWLEDGMENTS

The authors gratefully acknowledge the financial support of the CCBNEP through the TNRCC and the many individuals in the Program and Commission who offered guidance, counsel, and encouragement during the course of the project. To the staff of the Center for Research in Water Resources and the Department of Civil Engineering at The University of Texas at Austin who took part in or supported the project administratively, we also offer our thanks.

CHAPTER 2

PREVIOUS LOADING ESTIMATES

2.1 INTRODUCTION

The literature reviewed consisted of several reports and studies that would indicate the historical and current loading of conventional, nonconventional, and toxic pollutants to the Corpus Christi Bay system from permitted dischargers, tributaries, and non-point sources. This chapter contains a review of these loading estimates and a short description of the Corpus Christi Bay system so that loading sources and receiving systems can be identified.

2.2 CORPUS CHRISTI BAY SYSTEM

Corpus Christi Bay is part of the Nueces and Mission-Aransas estuaries system which includes Copano Bay, Aransas Bay, Nueces Bay, Corpus Christi Bay, and several smaller bays. About 19,497 mi^2 of Texas contribute inflow to these estuaries, including the entire Nueces River basis and parts of the San Antonio - Nueces and the Nueces - Rio Grande Coastal Basins (TDWR 1981). The San Antonio, Mission, Aransas, and Nueces rivers contribute most of the freshwater inflows to the estuaries and bays of the region. These estuaries have limited exchange with the Gulf of Mexico, and most of the freshwater inflows exchange with the Gulf through Aransas Pass. This restricted water circulation and exchange patterns contribute to the high residence times of water in the bays and estuaries of this area, and these high residence times, combined with high evaporation rates and occasional high stream flows from tropical storms, results in a wide range of salinity (TNRCC 1994).

As noted in TNRCC (1994), mean annual inflows to all three major estuaries are greater than median annual inflows indicating that the discharges from rivers during episodic events and storms are significantly greater than the volume of water discharged during normal flows. On average, water in the upper Laguna Madre is completely replaced only once every 3.3 years, in Corpus Christi Bay every 1.4 years, and in Aransas Bay every 1.56 years. These estimates are based on hydrology alone and do not include exchange that occurs through tidal action which will tend to lower residence time. They also do not take into account precipitation and evaporation which affects the water budget of each estuary dramatically. In the Aransas-Copano system, there is an inflow balance, i.e., of the 808,639 acre-ft was freshwater inflow coming into the estuary each year from gauged and ungauged inflows, some 614,715 acre-ft/year is lost to evaporation leaving a net inflow balance of 193,923 acre-ft/year. For the Corpus Christi estuary, there is a net inflow balance of 326,555 acre-ft/year out of the total of 935,524 acre-ft/year of freshwater that enters the system. The upper Laguna Madre, on the other hand, has a negative inflow balance of 288,665 acre-ft/year meaning that a substantial portion of the 554,234 acre-ft/year of freshwater entering the system is lost as evaporation.

The study area for this project encompasses the estuarine and coastal nearshore areas of the Coastal Bend area, extending from the mud flats (a.k.a. middle ground, a.k.a. landbridge, a.k.a.

landcut) of the Laguna Madre to the southern limit of San Antonio Bay, and includes Baffin Bay, Corpus Christi Bay proper and its secondary embayments, the Aransas-Copano system, and Mesquite/Ayres Bay (see Figure 2.1). Aransas, Copano and their secondary systems (including Mesquite) are referred to as the upper bays, and Baffin Bay and the Upper Laguna Madre as the lower bays.

2.3 EARLY ESTIMATES OF POLLUTANT LOADING

Estimates of conventional, nonconventional, and toxic pollutant loadings for the Corpus Christi Bay system prior to 1968 could not be located. There have been early estimates of some constituent loadings for restricted portion of the system or for political jurisdictions, namely counties, and these and others are given in this section.

2.3.1 ESTIMATES OF POLLUTANT LOADS BY COUNTY

In a survey of waste discharges in the Texas coastal zone, Malina (1970) examined waste discharge permit and self-reporting data available from the TWQB and TWDB and determined the number of, quantity of flow from, and loading of BOD (presumably BOD_5), COD, suspended solids, and phosphates from municipal and industrial wastewater discharges for roughly the 1970 period. Texas has a permitting and self-reporting system in place long before the federal 1972 Clean Water Act was passed which required such permitting, thus, the data were available in 1970 for Malina (1970) to make his estimates. There was concern expressed from some dischargers (not necessarily in the Study Area of this project) about the accuracy of the data in the self-reporting system (Malina, 1997), thus, the estimates must be used with some caution. He aggregated his results by county, and, for the counties in the Study Area, his results are given in Table 2.1. Although it is unclear in his report exactly how loadings were calculated, Malina (1970) apparently used a combination of flows and concentrations reported with permit applications, reports of flow and constituent data for various dischargers, and perhaps typical concentrations of BOD_5, TSS, COD, and phosphates in municipal and industrial wastewaters at that time. Loads were then estimated from the product of flows and concentrations.

Malina (1970) found there were 72 municipal and industrial dischargers in the eleven county area, 41 municipal and 31 industrial. The estimated municipal wastewater flow was 41.14 MGD (15,016 MG/yr) while the industrial was 197.65 MGD (72,142 MG/yr) (did not include Central Power and Light Company power plant cooling water flows) for a total of 238.79 MGD (87,158 MG/yr). Similarly, the total BOD_5 load for the eleven county area was estimated to be 82,459 lbs/day (30,098 10^3 lbs/yr) with 16,909 lbs/day (6,172 10^3 lbs/yr) from municipal discharges and 65,550 lbs/day (23,926 10^3 lbs/yr) from industrial sources. Dividing estimated BOD5 loads by flows gives estimates of overall BOD5 concentrations in these municipal and industrial wastewater discharges. For municipal discharges, the average BOD5 concentration is calculated as 49.3 mg/L and, for industrial discharges, it is 39.8 mg/L. Similar calculations for TSS using data in Table 2.1 give concentrations of 69.4 mg/L and 47.3 mg/L, respectively. The estimated concentrations are significant, because, as will be seen later, there have been dramatic reductions in wastewater flows, primarily industrial, and effluent concentrations of BOD5 and TSS giving reduced loadings of these two constituents to the Corpus Christi Bay system.

Finally, also shown in Table 2.1 are the five county (coastal counties: Aransas, Kleberg, Nueces, Refugio, and San Patricio) totals for number of discharges, flow, BOD5, and TSS. Clearly, these five coastal counties house most of the dischargers in the eleven county Study Area and receive directly over 85 percent of the flow and BOD5 and TSS loads from municipal and industrial sources.

2.3.2 PACHECO ET AL. (1990) LOADING ESTIMATES

More recently, Pacheco et al. (1990) estimated the discharge of conventional, nonconventional, and toxic pollutants to the Corpus Christi Bay system as part of a larger study to estimate loadings of pollutants to the Texas coast. Their report summarized annual wastewater pollutant discharge estimates for 15 pollutants (process flow, BOD_5, TSS, total nitrogen, total phosphorus, fecal coliforms, oil and grease, and eight metals, arsenic, cadmium, total chromium, copper, iron, lead, mercury, and zinc) for 307 Major and 2274 Minor (Major and Minor are EPA categories) point sources in the National Coastal Pollutant Discharge Inventory (NCPDI) study in Texas. The estimates reflected discharges between December 1986 and November 1987 and are organized by eight Estuarine Drainage Areas, three of which encompass the study area; these Areas are: Aransas Bay; Corpus Christi Bay; and Laguna Madre. The latter Area extends to the Rio Grande River, so where possible dischargers in the Upper Laguna Madre have been included here. The sources they used to derive their estimates included the EPA's Permit Compliance System, the Industrial Facility Discharge File, and the 1986 Construction Grants Needs Survey, the TNRCC's (then TWC) self-monitoring reports, NPDES permit files containing monitoring data, and interviews and discussions with Commission staff.

Pacheco et al. (1990) found that less than half of all dischargers identified in the study area based on EPA information were included in the TWC inventory. They noted that the difference in these facility counts could be attributed to the fact that EPA's Permit Compliance System is required to maintain a record for every facility that discharges or proposes to discharge to surface waters, whereas the TWC only issues a discharge permit to a facility if it determines that the facility has a significant impact on the receiving water. Whether that ratio pertained to the Corpus Christi Bay system was unclear. They did identify over 28 Major and over 300 Minor facilities in the Corpus Christi Bay system of which 27 Major and 63 Minor facilities were used for loading estimates, and of these 91 total facilities, some 39 were wastewater treatment plants, 50 were industrial discharges, and 2 were power plants. Of the 91 facilities used, only 28 were considered significant enough to list in detailed tabular form in their report.

Discharge estimates were based on monitoring data, permit data, typical concentrations of pollutants in effluents (based on SIC category), and other information. Generally, Pacheco et al. (1990) found that monitoring data were available for flow, BOD_5 and TSS, but such data for metals were poor. Monitoring data taken from NPDES compliance monitoring results, reported in each facility's Discharge Monitoring Reports, for the period December 1986 through November 1987 were used wherever possible. If monitoring data were not available, NPDES permit limits were used. If no monitoring or permit data were available, Typical Pollutant Concentrations were used. The typical concentrations were assigned based on the type of industrial or commercial activity taking place at the facility, or, if the facility was a wastewater treatment plant, the level of wastewater treatment. Daily discharge estimates were computed, adjusted to annual discharges given the number of days of discharge and adjusted seasonally if appropriate. The authors caution that the discharge estimates should be used for screening purposes only. Some facilities may have been missed, and the Typical Pollutant Concentrations were based on effluent limit development document information which was 10 to 15 years old and thus might be erroneous.

With the understanding about the completeness and accuracy of the discharge data in mind, the reader is referred to Table 2.3 through Table 2.5 which contains the estimates of pollutant discharges by Pacheco et al. (1990) for Aransas Bay, Corpus Christi Bay, Laguna Madre (estimated by the authors), and the total of the three, respectively. It is important to note that total flow includes process flow and cooling water flow and that process flow is discharged wastewater. Only 12.6 percent of the discharge flow to Corpus Christi Bay was estimated by Pacheco et al. (1990) to be process water; most of the discharge flow was from once-through cooling systems. Almost 1.76 million lbs/yr of BOD_5 was estimated to be discharged to Corpus Christi Bay from permitted point sources, over 1.61 million lbs/yr of TSS, just under 1.58 million lbs/yr of total nitrogen, over 0.82 million lbs/yr of total phosphorus, various amounts of heavy metals (all under 100,000 lbs/yr), and over 1.49 million lbs/yr of oil and grease. Except for mercury, municipal wastewater dischargers dominated loadings of all the pollutants considered.

2.3.3 Brine Discharges

Malina (1970) also reported on the discharge of salt brine from oil production wells based on a survey by the Texas Railroad Commission (TRC) in 1961 (see Table 2.6). Again, aggregating by county, he found that a total of 32.56 MG/yr of salt brine was being produced and disposed of, and, of that amount, 3.9 MG/yr (or 12 percent) were being discharged to surface waters.

Mackin (1971) reported on brine discharges in a portion of the Study Area, namely Baffin Bay, and provided discharge estimates for several fields. He indicated that the discharge estimates were taken from an application for permit to discharge on July 1, 1971. The total amount of brine to be discharged was 20,100 bbl/day (0.84 MG/day) (308.1 MG/yr) which would be a substantial increase over that reported by Malina (1970). Even so, Mackin does not report the portion of the brine discharge which would actually be discharged to surface water, but if the proportions were to be similar to those reported by Malina (1970) for Kleberg County, then over 0.7 MG/day would be expected.

Field Discharging Brine to Area	Tributary Carrying Discharge to Area	Vol. Disch. (bbl/day)	Vol. Disch. (MG/yr)	Sal. of Disch. (ppt)
Arnold Davis Field	Petronilla Creek	600	9.2	119
North Alazan and Madera Field	Tunas Creek	14,500	222.3	110

Alazan Field	Cayo De Hinojoso	3,200	49.1	113
Sarita Field	Laguna Salado	1,800	27.6	96

Later estimates of brine discharge were reported by Boesch and Rabalais (1989) who compiled data from the records of regulatory agencies in Louisiana and Texas. They found that the total volume of produced waters permitted to be discharged to Texas waters as of November 23, 1987 was 823,575 bbl/day. Of that total, some 735,854 bbl/day were permitted to be discharged into Texas coastal waters (inclusive of the 9-mile territorial limit), and of that total 721,745 bbl/day were permitted for Texas estuarine waters (which included some discharge points more inland that flow into tertiary bays or streams that empty into tertiary bays. For the CCBNEP study area, the breakdown of discharge amounts were as given below. The columns labeled Percent of Total Volume, Coastal Volume, and Estuarine Volume give the proportion that the permitted discharge made up of the totals given above, respectively. The Galveston-Trinity Bay system had the largest proportions of any Texas coastal area while the Matagorda - Lavaca Bay system had the second largest. The Corpus Christi-Nueces Bay system was third, and for this area most of the produced water (54 discharge points totaling 65,650 bbl/day or 2.76 MG/day) were permitted to be discharged to Nueces Bay or the Nueces River. Produced water discharges to the Laguna Madre were primarily via tributaries to Alazan Bay, an arm of Baffin Bay. Until January 1987, there were 12 permitted discharge points into Petronilla Creek (5,770 bbl/day) and 24 permitted discharge points into Tunas Creek (11,390 bbl/day). In January 1987, all discharges upstream of SH 70 where it crosses Petronilla Creek were stopped by the TRC, and the TRC allowed a single discharge to remain downstream of SH 70 in the tidal portion of Petronilla Creek. The total produced water discharge permitted to the Study Area was 102,500 bbl/day (4.3 MG/day) (1,571.3 MG/yr).

Area	No. Not Active	No. Active	Vol. Perm. (bbl/day)	Percent of Total Volume (%)	Percent of Coastal Volume (%)	Percent of Estuarine Volume (%)
Aransas-Copano	38	47	9,007	1	1	1
Corpus Christi-Nueces	84	79	70,010	8	10	10
Laguna Madre	140	95	23,483	3	3	3

Caudle (1993) examined the produced water discharges into Nueces River and Bay further and found a total of 16 active (of the 33 permitted) produced water discharges releasing 15,584 bbl/day (0.65 MG/day) of brine water. The average flow of each discharge was 28.41 gpm (std. dev. = 31.5 gpm, range 0.33 gpm to 100 gpm). As part of this work, produced water was subjected to chemical analysis, and the following were found for constituents pertinent to this study. The TNRCC (1994) also reported that all sampled discharges were acutely toxic at 100 percent wastewater and 63 percent were acutely toxic at 30 percent dilution. Further, all samples were chronically toxic at 100 percent and 30 percent effluent dilutions, and 30 percent were chronically toxic at 3 percent dilution.

Parameter	Units	Mean	Std. Dev.	Range

Temperature	°C	28	6.2	22.7 - 45.0
pH	Std. Units	6.53	0.38	6.28 - 7.57
DO (mg/L)	mg/L	2.23	1.15	0.86 - 4.28
Conductivity	_mho/cm	107,656.3	29,869	41,600 - 136,400
Salinity	ppt	73.1	20.3	26.7 - 93.0
Chloride	mg/L	42,731.3	12,137.9	22,000 - 61,000
Nitrogen (NH_3+NO_3+NO_2)	mg/L	12.8		
TSS	mg/L	42.9	51.2`	13 - 223
TOC	mg/L	96.1	128.1	5 - 398
Oil & Grease	mg/L	37.0	40.9	1 - 162

2.3.4 Spills

Information on spills has been confined to recent years in which the volumes and types of materials spilled have been more reliably recorded and reported. Thus, no historical data are presented here.

Table 2.1 - Estimates of Municipal and Industrial Wastewater Discharges by County (circa 1970 by Malina 1970)

Corpus Christi Bay National Estuary Program
Point Source Load Characterization Project

Municipal Discharges

County	No. Of Disch.	Estimated Flow (MGD)	BOD_5 (lbs/day)	Suspended Solids (lbs/day)	Phosphates (lbs/day)
Aransas	3	1.39	564	867	71
Bee	3	1.30	314	240	366
Duval	3	0.50	200	218	15
Jim Wells	4	2.60	990	12,575	1,002
Kenedy					
Kleberg	3	2.10	685	633	214
Live Oak	2	0.55	102	274	59
McMullen					
Nueces	12	28.5	11,825	5,980	5,815
Refugio	4	0.86	476	664	199
San Patricio	7	3.34	1,753	2,373	915
Totals	41	41.14	16,909	23,824	8,656
5 Co. Totals	29	36.19	15,303	10,517	7,214

Industrial Discharges

County	No. Of Disch.	Estimated Flow (MGD)	BOD_5 (lbs/day)	Suspended Solids (lbs/day)	COD (lbs/day)
Aransas					
Bee	2	0.2	350	856	1,401
Duval	1				
Jim Wells	1	0.09	66	55	162
Kenedy					
Kleberg	1				
Live Oak	2	0.12	2		
McMullen	1	0.07	1	60	11,885
Nueces	19	196.83	65,106	76,935	934,978
Refugio	1	0.04	1	4	5
San Patricio	3	0.3	24	35	495
Totals	31	197.65	65,550	77,945	948,926
5 Co. Totals	24	197.17	65,131	76,974	947,363

Total of Dischargers

Source: Malina (1970)

2.2 - Annual Pollutant Discharges by Major Source Category and Percent of Annual Total Discharge to Ara Bay (1987)

ource Load Characterization Project
Christi Bay National Estuary Program

tem/Constituent	Units	WWTP	Industry	Power Plants	Total
r of Facilities	No.	16	18	0	34
	%	47%	53%	0%	100%
low	10^9 gal/yr	2	<1	0	2
	%	100%	<1	0%	100%
Flow	10^9 gal/yr	2	<1	0	2
	%	100%	<1	0%	100%
	10^3 lbs/yr	187	6	0	193
	%	97%	3%	0%	100%
	kg/yr	84,807	2,721	0	87,528
uspended Solids	10^3 lbs/yr	282	5	0	287
	%	98%	2%	0%	100%
	kg/yr	127,891	2,268	0	130,159
itrogen	10^3 lbs/yr	191	2	0	193
	%	99%	1%	0%	100%
	kg/yr	86,621	907	0	87,528
hosphorus	10^3 lbs/yr	119	1	0	120
	%	99%	1%	0%	100%
	kg/yr	54	0	0	54
oliform Bacteria	10^9 col./yr	15,475	148	0	15,623
	%	99%	1%	0%	100%
c	10 lbs/yr	55	<1	0	55
	%	100%	<1	0%	100%
	kg/yr	249	<1	0	249
um	10 lbs/yr	19	<1	0	19
	%	100%	<1	0%	100%
	kg/yr	86	<1	0	86
ium	10 lbs/yr	73	1	0	74
	%	99%	1%	0%	100%
	kg/yr	331	5	0	336
	10 lbs/yr	63	1	0	64
	%	98%	2%	0%	100%
	kg/yr	286	5	0	290
	10 lbs/yr	1,194	11	0	1,205
	%	99%	1%	0%	100%
	kg/yr	5,415	50	0	5,465
	10 lbs/yr	76	1	0	77
	%	99%	1%	0%	100%

: Pacheco et al. (1990)

2.3 - Annual Pollutant Discharges by Major Source Category and Percent of Annual Total Discharge to Cor Christi Bay (1987)

ource Load Characterization Project
Christi Bay National Estuary Program

tem/Constituent	Units	WWTP	Industry	Power Plants	Total
r of Facilities	No.	21	31	2	54
	%	39%	57%	4%	100%
low	10^9 gal/yr	11	9	143	163
	%	7%	6%	88%	100%
s Flow	10^9 gal/yr	11	8	0	19
	%	58%	42%	0%	100%
	10^3 lbs/yr	1,172	391	0	1,563
	%	75%	25%	0%	100%
	kg/yr	531,519	177,324	0	708,844
uspended Solids	10^3 lbs/yr	656	655	17	1,328
	%	49%	49%	1%	100%
	kg/yr	297,506	297,052	7,710	602,268
itrogen	10^3 lbs/yr	1,071	313	0	1,384
	%	77%	23%	0%	100%
	kg/yr	485,714	141,950	0	627,664
hosphorus	10^3 lbs/yr	669	33	0	702
	%	95%	5%	0%	100%
	kg/yr	303	15	0	318
oliform Bacteria	10^9 col./yr	86,733	4,490	0	91,223
	%	95%	5%	0%	100%
c	10 lbs/yr	309	154	0	463
	%	67%	33%	0%	100%
	kg/yr	1,401	70	0	1,471
um	10 lbs/yr	108	123	0	231
	%	47%	53%	0%	100%
	kg/yr	490	56	0	546
ium	10 lbs/yr	410	228	0	638
	%	64%	36%	0%	100%
	kg/yr	1,859	1,034	0	2,893
	10 lbs/yr	356	336	239	931
	%	38%	36%	26%	100%
	kg/yr	1,615	1,524	1,084	4,222
	10 lbs/yr	6,692	598	0	7,290
	%	92%	8%	0%	100%
	kg/yr	30,349	2,712	0	33,061
	10 lbs/yr	427	68	0	495
	%	86%	14%	0%	100%

: Pacheco et al. (1990)

2.4 - Annual Pollutant Discharges by Major Source Category and Percent of Annual Total Discharge to Lag Madre (1987)

ource Load Characterization Project
Christi Bay National Estuary Program

tem/Constituent	Units	WWTP	Industry	Power Plants	Total
r of Facilities	No.	2	1	0	3
	%	67%	33%	0%	100%
low	10^9 gal/yr	1	0	0	1
	%	68%	32%	0%	100%
s Flow	10^9 gal/yr	1	0	0	1
	%	68%	32%	0%	100%
	10^3 lbs/yr	46	32	0	78
	%	59%	41%	0%	100%
	kg/yr	20,907	14,649	0	35,556
uspended Solids	10^3 lbs/yr	68	52	274	393
	%	17%	13%	70%	100%
	kg/yr	30,612	23,356	124,263	178,231
litrogen	10^3 lbs/yr	72	0	0	72
	%	100%	0%	0%	100%
	kg/yr	32,698	0	0	32,698
hosphorus	10^3 lbs/yr	45	0	9	54
	%	83%	0%	17%	100%
	kg/yr	20	0	4	24
Coliform Bacteria	10^9 col./yr	5,836	0	0	5,836
	%	100%	0%	0%	100%
c	10 lbs/yr	21	0	0	21
	%	100%	0%	0%	100%
	kg/yr	94	0	0	94
um	10 lbs/yr	7	0	0	7
	%	100%	0%	0%	100%
	kg/yr	33	0	0	33
ium	10 lbs/yr	28	20	2	50
	%	55%	41%	4%	100%
	kg/yr	125	93	9	227
	10 lbs/yr	24	13	1	38
	%	63%	35%	3%	100%
	kg/yr	109	60	5	173
	10 lbs/yr	450	0	0	450
	%	100%	0%	0%	100%
	kg/yr	2,042	0	0	2,042
	10 lbs/yr	29	0	0	29
	%	100%	0%	0%	100%

: Pacheco et al. (1990)

2.5 - Annual Pollutant Discharges by Major Source Category and Percent of Annual Total Discharge into th
Study Area (1987)

ource Load Characterization Project
Christi Bay National Estuary Program

tem/Constituent	Units	WWTP	Industry	Power Plants	Total
r of Facilities	No.	39	50	2	91
	%	43%	55%	2%	100%
low	10^9 gal/yr	14	9	143	166
	%	8%	6%	86%	100%
s Flow	10^9 gal/yr	14	8	0	22
	%	62%	38%	0%	100%
	10^3 lbs/yr	1,405	429	0	1,834
	%	77%	23%	0%	100%
	kg/yr	637,234	194,694	0	831,927
uspended Solids	10^3 lbs/yr	1,006	712	291	2,008
	%	50%	35%	14%	100%
	kg/yr	456,009	322,676	131,973	910,658
litrogen	10^3 lbs/yr	1,334	315	0	1,649
	%	81%	19%	0%	100%
	kg/yr	605,034	142,857	0	747,891
hosphorus	10^3 lbs/yr	178	5	9	192
	%	93%	3%	5%	100%
	kg/yr	80,545	2,256	4,082	86,883
oliform Bacteria	10^9 col./yr	108,044	4,638	0	112,682
	%	96%	4%	0%	100%
c	10 lbs/yr	385	154	0	539
	%	71%	29%	0%	100%
	kg/yr	1,745	69,841	0	71,586
um	10 lbs/yr	134	123	0	257
	%	52%	48%	0%	100%
	kg/yr	609	55,782	0	56,391
ium	10 lbs/yr	511	249	2	762
	%	67%	33%	0%	100%
	kg/yr	2,316	113,107	9	115,431
	10 lbs/yr	443	350	240	1,033
	%	43%	34%	23%	100%
	kg/yr	2,009	158,821	1,088	161,918
	10 lbs/yr	8,336	609	0	8,945
	%	93%	7%	0%	100%
	kg/yr	37,806	276,190	0	313,997
	10 lbs/yr	532	69	0	601
	%	89%	11%	0%	100%

: Pacheco et al. (1990)

Table 2.6 - Estimates of Salt Brine Discharges and Disposal Method by County in the Corpus Christi Bay Area (circa 1961)

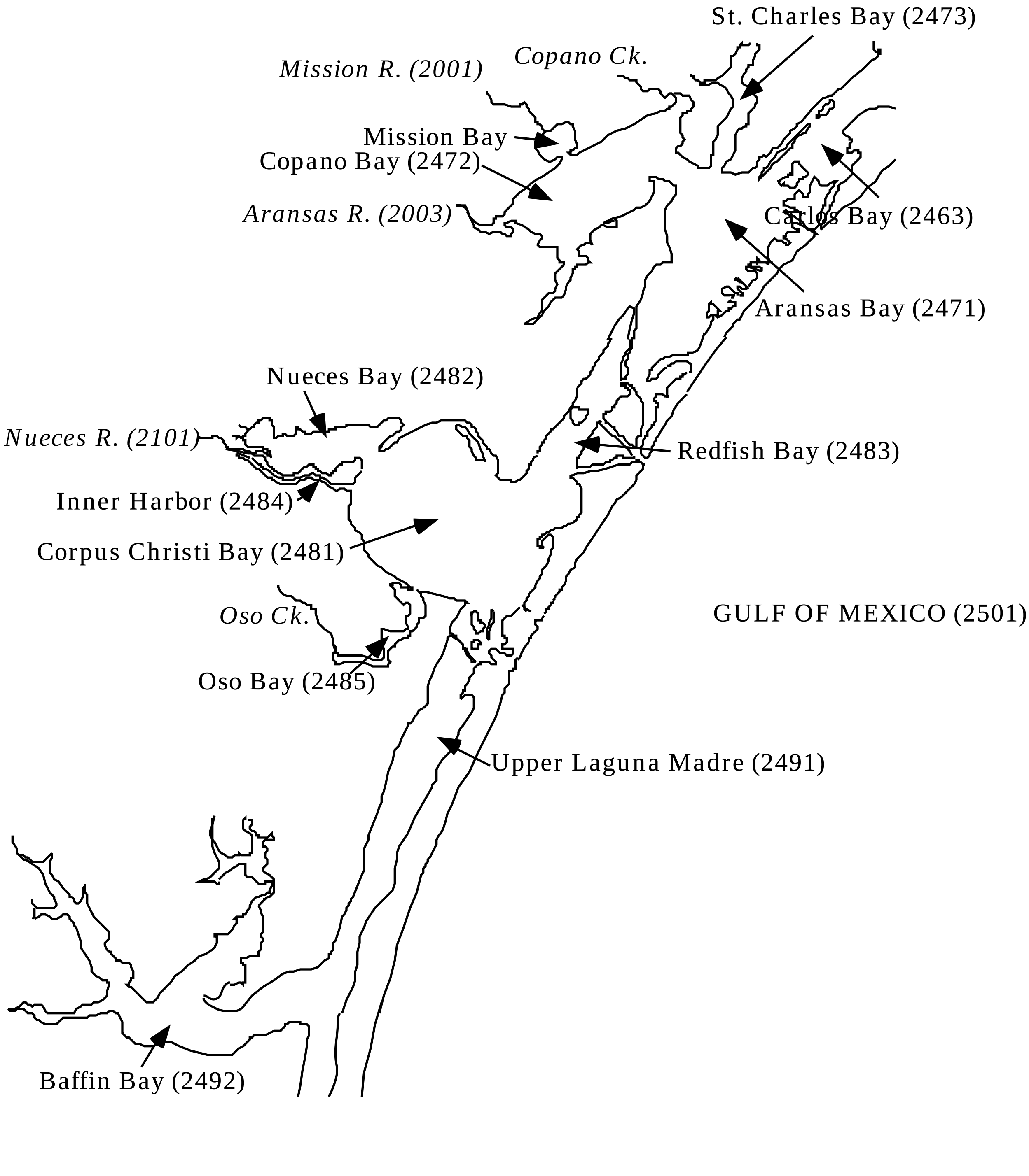
Point Source Load Characterization Project
Corpus Christi Bay National Estuary Program

County	Total Flow (MGD)	Injection Wells (MGD)	Open Pits (MGD)	Surface Water (MGD)	Other (MGD)
Aransas	0.44		0.20	0.24	
Bee	0.74	0.43	0.31		<0.01
Duval	7.31	5.19	2.06		0.06
Jim Wells	0.62	0.30	0.32		<0.01
Kenedy	0.02	0.01		<0.01	
Kleberg	0.21		0.19	0.02	<0.01
Live Oak	0.27	0.01	0.26		<0.01
McMullen	0.60		0.60		
Nueces	6.04	1.40	1.98	2.64	0.02
Refugio	5.21	2.68	1.54	0.99	
San Patricio	11.10	0.88	2.93	7.27	0.02
Totals	32.56	10.02	7.46	3.9	0.12

Source: Malina (1970)

Figure 2.1 - Corpus Christi Bay system with bays, tributaries, and water quality segments (Segment Numbers in parentheses)

Point Source Characterization Project
Corpus Christi Bay National Estuary Project



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CHAPTER 3

METHODS FOR ESTIMATING LOADS

3.1 INTRODUCTION

The overall objective of this study was to characterize the current status and spatial and temporal trends in permitted and nonpermitted point source loadings of constituents into the Corpus Christi Bay system, and to that end the following steps were followed: (1) research and compile long-term point source loadings data; (2) determine data gaps and the reliability of loading data sets; (3) describe existing permitted point source loading and historical (temporal) trends; (4) determine spatial loading trends; and (5) determine cumulative loadings and identify potential problem areas.

The first step in compiling the long-term loading data set was to determine all of the potential sources of data. The sources from which point source loading data were most readily available were those listed in the Contract Scope of Services, namely: TNRCC (permits, waste load evaluations, and self-reporting data sections); EPA (Permits Compliance System, Emergency Response Notification System or ERNS); the Texas Railroad Commission (TRC), and the Toxics Residuals Inventory (TRI).

3.2 SELF REPORTING DATA

3.2.1 TEXAS NATURAL RESOURCE CONSERVATION COMMISSION DATA

3.2.1.1 Data Acquisition

The self-reporting data for permitted point sources were obtained in a form suitable for analysis. The period covered by the data was from 1976 through 1995. The data were provided by the Commission on floppy discs; they were transferred to hard disk storage on Macintosh personal computers at The University of Texas at Austin for manipulation. Other information pertinent to an understanding of the nature, location (longitude and latitude or other similar identification of specific location), magnitude of and potential problems caused by the discharge was compiled through examination of permit files at Central Records of TNRCC, through further documents, or through conversations with them.

As provided on the floppy discs, the data were in ASCII format and in a format like the hard copy printouts normally provided by TNRCC (see Figure 3.1). This format was different than that used by the TNRCC a few years ago because a new program had been written to store and retrieve self reporting data. For each discharger represented on the floppy discs, three types of information were provided. The first type consisted of information about the discharger (permit number, facility name, etc.), the second was the permitted discharge information (i.e., loads or concentrations that were permitted to be discharged), while the third was the self reporting data (i.e., what was reported by each discharger to the TNRCC on a monthly basis generally). For each constituent, permitted and reported values were provided for each month of each year. Information on all three types needed to be extracted for subsequent analysis.

3.2.1.2 Data Stripping

Extraction of data from the downloaded files was achieved with a program written in QuickBASIC. With this program, sequential records (lines) of the ASCII files were read as strings, checks made to ascertain the precise location of the string within the three groups of information noted above, and particular pieces of information or data were extracted from each string for storage in separate ASCII files. The Commission had supplied the self-reporting data in files of data which corresponded to groups of years, usually five, and that number of year's worth of data were processed at one time.

Because the Commission had changed its format for storing self reporting data since the authors processed similar data for the Galveston Bay National Estuary Program point source loads estimates (Armstrong and Ward, 1994), the programs written to process the Galveston Bay data had to be rewritten for the new format. The extraction process was made especially challenging by the variable lengths of the permit files for each discharger. Many files would contain information that would fill no more than one page on the TNRCC printouts, and those were easiest to process; others continued for many pages and the ultimate length of each file was determined by how many constituents the discharger had to report.

Each page of data (see Figure 3.1 for an example) contained the permittee's name, permit numbers (TNRCC and EPA), facility name, an extension number, location (by segment number, county, and river basin). These particular pieces of information were removed and stored in an ASCII file marked for permit information only (see Figure 3.2). Also on each page were data for permitted discharge of flow and particular constituents as well as notes on sampling frequency and sample type, and these data were extracted and stored in a second ASCII file (see Figure 3.3) linked to the TNRCC permit number. This latter file would permit later comparison of permitted discharge amounts (as mass/day) and concentrations against actual self-reported discharge amounts so that possible problem areas could be noted. The third ASCII file created from this data stripping process was filled with the self-reporting data (see Figure 3.4). Constituent parameter code, value (load and/or concentration), type of sampling, and excursion data were stored in this file by permit number for subsequent calculation of loading to the Bay.

3.2.1.3 Database Creation

The data processed, extracted, and stored in ASCII files as described above were entered into a dBASE IV computer-manipulable database. Three database files were created for each year: one for the permit information about the discharger (CCPERM*YY*); one for the permitted discharge information (CCPERD*YY*); and a third for the self-reporting data (CCSELF*YY*). *YY* in each name represents the year of the data (e.g., 95 for 1995). The size of these files depended on the number of permitted dischargers and the amount of self-reporting data obviously, and the three totaled just under 10 megabytes for 1995 data and slightly lesser amounts for earlier years with fewer permitted discharges. A listing of permitted dischargers to the Corpus Christi Bay system in 1995 is given in Appendix A.

In dBASE IV database form, these data could be manipulated and processed in different ways to extract desired data, calculate loads for the water quality segments given in Table 3.1 and the constituents given in Table 3.2 and create files to be used for tabular and graphical presentations. The specific database structures of these files are described in Appendix B.

3.2.1.4 Data Extraction

As it was desired to estimate loadings of constituents contained in the self-reporting database, the databases created had to be queried for various types of retrievals such as permitted discharger lists, loading data aggregated by water quality segment and by year, etc. The constituents in the self-reporting database were extracted first from the permitted data file and a final list created. For the 1995 data, the list contained over 260 entries indicating the variety of constituents being sampled and various forms of constituents being reported. The parameter codes used by the TNRCC in self-reporting data consist of a five digit prefix and a four digit suffix. The prefix was the parameter code for the constituent which in this case corresponded to the EPA STORET number, and the suffix was a numerical code representing the particular units of the parameter. For example, the STORET code for Rate of Flow was 50050 and the code corresponding to reporting units of 30-d Average (MGD) was 7124; thus, the whole parameter code used in the self-reporting data for 30-d average flow in units of MGD was 500507124. The other flow unit used was Daily Max (MGD) with a 7150 suffix. Constituent units could be reported as Daily or 30-d Avg (mg/L), Indiv. Grab (mg/L), Daily Max. (mg/L), 24-hr Comp. (mg/L), Max (mg/L), Min. Grab (mg/L), Indiv. Grab (mg/L), Indiv. Grab (mg/kg), Daily or 30-d Avg (lbs/d), Daily Annual Avg (lbs/d), Daily Max (lbs/d), and Max (lbs/d). Obviously, a wide variety of reporting possibilities existed for most constituents, and consideration of such forms had to be taken into account when processing the data for load estimation. A listing of these constituents, their STORET numbers, and the four-digit extensions used the TNRCC for identifying different report units is given in Table 3.3.

The Scope of Services called for 15 water quality segments to be used in the data analysis and for the constituents being discharged to be aggregated by segment. To achieve this type of analysis, several programs were written in dBASE IV language to query the databases, extract the desired information, and to write files that could be transferred to the spreadsheet program Excel on the Macintosh computer for final processing.

3.2.1.5 Loading Estimates

Loadings and other analyses were to be done on self-reporting data from dischargers to the 15 water segments listed in Table 3.1 and for the constituents listed in Table 3.2. Because the groupings of some of the constituents listed in Table 3.2 actually included a number of individual chemicals, the final list was simply the constituents monitored by dischargers through self-reporting.

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, loading estimates based on self-reporting data alone would by definition be inaccurate for they would fail to reflect pollutants being discharged but just not reported. To correct this deficiency, the procedures outlined in a NOAA report on waste loading estimates (Pacheco et al. 1990) to calculate loads for those constituents were used. This report was produced by the National Coastal Pollutant Discharge Inventory Program (NCPDI) within NOAA. Such estimates relied on knowing the SIC codes for the dischargers and being able to relate the SIC codes to a typical pollutant concentration for each code for a number of constituents, primarily conventional pollutants and metals. The origin of the typical pollutant concentrations or TPCs was described by Pacheco et al. (1990) as

> These TPC values in the matrix are drawn primarily from the EPA's Development Documents for Effluent Limitations, Guidelines, and Standards. These documents were produced as part of the EPA's process of determining effluent guidelines for direct discharging point sources. Each document contains a profile of the manufacturing processes and effluent characteristics of each major industrial category. The effluent characteristics in the document are based on monitoring studies conducted at a representative sample of facilities engaged in the industrial activity. The monitoring studies were conducted between the mid-1970s and the mid-1980s, depending on the industrial category. Thus, some of the values are dated. It is important to understand that the values represent average end-of-pipe discharge concentrations after the treatment technologies typically used by the industry have been applied. Thus, the concentrations are an approximation of the pollutant discharge of a typical plant, and are not equivalent to the federal effluent guidelines for the industrial category.

Pacheco et al. (1990) grouped the SIC codes into 88 discharge categories similar to those used by the EPA to group facilities having similar industrial activities for the effluent guidelines development process. These 88 categories and the TPCs used for each are given in Table 3.4, and the correspondence of SIC category to each category is given in Appendix C. It should be noted that the TPCs for mercury given in Pacheco et al. (1990) were listed with incorrect units; the units should have been _g/L instead of mg/L. In addition, the mercury concentrations given for residential wastes and municipal wastewater dischargers were 1,000 times too small. Fecal coliform concentration units were also given as colonies/L but should have been colonies/100 mL (Pacheco 1993). These corrections were made to the tables used in this study.

SIC information for each discharger as well as information on the source of the wastewater from within each discharger were obtained from the TNRCC permit files. The Source of Wastewater Codes (see Table 3.5) used by the TNRCC to describe the origin of wastewater within a discharger did not match the three main sources (municipal wastewater, process wastewater, and cooling water) used by Pacheco et al. (1990). They did, however, allow a more exact matching of TPCs in process wastewaters discharged by industry. Upon manually entering this TNRCC information into the database, it was found that as many as three SIC codes and five or more Source of Wastewater Codes were listed for some dischargers effluents (individual pipes really).

The multiple SIC codes for a given discharger meant that the effluent stream from that discharger contained waste constituents typical of each of those SIC code types, and the multiple Source of Wastewater Codes meant that wastes from each of those types of operations were contained in that single waste stream. Unfortunately, there was no way to assign fractions of the discharge to SIC codes nor Source of Wastewater Codes. Thus, deciding which single codes to use for each pipe was an early decision to be made, but, understanding that the first SIC code and the first Source of Wastewater Code listed indicated the major type of discharger and major source of the wastewater, respectively, those first listed codes were used as the only codes to use. Using the first Source of Wastewater Code and ignoring any others had an undetermined effect on estimated loadings. Conceivably, estimated loadings could have increased or decreased had it been possible to assign exact portions of the waste discharge to particular codes. One of the 1995 38 permitted municipal discharges had multiple source codes, so they were confined mostly to the 31 permitted industrial dischargers. Considering only the municipal and industrial process waste discharges, those with single or multiple source codes were as follows:

Number of Source of Wastewater Codes	Proportion of 1995 Permitted Industrial Process Discharges Having Indicated Number of Source Codes (%)	Proportion of Total 1995 Permitted Dischargers Having Indicated Number of Source Codes (%)
1	39	71
2	16	9
3	10	4
4	22	10
5 or more	13	6

Thus, 71 percent of all municipal and industrial dischargers were characterized by one source code and 78 percent were characterized by two. The remaining 22 percent had from three to five or more source codes. For 71 percent of the permitted point source dischargers to Corpus Christi Bay, however, the source code described the discharge completely. The impact on loading estimates of making assuming the first source code represented fully the type of waste discharge for the other 29 percent is not known. A listing of each discharger included in the waste loading estimates, their SIC codes, and their Source of Wastewater Codes are given in Appendix A.

With a single SIC code and single Source of Wastewater Code assigned to each pipe, the Source of Wastewater Codes were matched with the 88 NCPDI categories of TPCs that Pacheco et al. (1990) had developed from EPA effluent limit development documents from the 1970s and early 1980s. 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 TPCs were multiplied by actual discharge flows calculated from the self-reporting data in the database to get loads for each discharger. This step was complicated a bit by the fact that the some flow data had been entered into the Commission's self-reporting database in error. Some monthly flows, for example, were 100,000 times what they should have been. For municipal dischargers, such flow discrepancies were relatively easy to discover because of the regularity of flow, but for industrial dischargers they were not.

Because third round permitting in which more stringent effluent limits on metals and complex organics has been essentially completed, the updated TPCs used by Armstrong and Ward (1994) in the Galveston Bay National Estuary Program point source loadings study were used here. A procedure used by the TNRCC (and based on procedures described in EPA's 1991 "Toxic Support Document for Water Quality-based Toxics Control") to estimate effluent limits for metals was incorporated. In this methodology (TWC 1992), the Commission determines an allowable long term average effluent concentration for a metal based on the likelihood of the discharge of that metal causing water quality standards for the protection of aquatic life and human health in the receiving water to be violated. A skewed (to the right) distribution of concentrations in the effluent is assumed, the long term average concentration of the constituent in the effluent (which becomes the effluent limit concentration) is related through the coefficient of variation to a waste load allocation concentration based on a waste load allocation in the effluent. This waste load allocation concentration is determined by calculating what the metal concentration could be in the effluent after dilution so that the receiving water standard is not exceeded. The methods for determining these concentrations is fully described in Armstrong and Ward (1993) and resulted in a set of updated TPC values were applied here to waste load estimates for 1986, 1990, and 1995. Thus, the original Pacheco et al. (1990) TPCs were used for the 1980 load estimates while the updated TPCs, given in Table 3.6 were used for 1986, 1990, and 1995.

For 1980 constituent load estimates, municipal and industrial treatment plants for sanitary wastes were assumed to be treating at a level indicative of secondary treatment with activated sludge. For 1986, 1990, and 1995 constituent load estimates, tertiary treatment was assumed to lower the BOD_5 and TSS concentrations down to levels that were being achieved.

Once discharge loads were estimated using actual self-reporting data or using the TPCs multiplied by actual monthly flows, there was a need to modify these loads if it could be shown that the TPCs used in the Pacheco et al. (1990) report were not representative of dischargers in the Corpus Christi Bay area. Thus, the next step was to determine if possible how the load estimates based on TPCs compared to those based on self-reporting. For those constituents like BOD, TSS, Oil and Grease, and some metals for which actual reported loads and estimated loads were available for individual dischargers, a comparison was made of the two so that the estimated loads could be corrected for all dischargers if a correction was needed. Municipal and industrial dischargers were examined separately. These comparisons were performed for the 1980 and 1995 data. For BOD_5 and TSS loadings from municipal discharges in 1980, the estimated loads were almost always lower than those actually reported indicating that the typical BOD_5 and TSS concentrations for the municipalities represented in the Corpus Christi Bay area were too low and did not represent current treatment practice. There were inadequate data to calculate any ratios for any constituents other than BOD_5 and TSS for municipal dischargers, and, even for some industrial discharges, the number of dischargers reporting some metals was so few that the ratio for those metals could not be determined directly. For 1995, the estimated loads for BOD_5 and TSS were much closer to those reported. Thus, the use of BOD_5 and TSS concentrations for tertiary treated effluents represented 1995 practice satisfactorily.

The final tables of loading estimates produced using this methodology show load estimates for individual dischargers within the 15 water quality segments and arranged to list loads estimated and reported for both municipal and industrial dischargers. Thus, it was possible to determine how much of the load from each discharger for any given constituent was estimated and how much was based on self-reporting data. These individual loads were summed within each water quality segment to give a segment total again broken down by estimated and reported. An example of the Excel summary table produced after these manipulations is given in Table 3.7.

3.2.2 EPA PERMIT COMPLIANCE SYSTEM DATA

To complement the TNRCC self-reporting data and the loads estimated from that database, self-reporting data were also obtained from the U.S. Environmental Protection Agency's Permit Compliance System. Self-reporting data for the 1995 calendar year were requested for Aransas, Bee, Duval, Jim Wells, Kenedy, Kleberg, Live Oak, McMullen, Nueces, Refugio, and San Patricio Counties from the EPA Region VI Office in Dallas, TX.

The data were delivered in compressed files via the Internet and in fixed field ASCII format. From the format, the data were uploaded to Excel spreadsheets by parsing the data using the fixed field lengths, sorted by constituent name, and STORET codes added to further identify the constituents. Individual spreadsheets were then created for each of the constituents for which discharge loadings had been estimated using the TNRCC self-reporting data and the TPCs. Then, within each constituent spreadsheet, the records were sorted by discharger using EPA permit numbers and by date. In this final format, it was then possible to estimate annual loadings for each discharger and for each constituent, where there was adequate data to perform the loading estimate.

To calculate annual loadings, the monthly average loads (given in lbs/day), which were listed for each of 12 months usually, were summed and multiplied by 365 days/12 months or 30.42 to obtain the annual load (in lbs/year). The more accurate method would have been, of course, to multiply each month's average load value by the number of days in the month and then total those values, but at this point the PCS data were being used to check the TNRCC self-reporting data primarily rather than provide new data. For those months in which less than 12 months of load estimates were provided, the data available were summed and extrapolated to 12 months to obtain an annual load. Also, for those constituents for which concentration only data were provided, the concentrations were averaged and multiplied by the average daily flow (from TNRCC self-reporting data) to obtain an annual load estimate (after time conversions). These results were then compared to load estimates calculated from TNRCC data.

3.2.3 EPA TOXIC RELEASE INVENTORY DATA

EPA Toxic Release Inventory data for 1995 were downloaded from the EPA Web page. All of the data for Texas were downloaded in .DBF format from the Web then uploaded into a FileMaker Pro database. Some 5,700 records were in this database. From this database, some 255 records that pertained to those counties in the study area were exported into a separate database. These records were then sorted by chemical name and EPA permit NPDES number, and a STORET code added to further identify the constituents. Finally, the annual load value given for discharges to surface water were extracted for each discharger and compared to TNRCC load estimates; discharger matches were made by EPA NPDES permit number.

3.3 SPATIAL AND TEMPORAL CHANGES IN LOADING

Loading estimates for each constituent from municipal and industrial dischargers were calculated for the 15 water segments for five year intervals, i.e., 1980, 1986, 1990, and 1995. The year 1986 was used because it was discovered late that the 1985 data set was incomplete. With these load estimates, temporal changes from the earlier estimates of 1961 to 1995 could be made. In addition, the spatial distributions of these loads and their change over time could also be ascertained.

3.4 BRINE WATER DISCHARGES

Data to estimate brine water discharges were obtained from the Texas Railroad Commission in March 1996. For permitted discharges, the Commission supplied information in two broad categories - active and inactive, and for each of those categories - inland and tidal. Permit information included for each discharger were the permit number, operator name, location (county, longitude and latitude, general area, TRC map number, and State Block), reliability of latitude/longitude values, original volume (flow) permitted, and volume (flow) as of a recent date. In addition, some constituent data were available for general parameters (e.g., temperature, pH, dissolved oxygen, total dissolved solids, total suspended solids, total organic carbon, oil and grease, ten inorganic ions, phenols, and naphthalene) and for toxic pollutants (e.g., aluminum, arsenic, barium, benzene, cadmium, chromium, copper, cyanide, lead, mercury, nickel, selenium, silver, and zinc).

Permit information was keyboarded into an Excel spreadsheet while the current flow and constituent data were placed in a second so that constituent loading could be more easily calculated. The data actually provided for each discharger were rather spotty.

3.5 SPILLS

Spill information was obtained from the U.S. Environmental Protection Agency's Emergency Response Notification System (ERNS) which provides such data at its World Wide Web site at the following URL: http://earth1.epa.gov//ERNS/. The database available is quite extensive and covers the U.S. coastline, specific harbors, and more. There are multiple sources of data for this spill database including EPA Regions and the U.S. Coast Guard. There are also several caveats of which users of the information must be aware, namely: completeness and accuracy of the data (the data usually represent initial accounts of releases and are usually not updated unless an EPA region is involved in the response action); multiple notifications (multiple notifications of some releases may exist because of multiple sources of information); data updates (data are updated in time); and data entry errors (data inconsistencies may occur because of keyboarding errors). Finally, the database includes records from 1987 to the present.

This database was queried for any spills that occurred in the Study Area, and the results of that query were downloaded for possible loading analysis.

3.6 DATA RELIABILITY AND DATA GAPS

The reliability of loading data sets was determined by reviewing, where available, the Quality Assurance/Quality Control procedures used to sample and analyze samples, to check for internal quality control, and to manage data. Guidance for this process was obtained from the "Guide for Preparation of Quality Assurance Project Plans for the National Estuary Program Quality Assurance Plan". For self-reporting data for permitted point sources, the QA/QC procedures required by the Commission and the U.S. Environmental Protection Agency were assumed be those used by dischargers. For data sets for which no QA/QC procedures are obvious, contacts with the source agency were initiated to collect that information. Using the information gathered about QA/QC procedures for each data source, the data were screened to flag those considered unreliable so they could be deleted from further use in estimating waste loadings.

Temporal and spatial gaps in the data that might impede an appraisal of temporal and spatial trends in water and sediment quality were noted. For the long-term period of analysis, significant gaps in priority pollutant loading information were noticeable.

In addition to identifying gaps in data, deficiencies in existing field and laboratory monitoring methodology which impeded the use of monitoring data for trend analysis were also noted. It was anticipated that most of these deficiencies dealt with analytical problems in extracting the constituent to be measured from the matrix in which it existed in the sample, as well as the detection capabilities of the instruments used to do the field and/or laboratory analysis.

A report by Battelle Ocean Services (1991) points out the difficulties in measuring trace metal concentrations in ambient waters and wastewater discharges. Examining metals concentrations in the New York City area wastewater discharges and in New York harbor waters, Battelle found overall poor comparability among laboratories analyzing samples from both media. Potential interferences and contamination were not identified, and the study concluded that much of the historical data were likely to overestimate trace metal concentrations in the water column of New York harbor. Similar concerns were raised for municipal wastewater discharges, particularly those containing low but variable levels of salt (which will be most because of the combined sewer system in New York and how it operates). There is a potential that such overestimates of metals concentrations in wastewater discharges to Corpus Christi Bay have also resulted.

Table 3.1 - Texas Natural Resource Conservation Commission Water Quality Segments Used to Aggregate Point Source Loading Estimates

Point Source Characterization Project
Corpus Christi Bay National Estuary Program

Basin	Segment Number	Segment Name
San Antonio-Nueces Coastal Basin		
	2001	Mission River Tidal (from the confluence with Mission Bay in Refugio County to a point 7.4 km (4.6 mi) downstream of US 77 in Refugio County)
	2003	Aransas River Tidal (from the confluence with Copano Bay in Aransas/Refugio County to a point 5.3 km (3.3 mi) upstream of Chiltipin Creek in Refugio/San Patricio County)
	2463	Mesquite Bay/Carlos Bay/Ayres Bay
	2471	Aransas Bay
	2472	Copano Bay/ Port Bay/ Mission Bay
	2473	St. Charles Bay
Nueces River Basin		
	2101	Nueces River Tidal (from the confluence with Nueces Bay in Nueces County to Calallen Dam 1.7 km (1.1 mi) upstream of US 77/IH 37 in Nueces/San Patricio County)
Corpus Christi Estuary		
	2481	Corpus Christi Bay
	2482	Nueces Bay
	2483	Redfish Bay
	2484	Corpus Christi Inner Harbor (from US 181 to Viola Turning Basin)
	2485	Oso Bay
Upper Laguna Madre		
	2491	Laguna Madre
	2492	Baffin Bay/ Alazan Bay/ Cayo del Grullo/ Laguna Salada
Gulf of Mexico		
	2501	Gulf of Mexico (surf zone to the northern and southern boundaries of the Study Area)

Table 3.2 - Water Quality Parameters Included in Point Source Loading Estimates

Point Source Characterization Project
Corpus Christi Bay National Estuary Program

1. Nutrients
    - Organic Carbon (as TOC)
    - Inorganic Carbon (as TIC)
    - Phosphorus (total and orthophosphorus, as available)
    - Nitrogen (total, organic, ammonia, nitrite, and nitrate, as available)

2. Biochemical Oxygen Demand (carbonaceous and nitrogenous, as available), Chemical Oxygen Demand, and Total Organic Carbon

3. Heavy Metals (total and dissolved)

4. Priority Pollutants, as reported

5. pH

6. Salinity/Conductivity/Total Dissolved Solids

7. Turbidity/Total Suspended Solids

8. Dissolved Oxygen

9. Fecal Coliforms

10. Chlorine Residual (total)

11. Flow

12. Occurrence of by-passes, overflows, and collection system discharges as documented by self-reporting data.

13. Thermal Wastes (i.e., power plant discharges in which temperature is of concern)