

## 3.0 METHODS

### 3.1 Literature Searches

JN conducted an extensive on-line library search for all data related to impingement and entrainment, as well as other information regarding man-induced fish kills. Specific on-line resources researched included:

- University of Texas at Austin General Library On-Line Catalog (UTCAT)
- Aquatic Sciences and Fisheries Abstracts Database (DIALOG)
- Scisearch
- Bioses Previews
- Oceanic Abstracts
- Pollution Abstracts
- Water Resources Abstracts
- Galveston Bay Information Center at Texas A&M University

Key words used for this on-line library search were: Galveston Bay, fish mortality, impingement, entrainment, and fish kills.

### 3.2 Authorized Water Intake Survey

Mr. J. Mark Evans with Water Rights and Uses Division of the Texas Water Commission (TWC) was contacted to obtain names and addresses of permitted water rights users within the Galveston Bay system. The TWC stream segments for which information was requested appear in Table 3.1. Of the eight water use types listed by the TWC (Appendix A), JN determined that the industrial, mining, hydroelectric, navigation, or other use categories would have a greater probability of impinging or entraining estuarine organisms. JN determined that municipal/domestic and irrigation uses would most likely use fresh water, and, therefore, would not impinge or entrain estuarine organisms.

As a result, 19 JN questionnaires (Appendix B) were sent to permitted water rights users that withheld water for the previously mentioned uses (Appendix C), and withdrew water directly from the segments identified in Table 3.1. Although Houston Lighting and Power (HL&P) has five water rights permits within the study area, they were not sent a letter because the information was available in several impingement and entrainment studies provided to JN by HL&P. The purpose of this questionnaire was to determine: (1) whether the permit was currently used; (2) the frequency and time of year of the diversion; (3) the quantity of water diverted; (4) the purpose of the diversion; (5) the intake rate and velocity; (6) methods used to divert fish from the intake; and (7) whether the user had conducted any impingement and entrainment studies at their facility. The location of facilities sent questionnaires and the location of HL&P generating stations appear in Figure 2.

**TABLE 3.1**  
**TWC STREAM SEGMENTS SURVEYED**  
**FOR PERMITTED WATER RIGHTS USERS**

<i>RIVER BASIN</i>	<i>SEGMENT NUMBERS</i>
<b>Neches-Trinity Coastal Basin</b> Intracoastal Waterway	0702
<b>Trinity River</b> Trinity River Tidal	0801
<b>Trinity-San Jacinto Coastal Basin</b> Cedar Bayou Tidal	0901
<b>San Jacinto River</b> San Jacinto River Tidal Houston Ship Channel/San Jacinto River Houston Ship Channel	1001 1005 1006
<b>San Jacinto-Brazos Coastal Basin</b> Clear Creek Tidal Clear Creek Above Tidal Dickinson Bayou Tidal Bastrop Bayou Tidal Chocolate Bayou Tidal Armand Bayou Tidal	1101 1102 1103 1105 1107 1113
<b>Bays and Estuaries</b> Upper Galveston Bay Trinity Bay East Bay West Bay Clear Lake Tabbs Bay San Jacinto Bay Black Duck Bay Scott Bay Burnett Bay Moses Lake Chocolate Bay Bastrop Bay/Oyster Lake Christmas Bay Drum Bay Barbours Cut Texas City Ship Channel Bay Port Ship Channel Lower Galveston Bay	2421 2422 2423 2424 2425 2426 2427 2428 2429 2430 2431 2431 2433 2434 2435 2436 2437 2438 2439

### **3.3 Effects of Cooling Water Operations - Impingement and Entrainment**

JN contacted Mr. Kerry M. Whelan, Houston Lighting and Power, HL&P, to obtain all impingement and entrainment studies conducted at HL&P generating stations on Galveston Bay. These studies were reviewed to determine the most abundant species impinged and entrained at HL&P stations and the length of individuals of these species most frequently impinged and entrained. These studies were also reviewed to determine injury rates and percent survival after impingement and entrainment, including the delayed effects of impingement and entrainment. The effects of elevated temperatures in discharge canal waters were obtained from these studies. These studies were also reviewed to determine impacts to commercially and recreationally important species that were not included with those species that were most frequently impinged or entrained. Data were available for the P.H. Robinson station (Landry 1971 and 1977; Chase 1977; McAden 1977; Chase 1978; and Greene et al. 1980), the Webster generating station (Greene et al. 1980b), the Bertron generating station (Greene et al. 1979), the Deepwater generating station (Greene 1980), and the Cedar Bayou Generating station (Jobe et al. 1980 and Southwest Research Institute (SRI) unpublished). Other studies reviewed included Seiler et al. (in print) and the Texas Department of Water Resources (1980). The literature review described in Section 3.1 did not reveal any other impingement and entrainment studies that were conducted on Galveston Bay facilities.

### **3.4 Fish Kill Records Review**

Several agencies were contacted to obtain fish kill records. These agencies included the U.S. Environmental Protection Agency (EPA)-Region VI, the Texas Parks and Wildlife Department (TPWD), the TWC and its predecessor agency the Texas Department of Water Resources (TDWR), the Harris County Pollution Control Department (HCPCD), and the Galveston County Health District. JN requested records only from the TPWD or the TWC because, after discussions with staff from all agencies, these agencies appeared to have the most complete and comprehensive data bases. In addition, all the other agencies reported fish kills to the TPWD or the TWC. However, several records were obtained from the Harris County Pollution Control Department.

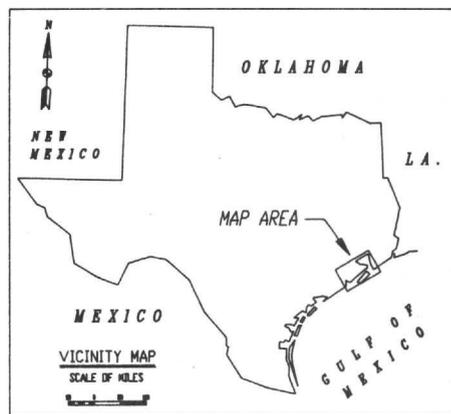
#### **3.4.1 Data Collection**

Reports used during the development of this study were limited to those containing numbers of fish killed and for which incidents occurred in either estuarine waters or tidally influenced waterways that are part of the Galveston Bay system. These data are maintained by the various agencies in the form of field investigation reports and data bases. The contents of the available fish kill investigation reports generally included identification of man-made sources of pollution, affected waterbodies, time of fish kills, quantification of numbers and sizes of species affected and other site specific information which can be used to implement policies designed to prevent or lessen the impact of future kills.

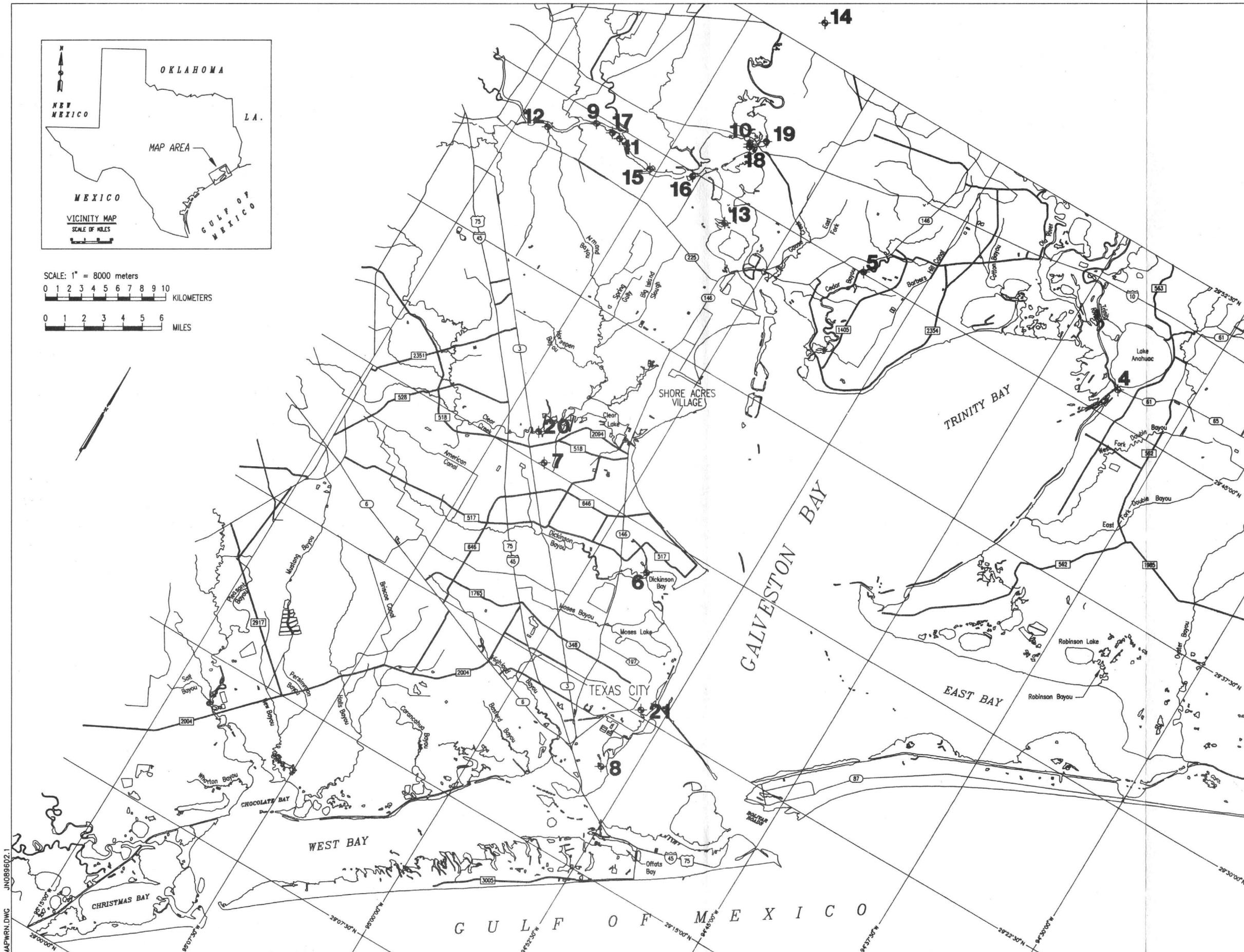
Sources of fish kills can be placed into three broad categories: point sources, nonpoint sources, and unknown sources. Point sources originate from localized areas for which the circumstances resulting in the release of a causal agent can be identified. These include wastewater outfalls,



# Galveston Bay National Estuary Program



SCALE: 1" = 8000 meters  
 0 1 2 3 4 5 6 7 8 9 10 KILOMETERS  
 0 1 2 3 4 5 6 MILES



SYMBOL NUMBER	COUNTY NAME	APPROPRIATOR	WATER RIGHT NUMBER	LAT. Dec.Deg.	LONG
1	CHAMBERS	EDWARDS, WILLIAM S	004305	29.899	94.387
2	CHAMBERS	JONES, CHARLES T ETAL	004304	29.828	94.413
3	CHAMBERS	TRINITY BAY CONSERVATION DIST	004307	29.827	94.408
4	CHAMBERS	CHAMBERS-LIBERTY COS ND	004279	29.772	94.686
5	CHAMBERS	HOUSTON LIGHTING & POWER CO.	003926	29.751	94.826
6	GALVESTON	HOUSTON L&P-ROBINSON PLANT	005363	29.471	94.953
7	GALVESTON	LEAGUE CITY, CITY OF	005178	29.503	95.077
8	GALVESTON	TEXAS COPPER CORPORATION	005286	29.327	94.900
9	HARRIS	ARMCO, INC.	003990	29.744	95.077
10	HARRIS	COOPER'S MARINE SER, INC	005334	29.79	95.068
11	HARRIS	ETHYL CORPORATION	003992	29.743	95.167
12	HARRIS	HOUSTON L&P CO-DEEPWTR	003988	29.723	95.225
13	HARRIS	HOUSTON L&P-SAM BERTRON	003996B	29.729	95.051
14	HARRIS	HOUSTON, CITY OF	004985	29.913	95.143
15	HARRIS	OILTANKING OF TEXAS, INC.	003993	29.735	95.131
16	HARRIS	PAKTANK CORPORATION-DEER PARK	005191	29.747	95.096
17	HARRIS	PHILLIPS 66 COMPANY	003991	29.744	95.175
18	HARRIS	SOUTHWESTERN BARGE FLEET SER.	005299	29.788	95.067
19	HARRIS	WESTERN TOWING CO	005340	29.798	95.057
20	HARRIS	HOUSTON L&P-WEBSTER	005350	29.521	95.085
21	GALVESTON	STERLING CHEMICALS, INC.	005361	29.521	95.085

THESE POINTS ARE OFF THE PROJECT MAP AREA. HOWEVER GEOGRAPHIC RELATIONSHIP TO MAP IS CORRECT.



FIGURE 2

Location of Water Rights Permittees Surveyed by JN Including the Location of HL&P Generating Stations



accidental spills, and localized detonation of explosives (e.g., seismic testing). Nonpoint sources include regional areas for which a single controllable point cannot be identified. Pollution emanating from these sources are generally driven by stormwater runoff occurring over a large area such as agricultural land, urban areas and landfills. Nonpoint source events were included in this study as a category separate from point sources since there is a certain amount of control potential associated with these and because they represent a large fraction of the fish kill incidents reported for the Galveston Bay area. A third category (unknown sources) was established for those incidents that were not attributable to either point or nonpoint sources. Unknown source categories were included because they correspond to 89 percent of the total number of fish reported killed. Fish kills identified as caused by "natural events" such as hurricanes, freeze kills, or redtides, were excluded from this study.

The consistency of the raw data obtained from available reports was limited by variable amounts and forms of information collected during field investigations. As would be expected, more detailed information was contained in reports for which a responsible party and/or cause could be identified. Since one of the primary focuses of the TWC and TPWD concerning fish kills is to ascertain damage to fisheries and to pursue fines, penalties, or other mitigative actions to be levied against the responsible party, the collection of biological information, water quality data, and descriptions of the actual causes is important in proving liability. For this reason, available fish kill information was more detailed for events involving identifiable point sources and those which affect commercial or sport fish species. Fish kills caused by point sources tend to be more detailed but involve fewer numbers of fish killed than those associated with nonpoint sources and unknown sources. Exact causes of fish kills due to nonpoint sources are much more difficult to identify and are frequently characterized as resulting from low dissolved oxygen levels due to nutrient input. A large amount of the available data could not be associated with either point sources or nonpoint sources and were categorized as unknown sources.

#### 3.4.2 Data Management

A single Lotus 123 spreadsheet (release 3.1) was developed to maintain all raw data collected from available sources. Summary tables were developed from the raw data to evaluate trends in the numbers of fish killed, sources of pollution, affected waterways, species size distribution, and seasonal patterns associated with fish kill incidents.

#### 3.4.3 Base Spreadsheet

The base spreadsheet includes 463 records (rows), each of which pertains to information specific to individual affected species (or the lowest reported taxonomic level) recorded for each incident. Each record includes 29 categories (columns) of information that are specific for each record. The contents of the base spreadsheet are provided in Appendix D. Descriptions for each of the columns contained in the base spreadsheet are provided in Appendix E.

#### 3.4.4 Summary Data Tables

Summary tables were developed which separate data into five basic categories. These include fish classification, sources of pollution, locations of fish kill incidents, types of pollutants, lengths of affected fish, and the months during which reported incidents occurred. For each of

these categories, data pertaining to numbers of each type of fish reported killed and the associated number of reported incidents were summarized for various subcategories. Data were ultimately developed into ratings tables in which categories were ranked according to severity.

### Fish Classification

Data were grouped according to the lowest practical taxonomic classification (LPT) of affected fish that was available. In some instances, the LPT identification allowed by the available data was by family or order. These were treated as categories separate from species designations. Fish mortality data reported by the TDWR (i.e. prior to 1985 when responsibilities were transferred to the TWC) represented 34 percent of the incidents and 93 percent of the total number of fish killed. These were grouped into only two categories: game fish and rough fish. The game fish listing included both commercial and sport fish while rough fish were considered to be any species other than commercial or sport fish. Because early TDWR fish kill reports did not differentiate between taxonomic groups within rough fish and game/commercial fish categories, a large fraction of the data could not be delineated by species. These designations were maintained in this report in the absence of more specific taxonomic information.

Established TPWD species codes were used to assign a unique identifier to each taxon or group designation. New codes were added for fish groups not included in the TPWD classification system and are identified by a decimal extension in the base spreadsheet and summary tables. A species list for affected fish that includes LPT codes used in the data base developed for this study are listed in Table 3.2.

For the purpose of evaluating pollution effects on commercial and recreational uses of waterbodies, mortality data were grouped into commercial fish, sport fish, and rough fish categories. Of the 38 LPTs delineated from the available data, 14 were rough fish and 22 were sport fish species. Thirteen of the sport fish taxons are also included in the commercial fish category. Undifferentiated game fish and rough fish were grouped separately.

### Sources of Fish Mortality

Source information was divided into primary, secondary and tertiary levels. The primary category includes point sources (PS), non-point sources (NPS) and unknown sources. Secondary sources describe the types of industries or activities which caused the fish kill and tertiary sources include the mechanism by which pollutants entered the environment such as pipe leaks, barge spills, mishandling accidents, etc.

For the purposes of this study, point sources include events that originate from a localized area whether or not the location is known. This includes not only stationary discharge points, but mobile sources such as barges, illegal waste disposal incidents, cull from commercial fishing boats, etc. Non-point sources categorized in this study include dispersed sources for which a localized origin cannot be identified and which is manifested in stormwater such as agricultural and urban runoff. Unknown sources comprise the majority of the data obtained from historical records and are treated as a separate (primary level) group.

**TABLE 3.2  
SPECIES AFFECTED DURING FISH KILLS**

LPT Species Code	Rough Fish	Commercial Fish *	Sport Fish *	Lowest Practical Taxon	Common Name
602		X	X	<i>Micropogonias undulatus</i>	Atlantic Croaker
665			X	<i>Strongylura marina</i>	Atlantic Needlefish
601	X			<i>Anchoa mitchilli</i>	Bay Anchovy
625		X	X	<i>Pogonias cromis</i>	Black drum
536			X	<i>Makaira nigricans</i>	Blue Marlin
658		X	X	<i>Brevoortia gunteri</i>	Finescale menhaden
98001				Unclassified Gamefish **	Game Fish (unclassified) **
465	X			Lepisosteidae (family)	Gar (family)
15	X			<i>Dorosoma cepedianum</i>	Gizzard Shad
780		X	X	<i>Paralichthys albigutta</i>	Gulf Flounder
604		X		<i>Brevoortia patronus</i>	Gulf Menhaden
689			X	<i>Opsanus beta</i>	Gulf Toadfish
610			X	<i>Arius felis</i>	Hardhead Catfish
458	X			Clupeidae (family)	Herring (family)
51	X			<i>Menidia beryllina</i>	Inland Silverside
434	X			Cyprinodontidae (family)	Killifish (family)
234		X	X	<i>Menticirrhus</i> sp.	Kingfish (unclassified)
375	X			Bothidae (family)	Lefteye Flounders (family)
50	X			<i>Gambusia affinis</i>	Mosquito Fish
633			X	<i>Lagodon rhomboides</i>	Pinfish
629		X ***	X	<i>Sciaenops ocellatus</i>	Red Drum
818		X	X	<i>Lutjanus campechanus</i>	Red Snapper
98002	X			Unclassified Rough Fish **	Rough Fish (unclassified) **
745	X			<i>Poecilia latipinna</i>	Sailfin Molly
613		X	X	<i>Cynoscion arenarius</i>	Sand Seatrout
458.1	X			<i>Dorosoma</i> sp.	Shad (unclassified)
621		X	X	<i>Archosargus probatocephalus</i>	Sheepshead
686	X			<i>Cyprinodon variegatus</i>	Sheepshead Minnow
627			X	<i>Bairdiella chrysoura</i>	Silver Perch
616		X	X	<i>Paralichthys lethostigma</i>	Southern Flounder
664			X	<i>Myrophis punctatus</i>	Speckled Worm Eel
608			X	<i>Leiostomus xanthurus</i>	Spot
2	X			<i>Lepisosteus oculatus</i>	Spotted Gar
614		X ***	X	<i>Cynoscion nebulosis</i>	Spotted Seatrout
111			X	<i>Morone saxatilis</i>	Striped Bass
612		X	X	<i>Mugil cephalus</i>	Striped Mullet
16	X			<i>Dorosoma petenense</i>	Threadfin Shad
849				Unidentified Fish	Unidentified Fish

\* Sport fish and commercial fish designations were assigned based on (Maddux, 1989) and (Quast, 1989)

\*\* Unclassified game fish and rough fish are included as a separate category since available data do not distinguish between game fish and commercial fish in some instances.

\*\*\* Commercial harvesting of this species is currently illegal.

To the extent practicable, the fish kill pollution source codes used by the TPWD were incorporated into the data base to define secondary pollution sources. This list was expanded as needed to better define sources that were not otherwise included. Secondary sources within the NPS category include nutrients from undefined sources, urban and agricultural nutrient sources, and industrial landfills. Secondary source descriptions are listed with their corresponding codes in Table 3.3.

Tertiary source categories define the control point for sources of pollution which can be managed either through improved maintenance and operation procedures, or by applying enforceable actions against responsible parties. Tertiary source codes that were delineated from the available data are listed with corresponding descriptions in Table 3.4.

Secondary and tertiary source descriptors are used in combination to define a source. Secondary codes are identified by a letter and tertiary codes are presented in integer form. Tertiary codes may apply to more than one secondary source but in combination describe an activity and release mechanism. An example of a source code would be "T30" identifying a sewage treatment plant (secondary code T) experiencing a lift station by-pass (tertiary code 30).

Impacts to fish species were evaluated based on the number of fish killed per incident. This allows prioritization of control measures for certain sources which historically have resulted in the largest number of fish killed from individual events. Throughout this report, the term impact refers to the number of fish killed per incident.

### Pollutant Categories

Source information was further subdivided into ten pollutant categories identified from the available data and listed in Table 3.5. These include seven point source and three nonpoint source pollutants. A separate category (U) was established for unknown sources. Nineteen (19) individual materials were identified for chemical spills and are listed in Table 3.6. For the nine other pollutant categories, no further delineation was possible based on available information. The numbers of incidents and numbers of fish killed were enumerated for each taxonomic group.

### Affected Waterways

Locations of fish kill incidents were identified according to basin, county, waterbody type and waterbody segment. Waterbody descriptions include types of waterbodies (bay, stream, ditch, etc.), and segment identification. Within each of the major basins, classified waterbody segments have been established by the TWC as having designated uses for protection on the basis of physical or water quality characteristics in order to formulate policies for regulating sources of pollution and to prevent future degradation. Unclassified waterways include those drainages for which designated uses have not been defined. Each of the historical records of fish kill incidents utilized during the development of this study were identified as to the directly affected waterbody whether a classified or unclassified segment. If the first affected waterbody was an unclassified segment, segment codes identifying the incident location are preceded by an "x" indicating an upstream unclassified waterbody was first affected. For these records, the attached segment number identifies the next downstream classified segment (e.g. "x1006"

**TABLE 3.3  
SECONDARY SOURCE CODE DESCRIPTIONS \***

<i>SOURCE CODE</i>	<i>SOURCE CATEGORY</i>
B	Undefined Activity
BB	Other Industries
CF	Agricultural Industry
DD	Nutrient Build-up from Unknown Sources
EE	Urban Nutrient Build-up
G	Construction Activity
I	Chemicals Manufacturing/Storing
J	Food Processing Industry
P	Oil Pipeline Conveyance
Q	Trucking Industry
QQ	Illegal Waste Disposal
S	Barge Operations
T	Sewage Treatment Plants/Septic Tanks
U	Industrial Landfills
V	Electrical Power Generation
X	Commercial Fishing
Y	Seismic Testing
ZZ	Ocean Dumping

\* Includes point sources and nonpoint sources

**TABEL 3.4  
TERTIARY SOURCE CODE DESCRIPTIONS \***

<i>MECHANISM CODE</i>	<i>CAUSAL MECHANISM</i>
4	Pipe Leaks
7	Nutrient Input
15	Rice Field Drainage
16	Unknown
17	Fish Process Waste Discharge
19	Collision Spills
21	Mishandling Spills
22	Liquid Transfer Spills
24	Cooling Tower Discharge
25	Cull from Shrimp Boats
30	Lift Station By-Pass
32	Sewer Line Leaks
33	STP Plant By-Pass
35	Storage Tank Leak
38	Industrial Landfarm Runoff
40	Unsecured Pipe
44	Elevated Pollutant Levels in Permitted Discharge
45	Runoff Caused by Greater than Design Storm
48	Accidental Explosions
50	Detonation of Explosives
51	Urban Runoff
52	Leakage from Holding Pit
58	Irrigation Tailwater Drainage
61	Impingement
62	Barge Leak

\* Includes point sources and nonpoint sources

**TABLE 3.5  
POLLUTANT CATEGORY LIST \***

<i>POLLUTANT CODE</i>	<i>POLLUTANT</i>
AR	Agricultural Runoff
C	Manufactured Chemicals
F	Food Industry Waste
H	Heated Water
I	Industrial Wastewater
O	Oil
S	Domestic Sewage
U	Unknown Pollutants
UNPS	Runoff from Undefined Areas
UR	Urban Runoff

\* Includes point source and nonpoint source pollutants

**TABLE 3.6**  
**IDENTIFIED MATERIALS ASSOCIATED**  
**WITH CHEMICAL SPILLS**

Benzene  
Butyl acrylate  
Chlorine  
Cleansing solutions  
Ferric chloride  
Fertilizer  
Hydrochloric acid  
Lannate  
Malathion  
Organic waste  
Pesticides  
Phenol  
Styrene  
Sugar  
Titanium chloride  
Toxic waste  
Unspecified chemical  
Vinyl acetate  
p-Xylene

indicates that a tributary to segment 1006 "the Houston Ship Channel" was the first affected waterbody). Classified and unclassified segments affected by historical human induced fish kill incidents in the Galveston Bay study area are listed in Table 3.7.

### Size Distribution

Fish length data were available for only 104 of the 220 available fish kill reports and corresponded to less than one percent of the total number of fish reported killed. Available data concerning lengths of fish killed were delineated into one-inch increments and tabulated for each taxonomic group. From these data, size distributions were described that indicate the most affected size range of the various taxonomic groups for each identified source. Size distribution patterns are described in Section 4.7.

### Seasonal Patterns

For the entire period of record, 1970 through 1990, fish kill incidents were delineated for each taxonomic group according to the month in which they occurred. Numbers of fish killed were organized graphically for each taxonomic group affected by point or nonpoint sources. Complete information concerning dates of incidents were available for all fish kill reports utilized in this study. The results are presented in Section 4.8.

**TABLE 3.7  
AFFECTED WATER BODY LIST**

<i>SEGMENT CODE</i>	<i>WATERBODY</i>
x0702	Tributary of Intracoastal Waterway
x0801	Tributary of Trinity River
x0901	Tributary of Cedar Bayou
0901	Cedar Bayou
1001	San Jacinto River (Tidal)
x1005	Tributary of Houston Ship Channel/San Jacinto River
1005	Houston Ship Channel/San Jacinto River
x1006	Tributary of Houston Ship Channel
1006	Houston Ship Channel
x1007	Tributary of Houston Ship Channel/Buffalo Bayou
1007	Houston Ship Channel/Buffalo Bayou
x1101	Tributary of Clear Creek (Tidal)
1101	Clear Creek (Tidal)
1103	Dickerson Bayou (Tidal)
x1107	Tributary Chocolate Bayou (Tidal)
1107	Chocolate Bayou (Tidal)
x1109	Tributary of Oyster Creek (Tidal)
x1113	Tributary of Armand Bayou (Tidal)
x2421	Tributary to Upper Galveston Bay
2421	Upper Galveston Bay
x2422	Tributary to Trinity Bay
2422	Trinity Bay
x2423	Tributary to East Galveston Bay
x2424	Tributary to Galveston Bay
2424	West Galveston Bay
x2425	Tributary to Clear Lake

**TABLE 3.7**  
**- CONTINUED -**

<i>SEGMENT CODE</i>	<i>WATERBODY</i>
2425	Clear Lake
x2426	Tributary to Tabbs Bay
x2427	Tributary to San Jacinto Bay
2427	San Jacinto Bay
2428	Black Duck Bay
2429	Scott Bay
x2431	Tributary to Moses Lake
2431	Moses Lake
x2432	Tributary to Chocolate Bay
2432	Chocolate Bay
2437	Texas City Ship Channel
x2438	Tributary to Bayport Channel
2438	Bayport Channel
x2439	Tributary to Lower Galveston Bay
2439	Lower Galveston Bay

