Total Maximum Daily Loads for PCBs in the Houston Ship Channel

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Quarterly Report 1

Prepared by
University of Houston
Parsons Water & Infrastructure

Principal Investigators
Hanadi Rifai
Randy Palachek

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TCEQ Contact:
Larry Koenig
TMDL Team
P.O. Box 13087, MC - 203
Austin, Texas 78711-3087
lkoenig@tceq.state.tx.us

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TABLE OF CONTENTS

1. INTRODUCTION

Polychlorinated biphenyls (PCBs) are widespread organic contaminants which are environmentally persistent and can be harmful to human health even at low concentrations. A major route of exposure for PCBs worldwide is through food consumption, and this route is especially significant in seafood. The discovery of PCBs in seafood tissue has led the Texas Department of State Health Services (TDSHS) to issue seafood consumption advisories, and some of these advisories have been issued for the Houston Ship Channel (HSC). Three specific advisories have been issued recently for all finfish species based on concentrations of PCBs, organochlorine pesticides, and dioxins. ADV-20 was issued in October 2001 and includes the HSC upstream of the Lynchburg Ferry crossing and all contiguous waters, including the San Jacinto River Tidal below the U.S. Highway 90 bridge. ADV-28 was issued in January 2005 for Upper Galveston Bay (UGB) and the HSC and all contiguous waters north of a line drawn from Red Bluff Point to Five Mile Cut Marker to Morgan's Point. In addition to these two finfish advisories, the TDSHS issued ADV-35 (for PCBs and dioxins) that advises against consumption of gafftopsail catfish and speckled trout in upper Galveston Bay, lower Galveston Bay, and Trinity Bay. These advisories represent a large surface water system for which a PCB TMDL needs to be developed and implemented. The overall purpose of this project is to develop a total maximum daily load (TMDL) allocation for PCBs in the Houston Ship Channel System, including upper Galveston Bay. Though ADV-35 covers surface water beyond upper Galveston Bay, the TMDL boundary is currently set for upper Galveston Bay. Tasks performed under this work order include monitoring and data collection, as well as data evaluation and analysis in the Houston Ship Channel. Chapter 2 presents the quality assurance activities while Chapters 3 and 4 present the ambient results from the sampling activities undertaken in FY09 and Chapter 5 presents the results from runoff and effluent sampling.

2. QUALITY ASSURANCE/QUALITY CONTROL

The quality assurance/quality control (QA/QC) tasks that are conducted include monitoring/coordinating sample deliveries to the laboratories, verifying laboratory compliance with the QAPP, and verification of data packages. There were no major noncompliant issues encountered in the shipping and receiving of the samples collected. All samples were received from the sample site to the UH laboratory and from the UH laboratory to the analytical laboratories without incident and were within the temperature range specified in the QAPP.

Once the sample results were obtained from the labs, the results are reviewed by UH/Parsons personnel using the QA/QC criteria specified in the QAPP. The QA/QC requirements outlined in the QAPP included: holding times, method blanks, initial calibration curves, ambient water reporting limits (AWRL) verification, laboratory control sample (LCS), field duplicates, matrix spikes/matrix spike duplicates, laboratory duplicates, continuing calibration samples, surrogates, and internal standards. Table 2.1 lists the samples collected, data received and data reviewed from the Spring-Summer 2009 sampling. Table 2.2 shows the data flags that are used to designate the data as needed based on the QA/QC review. All the sample results have been received and are being currently reviewed for QA/QC purposes.

Table 2.1 Sample results obtained and reviewed for QA/QC

Laboratory	Media	Analysis	Number of samples collected	Number of sample results obtained from laboratory	Sample results reviewed for QA/QC
Xenco/NWDL	Water	TSS, DOC, TOC	81	81	Ongoing
Xenco/PTS	Sediment	Grain size and Solids content	42	42	N/A
Maxxam	Water	PCB (209 Congeners)	174	174	Ongoing
Pace	Sediment	PCB (209 Congeners), TOC	42	42	Ongoing
Maxxam	Sediment	TOC	42	42	Ongoing
Pace	Fish	PCB (209 Congeners), Lipid and Moisture content	58	58	Ongoing

Table 2.2 Standardized flags assigned to sample results

Flag	Description
B	Blank contamination (result is less than twenty times the amount found in the associated blank).
U	Target analyte is not detected above the method detection level (MDL) in the sample.
J	Result is between the method detection limit (MDL) and the reporting level (RL) or the value is to be considered an estimate due to quality control issues involved in the analysis.
H	Holding time exceedance
I	Ion ratio failure
F	Field duplicate exceedance (%RPD of parent/duplicate sample > 50%)
L	Laboratory duplicate exceedance (%RPD of laboratory/laboratory duplicate sample > 50%)
S	Blank spike or laboratory control spike exceedance
Q	Limit of Quantification (LOQ) exceedance
D	Surrogate/Internal Standard exceedance
R	Sample result is to be rejected and is considered unusable.

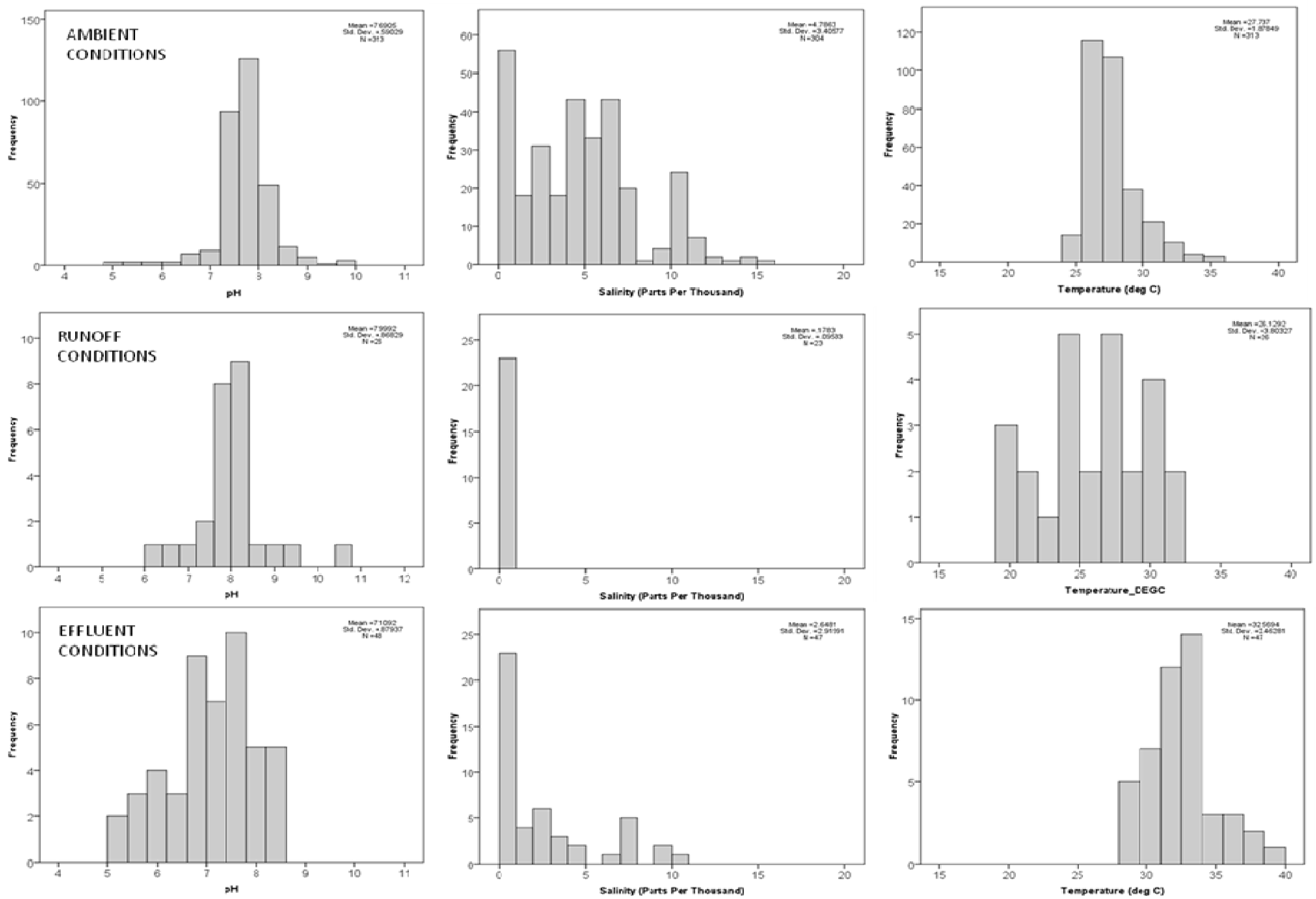
3. WATER AND SEDIMENT PHYSICAL PARAMETERS

This section provides a summary of the data that has been received from the 2009 sampling in the HSC. The data include field water quality parameters (pH, salinity, conductivity and water temperature), characteristics of water (TSS, TOC, and DOC), and sediment characteristics (TOC, Grain Size, and Moisture Content).

3.1 In-stream Water Quality

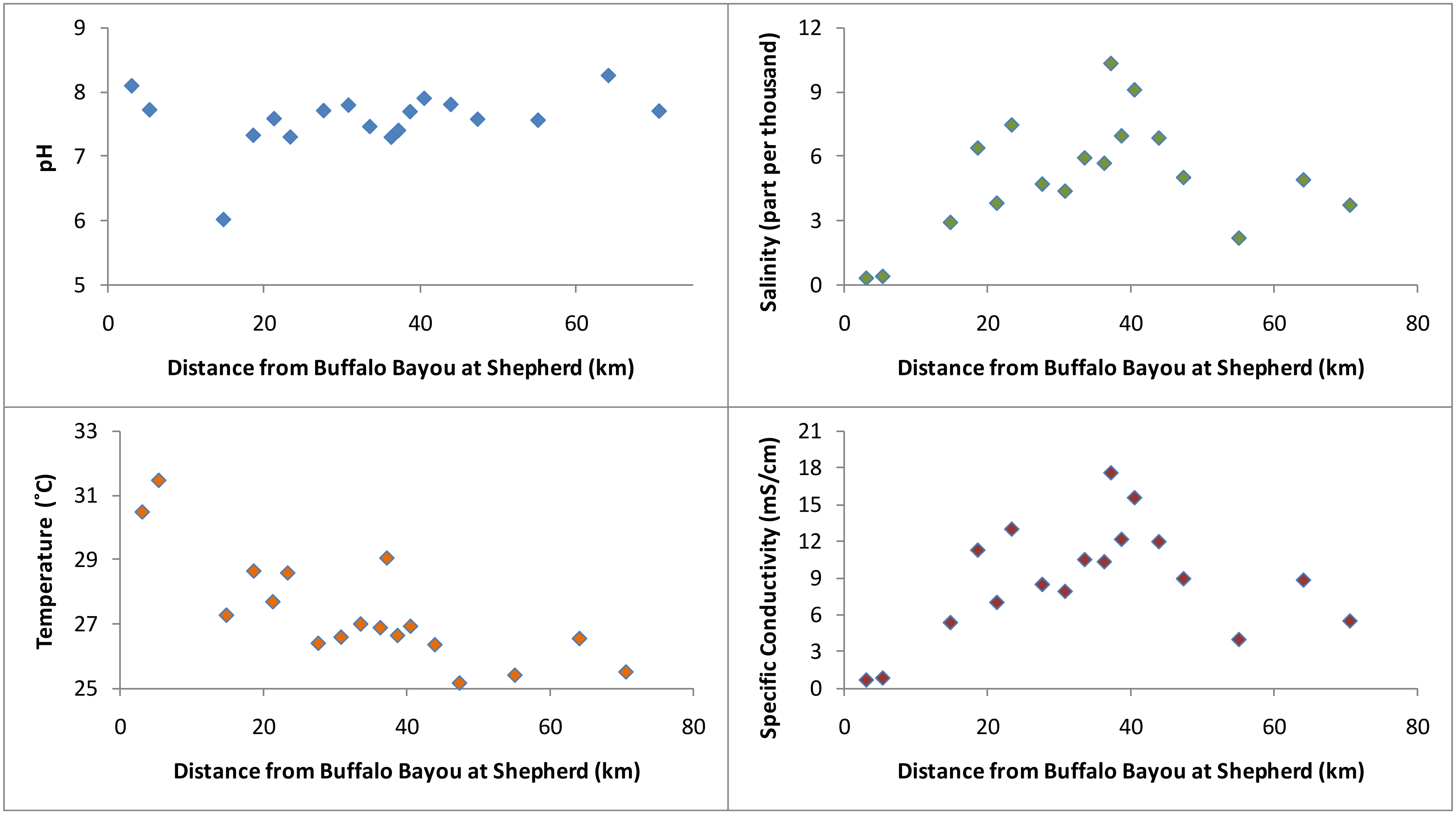
Appendix A provides a summary of field parameters measured during in-channel water sampling activities. It is standard procedure that all water samples collected will have field measured water quality parameters associated with them as shown in Figure 3.1. Here the water quality parameters were broken down by sampling type: ambient (dry weather), runoff, and effluent sampling. These parameters are measured multiple times during a sampling event, and many samples measured in ambient condition waters are measured at various depths as well. These histograms combine all of that data to show various comparisons between sampling event types. pH shows little difference between runoff and ambient sampling. These two distributions are highly constrained in a narrow range of pH, and they are also distributed relatively symmetrically. The effluent pH distribution stands in contrast to ambient and runoff pHs in that it is far more left skewed having far more sampling in the 5-6 pH range. Salinity histograms are more varied in the ambient sampling event, which reveals the fact that the sampling locations for ambient conditions sampling are spatially spread over the HSC region. Runoff samples are in more upstream areas where salinity is lowest sometimes even beyond what would be considered tidally influenced, and that water is further diluted with freshwater that washes as excess runoff into the bayous. The existence of >5 ppt values for some effluent samples is curious because effluent samples were collected prior to their introduction into any surface water. So in some cases then, increased salinity exists in the sample as it leaves the outfall before final discharge. Temperature histograms are disparate from one another in all three sampling conditions. The warmest waters were from the effluent sampling while the coolest were from runoff.

Figure 3.2 is a presentation of main channel HSC water quality parameter averages for all ambient conditions samples at a particular station. pH is fairly static along the length of the channel while temperature, salinity, and specific conductivity clearly show some variation, even trend. Temperature generally decreases relatively constantly as one moves from upstream of downtown Houston down out into the Bay. Salinity is a parameter calculated from conductivity, and so it is not surprising that these parameters follow the same pattern in the main channel. They both have a peak at around 40 km, which is where the SJR meets Buffalo Bayou. The lowest single value point after the SJR confluence is at Morgan's Point just below the surface (1 ft) at 1.37 ppt.



*Specific conductivity was measured but not plotted because it shows the same trends as salinity

Figure 3.1 Histogrammatic comparison of water quality in-situ measured parameters under ambient, runoff, and effluent conditions.



Values within each average were collected at multiple depths and during varying tidal conditions.

Figure 3.2 Water quality parameters from summer 2009 dry weather samplings averaged at stations along the main channel of the HSC.

Other laboratory based measures of water quality taken were TOC, DOC, and TSS. Table 3.1 summarizes the water quality parameters (TSS, DOC, and TOC) by station, while Figures 3.3, 3.4, and 3.5 show spatial locations of the DOC, TOC, and TSS values, respectively. The farther out towards the Bay and more tidally influenced, the lower was the DOC and TOC. TSS values, however, generally increased with flow, which is to say that the farther downstream, the higher was the TSS. Tributaries showed low TSS while the main channel showed an increase in TSS especially downstream of Lynchburg Ferry. The exact cause of these results is unknown though it is likely that higher velocities, higher tidal forces, wave action, increased ship traffic, and dredging activities suspend a great amount of sediment in the downstream waters.

Table 3.1 TSS, DOC and TOC measurements by station

Station ID	DOC (mg/L)	TOC (mg/L)	TSS (mg/L)
11115	7.77	8.87	20
11129	6.41	7.03	34
11132	7.9	7.4	29
11139	7.17	6.95	30
11193	5.63	5.18	41
11252	4.49	4.49	76
11258	2.56	2.58	58
11261[a]	5.92	6.03	4
11262	5.86	6.3	13
11264	6.63	7.54	27
11265	5.67	5.77	36
11270	6.57	6.57	21
11274	5.99	6.32	30
11279	6.69	6.53	38
11280	6.41	7.06	21
11285	6.25	7.01	9
11287	8.29	8.7	29
11288	6.46	6.47	13
11292	6.95	6.07	25
11347[a]	5.37	5.655	26
11387	6.86	6.41	9
13338	4.36	3.99	93
13340	6.36	3.64	68
13342	4.25	4.15	31
13344	3.46	3.26	36
13355[a]	2.17	2.095	23
13363	6.1	7.73	26
14560	2.44	2.05	81

Table 3.1 TSS, DOC and TOC measurements by station

Station ID	DOC (mg/L)	TOC (mg/L)	TSS (mg/L)
15301	6.67	7.41	43
15936	6.7	7	25
15979	6.36	6.62	23
16213	3.08	3.13	35
16499	6.75	6.31	37
16618	2.99	2.83	40
16622	11.4	11	28
16657	4.32	4.29	5
16872	6.27	6.78	5
17149	6.8	8.4	34
17157	15.5	16.81	61
18322	6.15	6.11	17
18363	5.7	5.82	< 4.0
20570	5.63	5.44	36
20574	9.85	9.94	52
20575	9.05	8.28	49
T002[a]	5.87	5.76	2
TBD10	6.22	6.66	13
TBD11	7.58	8.17	< 4.0
TBDVince	8.76	8.28	51

a Average of duplicate samples, otherwise concentration of a single sample

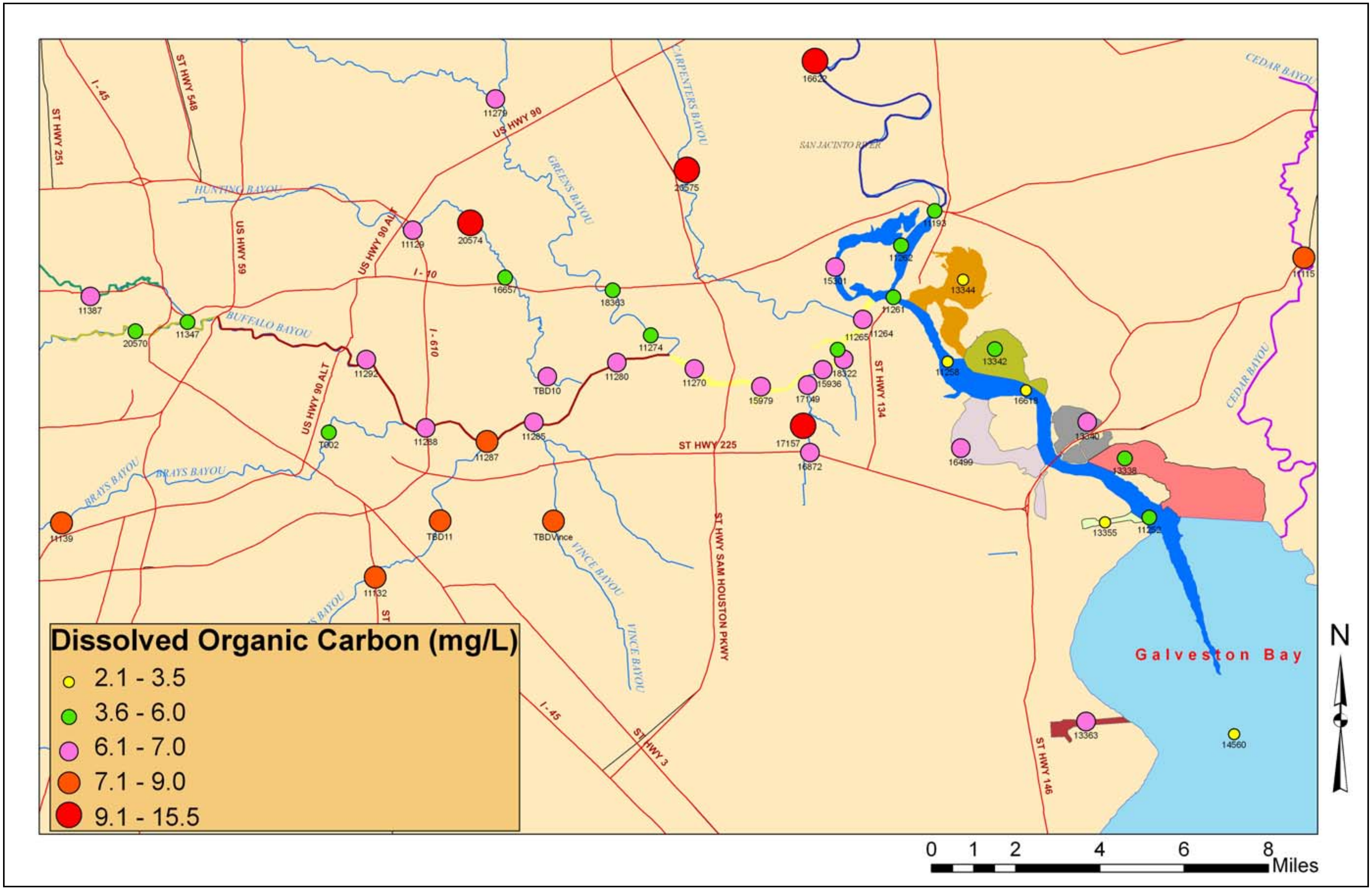


Figure 3.3 DOC measurement in water samples collected in Summer 2009

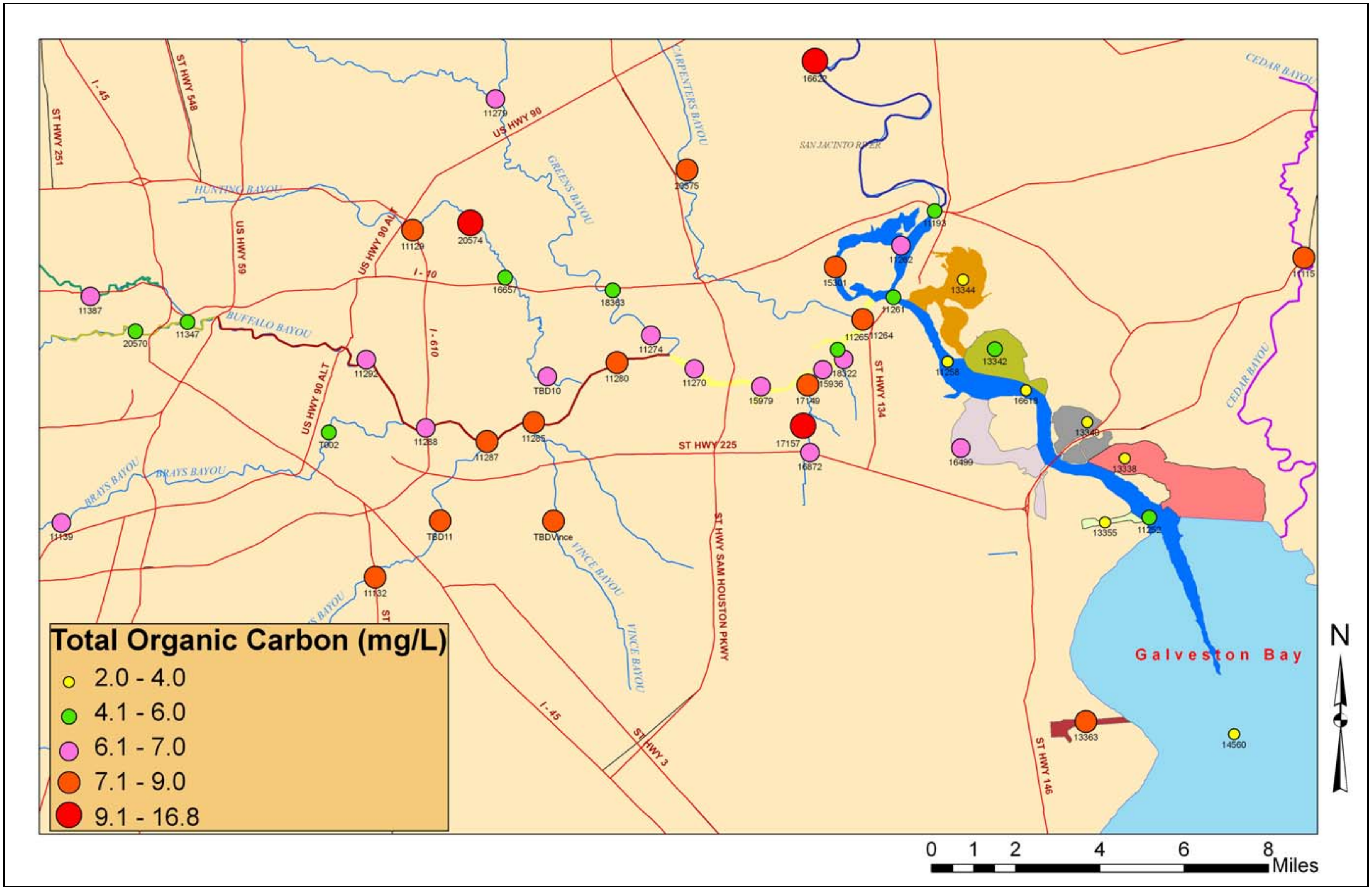


Figure 3.4 TOC measurement in water samples collected in Summer 2009

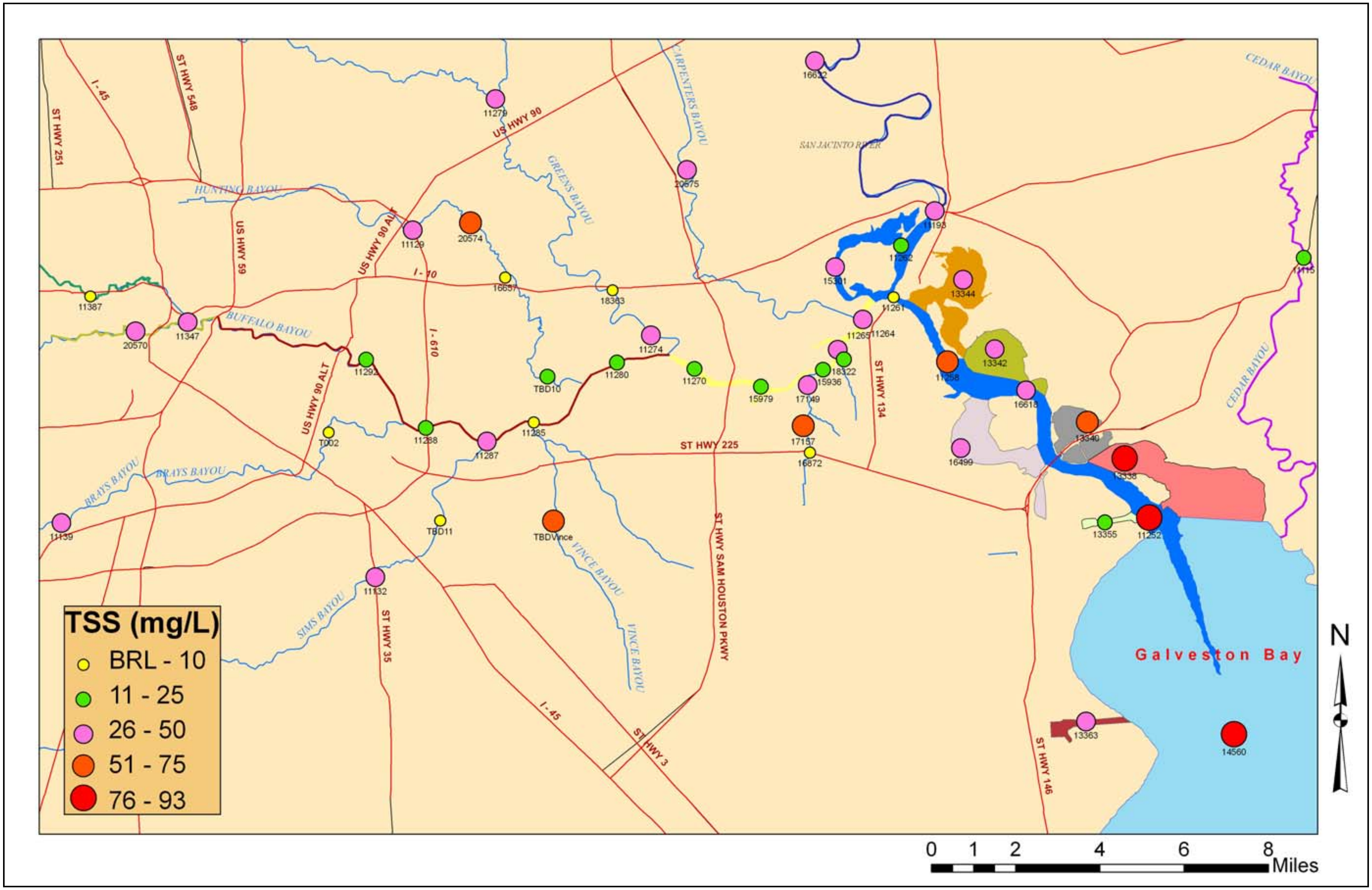


Figure 3.5 TSS measurements in water samples collected in Summer 2009

3.2 In-channel Sediment

Sediment sampling, in addition to PCBs, measured Grain Size, Solids Content, and TOC (Figures 3.6, 3.7, and 3.8, respectively). Table 3.2 summarizes the sediment quality parameters (TOC and moisture content) by station. The moisture content (%) of sediment is representative of the percent void space or interstitial volume within a bulk sediment sample. Generally larger grain size correlates with lower interstitial volume or pore space (% moisture). The measured grain size distributions shows all silts and clays with exceptions being higher fine sand. The higher sand content locations were in the upper reaches of Buffalo Bayou, San Jacinto River (SJR) and San Jacinto River Tidal, and the Side Bays along the lower reaches of the HSC. Most main channel sediments were smaller in size and more cohesive. TOC along the HSC did not show any significant spatial pattern and was in the range of 810-19000 mg/Kg (0.08-1.9%).

Table 3.2 Sediment quality measurements by station

Station ID	Moisture (wt %)	TOC	
		(mg/Kg)	(%)
11129	34.2	6700	0.67
11132	23.5	19000	1.9
11193	58.1	9300	0.93
11252	58.1	4200	0.42
11258	63.8	4300	0.43
11261	67.7	8500	0.85
11262	29.1	1900	0.19
11264	70.0	4700	0.47
11265	59.3	4300	0.43
11270[a]	44.9	5500	0.55
11274	26.7	4100	0.41
11280	50.6	5500	0.55
11285	58.3	8000	0.8
11287[a]	60.3	6700	0.67
11288	62.0	10000	1
11292	44.6	6800	0.68
11302	37.1	5900	0.59
11347	22.2	810	0.081
13338[a]	57.5	5850	0.585
13342	69.5	4000	0.4
13344	73.2	4400	0.44
15301	20.1	6200	0.62
15936	67.2	6300	0.63
15979	56.8	6000	0.6
16499	60.0	9500	0.95
16618	61.3	4000	0.4
16622	22.0	1700	0.17

Table 3.2 Sediment quality measurements by station

Station ID	Moisture (wt %)	TOC	
		(mg/Kg)	(%)
17149	61.9	18000	1.8
17157	39.9	10000	1
18322[a]	43.6	10300	1.03
18363	48.5	4500	0.45
20574	28.4	3000	0.3
T002	21.1	3800	0.38
TBD10	50.4	6800	0.68
TBD11	35.0	5200	0.52

[a] Average of duplicate samples, otherwise concentration of a single sample

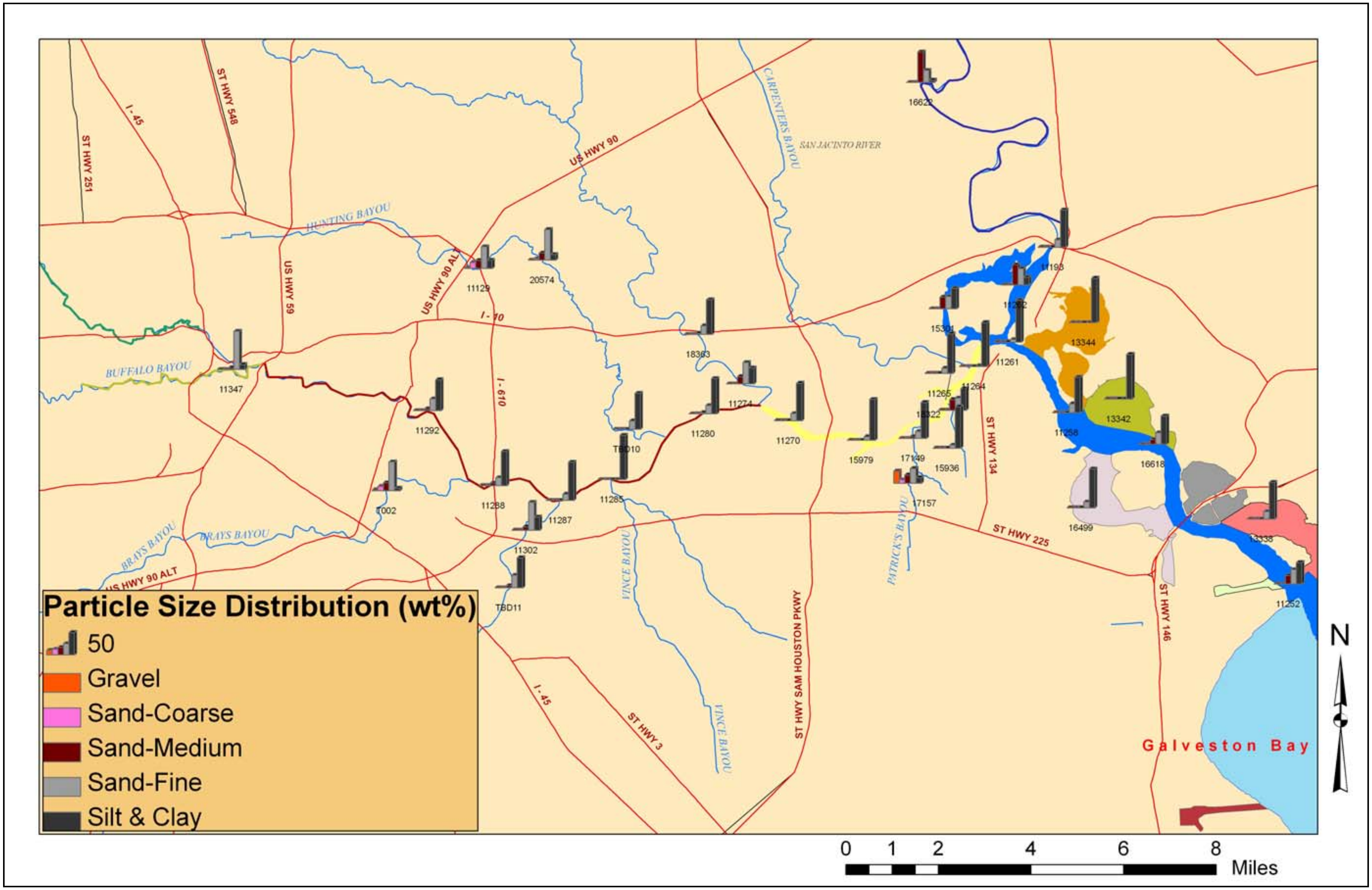


Figure 3.6 Grain size distributions in sediment samples collected in Summer 2009

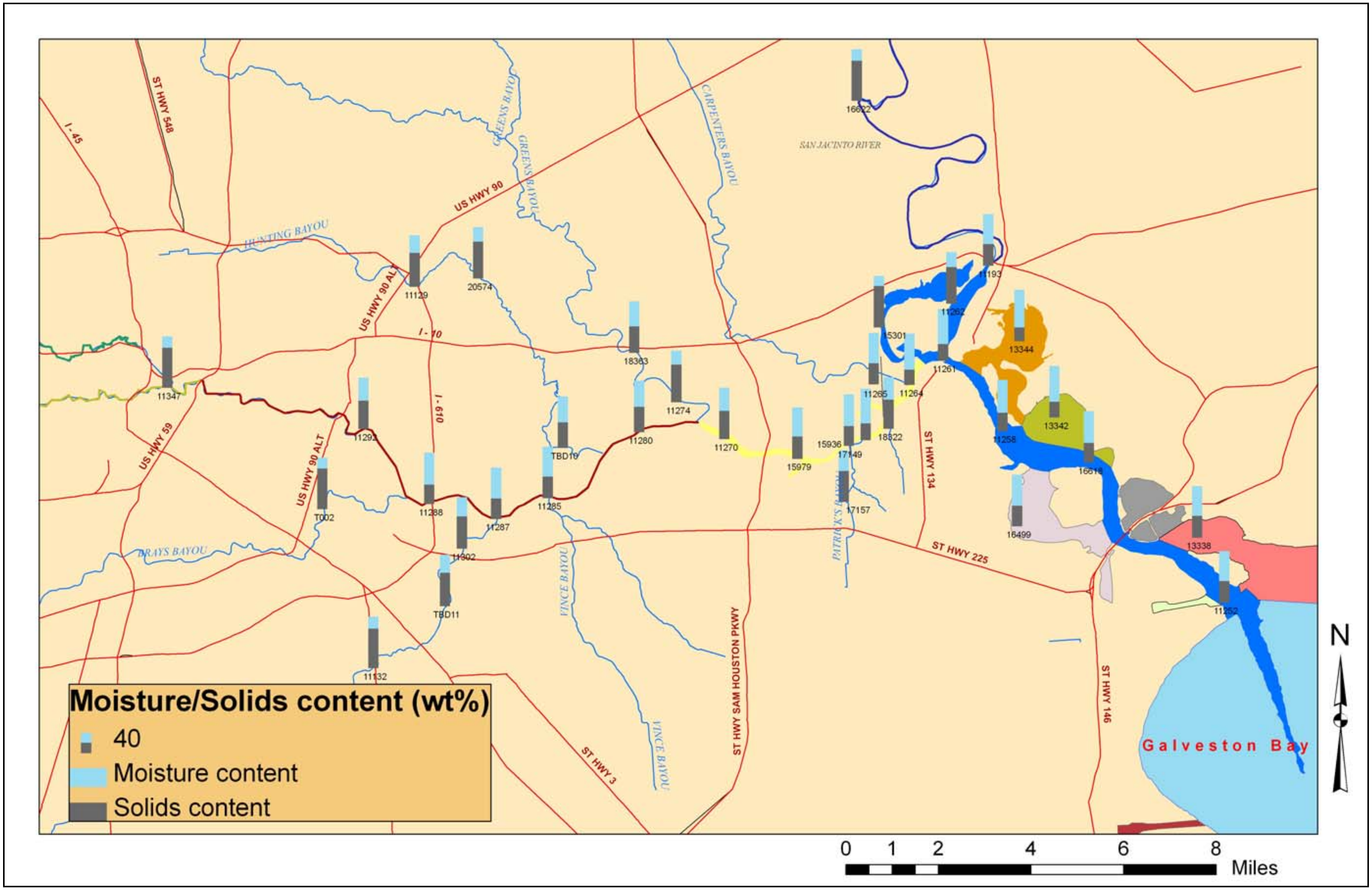


Figure 3.7 Moisture content in sediment samples collected in Summer 2009

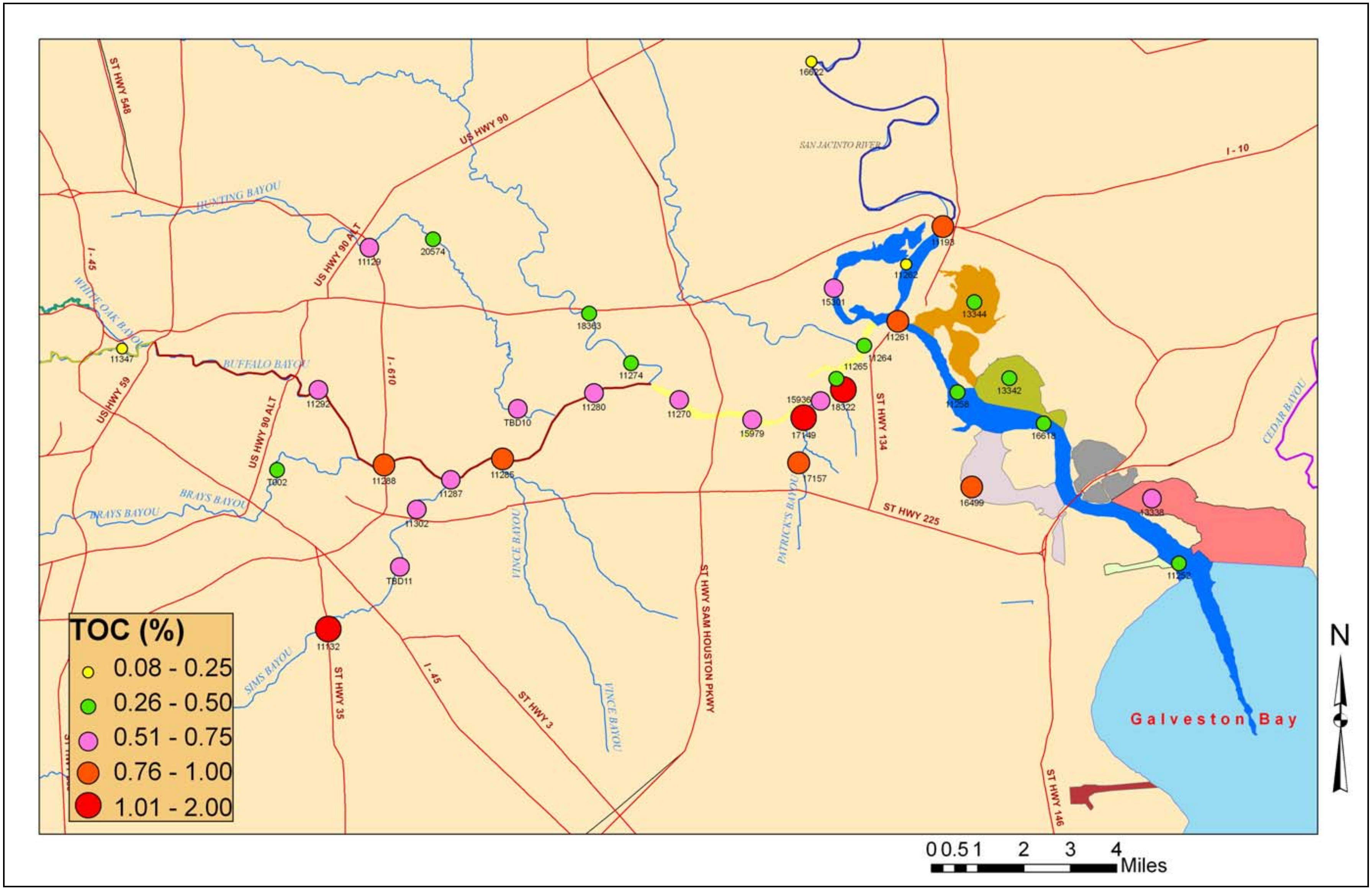


Figure 3.8 TOC in sediment samples collected in Summer 2009

4. SUMMARY OF AMBIENT PCB RESULTS BY MEDIA

4.1 PCB Quality Standards

Several national and state criteria and screening levels for PCBs in water and fish tissue exist. The state/federal Maximum Contaminant Level (MCL) for drinking water is 500 ng/L (ppt), while the human health water quality criterion based on uptake by fish consumption and water recommended by EPA is 0.17 ng/L (U.S. EPA, 1999). The Texas Surface Water Quality Standards (§307.1-307.10) include human health water quality criterion for total PCBs (based on Aroclors) of 1.3 ng/L and 0.885 ng/L in freshwater and saltwater, respectively. These concentrations are lower than the MCL for drinking water due to the fact that the highest exposure potential of PCBs in waters is through the bioaccumulation potential and consumption of contaminated fish (Webster et al., 1998). Additionally, fresh and saltwater criteria differ because it is assumed that consumption rates are higher for saltwater species. The Texas Department of Health based its health assessment of PCBs in the Houston Ship Channel (TDH, 2001) on a screening level of 47 ng /g-tissue. This screening value was derived from an EPA chronic oral reference dose (RfD) for Aroclor 1254 of 0.00002 mg/kg/day[1].

4.2 PCB Analytical Quantification

PCBs may be quantified as individual congeners, as Aroclor equivalents, or as homolog groups (i.e. monochlorobiphenyl, dichlorobiphenyl, etc). Aroclors are identified as commercial

[1] This is the lower of the carcinogen and noncarcinogen comparison values. The comparison value using the EPA slope factor of 2 $(mg/kg/day)^{-1}$ to account for the carcinogen effects of PCBs was 270 ng/g. Assumptions: bodyweight 70 kg, consumption rate 30 g/day, exposure period 30 yr (for carcinogens), and excess lifetime cancer risk of $1x10^{-4}$.

mixtures of PCB congeners. Historically, the most common PCB analysis has been through Aroclor analysis (EPA method 8082). However, the analysis of Aroclor may yield significant error in determining both total PCB and their total toxicity. This is because the Aroclor method assumes that the distribution of PCB congeners in environmental samples and parent Aroclor compounds is similar (U.S. EPA, 2000). Cogliano (1998) found that bioaccumulated PCBs are more toxic and persistent than the original Aroclor mixtures. Thus, the U.S. EPA (2000) recommends analysis of homologue groups or PCB congeners. However, it acknowledges that all health-based assessments are based on Aroclors. U.S. EPA (2000) suggests summing 18 congeners to compare to total PCB or Aroclor-based screening values, as recommended by the National Oceanic and Atmospheric Administration (USEPA, 2000). The 18 congeners include PCB-8, PCB-18, PCB-28, PCB-44, PCB-52, PCB-66, PCB-77, PCB-101, PCB-105, PCB-118, PCB-126, PCB-128, PCB-138, PCB-153, PCB-169, PCB-170, PCB-180, and PCB-187.

For PCBs, the USEPA suggests that each state measure congeners of PCBs in fish and shellfish rather than homologues or Aroclors because they consider congener analysis the most sensitive technique for detecting PCBs in environmental media. Although only about 130 PCB congeners were routinely present in PCB mixtures manufactured and commonly used in the U.S., all 209 possible PCB congeners are analyzed and reported. Despite EPA's suggestion that the states utilize PCB congeners rather than Aroclors or homologues for toxicity estimates, the toxicity literature does not reflect state-of-the-art laboratory science. To accommodate this inconsistency, the National Oceanic and Atmospheric Administration (Lauenstein, 1993) recommends the use of 43 congeners documented in McFarland and Clarke (1989), and from the USEPA's guidance documents for assessing contaminants in fish and shellfish (U.S.EPA, 2000; 2000a) to address PCB congeners in fish and shellfish samples. The preceding references recommend using 43 congeners for their likelihood of occurrence in fish, the likelihood of significant toxicity -- based on structure-activity relationships – and for the relative environmental abundance of the congeners. Thus, in this study, the 43 suggested congeners were summed to derive a "total" PCB concentration in each sample. Using only a few PCB congeners to determine total PCB concentrations could conceivably underestimate PCB levels in fish tissue. Nonetheless, the method complies with expert recommendations on evaluation of PCBs in fish or shellfish. The 43 congeners include PCB-8, PCB-18, PCB-28, PCB-37, PCB-44, PCB-49, PCB-52, PCB-60, PCB-66, PCB-70, PCB-74, PCB-77, PCB-81, PCB-82, PCB-87, PCB-99, PCB-101, PCB-105, PCB-114, PCB-118, PCB-119, PCB-123, PCB-126, PCB-128, PCB-138, PCB-151, PCB-153, PCB-156, PCB-157, PCB-158, PCB-166, PCB-167, PCB-168, PCB-169, PCB-170, PCB-177, PCB-179, PCB-180, PCB-183, PCB-187, PCB-189, PCB-194, PCB-201.

4.3 Summary of PCB Sample Locations in the Houston Ship Channel

During the Summer 2009, concentrations of the 209 PCB congeners (EPA Method 1668A) were analyzed and results obtained for 48 ambient water locations, 35 in-stream sediment locations, 30 locations for Catfish, and 16 locations for Seatrout/Atlantic Croaker.

4.3.1 In-stream Water PCB Concentrations

The total PCB concentrations in water (dissolved plus suspended PCB) were calculated using three different approaches: (i) sum of 18 NOAA congeners (ii) sum of 43 congeners from McFarland and Clarke, and (iii) sum of all 209 congeners. For stations for which duplicate samples were collected, the PCB results for that station was calculated as the average of duplicate and parent sample. The total PCB concentrations were calculated with non-detects (ND) assumed to be zero and non-detects assumed to be half the detection limit.[2] The PCB results by station from the three summation approaches and two ND approaches are summarized in Table 4.1 and a statistical summary of PCB results is given in Table 4.2. As expected, the total PCB concentrations were the highest when calculations were made with the summation of 209 congeners followed by the summation of 43 congeners and the lowest was obtained with the summation of 18 congeners. The use of non-detects as zero or half the detection limit did not yield significantly different results regardless of the summation approach. The concentrations observed in Patrick bayou are significantly greater than concentrations observed in other areas regardless of the summation approach. Based on the method of calculation, the PCB concentrations varied substantially and the inferences differed:

1) The summation of 209 congeners yielded total PCB concentrations in the range of 0.55 and 187 ng/L with median concentration of 2.18 ng/L for the 48 locations sampled. As can be seen in Table 4.1, 45 out of the 48 locations (94%) sampled in Summer 2009 exceeded the Texas Surface Water Quality Standard (WQS) for human health protection of 0.885 ng/L. In addition, the median concentration was higher than the WQS.
2) The summation of 43 congeners yielded total PCB concentrations in the range of 0.23 and 100 ng/L with median concentration of 0.94 ng/L for the 48 locations sampled. As can be seen in Table 4.1, 28 out of the 48 locations (58%) sampled in Summer 2009

[2] Additionally all PCB totals that did not use all 209 congeners involved the use of coeluant groups as the concentration for the congener needed in the total. For example in a PCB 43 total, PCB-28 co-elutes with PCB-20 as received from the laboratory. The exact split between the two congeners is not known, and thus, the total of the two was chosen to be representative of the concentration of PCB-28.

exceeded the Texas Surface Water Quality Standard (WQS) for human health protection of 0.885 ng/L. In addition, the median concentration was higher than the WQS.

3) The summation of 18 congeners yielded total PCB concentrations in the range of 0.17 and 67.8 ng/L with median concentration of 0.74 ng/L for the 48 locations sampled. As can be seen in Table 4.1, 14 out of the 48 locations (29%) sampled in Summer 2009 exceeded the Texas Surface Water Quality Standard (WQS) for human health protection of 0.885 ng/L.

Table 4.1 PCB concentrations in water (ng/L)

Station ID	∑209 congeners		∑43 congeners		∑NOAA 18 congeners	
	Total PCBs (ng/L)[a]	Total PCBs (ng/L)[b]	Total PCBs (ng/L)[a]	Total PCBs (ng/L)[b]	Total PCBs (ng/L)[a]	Total PCBs (ng/L)[b]
11115	1.787	1.757	0.684	0.680	0.613	0.612
11129	8.519	8.501	4.493	4.489	3.281	3.280
11132	3.179	3.105	1.442	1.434	1.189	1.187
11139	2.087	2.016	0.833	0.827	0.723	0.722
11193	1.776	1.768	0.811	0.810	0.637	0.637
11252	2.075	2.021	0.935	0.930	0.657	0.656
11258	2.958	2.947	1.313	1.311	0.981	0.980
11261[c]	2.179	2.170	0.945	0.944	0.740	0.740
11262	1.563	1.547	0.747	0.745	0.540	0.539
11264	2.988	2.976	1.466	1.465	1.008	1.007
11265	3.918	3.909	1.959	1.959	1.325	1.325
11270	3.996	3.986	1.868	1.867	1.420	1.420
11274	2.363	2.352	1.060	1.060	0.764	0.764
11279	0.819	0.793	0.323	0.318	0.268	0.266
11280	1.839	1.819	0.908	0.907	0.665	0.665
11285	2.542	2.524	1.181	1.181	0.850	0.850
11287	7.286	7.276	3.491	3.490	2.427	2.427
11288	3.958	3.941	2.001	1.999	1.421	1.420
11292	1.409	1.395	0.652	0.650	0.486	0.485
11347[c]	1.782	1.758	0.763	0.762	0.602	0.602
11387	1.016	0.926	0.341	0.320	0.284	0.279
13338	1.077	1.003	0.469	0.462	0.325	0.324
13340	2.302	2.230	0.963	0.955	0.818	0.816
13342	1.993	1.983	0.910	0.909	0.632	0.632
13344	2.197	2.190	1.037	1.036	0.747	0.747
13355[c]	1.581	1.573	0.737	0.736	0.534	0.533
13363	0.552	0.536	0.234	0.231	0.172	0.170
14560	1.672	1.591	0.626	0.612	0.543	0.539
15301	2.321	2.311	1.047	1.045	0.734	0.733
15936	2.730	2.722	1.277	1.277	0.880	0.879
15979	2.672	2.657	1.228	1.227	0.880	0.879
16213	2.008	1.913	0.779	0.760	0.665	0.660
16499	2.920	2.858	1.268	1.262	0.999	0.998
16618	2.273	2.260	0.975	0.973	0.757	0.756
16622	2.125	2.116	1.122	1.121	0.723	0.723

Table 4.1 PCB concentrations in water (ng/L)

Station ID	∑209 congeners		∑43 congeners		∑NOAA 18 congeners	
	Total PCBs (ng/L)[a]	Total PCBs (ng/L)[b]	Total PCBs (ng/L)[a]	Total PCBs (ng/L)[b]	Total PCBs (ng/L)[a]	Total PCBs (ng/L)[b]
16657	0.732	0.722	0.302	0.300	0.210	0.209
16872	1.304	1.267	0.584	0.578	0.459	0.457
17149	160.479	160.380	52.399	52.392	33.936	33.935
18322	5.845	5.830	2.895	2.895	1.965	1.965
18363	4.614	4.594	2.102	2.100	1.521	1.521
20570	2.134	2.118	0.800	0.798	0.710	0.709
20574	8.956	8.913	4.384	4.383	3.311	3.311
20575	2.351	2.278	0.862	0.851	0.759	0.756
T002[c]	1.935	1.893	0.794	0.788	0.658	0.656
TBD10	1.796	1.781	0.905	0.903	0.643	0.642
TBD11	1.749	1.730	0.732	0.729	0.549	0.548
17157	187.053	186.976	100.197	100.197	67.790	67.790
TBDVINCE	2.179	2.170	0.826	0.825	0.750	0.750

∑209 congeners is total PCB concentration calculated as the sum of all 209 congeners

∑ 43 congeners is total PCB concentration calculated as the sum of the 43 congeners from McFarland and Clarke (1989)

∑NOAA 18 congeners is total PCB concentration calculated as the sum of the 18 congeners

a Non-detects assumed to be 1/2 detection limit

b Non-detects assumed to be zero

c Average of duplicate samples, otherwise concentration of a single sample

Exceeds the WQS (0.885 ng/L)

Table 4.2 Statistical summary of PCB concentrations in water

	∑209 congeners		∑43 congeners		∑18 congeners	
	Total PCBs (ng/L)[a]	Total PCBs (ng/L)[b]	Total PCBs (ng/L)[a]	Total PCBs (ng/L)[b]	Total PCBs (ng/L)[a]	Total PCBs (ng/L)[b]
Min	0.55	0.54	0.23	0.23	0.17	0.17
Max	187.1	187	100.2	100.2	67.8	67.8
Average	9.78	9.75	4.35	4.34	2.99	2.99
Stdev	34.71	34.7	15.97	15.97	10.7	10.7
Median	2.18	2.17	0.94	0.94	0.74	0.74
% stations that exceed WQS	94 %		58 %		29 %	

∑209 congeners is total PCB concentration calculated as the sum of all 209 congeners

∑43 congeners is total PCB concentration calculated as the sum of the 43 congeners from McFarland and Clarke (1989)

∑18 congeners is total PCB concentration calculated as sum of the 18 congeners

a Non-detects assumed to be 1/2 detection limit

b Non-detects assumed to be zero

Figures 4.1a, 4.1b, and 4.1c show the spatial distribution of total PCBs in water in the Houston Ship Channel System based on calculations made by summation of 209, 43, and 18 congeners respectively. The green and yellow circles in the figures indicate the stations that do not exceed the WQS, while the circles in other colors (black, brown, orange, and red) exceed the WQS for human health protection of 0.885 ng/L. The figures show the lower PCB concentrations in the San Jacinto river and downstream of San Jacinto in the HSC. The highest PCB concentrations were found in mid and downstream of Patrick bayou (17149 and 17157), concentrations significantly higher than the upstream station in Patrick bayou (16872).

Figures 4.2a, 4.2b, and 4.2c compare the mean dissolved, suspended and total PCB concentrations by segment based on summation of 209, 43, and 18 congeners, respectively. The figures also show the segments that exceed the WQS of 0.885 ng/L. The use of ∑18 summation approach showed that segments 2427, 1007 and 1006 exceeded the WQS. In addition to the above mentioned segments, segments 1001, 1005, 2428, 2429, and 2430 exceeded the WQS in the case of the ∑43 congener approach. The use of the congener 209 summation approach showed that all segments except 2438 exceeded the WQS. The high spikes in segment 1006 were due to the high PCB concentrations observed in Patrick bayou.

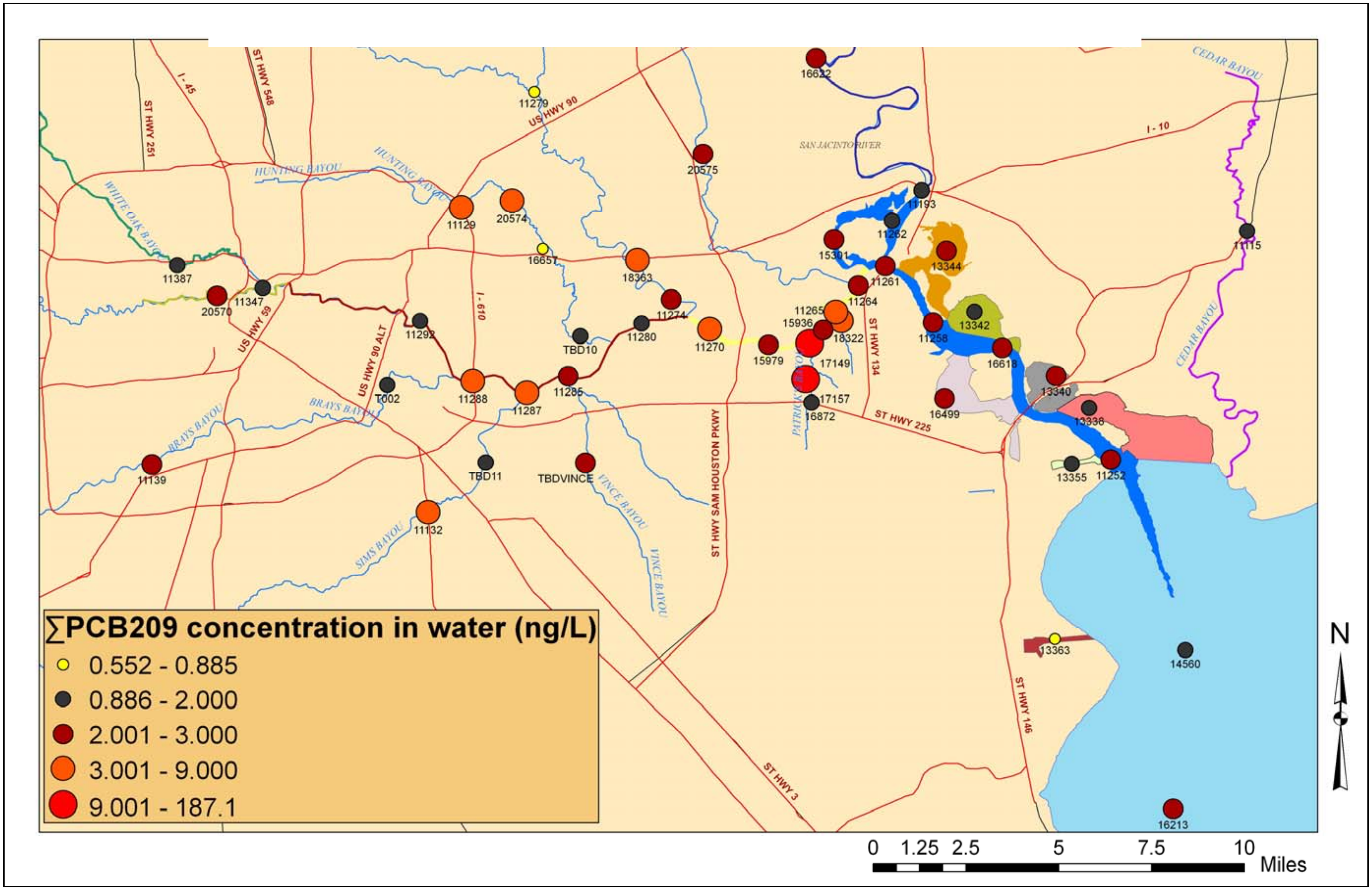


Figure 4.1a Total PCB concentrations in water calculated as sum of 209 congeners

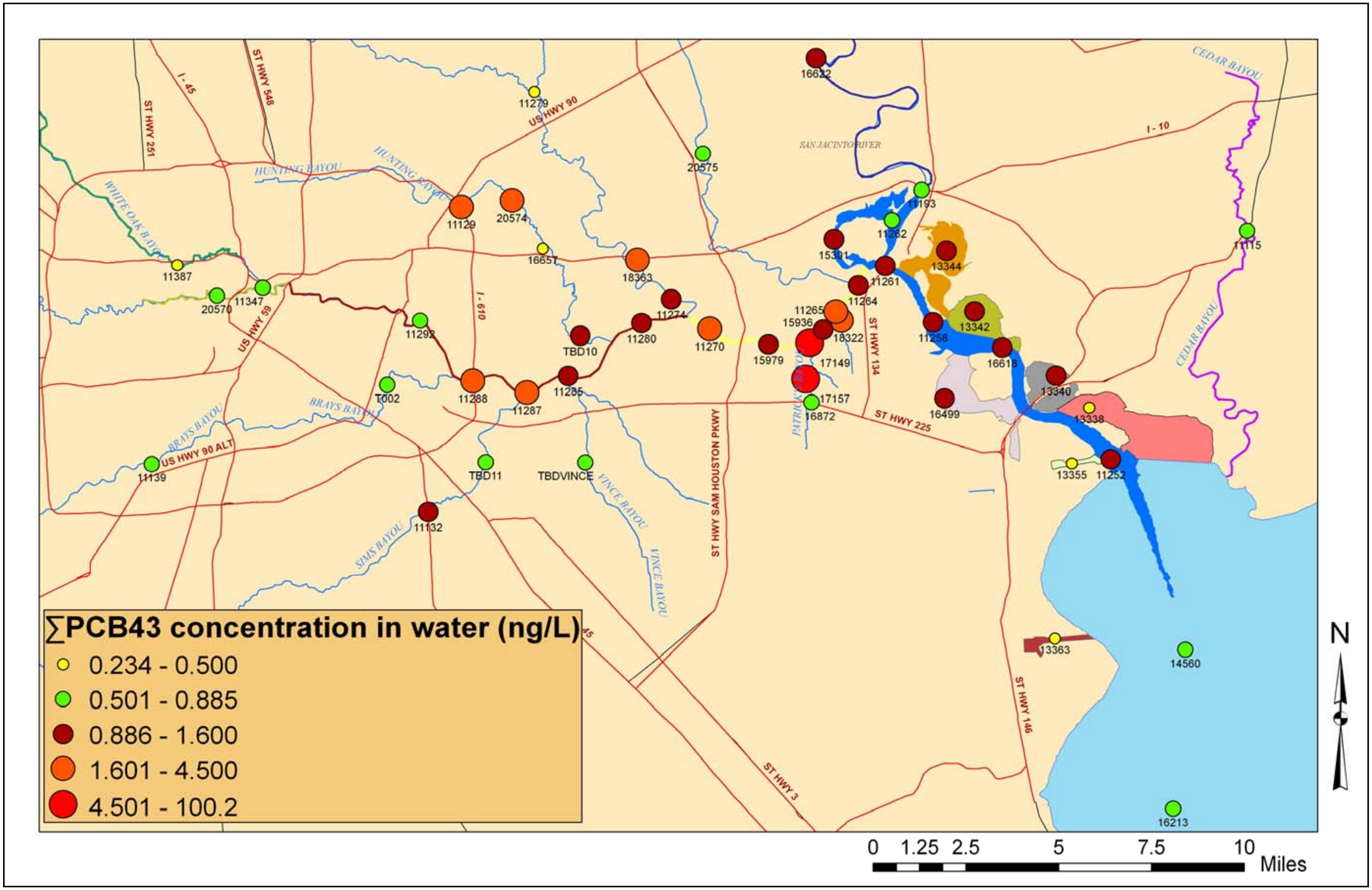


Figure 4.1b Total PCB concentrations in water calculated as sum of 43 congeners

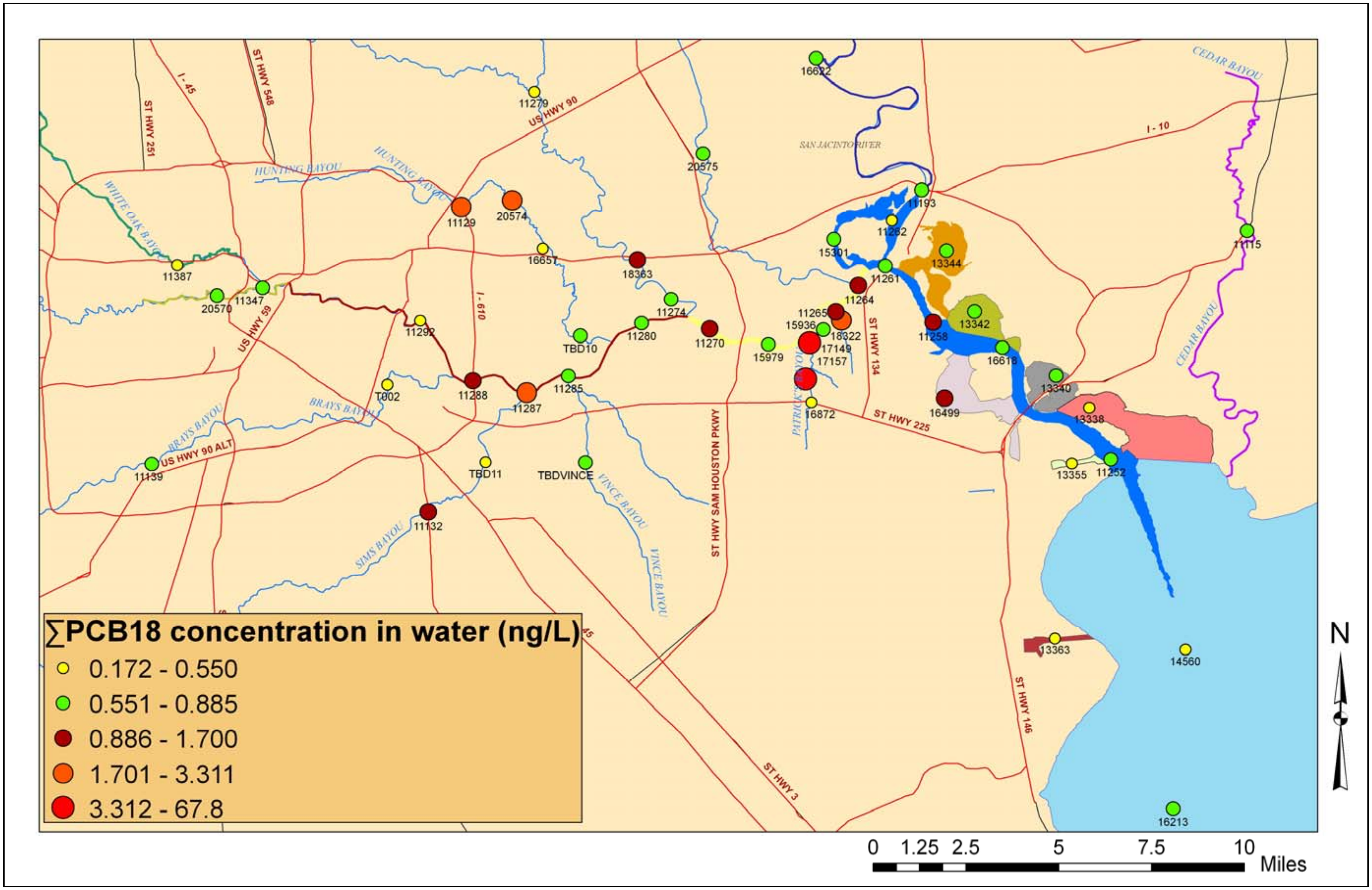


Figure 4.1c Total PCB concentrations in water calculated as sum of 18 congeners

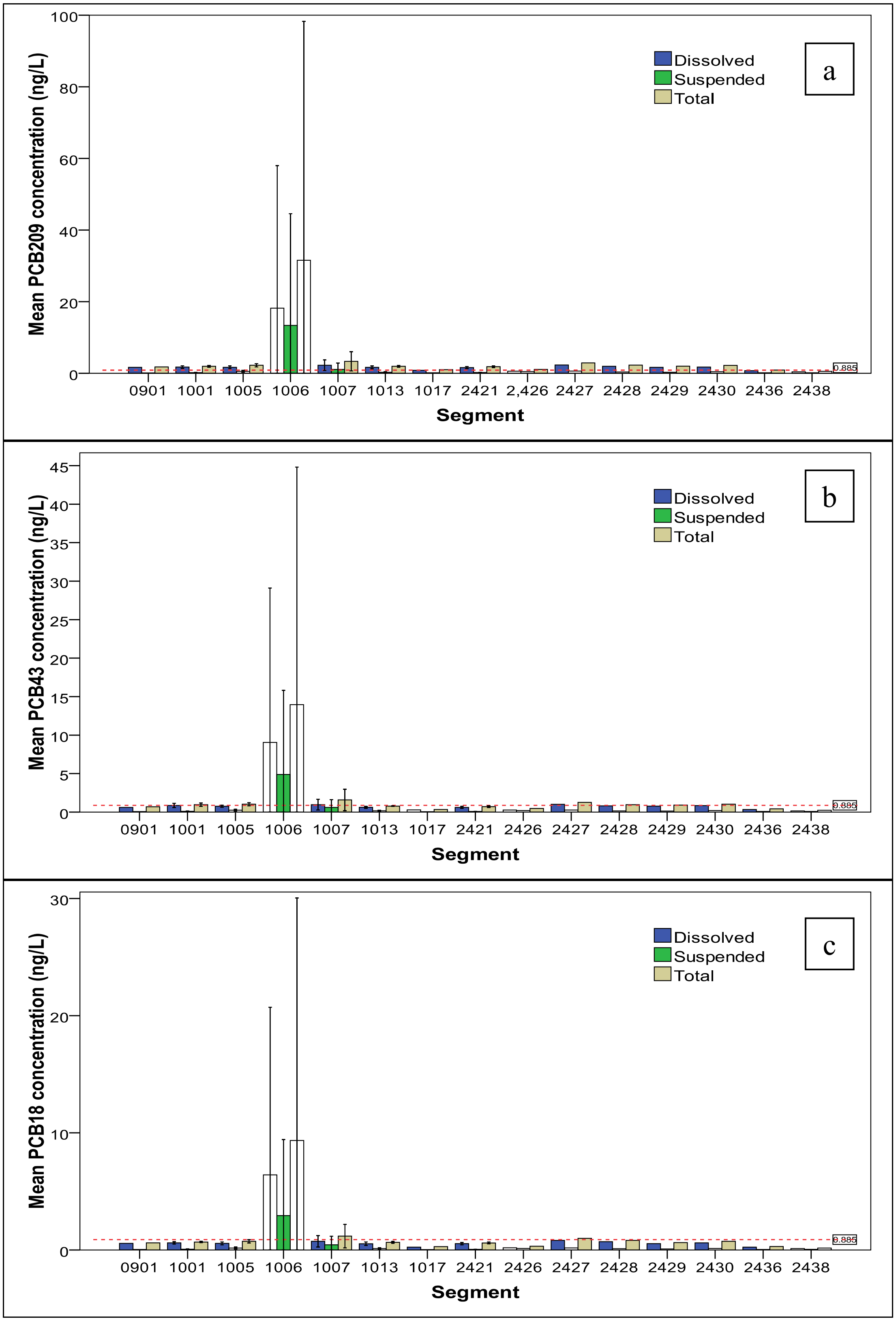


Figure 4.2 Comparison of PCB concentrations in water by segment. (a. ∑ PCB 209 congeners, b. ∑ PCB 43 congeners, c. ∑ PCB 18 congeners)

Figure 4.3 compares the dissolved and suspended phase water PCB concentrations for all congener summation approaches from the 2009 dataset. As was observed during the 2008 and the 2002-2003 studies, higher PCB concentrations were observed in the dissolved phase (> 50%) than in the suspended phase. All the stations except 11129, 17149 and 20574 had PCB concentrations higher in the dissolved phase (>50%) than in the suspended phase. Table 4.3 compares the percentage sampling stations that had greater than 50% of the total PCB in the dissolved phase from the 2002-2003, 2008 and 2009 studies. As can be observed from Table 4.3, > 80 % of sampling stations had greater than 50% of the total PCB in the dissolved phase.

The higher PCB concentrations in the dissolved phase are not uncommon and have been reported by other studies around the world. Maldonado and Bayona (2002) reported that the dissolved PCB concentrations are particles less than 1-µm and so passage of colloidal particles (0.45- 1.0 µm) could have caused the observed dissolved PCB concentrations to be significantly greater than they are actually dissolved. This behavior was further attributed to be the cause of a lower than expected suspended sediment/water partitioning coefficient (K_d).

While the finding of a higher dissolved concentration for PCB was not uncommon relative to other water bodies around the world, it does stand out to be in contrast relative to dioxin, another hydrophobic POP that has similar characteristics to PCB. Suarez et al. (2006) showed that >90% of the total dioxin concentrations in water to be in the suspended phase. Based on the PCB finding, the dioxin results should have also shown higher dissolved concentrations had the colloidal phase been the reason as reported by others. Further study is needed to fully understand the difference in dissolved/suspended partitioning for PCBs and dioxins. However, an analysis of the partition coefficients and individual PCB/dioxin congener concentrations revealed that the difference in behavior between dioxin and PCB may be significantly affected by the congener type present in the system and their respective octanol/water partition coefficients. In the case of dioxin, for example, the total dioxin concentration was attributed to OCDD (91%) followed by 1234678-HpCDD (3.6%) and OCDF (3.2%) whose $\log K_{ow}$ values are 10.06, 10.24, and 10.14, respectively. In comparison, mono- di-, tri-, tetra-, penta- and hexa- chlorobiphenyls accounted for >95% of the total PCB concentration and their $\log K_{ow}$ values are 4.61, 5.09, 5.55, 5.98, 6.4, and 6.8, respectively. The partition coefficients for dioxins are 3-5 orders of magnitude higher than the PCB congeners that are present in the HSC system. Thus, the adsorption/transfer of hydrophobic contaminants from the dissolved phase onto the suspended phase will also be favored for highly hydrophobic contaminants due to the limitation of adsorption sites. Considering that the HSC accounts for significant quantities of chemical production and oil refineries, it is understandable that there is going to be significant competition for adsorption sites from highly hydrophobic organic contaminants in the water body, thus limiting the possible adsorption of PCBs.

Thus, even though theoretically high PCB concentrations are expected in the particulate phase, higher PCB concentrations in the dissolved phase are possibly due to

- the passage of colloids (as mentioned in other studies), and
- the low partition coefficients of PCBs in comparison to other strongly hydrophobic contaminants present in the system thereby limiting the adsorption, and discharge of PCBs from fresh sources.

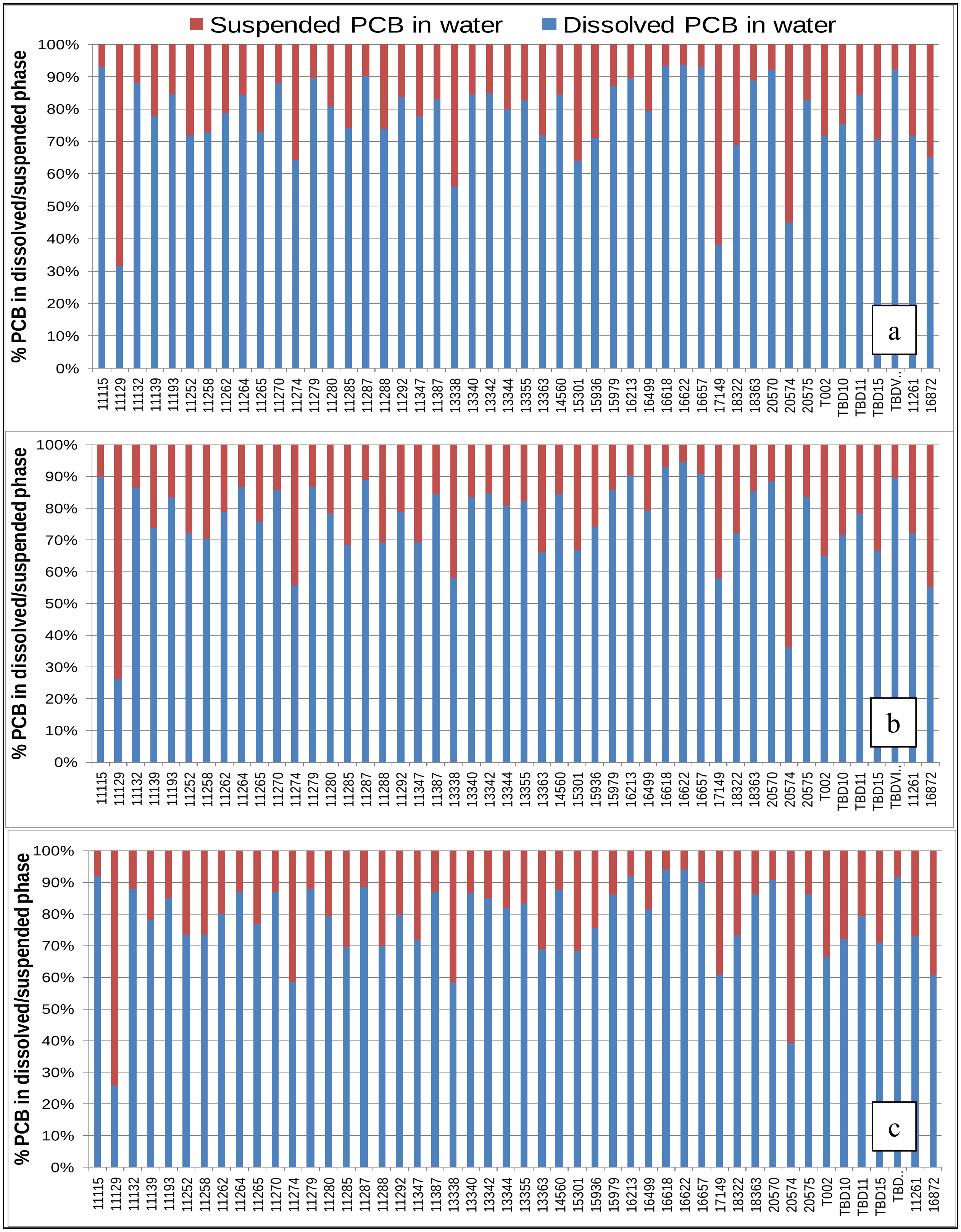


Figure 4.3 Partitioning of PCBs between Dissolved and Suspended Phases in the HSC from 2008 study. (a. ∑ PCB 209 congeners, b. ∑ PCB 43 congeners, c. ∑ PCB 18 congeners)

Table 4.3 Percentage stations that had PCB water concentrations higher in dissolved phase than in suspended phase in the HSC

Year of study	Summation method	Stations sampled	No of stations where dissolved PCB greater than suspended PCB	% stations where dissolved PCB greater than suspended PCB
2002-2003	∑209 congeners	32	26	81.3%
	∑43 congeners	32	27	84.4%
	∑18 congeners	32	26	81.3%
2008	∑209 congeners	37	35	94.6%
	∑43 congeners	37	35	94.6%
	∑18 congeners	37	35	94.6%
2009	∑209 congeners	48	45	93.8%
	∑43 congeners	48	46	95.8%
	∑18 congeners	48	46	95.8%

4.3.2 Sediment PCB Concentrations

PCB results from the in-channel sediment samples collected in Summer 2009 by station from the three congener summation approaches and the two ND approaches are summarized in Table 4.4, while the statistical summary is given in Table 4.5. Depending on the method of calculation of total PCBs, the sediment PCB concentrations varied significantly. The use of non-detects as zero or half the detection limit did yield significantly different results, in particular low PCB concentration levels. The summation of 209 congeners yielded total PCB concentrations in the range of 4.1 and 9496 ng/g with median concentration of 61 ng/g for the 35 locations sampled. The summation of 43 congeners yielded total PCB concentrations in the range of 1.3 and 5544 ng/g with median concentration of 35 ng/g for the 35 locations sampled. The summation of 18 congeners yielded total PCB concentrations in the range of 0.54 and 3272 ng/g with median concentration of 23 ng/g for the 25 locations sampled. As expected, the total PCB concentration decreased with the decrease in the number of congener summation method. Figures 4.4a, 4.4b, and 4.4c show the distribution of total PCBs in sediment using the three different methods, respectively. It can be seen that the higher PCB concentrations in sediment were found upstream of the confluence with the San Jacinto River, in particular stations in Patrick bayou (17149 and 17157), HSC at Vince bayou (11285) and near the SanJacinto pit (11193).

Figure 4.6 compares the sediment PCB concentrations by segment. Regardless of the basis of the summation, the highest PCB concentrations were observed in segments 1006, 1001 and 1007. The PCB concentrations were significantly lower in Galveston Bay segments compared to other segments.

Table 4.4 PCB concentrations in sediment (ng/g-wet wt.)

Station ID	∑209 congeners		∑43 congeners		∑18 congeners	
	Total PCBs (ng/g)[a]	Total PCBs (ng/g)[b]	Total PCBs (ng/g)[a]	Total PCBs (ng/g)[b]	Total PCBs (ng/g)[a]	Total PCBs (ng/g)[b]
11129	18.22	16.27	9.99	9.81	6.84	6.78
11132	18.31	15.40	9.88	9.64	6.67	6.59
11193	1339.37	1338.73	752.77	752.75	504.32	504.30
11252	9.94	6.56	4.38	3.51	2.54	2.36
11258	25.19	22.68	12.55	12.30	7.78	7.74
11261	43.46	41.36	21.79	21.61	13.47	13.42
11262	6.09	1.44	1.85	0.39	0.90	0.36
11264	211.9	210.65	112.22	112.14	68.07	68.04
11265	84.13	82.46	42.13	41.98	26.66	26.61
11270[c]	69.79	68.28	41.60	41.47	27.09	27.05
11274	77.44	75.61	41.10	40.94	26.06	26.01
11280	234.94	234.02	143.02	142.98	89.35	89.33
11285	1289	1288	813.5	813.4	509.6	509.6
11287[c]	136.21	135.11	73.65	73.58	48.48	48.43
11288	277.72	276.92	162.79	162.75	105.36	105.34

Table 4.4 PCB concentrations in sediment (ng/g-wet wt.)

Station ID	∑209 congeners		∑43 congeners		∑18 congeners	
	Total PCBs (ng/g)[a]	Total PCBs (ng/g)[b]	Total PCBs (ng/g)[a]	Total PCBs (ng/g)[b]	Total PCBs (ng/g)[a]	Total PCBs (ng/g)[b]
11292	74.22	72.69	43.28	43.16	28.78	28.73
11302	80.94	79.21	39.89	39.69	26.83	26.78
11347	4.07	0.03	1.32	0.00	0.54	0.00
13338[c]	13.62	10.77	6.41	5.79	4.30	4.19
13342	37.59	35.59	18.23	18.05	11.66	11.61
13344	32.87	30.74	15.83	15.65	10.43	10.38
15301	14.70	11.36	6.25	5.46	4.11	3.99
15936	186	185.00	95.63	95.55	59.84	59.79
15979	75.73	73.84	41.50	41.31	26.43	26.38
16499	73.36	71.86	35.29	35.17	23.45	23.40
16618	29.11	26.68	14.44	14.20	8.78	8.73
16622	4.86	0.19	1.61	0.12	0.70	0.12
17149	7319	7319	1383	1383	812	812
17157	9496	9495	55434	5544	3272	3271.5
18322[c]	400	399	217	217	137	137
18363	34.42	32.17	19.06	18.87	12.39	12.34
20574	11.12	7.53	5.50	4.64	3.62	3.44
T002	10.33	7.29	5.22	4.47	3.65	3.50
TBD10	60.97	59.08	34.71	34.56	23.06	23.01
TBD11	25.63	23.25	13.90	13.71	9.55	9.50

∑209 congeners is total PCB concentration calculated as the sum of all 209 congeners

∑43 congeners is total PCB concentration calculated as the sum of the 43 congeners from McFarland and Clarke (1989)

∑18 congeners is total PCB concentration calculated as the sum of 18 congeners

a Non-detects assumed to be 1/2 detection limit;

b Non-detects assumed to be zero

c Average of duplicate samples, otherwise concentration of a single sample

Table 4.5 Statistical summary of PCB concentration in sediment

	∑209 congeners		∑43 congeners		∑18 congeners	
	Total PCBs (ng/g)[a]	Total PCBs (ng/g)[b]	Total PCBs (ng/g)[a]	Total PCBs (ng/g)[b]	Total PCBs (ng/g)[a]	Total PCBs (ng/g)[b]
Min	4.07	0.03	1.32	0.00	0.54	0.00
Max	9495.82	9495.39	5543.48	5543.46	3271.49	3271.47
Average	623.61	621.56	279.58	279.24	169.21	169.11
Stdev	1985.45	1985.95	959.05	959.14	566.96	566.99
Median	60.97	59.08	34.71	34.56	23.06	23.01

∑209 congeners is total PCB concentration calculated as the sum of all 209 congeners

∑43 congeners is total PCB concentration calculated as the sum of the 43 congeners from McFarland and Clarke (1989)

∑18 congeners is total PCB concentration calculated as the sum of the 18 congeners

a Non-detects assumed to be 1/2 detection limit

b Non-detects assumed to be zero

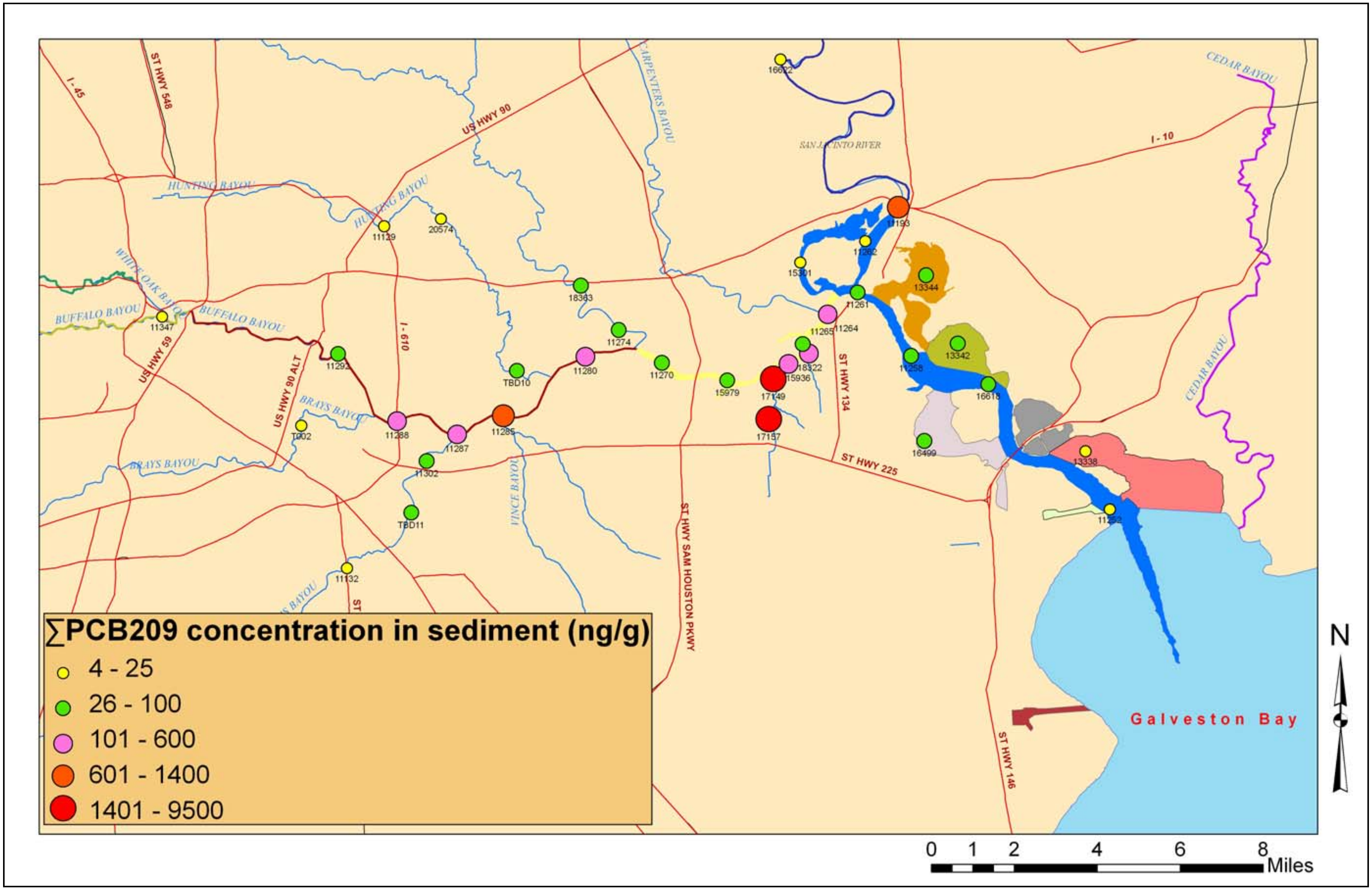


Figure 4.4a Total PCB concentrations in sediment calculated as sum of 209 congeners

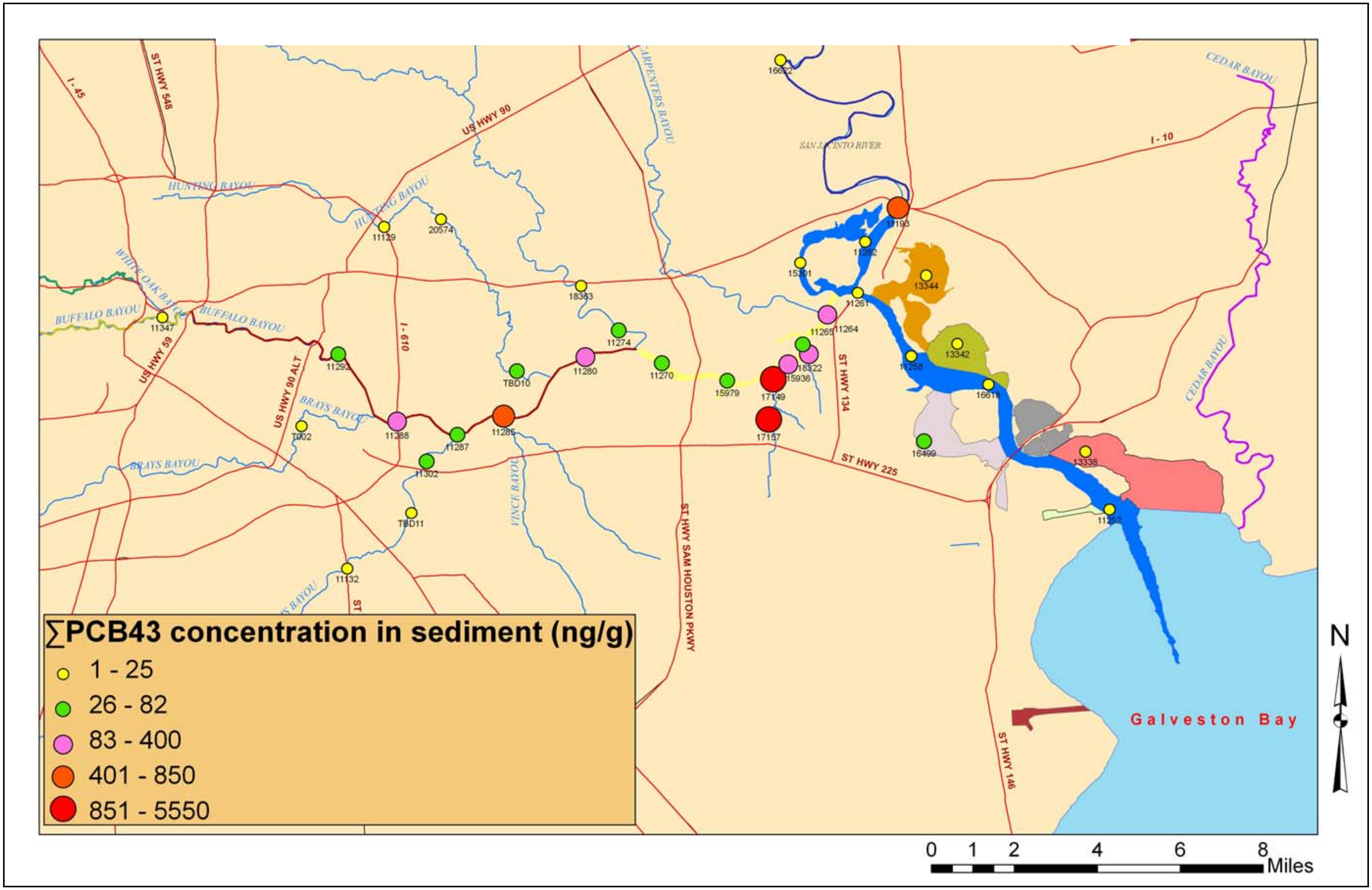


Figure 4.4b Total PCB concentrations in sediment calculated as sum of 43 congeners

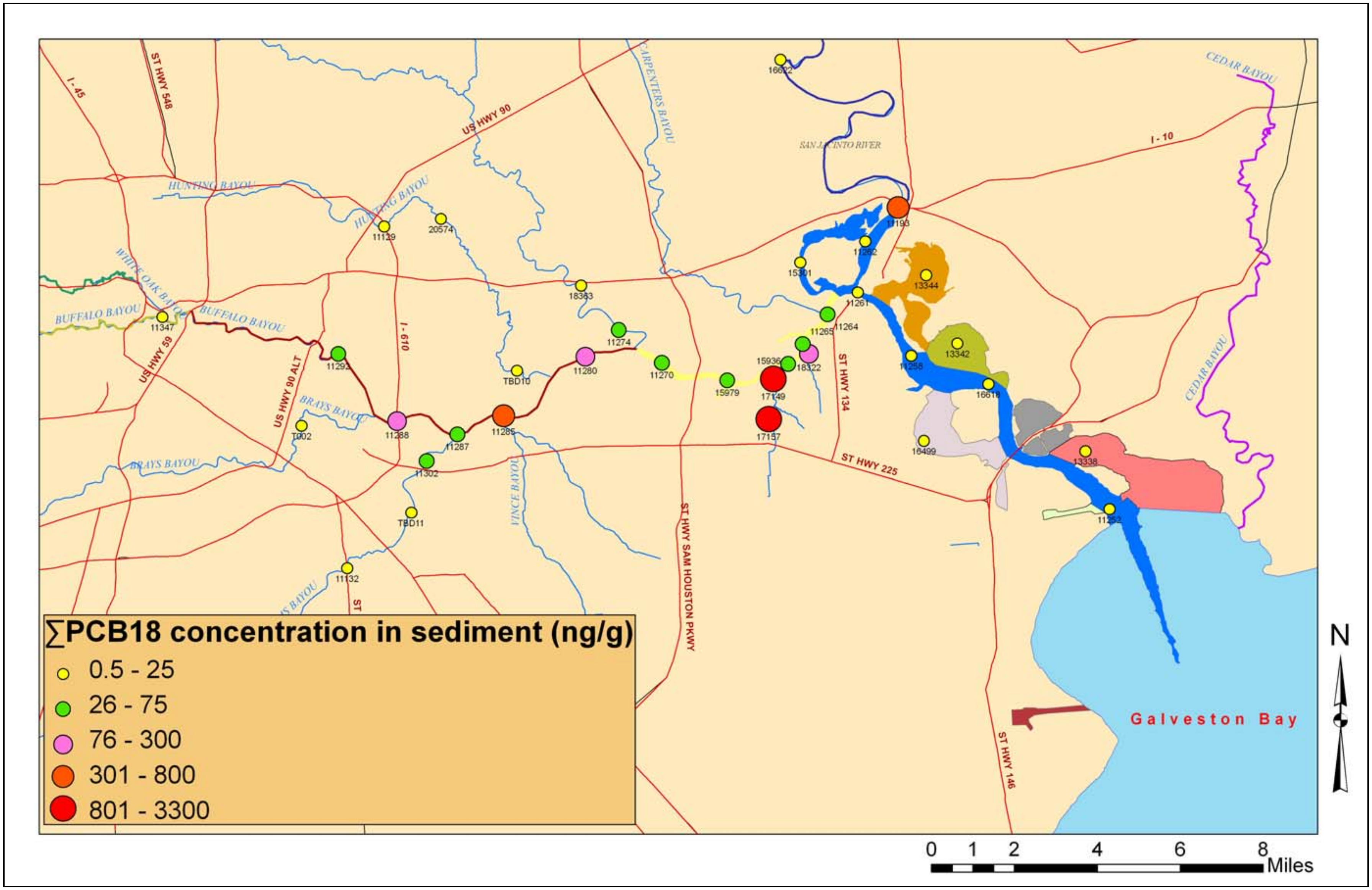


Figure 4.4c Total PCB concentrations in sediment calculated as sum of 18 congeners

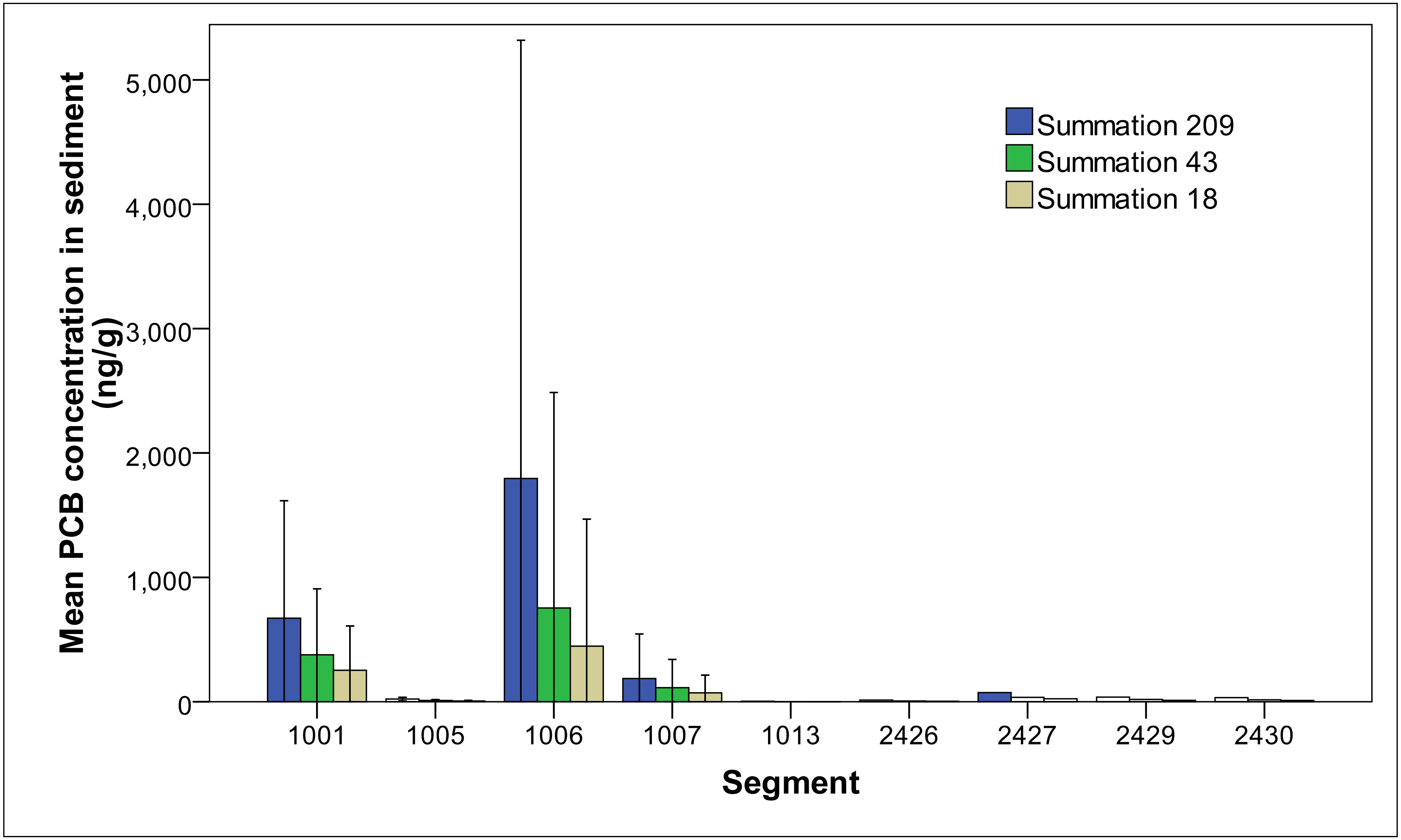


Figure 4.5 Comparison of PCB concentrations in sediment by segment

4.3.3 Tissue PCB Concentrations

The total PCB concentrations in catfish and seatrout/atlantic croaker tissue are included in Table 4.6, while the statistical summary of PCB concentrations in catfish and seatrout/atlantic croaker are given in Tables 4.7 and 4.8, respectively. The PCB concentrations in catfish and seatrout/atlantic croaker for the three summation methods are mapped in Figures 4.6 and 4.7, respectively. The green fish symbols in the figures indicate the stations that do not exceed the DSHS Health Assessment Comparison Value (47 ng/g), while the other fish symbols indicate the exceedance of DSHS Health Assessment Comparison Value. The usage of the non-detects as half the detection limit or zero ng/g did not make any significant difference in the total PCB concentration nor in the conclusions made.

1) The summation of 209 congeners yielded tissue PCB concentrations in the range of 14-559 ng/g in the case of catfish, and 36-2561 ng/g in the case of seatrout/atlantic croaker. As can be seen in Table 4.6, 26 out of the 30 locations (87%) sampled for catfish and 16 out of 18 species (89%) sampled for seatrout/atlantic croaker exceeded the DSHS Health Assessment Comparison Value (47 ng/g). In addition, the median concentration of catfish (114 ng/g) and seatrout/atlantic croaker (137 ng/g) was also higher than the Health Assessment Comparison Value.
2) The summation of 43 congeners yielded tissue PCB concentrations in the range of 11-448 ng/g in the case of catfish, and 25-1742 ng/g in the case of seatrout/atlantic croaker. In this case, 19 out of the 26 locations (73%) sampled for catfish and 16 out of 19 locations (84%) sampled for seatrout/atlantic croaker exceeded the DSHS Health Assessment Comparison Value (47 ng/g). In addition, the median concentration of catfish (83 ng/g)

and seatrout/atlantic croaker (92 ng/g) was also higher than the Health Assessment Comparison Value.

3) The summation of 18 congeners yielded tissue PCB concentrations in the range of 8-307 ng/g in the case of catfish, and 17-1101 ng/g in the case of seatrout/atlantic croaker. For this scenario, 16 out of the 26 locations (62%) sampled for catfish and 15 out of 19 locations (79%) sampled for seatrout/atlantic croaker exceeded the DSHS Health Assessment Comparison Value (47 ng/g). In addition, the median concentration of catfish (60 ng/g) and seatrout/atlantic croaker (62 ng/g) was also higher than the Health Assessment Comparison Value.

Table 4.6 PCB Concentrations in Fish Tissue (ng/g-wet wt.)

Station ID	Species	∑209 congeners		∑43 congeners		∑NOAA 18 congeners	
		Total PCBs (ng/g)[a]	Total PCBs (ng/g)[b]	Total PCBs (ng/g)[a]	Total PCBs (ng/g)[b]	Total PCBs (ng/g)[a]	Total PCBs (ng/g)[b]
11193	Catfish	40.71	39.84	27.37	27.29	18.78	18.74
11193[c]	Catfish	88.51	87.75	66.60	66.54	49.74	49.70
11252[c]	Catfish	64.11	63.17	49.84	49.77	37.49	37.45
11258	Catfish	102.64	101.91	77.29	77.23	57.40	57.36
11261	Catfish	26.42	25.33	17.66	17.54	12.64	12.60
11262[c]	Catfish	162.50	161.85	122.47	122.42	91.00	90.97
11264	Catfish	156.08	155.45	124.79	124.74	90.82	90.79
11265[c]	Catfish	163.13	162.53	130.06	130.02	92.43	92.40
11270	Catfish	146.28	145.60	116.30	116.26	84.78	84.75
11271	Catfish	113.70	113.01	87.52	87.47	63.09	63.05
11274	Catfish	54.38	53.60	38.30	38.25	26.54	26.52
11280	Catfish	164.14	163.60	127.38	127.37	93.67	93.67
11287	Catfish	114.74	114.20	77.82	77.79	54.93	54.91
11288	Catfish	139.59	139.14	95.15	95.13	66.86	66.85
11292[c]	Catfish	132.81	132.07	92.32	92.25	65.78	65.76
11347	Catfish	50.47	49.57	35.40	35.33	25.45	25.42
13338	Catfish	44.99	43.97	35.63	35.54	26.91	26.87
13342	Catfish	67.49	66.65	51.18	51.11	37.60	37.56
13344	Catfish	126.02	125.37	98.32	98.28	73.04	73.01
13355	Catfish	122.44	121.78	93.46	93.41	69.75	69.71
13363	Catfish	67.76	66.92	51.25	51.18	38.73	38.69
14560	Catfish	14.14	12.68	10.61	10.46	7.92	7.87
15301	Catfish	199.12	198.55	152.43	152.40	111.73	111.70
15936	Catfish	559.22	558.85	448.03	448.02	307.32	307.31

Table 4.6 PCB Concentrations in Fish Tissue (ng/g-wet wt.)

Station ID	Species	∑209 congeners		∑43 congeners		∑NOAA 18 congeners	
		Total PCBs (ng/g)[a]	Total PCBs (ng/g)[b]	Total PCBs (ng/g)[a]	Total PCBs (ng/g)[b]	Total PCBs (ng/g)[a]	Total PCBs (ng/g)[b]
15979	Catfish	232.57	232.09	186.07	186.04	131.32	131.30
16499	Catfish	91.94	91.15	71.50	71.44	53.87	53.84
16618	Catfish	67.92	66.96	52.44	52.37	39.06	39.02
16622	Catfish	73.14	72.45	49.69	49.65	34.35	34.33
17149	Catfish	400.49	400.11	324.66	324.66	224.69	224.69
18322	Catfish	287.83	287.37	230.17	230.16	158.05	158.04
11193	Seatrout/Atlantic Croaker	138.36	137.87	91.92	91.90	62.22	62.21
11252	Seatrout/Atlantic Croaker	41.17	40.34	27.19	27.12	18.23	18.21
11258	Seatrout/Atlantic Croaker	148.27	147.77	98.34	98.31	66.14	66.11
11261	Seatrout/Atlantic Croaker	438.83	438.51	292.65	292.63	198.06	198.04
11262	Seatrout/Atlantic Croaker	87.74	87.11	62.00	61.96	43.96	43.93
11264	Seatrout/Atlantic Croaker	190.09	189.53	130.67	130.63	87.57	87.54
11280	Seatrout/Atlantic Croaker	300.16	299.75	199.66	199.63	134.38	134.37
13338	Seatrout/Atlantic Croaker	73.81	73.12	48.30	48.25	32.32	32.29
13342	Seatrout/Atlantic Croaker	90.87	90.24	60.77	60.74	40.46	40.44
13344	Seatrout/Atlantic Croaker	136.13	135.29	91.23	91.18	61.41	61.38
13355	Seatrout/Atlantic	93.34	92.70	62.16	62.12	41.71	41.68

Table 4.6 PCB Concentrations in Fish Tissue (ng/g-wet wt.)

Station ID	Species	∑209 congeners		∑43 congeners		∑NOAA 18 congeners	
		Total PCBs (ng/g)[a]	Total PCBs (ng/g)[b]	Total PCBs (ng/g)[a]	Total PCBs (ng/g)[b]	Total PCBs (ng/g)[a]	Total PCBs (ng/g)[b]
	Croaker						
13355	Seatrout/Atlantic Croaker	165.22	164.71	115.84	115.82	79.77	79.75
13363	Seatrout/Atlantic Croaker	85.53	84.94	60.38	60.35	42.79	42.77
13363[c]	Seatrout/Atlantic Croaker	91.35	90.61	64.98	64.93	45.54	45.52
15936	Seatrout/Atlantic Croaker	2561.61	2561.18	1741.48	1741.47	1101.26	1101.25
15979	Seatrout/Atlantic Croaker	36.48	35.57	24.83	24.76	17.21	17.17
16499	Seatrout/Atlantic Croaker	162.65	161.92	108.28	108.24	73.57	73.54
16618	Seatrout/Atlantic Croaker	215.08	214.50	142.49	142.44	93.50	93.47

∑209 congeners is total PCB concentration calculated as the sum of all 209 congeners

∑ 43 congeners is total PCB concentration calculated as the sum of the 43 congeners from McFarland and Clarke (1989)

∑NOAA 18 congeners is total PCB concentration calculated as the sum of the 18 congeners

a Non-detects assumed to be 1/2 detection limit

b Non-detects assumed to be zero

c Average of duplicate samples, otherwise concentration of a single sample

Exceeds the DSHS Health assessment comparison value (47 ng/g)

Table 4.7 Summary statistics of PCB concentrations in Catfish

	∑209 congeners		∑43 congeners		∑NOAA 18 congeners	
	Total PCBs (ng/g)[a]	**Total PCBs (ng/g)[b]**	**Total PCBs (ng/g)[a]**	**Total PCBs (ng/g)[b]**	**Total PCBs (ng/g)[a]**	**Total PCBs (ng/g)[b]**
Min	14.14	12.68	10.61	10.46	7.92	7.87
Max	559.22	558.85	448.03	448.02	307.32	307.31
Average	135.84	135.12	104.72	104.67	74.86	74.83
Stdev	113.87	114.04	92.57	92.60	63.49	63.50
Median	114.22	113.61	82.67	82.63	60.24	60.20
% stations that exceed health standard	87		80		63	

a Non-detects assumed to be 1/2 detection limit

b Non-detects assumed to be zero

Table 4.8 Summary statistics of PCB concentrations in Seatrout/Atlantic Croaker

	∑209 congeners		∑43 congeners		∑NOAA 18 congeners	
	Total PCBs (ng/g)[a]	**Total PCBs (ng/g)[b]**	**Total PCBs (ng/g)[a]**	**Total PCBs (ng/g)[b]**	**Total PCBs (ng/g)[a]**	**Total PCBs (ng/g)[b]**
Min	36.48	35.57	24.83	24.76	17.21	17.17
Max	2561.6	2561.2	1741.5	1741.5	1101.3	1101.3
Average	280.93	280.32	190.18	190.14	124.45	124.43
Stdev	577.45	577.51	392.52	392.53	247.62	247.62
Median	137.24	136.58	91.58	91.54	61.82	61.79
% stations that exceed health standard	89		89		56	

a Non-detects assumed to be 1/2 detection limit

b Non-detects assumed to be zero

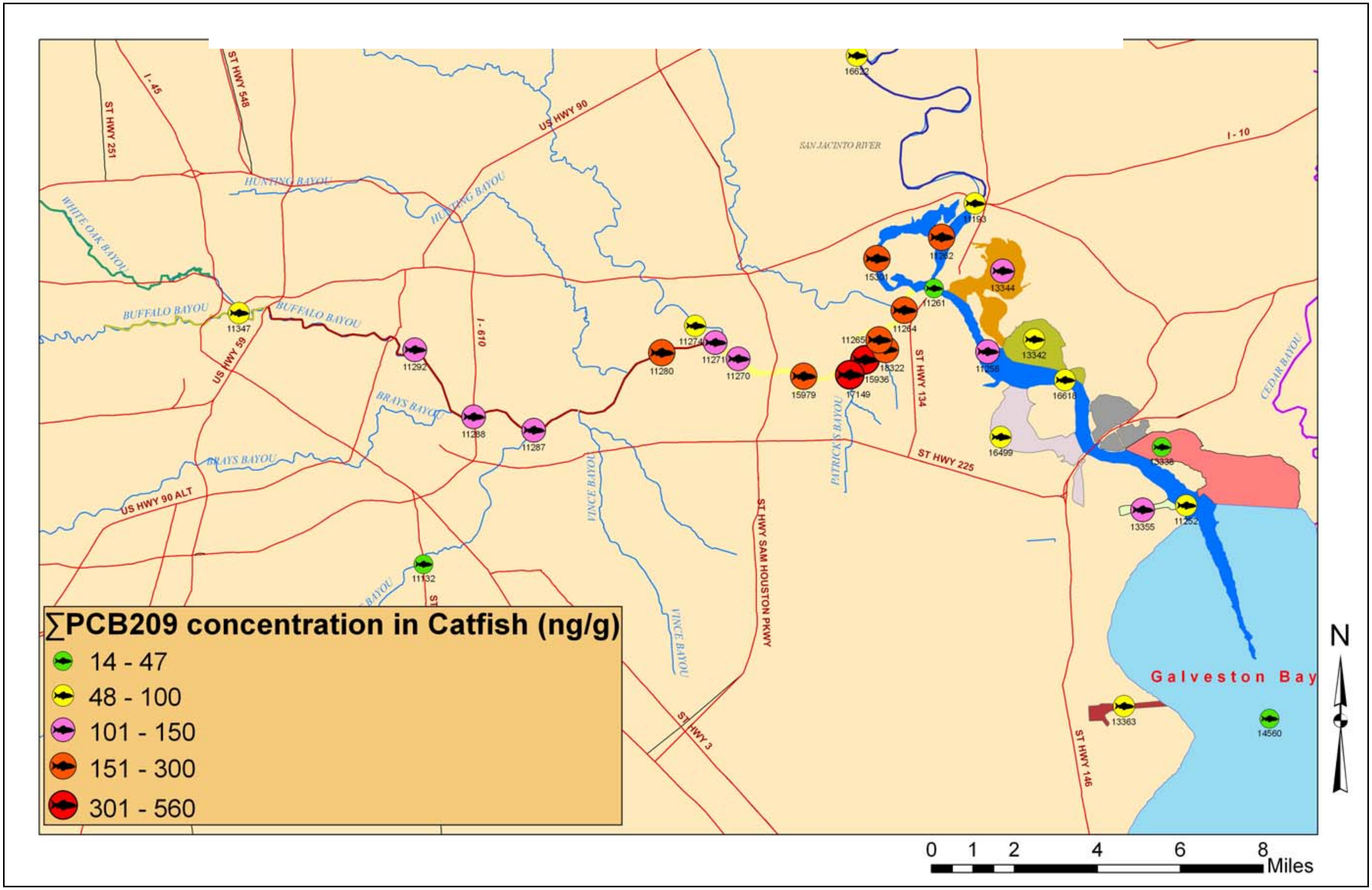


Figure 4.6a Total PCB concentrations in Catfish calculated as sum of 209 congeners

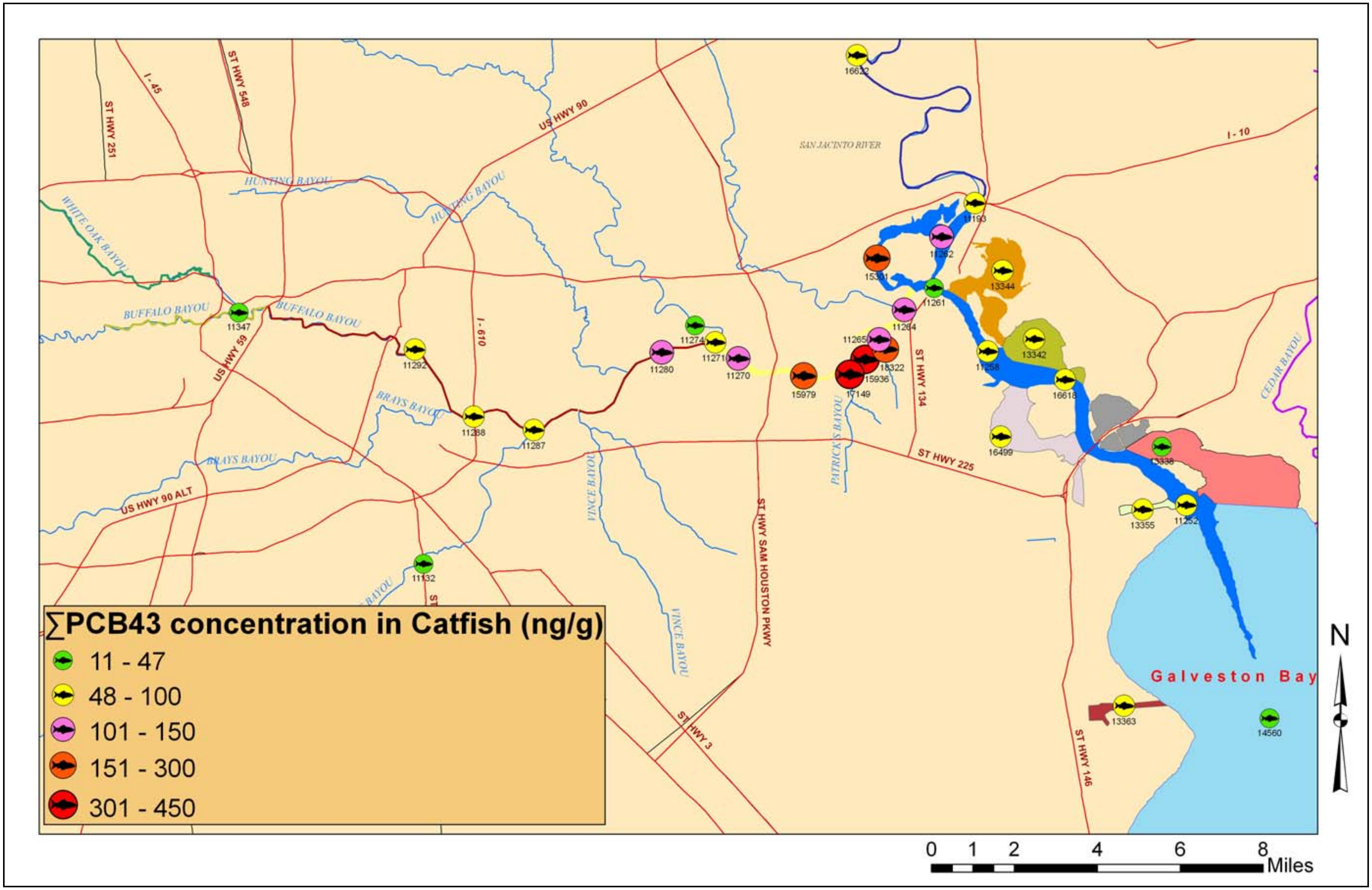


Figure 4.6b Total PCB concentrations in Catfish calculated the sum of 43 congeners

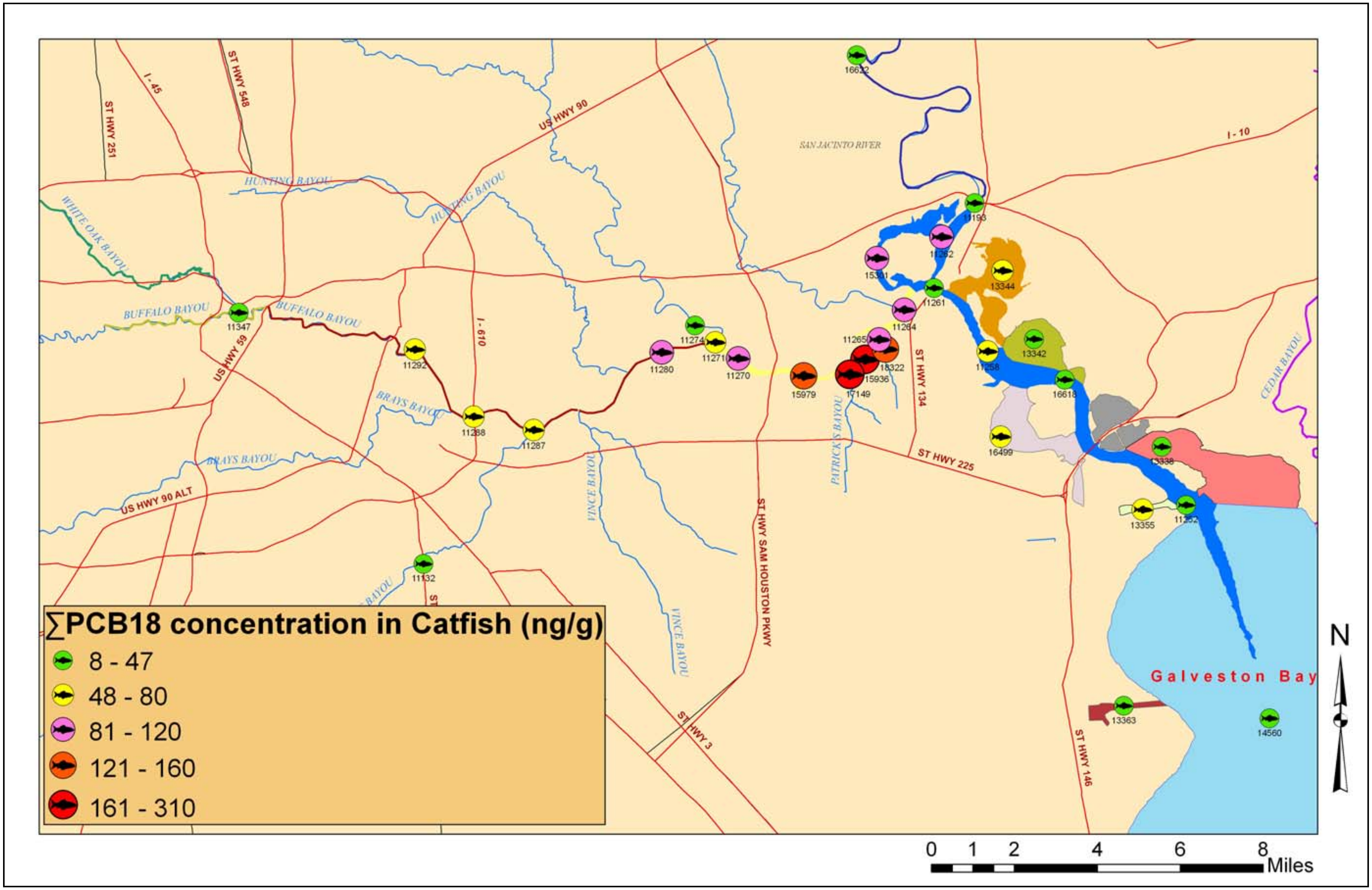


Figure 4.6c Total PCB concentrations in Catfish calculated as sum of 18 congeners

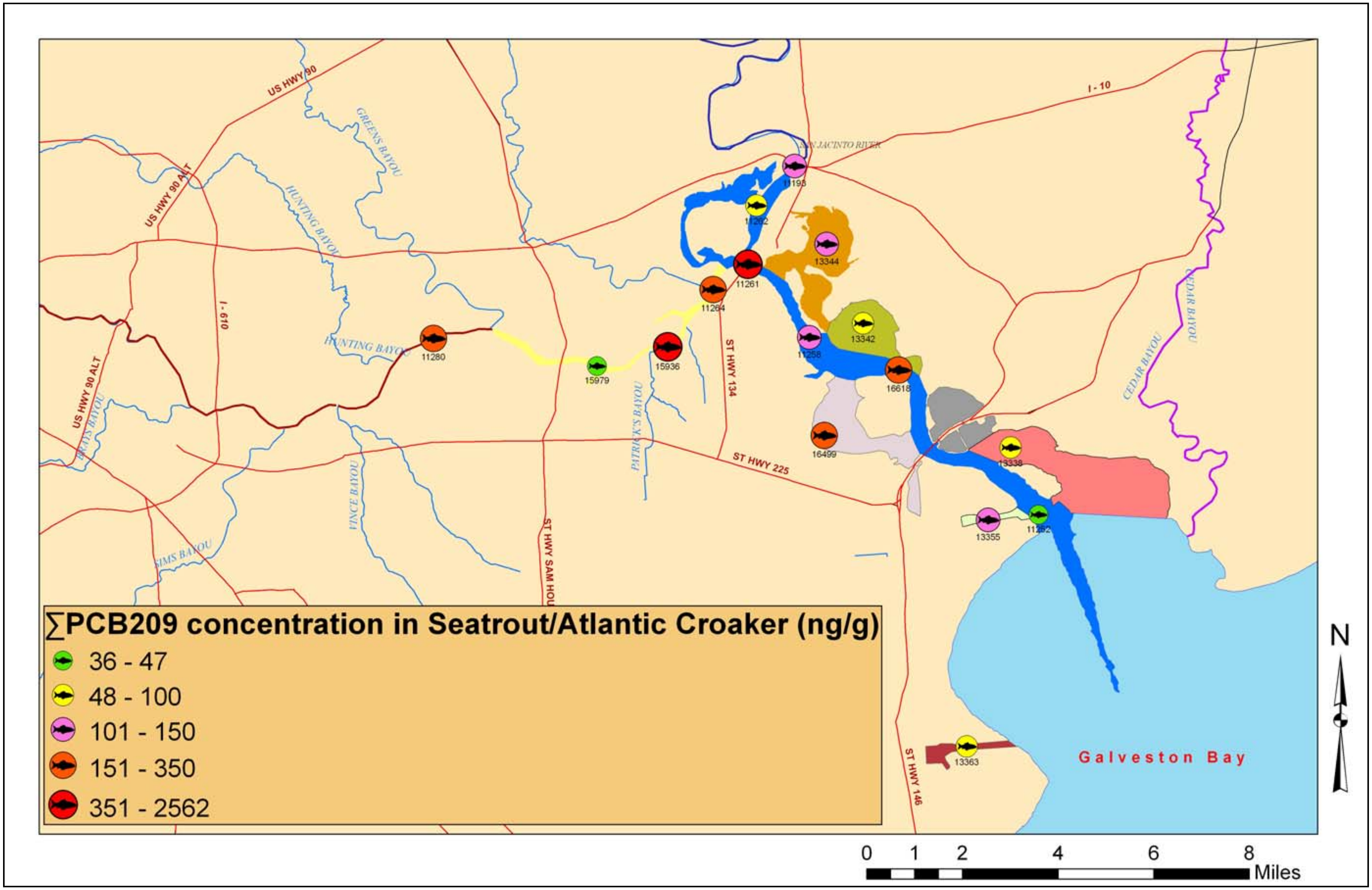


Figure 4.7a Total PCB concentrations in Seatrout/Atlantic croaker calculated as sum of 209 congeners

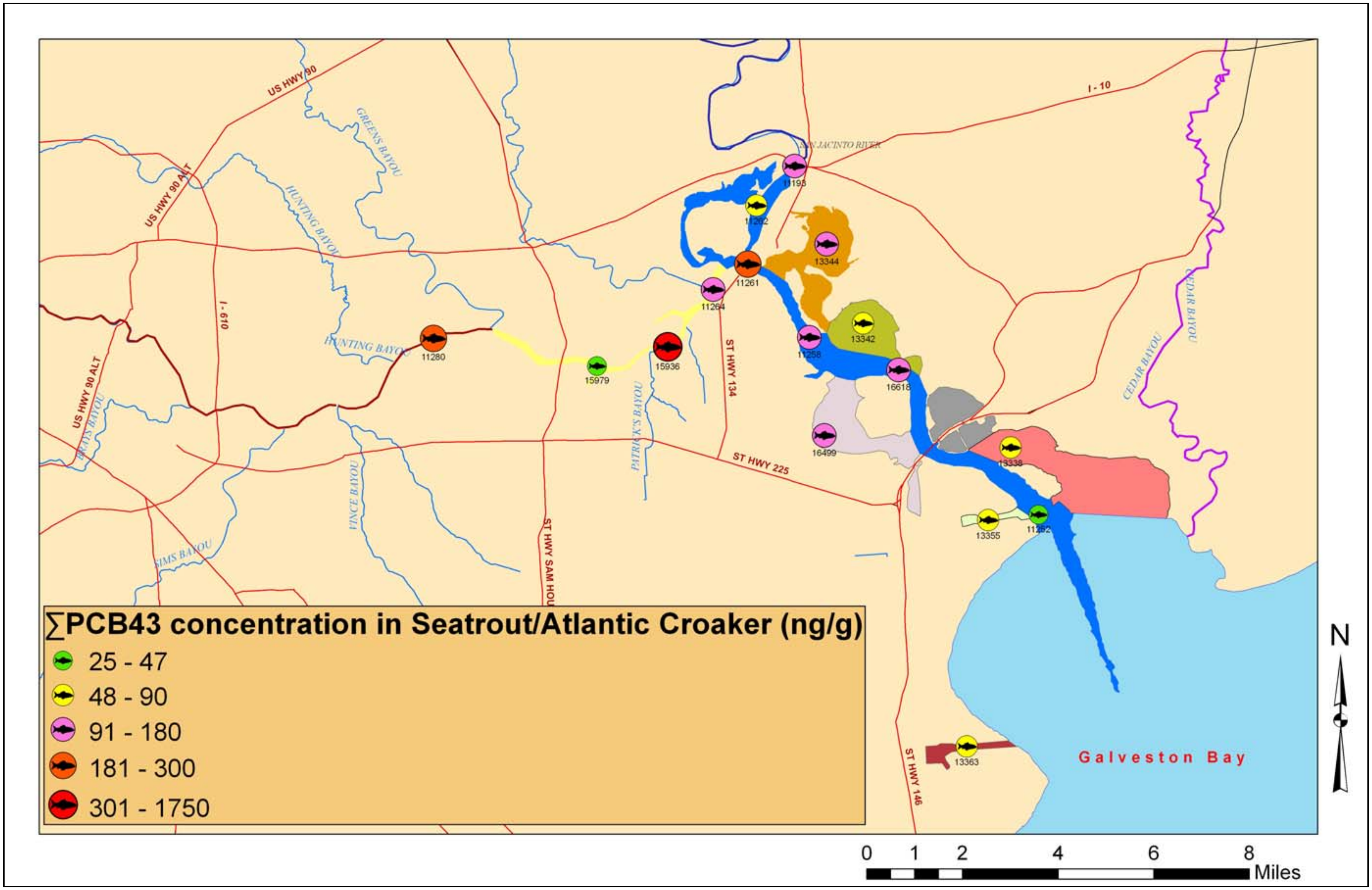


Figure 4.7b Total PCB concentrations in Seatrout/Atlantic croaker calculated as sum of 43 congeners

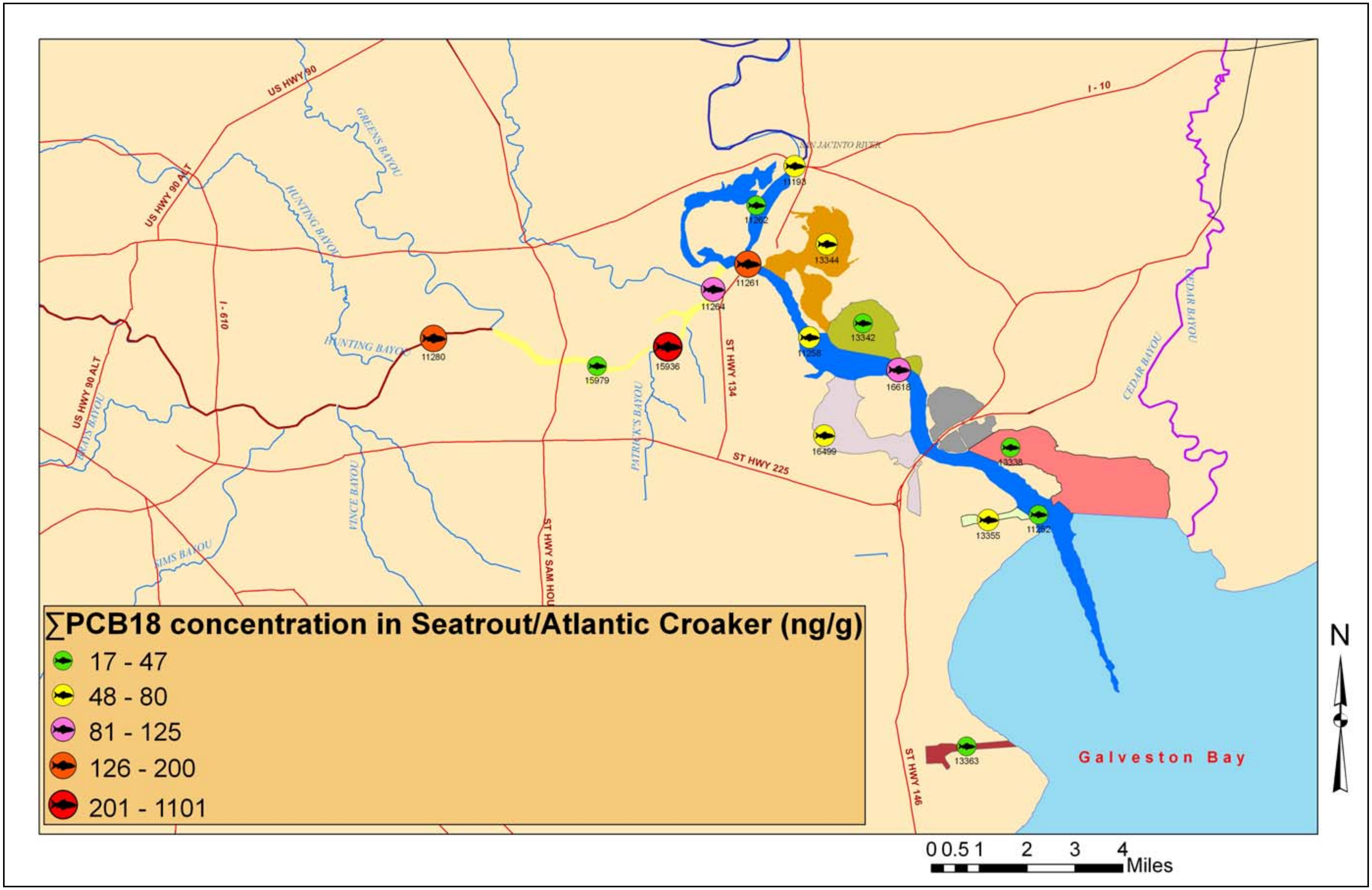


Figure 4.7c Total PCB concentrations in Seatrout/Atlantic croaker calculated as sum of 18 congeners

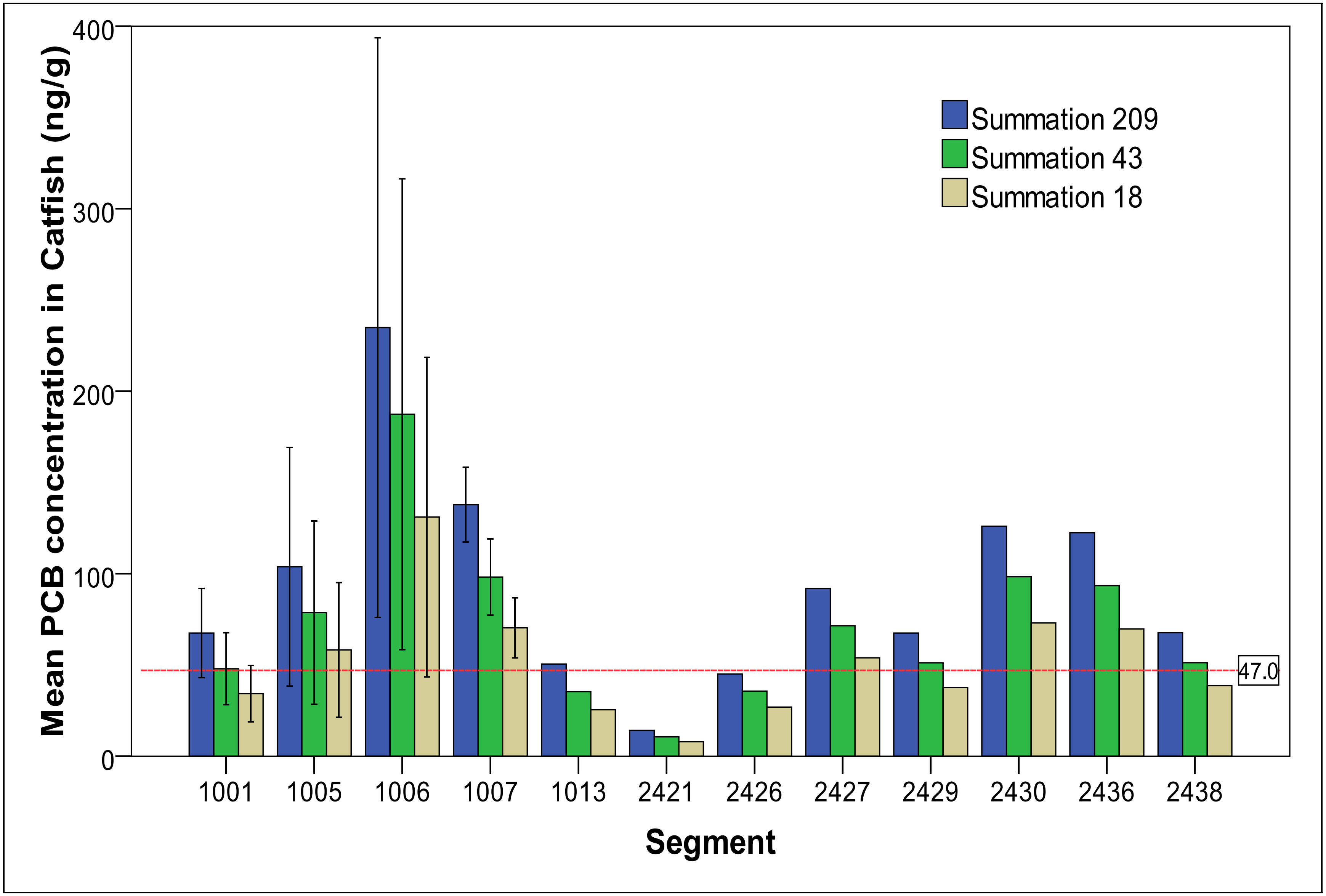


Figure 4.8a Comparison of catfish PCB concentrations by segment

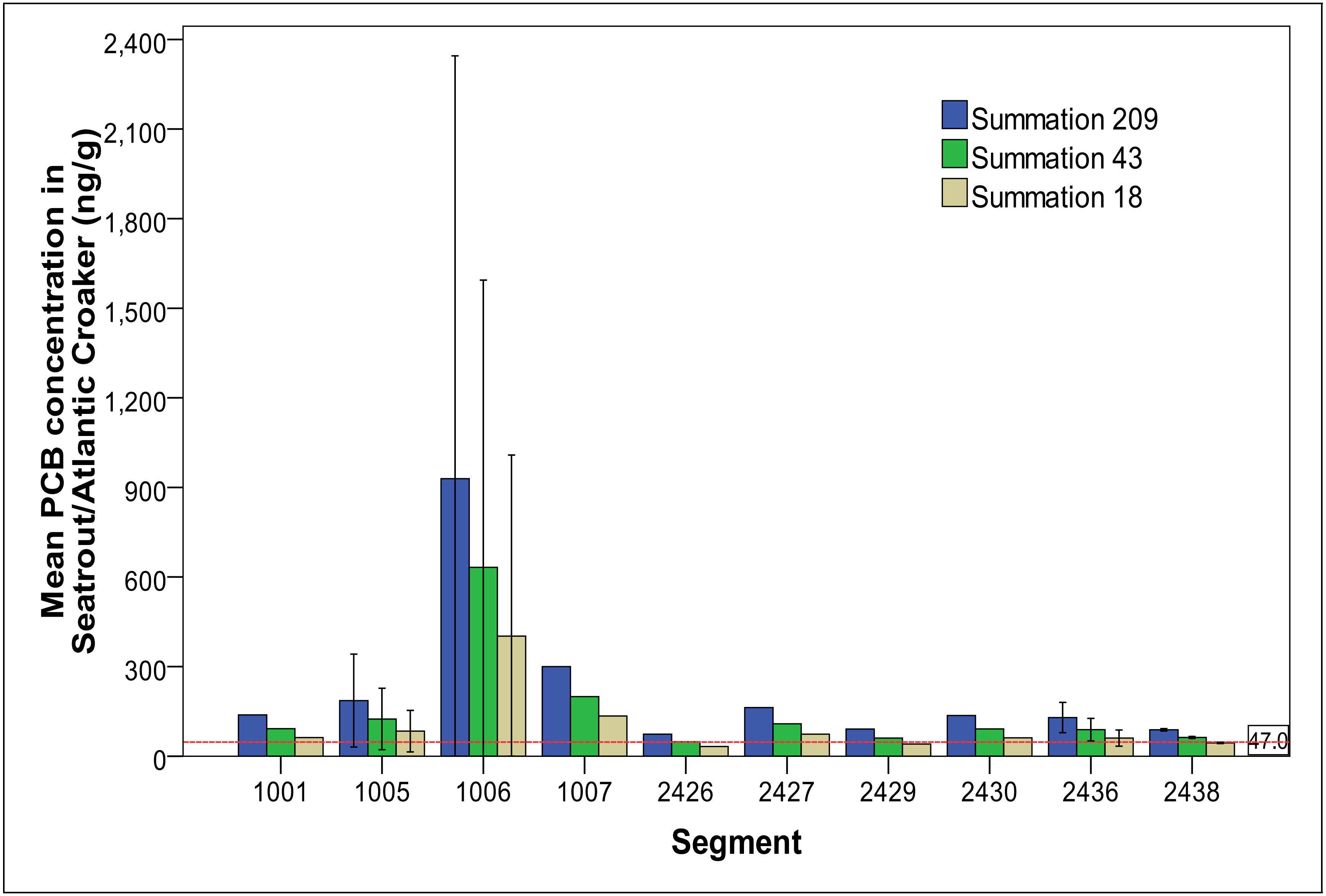


Figure 4.8b Comparison of seatrout/atlantic croaker PCB concentrations by segment

Figure 4.8a compares the PCB concentrations in Catfish by segment based on summation of the three congener approaches. The figure also shows the segments that exceed the standard of 47 ng/g. The use of 18 congeners showed that all segments except 1001, 1013, 2421, 2426, 2429, and 2438 exceeded the standard. All segments except 1013, 2421, and 2426 exceeded the standard in the case of ∑43 congener approach, while only segment 2421 and 2426 did not exceed the standard in the case of the 209 summation approach. The highest concentrations were observed upstream of the HSC and the concentrations decreased as one moved towards Galveston Bay. Figure 4.8b compares the PCB concentrations in Seatrout/Atlantic Croaker by segment based on the three congener approaches. The figures also show the segments that exceed the standard of 47 ng/g. All segments except segment 2426 in the case of ∑18 congener approach exceeded the health standard criteria of 47 ng/g. The highest concentrations were observed upstream of the HSC in segments 1006 and 1007. Figure 4.9 compares the PCB concentrations by species (Catfish vs Seatrout/Atlantic Croaker) and by segment for ∑43 congener approach. It can be observed that the concentrations in Seatrout/Atlantic Croaker were significantly higher compared to concentrations in Catfish regardless of segment. The health standard exceedances and the concentration ranges were higher in the case of Seatrout/Atlantic Croaker when compared to Catfish.

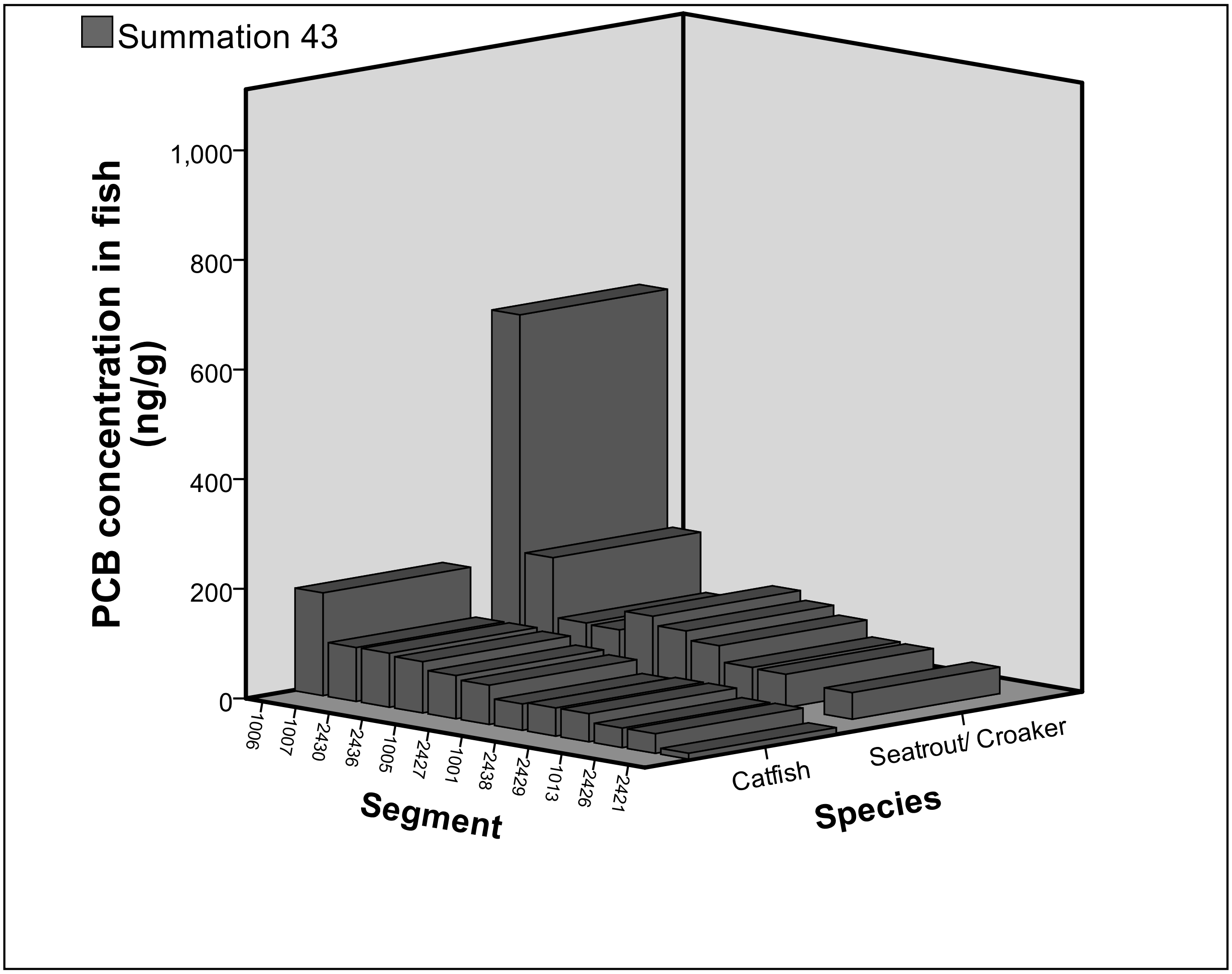


Figure 4.9 Comparison of PCB concentrations by species and segment

4.4 PCB concentrations over time

The following is a comparison of data from the current 2009 data to the 2002-2003 and 2008 studies. Figure 4.10 - 4.13 compares the 2009 PCB concentrations to 2008 concentrations, while Figures 4.14 - 4.16 compare the 2009 PCB concentrations to 2002-2003 concentrations. Figure 4.10 compares PCB water concentrations in stations sampled both in 2009 and 2008 using summation of 43 congeners, while Figure 4.14 compares PCB water concentrations in stations sampled both in 2009 and 2002-2003. A comparison of PCB concentrations in the two timeframes (2009 and 2008) indicates a possible increase in PCB concentrations, i.e., the PCB concentrations in 2009 are similar or higher than PCB concentrations in 2008 for most stations (Figure 4.10). However a comparison of PCB concentrations in the two timeframes (2008 and 2002-2003) had indicated a decrease in PCB concentrations. So it seems that the PCB concentrations in water have increased and gone back to 2002-2003 PCB concentrations; this can be observed from Figure 4.14, which indicated no trend in the 2009 and 2002-2003 PCB concentration comparisons. Table 4.9 compares the percentage stations that exceeded the WQS in 2009, 2008 and in 2002-2003. The percentage of stations that exceeded the WQS was similar in all timeframes regardless of the PCB summation approach (e.g. 58%, 41%, and 38% in 2009, 2008 and 2002-2003, respectively using ∑43 congeners).

Figure 4.11 compares PCB sediment concentrations in stations sampled both in 2009 and 2008. The comparison of PCB concentrations in the two timeframes indicates possible increase in sediment PCB concentrations, i.e., the PCB concentrations in 2009 are higher than the PCB concentrations in 2008, in particular stations downstream of SJR. However a comparison of PCB concentrations in the two timeframes (2008 and 2002-2003) had indicated a decrease in sediment PCB concentrations. So it seems that similar to the water observations, the sediment PCB concentrations have increased and gone back to 2002-2003 PCB concentrations as can be observed from Figure 4.15, which indicates an increase in some stations and a decrease in some.

Figure 4.12 compares catfish PCB concentrations in stations sampled both in 2009 and 2008, while Figure 4.16 compares catfish PCB concentrations in stations sampled both in 2009 and 2002-2003. The comparison of 2009 catfish PCB concentrations to 2008 and 2002-2003 concentrations indicated no trend, i.e., an increase in some stations and a decrease in some. Table 4.10 compares the percentage stations that exceeded the Health Assessment Comparison Value in 2009, 2008 and in 2002-2003. It was found that the percentage stations that exceeded the Health Assessment Comparison Value were similar in all timeframes regardless of the PCB summation approach (80%, 73%, and 80% in 2009, 2008 and 2002-2003, respectively using ∑43 congeners). Figure 4.13 compares seatrout/croaker PCB concentrations in stations sampled both in 2009 and 2008. The comparison of 2009 seatrout/croaker PCB concentrations to 2008 concentrations also indicated no trend. The results from the 2009 tissue concentrations observed in Seatrout/Atlantic Croaker could not be compared to 2002-2003 since the species was not caught during 2002-2003 sampling. The percentage stations that exceeded the Health Assessment Comparison Value were similar in both timeframes regardless of the PCB summation approach (89% and 84% in 2009 and 2008, respectively using ∑43 congeners). The percentage exceedance with Seatrout/Atlantic Croaker was slightly higher than with Catfish.

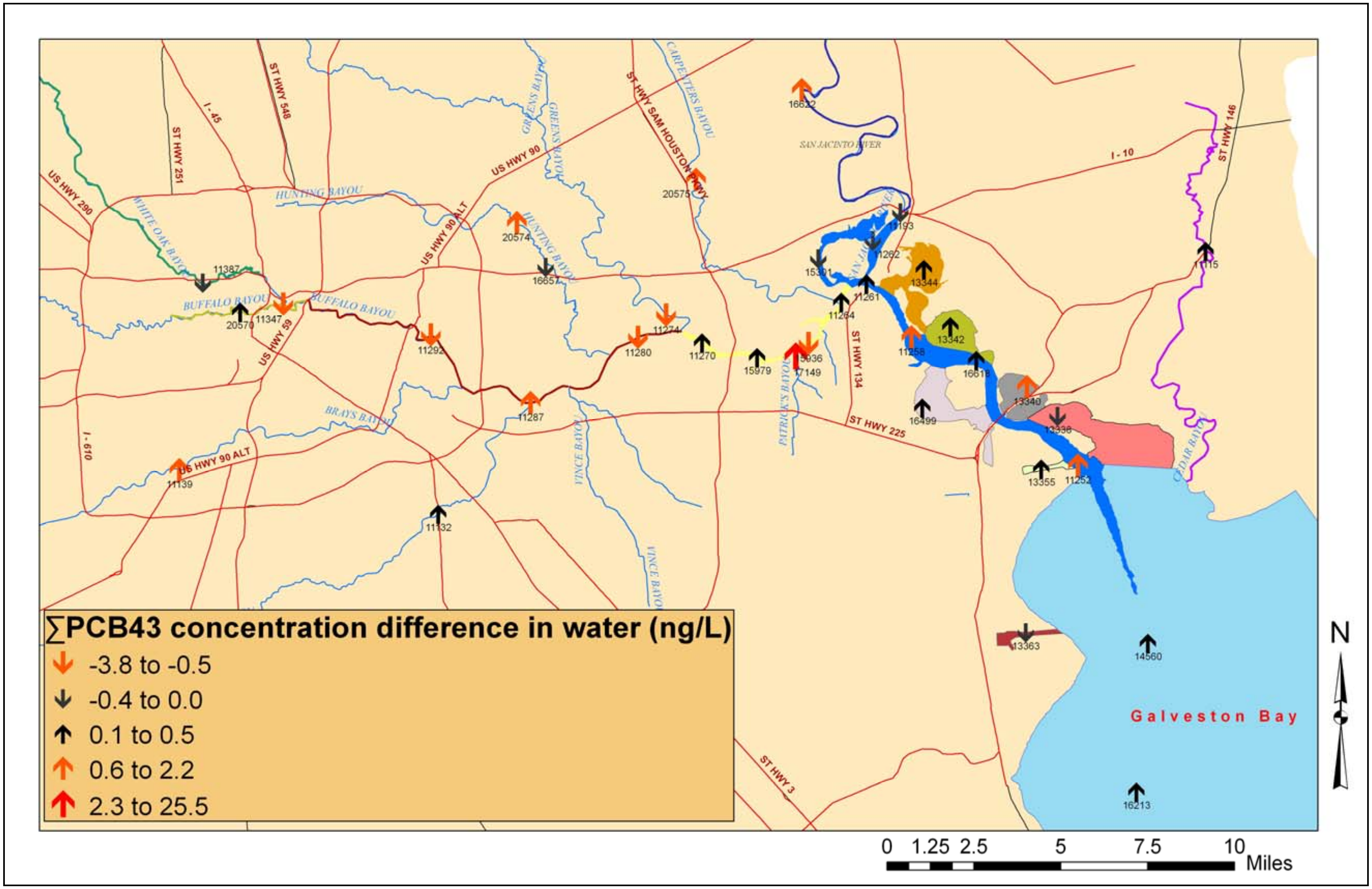
Table 4.10 Comparison of water/tissue quality standard exceedances by media, sample event and congener summation approach

Media	∑PCB =	2009 Sampling			2008 Sampling			2002-2003 Sampling		
		Stations sampled	Stations that exceed standard	Station exceedance (%)	Stations sampled	Stations that exceed standard	Station exceedance (%)	Stations sampled	Stations that exceed standard	Station exceedance (%)
Water[a]	∑209 congeners	48	45	94%	37	30	81%	32	25	78%
	∑43 congeners	48	28	58%	37	15	41%	32	12	38%
	∑18 congeners	48	14	29%	37	10	27%	32	6	19%
Catfish[b]	∑209 congeners	30	26	87%	26	22	85%	45	41	91%
	∑43 congeners	30	24	80%	26	19	73%	45	36	80%
	∑18 congeners	30	19	63%	26	16	62%	45	32	71%
Seatrout/Atlantic Croaker[b]	∑209 congeners	18	16	89%	19	17	90%	Not sampled		
	∑43 congeners	18	16	89%	19	16	84%			
	∑18 congeners	18	10	56%	19	15	79%			

* All concentrations based on 1/2 detection limit

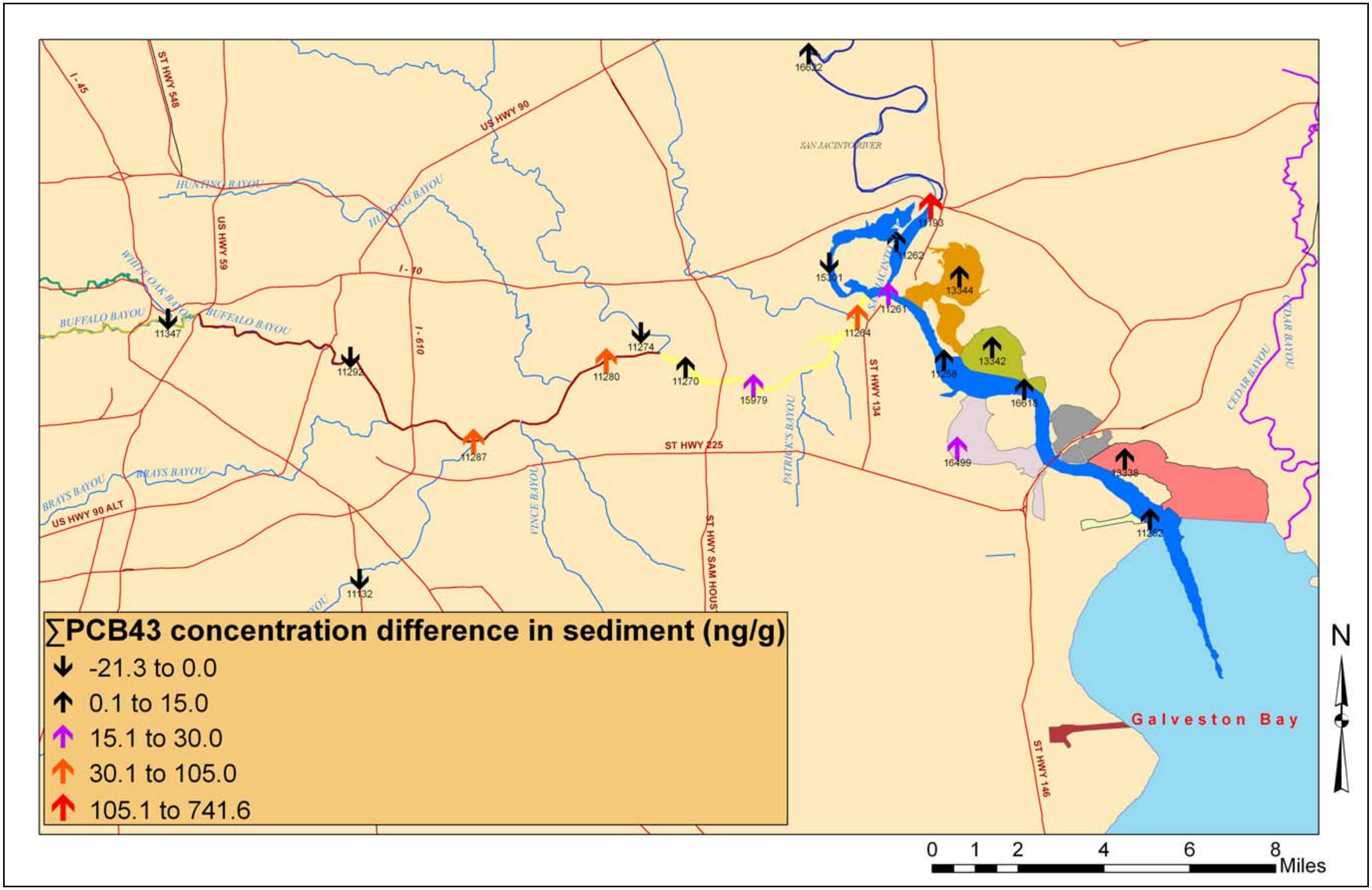
[a] WQS (0.885 ng/L)

[b] DSHS Health Assessment Comparison Value (47 ng/g)



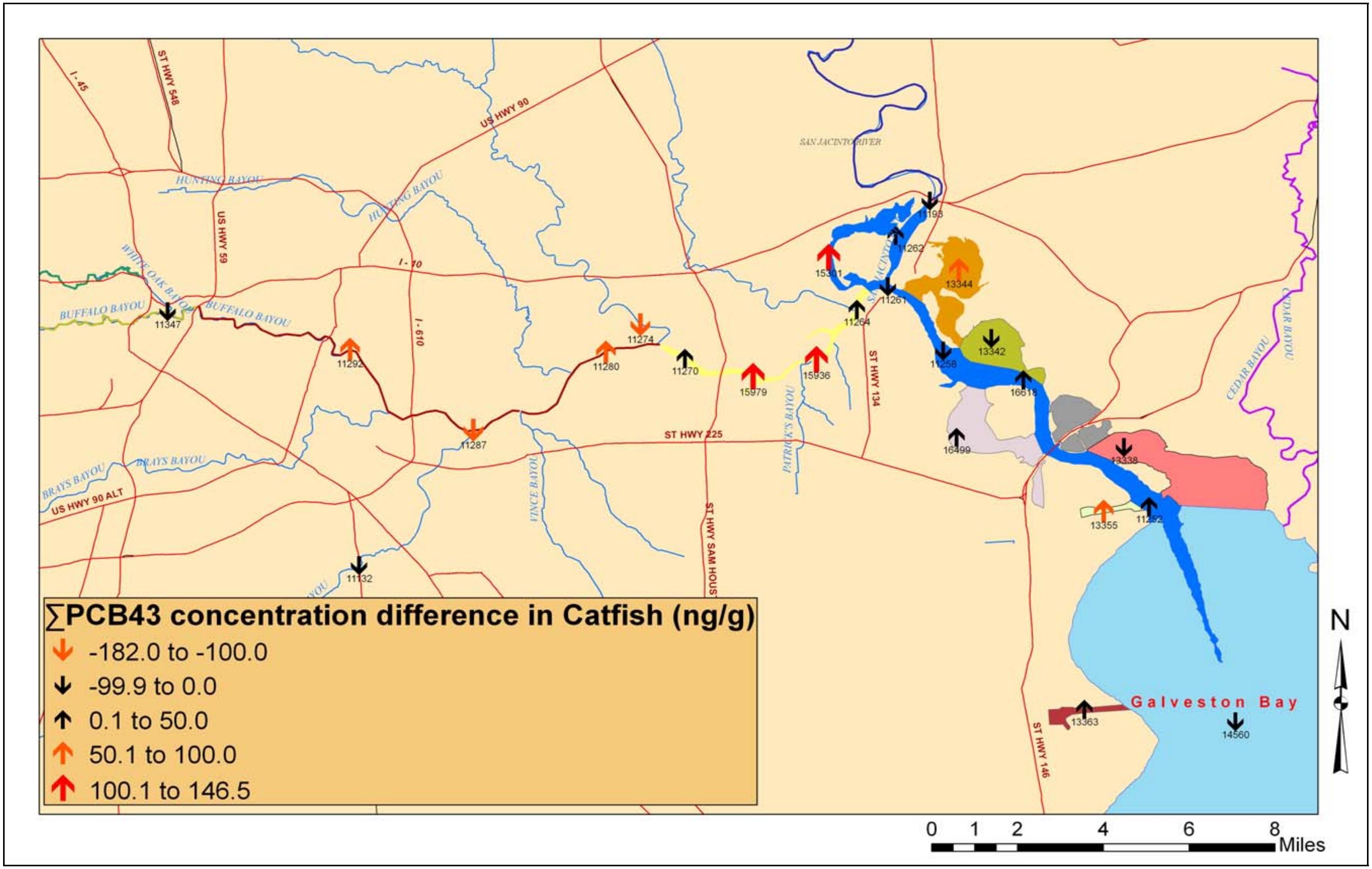
* All concentrations based on 1/2 detection limit for non-detects and ∑43 congeners.

Figure 4.10 Comparison of water PCB concentrations between 2009 and 2008



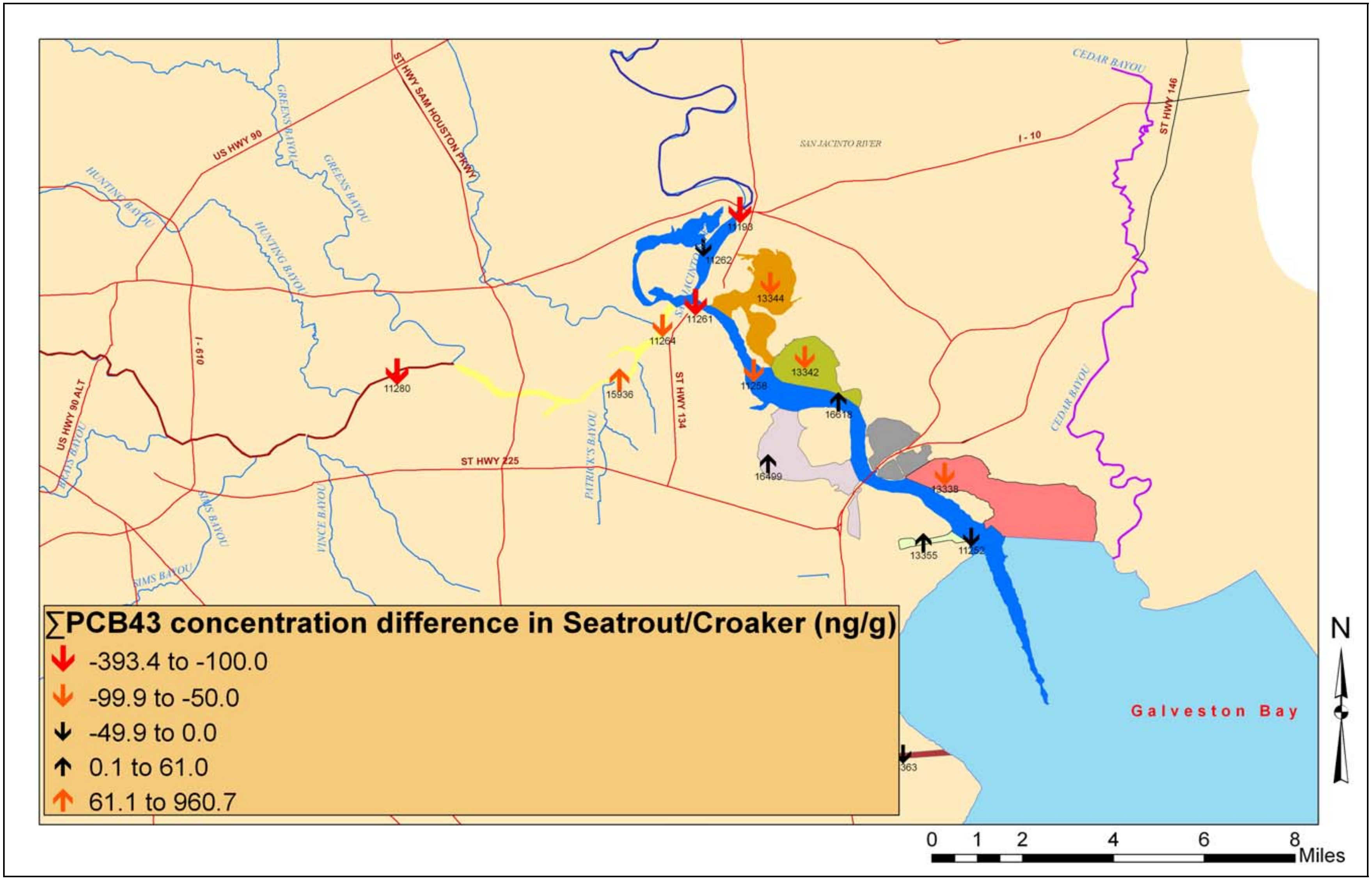
∗ All concentrations based on 1/2 detection for non-detects and ∑43 congeners.

Figure 4.11 Comparison of sediment PCB concentrations between 2009 and 2008



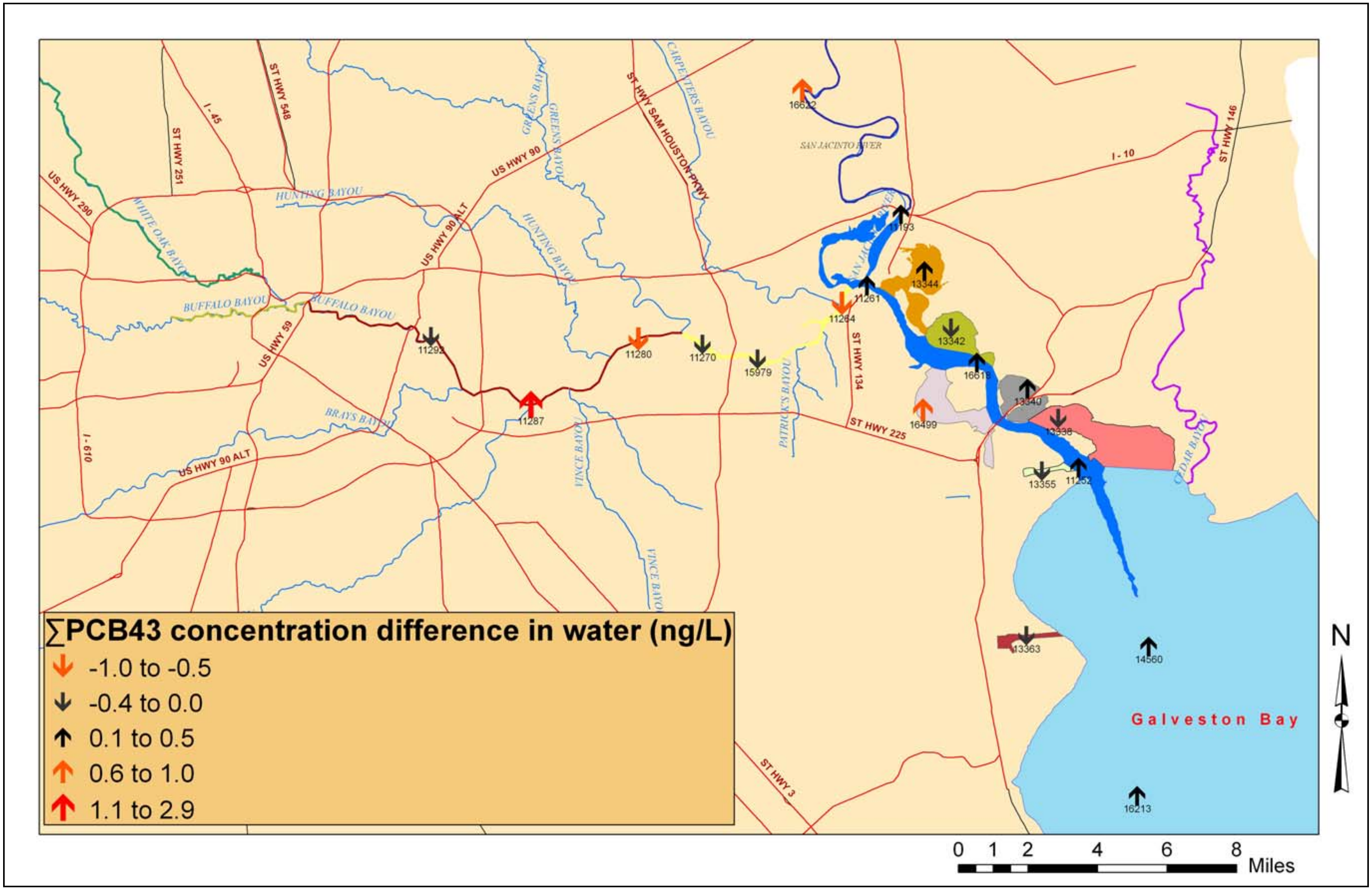
* All concentrations based on 1/2 detection limit for non-detects and ∑43 congeners.

Figure 4.12 Comparison of PCB concentrations in catfish between 2009 and 2008



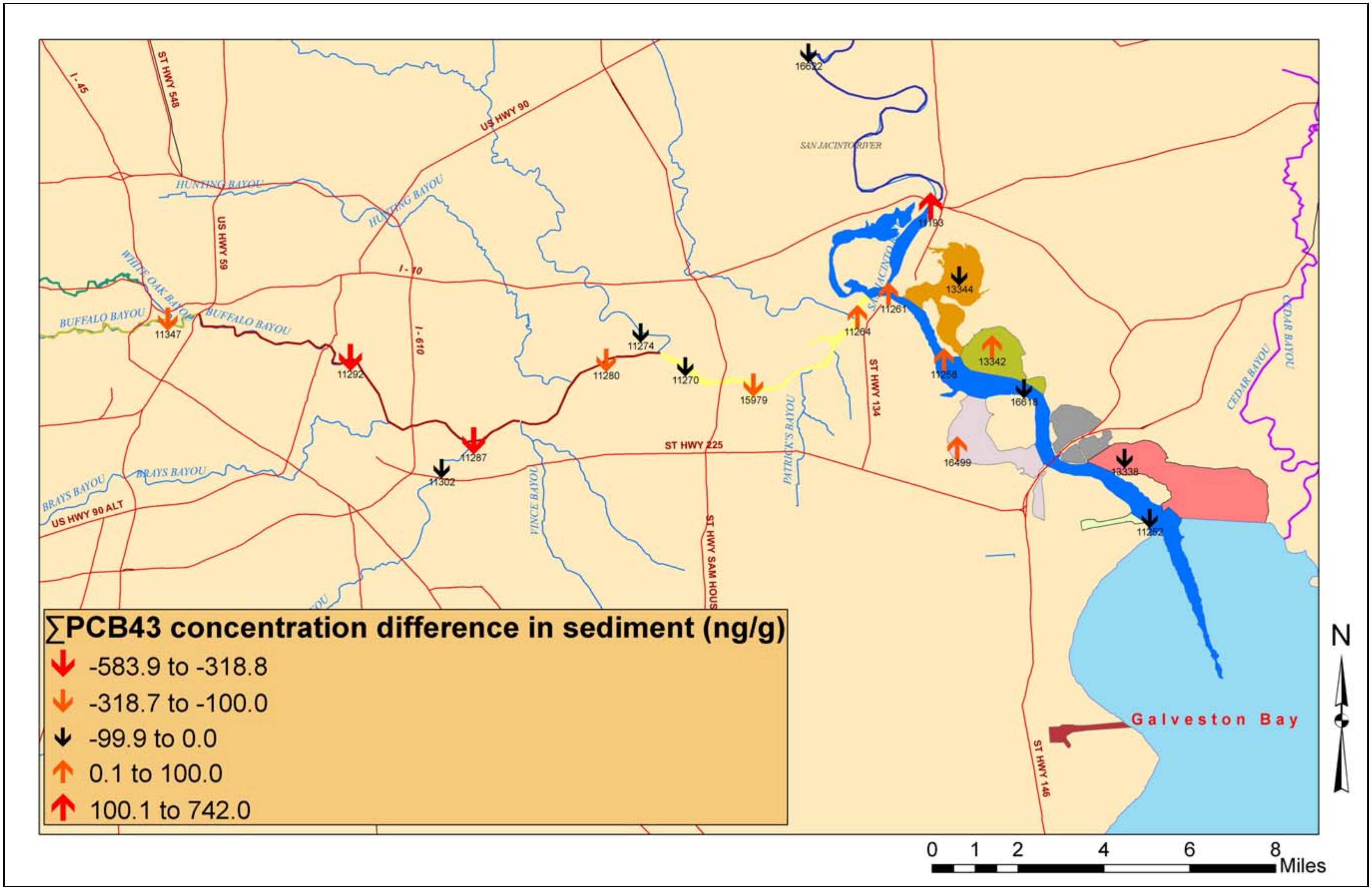
* All concentrations based on 1/2 detection limit for non-detects and ∑43 congeners.

Figure 4.13 Comparison of PCB concentrations in seatrout/croaker between 2009 and 2008



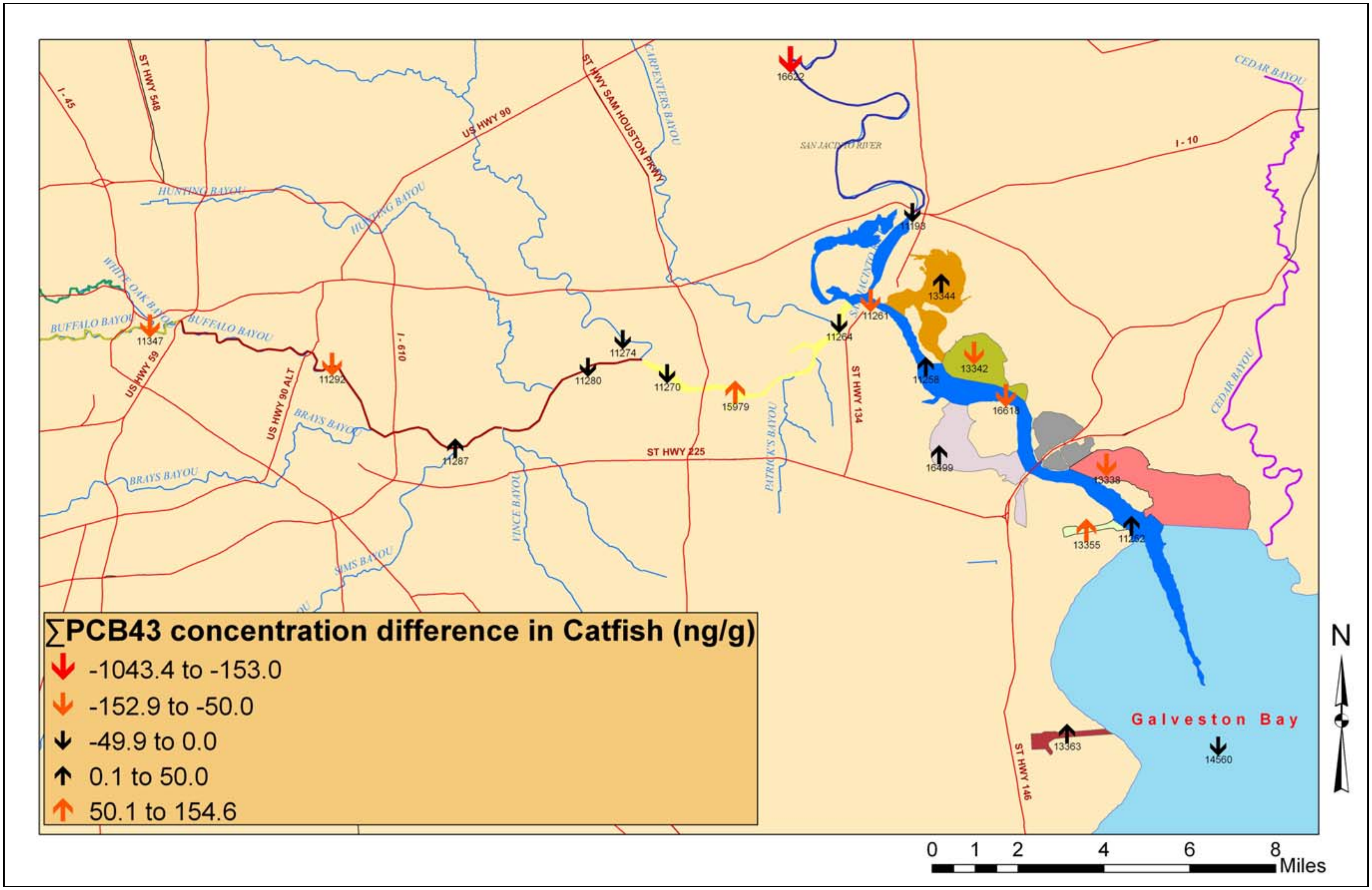
* All concentrations based on 1/2 detection limit for non-detects and ∑43 congeners.

Figure 4.14 Comparison of water PCB concentrations between 2009 and 2002-2003



* All concentrations based on 1/2 detection for non-detects and ∑43 congeners.

Figure 4.15 Comparison of sediment PCB concentrations between 2009 and 2002-2003



* All concentrations based on 1/2 detection limit for non-detects and ∑43 congeners.

Figure 4.16 Comparison of PCB concentrations in catfish between 2009 and 2002-2003

5. PCB SOURCES

5.1 Runoff Sampling and Results

Runoff sampling was undertaken in Spring and Summer of 2009 at the predetermined 12 runoff sites. Sites were chosen that would be fairly accessible[‡] during a rain event and that are part of a tributary that has sizeable flows going into the HSC. Due to the higher frequency of tributaries in the HSC upstream of the SJR-HSC confluence, this Upper HSC region is where nearly all of the samples sites were chosen. Additionally, each chosen site had been sampled in the summer of 2008 and 2009 during dry weather flows.

The sampling procedure was altered from what is normally done at a dry weather high volume sampling event. When rains looked imminent or had already begun, a team was sent to the location to personally examine the flow conditions and decide with the help of the runoff sampling coordinator if the site should definitely be sampled. Little rise in river stage, too light of a rain intensity, trending towards low total rain accumulation (goal of at least 0.25" sought), clear evidence that significant rain had already impacted the site, and safety were all reasons for cancelling the sampling event. If, however, sampling was recommended, the following procedural differences were enacted which are distinct from dry weather sampling. Previous experience with runoff sampling for PCDD/Fs indicated that the glass fiber filters (GFFs) at a size of 1-µm would almost certainly be inundated with too many solids due to the rain. Thus, pre-cleaned GFFs of 40-µm nominal pore size diameter (same cleaning and proofing procedure as 1-µm GFFs) were placed in the high volume sampler immediately prior to the 1-µm GFF stage. The high volume samplers themselves have proven at times to have insufficient pump

[‡] Two sites along Patricks Bayou (17157 Patrick Bayou at Shell Outfall 001 and 17149 Patrick Bayou Upstream of Tidal Road (OxyVinyls)) were not truly accessible since private property would have to be accessed during a rain event.

power to generate high sampling flow rates even in dry weather. It was suspected that the wet weather might be too much for the samplers, and so a Grundfos Redi-Flo submersible pump was used in the flowing bayou to pump water into a cleaned stainless steel canister. The high volume sampler pumped water from that container into the progressively size decreasing (40 μm → 1 μm) GFFs and XAD2 resin. One concern with using the submersible pump as a "booster" pump in this way was that the stainless steel canister might allow the solids that were pumped to settle out and avoid collection. While this possibility could not be completely eliminated, the booster pumps were run at a flow that was many times higher than the high volume sampler with the thought that this would generate a constant turbulence within the can to keep most of the solids from being lost from the sampler. Ambient water (non-high volume) samples analyzed for TOC, TSS, and DOC were obtained directly from the booster pump outlet.

Up to two sampling events were allowed for each site depending on the frequency of rain. The goal was to obtain more than one intensity rain event at each site to judge the difference in response that may occur from different duration and size storms. Nine samples were collected during that time period. Seven sites were sampled once (Table 5.1), and one site was sampled twice (11139 Brays Bayou at S. Main). Distributionally, the results were fairly normal with quantile-quantile plots that followed a linear trend of normality for the dissolved, suspended, and total water phases ($\sum$209 congeners totaling used). Also, Shapiro-Wilks W tests all failed to reject the null hypothesis of normality ($p > 0.2$ for all cases). This result is interesting in and of itself because rarely if ever in the HSC region has PCDD/F or PCB concentrations in any media tested since 2002 been anything close to log-normal, let alone normal. Normality is further confirmed in noticing that coefficients of variation (CVs) are well below 1.1-1.2, what is normally considered a transition between normal and non-normal datasets. Variation is generally fairly low as indicated by CVs that are low enough to be considered normal and small (<0.72), but there is a slight distinction in variation between the different water sample components. Standard deviations for the components go as Suspended (>40 μm) (1.47 ng/L) > Suspended (1-40 μm) (0.95 ng/L) > Dissolved (<1 μm) (0.83 ng/L) compared to 2.92 ng/L standard deviation of the total water (dissolved and suspended) concentrations. Differences in suspended and dissolved variations likely relate to the variable amount of sediment that is transported to the tributary, which is a function of both site characteristics and the rain event sampled.

Figures 5.1a, b, and c present the spatial distribution of concentrations as congener summations of all 209, the McFarland and Clark 43, and the NOAA 18, respectively. The Cedar Bayou station 11115 is below the 0.885 ng/L screening value according to all measures, and one sampling event at 11139 Brays Bayou (9/9/2009) shows the sum of 43 and 18 congeners below 0.885 ng/L though not the total. All other stations and rain events were well above the screening level (minimum concentration of 1.417 ng/L for NOAA 18 congener set at 16657, 1.6 times greater), and there is a obvious break in concentrations for the highest two stations (20570 Buffalo Bayou and 20574 Hunting Bayou) that is around 9.4 ng/L (∑209) compared with 5.761 ng/L at 11387 White Oak Bayou, a separation of 3.64 ng/L (39% decrease). Spatially, there does not appear to be any obvious pattern to the concentrations obtained, but it is seen that these concentrations are significant and quite different from the ambient concentrations. They are significant when compared with dry weather concentrations taken all over the HSC region. For example, the average runoff sample concentration of 5.00 ng/L (∑209) is higher than all but three of the thirty-seven stations sampled in 2008 and six of the forty eight stations sampled in 2009.

Table 5.1 Runoff and Effluent Summed Congener results in ng/L. Dates given with station 11139 are sample dates

Station	Latitude	Longitude	Type	Location Name	∑PCB18 concentration (ng/L)	∑PCB43 concentration (ng/L)	∑PCB209 concentration (ng/L)
11132	29.6739	-95.2890	Runoff	Sims Bayou at Telephone Road	1.806	2.515	4.479
11139 (7/23/09)	29.6973	-95.4120	Runoff	Brays Bayou at S. Main	1.764	2.498	4.629
11387	29.7750	-95.3969	Runoff	White Oak Bayou at Heights Blvd	2.248	2.920	5.761
16657	29.7755	-95.2325	Runoff	Unnamed Tributary of Hunting Bayou Immediately Upstream of John Ralston Rd	1.417	1.922	4.081
20570	29.7623	-95.3796	Runoff	Buffalo Bayou Just Downstream of Shepherd	3.494	4.827	9.420
20574	29.7949	-95.2453	Runoff	Hunting Bayou at Wallisville Rd	2.760	5.894	9.330
20575	29.8099	-95.1587	Runoff	Carpenters Bayou at Wallisville Rd	1.607	2.117	4.642
11115	29.7700	-94.9161	Runoff	Cedar Bayou Tidal at SH Highway 146	0.260	0.311	0.814
11139 (9/9/09)	29.6973	-95.4120	Runoff	Brays Bayou at S. Main	0.644	0.824	1.781
0000544-000	29.7193	-95.0832	Effluent	Ineos Polyethylene North America	0.186	0.258	0.522
0001984-000	29.7259	-95.0924	Effluent	Intercontinental Terminals Co.	2.602	3.214	7.863
0010495-009	29.6469	-95.3388	Effluent	Chocolate Bayou WWTP	0.213	0.299	0.676
00402-000	29.7163	-95.1152	Effluent	Shell Oil Company	0.642	0.876	2.049
00458-000	29.7341	-95.0984	Effluent	Rohm & Hass Texas Inc.	0.491	0.667	1.761
00492-000	29.7424	-95.1670	Effluent	Albemarle Corporation	1.199	1.785	3.148
00587-000	29.7013	-95.2521	Effluent	Texas Petrochemicals LP and Kemira	0.599	0.788	1.587

Station	Latitude	Longitude	Type	Location Name	∑PCB18 concentration (ng/L)	∑PCB43 concentration (ng/L)	∑PCB209 concentration (ng/L)
				Water Solutions			
01740-000	29.7234	-95.2199	Effluent	Gulf Coast Waste Disposal Authority	0.756	1.039	2.174
10206-000	29.6139	-95.0216	Effluent	Gulf Coast Waste Disposal Authority	0.282	0.318	0.868
10206-001	29.6494	-95.0221	Effluent	Little Cedar Bayou WWTP	0.315	0.411	0.965
10395-008	29.7924	-95.0596	Effluent	General District Plant	0.261	0.288	0.992
10495-003	29.6286	-95.4071	Effluent	Almeda-Sims WWTP	0.324	0.404	1.012
10495-090	29.7545	-95.2982	Effluent	69th Street WWTP	0.637	0.870	1.847
FWSD 51	29.7924	-95.1596	Effluent	Harris County FWSD NO. 51-WWTP	0.099	0.136	0.368
WQ0000749	29.7636	-95.1685	Effluent	GB Biosciences Corporation	0.218	0.235	0.731
WQ0001429	29.7286	-95.0963	Effluent	Clean Harbors Deer Park WWTP	0.908	1.171	2.615

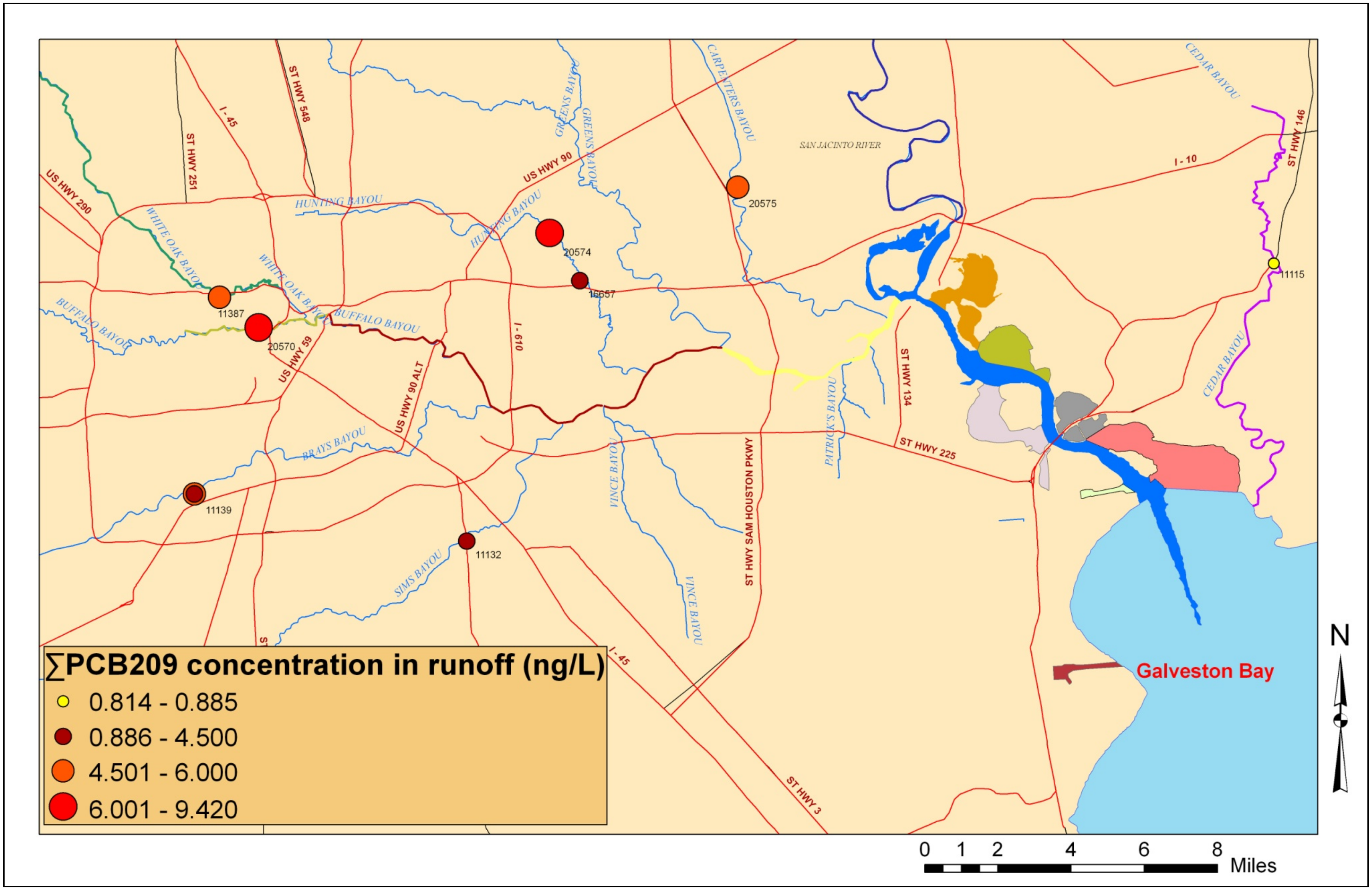


Figure 5.1a Total PCB concentrations in runoff calculated as sum of 209 congeners

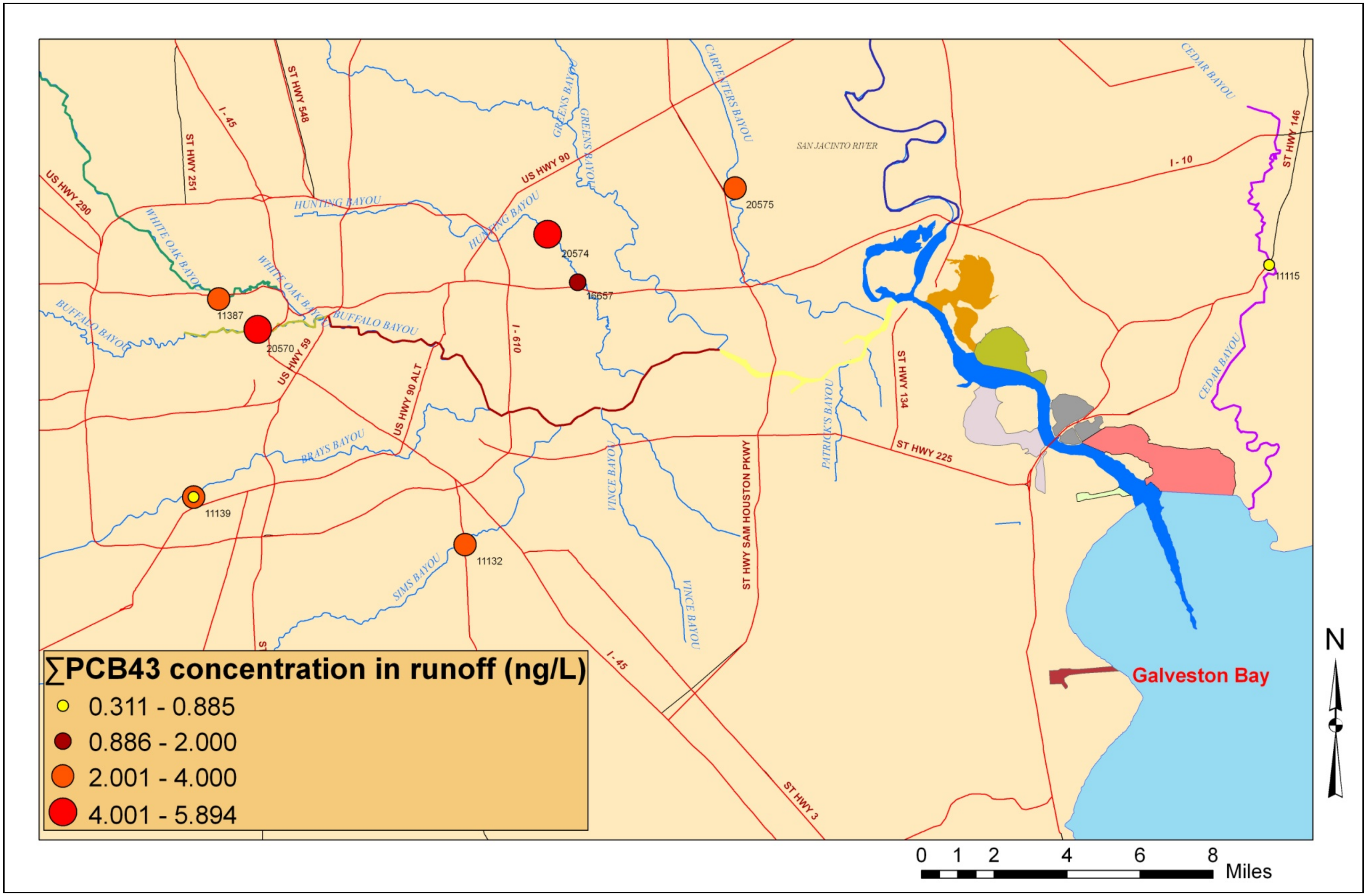


Figure 5.1b Total PCB concentrations in runoff calculated as sum of 43 congeners

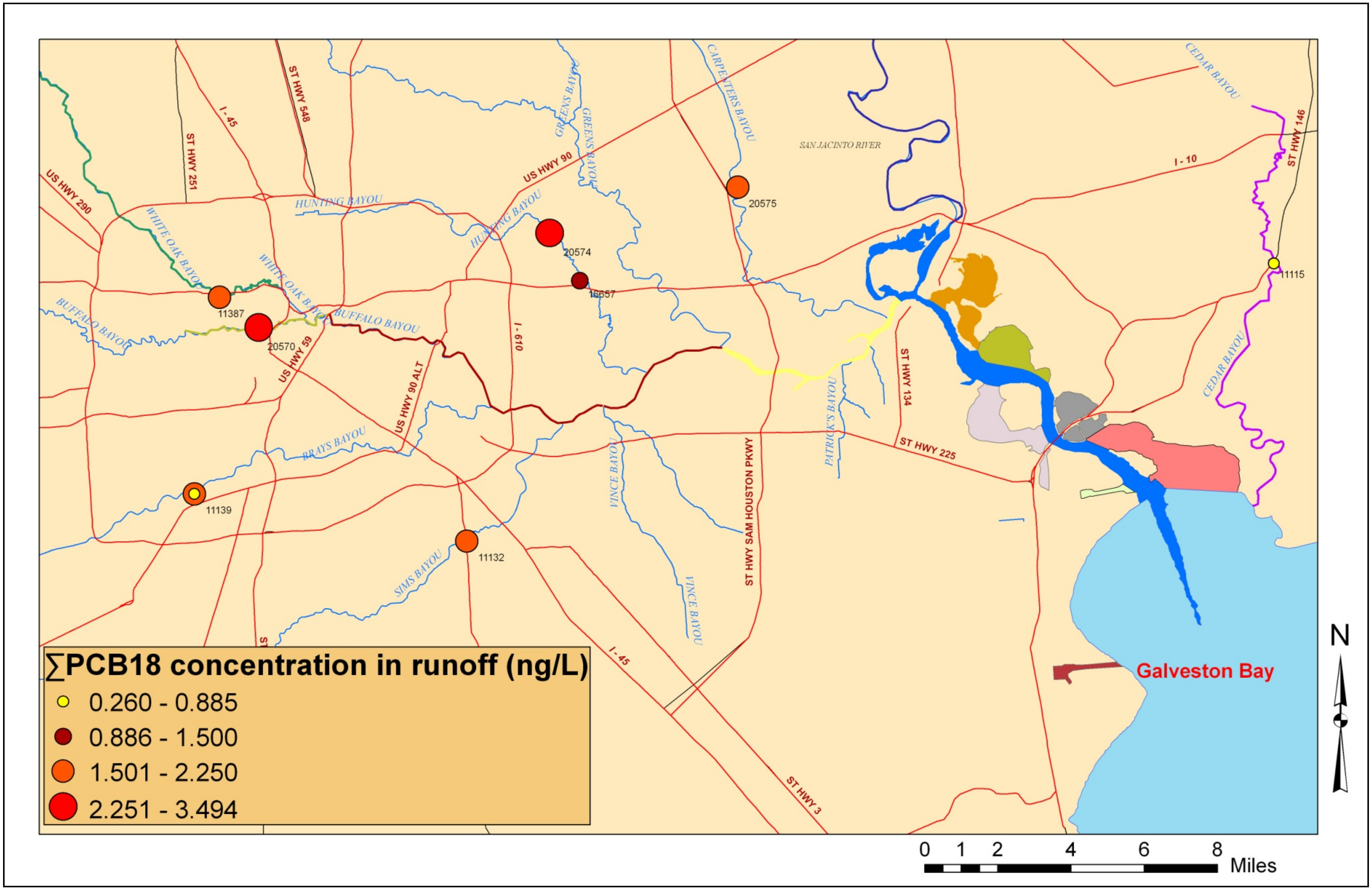


Figure 5.1c Total PCB concentrations in runoff calculated as sum of 18 congeners

5.2 Effluent Sampling and Results

Effluent sampling was conducted in August 2009 using essentially the same method of collection normally used for a dry weather high volume sample. Samples were taken directly from the outfalls as near to the point of deposit into the receiving stream as possible. In most cases, this was directly before a weir that measured the discharge from the outfall. Access was gained to each location by sending a letter of request to each facility detailing the type of sampling being conducted and its purpose. Facilities were given the opportunity of taking a split sample that might be analyzed by another party. When this split sample was collected, it was collected in the same manner as what is normally done for high volume sample duplicate, which is to use a separate and independent high volume pump with its own 1 μm GFF and XAD2 resin. The facility and the outfall within each facility was selected according to the following characteristics: proximity to HSC, proximity to known PCB hot spots in water, sediment, and fish, industry type, the nature of the receiving stream (tributary or ship channel), the known history of upset and spill events, facility longevity, and the amount of discharge compared to receiving waters. A total of twenty-six letters were mailed to the facilities. Five facilities flatly denied access, three facilities gave no response, one facility gave access but legal liability questions prevented the sampling (Calpine Deer Park Energy), one facility gave access but with sampling still pending (Oxy Vinyls Deer Park), and sixteen facilities granted access and were sampled (Table 5.2).

Results of the effluent sampling are 16 samples that are decidedly non-normal ($p < 0.05$, Shapiro-Wilks W) and have a higher variation than what was seen in runoff samples (CVs for all congener summation groups ~1). Concentration maps are given in Figure 5.2a through 5.2c. These results show that there is one sample much higher than the rest of the group, which is at

Intercontinental Terminals Company (ITC). The total water concentration here was 7.86 ng/L (∑209) with the next two closest being at Albemarle (3.15 ng/L) and Clean Harbors Deer Park (2.62 ng/L). Of the lower concentration side of samples, there are actually five out of the total sixteen effluents sampled that are below the 0.885 ng/L surface water quality criterion. The remainder of the samples (8) have an average concentration of 1.55 ng/L. It is also to be noted that only one of the effluent concentration was larger than the mean value for runoff concentrations.

These effluent samples were not designed in such a way to provide a complete spatial representation of all areas in the HSC that receive wastewater. It is seen that the higher concentrations are generally right along the ship channel and in Tucker and Patricks bayous. Even far upstream of the Turning Basin, an area where contamination is generally not considered to be excessive, the 69^{th} St wastewater treatment plant yields a fairly high ∑PCB209 concentration (1.847 ng/L). What is somewhat surprising is that the GB Biosciences effluent is so low (0.731 ng/L) when the ambient dataset shows extremely high sediment PCB concentration and the ambient dataset shows a water concentration of 6.17 ng/L (third highest of 2008) in the vicinity. It is also surprising in light of the fact that chlorination based processes occur here (SIC code 2879 Pesticides & Agricultural Chemicals), but the effluent has such low PCB concentration (lower than several of the municipal WWTPs sampled) compared with other facilities that also use chlorination processes (Albemarle, Clean Harbors, Shell, Rohm & Haas) and have higher PCB effluent concentrations. There is not much difference in facility-to-facility relative concentration spatial profiling between the different congener summation methods as shown in Figure 5.2 except that the region of higher PCB concentration effluents appears to be concentrated around the region of HSC between Greens Bayou and SJR as one moves from 209

→ 43 → 18 congeners. The effluents sampled in this higher concentration region likely remain high in the 18 and 43 congeners within these sub-groupings while the other effluents that are higher outside of the Greens→SJR region have higher concentrations due to a different set of PCB congeners.

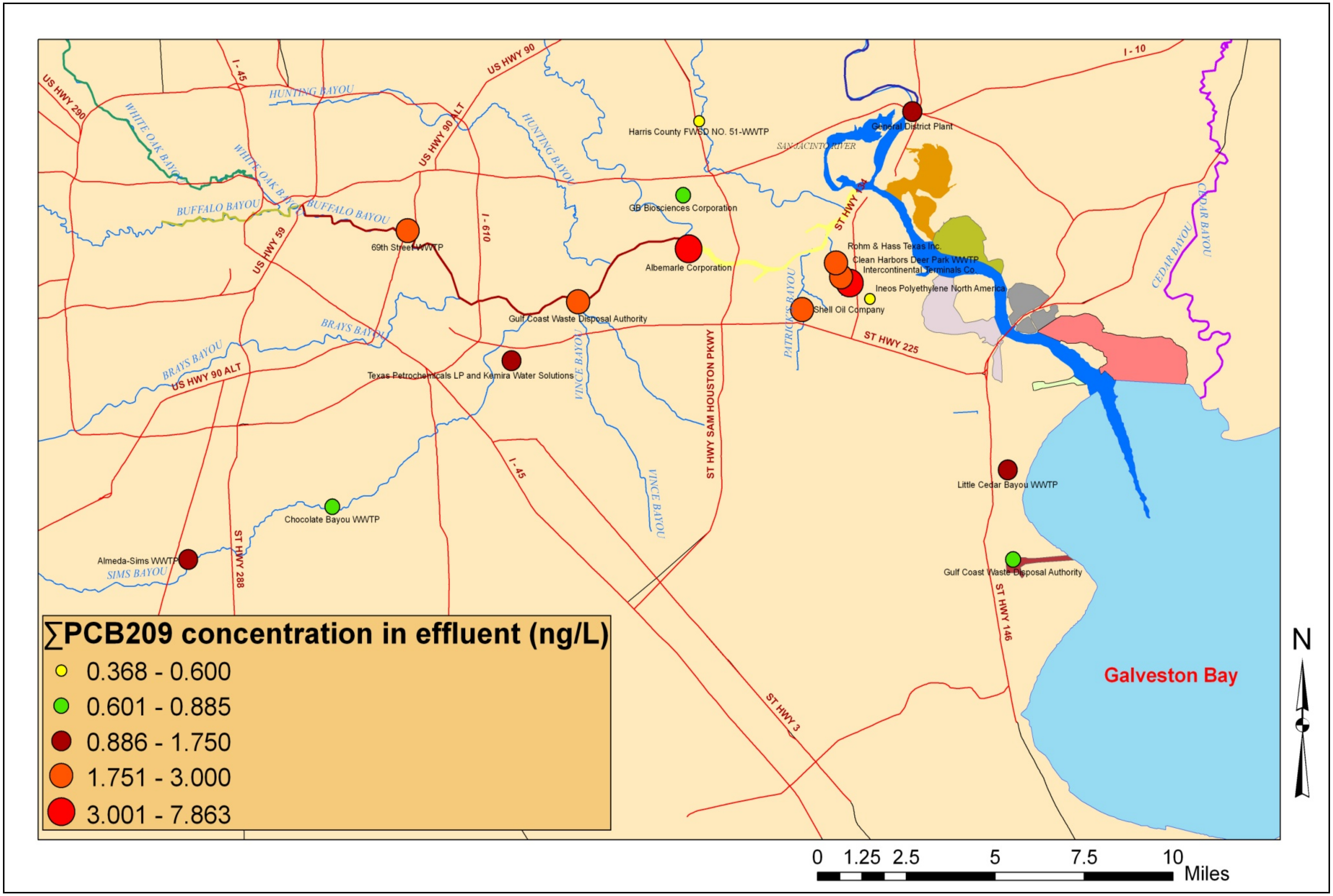


Figure 5.2a Total PCB concentrations in effluent calculated as sum of 209 congeners

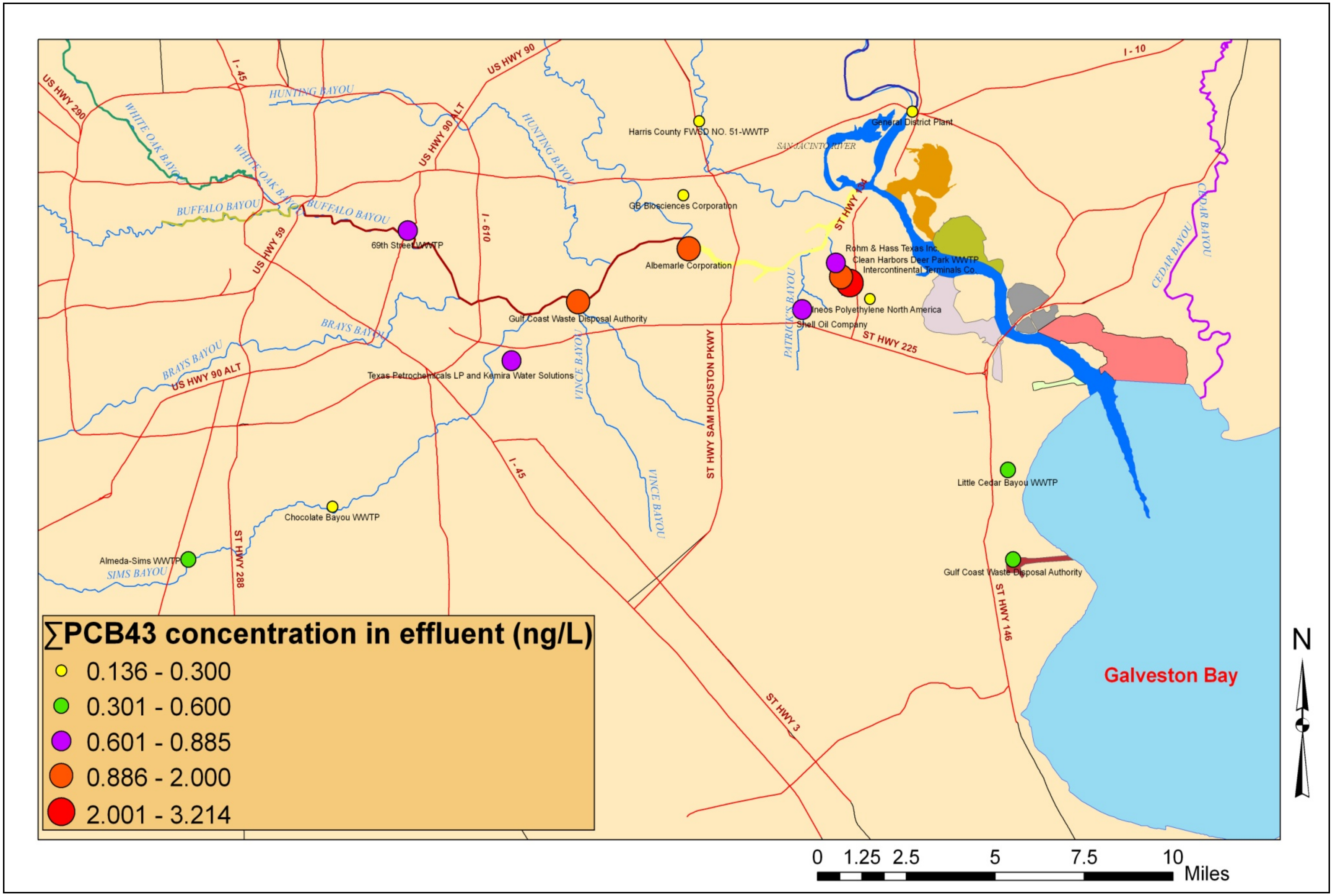


Figure 5.2b Total PCB concentrations in effluent calculated as sum of 43 congeners

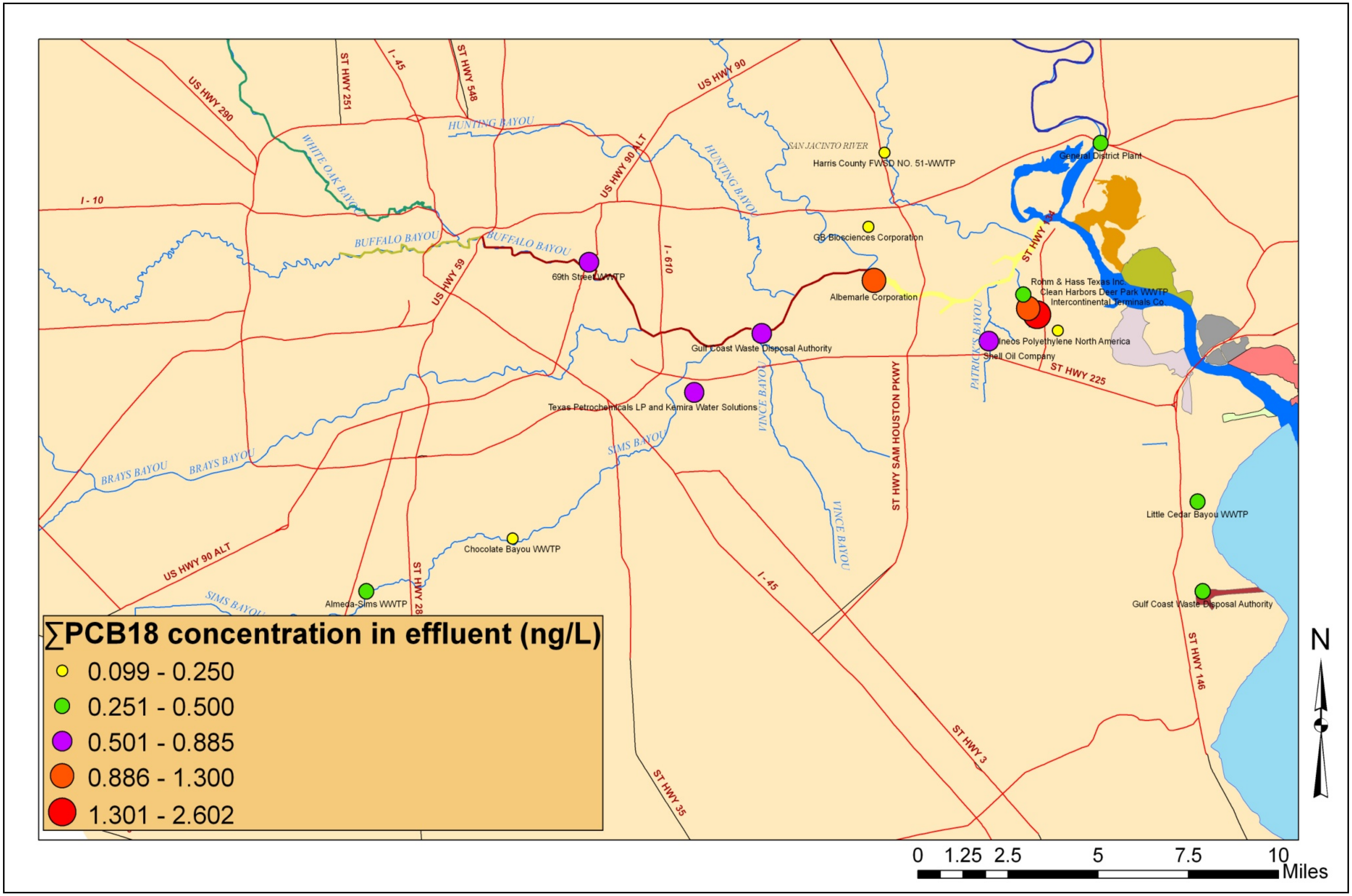


Figure 5.2c Total PCB concentrations in effluent calculated as sum of 18 congeners

Table 5.2 List of facilities where effluent sampling access was requested by TCEQ by letter

NPDES Permit	TCEQ Permit	Entity Name	Facility Name	City	Industry Type	Response to Effluent Sampling Request	Sampling Status
TX0005380	WQ0001054-000	Gulf Coast Waste Disposal Authority	Bayport Faciltiy	Pasadena	Sewerage Systems	Access granted	Sampled
TX0052591	WQ0001740-000	Gulf Coast Waste Disposal Authority	Washburn Tunnel Facility	Pasadena	Sewerage Systems	Access granted	Sampled
TX0006033	WQ0000544-000	Ineos Polyethylene North America	La Porte Plant	La Porte	Plstc Mat./Syn. Resins/NV Elast	Access granted	Sampled
TX0004863	WQ0000402-000	Shell Oil Company	Deer Park Chemical Plant	Deer Park	Plstc Mat./Syn Resins/NV Elast.	Access granted	Sampled
TX0004731	WQ0000492-000	Albemarle Corporation	Pasadena Plant	Pasadena	Industrial Organic Chemicals, NEC	Access granted	Sampled
TX0006084	WQ0000458-000	Rohm & Haas Texas Incorporate	Rohm & Hass Texas Inc.	Deer Park	Industrial Organic Chemicals, NEC	Access granted	Sampled
TX0004961	WQ0000587-000	Texas Petrochemicals LP and Kemira Water Solutions	Texas Petrochemicals LP and Kemira Water Solutions	Houston	Industrial Organic Chemicals, NEC	Access granted	Sampled
TX0007439	WQ0000749-000	GB Biosciences Corporation	Greens Bayou Plant	Houston	Pesticides and Agricultural Chem.	Access granted	Sampled

NPDES Permit	TCEQ Permit	Entity Name	Facility Name	City	Industry Type	Response to Effluent Sampling Request	Sampling Status
TX0068349	WQ0001984-000	Intercontinental Terminals Co.	ITC	Deer Park	Special Warehousing and Storage	Access granted	Sampled
TX0005941	WQ0001429-000	Clean Harbors Deer Park L.P.	Clean Harbors Deer Park WWTP	Deer Park	Refuse Systems	Access granted	Sampled
TX0072834	WQ0010395-008	City of Baytown	General District Plant	Baytown	Sewerage Systems	Access granted	Sampled
TX0025062	WQ0010032-001	Harris County FWSD 51	Harris County FWSD NO. 51-WWTP	Houston	Sewerage Systems	Access granted	Sampled
TX0034924	WQ0010495-003	City of Houston	Almeda-Sims WWTP	Houston	Sewerage Systems	Access granted	Sampled
TX0096172	WQ0010495-090	City of Houston	69th Street WWTP	Houston	Sewerage Systems	Access granted	Sampled
TX0063061	WQ0010495-009	City of Houston	Chocolate Bayou WWTP	Houston	Sewerage Systems	Access granted	Sampled
TX0022799	WQ0010206-001	City of La Porte	Little Cedar Bayou WWTP	La Porte	Sewerage Systems	Access granted	Sampled

NPDES Permit	TCEQ Permit	Entity Name	Facility Name	City	Industry Type	Response to Effluent Sampling Request	Sampling Status
TX0007412	WQ0000305-000	Oxy Vinyls LP	Deer Park Plant	Deer Park	Alkalies and Chlorine	Access delayed until later date	Delayed access prevented sampling
TX0124303	WQ0004344-000	Deer Park Energy Center LP	Deer Park Energy Center	Deer Park	Electrical Services	Access delayed until later date	Delayed access prevented sampling
TX0002798	WQ0001499-000	Bayer Material Science LLC	Bayer WWTP	Baytown	Industrial Organic Chemicals, NEC	Access denied	Not sampled
TX0003531	WQ0000391-000	Equistar Chemicals L.P.	Channelview Complex	Houston	Industrial Organic Chemicals, NEC	Access denied	Not sampled
TX0119792	WQ0004013-000	Equistar Chemicals L.P.	Polyethylene Plant	Deer Park	Plstc Mat./Syn Resins/NV Elast	Access denied	Not sampled
TX0007552	WQ0000815-000	Chevron Phillips Chemical Co.	Pasadena Plastics Complex	Pasadena	Plstc Mat./Syn Resins/NV Elast	Access denied	Not sampled
TX0069493	WQ0002927-000	Lyondell Chemical Company	Channelview Facility	Channelview	Cyclic Crudes Interm. Dyes	Access denied	Not sampled
TX0002976	WQ0000535-000	Valero Refining - Texas L.P.	Valero Refining - Texas L.P.	Houston	Petroleum Refining	No response	Not sampled
TX0006378	WQ0001031-000	Reliant Energy Incorporated	NRG Texas Power LLC	La Porte	Electrical Services	No response	Not sampled
TX0053970	WQ0010195-001	City of Jacinto City	City of Jacinto City WWTP	Jacinto City	Sewerage Systems	No response	Not sampled

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APPENDIX A

Water Quality Parameters - FY 2009 Sampling

Water Quality Parameters - FY 2009 Sampling

Sample Type	Station	Site Description	Sample Date	Sample Time	Depth (ft)	pH	Salinity (ppt)	Specific Conductivity (mS/cm)	Temperature (˚C)
Ambient	11115	Cedar Bayou at Highway 146	6/25/2009	12:15	1	8.51	4.96	8.92	32.05
Ambient	11129	Hunting Bayou at North Loop East	6/26/2009	15:45	2	7.77	0.35	0.74	35.3
Ambient	11129	Hunting Bayou at North Loop East	6/26/2009	16:42	2	7.98	0.35	0.726	35.57
Ambient	11129	Hunting Bayou at North Loop East	6/26/2009	17:42	2	8.04	0.35	0.728	35.69
Ambient	11132	Sims at Telephone Rd	5/12/2009	9:39	1	7.76	0.46	0.933	27
Ambient	11132	Sims at Telephone Rd	5/12/2009	11:08	1	7.66	0.46	0.936	27.56
Ambient	11132	Sims at Telephone Rd	5/12/2009	12:15	1	7.72	0.46	0.936	27.97
Ambient	11139	Brays Bayou at Main	5/13/2009	12:17	1	8.49	0.38	0.782	29.9
Ambient	11139	Brays Bayou at Main	5/13/2009	14:18	1	9.13	0.37	0.772	32
Ambient	11139	Brays Bayou at Main	5/13/2009	15:37	1	9.45	0.36	0.741	33.82
Ambient	11193	San Jacinto River at I-10	5/20/2009	15:35	4	8.05	1.41	2.734	25.61
Ambient	11193	San Jacinto River at I-10	5/20/2009	15:35	8	8.1	1.42	2.763	25.48
Ambient	11193	San Jacinto River at I-10	5/20/2009	15:35	13	8.08	1.13	2.249	25.96
Ambient	11193	San Jacinto River at I-10	5/22/2009	10:00	2	7.74	-	-	26.28
Ambient	11193	San Jacinto River at I-10	5/22/2009	10:00	10	7.51	-	-	25.95
Ambient	11193	San Jacinto River at I-10	5/22/2009	10:00	20	7.38	-	-	26.01
Ambient	11193	San Jacinto River at I-10	5/22/2009	11:20	2	7.76	-	-	26.39
Ambient	11193	San Jacinto River at I-10	5/22/2009	11:20	10	7.69	-	-	25.98
Ambient	11193	San Jacinto River at I-10	5/22/2009	11:20	20	7.44	-	-	26.03
Ambient	11193	San Jacinto River at I-10	5/22/2009	12:20	2	7.76	-	-	26.76
Ambient	11193	San Jacinto River at I-10	5/22/2009	12:20	10	7.64	-	-	26.96
Ambient	11193	San Jacinto River at I-10	5/22/2009	12:20	20	7.5	-	-	26.05
Ambient	11193	San Jacinto River at I-10	5/22/2009	13:47	2	7.95	2.05	3.902	27.34
Ambient	11193	San Jacinto River at I-10	5/22/2009	13:47	10	7.88	2.83	5.277	26.18
Ambient	11193	San Jacinto River at I-10	5/22/2009	13:47	20	7.69	5.65	10.05	25.99
Ambient	11252	HSC at Morgan's Point	5/4/2009	14:39	9	7.82	3.2	6.016	24.71
Ambient	11252	HSC at Morgan's Point	5/4/2009	14:44	5	7.86	1.39	2.667	25.34
Ambient	11252	HSC at Morgan's Point	5/4/2009	15:46	1	7.7	1.37	2.654	26.02
Ambient	11258	HSC at CM120	5/21/2009	15:18	1	7.81	6.17	10.86	26.79
Ambient	11258	HSC at CM120	5/21/2009	15:18	5	7.82	6.57	11.57	26.39
Ambient	11258	HSC at CM120	5/21/2009	15:18	12	7.83	6.6	11.61	26.38
Ambient	11258	HSC at CM120	5/21/2009	15:18	15	7.84	6.73	11.91	26.28
Ambient	11258	HSC at CM120	5/21/2009	15:18	20	7.83	7.66	13.34	26.03
Ambient	11258	HSC at CM120	5/21/2009	15:18	25	7.83	9.04	15.05	25.77

Sample Type	Station	Site Description	Sample Date	Sample Time	Depth (ft)	pH	Salinity (ppt)	Specific Conductivity (mS/cm)	Temperature (˚C)
Ambient	11258	HSC at CM120	5/21/2009	16:08	1	7.78	6.32	11.17	26.64
Ambient				16:08	5	7.8	6.33	11.19	26.58
Ambient				16:08	12	7.8	6.7	11.82	26.28
Ambient				16:08	15	7.82	7.25	12.21	26.16
Ambient				16:08	20	7.82	7.25	12.64	26.15
Ambient				16:08	25	7.84	7.37	12.87	26.14
Ambient				17:20	1	7.77	6.27	11.08	26.78
Ambient				17:20	5	7.77	6.26	11.1	26.74
Ambient				17:20	12	7.78	6.5	11.51	26.38
Ambient				17:20	15	7.79	6.9	12.1	26.32
Ambient				17:20	20	7.83	6.86	12.03	26.32
Ambient				17:20	25	7.85	6.85	12.02	26.34
Ambient	11261	HSC at Lynchburg	5/20/2009	15:05	6	7.65	4.61	8.366	26.09
Ambient				15:05	25	7.73	5.5	9.824	26.34
Ambient				15:05	30	7.71	4.9	8.938	26.3
Ambient				9:45	2	7.94	10.83	18.36	27.22
Ambient				9:45	7	7.97	11.58	19.53	27.21
Ambient				10:45	2	8.11	10.49	17.79	27.3
Ambient				10:45	7	8.17	11.36	19.18	27.2
Ambient				11:45	2	7.93	11.09	18.75	27.45
Ambient				11:45	7	7.96	11.66	19.68	27.29
Ambient	11262	SJR Tidal Downstream of I-10	6/5/2009	13:15	2	7.88	9.9	16.76	28.15
Ambient				13:15	7	7.9	10.6	18.01	27.47
Ambient				14:15	2	7.84	9.77	16.7	28.14
Ambient				14:15	7	7.81	10.51	17.88	27.55
Ambient				15:15	2	7.64	9.09	15.38	28.67
Ambient				15:15	7	7.39	10.14	17.29	28.01
Ambient	11264	HSC at Battleship	5/27/2009	15:15	2	7.62	6.9	12.11	26.65
Ambient				15:15	5	7.62	6.93	12.13	26.64
Ambient				15:15	10	7.64	6.85	11.9	26.62
Ambient				16:30	2	7.73	6.81	11.95	26.65
Ambient				16:30	5	7.76	6.82	11.97	26.65
Ambient				16:30	10	7.79	7	12.27	26.64
Ambient				17:15	2	7.71	6.8	11.95	26.72
Ambient				17:15	5	7.72	7.01	12.29	26.64

Sample Type	Station	Site Description	Sample Date	Sample Time	Depth (ft)	pH	Salinity (ppt)	Specific Conductivity (mS/cm)	Temperature (˚C)
Ambient	11264	HSC at Battleship	5/27/2009	17:15	10	7.72	7.58	13.22	26.61
Ambient	11265	CM 136, Tuckers Bayou at HSC	6/12/2009	14:34	1	7.45	10.33	17.62	29.35
Ambient				14:34	3	7.45	10.43	17.76	28.82
Ambient				14:34	6	7.48	10.3	17.55	28.77
Ambient				15:36	1	7.37	10.38	17.71	29.13
Ambient				15:36	3	7.37	10.38	17.7	29.08
Ambient				15:36	6	7.38	10.41	17.71	28.88
Ambient				16:55	1	7.4	10.22	17.44	29.32
Ambient				16:55	3	7.4	10.25	17.48	29.3
Ambient				16:55	6	7.38	10.39	17.76	28.87
Ambient	11270	HSC at CM150	5/27/2009	10:43	2	7.88	4.24	7.67	26.75
Ambient				10:43	6	8.03	4.52	8.144	26.55
Ambient				12:05	2	7.73	4.3	7.801	26.59
Ambient				12:05	6	7.8	4.31	7.829	26.58
Ambient				13:10	2	7.64	4.45	8.025	26.55
Ambient				13:10	6	7.73	4.53	8.184	26.55
Ambient	11274	Greens Bayou at Mechling Barge	6/4/2009	11:30	2	7.79	4.02	7.33	27.49
Ambient				11:30	7	7.76	5.71	10.16	27.26
Ambient				11:30	12	7.79	6.06	10.73	27.27
Ambient				12:30	2	7.48	3.86	6.98	27.84
Ambient				12:30	7	7.43	5.23	9.27	27.32
Ambient				12:30	12	7.44	6.05	10.71	27.27
Ambient				13:30	2	7.74	3.59	6.61	28.13
Ambient				13:30	7	7.71	5.06	9.08	27.34
Ambient				13:30	12	7.73	6.22	10.99	27.27
Ambient	11279	Greens Bayou at Greens River Rd	5/14/2009	9:15	1	8.04	0.31	0.65	27.8
Ambient				10:45	1	7.8	0.31	0.645	28
Ambient				11:35	1	7.82	0.31	0.648	28.25
Ambient	11280	HSC at Armco Steel	5/28/2009	9:45	2	7.94	4.55	8.225	26.27
Ambient				9:45	6	8.02	4.77	8.605	26.31
Ambient				9:45	12	8.13	4.85	8.719	26.3
Ambient				10:45	2	7.66	4.63	8.354	26.5
Ambient				10:45	6	7.8	4.64	8.365	26.44
Ambient				10:45	12	7.89	4.85	8.731	26.29
Ambient				11:30	2	7.34	4.59	8.297	26.86

Sample Type	Station	Site Description	Sample Date	Sample Time	Depth (ft)	pH	Salinity (ppt)	Specific Conductivity (mS/cm)	Temperature (˚C)
Ambient	11280	HSC at Armco Steel	5/28/2009	11:30	6	7.34	4.68	8.456	26.33
Ambient				11:30	12	7.33	4.92	8.837	26.31
Ambient	11285	HSC at Vince Bayou	6/12/2009	9:31	1	7.41	6.84	12.05	28.4
Ambient				9:31	8	7.4	7.44	13	28.4
Ambient				9:31	16	7.47	7.71	13.46	28.38
Ambient				10:50	1	7.23	7.07	12.37	28.99
Ambient				10:50	8	7.2	7.39	12.91	28.41
Ambient				10:50	16	7.22	7.61	13.29	28.38
Ambient				12:20	1	7.3	7.62	13.05	29.3
Ambient				12:20	8	7.25	7.68	13.4	28.6
Ambient				12:20	16	7.28	7.93	13.8	28.49
Ambient	11287	HSC at Confluence with Sims Bayou	6/4/2009	15:20	2	7.5	2.88	5.667	27.68
Ambient				15:20	7	7.42	4.29	7.846	27.32
Ambient				15:20	12	7.5	4.59	8.301	27.3
Ambient				16:30	2	7.7	2.98	5.539	28.06
Ambient				16:30	7	7.69	4.14	7.524	27.55
Ambient				16:30	12	7.72	4.38	7.948	27.39
Ambient				17:30	2	7.65	2.51	4.73	29.03
Ambient				17:30	7	7.57	4.19	7.625	27.6
Ambient				17:30	12	7.58	4.51	8.172	27.35
Ambient	11288	HSC at 610 Bridge	6/11/2009	15:00	2	7.39	6.14	10.89	28.75
Ambient				15:00	6	7.42	6.22	11.03	28.56
Ambient				15:00	10	7.44	6.85	12.08	28.23
Ambient				16:05	2	7.33	6.17	10.95	28.95
Ambient				16:05	6	7.33	6.25	10.99	28.89
Ambient				16:05	10	7.36	6.62	11.67	28.48
Ambient				17:05	2	7.24	6.18	10.97	28.98
Ambient				17:05	6	7.23	6.4	11.3	28.63
Ambient				17:05	10	7.26	6.79	11.96	28.42
Ambient	11292	HSC at Turning Basin	6/3/2009	10:30	2	7.7	0.71	1.423	27.71
Ambient				10:30	7	7	2.99	5.607	27.02
Ambient				10:30	12	7.25	4.82	8.763	26.75
Ambient				11:30	2	6.04	0.72	1.448	27.56
Ambient				11:30	7	5.22	3.14	5.866	27.08
Ambient				11:30	12	4.9	4.43	7.998	26.84

Sample Type	Station	Site Description	Sample Date	Sample Time	Depth (ft)	pH	Salinity (ppt)	Specific Conductivity (mS/cm)	Temperature (˚C)
Ambient	11292	HSC at Turning Basin	6/3/2009	12:30	2	5.89	0.82	1.605	28.56
Ambient				12:30	7	5.29	3.17	5.872	27.15
Ambient				12:30	12	4.93	5.6	9.951	26.83
Ambient	11347	Buffalo Bayou at Main Street	6/29/2009	10:50	2	7.76	0.42	0.864	31.42
Ambient				10:50	6	7.77	0.42	0.863	31.35
Ambient				10:50	11	7.79	0.42	0.864	31.35
Ambient				11:35	2	7.69	0.42	0.862	31.49
Ambient				11:35	6	7.68	0.42	0.863	31.42
Ambient				11:35	11	7.71	0.42	0.863	31.36
Ambient				12:50	2	7.71	0.42	0.865	31.79
Ambient				12:50	6	7.71	0.42	0.864	31.65
Ambient				12:50	11	7.74	0.42	0.863	31.5
Ambient	11387	Whiteoak Bayou at Heights Blvd	5/14/2009	14:20	1	5.72	0.42	0.861	30.64
Ambient				15:38	1	8.82	0.41	0.849	30.88
Ambient				16:10	1	8.85	0.41	0.849	31.08
Ambient	13338	Tabbs Bay near Goose Greek	5/6/2009	11:42	1	7.37	3.7	6.771	26.14
Ambient				11:42	4	7.2	3.71	6.799	26.15
Ambient				12:48	1	7.69	3.7	6.775	26.52
Ambient				12:48	4	7.67	3.69	6.753	26.5
Ambient				14:09	1	7.64	3.73	6.836	27.07
Ambient				14:09	4	7.61	3.73	6.837	27
Ambient	13340	Black Duck Bay at Mid-Bay	5/6/2009	15:45	1	8.26	2.33	4.4	27.29
Ambient				15:45	3	8.26	2.33	4.405	27.3
Ambient				15:45	6	8.29	2.34	4.408	27.27
Ambient				17:08	1	8.31	2.36	4.438	27.43
Ambient				17:08	3	8.34	2.36	4.428	27.41
Ambient				17:08	6	8.32	2.41	4.536	27.46
Ambient				17:55	1	8.47	2.36	4.503	27.48
Ambient				17:55	3	8.43	2.36	4.453	27.47
Ambient				17:55	6	8.44	2.39	4.501	27.48
Ambient	13342	Scott Bay at Midbay	5/19/2009	14:05	1	7.23	2.62	4.891	25.55
Ambient				15:05	1	7.19	2.71	5.051	25.81
Ambient				16:25	1	7.62	2.8	5.213	25.89
Ambient				14:36	3	7.7	4.15	7.212	25.06

Sample Type	Station	Site Description	Sample Date	Sample Time	Depth (ft)	pH	Salinity (ppt)	Specific Conductivity (mS/cm)	Temperature (˚C)
Ambient	13344	Burnett Bay at Midbay	5/20/2009	14:00	1	7.66	4.32	7.832	25.42
Ambient				10:15	1	8.26	3.87	7.077	25.09
Ambient				10:15	4	8.28	4.03	7.114	25.8
Ambient				10:15	8	8.27	4.92	8.796	25.6
Ambient				11:26	1	7.54	3.79	6.932	25.96
Ambient				11:26	4	7.36	4.03	7.323	25.51
Ambient				11:26	8	7.29	5.02	8.987	25.73
Ambient				12:26	1	7.95	3.61	6.75	26.38
Ambient				12:26	4	7.73	4.3	7.76	25.22
Ambient				12:26	8	7.68	5.2	9.277	25.88
Ambient	13355	Barbours Cut Midpoint	5/29/2009	13:00	5	6.42	11.39	19.24	27.03
Ambient				14:00	5	6.41	11.7	19.68	26.91
Ambient				15:00	5	6.44	11.58	19.52	27.07
Ambient	13363	Bayport Channel Midpoint	5/29/2009	9:30	3	6.7	13.61	22.73	26.6
Ambient				10:30	3	7	12.38	20.86	27.28
Ambient				11:30	3	7.04	12.72	21.33	27.5
Ambient	14560	HSC at Channel Marker 75	5/7/2009	9:30	1	8.3	4.39	7.97	26.45
Ambient				9:30	5	8.31	4.9	8.92	26.35
Ambient				9:30	10	8.46	5.73	10.35	26.32
Ambient				11:00	1	8.17	4.69	8.46	26.68
Ambient				11:00	5	8.18	4.72	8.53	26.59
Ambient				11:00	10	8.18	5.58	9.91	26.35
Ambient				12:10	1	8.21	4.74	8.54	26.76
Ambient				12:10	5	8.23	4.75	8.55	26.74
Ambient				12:10	10	8.32	4.76	8.59	26.71
Ambient	15301	Old River/HSC Lakeside Drive	5/26/2009	9:50	3	8.07	5.32	4.51	27.21
Ambient				11:00	3	7.98	5.56	9.923	27.28
Ambient				11:30	3	7.92	5.69	10.14	27.24
Ambient	15936	HSC at Oxychem Ditch	5/26/2009	13:35	2	7.61	5.35	9.555	27.32
Ambient				13:35	5	7.57	5.78	10.43	27.06
Ambient				13:35	10	7.58	6.09	10.78	26.49
Ambient				14:35	2	7.56	5.48	9.791	27.17
Ambient				14:35	5	7.55	5.49	9.876	27.05
Ambient				14:35	10	7.52	6.34	11.16	26.41
Ambient				15:45	2	6.83	5.44	9.656	27.1

Sample Type	Station	Site Description	Sample Date	Sample Time	Depth (ft)	pH	Salinity (ppt)	Specific Conductivity (mS/cm)	Temperature (˚C)
Ambient	15936	HSC at Oxychem Ditch	5/26/2009	15:45	5	6.68	5.45	9.768	26.85
Ambient				15:45	10	6.82	5.8	12.27	26.53
Ambient	15979	HSC at Shell Barge Cut	5/28/2009	13:00	2	7.61	5.9	10.47	26.7
Ambient				13:00	6	7.73	6.11	10.81	26.45
Ambient				14:25	2	7.35	5.86	10.41	27.46
Ambient				14:25	6	7.34	5.95	10.55	26.82
Ambient				15:00	2	7.39	5.85	10.39	27.66
Ambient				15:00	6	7.39	5.98	10.6	26.93
Ambient	16213	Upper Galveston Bay at 97GB019	5/5/2009	13:00	2	7.75	2.81	5.24	25.87
Ambient				13:00	5	7.79	2.82	5.24	25.4
Ambient				13:00	10	7.69	3.3	5.96	25.3
Ambient				13:55	2	7.21	2.84	5.297	25.52
Ambient				13:55	5	7.7	2.94	5.52	25.35
Ambient				13:55	10	7.62	5.04	6.032	25.15
Ambient				14:35	2	7.83	7.98	5.46	25.7
Ambient				14:35	5	7.83	2.93	5.44	25.7
Ambient				14:35	10	7.96	2.99	5.52	25.6
Ambient	16499	San Jacinto Bay (98GB007)	5/7/2009	13:50	1	8.47	1.33	2.584	26.74
Ambient				13:50	5	8.57	1.33	2.591	26.7
Ambient				13:50	10	8.71	1.51	2.929	26.72
Ambient				15:00	1	8.32	1.21	2.36	26.84
Ambient				15:00	5	8.38	1.21	2.37	26.81
Ambient				15:00	10	8.38	1.71	3.22	26.61
Ambient				16:00	1	8.24	1.18	2.317	26.85
Ambient				16:00	5	8.29	1.19	2.336	26.72
Ambient				16:00	10	8.27	1.6	3.063	26.57
Ambient	16618	HSC/SJR at Exxon Docks	5/19/2009	10:15	1	7.52	4.9	8.794	24.68
Ambient				11:10	1	7.65	5.16	9.24	25.48
Ambient				12:10	1	7.58	5.02	8.901	25.33
Ambient	16622	SJR at Banana Bend	5/22/2009	11:34	1	8.3	0.11	0.226	27.16
Ambient				11:34	6	8.33	0.11	0.225	26.36
Ambient				11:34	13	8.39	0.11	0.227	26.38
Ambient				12:46	1	8.19	0.1	0.222	27.13
Ambient				12:46	6	8.19	0.1	0.223	26.64
Ambient				12:46	13	8.19	0.11	0.227	26.52

Sample Type	Station	Site Description	Sample Date	Sample Time	Depth (ft)	pH	Salinity (ppt)	Specific Conductivity (mS/cm)	Temperature (˚C)
Ambient	16622	SJR at Banana Bend	5/22/2009	13:00	1	8.23	0.1	0.22	27.54
Ambient				13:00	6	8.26	0.11	0.226	26.65
Ambient				13:00	13	8.29	0.11	0.227	26.59
Ambient	16657	Tributary of Hunting Bayou at John Ralston Road	6/25/2009	15:20	1	8.86	0.25	0.528	29.63
Ambient				16:20	1	8.48	0.25	0.526	29.83
Ambient				17:20	1	8.34	0.25	0.524	29.37
Ambient	16872	Patrick Bayou at State Highway 225	8/31/2009	10:39	1	7.69	0.34	0.71	30.02
Ambient				11:43	1	7.5	0.34	0.713	30.28
Ambient				13:17	1	7.73	0.34	0.705	30.52
Ambient	17149	Patrick Bayou upstream of Tidal Road	7/14/2009	10:32	2.5	7.99	15.17	25.13	30.02
Ambient				11:26	2.5	8.06	14.75	24.46	30.09
Ambient				12:45	2.5	8.07	14.82	24.56	30.28
Ambient	18322	Tuckers Bayou at First Bend	6/9/2009	15:40	2	7.42	10.47	17.81	29.11
Ambient				15:40	6	7.45	10.55	17.95	28.06
Ambient				15:40	10	7.46	10.59	17.95	28
Ambient				16:21	2	7.47	10.53	17.94	28.92
Ambient				16:21	6	7.48	10.56	17.96	28.42
Ambient				16:21	10	7.52	10.6	18.01	28.13
Ambient				17:25	2	7.44	10.56	17.96	28.78
Ambient				17:25	6	7.47	10.58	18	28.19
Ambient				17:25	10	7.52	10.62	18.06	28.05
Ambient	18363	Greens Bayou at Market Street	6/9/2009	11:20	2	7.69	2.25	4.272	28.54
Ambient				11:20	4	7.7	2.27	4.305	28.36
Ambient				11:20	7	7.66	4.05	7.412	28.06
Ambient				12:20	2	7.64	2.25	4.273	28.73
Ambient				12:20	4	7.6	2.4	4.75	28.36
Ambient				12:20	7	7.51	5.14	9.235	27.98
Ambient				13:20	2	7.58	2.33	4.383	29.11
Ambient				13:20	4	7.52	2.37	4.505	28.95
Ambient				13:20	7	7.35	4.96	8.892	27.99
Ambient	20570	Buffalo Bayou near Eleanor Tinsky	5/13/2009	18:22	1	9.16	0.05	0.113	25.87
Ambient				15:45	4	7.77	0.43	0.892	32.1
Ambient				16:45	4	7.75	0.43	0.894	32.07
Ambient				17:20	4	7.73	0.43	0.894	31.94
Ambient	20574	Hunting Bayou at Wallisville	6/26/2009	10:50	1	7.98	0.5	1.027	30.94

Sample Type	Station	Site Description	Sample Date	Sample Time	Depth (ft)	pH	Salinity (ppt)	Specific Conductivity (mS/cm)	Temperature (˚C)
Ambient	20574	Hunting Bayou at Wallisville	6/26/2009	11:53	1	7.78	0.49	1.008	32.17
Ambient				12:50	1	7.83	0.44	0.917	33.28
Ambient				12:50	1	8.68	0.23	0.479	28.39
Ambient	20575	Carpenters Bayou at Wallisville	5/11/2009	14:02	1	8.31	0.23	0.487	28.65
Ambient				14:53	1	8.14	0.23	0.484	28.22
Ambient				10:50	2	7.51	0.97	1.93	28.68
Ambient				10:50	6	7.47	1.23	2.286	28.15
Ambient				10:50	10	7.28	6.41	11.33	27.37
Ambient				11:50	2	7.44	1	1.971	28.99
Ambient	T002	Brays Bayou at Lawndale	6/11/2009	11:50	6	7.26	3.73	6.9	27.87
Ambient				11:50	10	7.18	6.56	11.57	27.43
Ambient				12:50	2	7.52	1.09	2.143	29.04
Ambient				12:50	6	7.42	1.59	3.042	28.23
Ambient				12:50	10	7.3	6.47	11.41	27.42
Ambient				10:00	2	7.95	6.1	10.66	28.12
Ambient				10:00	7	8.05	7.58	13.21	28.07
Ambient				11:00	2	7.29	5.16	8.925	28.69
Ambient	TBD10	Hunting Bayou at Federal Road	6/10/2009	11:00	7	7.25	7.71	13.43	28.05
Ambient				12:00	2	7.25	6.53	11.5	28.25
Ambient				12:00	7	7.22	7.67	13.38	28.08
Ambient				14:00	2	7.71	2.75	5.074	29.93
Ambient				14:00	5	7.51	5.86	10.42	28.04
Ambient				14:00	10	7.6	6.58	11.6	27.72
Ambient	TBD11	Sims Bayou at Galveston Road	6/10/2009	15:00	2	7.26	3	5.558	30
Ambient				15:00	5	7.04	6.45	11.37	27.82
Ambient				15:00	10	7.03	5.93	11.65	27.72
Ambient				15:50	2	7.68	3.18	5.977	30.23
Ambient				15:50	5	7.37	5.04	9.07	28.37
Ambient	TBD11	Sims Bayou at Galveston Road	6/10/2009	15:50	10	7.45	6.62	11.67	27.73
Ambient				10:05	1	6.45	10.97	18.792	30.28
Ambient	17157	Patrick Bayou at Shell	8/11/2009	11:05	1	6.44	8.6	14.539	31.2
Ambient				12:11	1	6.38	7.94	14.013	31.82
Ambient				15:59	1	9.65	0.21	0.448	34.31
Ambient	TBDVince	Vince Bayou at Southmore	5/12/2009	17:04	1	9.8	0.19	0.401	33.55
Ambient				18:31	1	9.63	0.19	0.392	30.1

Sample Type	Station	Site Description	Sample Date	Sample Time	Depth (ft)	pH	Salinity (ppt)	Specific Conductivity (mS/cm)	Temperature (˚C)
Effluent	WQ0000402-000	Shell Deer Park Chemical Plant	8/12/2009	11:20	1	7.6	7.33	12.9	32.69
Effluent				12:10	1	7.82	7.33	12.93	33.01
Effluent				14:32	1	7.85	7.34	12.87	33.18
Effluent	WQ0000458-000	Rohm and Haas	8/6/2009	9:50	1	7.05	-	-	34.1
Effluent				10:47	1	7.01	4.71	8.562	34.4
Effluent				11:40	1	6.97	4.74	8.617	34.8
Effluent	WQ0000492-000	Albemarle	8/12/2009	14:35	1	5.3	2.4	4.561	33.56
Effluent				15:38	1	5.36	2.38	4.522	32.78
Effluent				16:52	1	5.72	2.38	4.516	32.49
Effluent	WQ0000544-000	Ineos Polyethylene	8/17/2009	11:50	0.5	7.8	1.14	2.257	32.83
Effluent				12:50	0.5	7.8	0.99	1.979	32.96
Effluent				14:15	0.5	7.89	0.85	1.675	33.59
Effluent	WQ0000587-000	Texas Petrochemicals	8/11/2009	10:15	1	7.49	0.9	1.785	29.12
Effluent				11:16	1	7.68	0.89	1.771	29.31
Effluent				12:05	1	7.68	0.88	1.754	29.5
Effluent	WQ0000749-000	GB Biosciences	8/14/2009	10:04	0.5	6.98	9.71	16.72	33.08
Effluent				11:06	0.5	6.99	9.77	16.9	33.3
Effluent				12:07	0.5	7.07	10.06	17.29	33.49
Effluent	WQ0001054-000	GCWDA Bayport	8/4/2009	15:25	1	5.84	3.14	5.795	36.31
Effluent				16:37	1	5.88	3.06	5.76	36.72
Effluent				17:45	1	6.43	3.06	5.754	36.56
Effluent	WQ0001429-000	Clean Harbors	8/13/2009	11:48	1.5	8.36	7.02	12.35	33.19
Effluent				12:49	1.5	8.52	6.99	12.35	33.38
Effluent				13:37	1.5	8.52	7	12.38	33.67
Effluent	WQ0001740-000	GCWDA Washburn Tunnel	8/7/2009	14:47	1	7.31	2.09	4.039	38.76
Effluent				15:48	1	7.74	2.1	4.059	38.48
Effluent	WQ0001 740-000	GCWDA Washburn Tunnel	8/7/2009	16:49	1	8.11	2.1	4.051	38
Effluent	WQ0001984-000	Intercontinental Terminals (ITC)	8/18/2009	10:00	0.3	7.33	1.68	3.242	30.24
Effluent				11:00	0.3	8.28	1.69	3.264	30.24
Effluent				11:55	0.3	8.31	1.69	-	-
Effluent	WQ0010032-001	Harris County FWSD 51	8/3/2009	11:45	1	7.11	0.6	1.22	30.8
Effluent				12:40	1	6.65	0.6	1.22	31.09
Effluent				13:57	1	6.6	0.6	1.22	31.41

Sample Type	Station	Site Description	Sample Date	Sample Time	Depth (ft)	pH	Salinity (ppt)	Specific Conductivity (mS/cm)	Temperature (˚C)
Effluent	WQ0010206-001	City of La Porte WWTP (Little Cedar Bayou WWTP)	8/4/2009	8:49	1	8.1	0.38	0.778	28.93
Effluent				9:47	1	6.35	0.38	0.775	28.99
Effluent				10:50	1	6.06	0.37	0.772	29.11
Effluent	WQ0010395-008	City of Baytown General District Plant	8/6/2009	15:45	1	6.98	0.35	0.733	31.41
Effluent				16:15	1	6.87	0.35	0.735	31.49
Effluent				17:36	1	6.73	0.35	0.734	31.31
Effluent	WQ0010495-003	Almeda-Sims WWTP	8/5/2009	11:55	1	5.4	0.55	1.152	31.37
Effluent				12:53	1	6.04	0.62	1.319	31.63
Effluent				13:55	1	5.57	0.65	1.336	31.68
Effluent	WQ0010495-009	Chocolate Bayou WWTP	8/18/2009	14:54	2.5	7.7	0.39	0.806	30.17
Effluent				15:43	2.5	7.7	0.39	0.806	30.2
Effluent				16:46	2.5	7.73	0.39	0.806	30.22
Effluent	WQ0010495-090	City of Houston 69th Street Plant	8/7/2009	9:00	1	7.11	0.84	1.7	32.33
Effluent				10:19	1	6.93	0.5	1.031	32.42
Effluent				11:10	1	6.92	0.73	1.472	32.46
Runoff	11115	Cedar Bayou at Highway 146	9/23/2009	11:15	1	6.85	-	-	22.23
Runoff				12:23	1	6.28	-	-	21.78
Runoff				13:30	1	6.58	-	-	23.58
Runoff	11132	Sims at Telephone Rd	7/23/2009	16:50	1.5	8.1	0.43	0.892	32.25
Runoff				17:50	1.5	8.06	0.28	0.588	30.9
Runoff				18:50	1.5	8.09	0.27	0.575	30.84
Runoff	11139	Brays Bayou at South Main	7/23/2009	17:23	1	10.67	0.08	0.17	27.59
Runoff				18:40	1	9.49	0.09	0.191	27.44
Runoff				19:23	1	9.14	0.11	0.228	28.05
Runoff	11139	Brays Bayou at South Main	9/9/2009	12:32	1	7.78	0.26	0.544	28
Runoff				13:43	1	7.66	0.17	0.355	27.84
Runoff				14:44	1	7.59	0.13	0.274	27.42
Runoff	11387	Heights Boulevard	4/27/2009	17:01	1	8.26	0.3	0.631	26.32
Runoff				18:27	1	8	0.19	0.402	24.37
Runoff	16657	Tributary to Hunting Bayou at John Ralston Road	4/27/2009	17:47	1	8.75	0.11	2.35	24.78
Runoff				18:41	1	7.92	0	0.005	24.11
Runoff				19:45	1	8.31	0.06	0.25	21.77
Runoff	20570	Buffalo Bayou at Elanor Tinsley Park	4/17/2009	16:40	1	7.69	0.22	0.46	20.44
Runoff				18:30	1	7.85	0.1	0.206	19.31
Runoff				20:06	1	7.79	0.12	0.25	19.49

Sample Type	Station	Site Description	Sample Date	Sample Time	Depth (ft)	pH	Salinity (ppt)	Specific Conductivity (mS/cm)	Temperature (˚C)
Runoff	20574	Hunting Bayou at Wallisville Rd	8/13/2009	18:38	1	7.51	0.23	0.48	30.74
Runoff				19:43	1	7.62	0.23	0.476	31
Runoff				20:38	1	7.61	0.22	0.465	30.98
Runoff	20575	Carpenters Bayou at Wallisville	5/11/2009	17:36	1	8.34	0.2	0.413	27.42
Runoff				18:46	1	8.03	0.13	0.285	25.9
Runoff				19:36	1	8.01	0.17	0.352	24.81