FINAL REPORT
CHARACTERIZATION OF NON-POINT SOURCES AND LOADINGS TO GALVESTON BAY

EXECUTIVE SUMMARY

The Galveston Bay National Estuary Program (GBNEP) is a multi-agency environmental management planning program established for the protection and improvement of water quality and living resources within the Galveston Bay Estuary. In general terms, the project was designed to address one directive of the Clean Water Act: to develop the relationship between in-place loads and point and non-point loadings of pollutants to the estuarine zone and the potential uses of the zone, water quality, and natural resources. To meet these goals, the GBNEP has embarked on a three phase plan as mandated by the National Estuary Program: First, the problems in the estuary are prioritized; second, the estuary is scientifically characterized to better define the problems and link them with causes; and third, a series of action plans are created to solve these problems. The problem prioritization phase, conducted in 1989, identified non-point source pollutants entering Galveston Bay to be an important problem requiring further assessment.

This study, initiated in November 1990, and completed by Groundwater Services, Inc. (GSI), and the Department of Environmental Science and Engineering at Rice University (RU) as subcontractor, was aimed at characterizing non-point sources and loads into Galveston Bay. Non-point sources include a wide array of diffuse pollutant types and sources from major storm water outfalls, land drainage, and human activity. Pollutants include toxics, fecal coliform bacteria, oxygen demand, nutrients and sediments. Source activities include urban development, agricultural activities, and runoff from industrial and residential developments. One important aspect regarding non-point pollutants is that they occur intermittently and are very dependent on the volume and distribution of local rainfall in the watershed.

The objective of this work was to conduct a geographic analysis and priority ranking of possible non-point sources and loads to Galveston Bay. The study area was defined by GBNEP to include the entire Galveston Bay drainage area with the exception of the Lake Houston and Lake Livingston watersheds (Figure E.1); loadings from these upper watersheds were not mapped but were subjected to a separate pollutant loading analysis. The primary elements for the non-point analysis included watershed hydrology, load estimates, ranking of subwatersheds, upper watershed influences, and mapping. Exhibit E.1 presents a summary of the entire non-point source load calculation.

Watershed Hydrology. The study area (see above) was divided into 21 watersheds and 100 subwatersheds (Table E.1 and Figure E.2). Three rainfall cases were formulated from raingage data in the basin: an average year, a wet year with a 10-year return period, and an individual storm. The rainfall amounts were transformed into runoff using the Soil Conservation Service curve number method.

Land Use. An original land use database was developed from interpreted satellite imagery to provide a high resolution (approximate mapping resolution: 30 meter by 30 meter) snapshot of the watershed land use as it existed in 1990. The land uses that were delineated included the following categories: high-density urban, residential, open/pasture, agricultural, barren (exposed, eroded land and construction areas), wetlands, water and forest. These categories were considered to be sufficient for the purposes of calculating non-point source loads. Table E.2 lists the land use breakdown by watershed in the basin. Overall, land use in the project area is divided almost evenly between urban areas, agricultural lands, open/pasture areas, wetlands, and forests, as shown below:

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

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

To calculate non-point source loads from the basin, typical concentrations of each water quality constituent in runoff were estimated from a variety of local and nationwide data sources. These water quality data, defined as event mean concentrations (EMCs), were derived for each land use type defined for the Galveston Bay project (Table E.3 and Section 5.4).

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

The total loads calculated for each of the three storms considered are listed in Table E.4. In addition, the loads by land use for the average year are presented in Table E.5. In general, high density urban land use areas, consisting of industrial, commercial, multi-family residential, and transportation land uses, had higher NPS pollutant concentrations than most other non-urban land uses. Forest lands had the lowest concentrations of pollutants in runoff.

Ranking of Subwatershed Non-Point Source Loads. Based on the relative non-point source load estimates, subwatershed boundaries, and hydrologic features, each subwatershed was ranked relative to other subwatersheds for each of the non-point source parameter categories. The ranking for the three rainfall cases and for each non-point source parameter is presented in Table E.6 and shown graphically in several maps contained in Volume II of this report.

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

Pollutant loads from Lake Houston and Livingston were calculated for this project, however, in order to provide an total load estimate to the Bay and to identify the contribution of the upper watersheds. The calculation method was different than the spatial mapping calculation performed on the study area (lower watersheds). For both upper watersheds, historical runoff and water quality data were analyzed to arrive at estimates of Lake discharges for the three rainfall cases and to obtain average concentrations for lake runoff. Annual load estimates (comprised of point source loads, low-flow loads, and NPS loads) for the three cases were obtained by multiplying the average concentration for most parameters (or best estimate for parameters with limited data) by the total runoff for each rainfall event (Table E.4). Overall, Lake Livingston contributes a greater load to Galveston Bay than Lake Houston for all the parameters except for fecal coliform. Both lakes contribute substantial amounts of pollutants into the bay.

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

The Galveston Bay GIS database consists of six elements:

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

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

Project Results

The major conclusions observed from the project results and maps are:

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

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

2. Annual loads for Case 1, a year with average rainfall, were the following (see Table E.4):

Annual Non-Point Source Loads
Average Year
(thousands kg/yr, except where noted)

	Study Area Only	Entire Watershed
Runoff	3,010 ac-ft/yr	9,050 ac-ft/yr
Total Suspended Solids	481,000	581,000
Total Nitrogen	6,420	23,128
Total Phosphorus	1,110	3,711
Biochemical Oxygen Demand	26,300	46,500
Oil and Grease	14,200	14,200
Fecal Coliforms	355×10^{15} cfu/yr	355×10^{15} cfu/yr
Dissolved Copper	10.9	34.0
Pesticides	0.8	1.5

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

3. To assess the impact of non-point sources under high annual rainfall conditions, Case 2 analyses were conducted assuming annual rainfall that occurs, on the average, once every 10 years. The resulting runoff and loads were 40-60% higher than those found for Case 1 or the average year (Table E.4).

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

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

6. The pollutant load from the upper watersheds, which originates as discharge from Lake Houston and Lake Livingston, varied considerably among parameters. Over 70% of the annual nitrogen load, for example, originates from the upper watersheds and overwhelms the contribution from the local watersheds. For oil and grease and bacteria, however, the contribution of the upper watersheds was minor compared to the local watersheds in the study area (Table E.4). The results from Case 3 indicate that the lakes have a much lower impact on loads for small storms centered over the Houston metropolitan area. The loads from the lakes are not more than 2% of the total for any of the parameters for Case 3, Individual storm. For dry periods in the Houston area, however, the discharge from the upper watersheds may have a significant impact on the water quality of the bay.

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

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

8. A priority ranking of subwatersheds by NPS loading (kg/ha/yr) is provided in Table E.6 for each water quality parameter. This ranking can be used for the development of management activities and the implementation of activity plans for the immediate Galveston Bay watershed. For example, by using the priority ranking and the NPS maps (provided in Volume II), water quality managers can:

   - Identify areas with high sediment loads for the purpose of implementing special erosion control measures or for constructing sediment control structures.

   - Determine which municipalities have jurisdiction over high NPS areas.

- Compare the relative differences in NPS loads between high NPS source areas and low NPS areas.

- Locate areas with high NPS loadings within individual watersheds.

- Identify NPS "hot spots" on a subwatershed basis using the priority ranking.

- Identify NPS "hot spots" within each subwatershed by evaluating the high resolution land use maps provided for each watershed (see Volume II).

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

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

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

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

Table E.1 - Legend for Subwatersheds
Non-point Source Characterization Project
Galveston Bay National Estuary Program

Abbreviation	Watershed	# Subwatersheds
AB	Austin/Bastrop Bayous	3
AD	Addicks Reservoir	2
AT	Armand/Taylor Bayous	4
BF	Buffalo Bayou	5
BK	Barker Reservoir	2
BR	Brays Bayou	7
CC	Clear Creek	5
CE	Cedar Bayou	4
CH	Chocolate Bayou	3
DB	Dickinson Bayou	3
EB	East Bay	4
GR	Greens Bayou	7
NB	North Bay	1
SB	South Bay	4
SC	Ship Channel	9
SJ	San Jacinto River	2
SM	Sims Bayou	5
TB	Trinity Bay	4
TR	Trinity River	14
WB	West Bay	7
WO	White Oak Bayou	5
	Total Subwatersheds	100

Notes:
1. See Section 6.1 for description of watersheds and subwatersheds

Table E.2 - Project Land Use by Watershed

Non-Point Source Characterization Project
Galveston Bay National Estuary Program

Watershed	Land Use by Watershed (square miles)								Total	% of Total
	High-Density Urban	Residential	Open/ Pasture	Agriculture	Barren	Wetlands	Water	Forest		
Addicks Reservoir	13	9	32	66	3	10		1	134	3%
Armand/Taylor	15	10	28	10		9	1	3	77	2%
Barker Reservoir	7	4	23	65	8	13			122	3%
Bastrop/Austin	6	13	58	88	1	42	2	3	213	5%
Brays Bayou	53	27	26	16	1	4			127	3%
Buffalo Bayou	39	32	15	14		4		1	105	2%
Cedar Bayou	8	18	50	80	1	31	1	24	211	5%
Chocolate Bayou	4	6	32	95	1	26	1	5	170	4%
Clear Creek	20	15	67	44	1	28	3	3	182	4%
Dickinson Bayou	5	9	45	20		19	1	1	101	2%
East Bay	10	28	72	73		89	6	8	288	7%
Green's Bayou	37	52	54	18	1	14		31	208	5%
North Bay	6	5	9	1		2		1	25	1%
San Jacinto	5	11	17	8		8	4	15	68	2%
Ship Channel	56	31	42	15	1	13	4	4	166	4%
Sims Bayou	23	15	34	11		8		1	93	2%
South Bay	25	6	22	7		12	6		78	2%
Trinity Bay	6	19	69	79		67	14	62	317	7%
Trinity River	11	34	135	145	2	151	7	613	1099	26%
West Bay	30	22	105	79	1	94	11	2	344	8%
White Oak Bayou	39	32	25	10	1	3			110	3%
Total (sq mi)	418	400	962	947	22	648	62	779	4238	100%
% of Total	10%	9%	23%	22%	1%	15%	1%	18%	100%	

Notes:

1. Source LANDSAT imagery taken November, 1990 as interpreted by Intera Aero Services, Inc.

Table E.3 - Event Mean Concentrations (EMCs) Used for Non-Point Source (NPS) Calculation
Non-Point Source Characterization Project
Galveston Bay National Estuary Program

Water Quality Parameters Used for Mapping								
Land Use Category	Total Suspended Solids (mg/l)	Total Nitrogen (mg/l)	Total Phosphorus (mg/l)	Biochemical Oxygen Demand (mg/l)	Oil and Grease (mg/l)	Fecal Coliforms (colonies/ 100 ml)	Dissolved Copper (μg/l)	Pesticides (μg/l)
High Density Urban	166	2.10	0.37	9	13	22,000	3.1	0.4
Residential	100	3.41	0.79	15	4	22,000	3.1	0.4
Agricultural	201	1.56	0.36	4	0	2,500	3.1	0.1
Open/Pasture	70	1.51	0.12	6	0	2,500	3.1	0.1
Forest	39	0.83	0.06	6	0	1,600	3.1	0.1
Wetlands	39	0.83	0.06	6	0	1,600	3.1	0.0
Water		0.00	0.00	0	0	0	0.0	0.0
Barren	2200	5.20	0.59	13	0	1,600	3.1	0.1

Supplemental Metals and Synthetic Organic Hydrocarbons (not mapped) (μg/l)								
Land Use Category	Dissolved Lead	Dissolved Zinc	Dissolved Arsenic	Dissolved Cadmium	Dissolved Chromium	Dissolved Mecury	Dissolved Silver	
High Density Urban	2.4	18.3	3.0	0.5	5.0	0.1	0.5	
Residential	2.4	18.3	3.0	0.5	5.0	0.1	0.5	
Agricultural	2.4	18.3	3.0	0.5	5.0	0.1	0.5	
Open/Pasture	2.4	18.3	3.0	0.5	5.0	0.1	0.5	
Forest	2.4	18.3	3.0	0.5	5.0	0.1	0.5	
Wetlands	2.4	18.3	3.0	0.5	5.0	0.1	0.5	
Water	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
Barren	2.4	18.3	3.0	0.5	5.0	0.1	0.5	

Table E.4 - Summary of Non-Point Source Loads

Non-Point Source Characterization Project

Galveston Bay National Estuary Program

CASE 1 Average Year	Runoff Volume (thousand ac-ft)	Total Suspended Solids (million kg)	Total Nitrogen (thousand kg)	Total Phosphorus (thousand kg)	Biochemical Oxygen Demand (million kg)	Oil and Grease (million kg)	Fecal Coliform (xE15 col)	Dissolved Copper (kg)	Pesticides (kg)
GBNEP	3,010	481	6,420	1,110	26.3	14.2	355	10,900	749
Lake Houston	1,380	43	2,451	647	5.8	0.0 [1]	5.6	5,277 [2]	170 [3]
Lake Livingston	4,660	57	14,257	1,955	14.4	0.0 [1]	1.1	17,821	575 [3]
Total	9,050	581	23,128	3,711	46.5	14.2	362	33,998	1,494
% Lakes of Total	67%	17%	72%	70%	43%	0%	2%	68%	50%
CASE 2 Wet Year									
GBNEP	4,790	747	10,100	1,730	41.5	20.4	531	17,500	1,140
Lake Houston	2,200	68	3,908	1,031	9.2	0.0 [1]	9.0	8,413 [2]	271 [3]
Lake Livingston	6,800	84	20,804	2,852	21.0	0.0 [1]	1.6	26,005	839 [3]
Total	13,790	899	34,812	5,613	71.7	20.4	542	51,918	2,250
% Lakes of Total	65%	17%	71%	69%	42%	0%	2%	66%	49%
CASE 3 Individual Storm									
GBNEP	603	92	1,230	205	5.1	1.8	55	2,250	125
Lake Houston	2.1	0.1	3.7	1.0	0.01	0.0 [1]	0.01	8 [2]	0.3 [3]
Lake Livingston	5.4	0.1	16.4	2.3	0.02	0.0 [1]	0.001	21	0.7 [3]
Total	610	92	1,250	208	5.1	1.8	55	2,279	126
% Lakes of Total	1%	0%	2%	2%	0%	0%	0%	1%	1%

NOTES:
1. Calculated assuming GBNEP Oil & Grease concentration of 0.0 mg/l.
2. Calculated assuming GBNEP Copper concentration of 3.1 µg/l
3. Calculated assuming GBNEP Pesticide concentration of 0.1 µg/l.

Table E.5 - Non-Point Source (NPS) Loads by Land Use for Case 1 (Average Year)
Non-Point Source Characterization Project
Galveston Bay National Estuary Program

NPS Parameter	Units	H. Den. Urb.	Residential	Open	Agriculture	Barren	Wetlands	Water	Forest	Total
Runoff Volume	thousand ac-ft	766	371	567	593	21	187	164	345	3,014
TSS	million kg	157	46	49	147	57	9	0	17	481
Total Nitrogen	thousand kg	1,985	1,561	1,056	1,142	134	192	0	353	6,422
Total Phosphorus	thousand kg	350	362	84	264	15	14	0	26	1,113
BOD	million kg	8	7	4	3	0	1	0	3	26
Oil and Grease	million kg	12	2	0	0	0	0	0	0	14
Fecal Coliform	xE15 col	208	101	17	18	0	4	0	7	355
Dissolved Copper	kg	2,930	1,419	2,167	2,269	80	716	0	1,318	10,900
Pesticides	kg	378	183	70	73	3	0	0	43	749
Total		6,794	4,051	4,014	4,510	311	1,123	164	2,110	23,077

Table E.6 - Priority Ranking of Annual NPS Loads by Subwatershed for Case 1

Non-Point Source Characterization Project
Galveston Bay National Estuary Program

Total Suspended Solids (kg/ha/yr)								
	Subwatershed	TSS		Subwatershed	TSS		Subwatershed	TSS
1	TR02	1,829	34	AD01	649	67	CE04	395
2	BF05	1,163	35	GR02	629	68	CH03	373
3	BK01	1,125	36	GR01	626	69	CH02	369
4	BF04	1,101	37	CC03	622	70	TB02	356
5	BR03	1,028	38	NB01	621	71	EB01	355
6	WO05	997	39	AT01	615	72	EB02	351
7	SC04	991	40	SM01	611	73	GR05	346
8	BR07	969	41	GR03	595	74	WB01	345
9	BR05	967	42	SM03	574	75	WB07	336
10	WO02	936	43	SB03	570	76	WB03	332
11	SM04	920	44	CE01	542	77	DB02	326
12	WO03	911	45	AT04	535	78	TB04	326
13	SC01	897	46	SC08	524	79	DB01	320
14	BR06	876	47	CC01	509	80	AB03	318
15	WB06	845	48	BK02	508	81	TR11	317
16	SB02	841	49	SM02	505	82	TR13	315
17	SC06	837	50	GR06	497	83	TB01	305
18	SC09	832	51	CH01	494	84	WB04	303
19	SC02	821	52	AD02	486	85	WB05	288
20	WO04	805	53	GR04	462	86	EB03	283
21	BR04	798	54	SJ02	454	87	TB03	280
22	SC03	795	55	CC04	452	88	DB03	277
23	BF03	794	56	TR12	450	89	SB04	262
24	SM05	792	57	CC02	450	90	TR14	257
25	AT02	789	58	CE02	446	91	TR10	239
26	BR01	785	59	AT03	446	92	TR04	217
27	BF02	772	60	SB01	443	93	TR03	211
28	WO01	757	61	WB02	435	94	TR09	205
29	BR02	756	62	AB01	428	95	TR08	202
30	GR07	722	63	CE03	423	96	TR05	132
31	SC05	717	64	EB04	418	97	TR07	127
32	SC07	707	65	AB02	417	98	TR06	96
33	BF01	651	66	CC05	401			

NOTES:

1. Key to Subwatershed identification:
   TR02 = Subwatershed 2 of the Trinity River Watershed (see Figure E.2)
2. Key to Watersheds:
   AB = Austin/Bastrop
   AD = Addicks Reservoir
   AT = Armand/Taylor
   BF = Buffalo
   BK = Barker Reservoir
   BR = Brays
   CC = Clear Creek
   CE = Cedar
   CH = Chocolate
   DB = Dickinson
   EB = East Bay
   GR = Greens
   NB = North Bay
   SB = South Bay
   SC = Ship Channel
   SJ = San Jacinto
   SM = Sims
   TB = Trinity Bay
   TR = Trinity River
   WB = West Bay
   WO = White Oak
3. See Figures E.5 and 7.2 for map of loads.

Table E.6 - Priority Ranking of Annual NPS Loads by Subwatershed for Case 1

Non-Point Source Characterization Project
Galveston Bay National Estuary Program

Total Nitrogen (kg/ha/yr)								
	Subwatershed	Nitrogen		Subwatershed	Nitrogen		Subwatershed	Nitrogen
1	TR02	24.58	34	CC03	9.29	67	CE01	5.20
2	BF05	16.59	35	AT02	9.27	68	CC01	5.08
3	BF04	16.04	36	BR01	9.15	69	WB07	4.87
4	WO05	15.71	37	AT04	9.02	70	TR11	4.79
5	BR07	15.07	38	BR02	9.02	71	DB01	4.78
6	BR05	14.84	39	GR02	8.91	72	EB02	4.71
7	BR06	14.66	40	AT01	8.81	73	WB05	4.64
8	BF02	14.38	41	SC08	8.58	74	EB01	4.63
9	WO04	14.33	42	BF01	8.45	75	TB02	4.63
10	SC01	14.04	43	SM01	8.18	76	TR13	4.59
11	BF03	14.02	44	CE04	7.90	77	TR14	4.57
12	WO03	13.97	45	SB03	7.50	78	CH03	4.49
13	BR03	13.92	46	CE03	7.47	79	AB01	4.43
14	WO02	13.62	47	CC04	7.29	80	WB01	4.26
15	SC04	13.47	48	SJ02	7.11	81	AB03	4.23
16	SM04	13.37	49	AT03	7.11	82	WB03	4.23
17	SC03	12.88	50	SM02	7.05	83	WB04	4.22
18	BR04	12.87	51	EB04	6.97	84	CH01	4.15
19	SC02	12.63	52	WB02	6.90	85	BK02	4.15
20	SM05	12.22	53	GR04	6.75	86	CH02	4.12
21	GR07	12.10	54	GR05	6.71	87	TB03	4.11
22	SC09	11.93	55	AD02	6.51	88	SB04	4.10
23	SC06	11.24	56	SB01	6.44	89	DB03	4.00
24	SB02	10.82	57	CC05	6.20	90	TB01	3.75
25	SC05	10.68	58	CC02	5.98	91	TR10	3.70
26	WO01	10.49	59	BK01	5.97	92	TR09	3.25
27	GR06	10.40	60	TB04	5.79	93	TR08	2.78
28	WB06	10.30	61	DB02	5.68	94	TR03	2.62
29	GR03	10.13	62	EB03	5.56	95	TR04	2.53
30	NB01	10.04	63	TR12	5.52	96	TR07	1.80
31	SM03	9.43	64	CE02	5.51	97	TR05	1.44
32	SC07	9.40	65	AD01	5.37	98	TR06	1.26
33	GR01	9.35	66	AB02	5.37			

NOTES:

1. Key to Subwatershed identification:
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   DB = Dickinson
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   GR = Greens
   NB = North Bay
   SB = South Bay
   SC = Ship Channel
   SJ = San Jacinto
   SM = Sims
   TB = Trinity Bay
   TR = Trinity River
   WB = West Bay
   WO = White Oak
3. See Figures E.6 and 7.3 for map of loads.

Table E.6 - Priority Ranking of Annual NPS Loads by Subwatershed for Case 1

Non-Point Source Characterization Project
Galveston Bay National Estuary Program

Total Phosphorus (kg/ha/yr)								
	Subwatershed	Phosphorus		Subwatershed	Phosphorus		Subwatershed	Phosphorus
1	TR02	3.28	34	BR01	1.62	67	CC01	0.87
2	BF05	3.08	35	SC07	1.62	68	EB02	0.86
3	WO05	3.05	36	BR02	1.61	69	CH01	0.85
4	BF04	2.98	37	GR02	1.60	70	AB01	0.84
5	BF02	2.90	38	BF01	1.58	71	AB02	0.82
6	BR07	2.84	39	AT02	1.57	72	EB01	0.82
7	BR06	2.83	40	CC03	1.56	73	WB07	0.80
8	WO04	2.82	41	CE04	1.55	74	CH03	0.80
9	BF03	2.79	42	SC08	1.48	75	TR14	0.79
10	BR05	2.78	43	AT01	1.44	76	DB01	0.76
11	WO03	2.69	44	SM01	1.34	77	TB02	0.76
12	SC01	2.64	45	CE03	1.32	78	BK02	0.75
13	BR03	2.53	46	SB03	1.28	79	WB03	0.75
14	WO02	2.51	47	CC04	1.27	80	WB05	0.74
15	SM04	2.49	48	GR05	1.25	81	AB03	0.74
16	BR04	2.46	49	SJ02	1.24	82	TR13	0.71
17	SC04	2.45	50	GR04	1.22	83	WB04	0.70
18	SC03	2.39	51	AD02	1.22	84	CH02	0.69
19	SC02	2.33	52	AT03	1.21	85	SB04	0.67
20	GR07	2.31	53	EB04	1.21	86	TB03	0.66
21	SM05	2.18	54	WB02	1.15	87	TR11	0.64
22	SC09	2.10	55	SM02	1.14	88	WB01	0.63
23	GR06	2.03	56	SB01	1.10	89	DB03	0.60
24	SC06	1.98	57	TB04	1.06	90	TB01	0.59
25	SC05	1.97	58	CE01	1.02	91	TR10	0.43
26	SB02	1.93	59	CC05	1.01	92	TR03	0.42
27	WO01	1.89	60	BK01	1.01	93	TR04	0.38
28	GR03	1.84	61	CC02	0.99	94	TR09	0.36
29	WB06	1.81	62	AD01	0.97	95	TR08	0.34
30	NB01	1.76	63	CE02	0.94	96	TR07	0.24
31	SM03	1.68	64	DB02	0.93	97	TR05	0.23
32	AT04	1.66	65	EB03	0.93	98	TR06	0.16
33	GR01	1.65	66	TR12	0.89			

NOTES:

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   SB = South Bay
   SC = Ship Channel
   SJ = San Jacinto
   SM = Sims
   TB = Trinity Bay
   TR = Trinity River
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   WO = White Oak
3. See Figures E.7 and 7.4 for map of loads.

Table E.6 - Priority Ranking of Annual NPS Loads by Subwatershed for Case 1

Non-Point Source Characterization Project
Galveston Bay National Estuary Program

Total Biological Oxygen Demand (kg/ha/yr)								
	Subwatershed	BOD		Subwatershed	BOD		Subwatershed	BOD
1	TR02	125.95	34	AT04	37.76	67	AB02	20.68
2	BF05	68.13	35	CC03	37.59	68	TR10	19.90
3	BF04	66.05	36	GR02	36.47	69	WB07	19.81
4	WO05	65.13	37	AT02	36.16	70	WB05	18.91
5	BR07	62.41	38	BR01	35.67	71	BK01	18.67
6	BR05	61.27	39	SC08	35.26	72	DB01	18.60
7	BR06	61.05	40	AT01	35.24	73	EB02	18.31
8	BF02	60.67	41	BR02	35.12	74	TB02	18.15
9	WO04	60.07	42	CE04	33.91	75	AD01	18.03
10	BF03	59.03	43	BF01	33.08	76	CC01	17.96
11	SC01	57.96	44	SM01	32.15	77	TR09	17.95
12	WO03	57.57	45	CE03	31.47	78	EB01	17.76
13	BR03	56.46	46	SJ02	30.68	79	TB03	16.99
14	WO02	55.42	47	SB03	30.35	80	CE01	16.95
15	SC04	54.87	48	CC04	29.99	81	CH03	16.68
16	SM04	54.66	49	GR05	29.82	82	WB04	16.59
17	SC03	53.10	50	AT03	29.59	83	WB03	16.52
18	BR04	53.07	51	EB04	29.50	84	SB04	16.49
19	SC02	52.26	52	GR04	28.94	85	AB03	16.32
20	GR07	50.89	53	SM02	28.36	86	TB01	16.13
21	SM05	50.00	54	WB02	27.80	87	WB01	16.03
22	SC09	48.76	55	SB01	26.59	88	DB03	16.01
23	GR06	45.82	56	AD02	26.33	89	AB01	14.94
24	SC06	45.56	57	CC05	25.57	90	TR08	14.92
25	SC05	43.88	58	TB04	24.19	91	CH02	14.58
26	SB02	43.62	59	EB03	23.53	92	BK02	14.37
27	WO01	42.17	60	DB02	23.33	93	CH01	12.60
28	GR03	42.03	61	TR11	23.20	94	TR03	11.53
29	NB01	41.56	62	CC02	22.92	95	TR04	11.52
30	WB06	41.42	63	TR12	22.23	96	TR07	8.95
31	SM03	38.63	64	CE02	21.46	97	TR06	6.77
32	GR01	38.31	65	TR14	20.95	98	TR05	6.77
33	SC07	38.22	66	TR13	20.90			

NOTES:

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   SC = Ship Channel
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   SM = Sims
   TB = Trinity Bay
   TR = Trinity River
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   WO = White Oak
3. See Figures E.8 and 7.5 for map of loads.

Table E.6 - Priority Ranking of Annual NPS Loads by Subwatershed for Case 1

Non-Point Source Characterization Project
Galveston Bay National Estuary Program

Total Oil and Grease (kg/ha/yr)								
	Subwatershed	O&G		Subwatershed	O&G		Subwatershed	O&G
1	BF05	83.36	34	SC05	30.70	67	TR02	7.06
2	BF04	79.28	35	GR01	30.37	68	DB03	6.49
3	WO05	65.98	36	BF01	30.23	69	WB04	6.35
4	BR07	65.59	37	GR03	29.10	70	DB01	5.66
5	BR05	64.85	38	GR02	28.09	71	CE02	5.55
6	SC04	61.78	39	SM03	27.24	72	EB03	5.45
7	BR03	61.23	40	SB01	27.20	73	CC01	5.19
8	SB02	59.71	41	AT04	26.22	74	TR11	5.06
9	SC01	59.48	42	SM01	24.85	75	CH03	4.94
10	WO02	57.90	43	GR06	22.52	76	BK02	4.44
11	BR06	57.35	44	SC08	22.36	77	TB02	4.04
12	WB06	53.81	45	CC04	21.41	78	TR14	3.76
13	SM04	52.77	46	EB04	19.49	79	AB03	3.72
14	SC02	51.80	47	CC05	18.89	80	TB03	3.70
15	WO03	51.05	48	SM02	17.67	81	WB01	3.55
16	WO04	50.86	49	AT03	17.17	82	AB01	3.38
17	SC03	49.71	50	WB02	17.09	83	EB02	3.20
18	SM05	48.71	51	WB07	16.61	84	TR12	3.03
19	SC09	48.08	52	GR04	15.98	85	EB01	2.90
20	BF03	48.02	53	CE03	15.02	86	CH02	2.89
21	SC06	47.83	54	SJ02	13.20	87	TR13	2.78
22	BF02	46.75	55	CE04	13.00	88	TR03	2.09
23	BR04	43.71	56	GR05	12.91	89	TR08	2.03
24	BR01	40.56	57	AD02	12.19	90	TR10	1.87
25	BR02	40.22	58	WB05	11.62	91	CE01	1.80
26	SC07	37.77	59	DB02	10.47	92	TR09	1.43
27	GR07	36.16	60	AD01	10.27	93	CH01	1.43
28	SB03	35.74	61	CC02	10.20	94	TB01	1.28
29	WO01	35.19	62	AB02	10.12	95	TR04	1.25
30	NB01	33.93	63	SB04	9.25	96	TR07	1.22
31	CC03	33.00	64	WB03	8.25	97	TR05	0.90
32	AT02	31.44	65	TB04	7.48	98	TR06	0.38
33	AT01	30.84	66	BK01	7.10			

NOTES:

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   SM = Sims
   TB = Trinity Bay
   TR = Trinity River
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   WO = White Oak
3. See Figures E.9 and 7.6 for map of loads.

Table E.6 - Priority Ranking of Annual NPS Loads by Subwatershed for Case 1

Non-Point Source Characterization Project
Galveston Bay National Estuary Program

Total Fecal Coliforms (xE12 col/ha/yr)								
	Subwatershed	FC		Subwatershed	FC		Subwatershed	FC
1	BF05	1.56	34	GR01	0.67	67	WB03	0.21
2	BF04	1.49	35	SB03	0.65	68	CE02	0.20
3	WO05	1.37	36	SM03	0.64	69	DB01	0.19
4	BR07	1.32	37	AT02	0.64	70	TR14	0.19
5	BR05	1.29	38	AT04	0.63	71	BK01	0.19
6	BR06	1.23	39	GR02	0.63	72	WB04	0.18
7	SC01	1.20	40	BF01	0.63	73	TR11	0.18
8	BR03	1.19	41	AT01	0.62	74	DB03	0.17
9	SC04	1.18	42	TR02	0.58	75	CH03	0.17
10	WO04	1.16	43	SC08	0.54	76	CC01	0.17
11	WO02	1.15	44	SM01	0.52	77	EB02	0.16
12	BF02	1.14	45	SB01	0.52	78	TR12	0.16
13	BF03	1.12	46	CC04	0.49	79	AB03	0.16
14	WO03	1.12	47	EB04	0.46	80	TB02	0.16
15	SM04	1.09	48	CE04	0.46	81	EB01	0.15
16	SC02	1.05	49	AT03	0.43	82	TB03	0.15
17	SC03	1.04	50	CE03	0.43	83	TR13	0.15
18	SB02	1.04	51	GR04	0.42	84	BK02	0.14
19	BR04	0.99	52	WB02	0.41	85	AB01	0.14
20	SM05	0.99	53	SM02	0.41	86	WB01	0.13
21	SC09	0.96	54	CC05	0.41	87	CE01	0.13
22	WB06	0.95	55	GR05	0.41	88	CH02	0.12
23	SC06	0.92	56	SJ02	0.39	89	TR10	0.10
24	GR07	0.88	57	AD02	0.37	90	TB01	0.09
25	WO01	0.76	58	WB07	0.34	91	CH01	0.09
26	BR01	0.75	59	DB02	0.30	92	TR03	0.09
27	BR02	0.74	60	TB04	0.29	93	TR09	0.09
28	NB01	0.74	61	CC02	0.28	94	TR08	0.08
29	SC07	0.74	62	WB05	0.27	95	TR04	0.07
30	SC05	0.73	63	AB02	0.25	96	TR07	0.05
31	GR03	0.70	64	EB03	0.24	97	TR05	0.05
32	GR06	0.69	65	AD01	0.24	98	TR06	0.03
33	CC03	0.67	66	SB04	0.23			

NOTES:

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3. See Figures E.10 and 7.7 for map of loads.

Table E.6 - Priority Ranking of Annual NPS Loads by Subwatershed for Case 1

Non-Point Source Characterization Project
Galveston Bay National Estuary Program

Total Copper (kg/ha/yr)								
	Subwatershed	Copper		Subwatershed	Copper		Subwatershed	Copper
1	TR02	0.067	34	GR06	0.014	67	DB02	0.009
2	BF05	0.023	35	BR01	0.014	68	EB03	0.009
3	BF04	0.022	36	BR02	0.014	69	TR09	0.009
4	WO05	0.020	37	GR01	0.014	70	TB04	0.009
5	BR07	0.020	38	SM03	0.014	71	AD01	0.009
6	BR05	0.020	39	SC08	0.013	72	AD02	0.009
7	BR03	0.019	40	SM01	0.013	73	EB01	0.009
8	SC04	0.019	41	AT04	0.013	74	EB02	0.009
9	BR06	0.019	42	GR02	0.013	75	BK01	0.009
10	SC01	0.019	43	BF01	0.012	76	TR14	0.009
11	WO02	0.019	44	CE03	0.012	77	TB01	0.009
12	SM04	0.018	45	SM02	0.011	78	DB01	0.008
13	WO03	0.018	46	SJ02	0.011	79	AB01	0.008
14	WO04	0.018	47	TR12	0.011	80	CH03	0.008
15	SC03	0.018	48	SB03	0.011	81	CH01	0.008
16	SC02	0.018	49	AT03	0.011	82	TB03	0.008
17	BF03	0.017	50	CC04	0.011	83	WB07	0.008
18	BF02	0.017	51	CE04	0.011	84	WB01	0.008
19	SM05	0.017	52	EB04	0.011	85	CH02	0.008
20	SC09	0.017	53	TR11	0.011	86	WB04	0.008
21	BR04	0.017	54	WB02	0.011	87	WB03	0.008
22	SC06	0.017	55	CC02	0.010	88	AB03	0.008
23	GR07	0.016	56	CE02	0.010	89	TR08	0.008
24	SB02	0.016	57	GR04	0.010	90	WB05	0.007
25	SC05	0.015	58	CE01	0.010	91	DB03	0.007
26	WB06	0.015	59	TR13	0.010	92	BK02	0.007
27	WO01	0.015	60	GR05	0.010	93	SB04	0.007
28	NB01	0.015	61	CC05	0.010	94	TR04	0.006
29	CC03	0.014	62	SB01	0.010	95	TR03	0.006
30	SC07	0.014	63	TR10	0.010	96	TR07	0.005
31	AT02	0.014	64	CC01	0.009	97	TR06	0.004
32	AT01	0.014	65	AB02	0.009	98	TR05	0.003
33	GR03	0.014	66	TB02	0.009			

NOTES:

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2. Key to Watersheds:

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AT = Armand/Taylor	DB = Dickinson	SM = Sims
BF = Buffalo	EB = East Bay	TB = Trinity Bay
BK = Barker Reservoir	GR = Greens	TR = Trinity River
BR = Brays	NB = North Bay	WB = West Bay
CC = Clear Creek	SB = South Bay	WO = White Oak

3. See Figures E.11 and 7.8 for map of loads.

Table E.6 - Priority Ranking of Annual NPS Loads by Subwatershed for Case 1

Non-Point Source Characterization Project
Galveston Bay National Estuary Program

Total Pesticides (kg/ha/yr)								
	Subwatershed	Pesticides		Subwatershed	Pesticides		Subwatershed	Pesticides
1	BF05	0.00285	34	CC03	0.00131	67	TR11	0.00048
2	BF04	0.00273	35	GR01	0.00129	68	SB04	0.00047
3	WO05	0.00250	36	AT02	0.00125	69	TR12	0.00046
4	BR07	0.00243	37	SM03	0.00125	70	BK01	0.00046
5	BR05	0.00239	38	AT01	0.00122	71	TR14	0.00046
6	BR06	0.00227	39	SB03	0.00122	72	DB01	0.00045
7	TR02	0.00225	40	GR02	0.00122	73	WB03	0.00044
8	SC01	0.00223	41	AT04	0.00121	74	CC01	0.00043
9	BR03	0.00221	42	BF01	0.00120	75	TR13	0.00042
10	SC04	0.00218	43	SC08	0.00108	76	WB04	0.00041
11	WO02	0.00214	44	SM01	0.00106	77	CH03	0.00041
12	WO04	0.00214	45	SB01	0.00098	78	TB02	0.00040
13	BF02	0.00209	46	CC04	0.00096	79	DB03	0.00039
14	WO03	0.00208	47	CE04	0.00091	80	EB02	0.00039
15	BF03	0.00207	48	EB04	0.00088	81	CE01	0.00038
16	SM04	0.00204	49	CE03	0.00088	82	EB01	0.00037
17	SC02	0.00196	50	AT03	0.00087	83	AB03	0.00036
18	SC03	0.00195	51	GR04	0.00085	84	AB01	0.00036
19	SB02	0.00192	52	WB02	0.00084	85	TB03	0.00036
20	SM05	0.00186	53	SM02	0.00084	86	TR10	0.00035
21	BR04	0.00186	54	GR05	0.00082	87	WB01	0.00035
22	SC09	0.00181	55	SJ02	0.00082	88	BK02	0.00034
23	WB06	0.00176	56	CC05	0.00081	89	CH02	0.00032
24	SC06	0.00173	57	AD02	0.00073	90	TR09	0.00031
25	GR07	0.00167	58	WB07	0.00066	91	TB01	0.00031
26	WO01	0.00146	59	DB02	0.00063	92	CH01	0.00029
27	BR01	0.00142	60	CC02	0.00061	93	TR08	0.00028
28	SC05	0.00142	61	TB04	0.00059	94	TR03	0.00024
29	NB01	0.00142	62	AB02	0.00056	95	TR04	0.00022
30	BR02	0.00141	63	WB05	0.00056	96	TR07	0.00016
31	SC07	0.00139	64	AD01	0.00054	97	TR05	0.00013
32	GR03	0.00136	65	EB03	0.00052	98	TR06	0.00012
33	GR06	0.00133	66	CE02	0.00050			

NOTES:

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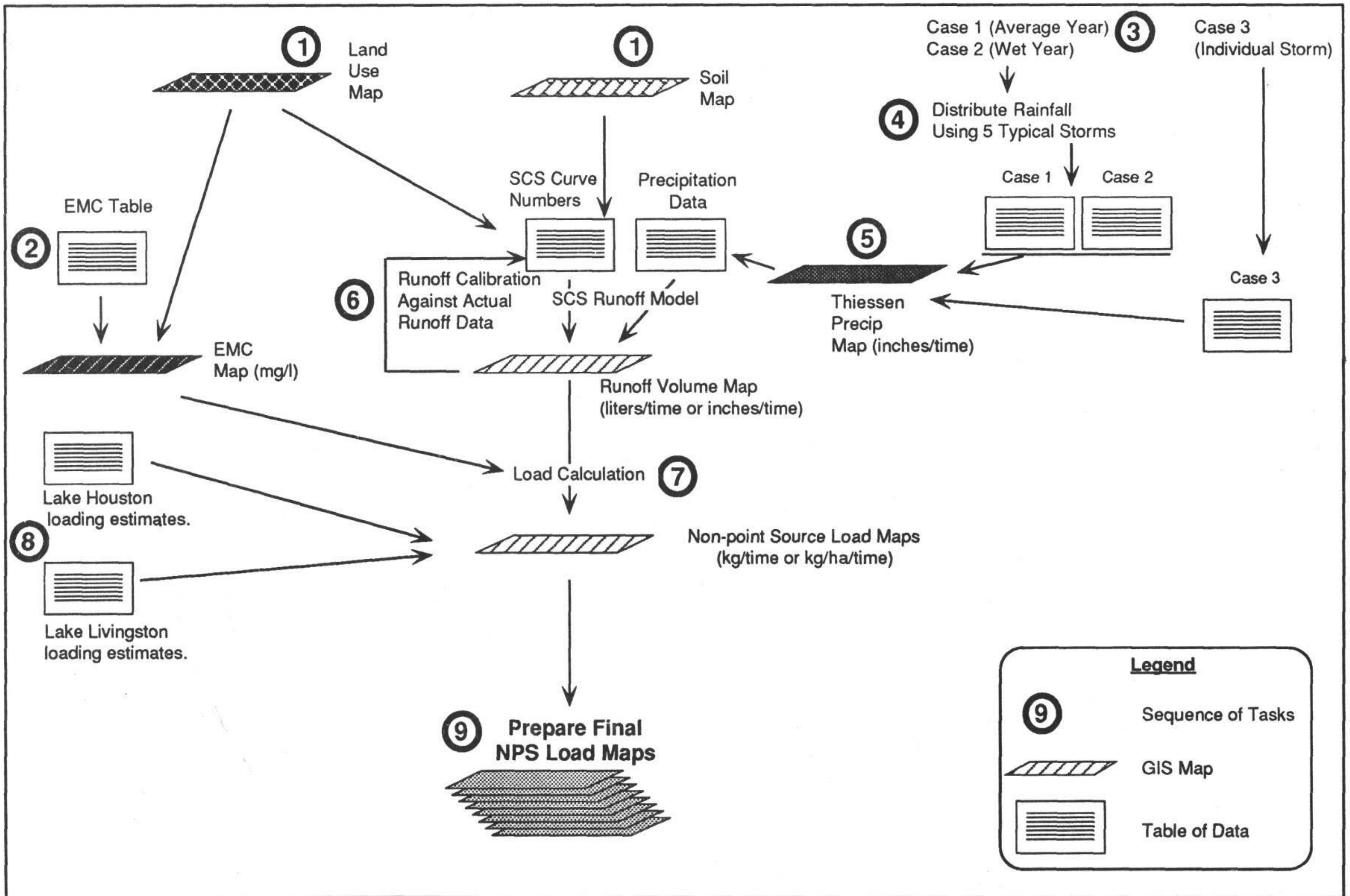
3. See Figures E.12 and 7.9 for map of loads.



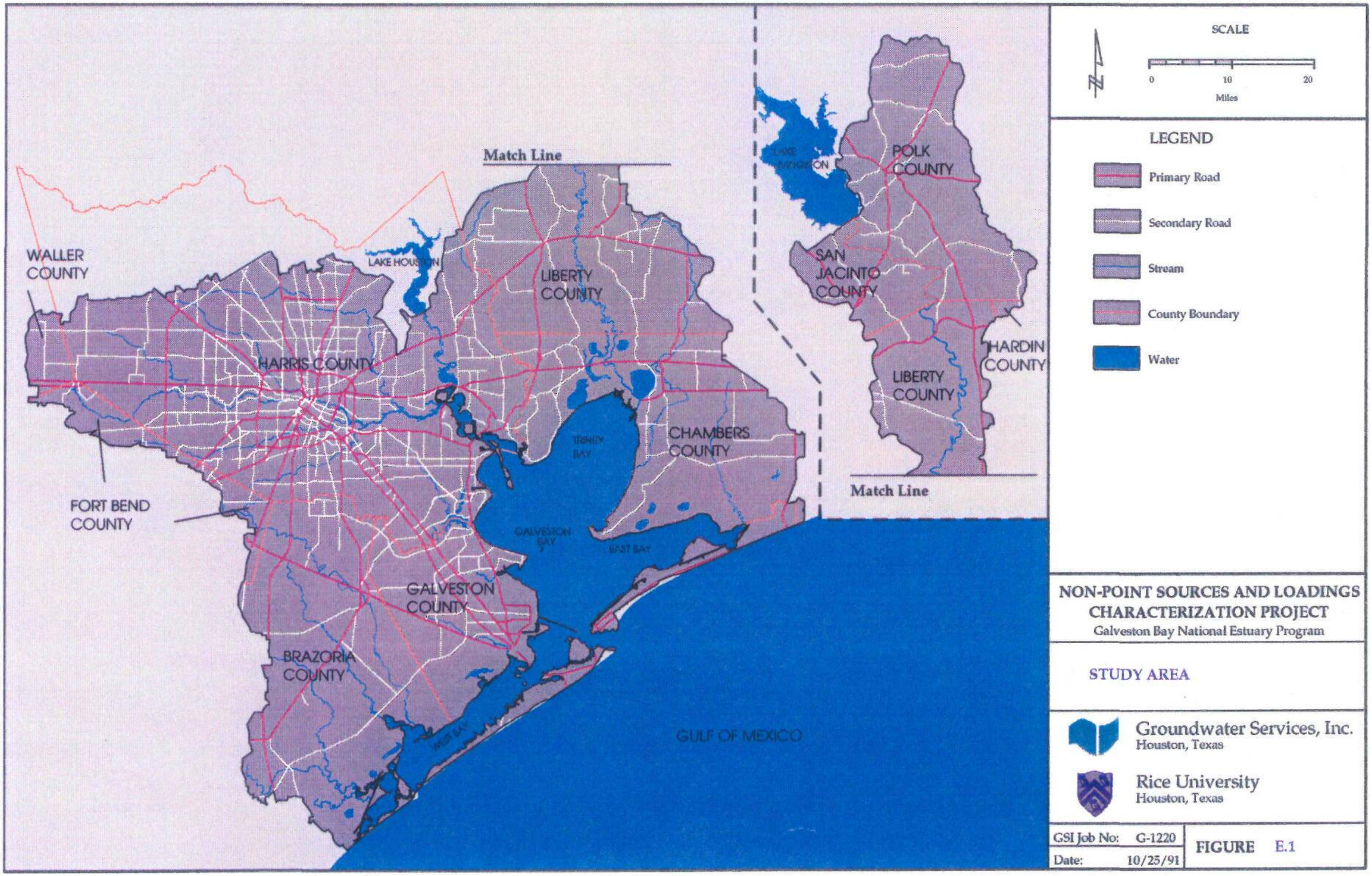
Groundwater Services, Inc.
Houston, Texas

Rice University
Dept. of Environmental Science and Engineering

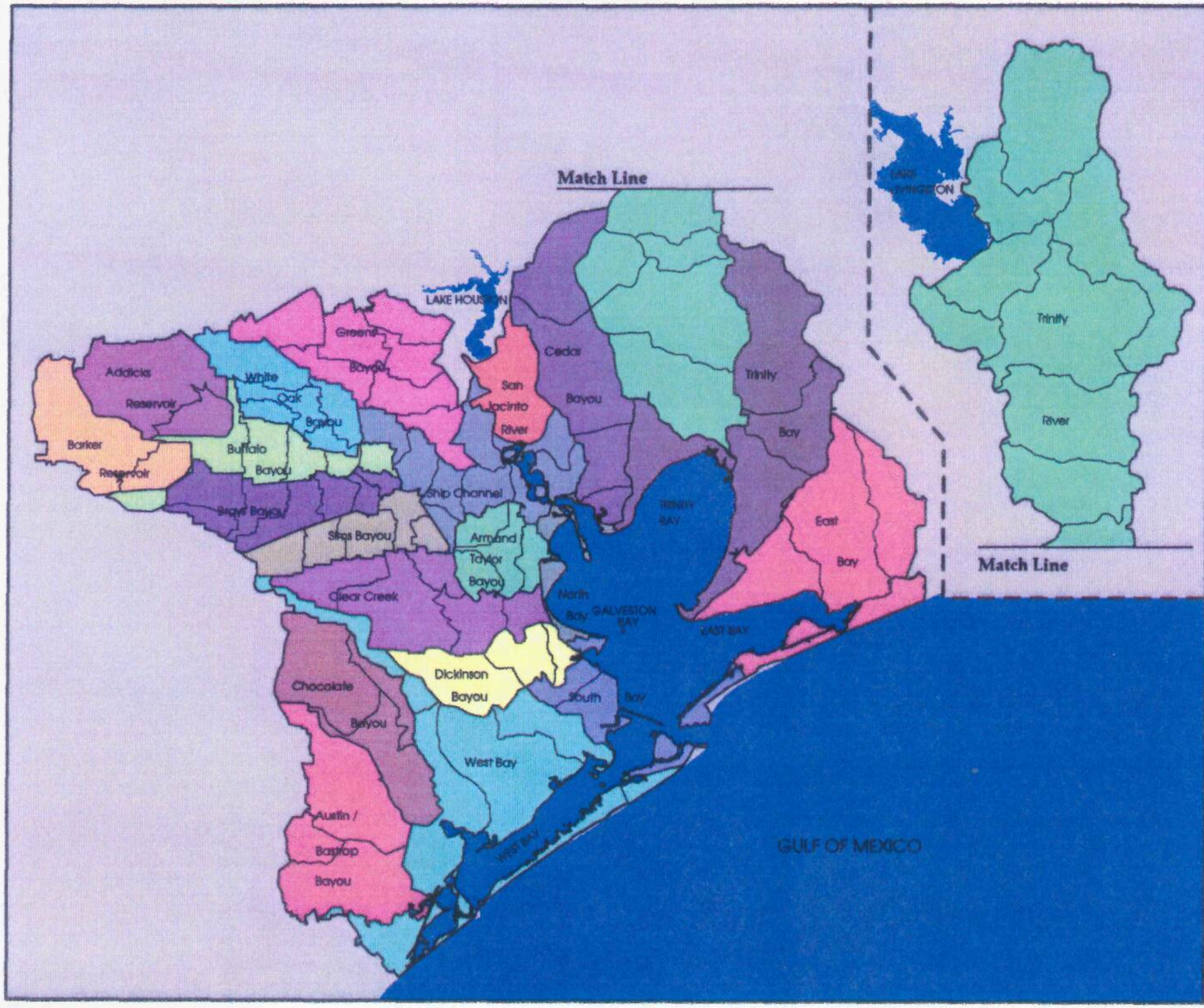
GSI JOB NO.	G-1220
ISSUED:	10/25/91
REVISED:	
EXHIBIT: E.1	

FLOWCHART OF NON-POINT SOURCE LOAD CALCULATION

Non-Point Source Characterization Project
Galveston Bay National Estuary Program



SOURCE: Digitized 1:100,000 USGS maps.



SCALE

0 10 20

Miles

LEGEND

- Austin/Bastrop Bayou
- Addicks Reservoir
- Armand/Taylor Bayou
- Buffalo Bayou
- Barker Reservoir
- Brays Bayou
- Clear Creek
- Cedar Bayou
- Chocolate Bayou
- Dickinson Bayou
- East Bay
- Greens Bayou
- North Bay
- South Bay
- Ship Channel
- San Jacinto River
- Sims Bayou
- Trinity Bay
- Trinity River
- West Bay
- White Oak Bayou

NON-POINT SOURCES AND LOADINGS CHARACTERIZATION PROJECT

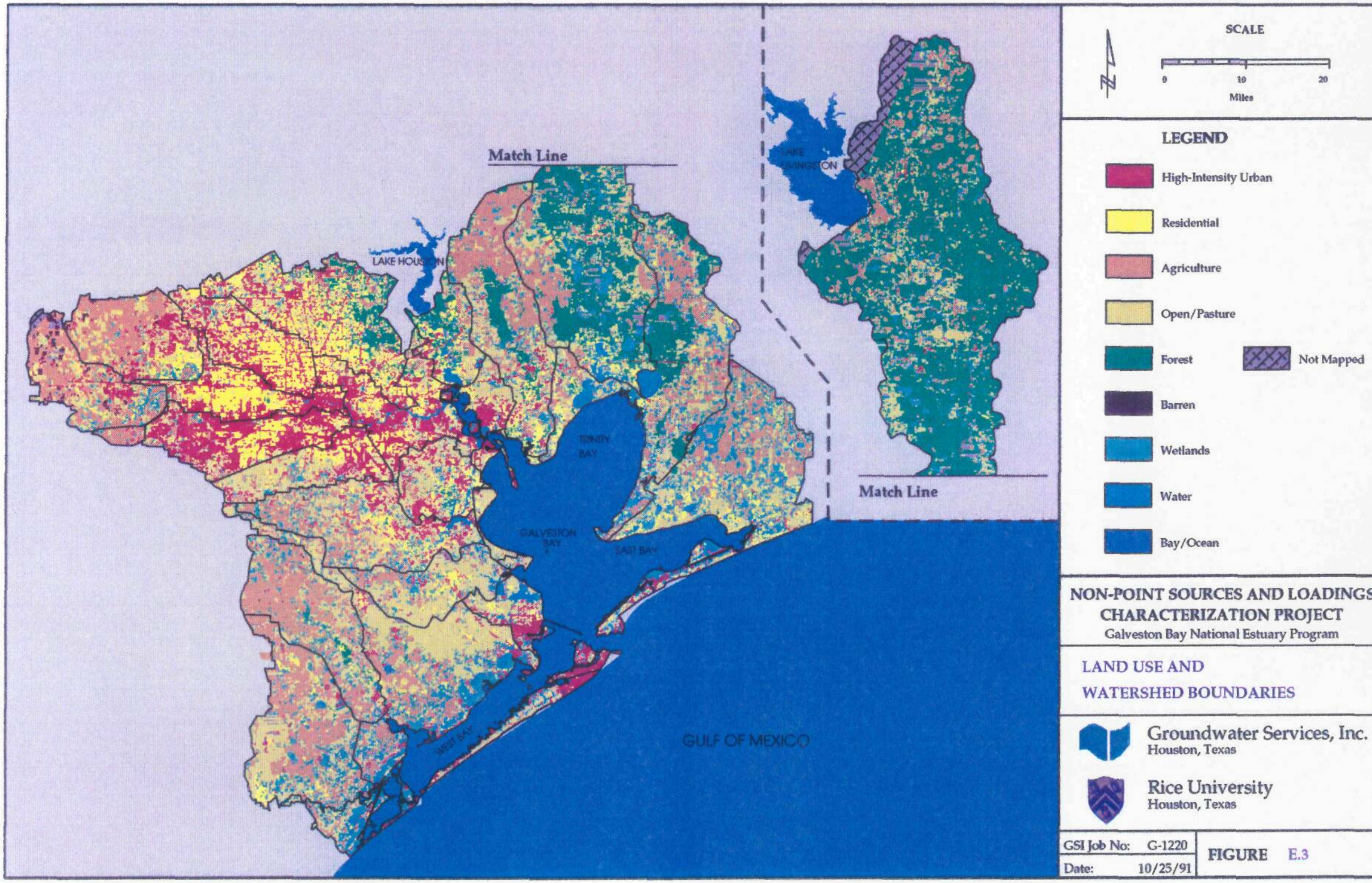
Galveston Bay National Estuary Program

SUBWATERSHED DELINEATION

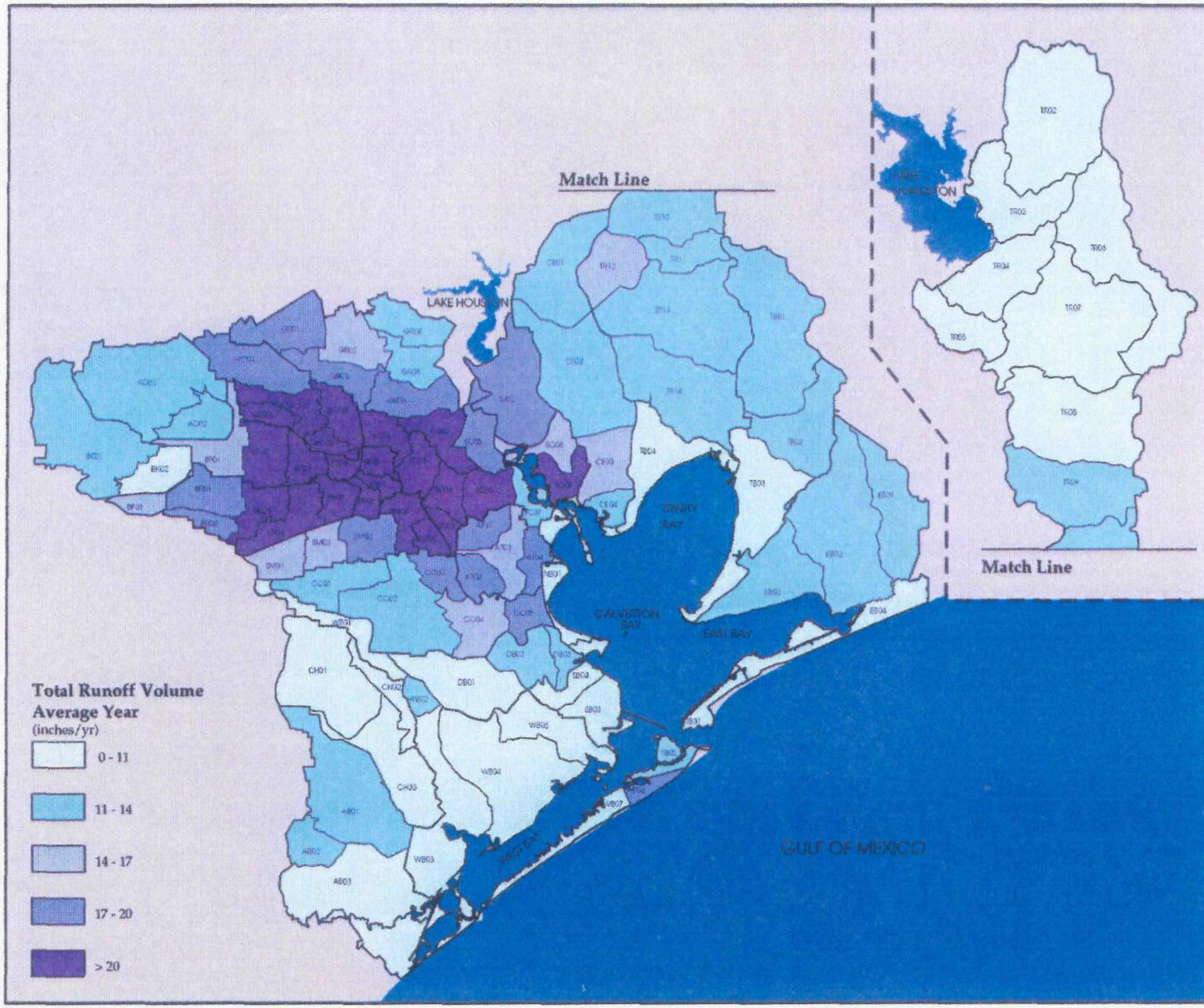
Groundwater Services, Inc.
Houston, Texas

Rice University
Houston, Texas

GSI Job No:	G-1220	**FIGURE** E.2
Date:	10/25/91	



SOURCE: LANDSAT imagery taken November, 1990. Interpretation performed by Intera Aero Service.



NON-POINT SOURCES AND LOADINGS CHARACTERIZATION PROJECT

Galveston Bay National Estuary Program

TOTAL RUNOFF VOLUME

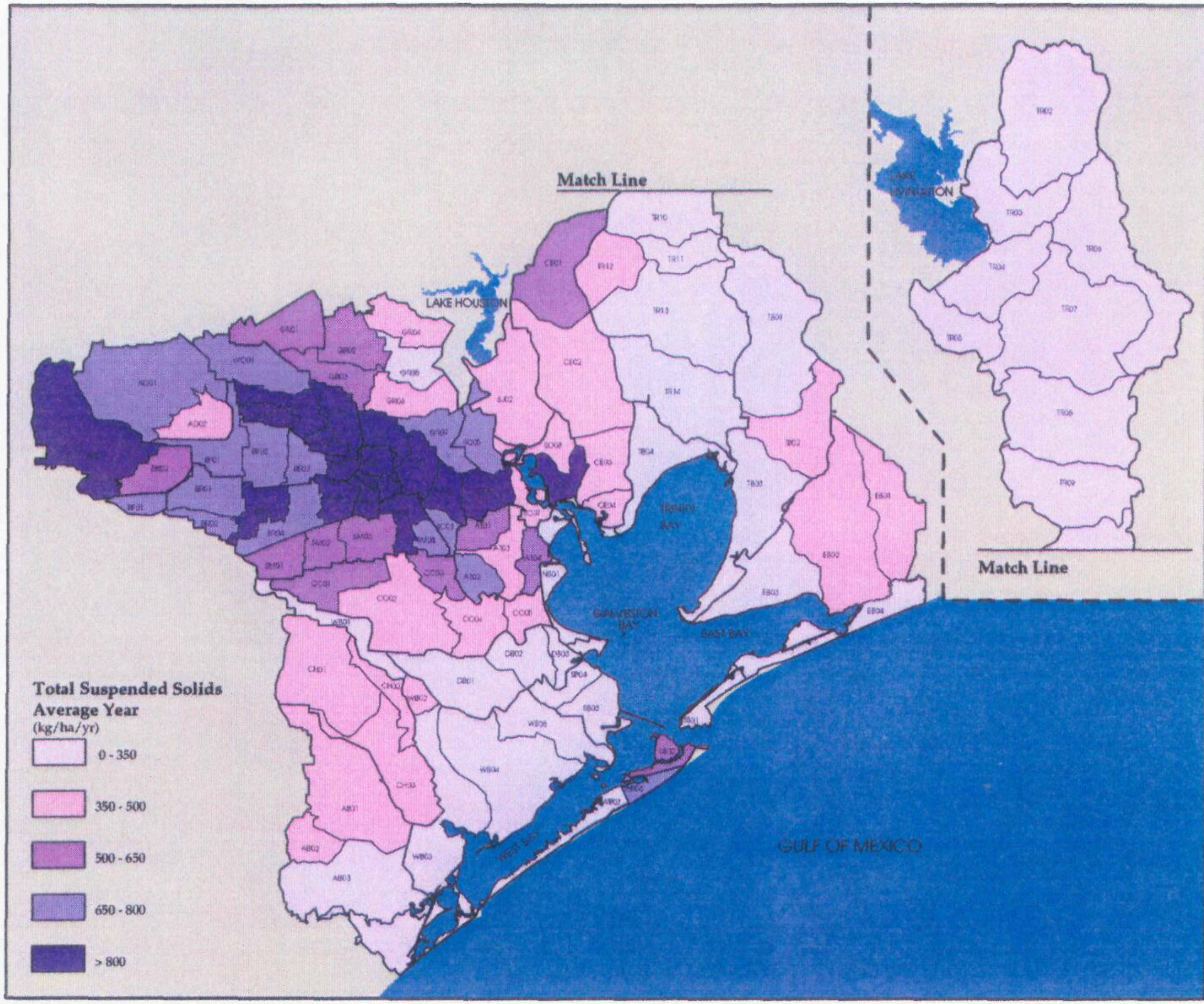
CASE 1: Average Year

Groundwater Services, Inc.
Houston, Texas

Rice University
Houston, Texas

GSI Job No: G-1220
Date: 10/25/91

FIGURE E.4



LEGEND

AB	Austin/Bastrop Bayou
AD	Addicks Reservoir
AT	Armand/Taylor Bayou
BF	Buffalo Bayou
BK	Barker Reservoir
BR	Brays Bayou
CC	Clear Creek
CE	Cedar Bayou
CH	Chocolate Bayou
DB	Dickinson Bayou
EB	East Bay
GR	Greens Bayou
NB	North Bay
SB	South Bay
SC	Ship Channel
SJ	San Jacinto River
SM	Sims Bayou
TB	Trinity Bay
TR	Trinity River
WB	West Bay
WO	White Oak Bayou

NON-POINT SOURCES AND LOADINGS CHARACTERIZATION PROJECT
Galveston Bay National Estuary Program

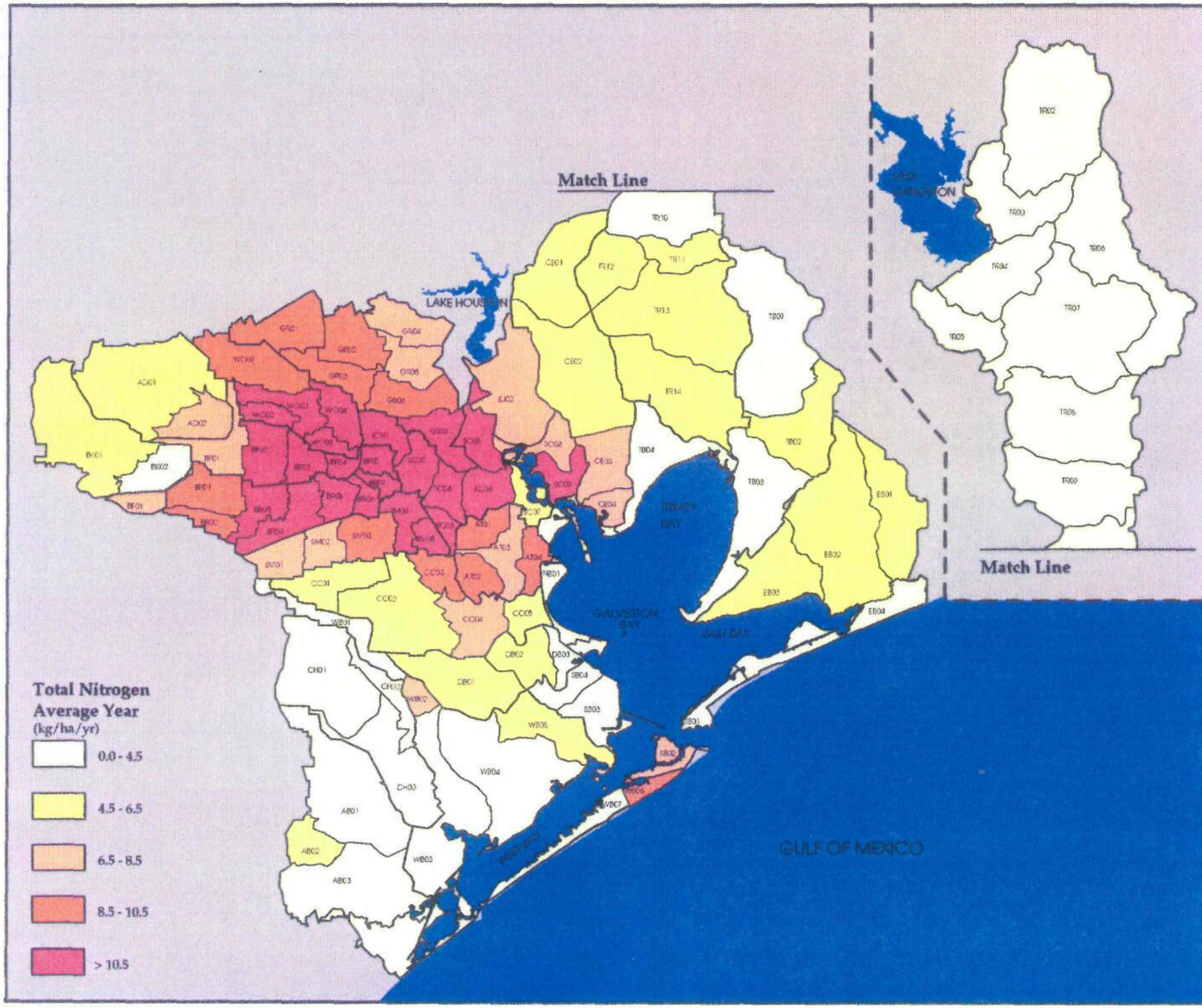
TOTAL SUSPENDED SOLIDS
CASE 1: Average Year
NPS Load Per Unit Area

Groundwater Services, Inc.
Houston, Texas

Rice University
Houston, Texas

GSI Job No:	G-1220	FIGURE E.5
Date:	10/25/91	

NOTE: 1 hectare (ha) = 2.47 acres.



SCALE

0 10 20

Miles

LEGEND

AB	Austin/Bastrop Bayou
AD	Addicks Reservoir
AT	Armand/Taylor Bayou
BF	Buffalo Bayou
BK	Barker Reservoir
BR	Brays Bayou
CC	Clear Creek
CE	Cedar Bayou
CH	Chocolate Bayou
DB	Dickinson Bayou
EB	East Bay
GR	Greens Bayou
NB	North Bay
SB	South Bay
SC	Ship Channel
SJ	San Jacinto River
SM	Sims Bayou
TB	Trinity Bay
TR	Trinity River
WB	West Bay
WO	White Oak Bayou

NON-POINT SOURCES AND LOADINGS CHARACTERIZATION PROJECT

Galveston Bay National Estuary Program

TOTAL NITROGEN
CASE 1: Average Year
NPS Load Per Unit Area

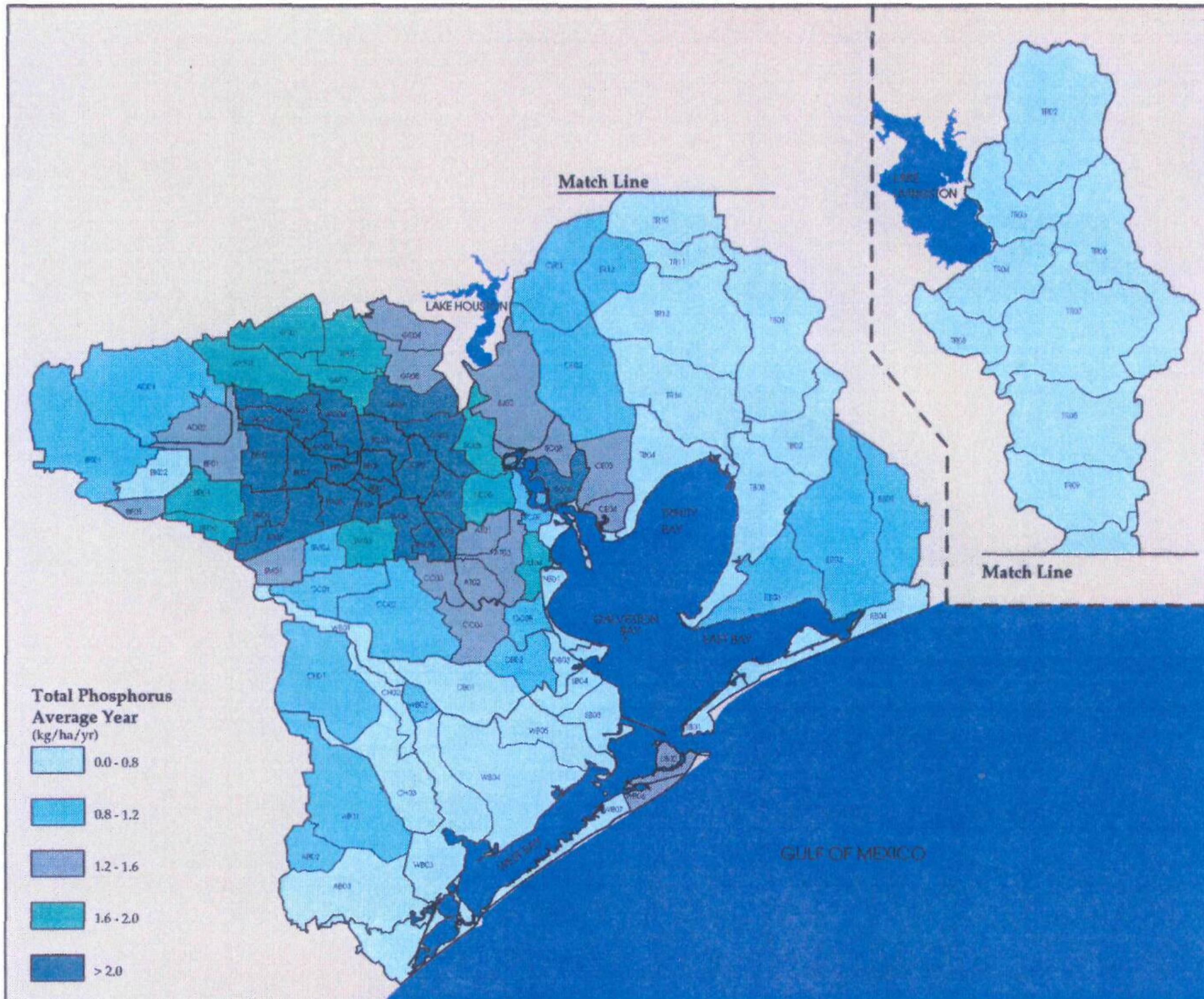
Groundwater Services, Inc.
Houston, Texas

Rice University
Houston, Texas

GSI Job No: G-1220
Date: 10/25/91

FIGURE E.6

NOTE: 1 hectare (ha) = 2.47 acres.



SCALE

0 10 20

Miles

LEGEND

AB	Austin/Bastrop Bayou
AD	Addicks Reservoir
AT	Armand/Taylor Bayou
BF	Buffalo Bayou
BK	Barker Reservoir
BR	Brays Bayou
CC	Clear Creek
CE	Cedar Bayou
CH	Chocolate Bayou
DB	Dickinson Bayou
EB	East Bay
GR	Greens Bayou
NB	North Bay
SB	South Bay
SC	Ship Channel
SJ	San Jacinto River
SM	Sims Bayou
TB	Trinity Bay
TR	Trinity River
WB	West Bay
WO	White Oak Bayou

NON-POINT SOURCES AND LOADINGS CHARACTERIZATION PROJECT

Galveston Bay National Estuary Program

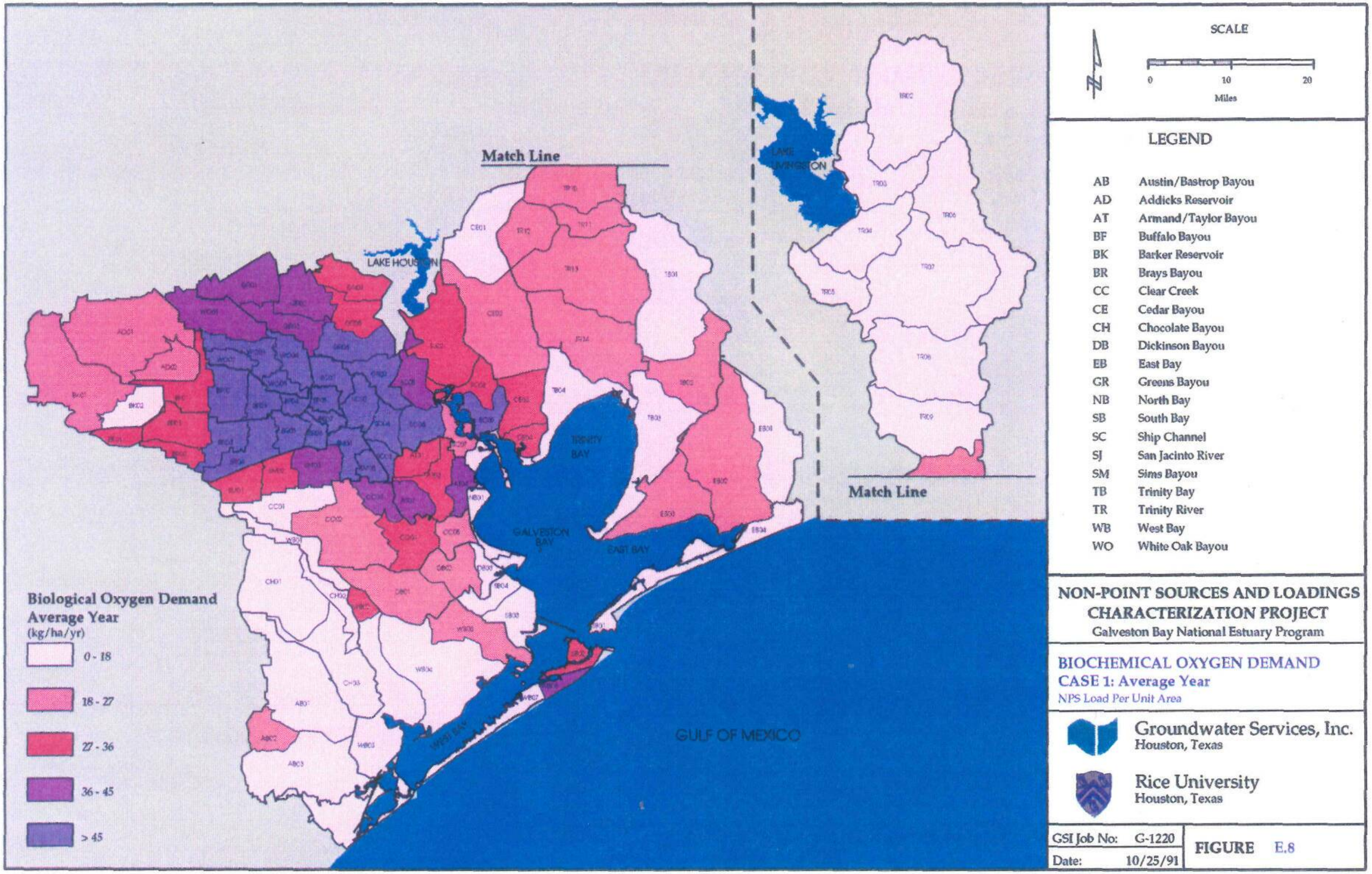
TOTAL PHOSPHOROUS
CASE 1: Average Year
NPS Load Per Unit Area

Groundwater Services, Inc.
Houston, Texas

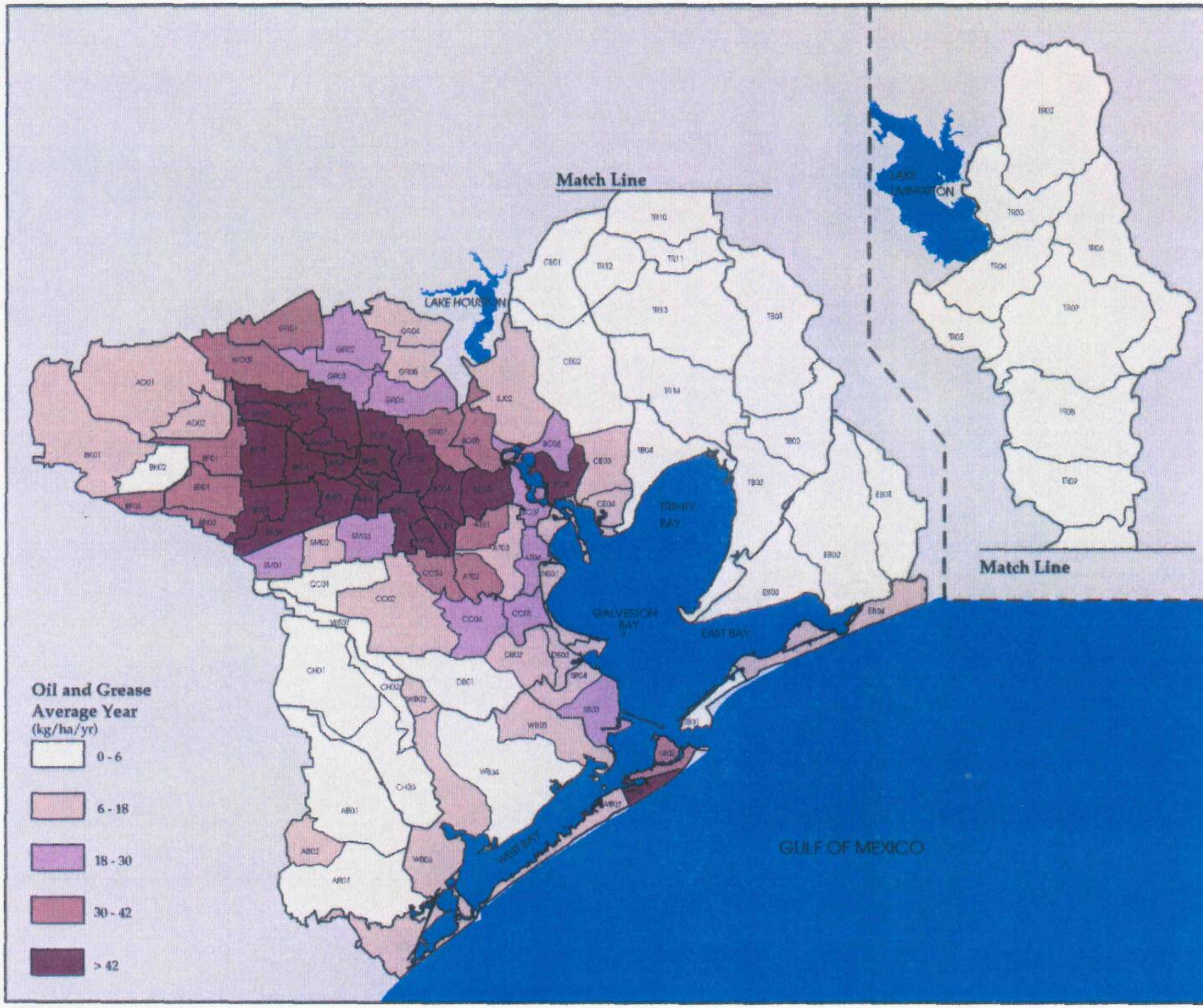
Rice University
Houston, Texas

GSI Job No: G-1220		**FIGURE** E.7
Date: 10/25/91		

NOTE: 1 hectare (ha) = 2.47 acres.



NOTE: 1 hectare (ha) = 2.47 acres.



NOTE: 1 hectare (ha) = 2.47 acres.

SCALE

0 10 20

Miles

LEGEND

AB	Austin/Bastrop Bayou
AD	Addicks Reservoir
AT	Armand/Taylor Bayou
BF	Buffalo Bayou
BK	Barker Reservoir
BR	Brays Bayou
CC	Clear Creek
CE	Cedar Bayou
CH	Chocolate Bayou
DB	Dickinson Bayou
EB	East Bay
GR	Greens Bayou
NB	North Bay
SB	South Bay
SC	Ship Channel
SJ	San Jacinto River
SM	Sims Bayou
TB	Trinity Bay
TR	Trinity River
WB	West Bay
WO	White Oak Bayou

NON-POINT SOURCES AND LOADINGS CHARACTERIZATION PROJECT

Galveston Bay National Estuary Program

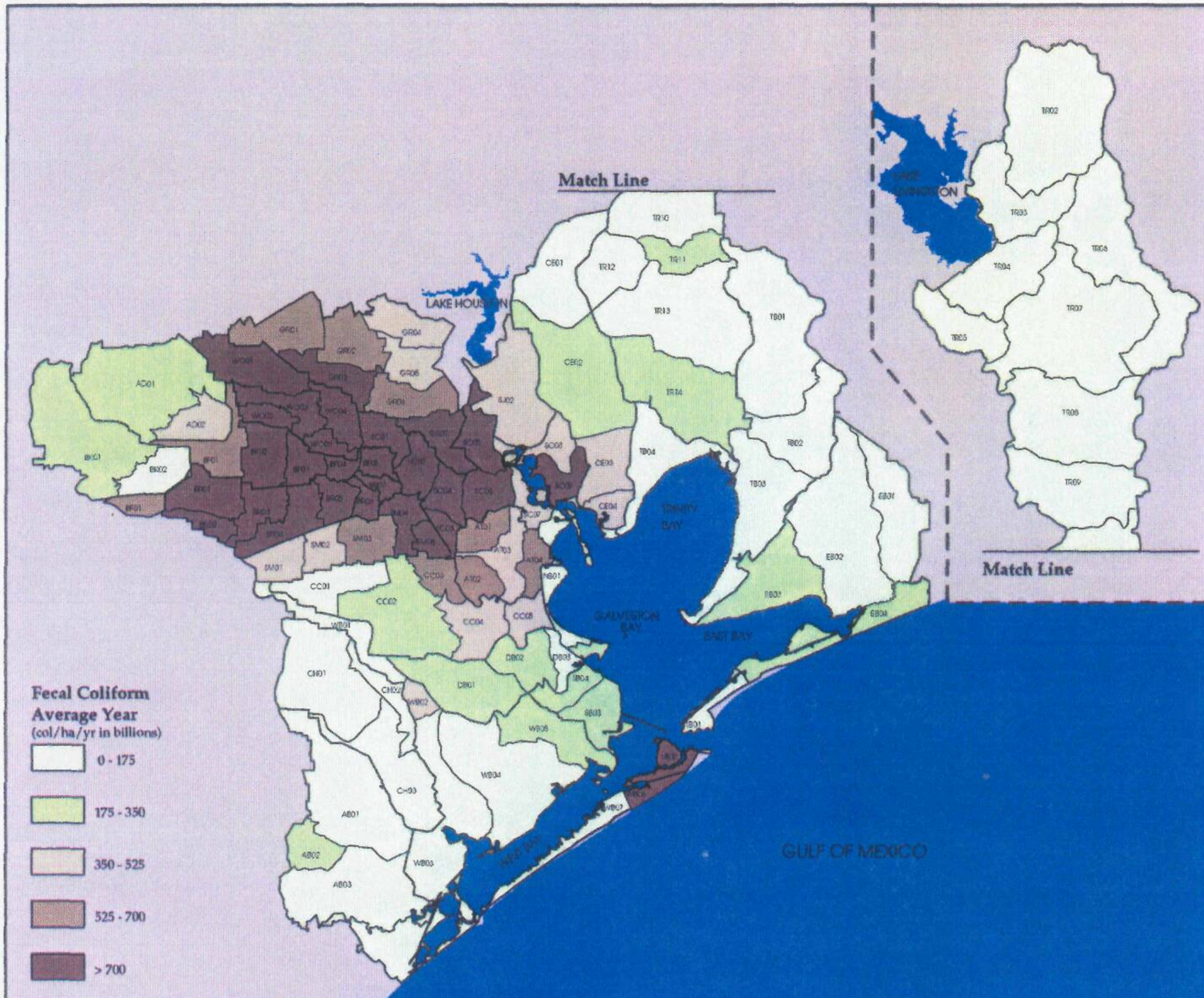
OIL AND GREASE
CASE 1: Average Year
NPS Load Per Unit Area

Groundwater Services, Inc.
Houston, Texas

Rice University
Houston, Texas

GSI Job No: G-1220
Date: 10/25/91

FIGURE E.9



SCALE

0 10 20

Miles

LEGEND

AB	Austin/Bastrop Bayou
AD	Addicks Reservoir
AT	Armand/Taylor Bayou
BF	Buffalo Bayou
BK	Barker Reservoir
BR	Brays Bayou
CC	Clear Creek
CE	Cedar Bayou
CH	Chocolate Bayou
DB	Dickinson Bayou
EB	East Bay
GR	Greens Bayou
NB	North Bay
SB	South Bay
SC	Ship Channel
SJ	San Jacinto River
SM	Sims Bayou
TB	Trinity Bay
TR	Trinity River
WB	West Bay
WO	White Oak Bayou

NON-POINT SOURCES AND LOADINGS CHARACTERIZATION PROJECT
Galveston Bay National Estuary Program

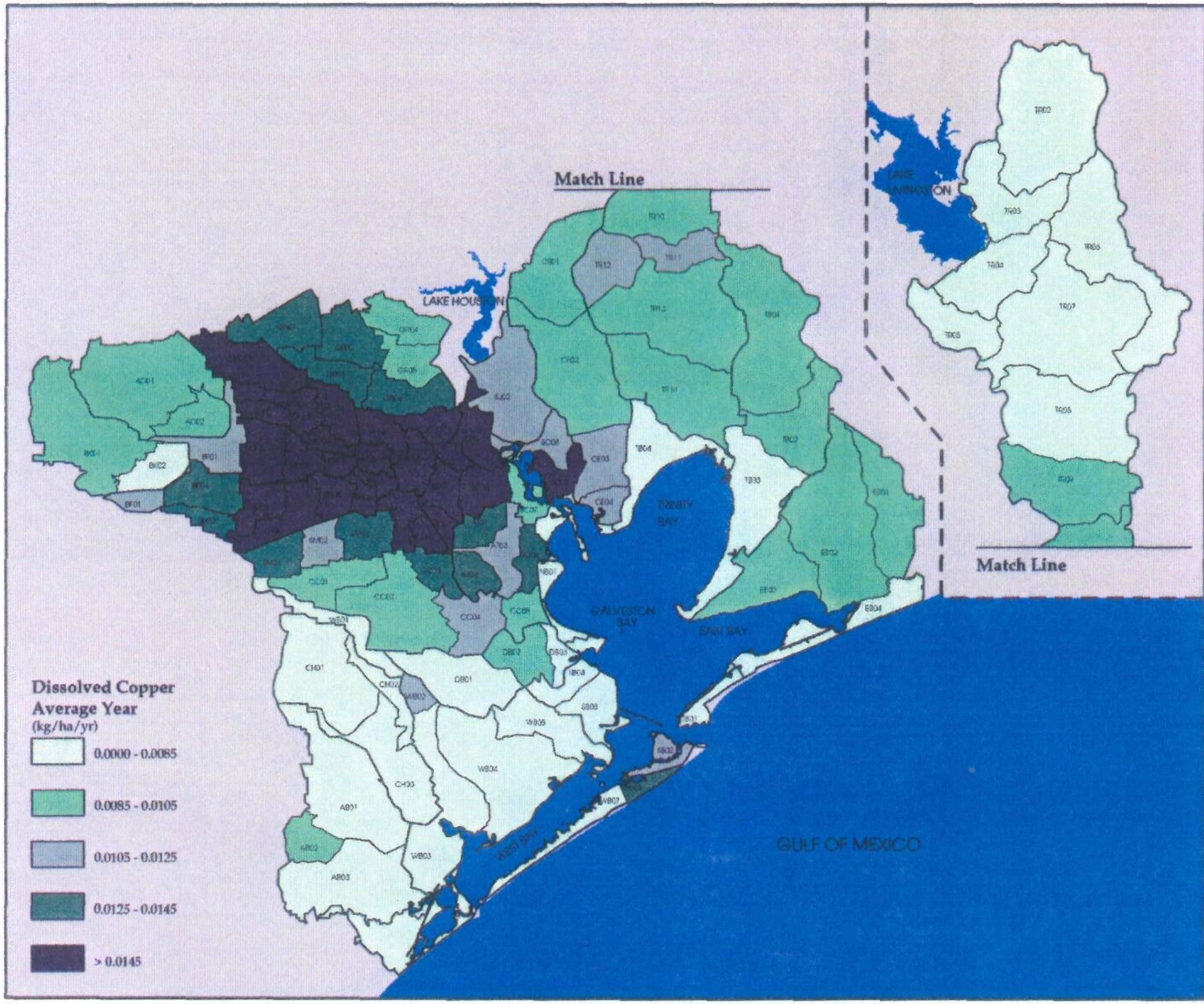
FECAL COLIFORM
CASE 1: Average Year
NPS Load Per Unit Area

Groundwater Services, Inc.
Houston, Texas

Rice University
Houston, Texas

GSI Job No: G-1220		FIGURE E.10
Date: 10/25/91		

NOTE: 1 hectare (ha) = 2.47 acres.



SCALE

0 10 20

Miles

LEGEND

AB	Austin/Bastrop Bayou
AD	Addicks Reservoir
AT	Armand/Taylor Bayou
BF	Buffalo Bayou
BK	Barker Reservoir
BR	Brays Bayou
CC	Clear Creek
CE	Cedar Bayou
CH	Chocolate Bayou
DB	Dickinson Bayou
EB	East Bay
GR	Greens Bayou
NB	North Bay
SB	South Bay
SC	Ship Channel
SJ	San Jacinto River
SM	Sims Bayou
TB	Trinity Bay
TR	Trinity River
WB	West Bay
WO	White Oak Bayou

NON-POINT SOURCES AND LOADINGS CHARACTERIZATION PROJECT

Galveston Bay National Estuary Program

DISSOLVED COPPER
CASE 1: Average Year
NPS Load Per Unit Area

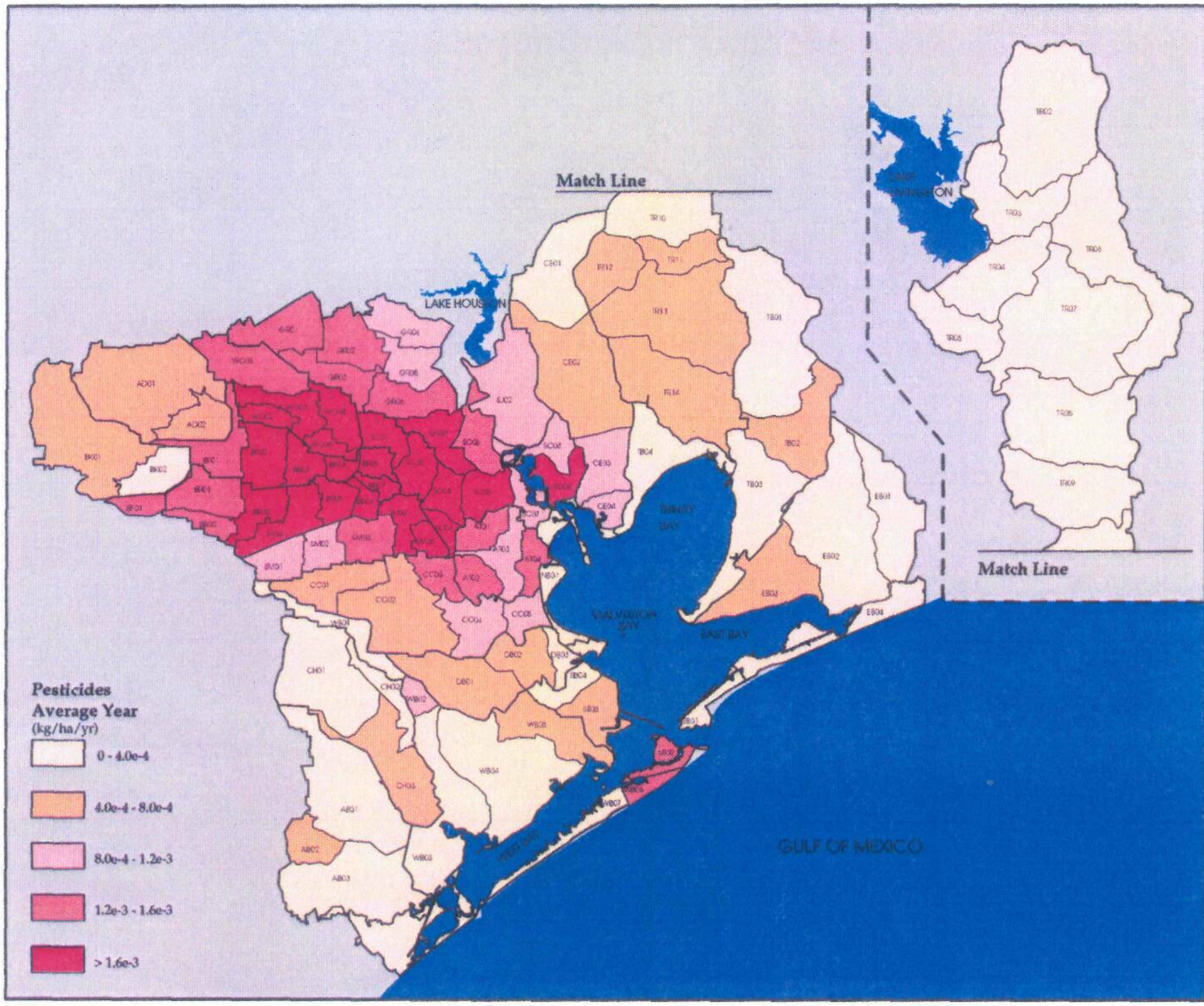
Groundwater Services, Inc.
Houston, Texas

Rice University
Houston, Texas

GSI Job No: G-1220
Date: 10/25/91

FIGURE E.11

NOTE: 1 hectare (ha) = 2.47 acres.



SCALE

0 10 20

Miles

LEGEND

AB	Austin/Bastrop Bayou
AD	Addicks Reservoir
AT	Armand/Taylor Bayou
BF	Buffalo Bayou
BK	Barker Reservoir
BR	Brays Bayou
CC	Clear Creek
CE	Cedar Bayou
CH	Chocolate Bayou
DB	Dickinson Bayou
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SC	Ship Channel
SJ	San Jacinto River
SM	Sims Bayou
TB	Trinity Bay
TR	Trinity River
WB	West Bay
WO	White Oak Bayou

NON-POINT SOURCES AND LOADINGS CHARACTERIZATION PROJECT

Galveston Bay National Estuary Program

PESTICIDES

CASE 1: Average Year

NPS Load Per Unit Area

Groundwater Services, Inc.
Houston, Texas

Rice University
Houston, Texas

GSI Job No: G-1220		FIGURE E.12
Date: 10/25/91		

NOTE: 1 hectare (ha) = 2.47 acres.