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 Galveston 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: TWC (permits, waste load evaluations, and self-reporting data sections); EPA (Permits Compliance System); and the Texas Railroad Commission (TRC).

3.2 SELF REPORTING DATA

3.2.1 Data Preparation

3.2.1.1 Acquisition From Texas Water Commission

The self-reporting data for permitted point sources was requested from the TWC in February 1991 and obtained in a form suitable for analysis in late July 1991. The period covered by the data was from 1970 through mid 1991, but only data through the last full year (1990) were used. The data were provided by the Commission on magnetic tape which was transferred to The University of Texas at Austin VAX system in the Computation Center 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 further documents or microfiche supplied by Commission staff or through conversations with them.

The total information provided by the Commission was estimated to be over 100 megabytes in size, and the task of downloading and processing these data was by no means a small one.

3.2.1.2 Downloading To PC

Data on the magnetic tapes received from the TWC were transferred to hard disk storage on The University's VAX cluster system, and from there it was downloaded via KERMIT to a Macintosh hard disk, translated to a 386 class IBM compatible machine using Apple Exchange, then readied for data stripping.

In this form, the data were in ASCII format and in a format like the hard copy printout provided by the Commission with the magnetic tape (see Figure 3.1). For each discharger represented on the tapes, two blocks of information were provided. The first block consisted of the permitted discharge information (Figure 3.1) while the second held the self reporting data (Figure 3.2). Information from both blocks needed to be extracted for subsequent analysis.

Before proceeding further, the data so downloaded were compressed with PKZIP and stored on floppy disk in duplicate for archive purposes.

3.2.1.3 Data Stripping

Extraction of data from the downloaded files was achieved with a program written in Quick BASIC. With this program, sequential records (lines) were read as strings, checks made to ascertain the precise location of the string within the two blocks of information mentioned above, and particular pieces of information or data were extracted from each string for storage in another, smaller ASCII file. The Commission had supplied the self-reporting data in files of data which happened to correspond to years, and thus one year's worth of data were processed at one time.

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 TWC 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. One discharger was reporting for more constituents than even the TWC format was able to handle, and data for that discharger had to be entered manually after copies of the discharger's original self-reporting forms were obtained from the Commission.

In the first information block (Figure 3.1) containing permitted discharge information, the permittee's name, permit numbers (EPA and TWC), location (by segment number, country, and river basin), permit status (interim or final), and start and end dates for the permit were removed and stored in a an ASCII file marked for permit information only (see Figure 3.3). Also in this information block 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 3.4) linked to the TWC 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 and largest ASCII file created from this data stripping process was filled with the self-reporting data (see Figure 3.5). Constituent parameter code and value (load and/or concentration) data were stored in this file by permit number for subsequent calculation of loading to the Bay.

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MONTHLY EFFLUENT DATA

JUNE 24, 1991

PERMITTEE: KIRBY FOREST INDUSTRIES, INC.
FACILITY : OTFL 001 PLYWOOD MANUFACTURING

DISTRICT---- 07 DEER PARK
COUNTY------ 146 LIBERTY
RIV. BASIN-- 08 TRINITY RIVER BASIN
STREAM SEG.- 802

	PERMIT	OTFL	HRN
PRIMARY	WQ0002196	001	001
SECOND	TX0077143		000

****
* PERMITTED CONDITIONS *
****

EFFLUENT SETS IN EFFECT FOR THIS PERIOD:

SET 01 I BEGINS - 19790723 ENDS - 19841112
SET 02 F BEGINS - 19841113 ENDS - 19900630

	000035342 DISCHRGE DAYS/MTH VALUE	DAYS FR	TY	003401080 COD MAXIMUM VALUE	MG/L FR	TY	004006080 PH MAXIMUM VALUE	STD UNIT FR	TY	004006081 PH MINIMUM VALUE	STD UNIT FR	TY	005521080 OIL&GRES MAXIMUM VALUE	MG/L FR	TY
SET 01		01	01	200.00	08	02	9.00	14	02	6.00	14	02	15.00	08	02
SET 02		01	01	200.00	14	02	9.00	14	02	6.00	14	02	15.00	14	02

	500507124 FLOW DLY.AVG. VALUE	MGD FR	TY	500507150 FLOW DLY.MAX. VALUE	MGD FR	TY
SET 01	.100000	08	13			
SET 02	.100000	14	13		14	13

SAMPLING FREQUENCIES USED:
01) NOT APPLICABLE
08) ONE / DAY
14) ONE / WEEK

SAMPLE TYPES USED:
01) NOT APPLICABLE
02) GRAB LESS THAN 15 MINUTES
13) ESTIMATE

Fig. 3.1. Example Of Self-Reporting Data (Permitted Conditions) Received From Texas Water Commission

FORM DW0720   * * * T E X A S W A T E R C O M M I S S I O N * * *   PAGE 35

MONTHLY EFFLUENT DATA

JUNE 24, 1991

	PERMIT	OTFL	HRN
PRIMARY	WQ0002196	001	001
SECOND	TX0077143		000

PERMITTEE: KIRBY FOREST INDUSTRIES, INC.
FACILITY : OTFL 001 PLYWOOD MANUFACTURING

DISTRICT---- 07 DEER PARK
COUNTY------ 146 LIBERTY
RIV. BASIN-- 08 TRINITY RIVER BASIN
STREAM SEG.- 802

REPORT MONTH YY/MM	VALUE FR TY NE	VALUE FR TY NE	VALUE FR TY NE	VALUE FR TY NE	VALUE FR TY NE
	000035342 DISCHRGE DAYS DAYS/MTH	003401080 COD MG/L MAXIMUM	004006080 PH STD UNIT MAXIMUM	004006081 PH STD UNIT MINIMUM	005521080 OIL&GRES MG/L MAXIMUM
84/01					
84/02	0 01 01				
84/03	01 01	134. 08 02	7.39 14 02	7.03 14 02	4.6 08 02
84/04	0 01 01				
84/05	01 01	99. 08 02	7.30 14 02	6.26 14 02	6.30 08 02
84/06	01 01	142.0 08 02	7.99 14 02	7.99 14 02	3.37 08 02
84/07	01 01	150. 08 02	8.37 14 02	6.89 14 02	2.13 08 02
84/08	01 01	99.0 08 02	7.57 14 02	7.57 14 02	1.2 08 02
84/09	01 01	175. 08 02	7.97 14 02	6.50 14 02	1.47 08 02
84/10	01 01	133. 08 02	8.35 14 02	6.44 14 02	3.20 08 02
84/11	01 01	35.0 08 02	7.21 14 02	6.82 14 02	2.27 08 02
84/12	0 01 01				

SAMPLING FREQUENCIES USED:
01) NOT APPLICABLE
08) ONE / DAY
14) ONE / WEEK

SAMPLE TYPES USED:
01) NOT APPLICABLE
02) GRAB LESS THAN 15 MINUTES
13) ESTIMATE

REPORT MONTH YY/MM	500507124 FLOW MGD DLY.AVG.	500507150 FLOW MGD DLY.MAX.
84/01		
84/02		
84/03	0. 08 13	
84/04		
84/05	0. 08 13	
84/06	0. 08 13	
84/07	0. 08 13	
84/08	0. 08 13	
84/09	0. 08 13	
84/10	0. 08 13	
84/11	0. 08 13	
84/12		

Fig. 3.2. Example Of Self-Reporting Data (Reported Data) Received From The Texas Water Commission

```
"TEXASGULF, INC.                  ","OTFL 001 MOSS BLUFF DOME
",7,146,8,801,"WQ0000952","001","001","TX0005622","    ","000","2","F
","07/30/79","06/13/84"
"TEXASGULF CHEMICAL CO            ","OTFL 002 MOSS BLUFF DOME
",7,146,8,801,"WQ0000952","001","002","TX0005622","    ","000","3","I
","09/14/81","08/19/85"
"MAGNA CORPORATION/BAKER          ","OTFL 001
",7,146,8,801,"WQ0001969","001","001","TX0065676","    ","000","1","I
","10/28/75","08/13/84"
"MAGNA CORPORATION/BAKER          ","OTFL 001
",7,146,8,801,"WQ0001969","001","001","TX0065676","    ","000","2","F
","08/14/84","03/31/90"
"MAGNA CORPORATION/BAKER          ","OTFL 002
",7,146,8,801,"WQ0001969","002","002","TX0065676","    ","000","1","F
","08/14/84","03/31/90"
"LIBERTY, CITY OF                 ","OTFL 001 MAIN PLANT
",7,146,8,801,"WQ0010108","001","001","TX0074284","    ","000","2","F
","01/01/81","09/30/91"
"LIBERTY, CITY OF                 ","OTFL 003 TREE TOP PLANT
",7,146,8,801,"WQ0010108","003","003","TX0074411","    ","000","2","F
","03/28/83","12/31/86"
"DAYTON, CITY OF                  ","OTFL 001 NORTHEAST
",7,146,8,801,"WQ0010564","001","001","TX0027286","    ","000","1","I
","07/23/74","03/30/89"
"DAYTON, CITY OF                  ","OTFL 002 SOUTHEAST
",7,146,8,801,"WQ0010564","002","002","TX0027278","    ","000","1","I
","11/26/74","03/30/89"
"MONT BELVIEU, CITY OF            ","OTFL 001 COTTON BAYOU
",7,36,8,801,"WQ0011030","001","001","TX0053317","    ","000","3","F
","07/01/83","09/30/91"
"HARRINGTON, R. R., JR.           ","OTFL 001 COTTON BAYOUMANOR-
MHP",7,36,8,801,"WQ0011109","001","001","TX0085961","    ","000","1","F
","03/24/76","06/30/91"
"DUTTON, E. A.                    ","OTFL 001 COVE PARK MHP
",7,36,8,801,"WQ0011449","001","001","TX0066656","    ","000","1","F
","01/28/76","03/31/91"
"DERRINGTON, C.W.                 ","OTFL 001 DERRINGTON TRAILER
PK",7,146,8,801,"WQ0011838","001","001","TX0072516","    ","001","2","F
","05/03/82","03/31/88"
"KIRBY FOREST INDUSTRIES, INC. ","OTFL 001 PLYWOOD
MANUFACTURING",7,146,8,802,"WQ0002196","001","001","TX0077143","
","000","1","I ","07/23/79","11/12/84"
"KIRBY FOREST INDUSTRIES, INC. ","OTFL 001 PLYWOOD
MANUFACTURING",7,146,8,802,"WQ0002196","001","001","TX0077143","
","000","2","F","11/13/84","06/30/90"
"KIRBY FOREST INDUSTRIES, INC. ","INPT 101 PLYWOOD
MANUFACTURING",7,146,8,802,"WQ0002196","101","101","TX0077143","
","000","1","F ","11/13/84","06/30/90"
"LIVINGSTON, CITY OF              ","OTFL 001
",6,187,8,802,"WQ0010208","001","001","TX0024163","    ","000","3","I
","07/01/83","12/15/86"
"MOSCOW WATER SUPPLY CORP.        ","OTFL 001
",6,187,8,802,"WQ0011139","001","001","TX0075701","    ","000","2","F
","07/06/81","09/30/91"
```

Fig. 3.3. Example Of Permit Information Stripped from Original File

```
"WQ0002196","001","001","F ",1,"000035342"," ",0.000000,1,1
"WQ0002196","001","001","F ",1,"003401080"," ",200.000000,8,2
"WQ0002196","001","001","F ",1,"004006080"," ",9.000000,14,2
"WQ0002196","001","001","F ",1,"004006081"," ",6.000000,14,2
"WQ0002196","001","001","F ",1,"005521080"," ",15.000000,8,2
"WQ0002196","001","001","F ",2,"000035342"," ",0.000000,1,1
"WQ0002196","001","001","F ",2,"003401080"," ",200.000000,14,2
"WQ0002196","001","001","F ",2,"004006080"," ",9.000000,14,2
"WQ0002196","001","001","F ",2,"004006081"," ",6.000000,14,2
"WQ0002196","001","001","F ",2,"005521080"," ",15.000000,14,2
"WQ0002196","001","001","F ",1,"500507124"," ",0.100000,8,13
"WQ0002196","001","001","F ",1,"500507150"," ",0.000000,0,0
"WQ0002196","001","001","F ",2,"500507124"," ",0.100000,14,13
"WQ0002196","001","001","F ",2,"500507150"," ",0.000000,14,13
"WQ0002196","101","101","F ",1,"000035342"," ",0.000000,1,1
"WQ0002196","101","101","F ",1,"003102024"," ",3.300000,14,2
"WQ0002196","101","101","F ",1,"003102050"," ",7.500000,14,2
"WQ0002196","101","101","F ",1,"004006080"," ",9.000000,14,2
"WQ0002196","101","101","F ",1,"004006081"," ",6.000000,14,2
"WQ0002196","101","101","F ",1,"005302024"," ",3.300000,14,2
"WQ0002196","101","101","F ",1,"005302050"," ",7.500000,14,2
"WQ0002196","101","101","F ",1,"500507124"," ",0.020000,8,12
"WQ0002196","101","101","F ",1,"500507150"," ",0.060000,8,12
```

Fig. 3.4. Example of Permitted Parameters File Stripped From Original File

```
"WQ0002196","001","001",802,"01/01/84","000035342"," ",0.000000,0,0,0
"WQ0002196","001","001",802,"01/01/84","003401080"," ",0.000000,0,0,0
"WQ0002196","001","001",802,"01/01/84","004006080"," ",0.000000,0,0,0
"WQ0002196","001","001",802,"01/01/84","004006081"," ",0.000000,0,0,0
"WQ0002196","001","001",802,"01/01/84","005521080"," ",0.000000,0,0,0
"WQ0002196","001","001",802,"02/01/84","000035342"," ",0.000000,1,1,0
"WQ0002196","001","001",802,"02/01/84","003401080"," ",0.000000,0,0,0
"WQ0002196","001","001",802,"02/01/84","004006080"," ",0.000000,0,0,0
"WQ0002196","001","001",802,"02/01/84","004006081"," ",0.000000,0,0,0
"WQ0002196","001","001",802,"02/01/84","005521080"," ",0.000000,0,0,0
"WQ0002196","001","001",802,"03/01/84","000035342"," ",0.000000,1,1,0
"WQ0002196","001","001",802,"03/01/84","003401080"," ",134.000000,8,2,0
"WQ0002196","001","001",802,"03/01/84","004006080"," ",7.390000,14,2,0
"WQ0002196","001","001",802,"03/01/84","004006081"," ",7.030000,14,2,0
"WQ0002196","001","001",802,"03/01/84","005521080"," ",4.600000,8,2,0
"WQ0002196","001","001",802,"04/01/84","000035342"," ",0.000000,1,1,0
"WQ0002196","001","001",802,"04/01/84","003401080"," ",0.000000,0,0,0
"WQ0002196","001","001",802,"04/01/84","004006080"," ",0.000000,0,0,0
"WQ0002196","001","001",802,"04/01/84","004006081"," ",0.000000,0,0,0
"WQ0002196","001","001",802,"04/01/84","005521080"," ",0.000000,0,0,0
"WQ0002196","001","001",802,"05/01/84","000035342"," ",0.000000,1,1,0
"WQ0002196","001","001",802,"05/01/84","003401080"," ",99.000000,8,2,0
"WQ0002196","001","001",802,"05/01/84","004006080"," ",7.300000,14,2,0
"WQ0002196","001","001",802,"05/01/84","004006081"," ",6.260000,14,2,0
"WQ0002196","001","001",802,"05/01/84","005521080"," ",6.300000,8,2,0
"WQ0002196","001","001",802,"06/01/84","000035342"," ",0.000000,1,1,0
"WQ0002196","001","001",802,"06/01/84","003401080"," ",142.000000,8,2,0
"WQ0002196","001","001",802,"06/01/84","004006080"," ",7.990000,14,2,0
"WQ0002196","001","001",802,"06/01/84","004006081"," ",7.990000,14,2,0
"WQ0002196","001","001",802,"06/01/84","005521080"," ",3.370000,8,2,0
"WQ0002196","001","001",802,"07/01/84","000035342"," ",0.000000,1,1,0
"WQ0002196","001","001",802,"07/01/84","003401080"," ",150.000000,8,2,0
"WQ0002196","001","001",802,"07/01/84","004006080"," ",8.370000,14,2,0
"WQ0002196","001","001",802,"07/01/84","004006081"," ",6.890000,14,2,0
"WQ0002196","001","001",802,"07/01/84","005521080"," ",2.130000,8,2,0
"WQ0002196","001","001",802,"08/01/84","000035342"," ",0.000000,1,1,0
"WQ0002196","001","001",802,"08/01/84","003401080"," ",99.000000,8,2,0
"WQ0002196","001","001",802,"08/01/84","004006080"," ",7.570000,14,2,0
"WQ0002196","001","001",802,"08/01/84","004006081"," ",7.570000,14,2,0
"WQ0002196","001","001",802,"08/01/84","005521080"," ",1.200000,8,2,0
"WQ0002196","001","001",802,"09/01/84","000035342"," ",0.000000,1,1,0
"WQ0002196","001","001",802,"09/01/84","003401080"," ",175.000000,8,2,0
"WQ0002196","001","001",802,"09/01/84","004006080"," ",7.970000,14,2,0
"WQ0002196","001","001",802,"09/01/84","004006081"," ",6.500000,14,2,0
"WQ0002196","001","001",802,"09/01/84","005521080"," ",1.470000,8,2,0
```

Fig. 3.5 Example of Self-Reporting Data Stripped From Original File

Again, the data extracted from the Commission's formatted data were compressed using PKZIP and stored on floppy diskette in duplicate for archive purposes.

3.2.1.4 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 (GBPERM*YY*); one for the permitted discharge information (GBPERD*YY*); and a third for the self-reporting data (GBSELF*YY*). *YY* in each name represents the year of the data (e.g., 90 for 1990). 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 15 megabytes for 1990 data and lesser amounts for earlier years with fewer permitted discharges. A listing of permitted dischargers to the Galveston Bay system in 1990 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.

PKZIP was used to compress these database files also, and in compressed form the 1990 database files occupied about 1.4 megabytes which could be stored on floppy diskettes.

3.2.2 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 1990 data, the list contained over 250 entries indicating the variety of constituents being sampled and various forms of constituents being reported. The parameter codes used by the TWC 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. Other flow units were Daily Max (gal/min), Daily Annual Avg (MGD), Daily Max (MGD), Total (MG), Daily Avg (Bil gal/d), and Daily Max (Bil gal/d). 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),

Table 3.1 - Texas Water Quality Segments Used to Aggregate Point Source Loading Estimates

Point Source Characterization Project
Galveston Bay National Estuary Program

Basin	Segment Number	Segment Name
Trinity River		
	0801	Trinity River Tidal
	0802	Trinity River below Lake Livingston
Trinity-San Jacinto Coastal		
	0901	Cedar Bayou Tidal
	0902	Cedar Bayou Above Tidal
San Jacinto River		
	1001	San Jacinto River Tidal
	1005	Houston Ship Channel/San Jacinto River
	1006	Houston Ship Channel
	1007	Houston Ship Channel/Buffalo Bayou
	1013	Buffalo Bayou Tidal
	1014	Buffalo Bayou Above Tidal
San Jacinto-Brazos Coastal		
	1101	Cedar Creek Tidal
	1102	Clear Creek Above Tidal
	1103	Dickinson Bayou Tidal
	1104	Dickinson Bayou Above Tidal
	1105	Bastrop Bayou Tidal
	1107	Chocolate Bayou Tidal
	1108	Chocolate Bayou Above Tidal
	1113	Armand Bayou Tidal
Bays and Estuaries		
	2421	Upper Galveston Bay
	2422	Trinity Bay
	2423	East Bay
	2424	West Bay
	2425	Clear Lake
	2426	Tabbs Bay
	2427	San Jacinto Bay
	2428	Black Duck Bay
	2429	Scott Bay
	2430	Burnett Bay
	2431	Moses Lake
	2432	Chocolate Bay
	2433	Bastrop Bay/Oyster Lake
	2434	Christmas Bay
	2435	Drum Bay

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

Point Source Characterization Project
Galveston 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

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 TWC for identifying different report units is given in Table 3.3.

The Scope of Services called for 37 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.

3.2.3 Data Analysis

3.2.3.1 Loading Estimates

Loadings and other analyses were to be done on self-reporting data from dischargers to the 37 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.

Early data analysis focused on extracting loadings data reported by dischargers on self-reporting forms in loading units (e.g., lbs/day). For most of the constituents reported, one of the reporting forms was as a 30-day average for each month in lbs/day. These values were summed from all dischargers in each water quality segment for a given month, multiplied by the number of days in that month, and the products summed to produce an annual loading. Constituents which were reported in concentration-only format were not included, nor were constituents that were not included in the dischargers self-reporting forms.

Recognizing that essentially all municipal dischargers did not report nutrients, metals, and other constituents and some industrial dischargers are not required to report some constituents typically discharged, these early estimates were by definition inaccurate for they failed to reflect pollutants being discharged but just not reported. To correct this deficiency, the procedures outlined in a recent 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

Table 3.3 - Effluent Parameter Code Prefix and Suffix Match

Point Source Characterization Project
Galveston Bay National Estuary Program

Para-meter Code	Parameter Name	Texas Dept. Health Cert. 0001	Texas Dept. Health Cert. 0003	Daily or 30-d Avg. (mg/L) 1024	Indiv. Grab (mg/L) 1030	Daily Max (mg/L) 1050	24-hr Comp. (mg/L) 1060	Max (mg/L) 1080	Min. Grab (mg/L) 1081	Indiv Grab (ug/L) 1130	Indiv Grab (mg/kg) 1430	Daily or 30-d Avg. (lbs/d) 2024	Daily Annual Avg. (lbs/d) 2025	Daily Max (lbs/d) 2050	Max (lbs/d) 2080	Daily Avg. (gal/d) 2724	Daily Max (gal/d) 2750	Rain-fall (in/mo) 3044	PCB Daily Avg. (ppb) 3524	PCB Daily Max (ppb) 3550
34496	1,1 DICHLOROETHANE			x								x		x						
34501	1,1 DICHLOROETHYLENE			x								x		x						
34506	1,1,1 TRICHLOROETHANE				x	x		x				x		x						
34516	1,1,2,2-TETRACHLOROETHANE				x															
34511	1,1,2-TRICHLOROETHANE				x							x		x						
34346	1,2 DIPHENYLHYDRAZINE				x															
34551	1,2,4-TRICHLOROBENZENE				x							x		x						
34533	1,2-DICHLOETHANE			x	x	x						x		x						
34536	1,2-DICHLOROBENZENE				x							x		x						
34542	1,2-DICHLOROPROPANE				x							x		x						
34547	1,2-TRANS DICHLOROETHYLENE				x							x		x						
34566	1,3-DICHLOROBENZENE				x							x		x						
99101	1,3-DICHLOROPROPYLENE				x							x		x						
34571	1,4-DICHLOROBENZENE				x							x		x						
34403	1INOENO(123-CD)PYRENE				x															
34621	2,4,6 TRICHLOROPHENOL				x	x														
34601	2,4-DICHLOROPHENOL				x							x		x						
34606	2,4-DIMETHYLPHENOL				x							x		x						
34616	2,4-DINITROPHENOL				x							x		x						
34611	2,4-DINITROTOLUENE				x							x		x						
34576	2-CHLOROETHYLVINYAL ETHER				x															
34581	2-CHLORONAPHTHALENE				x															
34591	2-NITROPHENOL				x							x		x						
34586	2CHLOROPHENOL				x	x						x		x						
34631	3,3-DICHLOROBENZIDENE				x															
79531	3,4-BENZOFLUORANTHENE				x							x		x						
79533	4,6-DINITRO-O-CRESOL				x							x		x						
34636	4-BROMOPHENYL ETHER				x															
34646	4-NITROPHENOL				x	x						x		x						
34641	4CHLOROPHENYL PHENYL ETHER				x															
34206	ACENAPHTHENE				x							x		x						
34200	ACENAPHTHYLENE				x							x		x						
79539	ACETONE					x		x												
81553	ACETOPHENONE					x		x												
34210	ACROLEIN, TOTAL				x															
34215	ACRYLONITRILE				x	x						x		x						
01106	ALUMINUM, DISSOLVED							x												
01105	ALUMINUM, TOTAL			x				x												
39775	AMIBEN							x												
77089	ANILEINE							x												
34220	ANTHRACENE			x	x	x		x				x		x						
01097	ANTIMONY, TOTAL			x	x	x														
01002	ARSENIC, TOTAL			x	x	x		x				x		x						
01007	BARIUM, TOTAL			x	x	x														
34032	BENZENE			x				x				x		x						
34031	BENZENE, TOTAL			x	x	x		x				x		x						
39120	BENZIDINE				x															
34526	BENZO(A)ANTHRACENE				x							x		x						
34250	BENZO(A)PYRENE				x							x		x						
34521	BENZO(GHI)PERYLENE				x															
34242	BENZO(K)FLUORANTHENE				x							x		x						
01012	BERYLLIUM,TOTAL				x															
34278	BIS(2-CHLOROETHOXY) METHANE				x															
34273	BIS(2-CHLOROETHYL)ETHER				x															
34283	BIS(2-CHLOROISOPROPYL)				x															
39100	BIS(2-ETHYLHEXYL)PHTHALATE				x							x		x						
00310	BOD5			x	x	x	x	x				x	x	x						
80082	BOD5, CARBONACEOUS CON			x	x	x	x	x				x								
82198	BROMICAL					x														
32104	BROMOFORM				x															
84085	BTEX (BEN/TOL/ETHYL BEN/XYL)			x				x				x		x						
34292	BUTYLBENZYL PHTHALATE				x															

Table 3.3 - Effluent Parameter Code Prefix and Suffix Match

Point Source Characterization Project
Galveston Bay National Estuary Program

Parameter Code	Parameter Name	30-d Avg. (#/100 mL) 4024	Daily Max (#/100 mL) 4050	Inst. Max (#/100 mL) 4080	Spec. Cond. (µS/cm) 4280	Days/Mo (d) 5342	Max. (Std U) 6080	Min. (Std U) 6081	Daily Max (gal/min) 7050	30-d Avg. (MGD) 7124	Daily Annual Avg. (MGD) 7125	Daily Max (MGD) 7150	Total (MG) 7339	Daily Avg. (Bil gal/d) 7424	Daily Max (Bil gal/d) 7450	Daily or 30-d Avg. (Degr F) 8024	Indiv. Grab (Degr F) 8030	Daily Max. (Degr F) 8050	Max. (Degr F) 8080
34496	1,1 DICHLOROETHANE																		
34501	1,1 DICHLOROETHYLENE																		
34506	1,1,1 TRICHLOROETHANE																		
34516	1,1,2,2-TETRACHLOROETHANE																		
34511	1,1,2-TRICHLOROETHANE																		
34346	1,2 DIPHENYLHYDRAZINE																		
34551	1,2,4-TRICHLOROBENZENE																		
34533	1,2-DICHLOETHANE																		
34536	1,2-DICHLOROBENZENE																		
34542	1,2-DICHLOROPROPANE																		
34547	1,2-TRANS DICHLOROETHYLENE																		
34566	1,3-DICHLOROBENZENE																		
99101	1,3-DICHLOROPROPYLENE																		
34571	1,4-DICHLOROBENZENE																		
34403	1INOENO(123-CD)PYRENE																		
34621	2,4,6 TRICHLOROPHENOL																		
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34606	2,4-DIMETHYLPHENOL																		
34616	2,4-DINITROPHENOL																		
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34576	2-CHLOROETHYLVINYAL ETHER																		
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34591	2-NITROPHENOL																		
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79533	4,6-DINITRO-O-CRESOL																		
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34646	4-NITROPHENOL																		
34641	4CHLOROPHENYL PHENYL ETHER																		
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34210	ACROLEIN, TOTAL																		
34215	ACRYLONITRILE																		
01106	ALUMINUM, DISSOLVED																		
01105	ALUMINUM, TOTAL																		
39775	AMIBEN																		
77089	ANILEINE																		
34220	ANTHRACENE																		
01097	ANTIMONY, TOTAL																		
01002	ARSENIC, TOTAL																		
01007	BARIUM, TOTAL																		
34032	BENZENE																		
34031	BENZENE, TOTAL																		
39120	BENZIDINE																		
34526	BENZO(A)ANTHRACENE																		
34250	BENZO(A)PYRENE																		
34521	BENZO(GHI)PERYLENE																		
34242	BENZO(K)FLUORANTHENE																		
01012	BERYLLIUM,TOTAL																		
34278	BIS(2-CHLOROETHOXY) METHANE																		
34273	BIS(2-CHLOROETHYL)ETHER																		
34283	BIS(2-CHLOROISOPROPYL)																		
39100	BIS(2-ETHYLHEXYL)PHTHALATE																		
00310	BOD5																		
80082	BOD5, CARBONACEOUS CON																		
82198	BROMICAL																		
32104	BROMOFORM																		
84085	BTEX (BEN/TOL/ETHYL BEN/XYL)																		
34292	BUTYLBENZYL PHTHALATE																		

Table 3.3 - Parameter Code Prefix and Suffix Match

Point Source Characterization Project
Galveston Bay National Estuary Program

Parameter Code	Parameter Name	Texas Dept. Health Cert. 0001	Texas Dept. Health Cert. 0003	Daily or 30-d Avg. (mg/L) 1024	Indiv. Grab (mg/L) 1030	Daily Max (mg/L) 1050	24-hr Comp.. (mg/L) 1060	Max (mg/L) 1080	Min. Grab (mg/L) 1081	Indiv Grab (µg/L) 1130	Indiv Grab (mg/kg) 1430	Daily or 30-d Avg. (lbs/d) 2024	Daily Annual Avg. (lbs/d) 2025	Daily Max (lbs/d) 2050	Max (lbs/d) 2080	Daily Avg. (gal/d) 2724	Daily Max (gal/d) 2750	Rain-fall (in/mo) 3044	PCB Daily Avg. (ppb) 3524	PCB Daily Max (ppb) 3550
01027	CADMIUM, TOT			x	x	x		x			x	x		x						
32260	CARBON TETRACHLORIDE			x	x	x						x		x						
00680	CARBON, TOTAL ORGANIC			x		x		x				x		x						
00940	CHLORIDE, TOTAL			x																
39175	CHLORIDE, VINYL			x	x	x						x		x						
70352	CHLORIDES, TOTAL ORGANIC											x		x						
74052	CHLORINATED HYDROCARBONS, GEN			x		x						x		x						
74048	CHLORINATED HYDROCARBONS, TOT			x		x		x				x		x						
74048	CHLORINATED HYDROCARBONS, TOT					x		x				x		x						
50065	CHLORINATION AFTER DECHLOR.							x												
50064	CHLORINE, FREE AVAILABLE			x		x		x				x		x						
50061	CHLORINE, RESIDUAL							x	x											
50060	CHLORINE, TOTAL RESIDUAL			x		x						x		x						
34301	CHLOROBENZENE				x	x						x		x						
34306	CHLORODIBROMOMETHANE, TOTAL				x															
34311	CHLOROETHANE				x							x		x						
32106	CHLOROFORM			x	x	x						x		x						
77969	CHLORPYRIFOS									x										
01032	CHROMIUM, HEXAVALENT			x		x						x		x						
01034	CHROMIUM, TOTAL CONC.(MG/L)			x	x	x		x				x		x						
34320	CHRYSENE				x							x		x						
31616	COLIFORM, FEC MEMB.FILT																			
00950	CONDUCTANCE, SPECIFIC 25																			
01042	COPPER, TOTAL CONC			x	x	x		x			x	x		x						
00720	CYANIDE, TOTAL			x	x	x		x				x		x						
00722	CYANIDES, AMENABLE TO CHLOR.			x		x		x				x		x						
39769	DACONIL, TOTAL			x	x	x														
39770	DACTHAL, TOTAL			x	x	x														
00004	DAYS BYPASS MADE/MONTH																			
39110	DI-N-BUTYL PHTHALATE				x							x		x						
34596	DI-N-OCTYL PHTHALATE				x															
39570	DIAZINON									x										
78352	DIBENZO(A,H)ANTHRACENE				x															
32105	DICHLOROBROMOMETHANE				x															
81680	DICHLOROETHANE(1,2)			x		x						x		x						
34336	DIETHYL PHTHALATE				x							x		x						
77224	DIISOPROPYLBENZENE					x														
34341	DIMETHYL PHTHALATE				x							x		x						
34626	DINITROTOLUENE(2,6)				x															
00003	DISCHARGE DAYS PER MONTH																			
39544	EHTYL BENZENE				x	x						x		x						
50050	FLOW, RATE OF																			
50048	FLOW, WET WEATHER																			
34376	FLUORANTHENE				x							x		x						
34381	FLUORENE, TOTAL				x							x		x						
00951	FLUORIDE			x		x		x				x		x						
00952	FLUORIDE, WET					x														
00551	GREASE															x	x			
78115	HALOGEN, TOTAL ORGANIC							x												
39700	HEXACHLOROBENZENE			x	x	x						x		x						
39702	HEXACHLOROBUTADIENE				x							x		x						
34386	HEXACHLOROCYCLOPENTADENE				x															
34396	HEXACHLOROETHANE				x							x		x						
38817	HEXAZINONE					x														
74053	HYDROCARBONS, INCREASE					x														
82180	HYDROCARBONS, PETR. TOT. RECOV.											x		x						

Table 3.3 - Parameter Code Prefix and Suffix Mat

Point Source Characterization Project
Galveston Bay National Estuary Program

Para-meter Code	Parameter Name	30-d Avg. (#/100 mL) 4024	Daily Max (#/100 mL) 4050	Inst. Max (#/100 mL) 4080	Spec. Cond. (μmhos/cm) 4280	Days/ Mo (d) 5342	Max. (Std U) 6080	Min. (Std U) 6081	Daily Max (gal/min) 7050	30-d Avg. (MGD) 7124	Daily Annual Avg. (MGD) 7125	Daily Max (MGD) 7150	Total (MG) 7339	Daily Avg. (Bil gal/d) 7424	Daily Max (Bil gal/d) 7450	Daily or 30-d Avg. (Degr F) 8024	Indiv. Grab (Degr F) 8030	Daily Max. (Degr F) 8050	Max. (Degr F) 8080
01027	CADMIUM, TOT																		
32260	CARBON TETRACHLORIDE																		
00680	CARBON, TOTAL ORGANIC																		
00940	CHLORIDE, TOTAL																		
39175	CHLORIDE, VINYL																		
70352	CHLORIDES, TOTAL ORGANIC																		
74052	CHLORINATED HYDROCARBONS, GEN																		
74048	CHLORINATED HYDROCARBONS, TOT																		
74048	CHLORINATED HYDROCARBONS, TOT																		
50065	CHLORINATION AFTER DECHLOR.																		
50064	CHLORINE, FREE AVAILABLE																		
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34306	CHLORODIBROMOMETHANE, TOTAL																		
34311	CHLOROETHANE																		
32106	CHLOROFORM																		
77969	CHLORPYRIFOS																		
01032	CHROMIUM, HEXAVALENT																		
01034	CHROMIUM, TOTAL CONC.(MG/L)																		
34320	CHRYSENE																		
31616	COLIFORM, FEC MEMB.FILT	x	x	x															
00950	CONDUCTANCE, SPECIFIC 25				x														
01042	COPPER, TOTAL CONC																		
00720	CYANIDE, TOTAL																		
00722	CYANIDES, AMENABLE TO CHLOR.																		
39769	DACONIL, TOTAL																		
39770	DACTHAL, TOTAL																		
00004	DAYS BYPASS MADE/MONTH					x													
39110	DI-N-BUTYL PHTHALATE																		
34596	DI-N-OCTYL PHTHALATE																		
39570	DIAZINON																		
78352	DIBENZO(A,H)ANTHRACENE																		
32105	DICHLOROBROMOMETHANE																		
81680	DICHLOROETHANE(1,2)																		
34336	DIETHYL PHTHALATE																		
77224	DIISOPROPYLBENZENE																		
34341	DIMETHYL PHTHALATE																		
34626	DINITROTOLUENE(2,6)																		
00003	DISCHARGE DAYS PER MONTH					x													
39544	EHTYL BENZENE																		
50050	FLOW, RATE OF								x	x	x	x		x	x				
50048	FLOW, WET WEATHER											x							
34376	FLUORANTHENE																		
34381	FLUORENE, TOTAL																		
00951	FLUORIDE																		
00952	FLUORIDE, WET																		
00551	GREASE																		
78115	HALOGEN, TOTAL ORGANIC																		
39700	HEXACHLOROBENZENE																		
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Point Source Characterizaton Project
Galveston Bay National Estuary Program

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00640	INORGANIC NITROGEN, TOTAL											x		x						
01045	IRON, TOTAL			x		x		x				x		x						
34408	ISOPHORONE				x															
01051	LEAD, TOT			x	x	x		x			x	x		x						
39530	MALATHION									x										
01055	MANGANESE, TOTAL			x	x	x		x				x		x						
71900	MERCURY, TOTAL			x	x	x		x				x		x						
39051	METHOMYL					x														
34413	METHYL BROMIDE				x															
34418	METHYL CHLORIDE			x	x	x						x		x						
34423	METHYLENE CHLORIDE			x	x	x		x				x		x						
45097	METHYLSTYRENE, ALPHA					x		x												
34428	N-NITROSODI-N-PROPYLAMINE				x															
34438	N-NITROSODIMETHYLAMINE				x															
34443	N-NITROSODIPHENYLAMINE				x															
39250	NAPHTHALENE			x	x	x		x				x		x						
01067	NICKEL, TOTAL			x	x	x		x			x	x		x						
34447	NITROBENZENE				x							x		x						
00610	NITROGEN, TOTAL AMMONIA AS N			x	x	x	x	x			x	x		x						
00612	NITROGEN, TOT AMMONIA WINTER											x		x						
00614	NITROGEN, TOT AMMONIA, SUMMER											x		x						
00625	NITROGEN, TOT KJELD-N			x	x	x	x					x		x						
00629	NITROGEN, TOT. ORGANIC (KJEL)					x		x				x		x						
00600	NITROGEN, TOTAL AS N										x									
99100	NUSTAR					x														
00552	OIL & GREASE HEXANE EXTRACT			x		x		x				x		x	x					
00340	OXYGEN DEMAND, CHEMICAL			x	x	x		x				x		x						
00343	OXYGEN DEMAND, TOTAL											x		x						
00300	OXYGEN, DISSOLVED								x											
34452	P-CHLORO-M-CRESOL				x															
82416	PARAQUAT					x		x												
39513	PCB, PARTS PER BILLION							x											x	x
39032	PENTACHLOROPHENOL			x	x	x						x								
00400	PH																			
34461	PHENATHRENE, TOTAL			x	x	x						x		x						
34694	PHENOL LOADING											x		x						
32730	PHENOLS, TOTAL			x	x	x		x				x		x	x					
00665	PHOSPHATE AS PHOSPHORUS			x		x		x			x	x		x						
00937	POTASSIUM, TOTAL										x									
34469	PYRENE				x							x		x						
83012	RAINFALL, TOTAL IN/MO																	x		
01147	SELENIUM, TOTAL			x	x	x														
01077	SILVER, TOTAL			x	x	x						x		x						
39938	SODIUM SALT OF ACIFLUOROFEN					x														
70295	SOLIDS, TOTAL DISSOLVED			x		x		x				x		x						
00530	SOLIDS, TOTAL SUSPENDED			x	x	x	x	x				x	x	x						
81708	STYRENE, TOTAL					x														
00945	SULFATE			x		x								x						
00745	SULFIDE			x				x				x		x	x					
00010	TEMPERATURE																			
38884	TERBACIL					x														
34475	TETRACHLOROETHYLENE			x	x	x		x				x		x						
99000	TEX. DEPT. HEALTH CERT. NO.	x	x																	
01059	THALLIUM, TOTAL				x															
34010	TOLUENE			x	x	x		x				x		x						
39400	TOXAPHEN					x														
34485	TRICHLOROETHYLENE			x	x	x						x		x						
50049	WASTEWATER BYPASSED																			
81551	XYLENE, TOTAL			x				x				x		x						
01092	ZINC, TOTAL			x	x	x		x				x		x						

Table 3.3 - Effluent Parameter Code Prefix and Suffix Match

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Galveston Bay National Estuary Program

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00640	INORGANIC NITROGEN, TOTAL																		
01045	IRON, TOTAL																		
34408	ISOPHORONE																		
01051	LEAD, TOT																		
39530	MALATHION																		
01055	MANGANESE, TOTAL																		
71900	MERCURY, TOTAL																		
39051	METHOMYL																		
34413	METHYL BROMIDE																		
34418	METHYL CHLORIDE																		
34423	METHYLENE CHLORIDE																		
45097	METHYLSTYRENE, ALPHA																		
34428	N-NITROSODI-N-PROPYLAMINE																		
34438	N-NITROSODIMETHYLAMINE																		
34443	N-NITROSODIPHENYLAMINE																		
39250	NAPHTHALENE																		
01067	NICKEL, TOTAL																		
34447	NITROBENZENE																		
00610	NITROGEN, TOTAL AMMONIA AS N																		
00612	NITROGEN, TOT AMMONIA WINTER																		
00614	NITROGEN, TOT AMMONIA, SUMMER																		
00625	NITROGEN, TOT KJELD-N																		
00629	NITROGEN, TOT. ORGANIC (KJEL)																		
00600	NITROGEN, TOTAL AS N																		
99100	NUSTAR																		
00552	OIL & GREASE HEXANE EXTRACT																		
00340	OXYGEN DEMAND, CHEMICAL																		
00343	OXYGEN DEMAND, TOTAL																		
00300	OXYGEN, DISSOLVED																		
34452	P-CHLORO-M-CRESOL																		
82416	PARAQUAT																		
39513	PCB, PARTS PER BILLION																		
39032	PENTACHLOROPHENOL																		
00400	PH						x	x											
34461	PHENATHRENE, TOTAL																		
34694	PHENOL LOADING																		
32730	PHENOLS, TOTAL																		
00665	PHOSPHATE AS PHOSPHORUS																		
00937	POTASSIUM, TOTAL																		
34469	PYRENE																		
83012	RAINFALL, TOTAL IN/MO																		
01147	SELENIUM, TOTAL																		
01077	SILVER, TOTAL																		
39938	SODIUM SALT OF ACIFLUOROFEN																		
70295	SOLIDS, TOTAL DISSOLVED																		
00530	SOLIDS, TOTAL SUSPENDED																		
81708	STYRENE, TOTAL																		
00945	SULFATE																		
00745	SULFIDE																		
00010	TEMPERATURE															x	x	x	x
38884	TERBACIL																		
34475	TETRACHLOROETHYLENE																		
99000	TEX. DEPT. HEALTH CERT. NO.																		
01059	THALLIUM, TOTAL																		
34010	TOLUENE																		
39400	TOXAPHEN																		
34485	TRICHLOROETHYLENE																		
50049	WASTEWATER BYPASSED											x							
81551	XYLENE, TOTAL																		
01092	ZINC, TOTAL																		

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 μg/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).

SIC information for each discharger as well as information on the source of the wastewater from within each discharger were obtained from the TWC on microfiche. The Source of Wastewater Codes (see Table 3.5) used by the TWC 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 TWC information into the database, it was found that as many as five SIC codes and eight Source of Wastewater Codes were listed for some dischargers effluents (individual pipes really). (Some errors in SIC codes were also found which were brought to the TWC's attention.) 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

Table 3.4 - Typical Pollutant Concentrations from Pacheco et al. (1990)

Point Source Characterization Project
Galveston Bay National Estuary Program

NCPDI Code	NCPDI Code Category Name	Subname	BOD_5 (mg/L)	TSS (mg/L)	Total N (mg/L)	Total P (mg/L)	Fecal Coli. Bact. (col./L)	Total As (mg/L)	Cd (mg/L)	Cr (mg/L)	Cu (mg/L)	Fe (mg/L)	Pb (mg/L)	Hg (mg/L)	Zn (mg/L)	Oil & Grease (mg/L)	PCBs (mg/L)	Chlor. Hydro-carbons Pest. (mg/L)	Spec. Disch. Act. Code
1	ASBESTOS		16.0	26.0															
2	BAKERY PRODUCTS		8.0	12.0	2.4											1.600			
3	BATTERY MFG			125.4				1.000	0.001	9.000	0.400	0.080	1.500	0.16020	44.500	7.200			
4	BEVERAGE PRODUCTS	Beverages	219.6	34.2	16.8											4.500			
5	BEVERAGE PRODUCTS	Soft Drinks	70.0	40.0	8.6	4.0													
6	CANNED & PRESERVED FRUITS & VEGETABLES		116.0	246.0															P
6	CANNED & PRESERVED FRUITS & VEGETABLES																		Q
6	CANNED & PRESERVED FRUITS & VEGETABLES																		T
7	CANNED & PRESERVED SEAFOOD PRODUCTS	Seafood	417.4	213.1	22.6														V
7	CANNED & PRESERVED SEAFOOD PRODUCTS	Seafood																	F
8	CANNED & PRESERVED SEAFOOD PRODUCTS	Shellfish	669.7	402.2	22.6														W
8	CANNED & PRESERVED SEAFOOD PRODUCTS	Shellfish																	Y
9	CANNED & PRESERVED SEAFOOD PRODUCTS	Finfish	380.7	180.7	22.6														X
9	CANNED & PRESERVED SEAFOOD PRODUCTS	Finfish																	Z
10	CAR WASHES		35.1	68.6		8.2					0.005					21.000			
11	CEMENT			27.7						0.002		0.200	0.080						
12	CHEMICAL PRODUCTS	Inorganic Chemicals		46.0	1.9			0.040	0.030	0.070	0.070	0.020	0.200	0.00180	0.200				
13	CHEMICAL PRODUCTS	Nitrogenous Fertilizers		8.7	4.4					0.010									
14	CHEMICAL PRODUCTS	Phosphatic Fertilizers		2.5		2.8				0.010					0.005				
15	CHEMICAL PRODUCTS	Organic Chemicals	23.6	47.7	33.4			0.030	0.003	0.700	0.100		0.030	0.00360	0.300	15.500			
16	CHEMICAL PRODUCTS	Adhesives & Sealants	3.1	4.2		0.2				0.500	1.000				1.000				
17	CHEMICAL PRODUCTS	Gum & Wood Chemicals	69.8	27.0				0.030		0.300	0.700		0.006		0.200				
18	CHEMICAL PRODUCTS	Pesticides	43.5	15.3							0.001							22.700	
19	CHEMICAL PRODUCTS	Pharmaceutical	83.0	108.0						0.050	0.090		0.050	0.00030	0.300				
20	CHEMICAL PRODUCTS	Soaps & Detergents	2.0	1.9						0.050	0.020		0.007		0.030				
21	CONCRETE			8.5															
22	CLAY PRODUCTS	Structural Clay Products	14.0	25.0					0.020			1.700							
23	CLAY PRODUCTS	Pottery & Related Products	21.0	33.0					0.060	0.020		0.600	0.900		0.240				
24	DAIRY PRODUCTS		38.6	49.0	36.5	33.3													
25	EDIBLE OILS		45.3	47.8															
26	ELECTRICAL PRODUCTS	Electrical & Electronic Compon	21.4	10.9	7.3	1.0		0.030	0.050	0.090	0.200	0.300	0.100	0.00070	0.200				
27	ELECTRICAL PRODUCTS	Power Transformers	15.5	11.0					0.030	0.030	0.100		0.400		0.100		10.000		
28	FEEDLOTS		90.0	178.6	28.5	41.0													
29	FISH HATCHERIES		4.8	6.0	0.7	0.1													
30	FOUNDRIES			34.0	6.3			0.003	0.004	0.001	0.050	1.200	0.700		1.900				
31	FOOD & BEVERAGES (MISC)		44.1	48.0	17.9	6.7													
32	GLASS MFG		11.7	15.1		1.0		0.080	0.200	0.030	0.300	1.200	0.070		0.100				
33	GRAIN PROCESSING		17.1	21.6	39.9	19.5													
34	HOSPITALS		15.0	20.0	33.4	11.7				0.040	0.400	2.000		0.00530					
35	IRON & STEEL			12.3	2.9			0.020	0.010	0.020	0.020	0.100	0.040		0.100				
36	LAUNDRIES		122.9	79.5		2.7													
37	LEATHER TANNING		33.0	56.0	48.8					4.800	0.030		0.050	0.00030	0.100				
38	METAL FINISHING	Finishing		11.2					0.100	0.600	0.800		0.200		0.500				
39	METAL FINISHING	Coil Coating		48.4		2.5			0.050	1.200	0.007	2.600	0.040		5.700	18.100			
40	METAL FINISHING	Can Making		12.0		4.1		0.500	0.080	0.080	0.600	0.400	0.100	0.06000	0.300	10.000			
41	MACHINERY	Instruments	6.9	11.2	5.9	1.3		0.100	0.030	0.200	0.300	0.500	0.100	0.01000	0.400	5.900			
42	MACHINERY		10.1	10.0	3.0	0.9		0.0004	0.010	0.070	0.100	0.500	0.010	0.00200	0.100	4.300			
43	MISCELLANEOUS MANUFACTURING	Miscellaneous Manufacturing	8.9	7.0	25.8	0.6		0.200	0.020	0.100	1.500	0.300	0.070	0.00300	0.300	3.500			
44	SHIPBUILDING	Shipbuilding		26.7				0.060	0.070	0.100	0.200	3.400	0.090	0.01700	0.300	2.200			
45	TRANSPORTATION EQUIPMENT	Transporation Equipment	12.6	11.9	3.6	0.7		0.010	0.050	0.030	0.100	0.800	0.100	0.00100	0.200	3.400			
46	MINERAL MINING			9.0								0.400							
47	MISCELLANEOUS INDUSTRIAL, COMMERCIAL		23.9	22.1	11.2	7.0	2,000	0.003	0.001	0.040	0.040	0.700	0.050	0.00030	0.100	11.200			
48	NONFERROUS METALS	Primary Nonferrous Metals		26.7	8.5			0.040	0.020	0.050	0.100		0.070		0.050	7.000			
49	NONFERROUS METALS	Primary Zinc		1.1				0.500	0.080	0.080	0.600		0.100		0.300				
50	NONFERROUS METALS	Secondary Nonferrous Metals		126.3				0.300	0.090	0.060	0.200		1.700		0.500	0.300			
51	NONFERROUS METALS	Nonferrous Metal Forming		15.5	52.1				0.100	0.100	0.700	0.500	0.100		0.500	10.000			
52	NONFERROUS METALS	Aluminum Forming		34.4					0.002	3.300	9.000		0.030		8.100	34.600			
53	NONFERROUS METALS	Copper Forming		12.0		2.1			0.080	0.080	0.600	0.400	0.100		3.000	10.000			
54	ORE MINING AND DRESSING			5.0				0.500	0.005	0.050	0.030	0.500	0.070	0.00100	0.400				
55	PAVING AND ROOFING		9.5	40.0	0.1			0.002	0.100	0.200	0.100	0.600	1.000	0.00090	0.200	19.500			
56	PETROLEUM REFINING		13.5	26.1	6.8					0.100	0.010		0.005	0.00090	0.100	17.100			

Table 3.4 - Typical Pollutant Concentrations from Pacheco et al. (1990)

Point Source Characterization Project
Galveston Bay National Estuary Program

NCPDI Code	NCPDI Code Category Name	Subname	BOD_5 (mg/L)	TSS (mg/L)	Total N (mg/L)	Total P (mg/L)	Fecal Coli. Bact. (col./L)	Total As (mg/L)	Cd (mg/L)	Cr (mg/L)	Cu (mg/L)	Fe (mg/L)	Pb (mg/L)	Hg (mg/L)	Zn (mg/L)	Oil & Grease (mg/L)	PCBs (mg/L)	Chlor. Hydro-carbons Pest. (mg/L)	Spec. Disch. Act. Code
57	PHOTOGRAPHIC PROCESSING		143.1	5.9	21.0				0.050	0.050		6.700	0.080						
58	PLASTICS MOLDING & FORMING		11.7	86.4	0.2	1.1			0.006	0.020	0.006	0.300	0.090		0.080	7.500		1.600	
59	PORCELAIN ENAMELING			12.0		4.1		0.200	0.080	0.080	0.600	0.400	0.100		0.300	10.000			
60	PRINTING & PUBLISHING		6.0	3.5	7.6			0.006		0.400	0.200		0.800		2.900	7.000			
61	PULP AND PAPER		17.3	28.4	1.4					0.030	0.010		0.010	0.00010	0.200				
62	RENDERING		44.1	58.8	10.8	2.9	4,000												
63	RUBBER PROCESSING		33.0	40.0									0.010		0.400	15.000			
64	TIRE & INNER TUBE		7.2	40.0												10.000			
65	STEAM ELECTRIC	Non-Cooling Flows		30.0				0.070	0.009	0.060	0.090	0.800	0.010	0.00120	0.700	15.000			E
65	STEAM ELECTRIC	Non-Cooling Flows														15.000			P
65	STEAM ELECTRIC	Non-Cooling Flows														15.000			N
68	SUGAR PRODUCTS	Beet Sugar	68.5	478.0															
69	SUGAR PRODUCTS	Cane Sugar	57.0	180.3															
70	TEXTILE MFG	General Textile Mfg	22.4	49.1				0.020	0.003	0.060	0.060		0.060	0.00080	0.500	26.300			
71	TEXTILE MFG	Wool Scouring	50.0	230.1				0.040	0.030	0.040	0.080		0.900	0.00100	0.300	190.000			
72	TEXTILE MFG	Wool Finishing	25.0	60.0				0.020	0.006	0.400	0.020		0.100		2.300				
73	TEXTILE MFG	Low Water Use Textile Processi	30.4	88.0					0.005	0.010	0.040		0.080		2.300				
74	TEXTILE MFG	Woven Fabric Finishing	22.0	48.7				0.020	0.002	0.020	0.060		0.040	0.00080	0.400	14.000			
75	TEXTILE MFG	Knit Fabric Finishing	23.6	41.0				0.020	0.005	0.100	0.100		0.040	0.00140	0.300	21.000			
76	TEXTILE MFG	Carpet Finishing	35.0	65.0					0.004	0.200	0.040		0.030		0.200	6.000			
77	TEXTILE MFG	Stock and Yarn	10.0	25.0				0.006	0.005	0.070	0.090		0.080	0.00100	0.300	90.000			
78	TEXTILE MFG	Nonwoven mfg	35.0	65.0					0.004	0.200	0.040		0.030		0.200	4.800			
79	TEXTILE MFG	Felted Fabric	25.0	60.0						0.040			0.050			2.400			
80	TIMBER PRODUCTS	Sawmills	38.7	31.8						1.000	0.100		0.040		0.500	9.800			
81	TIMBER PRODUCTS	Plywood	20.0	33.5												15.000			
82	TRANSPORTATION	Railroads	17.4	19.9						0.200						10.200			
83	TRANSPORTATION	Trucking	22.3	19.9						0.200						10.400			
84	RESIDENTIALS	Residentials	113.9	156.8	14.2	10.0	2,000,000	0.005	0.002		0.072	1.300	0.097	0.0004	0.214	27.600			
98	RESIDENTIALS	Water Supply Treatment Plants		35.0															A
98	RESIDENTIALS	Water Supply Treatment Plants		50.0								50.000							F
99	RESIDENTIALS	Sewerage Systems	207.3	209.1	15.1	13.0	50,000,000	0.034	0.054	0.234	0.224	6.300	0.116	0.0007	0.869	50.700		0.001	U
99	RESIDENTIALS	Sewerage Systems	158.3	114.4	15.1	13.0	200,000	0.034	0.054	0.092	0.146	2.500	0.059	0.0006	0.502	27.600		0.001	P
99	RESIDENTIALS	Sewerage Systems	23.9	22.1	11.2	7.0	2,000	0.032	0.011	0.043	0.037	0.700	0.045	0.0003	0.165	11.200		0.001	S
99	RESIDENTIALS	Sewerage Systems	23.9	22.1	11.2	7.0	2,000	0.032	0.011	0.043	0.037	0.700	0.045	0.00030	0.165	11.200		0.001	T
100	COOLING WATER	Recycled Cooling		30.0				0.002	0.010	0.050	0.050	0.500	0.060	0.0004	0.080	0.060			R
100	COOLING WATER	Once Through Cooling									0.002								C

Table 3.5 - Texas Water Commission Source of Wastewater Codes

Point Source Characterization Project
Galveston Bay National Estuary Program

Code	Source Name
01	Treated Domestic Sewage Effluent
02	Septic Tank Waste
03	Potable Water Treatment Plant Waste
04	Cooling Water
05	Boiler Blowdown
06	Cooling Tower Blowdown
07	Process Water
08	Storm Water - Rainwater Runoff, except from animal confinement (See No. 14)
09	Lake Overflow
10	Demineralizer Backwash (Regeneration and/or Reverse Osmosis
11	Wash-down Water (Periodic cleanup wastewater such as washing down equipment, process rooms, etc. (See No. 22)
12	Salt Water Brine
13	Industrial Waste Chemicals
14	runoff from Animal and Poultry Confinement Areas
15	Land Fill Runoff
16	Raw Sewage
17	Wastewater from Air Pollution Control Stack Scrubbers (Quench Water)
18	Ship Ballast Water
19	Sump Drain
20	River or Lake Water, Ocean
21	Other
22	Washwater (Washwater which is an integral part of production such as ore washing, vegetable washing, gravel washing, etc.)
23	Filter Backwash Water
24	Heating Water
25	Metal Cleaning Wastewater
26	Ash Transport Water
27	Aquifer Restoration
28	Ground Water
29	Low Volume Wastewater
30	Steam Condensate/Air Conditioning

Source: Texas Water Commission (Revised 4/7/86) or decreased had it been possible to assign exact portions of the waste discharge to particular codes. None of the 472 permitted municipal discharges had multiple source codes, so they were confined to the 521 permitted industrial dischargers of which 266 were industrial process wastewater, 255 were stormwater and some 51 represented monitoring points within the process flow train leaving a total of 215 industrial process waste discharges to the Galveston Bay system. 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 Permitted Industrial Process Discharges Having Indicated Number of Source Codes (%)	Proportion of Total Permitted Dischargers Having Indicated Number of Source Codes (%)
1	28.4	77.6
2	30.7	9.6
3	17.2	5.4
4	13.5	4.2
5	7.9	2.5
6	1.4	0.4
7	0.1	0.3
8	0	0

Thus, over 77 percent of all municipal and industrial process dischargers were characterized by one source code and just under 90 percent were characterized by two. The remaining 10 percent had from three to seven source codes. About 22 percent of all discharges (just over 70 percent of industrial dischargers) had multiple source codes. For over 77 percent of the permitted point source dischargers to Galveston 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 22 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.

There was also some difficulty determining exactly which dischargers were still permitted to discharge. For example, the self-reporting data obtained from the TWC for 1990 had entries for about 60 dischargers which were no longer permitted for one reason or another, and the database had to be updated to reflect that. 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, but for industrial dischargers they were not. In each case, the Commission staff was consulted to determine what the correct flow should be.

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 Galveston 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. For BOD_5 loadings from industrial discharges, the comparison of estimated to reported loadings using TPCs is shown in Fig. 3.6. As can be seen, the estimated loads are almost always higher than those actually reported indicating that the typical BOD_5 concentrations for the industries represented in the Galveston Bay area were too high and did not represent current treatment practice. Calculating individual ratios of estimated to reported loads and eliminating ratios that were more than three standard deviations away from the first mean calculated, the final mean ratio was 4.90; that is, the estimated loads with TPCs were 4.90 times higher than those actually reported. For municipal discharges the difference was even greater (see Figure 3.7) and the final mean ratio between estimated and reported loads was 8.71. Other ratios calculated for TSS, Oil and Grease, and the metals arsenic, cadmium, chromium, copper, lead, mercury, and zinc are given in Table 3.6. 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 in dischargers reporting some metals was so few that the ratio for those metals could not be determined directly. An estimated ratio was used which was the average ratio for those metals for which ratios could be determined. Undoubtedly, the ratios determined with this procedure should not have been applied across the board to every discharger as the TPCs for some dischargers would still be appropriate. However, in the absence of any current refinement of the procedure, the across-the-board methodology was employed. While this methodology was believed to produce a more accurate overall estimate of loading, it was not possible to estimate the error between this estimate and the true loading of constituents to the Bay system.

The final tables of loading estimates produced using this methodology show load estimates for individual dischargers within the 37 water quality segments (actually only the 32 segments for which there were permitted municipal or industrial process wastewater discharges are listed in these particular tables) 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

Fig. 3.6 - Estimated vs. Reported Industrial Loading of BOD_5 into Galveston Bay in 1990

Point Source Characterization Project
Galveston Bay National Estuary Program

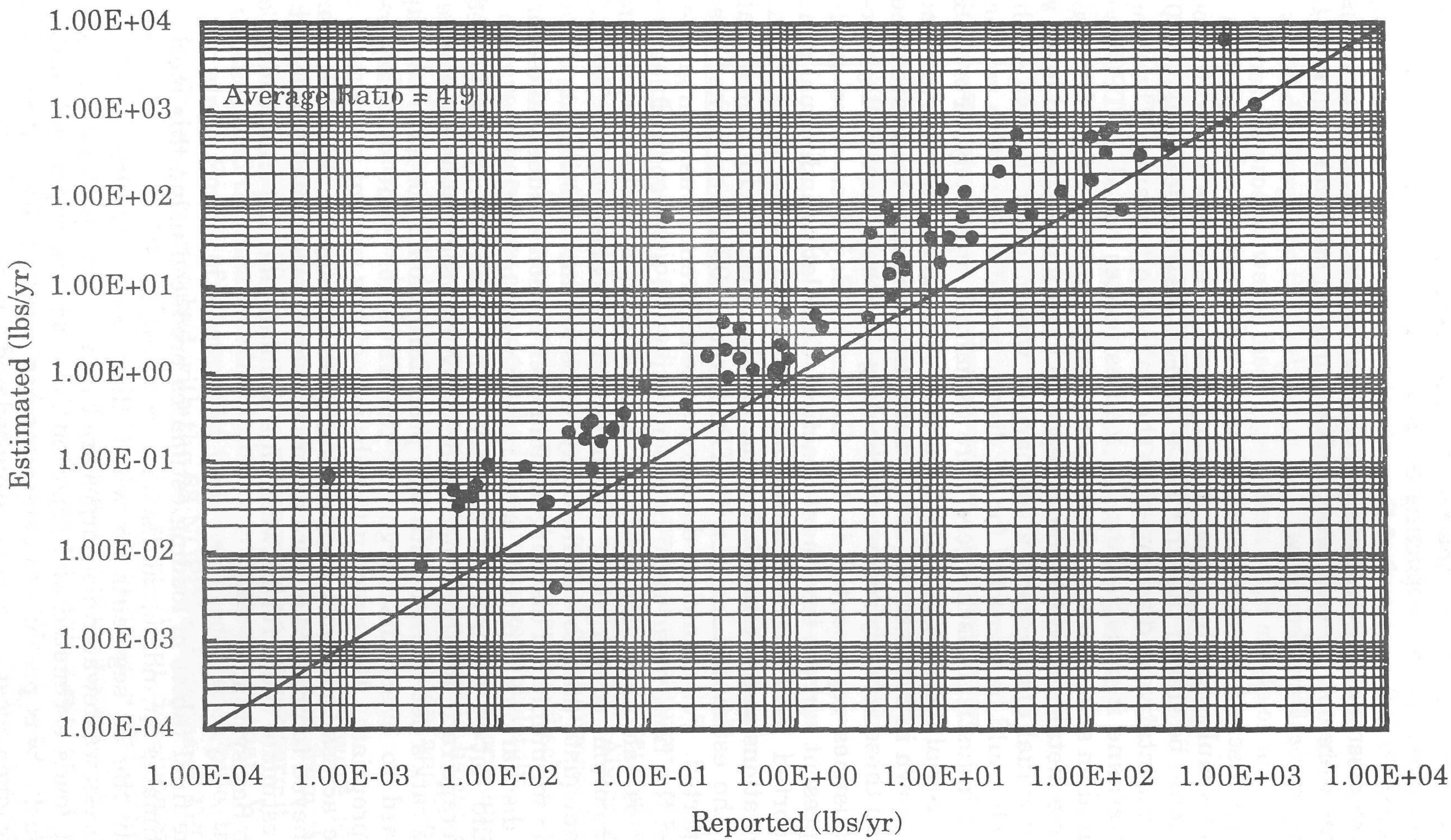


Fig. 3.7 - Estimated vs. Reported Municipal Loading of BOD_5 into Galveston Bay in 1990

Point Source Characterization Project
Galveston Bay National Estuary Program

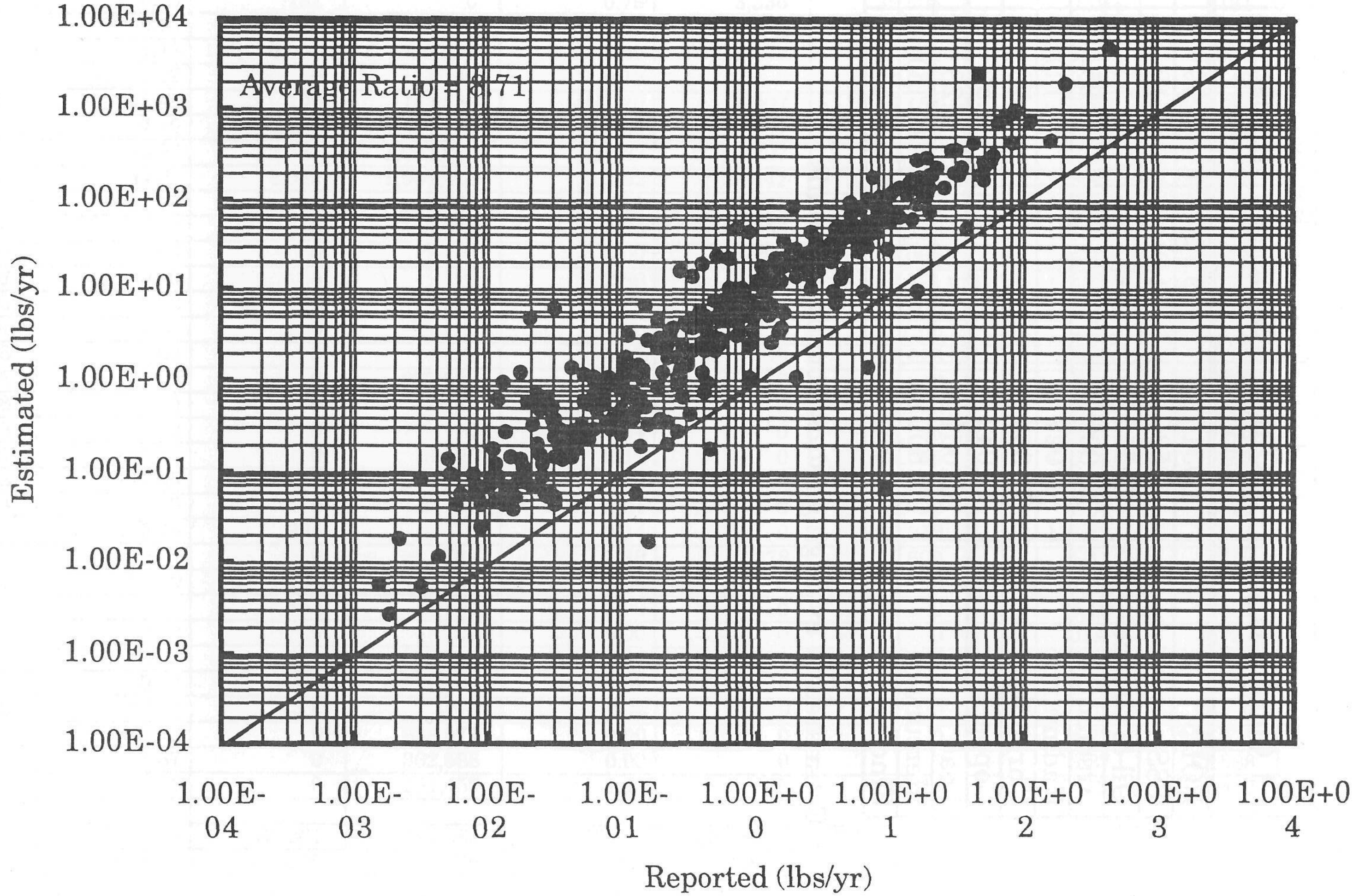


Table 3.6 - Ratios Used to Correct Typical Pollutant Concentrations from Experience with Galveston Bay System Dischargers

Point Source Characterization Project
Galveston Bay National Estuary Program

Constituent	STORET Code	Ratios		Maximum TPCs (mg/L)
		Municipal	Industrial	
BOD5	00310	8.71	4.90	
TSS	00530	1.0	2.10	
Oil & Grease	00552	-	7.15	
Arsenic	01002	-	1.25	0.2336
Cadmium	01027	-	(2.11)*	0.0715
Chromium	01034	-	2.70	0.5604
Copper	01042	-	1.52	0.0288
Lead	01051	-	2.28	0.1612
Mercury	71900	-	(2.11)*	0.0033
Zinc	01092	-	(2.11)*	0.2492

* Estimated by averaging ratios from other metals

Table 3.7 - Example of Effluent Load Summary for Loads of Pollutants into Galveston Bay in 1990

Point Source Load Characterization Project
Galveston Bay National Estuary Program

Stream Segment	Actual Average Industrial Flow (MG/yr)	Estimated Industrial Load With TPC (kg/yr)	Measured Industrial Load (kg/yr)	Actual Average Municipal Flow (MG/yr)	Estimated Municipal Load With TPC (kg/yr)	Measured Municipal Load (kg/yr)	Total Flow (MG/yr)	Total Industrial Load (kg/yr)	Total Municipal Load (kg/yr)	Total Load (kg/yr)
0801	0.00	181	0	0.79	3,536	35,605	0.79	181	39,141	39,322
0802	0.05	344	0	0.30	0	40,716	0.35	344	40,716	41,061
0901	1.18	6,055	39,827	0.89	70	55,432	2.08	45,882	55,502	101,384
0902	0.19	0	11,140	0.12	0	3,266	0.31	11,140	3,266	14,406
1001	2.41	106	141,588	1.20	2,907	45,154	3.60	141,694	48,061	189,754
1005	7.70	6,259	1,391,137	0.00	1	0	7.70	1,397,396	1	1,397,397
1006	45.97	12,327	1,663,915	17.87	66,307	363,256	63.84	1,676,243	429,564	2,105,806
1007	44.96	4,523	1,904,476	75.92	38,242	1,369,321	120.88	1,908,999	1,407,563	3,316,562
1013	0.01	0	1,065	6.62	95,141	61,690	6.63	1,066	156,831	157,897
1014	0.07	5	3,378	11.25	89,058	133,719	11.31	3,382	222,776	226,158
1101	0.00	0	0	3.00	33,739	27,067	3.00	0	60,806	60,806
1102	0.00	0	0	2.89	1,253	72,521	2.89	0	73,774	73,774
1103	0.02	0	2,974	0.98	0	45,909	1.00	2,974	45,909	48,882
1104	0.00	0	0	0.07	0	1,310	0.07	0	1,310	1,310
1105	0.00	0	0	0.12	0	9,026	0.12	0	9,026	9,026
1107	3.03	0	233,739	0.01	0	612	3.04	233,739	612	234,351
1108	0.00	0	30	0.02	0	1,029	0.02	30	1,029	1,059
1113	0.00	0	0	2.24	0	39,325	2.24	0	39,325	39,325
2421	434.46	0	3,993	2.12	0	71,264	436.58	3,993	71,264	75,257
2422	417.45	0	0	0.19	0	5,983	417.65	0	5,983	5,983
2424	0.00	0	95	2.04	0	52,723	2.04	95	52,723	52,818
2425	115.28	995	0	0.14	0	2,018	115.42	995	2,018	3,013
2426	0.01	0	789	1.39	2,078	52,608	1.41	789	54,686	55,475
2427	61.49	1,104	125,324	0.00	0	0	61.49	126,428	0	126,428
2429	0.10	461	0	0.00	0	0	0.10	461	0	461
2430	0.00	0	727	0.00	0	0	0.00	727	0	727
2431	0.08	0	5,546	2.26	0	161,536	2.34	5,546	161,536	167,082
2432	0.00	0	0	0.99	0	33,396	0.99	0	33,396	33,396
2436	0.00	0	0	0.02	479	0	0.02	0	479	479
2437	4.72	0	998,577	0.00	0	0	4.72	998,577	0	998,577
2438	3.87	0	362,588	0.00	0	0	3.87	362,588	0	362,588
2439	33.22	0	261,457	1.44	0	59,341	34.66	261,457	59,341	320,799
Totals	1,176.28	32,361	7,152,365	134.87	332,810	2,743,826	1,311.15	7,184,726	3,076,636	10,261,362
	89.71%	0.45%	99.55%	10.29%	10.82%	89.18%		70.02%	29.98%	

Note that Water Quality Segments 2423, 2428, 2433, 2434, and 2435 have no permitted discharges to them and are not included 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.

To estimate future loadings of metals after third-round effluent permitting is complete and effluent limits have been set for appropriate constituents, a procedure used by the TWC (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 here. 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. Because violations are determined at the edges of the zone of initial dilution and the mixing zone, some dilution is assumed to occur between the discharge point and edges of these zones. The TWC established dilutions to be used for discharges to streams, lakes, and estuarine/marine waters; the only receiving water used here was estuarine/marine which includes all of the Galveston Bay and Houston Ship Channel but does not include tributaries and streams. The assumption was that all permitted municipal and industrial process wastewaters were discharged directly to estuarine/marine waters; for those discharges to streams and lakes, the procedure underestimates or estimates depending on the magnitude of the freshwater acute and chronic criteria compared to those for marine waters. The TWC uses the magnitude of dilution for discharges as 30 percent at the edge of the zone of initial dilution and 8 percent at the edge of the mixing zone for aquatic life protection; that is, 30 percent and 8 percent of the wastewater would remain at the edges of these zones, respectively. These fractions of wastewater in receiving water are then used to calculate the concentrations that metal could have at the edge of the zone of initial dilution and at the edge of the mixing zone. Allowable long term average concentrations in the effluents are then calculated using the equations prescribed by the TWC (1992). Now, the surface water standard for metals is given in the dissolved metal form, and, to be able to calculate allowable effluent concentrations that are comparable to those required to be reported by dischargers, the dissolved metal form must be converted to the total metal form. Again, the Commission prescribes a procedure for doing this based on the partition coefficient for the metal and the TSS concentration in the receiving water. Partition coefficients are given in the TWC (1992) implementation procedure document. In addition, surface water quality standards for metals are given for acute and chronic conditions, and the more restrictive of the two applies. Thus, the procedure entails calculating total metal concentrations for acute and chronic standards, estimating the allowable effluent concentrations for each, and selecting the more restrictive as the effluent limit to be met. A table summarizing these calculations is given in Table 3.8 along with the daily average concentrations used here to estimate future loads.

As an example of this procedure for estimating effluent limits under third round permitting, the marine acute criteria for dissolved copper is 16.3 μg/L while that for the chronic criterion is 4.4 μg/L. To derive the waste load allocation concentration for these two criteria for copper, the following equations are used (TWC, 1992):

$$WLA_a = \frac{\text{Acute Criteria}}{\text{(Fraction Dissolved)(\% effluent @ ZID)}} \quad (3.1)$$

and

$$WLA_c = \frac{\text{Chronic Criteria}}{\text{(Fraction Dissolved)(\% Effluent @ MZ)}} \quad (3.2)$$

where:

WLA_a	=	acute waste load allocation concentration (μg/l)
WLA_c	=	chronic waste load allocation concentration (μg/L)
Acute Criteria	=	marine acute criterion from TWC Surface Water Quality Criteria (μg/L)
Chronic Criteria	=	marine acute criterion from TWC Surface Water Quality Criteria (μg/L)
Fraction Dissolved	=	fraction of metal in dissolved form based on partition coefficient and TSS concentration (in mg/L) in ambient waters
% Effluent	=	fraction of wastewater in receiving water assumed to exist at the edge of the zone of initial dilution (ZID) (0.30) for acute conditions and at the edge of the mixing zone (MZ) (0.08) for chronic conditions.

The fraction of metal in the dissolved form is determined by the equation (Thomann and Mueller, 1987):

$$f_d = \frac{1}{1+\P m} \quad (3.3)$$

in which ¶ is the partition coefficient (L/kg) and m is the TSS concentration (mg/L). For metals in marine waters, the method of calculating partition coefficients developed by Benoit and Santschi (1991) is used in which:

$$\P = K_{po}\, m^a \quad (3.4)$$

where ¶ is in units of L/kg and K_{po} and a are given as the intercept and slope, respectively, of a line representing the partition coefficient on a graph of log TSS (x axis) vs. log ¶ (y axis). For copper, the values of K_{po} and a are 4.845 and -0.72, respectively, so that:

$¶_{copper} = 10^{4.845}\ m^{-0.72}$.

For a TSS concentration of 8 mg/L, the partition coefficient for copper would be:

$$¶_{copper} = 10^{4.845}\ 8^{-0.72}$$

or

$$¶_{copper} = (70{,}000)(0.224)$$

$$= 15{,}680$$

Now ¶m is calculated as (15,680 L/kg)(8 mg/L)(10^{-6} kg/mg) or 0.125, and the fraction of copper dissolved at this TSS concentration is 1/(1+0.125) or 0.8885. Thus, to get the total copper criteria, one would divide the acute and chronic criteria by 0.8885. Finally, to calculate the WLA concentrations, one would divide the total copper criteria by 0.30 or 0.08, as appropriate, to obtain the acute and chronic values. In Table 3.8, these values for copper are 61.3 µg/L and 61.7 µg/L, respectively.

Substituting these limits into the long term average (LTA) equations from TWC (1992) gives an LTA_a value of 19.6 µg/L and an LTA_c of 37.6 µg/L, or:

$$LTA_a = 0.32 \times WLAa = 0.32 \times 61.3\ \mu g/L = 19.6\ \mu g/L$$

$$LTA_c = 0.61 \times WLAc = 0.61 \times 61.7\ \mu g/L = 37.6\ \mu g/L$$

Of these two values, the acute criterion is the more restrictive, so the Daily Average limit is based on the 19.6 µg/L and is calculated to be:

$$\text{Daily Average} = 1.47 \times LTA = 1.47 \times 19.6\ \mu g/L = 28.8\ \mu g/L.$$

The Daily Maximum value is similarly calculated as:

$$\text{Daily Maximum} = 3.11 \times LTA = 3.11 \times 19.6\ \mu g/L = 61.0\ \mu g/L.$$

Note that these limits apply to dischargers with ≤ 10 MGD effluent design flow; dischargers with flows higher than this are treated on a case by case basis (there were 23 dischargers with daily average flows > 10.0 MGD in 1990). In addition, the 70 percent and 85 percent of long term average concentrations are those values used by the TWC to determine if effluents limits or monitoring of the effluent may be needed. Dischargers with monitoring data showing average concentrations of these metals within 85 percent of the long term average will have limits for that metal added to their permit. Dischargers with metal concentration averages < 85 percent but more than 70 percent of the long term average will have monitoring for that

Table 3.8 - Determination of Allowable Concentrations of Metals in Effluents Discharging into Marine and Estuarine Waters

Point Source Characterization Project
Galveston Bay National Estuary Program

SURFACE WATER QUALITY CRITERIA

Metal	Partition Coefficient Coef.	Partition Coefficient Exponent	Marine Acute Criteria Dissolved Metal Form (µg/L)	Marine Chronic Criteria Dissolved Metal Form (µg/L)	Marine Acute Criteria Total Metal Form (µg/L)	Marine Chronic Criteria Total Metal Form (µg/L)
Aluminum	0	0.00	-	-	-	-
Arsenic	0	0.00	149.0	78.0	149.0	78.0
Cadmium	0	0.00	45.6	10.0	45.6	10.0
Chromium (Tri)	0	0.00	-	-	-	-
Chromium (Hex)	0	0.00	1,100.0	50.0	1,100.0	50.0
Copper	4.86	-0.72	16.3	4.4	18.4	4.9
Cyanide	0	0.00	5.6	5.6	5.6	5.6
Lead	6.06	-0.85	140.0	5.6	359.6	14.4
Mercury	0	0.00	2.1	0.9	2.1	0.9
Nickel	0	0.00	119.0	13.2	119.0	13.2
Selenium	0	0.00	564.0	136.0	564.0	136.0
Silver	5.86	-0.74	6.6	0.8	14.9	1.9
Zinc	5.36	-0.52	98.0	89.0	158.9	144.3

WASTELOAD ALLOCATION CONCENTRATIONS

Metal	WLAa (µg/L)	WLAc (µg/L)	Back-ground (µg/L)	MAL (µg/L)	LTAa (µg/L)	LTAc (µg/L)	Limiting LTA (µg/L)	Daily Average (µg/L)	Daily Max. (µg/L)
Aluminum	-	-	0		-	-	-	-	-
Arsenic	496.7	975.0	0	10	158.9	594.8	158.9	233.6	494.3
Cadmium	152.1	125.3	0	1	48.7	76.4	48.7	71.5	151.3
Chromium (Tri)	-	-	0	10	-	-	-	-	-
Chromium (Hex)	3,666.7	625.0	0	10	1,173.3	381.3	381.3	560.4	1,185.7
Copper	61.3	61.7	0	10	19.6	37.6	19.6	28.8	61.0
Cyanide (amenable)	18.7	70.0	0	20	6.0	42.7	6.0	8.8	18.6
Lead	1,198.6	179.8	0	5	383.6	109.7	109.7	161.2	341.1
Mercury	7.0	11.3	0	2	2.2	6.9	2.2	3.3	7.0
Nickel	396.7	165.0	0	10	126.9	100.7	100.7	148.0	313.0
Selenium	1,880.0	1,700.0	0	20	601.6	1,037.0	601.6	884.4	1,871.0
Silver	49.6	23.6	0	2	15.9	14.4	14.4	21.1	44.7
Zinc	529.7	1,804.0	0	0.5	169.5	1,100.4	169.5	249.2	527.2

Calculated using 0.30 dilution factor at edge of Zone of Initial Dilution and 0.08 dilution factor at edge of Mixing Zone and TSS = 8 mg/L

PERMIT LIMITS

Metal	70% Daily Average (µg/L)	85% Daily Average (µg/L)
Aluminum	-	-
Arsenic	163.5	198.6
Cadmium	50.1	60.8
Chromium (Tri)	-	-
Chromium (Hex)	392.3	476.4
Copper	20.2	24.5
Cyanide (amenable)	6.1	7.5
Lead	112.9	137.0
Mercury	2.3	2.8
Nickel	103.6	125.8
Selenium	619.1	751.7
Silver	14.8	18.0
Zinc	174.4	211.8

metal added to their permit. And dischargers with a metal average that is < 70 percent of the long term average concentration will have no additional requirements added to their permit for that metal. The concentrations of the metals for these 70 percent and 85 percent levels are also given in Table 3.8.

Similar calculations were done based on the human health criteria, for, according to TWC (1992), the more restrictive of the two LTA values is used to set the effluent limit. Of all the metals considered here, only lead was included in the TWC human health criteria, and, upon calculation of the LTA for lead based on human health, the value was over twice LTA based on aquatic organisms. Thus, the values given in Table 3.8 for aquatic organisms were used.

The TPCs listed in Table 3.4 were modified so that the largest concentration of a metal would equal the Daily Average concentration calculated in Table 3.8. TPCs less than this Daily Average were unchanged. A list of the final TPCs produced under these constraints is given in Table 3.9, and the maximum TPC values allowed for each metal are given in Table 3.6.

Finally, as assessment of the applicability of some of the TPCs was performed using metals data gathered in the summer of 1992. The EPA and TWC, working under a cooperative agreement, required sampling for total arsenic, total copper, total lead, total mercury, dissolved nickel, total silver, and total zinc as a prelude to the possible development of Total Maximum Daily Loads (TMDLs) for these metals. Sampling was required of a number of municipal and industrial dischargers. The raw data were made available by Dr. Lial Tischler (1993), and the data were keyboarded into an Excel file and processed as follows. Dischargers were matched with their SIC codes and Source of Wastewater Codes and then with the NCPDI categories described above. After aggregating the measured metals concentrations by SIC code, average values were calculated to produce TPC values. Further aggregation by NCPDI codes allowed calculation of TPCs for direct comparison to Pacheco et al. (1990). Results of this analysis is given in detail in Travers (1993) and are reported in the next chapter.

3.3 TRIBUTARY DATA

Loading of constituents into Galveston Bay from tributaries involved four main steps: data acquisition, data manipulation, loading calculations, and tabulations.

3.3.1 Data Acquisition

In estimating stream loading into Galveston Bay, eight U.S. Geological Survey (USGS) gauging stations were chosen in an effort to be as comprehensive as the available data would allow. These gauging stations were chosen for there location and their possession of extensive records of both water quality and flow. The gauges used and their drainage areas are listed in Table 3.10 and their locations (except for USGS gauge 08066500 for the Trinity River at Romayor) are shown on Figures 3.8 and 3.9. Lake Houston near Sheldon, TX. presented a special case which required a more complicated estimation of its water quality and flow over the

Table 3.9 - Typical Pollutant Concentrations Corrected to Meet Current Texas Surface Water Quality Criteria

Point Source Characterization Project
Galveston Bay National Estuary Program

NCPDI Code	NCPDI Code Category Name	Subname	BOD_5 (mg/L)	TSS (mg/L)	Total N (mg/L)	Total P (mg/L)	Fecal Coli. Bact. (col./L)	Total As (mg/L)	Cd (mg/L)	Cr (mg/L)	Cu (mg/L)	Fe (mg/L)	Pb (mg/L)	Hg (mg/L)	Zn (mg/L)	Oil & Grease (mg/L)	PCBs (mg/L)	Chlor. Hydro-carbons Pest. (mg/L)	Spec. Disch. Act. Code
1	ASBESTOS		16.0	26.0															
2	BAKERY PRODUCTS		8.0	12.0	2.4											1.6			
3	BATTERY MFG			125.4				0.164	0.001	0.392	0.020	0.080	0.113	0.0023	0.174	7.2			
4	BEVERAGE PRODUCTS	Beverages	219.6	34.2	16.8											4.5			
5	BEVERAGE PRODUCTS	Soft Drinks	70.0	40.0	8.6	4.0													
6	CANNED & PRESERVED FRUITS & VEGETABLES		116.0	246.0															P
6	CANNED & PRESERVED FRUITS & VEGETABLES																		Q
6	CANNED & PRESERVED FRUITS & VEGETABLES																		T
7	CANNED & PRESERVED SEAFOOD PRODUCTS	Seafood	417.4	213.1	22.6														V
7	CANNED & PRESERVED SEAFOOD PRODUCTS	Seafood																	F
8	CANNED & PRESERVED SEAFOOD PRODUCTS	Shellfish	669.7	402.2	22.6														W
8	CANNED & PRESERVED SEAFOOD PRODUCTS	Shellfish																	Y
9	CANNED & PRESERVED SEAFOOD PRODUCTS	Finfish	380.7	180.7	22.6														X
9	CANNED & PRESERVED SEAFOOD PRODUCTS	Finfish																	Z
10	CAR WASHES		35.1	68.6		8.2					0.005					21.0			
11	CEMENT			27.7						0.002		0.200	0.080						
12	CHEMICAL PRODUCTS	Inorganic Chemicals		46.0	1.9			0.040	0.030	0.070	0.020	0.020	0.113	0.0018	0.174				
13	CHEMICAL PRODUCTS	Nitrogenous Fertilizers		8.7	4.4					0.010									
14	CHEMICAL PRODUCTS	Phosphatic Fertilizers		2.5		2.8				0.010					0.005				
15	CHEMICAL PRODUCTS	Organic Chemicals	23.6	47.7	33.4			0.030	0.003	0.392	0.020		0.030	0.0023	0.174	15.5			
16	CHEMICAL PRODUCTS	Adhesives & Sealants	3.1	4.2		0.2				0.392	0.020				0.174				
17	CHEMICAL PRODUCTS	Gum & Wood Chemicals	69.8	27.0				0.030		0.300	0.020		0.006		0.174				
18	CHEMICAL PRODUCTS	Pesticides	43.5	15.3							0.001							22.7	
19	CHEMICAL PRODUCTS	Pharmaceutical	83.0	108.0						0.050	0.020		0.050	0.0003	0.174				
20	CHEMICAL PRODUCTS	Soaps & Detergents	2.0	1.9						0.050	0.020		0.007		0.030				
21	CONCRETE			8.5															
22	CLAY PRODUCTS	Structural Clay Products	14.0	25.0					0.020			1.700							
23	CLAY PRODUCTS	Pottery & Related Products	21.0	33.0					0.050	0.020		0.600	0.113		0.174				
24	DAIRY PRODUCTS		38.6	49.0	36.5	33.3													
25	EDIBLE OILS		45.3	47.8															
26	ELECTRICAL PRODUCTS	Electrical & Electronic Compon	21.4	10.9	7.3	1.0		0.030	0.050	0.090	0.020	0.300	0.100	0.0007	0.174				
27	ELECTRICAL PRODUCTS	Power Transformers	15.5	11.0					0.030	0.030	0.020		0.113		0.100		10.0		
28	FEEDLOTS		90.0	178.6	28.5	41.0													
29	FISH HATCHERIES		4.8	6.0	0.7	0.1													
30	FOUNDRIES			34.0	6.3			0.003	0.004	0.001	0.020	1.200	0.113		0.174				
31	FOOD & BEVERAGES (MISC)		44.1	48.0	17.9	6.7													
32	GLASS MFG		11.7	15.1		1.0		0.080	0.050	0.030	0.020	1.200	0.070		0.100				
33	GRAIN PROCESSING		17.1	21.6	39.9	19.5													
34	HOSPITALS		15.0	20.0	33.4	11.7				0.040	0.020	2.000		0.0023					
35	IRON & STEEL			12.3	2.9			0.020	0.010	0.020	0.020	0.100	0.040		0.100				
36	LAUNDRIES		122.9	79.5		2.7													
37	LEATHER TANNING		33.0	56.0	48.8					0.392	0.020		0.050	0.0003	0.100				
38	METAL FINISHING	Finishing		11.2					0.050	0.392	0.020		0.113		0.174				
39	METAL FINISHING	Coil Coating		48.4		2.5			0.050	0.392	0.007	2.600	0.040		0.174	18.1			
40	METAL FINISHING	Can Making		12.0		4.1		0.164	0.050	0.080	0.020	0.400	0.100	0.0023	0.174	10.0			
41	MACHINERY	Instruments	6.9	11.2	5.9	1.3		0.100	0.030	0.200	0.020	0.500	0.100	0.0023	0.174	5.9			
42	MACHINERY		10.1	10.0	3.0	0.9		0.000	0.010	0.070	0.020	0.500	0.010	0.0020	0.100	4.3			
43	MISCELLANEOUS MANUFACTURING	Miscellaneous Manufacturing	8.9	7.0	25.8	0.6		0.164	0.020	0.100	0.020	0.300	0.070	0.0023	0.174	3.5			
44	SHIPBUILDING	Shipbuilding		26.7				0.060	0.050	0.100	0.020	3.400	0.090	0.0017	0.174	2.2			
45	TRANSPORTATION EQUIPMENT	Transporation Equipment	12.6	11.9	3.6	0.7		0.010	0.050	0.030	0.020	0.800	0.100	0.0010	0.174	3.4			
46	MINERAL MINING			9.0								0.400							
47	MISCELLANEOUS INDUSTRIAL, COMMERCIAL		23.9	22.1	11.2	7.0	2,000	0.003	0.001	0.040	0.020	0.700	0.050	0.0003	0.100	11.2			
48	NONFERROUS METALS	Primary Nonferrous Metals		26.7	8.5			0.040	0.020	0.050	0.020		0.070		0.050	7.0			
49	NONFERROUS METALS	Primary Zinc		1.1				0.164	0.050	0.080	0.020		0.100		0.174				
50	NONFERROUS METALS	Secondary Nonferrous Metals		126.3				0.164	0.050	0.060	0.020		0.113		0.174	0.3			
51	NONFERROUS METALS	Nonferrous Metal Forming		15.5	52.1				0.050	0.100	0.020	0.500	0.100		0.174	10.0			
52	NONFERROUS METALS	Aluminum Forming		34.4					0.002	0.392	0.020		0.030		0.174	34.6			
53	NONFERROUS METALS	Copper Forming		12.0		2.1			0.050	0.080	0.020	0.400	0.100		0.174	10.0			
54	ORE MINING AND DRESSING			5.0				0.164	0.005	0.050	0.020	0.500	0.070	0.0010	0.174				
55	PAVING AND ROOFING		9.5	40.0	0.1			0.002	0.050	0.200	0.020	0.600	0.113	0.0009	0.174	19.5			
56	PETROLEUM REFINING		13.5	26.1	6.8					0.100	0.010		0.005	0.0009	0.100	17.1			
57	PHOTOGRAPHIC PROCESSING		143.1	5.9	21.0				0.050	0.050		6.700	0.080						
58	PLASTICS MOLDING & FORMING		11.7	86.4	0.2	1.1			0.006	0.020	0.006	0.300	0.090		0.080	7.5		1.6	
59	PORCELAIN ENAMELING			12.0		4.1		0.164	0.050	0.080	0.020	0.400	0.100		0.174	10.0			

Table 3.9 - Typical Pollutant Concentrations Corrected to Meet Current Texas Surface Water Quality Criteria

Point Source Characterization Project
Galveston Bay National Estuary Program

NCPDI Code	NCPDI Code Category Name	Subname	BOD_5 (mg/L)	TSS (mg/L)	Total N (mg/L)	Total P (mg/L)	Fecal Coli. Bact. (col./L)	Total As (mg/L)	Cd (mg/L)	Cr (mg/L)	Cu (mg/L)	Fe (mg/L)	Pb (mg/L)	Hg (mg/L)	Zn (mg/L)	Oil & Grease (mg/L)	PCBs (mg/L)	Chlor. Hydro-carbons Pest. (mg/L)	Spec. Disch. Act. Code
60	PRINTING & PUBLISHING		6.0	3.5	7.6			0.006		0.392	0.020		0.113		0.174	7.0			
61	PULP AND PAPER		17.3	28.4	1.4					0.030	0.010		0.010	0.0001	0.174				
62	RENDERING		44.1	58.8	10.8	2.9	4,000												
63	RUBBER PROCESSING		33.0	40.0									0.010		0.174	15.0			
64	TIRE & INNER TUBE		7.2	40.0												10.0			
65	STEAM ELECTRIC	Non-Cooling Flows		30.0				0.070	0.009	0.060	0.020	0.800	0.010	0.0012	0.174	15.0			E
65	STEAM ELECTRIC	Non-Cooling Flows														15.0			P
65	STEAM ELECTRIC	Non-Cooling Flows														15.0			N
68	SUGAR PRODUCTS	Beet Sugar	68.5	478.0															
69	SUGAR PRODUCTS	Cane Sugar	57.0	180.3															
70	TEXTILE MFG	General Textile Mfg	22.4	49.1				0.020	0.003	0.060	0.020		0.060	0.0008	0.174	26.3			
71	TEXTILE MFG	Wool Scouring	50.0	230.1				0.040	0.030	0.040	0.020		0.113	0.0010	0.174	190.0			
72	TEXTILE MFG	Wool Finishing	25.0	60.0				0.020	0.006	0.392	0.020		0.100		0.174				
73	TEXTILE MFG	Low Water Use Textile Processi	30.4	88.0					0.005	0.010	0.020		0.080		0.174				
74	TEXTILE MFG	Woven Fabric Finishing	22.0	48.7				0.020	0.002	0.020	0.020		0.040	0.0008	0.174	14.0			
75	TEXTILE MFG	Knit Fabric Finishing	23.6	41.0				0.020	0.005	0.100	0.020		0.040	0.0014	0.174	21.0			
76	TEXTILE MFG	Carpet Finishing	35.0	65.0					0.004	0.200	0.020		0.030		0.174	6.0			
77	TEXTILE MFG	Stock and Yarn	10.0	25.0				0.006	0.005	0.070	0.020		0.080	0.0010	0.174	90.0			
78	TEXTILE MFG	Nonwoven mfg	35.0	65.0					0.004	0.200	0.020		0.030		0.174	4.8			
79	TEXTILE MFG	Felted Fabric	25.0	60.0						0.040			0.050			2.4			
80	TIMBER PRODUCTS	Sawmills	38.7	31.8						0.392	0.020		0.040		0.174	9.8			
81	TIMBER PRODUCTS	Plywood	20.0	33.5												15.0			
82	TRANSPORTATION	Railroads	17.4	19.9						0.200						10.2			
83	TRANSPORTATION	Trucking	22.3	19.9						0.200						10.4			
84	RESIDENTIALS	Residentials	113.9	156.8	14.2	10.0	2,000,000	0.005	0.002		0.020	1.300	0.097	0.0004	0.174	27.6			
98	RESIDENTIALS	Water Supply Treatment Plants		35.0															A
98	RESIDENTIALS	Water Supply Treatment Plants		50.0								50.000							F
99	RESIDENTIALS	Sewerage Systems	207.3	209.1	15.1	13.0	50,000,000	0.034	0.050	0.234	0.020	6.300	0.113	0.0007	0.174	50.7		0.0	U
99	RESIDENTIALS	Sewerage Systems	158.3	114.4	15.1	13.0	200,000	0.034	0.050	0.092	0.020	2.500	0.059	0.0006	0.174	27.6		0.0	P
99	RESIDENTIALS	Sewerage Systems	23.9	22.1	11.2	7.0	2,000	0.032	0.011	0.043	0.020	0.700	0.045	0.0003	0.165	11.2		0.0	S
99	RESIDENTIALS	Sewerage Systems	2.8	22.1	14.0	7.0	2,000	0.032	0.011	0.043	0.020	0.700	0.045	0.0003	0.165	11.2		0.0	T
100	COOLING WATER	Recycled Cooling		30.0				0.002	0.010	0.050	0.020	0.500	0.060	0.0004	0.080	0.1			R
100	COOLING WATER	Once Through Cooling									0.002								C

Table 3.10 - USGS Gauge Names, Numbers, and Drainage Areas used in Estimating Tributary Loading into Galveston Bay

Point Source Characterization Project
Galveston Bay National Estuary Program

USGS Gauge Name	USGS Gauge Number	Drainage Area (mi^2)	Drainage Area (ha)
Trinity River at State Highway 787, Romayor, Tx.	08066500	17,186.0	4,451,047.3
Lake Houston near Sheldon, Tx.	08072000	2,828.0	732,431.2
Buffalo Bayou at West Belt Drive, Houston, Tx.	08073600	307.0	79,510.7
Whiteoak Bayou at Heights Blvd., Houston, Tx.	08074500	85.6	22,169.8
Brays Bayou at Main Street, Houston	08075000	91.7	23,749.6
Sims Bayou at State Highway 35, Houston	08075500	63.4	16,420.1
Huntington Bayou at Interstate Highway 610, Houston, Tx.	08075770	15.8	4,092.1
Greens Bayou at U.S. Highway 59, Near Houston, Tx.	08076000	71.1	18,414.4

Fig. 3.8 - Location of USGS Stream Gauges in Greater Houston Area

Point Source Characterization Project
Galveston Bay National Estuary Program

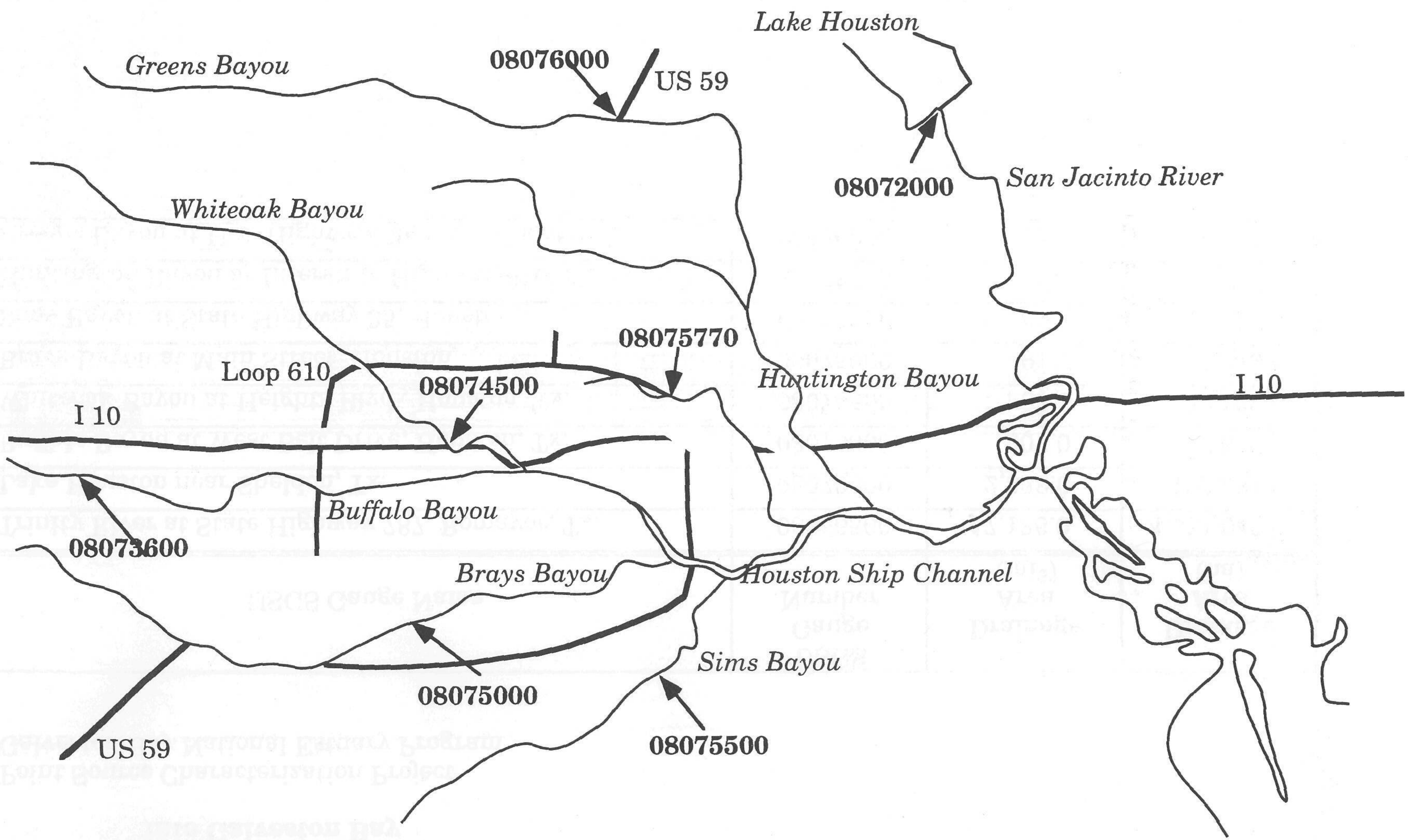
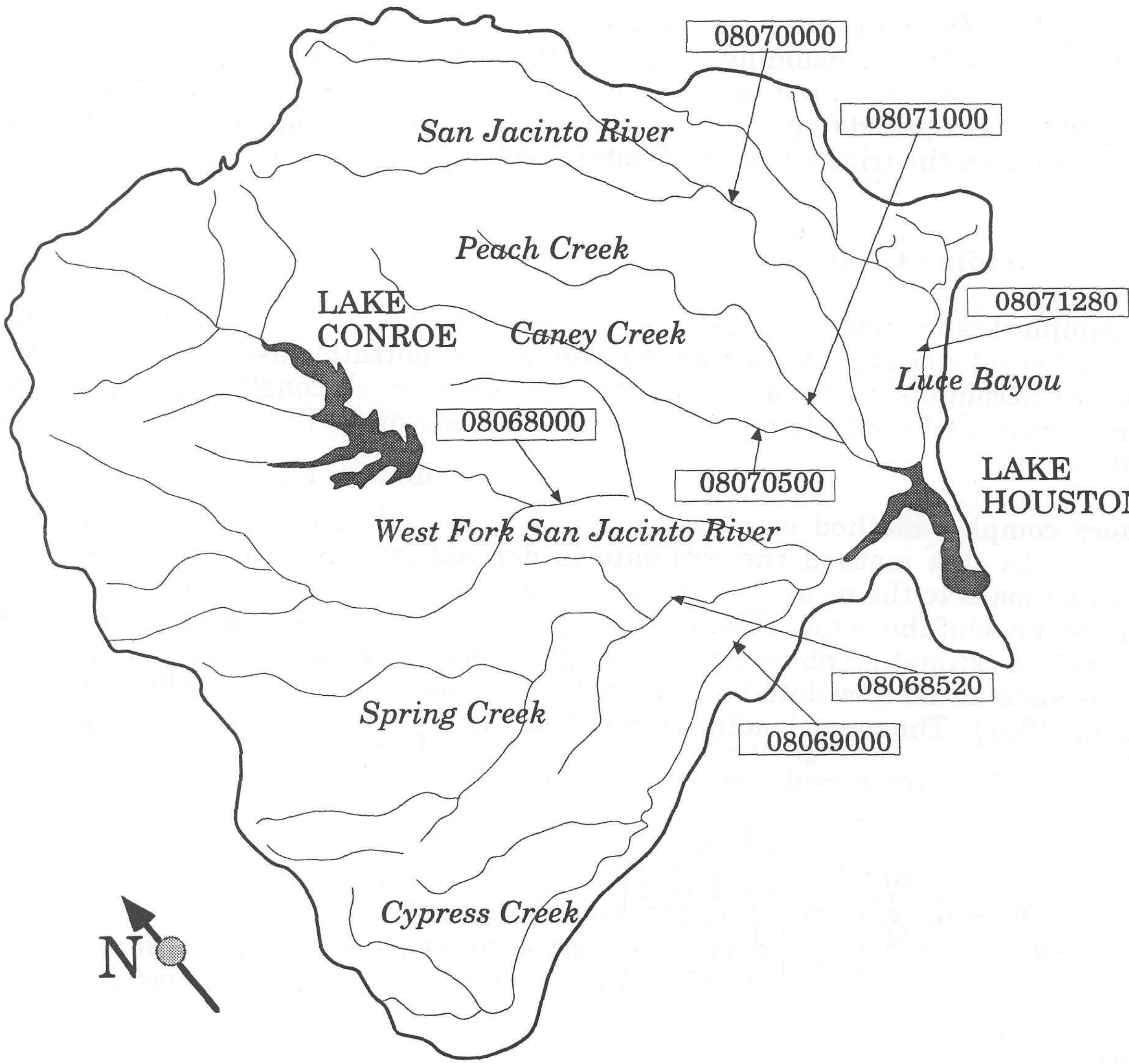


Figure 3.9 - Location of USGS Gauging Stations in the Lake Houston Watershed

Point Source Characterization Project
Galveston Bay National Estuary Program



spillway. It will be discussed in detail later.

The daily flow data for these gauges was downloaded onto a floppy disk from a ROM laser disk at the Texas Natural Resource Information System (TNRIS). The Water Quality Data was downloaded onto a floppy disk from the mainframe computer at the Austin USGS office.

3.3.2 Data Manipulation

Manipulating the data into a form that could be used in calculations proved to be one of the most time consuming aspects of this study. Both the flow data and the water quality data required substantial work. For a detailed explanation of the manipulations required to process the USGS data into a form suitable to calculation of loadings from the tributaries, the reader is referred to Gamblin (1993).

3.3.3 Loading Calculations

The simplest and most straightforward method (but not necessarily the most accurate) of calculating loading was the average concentration/average flow method. This was accomplished by averaging the values for each constituent for a given calendar year and multiplying that average by the average flow for that year from the flow data.

A more complex method employed was the unbiased stratified ratio estimator method. In this method the estimate is derived from a ratio of the mean of measured loads to the mean of flows when loads were measured. This ratio is used with the mean of the actual flow, to obtain the estimate. This method has shown to work well in estimating phosphorus loading and is ideally suited to situations where there is substantial flow data but relatively little concentration data (Thomann and Mueller, 1987). The mean loading is calculated as:

$$\overline{W}_p = \overline{Q}_p \frac{\overline{W}_c}{\overline{Q}_c} \left[\frac{1 + \left(\frac{1}{n}\right)\left(\frac{S_{QW}}{\overline{Q}_c \overline{W}_c}\right)}{1 + \left(\frac{1}{n}\right)\left(\frac{S_q^2}{\overline{Q}_c^2}\right)} \right] \qquad (3.5)$$

where

$\overline{W}_p$ = estimated average load for period p

$\overline{Q}_p$ = mean flow for period

$\overline{W}_c$ = mean daily loading for the days on which concentrations were determined

$\overline{Q}_c$ = mean daily flow for the days on which concentrations were determined n = number of days when concentrations were measured.

Also

$$S_{QW} = \left[\frac{1}{n-1}\right]\left[\left(\sum_{i=1}^{n} Q_{ci} W_{ci}\right) - n\overline{Q}_c \overline{W}_c\right] \qquad (3.6)$$

$$S_Q^2 = \left[\frac{1}{n-1}\right]\left[\left(\sum_{i=1}^{n} Q_{ci}^2\right) - n\overline{Q}_c^2\right] \qquad (3.7)$$

where

Q_{ci} = individually measured flows
W_{ci} = daily loading for each day on which concentration was measured

In the logarithmic regression method, a relationship between concentration and flow was desired and a least squares regression of natural log concentration on natural log flow was performed to try to define this relationship. The linear regression obtained was:

$$\ln(Y) = b + m(\ln(X)) \qquad (3.8)$$

which was transformed to obtain

$$Y = e^b X^m \qquad (3.9)$$

where

Y = daily concentration in mg/L or mg/L and
X = daily flow in cubic feet per second.

Once the equation was defined, it was used with the daily flow data to obtain daily loadings for the entire year; these daily loads were then summed to obtain the annual loading estimate.

The actual loading calculations were performed using three different methods: the average concentration time the average flow method, the Beale unstratified ratio estimator method, and the logarithmic regression method. Examples of using each of these three methods are given in Gamblin (1993).

3.3.4 Loading From Lake Houston

To incorporate the contribution of the San Jacinto River to stream loading, Lake Houston's spillway flow and water quality had to be estimated. The stage-discharge relationship for the spillway was found to be inaccurate, so the flow over the spillway had to be estimated. Two previous reports were reviewed which attempted to estimate this spillage. One was a thesis by Ernesto Baca at Rice University (1980) and the other was a report by Turner Collie and Braden Inc. (TCB) for the City of Houston (1989). These reports contained some discrepancies, so it was decided to reproduce the study, following closely the methodology in the TCB report. Another problem arose in that there is no water quality gauging station at the spillway, so the concentrations had to be combined and averaged from three related gauging stations.

In estimating the flow over the spillway, a water balance around Lake Houston was performed involving the inflow into the lake, the net evaporation, the withdrawals, and the change in lake storage. Estimating inflow involved eight subwatersheds and seven stream gauges. The annual gauge flows for a 24 year period (1965-1988) were copied into an Excel spreadsheet from a printout obtained from the TWC. These data were in acre-ft per year which had to be converted into cubic feet per second (cfs). Some of the gauges had missing data, so an estimation procedure had to be employed. This estimation involved the multiplication of the recorded flow at the nearest gauge by the drainage area ratio between the missing record areas and the nearest gauged areas. Caney Creek was used to estimate Peach Creek after 1976, East Fork was used to estimate Luce Bayou before 1985, and Spring Creek was used to estimate the lake environs (the area around the lake not contained in the drainage areas of the seven streams). As in the TCB report the yield method was used to estimate flows from each subwatershed which involved the multiplication of the recorded flow at the gauge by the drainage area ratio between the entire subwatershed and the gauge. The final estimates of inflows into Lake Houston from tributaries are given in Table 3.11.

Evaporation was estimated using a Lotus 1-2-3 macro program developed by the Water Rights and Uses Division of the TWC. The program required the centroid of the reservoir surface to be approximated and entered. The centroid of Lake Houston was estimated to be at latitude 30.08° and longitude 95.08°. In the program weighting factors were calculated, using the rectangular area method, which were multiplied by known quadrangle evaporation values. This calculated the evaporation at the centroid of the lake in feet on an annual basis. These values were entered into an Excel file and multiplied by the lake area to obtain lake evaporation in acre-feet per year which was converted to cubic feet per second. The average area of Lake Houston was taken to be the recreation pool spillway crest level area of 12,240 acres from a Dam Safety file at the TWC. Evaporation rates calculated are given in Table 3.12.

The withdrawals from Lake Houston were taken from the self reporting data files of the Water Rights and Uses Division of the TWC. Three entities reported withdrawals from the lake: the City of Houston, the San Jacinto River Authority, and a Mr. Seaburg. These reported withdrawals were entered in an Excel file as acre-feet per year and converted to cfs; they are presented in Table 3.13.

Monthly storage data in acre-feet for Lake Houston was obtained from TNRIS. The change in storage was computed by subtracting the previous year's December storage from the December storage of each year. Once this value was determined it was converted to cfs. Values determined are contained in Table 3.14.

Table 3.11 - Annual Inflows to Lake Houston (1965-88)

Point Source Characterization Project
Galveston Bay National Estuary Program

Year	Peach Creek 08071000 (cfs)	Caney Creek 08070500 (cfs)	East Fork 08070000 (cfs)	Luce Bayou 08071280 (cfs)	Spring Creek 08068520 (cfs)	West Fork 08068000 (cfs)	Cypress Creek 08069000 (cfs)	Lake Environs (cfs)	Total (cfs)
1965	25.6581	59.5991	83.2931	47.7463	73.5629	449.425	71.9902	15.7515	289.859
1966	59.4188	103.792	194.761	111.643	150.443	453.792	165.444	32.2133	620.057
1967	20.2564	46.0505	55.4603	31.7916	23.9112	96.4281	21.919	5.11994	177.47
1968	87.2273	198.091	383.928	220.08	339.304	990.848	288.936	72.6528	1228.63
1969	74.0878	139.289	261.279	149.773	174.897	619.779	138.983	37.4494	799.326
1970	45.2813	62.4856	75.6385	43.3584	72.9174	145.746	124.326	15.6133	299.681
1971	20.0058	35.2017	38.7121	22.191	18.9863	56.565	51.5881	4.0654	135.097
1972	56.5368	70.7408	113.629	65.1356	168.688	220.822	199.058	36.12	474.73
1973	323.861	334.056	735.953	421.872	647.666	921.071	503.49	138.68	2463.41
1974	220.503	317.657	571.282	327.477	323.259	852.145	312.575	69.2171	1760.18
1975	183.737	256.998	421.759	241.766	290.286	724.527	227.664	62.157	1394.55
1976	107.146	183.789	267.775	153.497	199.849	604.887	182.813	42.7922	912.056
1977	101.187	135.77	211.544	121.264	213.15	497.982	118.711	45.6403	782.915
1978	81.5864	109.47	153.993	88.274	193.028	316.986	167.878	41.3317	626.352
1979	286.858	384.898	638.806	366.184	774.068	1565.29	505.331	165.746	2450.81
1980	70.2501	94.2597	149.53	85.7154	177.793	350.778	192.02	38.0695	577.548
1981	102.077	136.963	114.482	65.6247	240.386	413.41	199.792	51.4721	659.532
1982	130.719	175.395	272.988	156.485	219.531	545.786	193.128	47.0066	955.117
1983	230.322	309.039	548.426	314.375	394.256	933.3	304.057	84.4192	1796.42
1984	119.349	160.139	325.386	186.522	149.224	526.086	128.814	31.9524	940.621
1985	129.638	173.944	304.079	208.575	372.735	677.557	224.387	79.8112	1188.97
1986	126.437	169.65	393.82	270.923	221.051	498.505	197.295	47.332	1181.88
1987	119.349	160.139	273.464	259.496	293.296	511.895	251.386	62.8015	1105.74
1988	50.317	67.514	94.5275	49.5058	70.9159	211.683	56.3543	15.1847	332.78

Table 3.12 - Evaporation from Lake Houston (1965-88)

Point Source Characterization Project
Galveston Bay National Estuary Program

Year	Net Evaporation (ft)	Annual Evaporation (acre-ft)	Average Evaporation (cfs)
1965	1.38	16,891.2	23.3314521
1966	1.11	13,586.4	18.7666027
1967	1.76	21,542.4	29.7560548
1968	1.05	12,852	17.7521918
1969	1.41	17,258.4	23.8386575
1970	1.37	16,768.8	23.1623836
1971	2.15	26,316	36.349726
1972	1.33	16,279.2	22.4861096
1973	0.68	8,323.2	11.4966575
1974	1.41	17,258.4	23.8386575
1975	1.33	16,279.2	22.4861096
1976	1.3	15,912	21.9789041
1977	1.8	22,032	30.4323288
1978	2.15	26,316	36.349726
1979	0.89	10,893.6	15.0470959
1980	2.43	29,743.2	41.0836438
1981	1.47	17,992.8	24.8530685
1982	1.89	23,133.6	31.9539452
1983	1.49	18,237.6	25.1912055
1984	2.11	25,826.4	35.6734521
1985	2.74	33,537.6	46.3247671
1986	1.62	19,828.8	27.3890959
1987	1.88	23,011.2	31.7848767
1988	2.68	32,803.2	45.3103562

Note: Area assumed = 12,240 acres

Table 3.13 - Withdrawals from Lake Houston (1965-88)

Point Source Characterization Project
Galveston Bay National Estuary Program

Year	City of Houston (acre-ft)	San Jacinto River Authority (acre-ft)	Seaburg (acre-ft)	Total (acre-ft)	Total (cfs)
1965	66,510	36,634	1,812	104,956	144.97
1966	70,251	33,503	1,460	105,214	145.33
1967	73,972	36,339	1,811	112,122	154.87
1968	74,968	36,119	1,570	112,657	155.61
1969	89,360	39,538	1,664	130,562	180.34
1970	96,922	39,192	1,723	137,837	190.39
1971	102,915	35,438	1,783	140,136	193.57
1972	105,910	33,334	1,805	141,049	194.83
1973	105,140	37,984	1,679	144,803	200.01
1974	111,688	43,973	1,622	157,283	217.25
1975	110,529	42,553	1,600	154,682	213.66
1976	131,039	49,092	1,620	181,751	251.05
1977	137,532	48,498	1,603	187,633	259.17
1978	146,423	48,879	1,600	196,902	271.98
1979	127,746	50,144	1,600	179,490	247.93
1980	130,510	56,707	1,600	188,817	260.81
1981	124,787	50,022	1,600	176,409	243.67
1982	186,217	48,252	1,600	236,069	326.08
1983	179,136	51,055	1,600	231,791	320.17
1984	198,000	51,216	1,600	250,816	346.45
1985	209,917	50,783	1,609	262,309	362.32
1986	148,433	54,372	1,097	203,902	281.65
1987	120,233	56,982	1,600	178,815	246.99
1988	208,055	56,504	1,600	266,159	367.64

Source: TWC Self-Reporting Data

Table 3.14 - Change in Storage in Lake Houston (1965-88)

Point Source Characterization Project
Galveston Bay National Estuary Program

Year	Storage As Of December (acre-ft)	Change In Storage (acre-ft)	Change In Storage (cfs)
1964	157,200		
1965	148,100	-9,100	-12.569635
1966	133,300	-14,800	-20.442922
1967	130,300	-3,000	-4.1438356
1968	149,400	19,100	26.3824201
1969	95,950	-53,450	-73.829338
1970	128,500	32,550	44.9606164
1971	130,600	2,100	2.90068493
1972	149,800	19,200	26.5205479
1973	153,300	3,500	4.83447489
1974	156,600	3,300	4.55821918
1975	157,700	1,100	1.51940639
1976	152,300	-5,400	-7.4589041
1977	143,600	-8,700	-12.017123
1978	151,500	7,900	10.9121005
1979	157,100	5,600	7.73515982
1980	136,700	-20,400	-28.178082
1981	151,200	14,500	20.0285388
1982	161,800	10,600	14.6415525
1983	147,700	-14,100	-19.476027
1984	158,900	11,200	15.4703196
1985	154,100	-4,800	-6.630137
1986	152,800	-1,300	-1.7956621
1987	154,900	2,100	2.90068493
1988	115,200	-39,700	-54.836758

The water balance was estimated using the following equation:

Lake Spillage = Lake inflows - Withdrawals - Net evaporation $\pm$ Change in lake storage

and the results of calculations of water balance in Lake Houston are in Table 3.15. The values were used coupled with the water quality data to calculate load of constituents leaving Lake Houston over the spillway and entering Galveston Bay via the San Jacinto River.

As with the other stream gauges the water quality data for Lake Houston was downloaded as ASCII files which had to be parsed and manipulated into a form to be used in loading calculations using the same methodology as previously mentioned.

The concentrations were estimated from the lake itself and a plant intake canal located near the dam. From 1968 to January 1983 the data were sparse and taken from the USGS gauge "Lake Houston NR Sheldon". After August 1983, the data was more extensive and taken from the gauge "Lake Houston site AC" which was determined to be the most representative of the water quality over the spillway. Parameter values, that were taken over a range of depths on the same day, were averaged. Data from the USGS gauge "Lake Houston plant intake at Galena Park, TX." was added for the years 1973 through 1986 and averaged with the other two gauges when samples were taken on the same day.

The estimated annual flows over the spillway (lake spillage) and the estimated water quality data were used to estimate loading. The only method applicable was the average concentration average flow method and the loadings were estimated and tabulated in the same manner as previously mentioned for the other gauges.

Finally, the loadings of metals from the tributaries had to be converted from the dissolved form to the total metal form. The USGS measures the dissolved form of metals in samples it takes from gauging stations; therefore, to compare loadings estimated for metals from tributaries to those from wastewater dischargers (which are reported in the total metal form), it was necessary to convert the dissolved form to total form. To do this, the procedures used by the TWC (1992) to determine allowable concentrations of total metals in effluents from allowable concentrations of dissolved metals in receiving waters (and described above) was used here. The estimated loads of each metal of concern here, i.e., those for which TPCs were available in Pacheco et al. (1990), were tabulated. The partition coefficient for each was calculated using relationships in the TWC (1992) document and average TSS concentrations determined by dividing the average TSS load in the tributary by the average flow over the same time period. Once the partition coefficient was calculated, the portion of the metal in the dissolved form could be calculated and that fraction used to convert the dissolved metal load to a total metal load. These conversions affected the loads of some metals markedly as will be seen in the next chapter. One should also expect any historical loading estimates based on USGS

Table 3.15 - Annual Water Balance in Lake Houston (1965-88)

Point Source Characterization Project
Galveston Bay National Estuary Program

Year	Inflows (cfs)	With-drawals (cfs)	Evap-oration (cfs)	Change In Storage (cfs)	Lake Spillage (cfs)	TCB Report (cfs)
1965	827.03	144.97	23.331	-12.57	671.29	
1966	1,271.5	145.33	18.767	-20.443	1,127.9	
1967	300.94	154.87	29.756	-4.1438	120.45	
1968	2,581.1	155.61	17.752	26.3824	2,381.3	
1969	1,595.5	180.34	23.839	-73.829	1,465.2	
1970	585.37	190.39	23.162	44.9606	326.85	
1971	247.32	193.57	36.35	2.90068	14.498	
1972	930.73	194.83	22.486	26.5205	686.9	
1973	4,026.6	200.01	11.497	4.83447	3,810.3	
1974	2,994.1	217.25	23.839	4.55822	2,748.5	
1975	2,408.9	213.66	22.486	1.51941	2,171.2	
1976	1,742.5	251.05	21.979	-7.4589	1,477	
1977	1,445.2	259.17	30.432	-12.017	1,167.7	
1978	1,152.5	271.98	36.35	10.9121	833.31	
1979	4,687.2	247.93	15.047	7.73516	4,416.5	
1980	1,158.4	260.81	41.084	-28.178	884.7	1,359
1981	1,324.2	243.67	24.853	20.0285	1,035.7	1,095
1982	1,741	326.08	31.954	14.6416	1,368.4	1,463
1983	3,118.2	320.17	25.191	-19.476	2,792.3	2,910
1984	1,627.5	346.45	35.673	15.4703	1,229.9	1,285
1985	2,170.7	362.32	46.325	-6.6301	1,768.7	1,787
1986	1,925	281.65	27.389	-1.7957	1,617.8	1,572
1987	1,931.8	246.99	31.785	2.90068	1,650.1	
1988	616	367.64	45.31	-54.837	257.89	

dissolved metal concentrations to substantially underestimate the total metal loading estimates, and such potential underestimates were noted in the previous chapter.

3.4 CONSTITUENT LOADING SUMMARIES

Once loading estimates for each constituent from municipal and industrial dischargers and tributaries were completed and aggregated by water quality segment, the total loads from each segment were combined into a summary table. This summary table for each constituent presented the total loading of the constituent, the percent contribution of effluent loads by segment and the percent contribution of the total load by effluents and by tributaries. This table made it possible to determine whether wastewater discharges or the tributaries were contributing the greater load of a given constituent and which water quality segments were receiving the larger (or smaller) loads of the constituent from wastewater discharges. No examples are given here, but in the next chapter, such tables begin with Table 4.30.

3.5 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 loading estimates from Lake Houston and Lake Livingston, flow and concentration data taken by the U.S. Geological Survey were used to the extent possible so Survey QA/QC procedures were also be reviewed. 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, but estimates of loading for some metals and organics (see Armstrong et al., 1977) were available. Goodman (1989) described the difficulty of relating recent waste loading data to in-bay sediment concentrations of priority pollutants and pointed out the deficiency in sediment data.

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