FINAL REPORT
POINT SOURCE LOADING CHARACTERIZATION OF GALVESTON BAY

EXECUTIVE SUMMARY

By

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NEED FOR PROJECT

Galveston Bay is the most important estuary on the Texas coast harboring the largest seaport, housing the largest industrial complex, and producing the largest shellfish catch on the Texas coast. 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 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-seventies, 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 (USEPA). 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). A comprehensive study of the bay system was initiated by state and federal agencies and spanned the years from 1966 to 1974. Following the study, several corrective measures helped to reduce the impact of municipal and industrial waste on Galveston Bay. 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. The EPA pointed out 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. For toxic materials in particular, two rather detailed loading analyses for permitted dischargers were performed by Neleigh (1974) and Goodman (1989) for point sources and for the Trinity and San Jacinto Rivers by Armstrong et al. (1977) and Goodman (1989). More reporting of toxic materials has being required since the period Goodman (1989) used to estimate toxic material loading to the Bay (i.e., 1985-87) and there are more dischargers now releasing a variety of conventional, nonconventional, and toxic pollutants to the Galveston Bay system. Thus, there was a need to update all of the loading estimates for constituents reaching Galveston Bay. As the goals of the 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 their causes, the determination of point source loading was a major step in characterizing one of the causes.

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 Galveston 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 and nonpermitted point source (major tributaries) loadings of constituents into the Galveston Bay system.

The overall and main objectives were accomplished through the following specific objectives: (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; (5) Determine cumulative loadings and identify potential problem areas; and (6) prepare a final report. 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 were available from the self-reporting data in the files of the Texas Natural Resource Conservation Commission (TNRCC). Compiling that information, calculating loads as necessary, and aggregating and presenting the loads by water quality 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 from USGS records, 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.

Brine discharge data were obtained from the Texas Railroad Commission and reported essentially as presented in the original data. Flows were converted from barrels per day to MG per year for compatibility with other discharge data presented herein.

Data reliability (Quality Assurance/Quality Control) and identification of data gaps (spatial and temporal) have been discussed.

PROJECT RESULTS

Estimation of point source loads of conventional, non-conventional, and priority pollutants to the Galveston 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 1990 calendar year, and it should be recognized that these loads have already changed and will continue to change as populations and industrial activities change in the Galveston Bay drainage area and as regulatory limits on what can be discharged become more stringent.

At the outset of this study, the definition of point source was considered to include permitted municipal wastewater discharges, industrial process wastewaters, cooling water discharges, and inflows from major tributaries (defined essentially as tributaries with USGS gauging stations or a reservoir spillway). Unpermitted wastewater discharges were not included, nor were permitted non-point sources. The discovery and identification of unpermitted wastewater discharges was within the scope of another GBNEP project as was the estimation of constituent loadings from non-point sources. Further, permitted municipal wastewater discharges, industrial process wastewaters, and cooling water discharges were considered to be those permitted by the Texas Water Commission (TWC) (now TNRCC). As noted by Pacheco et al. (1990), there were some dischargers permitted by the EPA that apparently were not by the TWC, and those not permitted by the TWC were considered to have little impact upon discharge. With regard to constituent loading, it was assumed that those dischargers permitted by the EPA but not by the TWC would produce very small loadings and thus not impact the loading picture. Even Pacheco et al. (1990), who included all dischargers permitted by the EPA in their load estimates, listed only dischargers permitted by both agencies in their report as the major dischargers and thereby support indirectly this assumption. However, for completeness, those EPA permitted dischargers not included in this study need to be considered in future load estimates.

Another assumption was that the typical pollutant concentrations (TPCs) taken from Pacheco et al. (1990) and modified in this study represented with some accuracy the concentrations of those constituents for which TPCs were available in the effluents of both municipal and industrial wastewaters. The cautions made by Pacheco et al. on the accuracy of the TPCs and the load estimates made from them (quoted earlier in this report) all speak to their tentative nature, and the reliance on local data for accurate load estimates must continue to be the goal of such efforts. The inaccuracy of some of the Pacheco et al. TPCs for BOD_5, TSS, total nitrogen, and the metals was shown in this study, and corrections were made in them to generate more accurate load estimates for those constituents. However, even more corrections to the TPCs for metals was shown to be needed by Travers (1993) who analyzed effluent metal concentration data gathered in a 1992 joint study by the EPA and the TWC involving a number of municipal and industrial dischargers in the Galveston Bay area. Reductions up to 90 plus percent for some of the Pacheco et al. (1990) metal TPCs were shown to be needed. Because these latter corrections to the TPCs could not be included in the metal load estimates contained in this report because of time constraints, the metal loads presented herein for municipal and industrial dischargers must be considered high.

Finally, the TPCs used herein represent only a small portion of the conventional, non-conventional, and priority pollutants which are now included in many NPDES permits. While many other priority pollutants are being monitored and reported to the TWC as part of self-reporting requirements, there are no TPCs for most of these constituents and consequently only a partial load can be calculated for them. The only way to insure a complete accounting for all of the conventional, non-conventional, and priority pollutants would be to require monitoring for them, but that would impose a substantial and probably unwarranted monitoring burden on dischargers. Other sources of data should be accessed first to make load estimates, and at least one of these sources is the very data used by the TWC and EPA to develop permit limits. These are the TWC and NPDES application forms for all permitted dischargers (Tischler, 1993). Every major industrial discharger is required to complete EPA Form 2C in which the discharger lists pollutants in their effluent and concentrations for them, and such information could be used to develop load estimates for these constituents as well as TPCs for them.

A complicating factor that has, at this point, an unknown impact on the loading estimates presented herein is the accuracy of the metal concentrations reported by dischargers and the USGS caused by the potential contamination of samples for metal analyses by field and laboratory procedures for handling and analyzing samples (Windom et al., 1991). With clean field and laboratory techniques, Windom et al. (1991) report that metal concentrations in East coast rivers were found to be up to 100 times lower than those measured by USGS. Benoit and Santschi (1991) report similar findings for water and sediment concentrations in Galveston Bay. Similar concerns exist for metal analyses in municipal and industrial wastewaters and in marine receiving waters (Battelle Ocean Services, 1991). Battelle found in the New York City area overall poor comparability among laboratories analyzing samples from both wastewater and New York harbor waters and concluded that much of the historical data were likely to overestimate trace metal concentrations. There is a potential that such overestimates of metals concentrations in wastewater discharges to Galveston Bay have also resulted. If metals data for both wastewater discharges and tributaries are actually lower than used in this study, then the loadings estimates will be lower. Whether the degree of lowering is the same for the two sources of loading is not known at this time, and the presumption would be that they are lowered by similar amounts. Thus, the relative or percentage contribution by both sources may be very similar even though the actual loading numbers are lower.

With these comments in mind, following are the major results of this work to estimate point source constituent loading.

1. Loading estimates for conventional, nonconventional, and toxic pollutants from municipal and industrial wastewater discharges and major tributaries for the Galveston Bay system were compiled. Combining these with the non-point source runoff estimates from Newell et al. (1992), the following results were obtained:

Constituent	Units	Total Effluent Load	Major Tributary Load	Non-Point Source Load	Total Load
Tot. Flow	(MG/yr)	1,311,151	1,973,647	980,813	4,265,611
	% of Total	30.7%	46.3%	23.0%	
Cooling Water	(MG/yr)	1,135,564	1,973,647	980,813	4,090,023
	% of Total	27.8%	48.3%	24.0%	
Process Flow	(MG/yr)	175,587	1,973,647	980,813	3,130,047
	% of Total	5.6%	63.1%	31.3%	
BOD_5	(kg/yr)	4,654,554	16,488,156	26,300,000	47,442,710
	% of Total	9.8%	34.8%	55.4%	
TSS	(kg/yr)	9,704,464	423,862,137	481,000,000	914,566,601
	% of Total	1.1%	46.3%	52.6%	
Oil & Grease	(kg/yr)	6,282,142	N/A	14,200,000	20,482,142
	% of Total	30.7%	-	69.3%	
Total N	(kg/yr)	8,425,474	9,686,843	6,420,000	24,532,317
	% of Total	34.3%	39.5%	26.2%	
Total P	(kg/yr)	4,002,666	1,522,930	1,110,000	6,635,596
	% of Total	60.3%	23.0%	16.7%	
Total As	(kg/yr)	20,123	54,562	32,813	107,498
	% of Total	18.7%	50.8%	30.5%	
Total Cd	(kg/yr)	6,397	16,882	5,500	28,779
	% of Total	22.2%	58.7%	19.1%	
Total Cr	(kg/yr)	32,167	166,436	10,057	208,660
	% of Total	15.4%	79.8%	4.8%	
Total Cu	(kg/yr)	27,960	194,481	54,500	276,941
	% of Total	10.1%	70.2%	19.7%	
Total Fe	(kg/yr)	422,791	660,217	N/A	1,083,008
	% of Total	39.0%	61.0%	-	
Total Pb	(kg/yr)	25,368	400,222	211,000	636,590
	% of Total	4.0%	62.9%	33.1%	
Total Hg	(kg/yr)	212	3,533	838	4,583
	% of Total	4.6%	77.1%	18.3%	
Total Zn	(kg/yr)	114,024	871,110	494,615	1,479,749
	% of Total	7.7%	58.9%	33.4%	
PCB	(kg/yr)	16	38	N/A	54
	% of Total	29.2%	70.8%	-	

Effluent loads from this study for 1990
Tributary loads from this study and include on Trinity River and San Jacinto River as spillage from Lake Houston and represent average of 1965-88

Non-point source loads from Newell et al. (1992) and represent average rainfall year (1987)
N/A means estimate not available

a. Flows of wastewater (for 1990), tributary inflow (average for 1965-88), and runoff (for average rainfall year 1987) totaled 4.26 trillion gallons per year, and of the 1.311 trillion gallons per year of wastewater discharged some 0.041 trillion gallons per year was industrial wastewater discharges, 1.136 trillion gallons per year was electrical utility cooling water, and 0.135 trillion gallons per year of municipal wastewater discharger flows.

b. BOD_5 loads to the Bay system amounted to 47.4 million kg/yr with less than 10 percent of that coming from permitted point sources , and of the 4.65 million kg/yr (17.2 percent) coming from wastewater discharges 70 percent originated from industrial sources and 30 percent from municipal sources.

c. Total suspended solids loads to the Bay system equaled 914.6 million kg/yr with only 9.70 million kg/yr (1.1 percent) coming from wastewater discharges (72.5 percent from industries and 27.5 percent from municipalities) and the rest (98.5 percent) from major tributaries.

d. Some 24.5 million kg/yr of total nitrogen reached the Bay of which 8.42 million kg/yr (34.3 percent) originated with wastewater discharges (15.2 percent from industrial and 84.8 percent from municipal) and the rest (65.7 percent) from major tributaries and non-point sources.

e. Total phosphorus loads totaled 6.64 million kg/yr with 4.00 million kg/yr (60.3 percent) originating with wastewater discharges (10.8 percent from industrial and 89.2 percent from municipal) and the rest (39.7 percent) from major tributaries and non-point sources.

f. Oil and grease loads totaled 20.5 million kg/yr with 6.28 million kg/yr (34.2 percent) coming from wastewater discharges (9.0 percent from industries and 91.0 percent from municipalities) and the rest (65.8 percent) from non-point sources

g. For all of the metals, the major source was the tributaries and non-point sources (usually over 75 percent), and, of the amount originating with the wastewater discharges, usually over 75 percent came from municipal discharges. It should be noted, however, that virtually all of the municipal loads and substantially all of the industrial load estimates were based on Typical Pollutant Concentrations.

h. Of the 54 kg/yr of PCBs reaching the Bay, just under 16 kg/yr come from a single permitted discharger and the rest from major tributaries (no estimate was available from non-point sources).

2. Loading estimates for the constituents reported have various levels of confidence.

a. Loading estimates for two of the conventional pollutants (BOD_5 and TSS) were considered to be fairly accurate considering they were required to be reported by most dischargers, they were analyzed by USGS in all major tributaries, and the precision and accuracy of analysis was good.

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 that may be present, and because Typical Pollutant Concentrations had to be employed to estimate loadings (nevertheless, the TPCs used for municipalities were based on local data and were considered reliable).

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), because the chemical forms (mainly total recoverable versus dissolved forms) analyzed were inconsistent between dischargers and USGS data and conversions from dissolved to total concentrations had to be made, 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, the lack of any Typical Pollutant Concentrations to use for estimation purposes, 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).

3. 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 each constituent estimated from measured (self-reporting) data and estimated (TPCs) are given below:

Constit-uent	Units	Estimated Total Load	Measured Total Load	Total Load
Total Flow	(MG/yr) % of Total	0 0.0%	1,311,151 100.0%	1,311,151
Process Flow	(MG/yr) % of Total	0 0.0%	175,587 100.0%	175,587
BOD5	(kg/yr) % of Total	165,642 3.6%	4,488,912 96.4%	4,654,554
TSS	(kg/yr) % of Total	102,286 1.1%	9,602,178 98.9%	9,704,464
Oil & Grease	(kg/yr) % of Total	5,774,725 91.9%	507,417 8.1%	6,282,142
Total N	(kg/yr) % of Total	8,425,474 100.0%	0 0.0%	8,425,474
Total P	(kg/yr) % of Total	3,998,716 99.9%	3,950 0.1%	4,002,666
Total As	(kg/yr) % of Total	20,118 100.0%	5 0.0%	20,123
Total Cd	(kg/yr) % of Total	6,387 99.8%	10 0.2%	6,397
Total Cr	(kg/yr) % of Total	24,615 76.5%	7,551 23.5%	32,167
Total Cu	(kg/yr) % of Total	27,439 98.1%	522 1.9%	27,960
Total Fe	(kg/yr) % of Total	422,762 100.0%	29 0.0%	422,791
Total Pb	(kg/yr) % of Total	24,988 98.5%	380 1.5%	25,368
Total Hg	(kg/yr) % of Total	209 94.5%	12 5.5%	221
Total Zn	(kg/yr) % of Total	101,216 88.8%	12,808 11.2%	114,024
PCB	(kg/yr) % of Total	0 0.0%	16 100.0%	16

4. The estimated 1990 municipal and industrial wastewater loading of BOD_5 to the Houston Ship Channel (summing loadings to Segments 1005, 1006, and 1007) is just over 3 million kg/yr, and basically this is the same loading estimated by others to the Channel in 1920 when there existed substantially fewer dischargers and far less population served by municipal discharges making the small 1990 load of BOD_5 to the Channel remarkable.

5. Toxic substance loading comparisons reveal substantial decreases in discharges of metals from municipal and especially industrial wastewater discharges.

a. Comparison of toxic substance loading estimates between this study and Neleigh's (1974) estimates of industrial waste loading shows substantial reductions in metal discharges by industry to Galveston Bay in less than two decades. The loading estimates are as follows:

Metal	Neleigh (1974) (kg/yr)	This Study (kg/yr)	Reduction (%)
Arsenic	28,037	3,796	86.5
Cadmium	9,599	785	91.8
Chromium	169,955	10,228	94.0
Copper	166,524	9,127	94.5
Iron		65,639	
Lead	17,982	2,408	86.6
Mercury	5,475	68	98.8
Zinc	1,005,843	30,041	97.0

Even greater reductions may have been evident if TPCs had been used to estimated effluent concentrations in those discharges not reporting certain constituents as done in this study.

b. Comparison of 1990 measured (as opposed to measured plus estimated) toxic substance loading estimates from this study to those of Goodman (1989) whose estimates were averages of measured discharges over the 1985-87 period, show the following:

Metal	Goodman (1989) (kg/yr)	This Study - Measured (kg/yr)	This Study - Total (kg/yr)	Reduction (%)
Arsenic	74	5	3,796	93.2
Cadmium	16,969	10	785	99.9
Chromium	13,099	7,551	10,228	42.3
Copper	1,601	522	9,127	67.4
Iron		29	65,639	
Lead	1,658	380	2,408	77.1
Mercury	10	12	68	-20
Zinc	73,469	12,808	30,041	83.6

Again, substantial reductions in metals loading are seen between the two studies and over a fairly short period of time except for mercury for which the changes are so small and the difference between the two loads so small that it is difficult to determine if there has been an actual increase in loading between the two studies.

c. Loading comparisons with Pacheco et al. (1990) reveal close similarities 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.

(1) This study calculated slightly more 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 discharges were estimated to be lower by about 20 percent 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.

(2) BOD_5 and TSS loading estimates were roughly half 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 Galveston Bay area.

(3) Total nitrogen and total phosphorus loads were very close to those by Pacheco et al. with that for total nitrogen being slightly higher because of the site-specific total nitrogen TPC used in this study and the total phosphorus load reflecting precisely the difference in effluent flows between this study and Pacheco et al.

(4) All of the metals loadings are close to Pacheco et al. (1990) accounting for the difference in flow estimates; however, it is clear from effluent sampling studies performed within the past year and the TPCs derived from the results of those studies (Travers, 1993) that the TPCs used herein for metals substantially overestimate the actual concentrations presently found in effluents. When such TPCs can be used in a recalculation of metal loadings, the metal loads are sure to be lower than estimated in this study.

(5) Because of these uncertainties surrounding the estimated loadings from this study as well as that of Pacheco et al. (1990), it is not possible to suggest any trends in constituent loadings; it is clear that the very low effluent concentrations of BOD_5 and TSS observed in the self-reporting data for municipalities demonstrate the high levels of removals being achieved and that the low metals concentrations found in municipal and industrial effluents (Travers, 1993) reflect the same.

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

a. Elevated concentrations of constituents in the upper Houston Ship Channel (Ward and Armstrong, 1992) were expected because of the quantity of wastewaters being discharged to that portion of the Galveston Bay System and because of the hydrologically constricted nature of this area; for example, about two-thirds of all municipal wastewater and industrial process wastewater reaching the Bay are discharged to Water Quality Segments 1005, 1006, and 1007.

b. For BOD_5, TSS, total nitrogen, total phosphorus, oil and grease, and fecal coliforms, over 60 percent of the municipal and industrial wastewater loads were discharged to Water Quality Segments 1006 and 1007 alone, and BOD_5 concentrations were highest there and dissolved oxygen concentrations were lowest. TSS concentrations were greatest in the Trinity River delta and portions of the Ship Channel reflecting the high tributary loadings in those areas ; wastewater loads make up less than 2 percent of TSS loads to the Bay, and their impacts would be very localized if at all.

c. About 25 percent of all the total nitrogen reaching the Bay was discharged to Segments 1006 and 1007 while 39 percent came in from the Trinity River, and ammonia nitrogen and nitrate nitrogen concentrations in the Bay reflected both of those loading points. For total phosphorus with 40 percent of total loading to the Bay from wastewater discharges into Segments 1006 and 1007 and 21 percent from the Trinity River, the highest concentrations were again in Segments 1006 and 1007 both in the water and sediment (where data were sparse); however, the higher concentrations throughout the Bay were found in areas receiving non-point sources as well.

d. Fecal coliform concentrations were clearly highest in Segments 1006 and 1007 and reflected non-point source runoff (see also Newell et al., 1992).

e. Oil and grease loadings were primarily to the Houston Ship Channel from tributaries and point sources, and sediment concentrations of oil and grease were highest in the Ship Channel with scattered high concentrations in Upper and Lower Galveston Bay, Trinity Bay, and West Bay; water concentrations of oil and grease were highest in the Texas City area and in Trinity Bay (Ward and Armstrong 1992). Thus, there was a general disagreement between Bay water and sediment concentrations of oil and grease and point source and tributary loading points suggesting other sources of oil and grease.

f. Loads of metals to Galveston Bay were found to be primarily from the major tributaries, particularly the Trinity River, but of the metals discharged with municipal and industrial wastewaters, the major loads were in the upper Houston Ship Channel. Metal concentration data in Bay water and sediments were sparse, but the data available indicated elevated concentrations in the upper Houston Ship Channel and on both sides of the Texas City Dike. High concentrations of copper occur in mid-Trinity Bay and mid-East Bay, while high concentrations of lead and zinc occur in lower Galveston Bay inside the inlet (Ward and Armstrong 1992).

g. So little data exist for complex organic compounds in the Bay that no comparisons of loading to receiving water concentrations could be made. With the increased scope of effluent monitoring taking place with third-round permitting and expanding sampling programs for complex organics in the Bay, such comparisons should be possible in the not too distant future.

7. The 1992 reported brine discharge flow by the TRC was 2,949 MG/yr with all that amount going to the Bay and most of it being discharged to Trinity Bay and Tabbs Bay.

8. The database to estimate point source loads of pollutants to Galveston Bay is overall relatively incomplete. While flow measurements in effluents and tributaries are the most complete sets of data available, the database for chemical constituents is rather sparse. Even for conventional pollutants like BOD_5 and TSS, the database available for tributaries to estimate loadings is sketchy with typically only four to six measurements acquired each year at each USGS gauge; for effluents of course, 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; a slightly better situation is true for the tributaries. 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. The situation is better for tributaries, but the uncertainties in the quality of the data for metals dictate great caution in using the results of loading estimates for them.

RECOMMENDATIONS

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

1. Loading estimates for toxic substances from wastewater discharges to Galveston Bay can be substantially enhanced by using the additional monitoring data being made available through third-round permitting sampling, through special sampling programs being conducted by the TNRCC, and through use of the TWC and NPDES application forms in which every major industrial discharger is required to complete EPA Form 2C and to list pollutants in their effluent and concentrations for them.

2. 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.

3. Typical Pollutant Concentrations need to be developed for complex organics to supplement those now available for metals.