Total Maximum Daily Loads for PCBs in the Houston Ship Channel

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Quarterly Report 1

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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 presents the updated results from the sampling activities undertaken in FY08.

2. QUALITY ASSURANCE/QUALITY CONTROL

The quality assurance/quality control (QA/QC) tasks that were conducted included 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 except for one sample (water for station 13363). All samples were received from the sample site to the UH laboratory and from the UH laboratory to analytical laboratories without incident and were within the temperature range specified in the QAPP. The water samples (filter and trap) collected for site 13363 for PCB analysis on 5/27/2008 was found to be contaminated with ice water and so had to be resampled.

Once the sample results were obtained from the labs, the results were reviewed by UH/Parsons personnel using 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 2008 sampling. The POC measurements were not completed for 3 stations (11171, 11270 and 11287) due to insufficient volume of water sample for filtration. The POC results are currently being evaluated using the QA/QC criteria. Table 2.2 shows the data flags that were used to designate the data as needed based on the QA/QC review.

Table 2.1 Percentage of sample results obtained and reviewed for QA/QC

Laboratory	Media	Analysis	Number of samples collected	Number of sample results obtained from laboratory	Number of sample results reviewed for QA/QC	% Results reviewed for QA/QC
Xenco	Water	TPH, TSS, DOC	44	44	44	100%
Xenco/PTS	Sediment	TPH, Grain size and Solids content	100	100	100	100%
Maxxam	Water	POC	40	40	0	0%
Maxxam	Water	PCB (209 Congeners)	91	91	91	100%
Maxxam	Sediment	PCB (209 Congeners), TOC	100	100	100	100%
Maxxam	Fish	PCB (209 Congeners), Lipid and Moisture content	53	53	52	98%

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.

2.1 QA/QC for Water Samples

2.1.1 TSS, TPH, and DOC

The following summary is for the 44 samples for which the QA/QC has been completed.

- The TSS analyses were performed using EPA Method 160.2. All samples were collected and analyzed following the procedures and protocols outlined in the QAPP. All samples were prepared and analyzed within the holding times (7 days) required by the method with the exception of samples listed below in Table 2.3. The holding time exceedances above are considered minor, although the TSS results were flagged “H” as estimated.

- The DOC analyses were performed using EPA Method SM5310. All samples were collected and analyzed following the procedures and protocols outlined in the QAPP. All samples were prepared and analyzed within the holding times as required by the method.
- The TPH analyses were performed using Texas 1005. All samples were collected and analyzed following the procedures and protocols outlined in the QAPP. All samples were prepared and analyzed within the holding times required by the method. The hydrocarbons analyzed for by this method include: C6-C12 (Gasoline), C12-C28 (Diesel) and C28-C35 (Oil) Range Hydrocarbons.

Table 2.3 Holding time exceedance of water samples analyzed for TSS

Sample ID	Collection date	Flag applied	Time exceeded (days)
11287-W-1	4/21/2008	H	2.89
13338-W-1-DUP	4/22/2008	H	1.87
13338-W-1	4/22/2008	H	1.93
11387-W-1	5/12/2008	H	1.09
15301-W-1	6/4/2008	H	1.30
11262-W-1	6/4/2008	H	1.30
11262-W-1-DUP	6/4/2008	H	1.30
11261-W-1	6/4/2008	H	1.30
TRIP2-W-1	6/4/2008	H	1.30

2.1.1.1 Bias (Accuracy)

Bias is a statistical measurement of correctness and includes components of systematic error. A measurement is considered unbiased when the value reported does not differ from the true value. Accuracy was evaluated using the percent recovery (%R) results for the blank spike

samples (BS) and/or Blank Spike Duplicate (BSD) samples in the case of TSS, DOC and TPH analysis. The BS/BSD %Rs were within method acceptance criteria for all data packages. Table 2.4 gives the summary statistics of the bias calculated from each data package. All the data packages were within QAPP requirements.

Table 2.4 Accuracy of water sample results for DOC, TPH and TSS analyses

	DOC (Water)	**TPH (Water)**	**TSS (Water)**
QAPP Bias Requirement (%)	80 - 120	70 - 135	80 - 120
Min Bias (%)	92.4	80.9	94.7
Max Bias (%)	103.0	122.5	107.0
Average Bias (%)	96.9	96.5	99.6
95% Confidence level of mean (%)	94.7 - 99.1	87.2 - 105.8	96.8 - 102.3

2.1.1.2 Precision

Precision was evaluated using the Relative Percent Difference (%RPD) obtained from either of the parent sample/field duplicate sample results, laboratory duplicate results, BS/BSD and/or MS/MSD results. Each TSS and TPH batch QC included a BS and BSD samples and all BS/BSD % RPDs were within the QAPP required tolerance. Each DOC batch QC included a laboratory duplicate and all %RPDs in general were within QAPP required tolerance. Table 2.5 gives the summary statistics of the precision calculated from each data package. All the data packages were within QAPP requirements.

Table 2.5 Precision of water sample results for DOC, TPH and TSS analyses

	DOC (Water)	TPH (Water)	TSS (Water)
QAPP Precision Requirement (%)	20	25	20
Min Precision (%)	0.0	0.7	0.0
Max Precision (%)	6.0	12.9	5.1
Average Precision (%)	2.4	4.2	1.5
95% Confidence level of mean (%)	1.1 - 3.6	2 - 6.5	0.4 - 2.5

2.1.1.3 Representativeness

Representativeness expresses the degree to which sample data accurately and precisely represent actual site conditions. Representativeness has been evaluated by:

- Comparing the chain-of-custody procedures to those described in the QAPP
- Evaluating holding times
- Examining method blanks for contamination of samples during analysis

The samples in the data packages were collected and analyzed following the QAPP, COC procedures, and analytical procedures. All samples were prepared and analyzed with the holding times required for the analysis with the exception of some of the TSS samples as noted above. There was at least one method blank analyzed with each batch associated with the TSS,DOC, and TPH analyses in each data package. The method blanks were in all cases below the RLs. As required by the QAPP, trip blanks were sent to the laboratory. The summary of trip blank results for TSS, DOC, and TPH analyses are summarized in Table 2.6. The laboratory changed the detection limit from 1 mg/L to 0.5 mg/L for DOC and from 5 mg/L to 4 mg/L for TSS in the case of Trip 3 blank. As can be seen from the table, TSS and TPH results for Trip blanks 1 and 2 were

less than the reporting limit. However, the Trip 3 blank was found to be contaminated with TSS and DOC and the Trip 2 blank was contaminated with DOC. It is not clear whether the DOC and TSS contamination occurred at the site or in the analytical laboratory. This issue will be addressed for future sampling trips.

Table 2.6 DOC, TSS and TPH results for trip blanks

	DOC (mg/L)	TSS (mg/L)	Total TPH (mg/L)
Trip1-W-1	<1.00	<5.00	<5.00
Trip2-W-1	2.62	<5.00	<5.00
Trip3-W-1	0.61	4.00	<5.00

2.1.1.4 Completeness

Completeness was evaluated by comparing the total number of samples collected with the total number of samples with valid analytical data. No reported results for samples have been rejected or invalidated (qualified "R"). The completeness of the data results obtained from laboratories and reviewed for QA/QC is 100% compared to the minimum acceptance limit of 90%.

2.1.1.5 Field and Laboratory Duplicates

A field duplicate is defined as a split sample (or measurement) from the same location, collected in immediate succession (after homogenization), using identical techniques. The following samples were collected and analyzed for field duplicate QC purposes: 13338-W-1

(sampled on 4/22/08), 13344-W-1 (sampled on 6/3/08), 13363A-W-1 (sampled on 6/11/08), and 11262-W-1 (sampled on 6/4/08). Field duplicates were collected at a frequency of 10%, well above the 5% frequency specified in the QAPP. Table 2.7 below summarizes the relative percent deviation of the field duplicates (FRPD) for TSS, DOC, and TPH. As can be observed, the average FRPDs for TSS, DOC, and TPH were 17%, 5%, and NC, respectively. All field duplicate results were within QAPP tolerance.

In addition to field duplicates, samples were analyzed in duplicate for laboratory QC purposes. All laboratory duplicate results were within QAPP tolerance. No laboratory duplicates were conducted in the case of TPH due to extraction processes involved in analysis. Laboratory duplicates were collected at a frequency of 31 and 20% for TSS and DOC, respectively, well above the 5% frequency specified in the QAPP.

Table 2.7 Relative Percent Deviation of the Field Duplicates

Sample ID	RPD[a] (%)		
	DOC	TPH	TSS
13338-W-1	11.59	NC	36.58
13344-W-1	5.71	NC	5.41
13363A-W-1	0.53	NC	8.00
11262-W-1	1.56	NC	16.09

[a]Field duplicate RPD specified in the QAPP is 50% or lower.
NC: Not Calculated due to non detect in samples

2.1.2 Polychlorinated Biphenyls

The data submitted by the laboratory have been reviewed and verified following the guidelines outlined in the QAPP and in the National Functional Guidelines for Organic and

Inorganic Data. Information reviewed in the data packages included sample results; the laboratory quality control results; instrument calibrations; blanks; case narrative and chain-of-custody forms. The verification protocol addressed the following parameters: method blanks, laboratory control spike recoveries, recoveries of labeled compounds (internal standards), continuing calibration verifications, laboratory and field duplicate sample percent reproducibility (%RPD), percent recovery (%R), and Level of Quantification (LOQ) standard results.

All samples were collected and analyzed following the procedures and protocols outlined in the QAPP. All samples collected were prepared and analyzed for PCB congeners within the holding times required by the method. Several water samples required dilution due to high PCBs and/or matrix interference. All 91 samples have been analyzed, results reported by the laboratories and reviewed for QA/QC.

2.1.2.1 Accuracy

Accuracy was evaluated using the percent recovery (%R) results for the blank spike samples (BS), Limit of Quantification (LOQ) samples, and labeled compound spikes. The BS, LOQ and labeled compound spike recoveries %Rs were within method acceptance criteria, except for some of the congeners in a limited number of samples. All LOQ failures were flagged "Q", blank spike failures were flagged "S" and labeled compound spike recovery failures were flagged "R". All associated congeners were flagged according to the QC failure type. .

2.1.2.2 Precision

Precision was evaluated using the Relative Percent Difference (%RPD) obtained from the parent sample/field duplicate sample results. The following samples were collected and analyzed in duplicate for field duplicate QC purposes: 13338-D-1-Trap, 13338-SU-1-Filter, 13344-D-1-Trap, 13344-SU-1-Filter, 13363-D-1-Trap, and 13363-SU-1-Filter. There were several exceedances for %RPD in field duplicates results and both the parent and field duplicate samples were flagged "F" indicating an estimated value if the %RPD was out of tolerance limits. All associated congeners, that weren't previously flagged "J", "U" or "B" by the laboratory, were flagged "F".

2.1.2.3 Representativeness

Representativeness expresses the degree to which sample data accurately and precisely to represent actual site conditions. Representativeness has been evaluated by:

- Comparing the chain-of-custody procedures to those described in the QAPP
- Evaluating holding times
- Examining method blanks for contamination of samples during analysis.

The samples were collected and analyzed following the QAPP, COC procedures, and analytical procedures. All samples were prepared and analyzed with the holding times required for the analysis. All initial calibration criteria, all continuing calibration criteria (BS), and all LOQ standard criteria were met with the exceptions mentioned above. There was at least one method blank analyzed with each batch associated with the PCB analyses. The method blanks

contained some PCB congeners above the RLs and the sample results that were less than five (5) times the amount found in the blank were "B" flagged indicating blank contamination.

Trip blanks were also collected as part of the sampling plan. A number of congeners were detected in both the trap trip blanks and the filter trip blanks.

2.1.2.4 Completeness

Completeness has been evaluated by comparing the total number of samples collected with the total number of samples with valid analytical data. No reported results so far have been rejected or invalidated. The completeness of the data results obtained from the laboratories and reviewed for QA/QC is 100% compared to the minimum acceptance limit of 90%.

2.1.2.5 Field and Laboratory duplicates

As mentioned earlier, parent and duplicate sample results were flagged if the congener was not within the 50% RPD tolerance specified in the QAPP. Samples were also analyzed in duplicate for laboratory duplicate QC purposes and all laboratory duplicate results were within QAPP tolerance. The frequency of field duplicates for the results reviewed was 9.4% which is higher than the required frequency of 5%. Laboratory duplicates were not possible for these matrices due to insufficient media.

2.2 QA/QC for Sediment Samples

2.2.1 TPH

For sediment, QA/QC analyses were focused on TPH only since particle size analysis and solids content measurements had no QA/QC requirements. The TPH analyses were performed using TPH by Texas 1005. All samples were collected and analyzed following the procedures and protocols outlined in the QAPP. All samples collected over the sampling phase have been reviewed for QA/QC except for one trip sample. All samples from the first phase and intensive sediment sampling phase have been analyzed, results reported by the laboratory and results reviewed for QA/QC (Table 2.1). All samples were prepared and analyzed within the holding times required by the method, with the exception of sample 16622-SE-1. This sample was analyzed 5.16 days outside of the required 14 day HT and an "H" flag was applied to the sample result. The hydrocarbon ranges analyzed for by this method included C6-C12 (Gasoline), C12-C28 (Diesel) and C28-C35 (Oil) Range Hydrocarbons.

2.2.1.1 Bias (Accuracy)

Accuracy was evaluated using the %R results for the blank spike samples (BS) and MS/MSD recovery results. The BS/MS/MSD %Rs were within method acceptance criteria for all data packages (Table 2.8). All MS/MSD recoveries were within acceptance criteria except for one batch which had a high concentration of C12-C28 in the parent sample. No corrective actions were required since the sample spiked was not from this project.

Table 2.8 Accuracy and precision of sediment sample results for TPH analyses

	Precision (%)	**Bias (%)**
QAPP requirement	25	70-135
Min	0.6	75.8
Max	13.5	169.5
Average	3.6	104.7
95% Confidence level of mean	0.9 - 6.4	86.9 - 122.5

2.2.1.2 Precision

Precision was evaluated using the Relative Percent Difference (%RPD) obtained from the parent sample/field duplicate sample results and the MS/MSD duplicate results. All field duplicate results and MS/MSD %RPD were within acceptance criteria. Each TPH batch QC included a BS/MS/MSD and all %RPDs were within the QAPP required tolerance (Table 2.8).

2.2.1.3 Representativeness

Representativeness expresses the degree to which sample data accurately and precisely represent actual site conditions. Representativeness has been evaluated by:

- Comparing the chain-of-custody procedures to those described in the QAPP
- Evaluating holding times
- Examining method blanks for contamination of samples during analysis.

The samples were collected and analyzed following the QAPP, COC procedures, and analytical procedures. All samples were prepared and analyzed with the holding times required for the analysis except for one sample for which a flag was applied. There was at least one method blank analyzed with each batch associated with the TPH analyses in each Sample

Delivery Group (SDG). The method and field blanks were below the RLs. Two trip blanks that were sampled and analyzed for TPH had values less than the reporting limit.

2.2.1.4 Completeness

Completeness has been evaluated by comparing the total number of samples collected with the total number of samples with valid analytical data. No reported results for TPH samples have been rejected or invalidated. The completeness of the data results obtained from the laboratories and reviewed for QA/QC is 100% compared to the minimum acceptance limit of 90%.

2.2.1.5 Field and Laboratory Duplicates

The following samples were collected and analyzed for TPH for field duplicate QC purposes: 11193-Se-1, 15301-Se-1, T014-Se-1, T009-Se-1, W002-Se-1, E011-Se-1, E013-Se-1-A, E013-Se-1-B, T001-Se-1. Field duplicates were collected at a frequency of 10%. The relative percent deviation of the field duplicates (FRPD) could not be evaluated since all samples were non detected (ND) for TPH. No laboratory duplicates were conducted in the case of TPH due to extraction processes involved in analysis.

2.2.2 Polychlorinated Biphenyls and Total Organic Carbon

The data from the first phase of sampling and intensive sediment sampling submitted by the laboratory have been reviewed and verified following the guidelines outlined in the QAPP and the National Functional Guidelines for Organic and Inorganic Data. Information reviewed in

the data packages included sample results; the laboratory quality control results; instrument calibrations; blanks; case narrative and chain-of-custody forms. The verification protocol addressed the following parameters: method blanks, laboratory control spike recoveries, recoveries of labeled compounds (internal standards), continuing calibration verifications, laboratory and field duplicate sample percent reproducibility (%RPD), percent recovery (%R), and Level of Quantification (LOQ) standard results.

2.2.2.1 Total Organic Carbon (TOC) in Sediment

The TOC analyses were performed using LECO Combustion. All samples were collected and analyzed following the procedures and protocols outlined in the QAPP. All samples were analyzed within the holding times as required by the method, with the exception of 13338. Sample 13338, collected on 4/24/08, was analyzed 2 days outside of the holding time and so the sample was flagged "H".

2.2.2.1.1 Accuracy and Precision

Accuracy was evaluated using the %R results for the blank spike samples (BS). The BS %R was 91% and well within QAPP acceptance criteria (80-120%). Precision was evaluated using the Relative Percent Difference (%RPD) obtained from the laboratory duplicate results. Each TOC batch QC included a laboratory duplicate, and %RPDs was 4.1 and within QAPP required tolerance of < 20.

2.2.2.1.2 Representativeness

Representativeness expresses the degree to which sample data accurately and precisely represent actual site conditions. Representativeness has been evaluated by:

- Comparing the chain-of-custody procedures to those described in the QAPP
- Evaluating holding times
- Examining method blanks for contamination of samples during analysis.

The samples were collected and analyzed following the QAPP, COC procedures, and analytical procedures. All samples were prepared and analyzed with the holding times required for the analysis. All initial calibration criteria and continuing calibration criteria (BS) were met. There was at least one method blank analyzed with each batch associated with the TOC analyses and the method blanks were below the RLs. Four trip blanks were collected in total, two for the first phase of sediment sampling and another two for the intensive sediment sampling phase. Trip blanks sampled and analyzed for TOC had values less than the reporting limit. The laboratory followed a reporting limit (LOQ) of 500 mg/Kg instead of 100 mg/Kg as specified in QAPP, the reason being that the laboratory was not able to meet the low LOQ requirement. No further action was taken because the sample results were well above the LOQ. This modification will be added to the QAPP when the annual update is prepared.

2.2.2.1.3 Completeness

Completeness has been evaluated by comparing the total number of samples collected with the total number of samples with valid analytical data. No reported results for samples in this SDG have been rejected or invalidated. The completeness of the data results obtained from

the laboratory and reviewed for QA/QC is 100% compared to the minimum acceptance limit of 90%.

2.2.2.1.4 Field and Laboratory duplicates

As mentioned earlier, samples were collected and analyzed in duplicate for field duplicate QC purposes. The field duplicate results that have been received were within QAPP tolerance except for sample 11258-SE-1 which exceeded the tolerance limit and so was flagged "F". Samples were also analyzed in duplicate for laboratory duplicate QC purposes and all laboratory duplicate results were within QAPP tolerance. The frequency of field and laboratory duplicates that have been collected and results reviewed is 11.1 and 9%, respectively which is higher than the required frequency of 5%.

2.2.2.2 Polychlorinated Biphenyls in Sediment

The PCB analyses were performed using USEPA Method 1668A. All samples were collected and analyzed following the procedures and protocols outlined in the QAPP. All samples were analyzed within the holding times required by the method. Some sediment samples required dilution due to the high PCB concentrations and/or matrix interference.

2.2.2.2.1 Accuracy

Accuracy was evaluated using the %R results for the blank spike samples (BS), Limit of Quantification (LOQ) samples, and labeled compound spikes. The BS, LOQ and labeled compound spike recoveries %Rs were within method acceptance criteria, except for some congeners. All LOQ failures were flagged "Q", blank spike failures are flagged "S" and labeled

compound spike recovery failures are flagged "R". All associated congeners are flagged according to the QC failure type. .

2.2.2.2.2 Precision

Precision was evaluated using the Relative Percent Difference (%RPD) obtained from the field and laboratory duplicate sample results. The following samples were collected and analyzed in duplicate for field duplicate QC purposes: 11193-SE-1 (collected 5/2/08), 15301-SE-1 (collected 6/2/08), 11258-SE-1 (collected 6/2/08), T-014-SE-1 (collected 7/15/08), T-001-SE-1 (collected 7/10/08), W-002-SE-1 (collected 7/11/08), E-011-SE-1 (collected 7/9/08), E013-SE-1-A (collected 7/13/08), E013-SE-1-B (collected 7/13/08), and T009-SE-1 (collected 7/13/08).

All field duplicate results were within QAPP tolerance except for some congeners that were flagged for both the parent and field duplicate samples as "F". All associated congeners, that weren't previously flagged "J", "B" or "U" by the laboratory, were flagged as estimated ("F"). The following samples were analyzed in duplicate for laboratory duplicate QC purposes: 13338-SE-1, 11262-SE-1, C004-SE-1A, W001-SE-1, E014-SE-1, T009-SE-1. All laboratory duplicate results were within QAPP tolerance.

2.2.2.2.3 Representativeness

Representativeness expresses the degree to which sample data accurately and precisely represent actual site conditions. Representativeness has been evaluated by:

- Comparing the chain-of-custody procedures to those described in the QAPP
- Evaluating holding times
- Examining method blanks for contamination of samples during analysis.

The samples were collected and analyzed following the QAPP, COC procedures, and analytical procedures. All samples were prepared and analyzed within the holding times required for the analysis. All initial calibration criteria were met and all continuing calibration criteria (BS) were met, with the exception of those mentioned above.

All LOQ standard criteria were met, and there was at least one method blank analyzed with each batch associated with the PCB analyses in each data package. The method blanks had many PCBs of concern above the RLs and the sample results that were less than five times the amount found in the blank were flagged "B" for having blank contamination.

2.2.2.2.4 Completeness

Completeness has been evaluated by comparing the total number of samples collected with the total number of samples with valid analytical data. No reported results for samples in this SDG have been rejected or invalidated. The completeness of the data results obtained from the laboratory and QA/QC reviewed is 100% compared to the minimum acceptance limit of 90%.

2.2.2.2.5 Field and Laboratory duplicates

As mentioned earlier, parent and duplicate sample results were flagged if the congener was not within QAPP tolerance of %RPD <50. Samples were also analyzed in duplicate for laboratory duplicate QC purposes and all laboratory duplicate results were within QAPP tolerance. The frequency of field and laboratory duplicates for the results reviewed is 11.1 and 6.7% respectively which is higher than the required frequency (5%).

2.3 QA/QC for Fish Samples

2.3.1 Polychlorinated Biphenyls

All 53 samples have been analyzed but only 52 sample results have been reviewed for QA/QC. Information reviewed in the data packages included sample results; the laboratory quality control results; instrument calibrations; method blanks; case narrative and chain-of-custody forms. The verification protocol addressed the following parameters: method blanks, laboratory control spike recoveries, recoveries of labeled compounds (internal standards), continuing calibration verifications, laboratory and field duplicate sample percent reproducibility (%RPD), percent recovery (%R), and Level of Quantification (LOQ) standard results. All samples collected were prepared and analyzed within the holding times required by the method.

2.3.1.1 Accuracy

Accuracy was evaluated using the percent recovery (%R) results from the blank spike samples (BS), Limit of Quantification (LOQ) samples, and labeled compound spikes. The BS, LOQ Check Standard, and labeled compound spike recoveries %Rs were within method acceptance criteria, except for some of congener groups. All LOQ failures were flagged “Q”, blank spike failures were flagged “S” and labeled compound spike recovery failures were flagged “R”. All associated congeners were flagged according to the QC failure type.

2.3.1.2 Precision

Precision was evaluated using the Relative Percent Difference (%RPD) obtained from the parent/duplicate sample results. The following samples were collected and analyzed in duplicate for field duplicate QC purposes: 15979-F1-Tissue (collected 4/30/08), 13363-F1-1-Tissue (collected 5/29/08), 15936-F1-1-Tissue (collected 4/30/08), and 11258-F1-1-Tissue (collected 5/30/08). All field duplicate results were within QAPP tolerance except for some congeners. The sample was flagged if the %RPD was not within QAPP tolerance. All associated congeners in the parent and field duplicate samples that weren't previously flagged "J", "B" or "U" by the laboratory, were flagged as estimated ("F") if the %RPD was out of tolerance limits. Laboratory duplicates results were within QAPP tolerance except for some of the congeners and the appropriate flag was applied when the result failed the %RPD criterion.

2.3.1.3 Representativeness

Representativeness expresses the degree to which sample data accurately and precisely represents actual site conditions. Representativeness has been evaluated by:

- Comparing the chain-of-custody procedures to those described in the QAPP
- Evaluating holding times
- Examining method blanks for contamination of samples during analysis.

The samples were collected and analyzed following the QAPP, COC procedures and analytical procedures. All samples were prepared and analyzed with the holding times required for the analysis. All initial calibration criteria, continuing calibration criteria (BS), and LOQ standard criteria were met. There was at least one method blank analyzed with each batch

associated with the PCB analyses in each batch. The method blanks had many PCBs of concern above the RLs and the sample results that were less than five (5) times the amount found in the blank were "B" flagged for having blank contamination. Three trip blanks were prepared in the all media sampling phase but the results have not been received yet.

2.3.1.4 Completeness

Completeness has been evaluated by comparing the total number of samples collected with the total number of samples with valid analytical data. No reported results for samples have been rejected or invalidated. The completeness of the data results obtained from the laboratory and reviewed for QA/QC was 100% compared to the minimum acceptance limit of 90%.

2.3.1.5 Field and laboratory duplicates

As mentioned earlier, samples were collected and analyzed in duplicate for field and laboratory duplicate QC purposes. The frequency of field and laboratory duplicates that have been collected and results reviewed is 8.3 and 7.7% respectively which was higher than the required frequency of 5%.

2.4 Summary

The results received thus far have been reviewed for QA/QC purposes. Table 2.9 lists the data received and reviewed to date and also lists the percent of samples that have been flagged. As can be seen from Table 2.9, the majority of the flags were associated with the PCB results in fish and water.

Table 2.9 Percentage sample results reviewed and flagged for QA/QC criteria

Analysis	Samples QA/QC reviewed/Samples collected*	Percentage results flagged for			
		U	B	J	H,I,F,L,S,Q,D,R
TPH-Water	41/41	2.40%	0%	0%	0%
DOC-Water	41/41	0%	0%	0%	0%
TSS-Water	41/41	2.40%	0%	0%	19.50%
TPH-Sediment	95/95	96%	0%	1.10%	0%
TOC-Sediment	95/95	0%	0%	0%	2.10%
PCB (209 Congeners)[¶] - Water	82/82	34%	1.90%	28.70%	51.50%
PCB (209 Congeners)[¶]- Fish	49/50	25.60%	3.10%	9.90%	52.50%
PCB (209 Congeners) [¶] -Sediment	95/95	19.50%	0.04%	14.30%	7.40%

*Samples do not include trip blanks and equipment rinse blanks

[¶] Flagging Percentage based on individual congeners in the case of PCB.

3. WATER, SEDIMENT AND TISSUE RESULTS

This section provides a summary of the data that has been received from the 2008 sampling in the HSC. The data include field water quality parameters (pH, salinity, conductivity and water temperature), characteristics of water (TSS, TPH, POC and DOC), sediment characteristics (TPH, Grain Size, TOC, Moisture Content), and lipid and moisture content analysis for tissue samples.

3.1 In-stream Water Quality

Appendix A provides a summary of field parameters measured during in-channel water sampling activities. The pH, salinity, and conductivity averages by station are shown in Figures 3.1, 3.2 and 3.3, respectively. The field parameters summarized by segment (see Figure 3.4 for segment numbers and locations) are shown in Figures 3.5, 3.6 and 3.7 for pH, salinity, and conductivity, respectively. From Figure 3.1, it can be seen that the pH was in the range of 7-8.5 in most stations, except for station 11171, Vince Bayou at W. Ellaine St, which had a pH value of 9.74 (complete range 9.26 – 10.26). The data in Appendix A for station 11171 indicate that the total depth is 0.1 ft for the station, so the pH may ne related to benthic algae present in the shallow, sunny, warm, and stagnant water. A pH in that range indicates dense algae and algal productivity that removes CO2 from the water column and affects the natural buffering capacity of the water causing the pH to be elevated during daylight hours. Except for station 11171, the pH was the same regardless of the segment or depth for stations where multiple depths were sampled for pH.

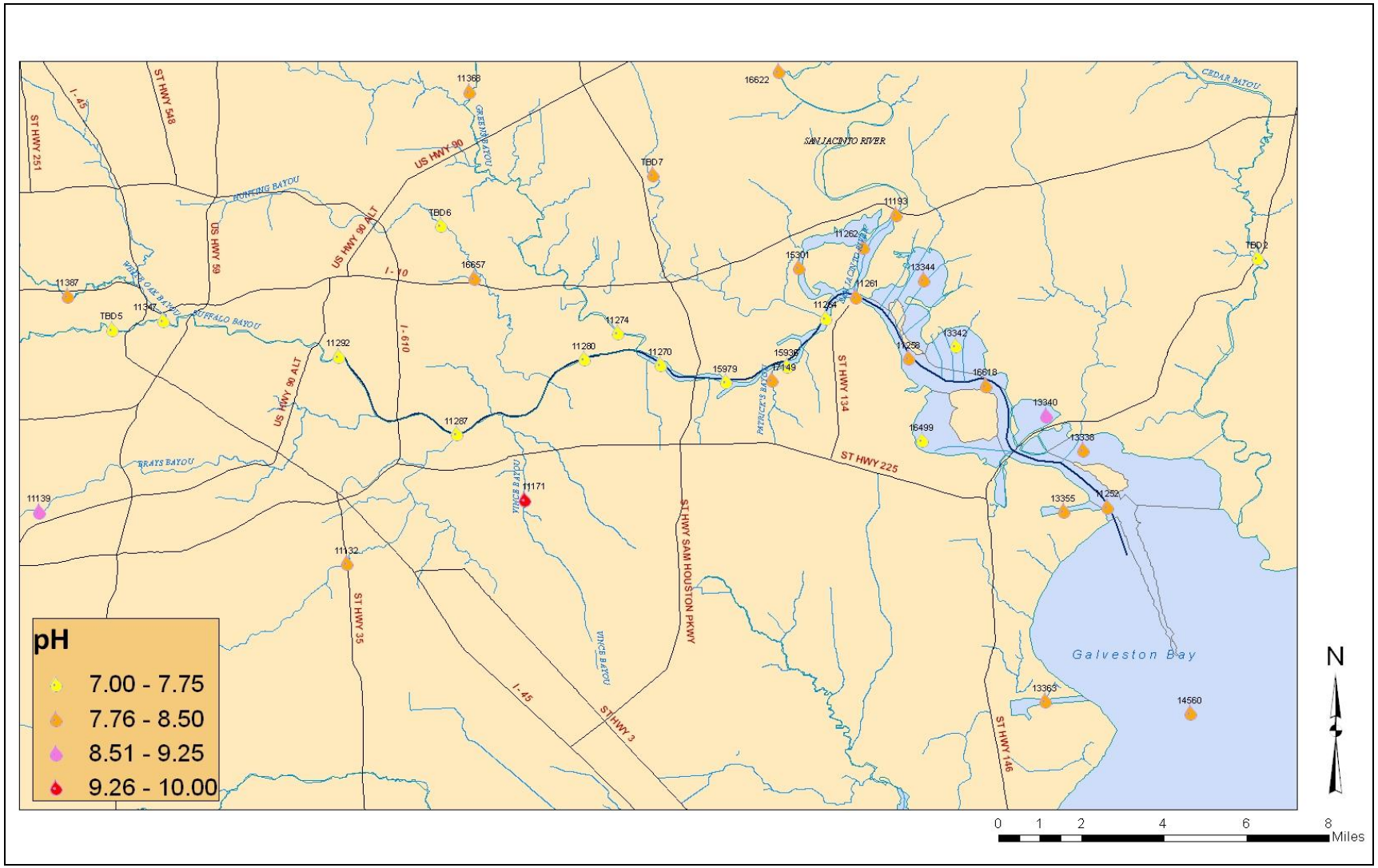


Figure 3.1 Depth and time averaged pH readings for water samples in Spring-Summer 2008 sampling

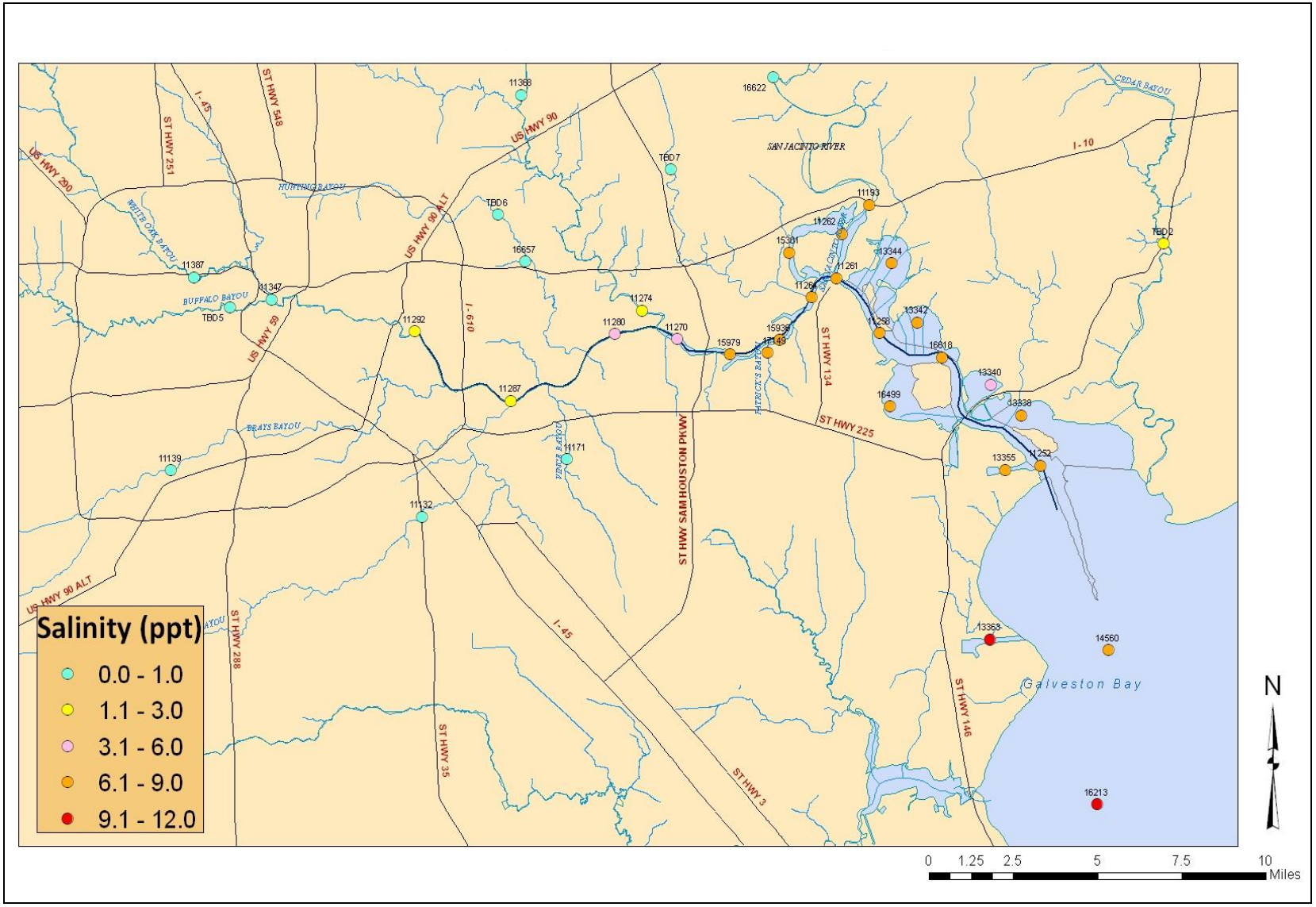


Figure 3.2 Depth and time averaged salinity measurements in part per thousand for the Spring-Summer 2008 water sampling

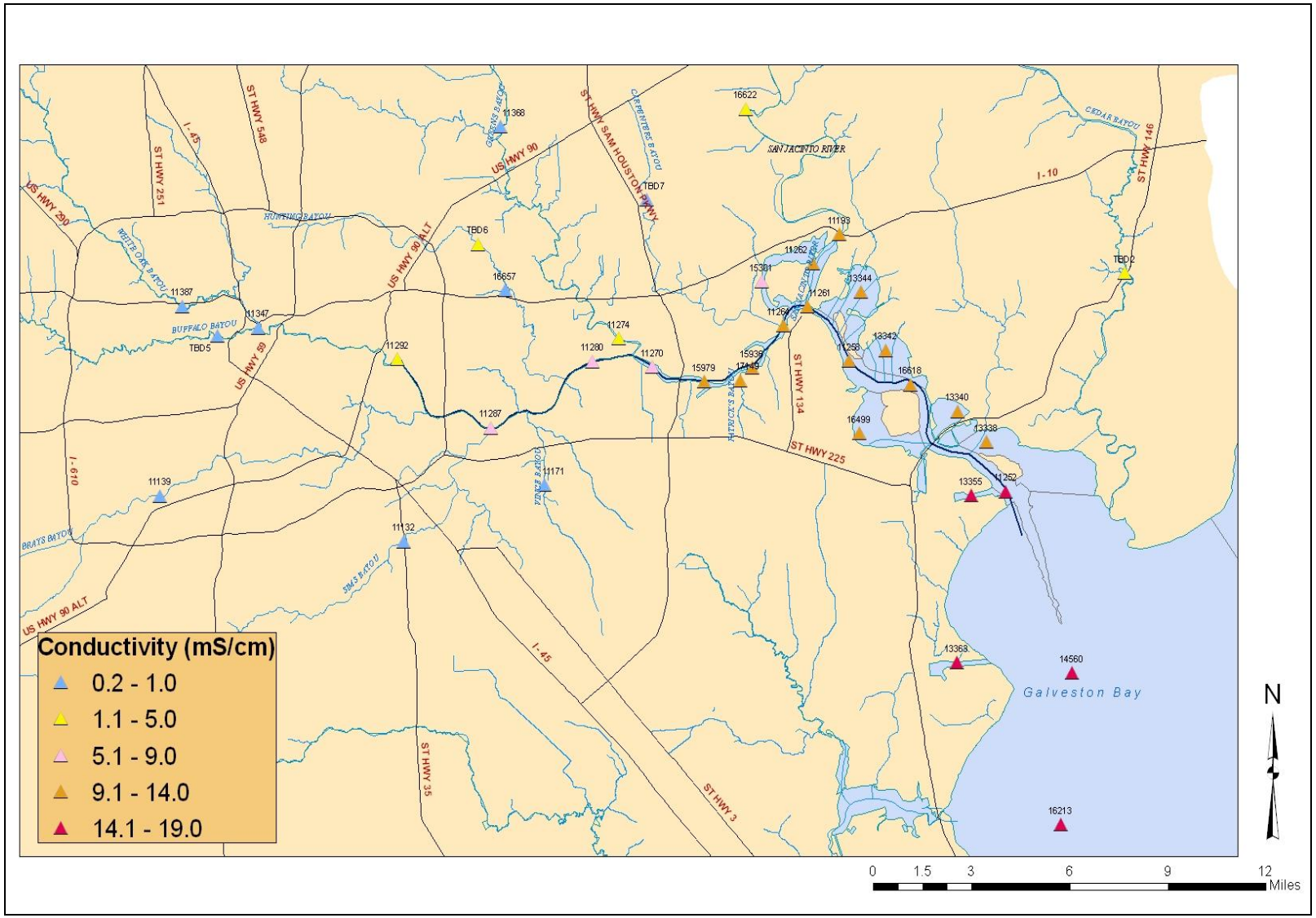


Figure 3.3 Depth and time averaged conductivity measurements from Spring-Summer 2008 water sampling

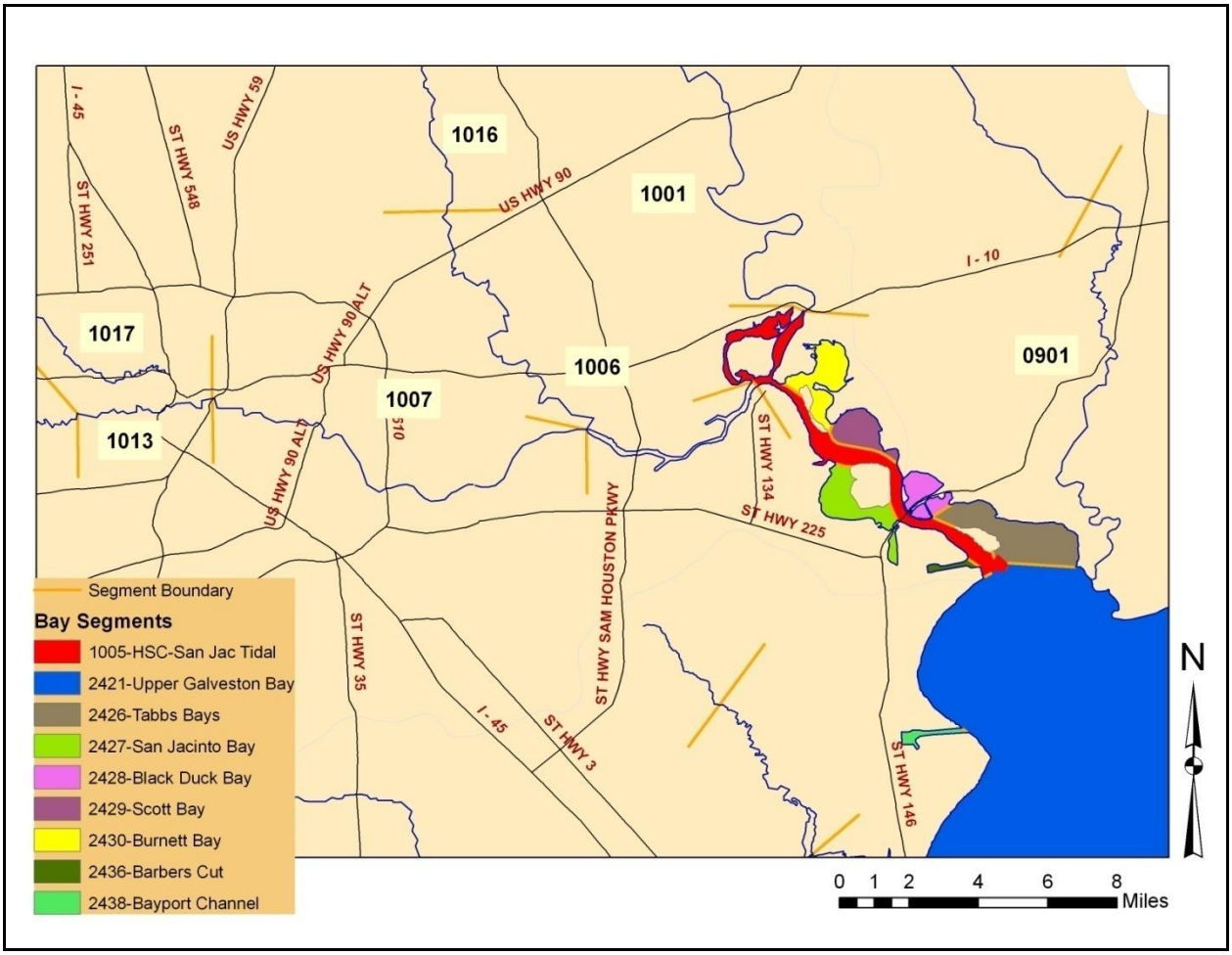


Figure 3.4 Houston Ship Channel water quality segments

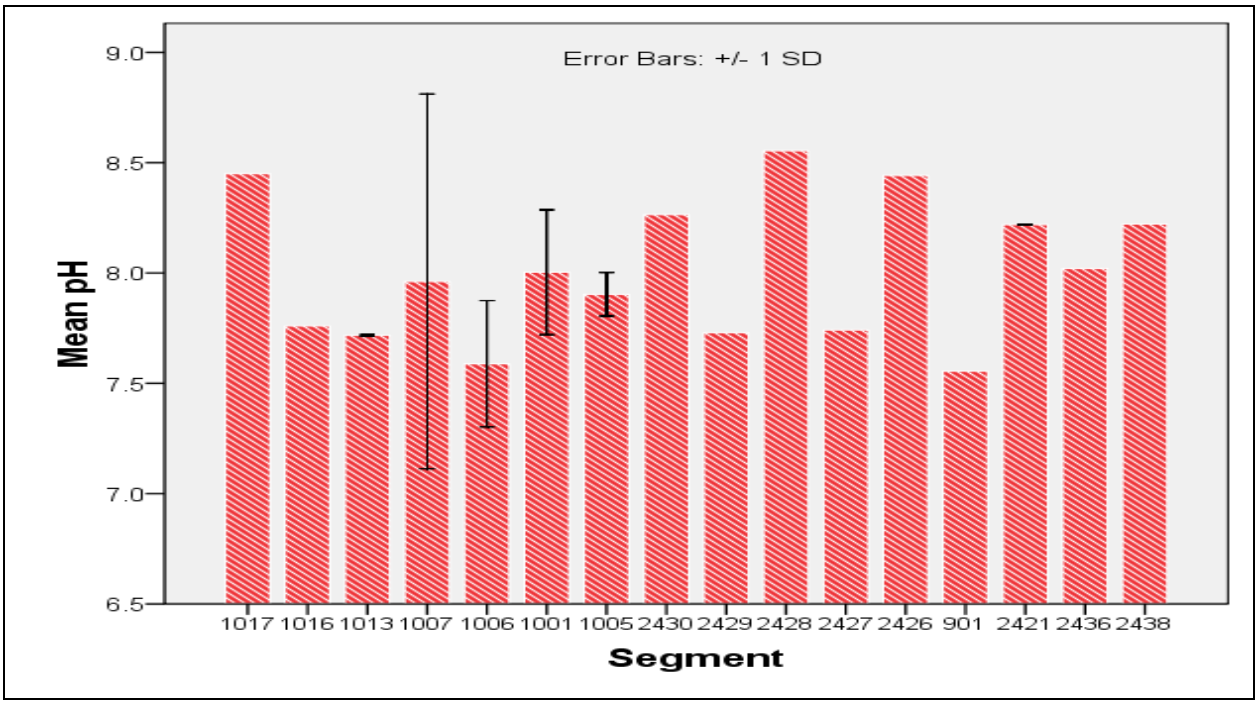


Figure 3.5 Depth and time averaged pH measurements averaged by segment

As expected, the salinity and conductivity were relatively low in the tributaries, while both salinity and conductivity increased with the approach of the channel to Galveston Bay understandably due to tidal influence (Figures 3.2 and 3.3). The increase in salinity can easily be observed from the salinity averages by station and segment shown in Figures 3.2 and 3.6 respectively. There was thermal variation with depth in some stations, and this trend was almost always a decrease in temperature with depth (average temperature slope -0.064˚C/ft). No appreciable and consistent trends were observed though the effect of salt wedge intrusion indicating the presence of salinity stratification was observed in some sites. The conductivity averages shown in Figures 3.3 and 3.7 indicate low conductivity values in fresh waters (tributaries) and an increase in the Main channel due to tidal influence and the influence of salinity.

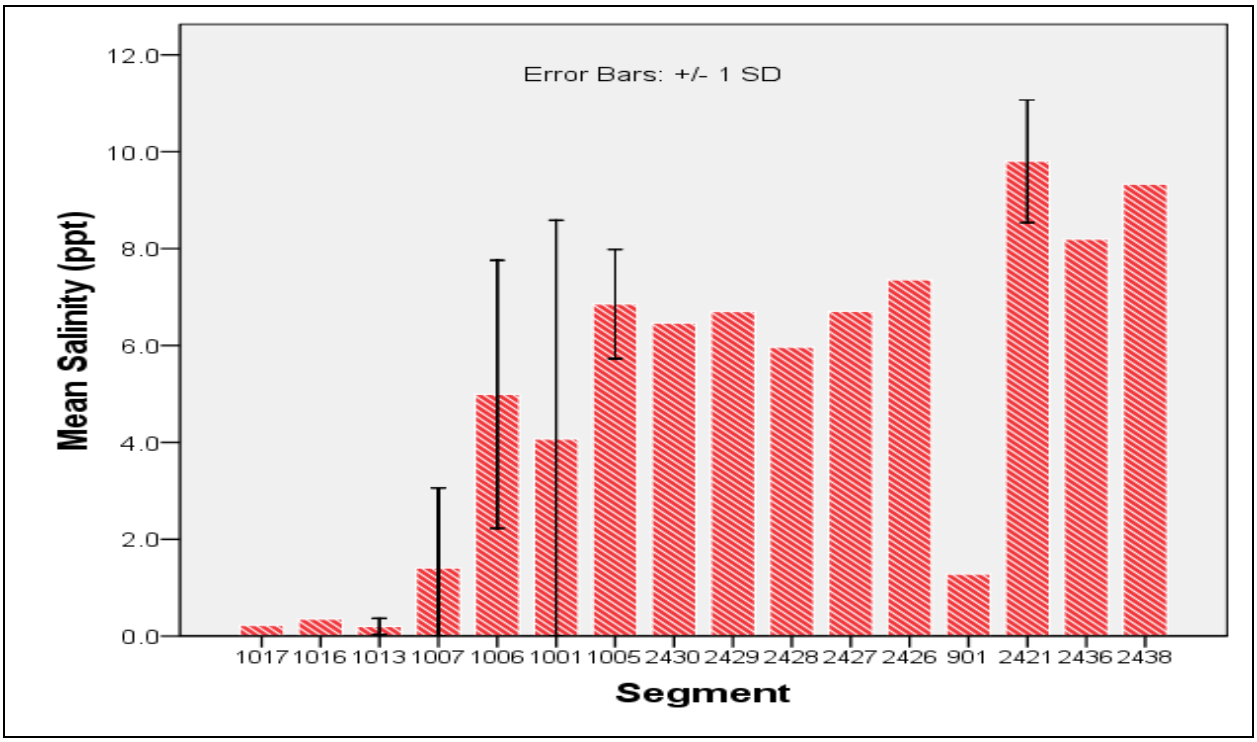


Figure 3.6 Average salinity values per segment in parts per thousand

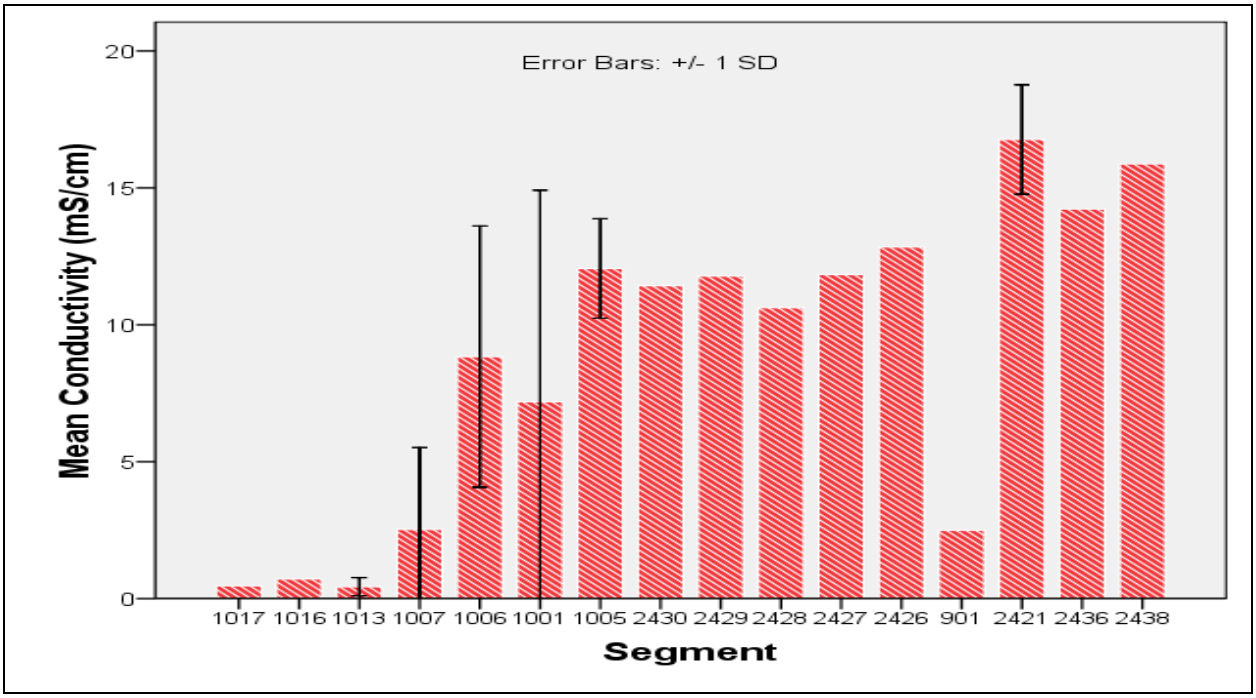


Figure 3.7 Average specific conductivity values per segment in mS/cm

Other laboratory based measures of water quality taken were TPH, DOC, TSS, and POC. Table 3.1 summarizes the water quality parameters (TSS, DOC, POC and TPH) by station. Figures 3.8, 3.9, 3.10, and 3.11 show spatial locations of the TPH, DOC, POC and TSS values, while Figures 3.12, 3.13, 3.14 and 3.15 show TPH, DOC, POC and TSS values averaged on a segment basis. The TPH results were non-detect in every sample except for station 11368, Greens Bayou at Brock Park. It was the intent in the sampling design to try and discover if some link existed between TPH concentrations and PCB concentrations. Since nearly all TPH analyses were non-detect, this link (at least in water) either does not exist or exists at lower TPH concentrations than what was tested. DOC had a pattern that appears to be almost opposite of the salinity pattern described previously. The farther out towards the Bay and the less tidal, the lower the DOC. The POC measurements were not made for 3 stations (11171, 11270 and 11287) due to insufficient volume of water sample for filtration. The segments along the HSC did not show any pattern for POC. TSS values, however, generally increased with flow, which is to say that the farther downstream, the higher 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 TPH measurements by station

Station ID	DOC (mg/L)	TPH (mg/L)	TSS (mg/L)	POC (mg/L)
11115	7.9	< 5.0	37	1.49
11132	8.75	< 5.0	74	4.44
11139	6.03	< 5.0	11	0.85
11171	6.69	< 5.0	0	na
11193	2.54	< 5.0	84	0.58
11252	1.98	< 5.0	106	1.40
11258	3.06	< 5.0	70	1.39
11261	2.55	< 5.0	71	2.38
11262[a]	2.56	< 5.0	43.5	1.39
11264	2.49	< 5.0	53	0.88
11270	3.19	< 5.0	32	na
11274	4.48	< 5.0	40	0.91
11280	3.16	< 5.0	35	0.72
11287	5.21	< 5.0	28	na
11292	7.56	< 5.0	22	0.09
11347	6.31	< 5.0	18	1.07
11368	7.96	13.67	24	1.01
11387	6.47	< 5.0	18	1.09
13338[a]	2.07	< 5.0	128.5	2.44
13340	3.38	< 5.0	102	3.23
13342	3.23	< 5.0	89	1.68
13344[a]	3.325	< 5.0	74	2.97
13355	1.83	< 5.0	95	1.00
13363[a]	1.875	< 5.0	50	1.89
14560	1.59	< 5.0	81	1.50
15301	3.01	< 5.0	50	1.76
15936	2.73	< 5.0	22	0.82

Table 3.1 TSS, DOC and TPH measurements by station

Station ID	DOC (mg/L)	TPH (mg/L)	TSS (mg/L)	POC (mg/L)
15979	2.62	< 5.0	21	0.51
16213	1.41	< 5.0	144	2.42
16499	2.27	< 5.0	83	1.01
16618	2.96	< 5.0	92	1.02
16622	9.31	< 5.0	24	2.54
16657	7.75	< 5.0	4	0.43
17149	2.06	< 5.0	90	2.36
TBD5	5.41	< 5.0	39	1.40
TBD6	6.22	< 5.0	20	1.17
TBD7	7.94	< 5.0	94	2.09

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

na Samples could not be analyzed due to insufficient volume for filtration

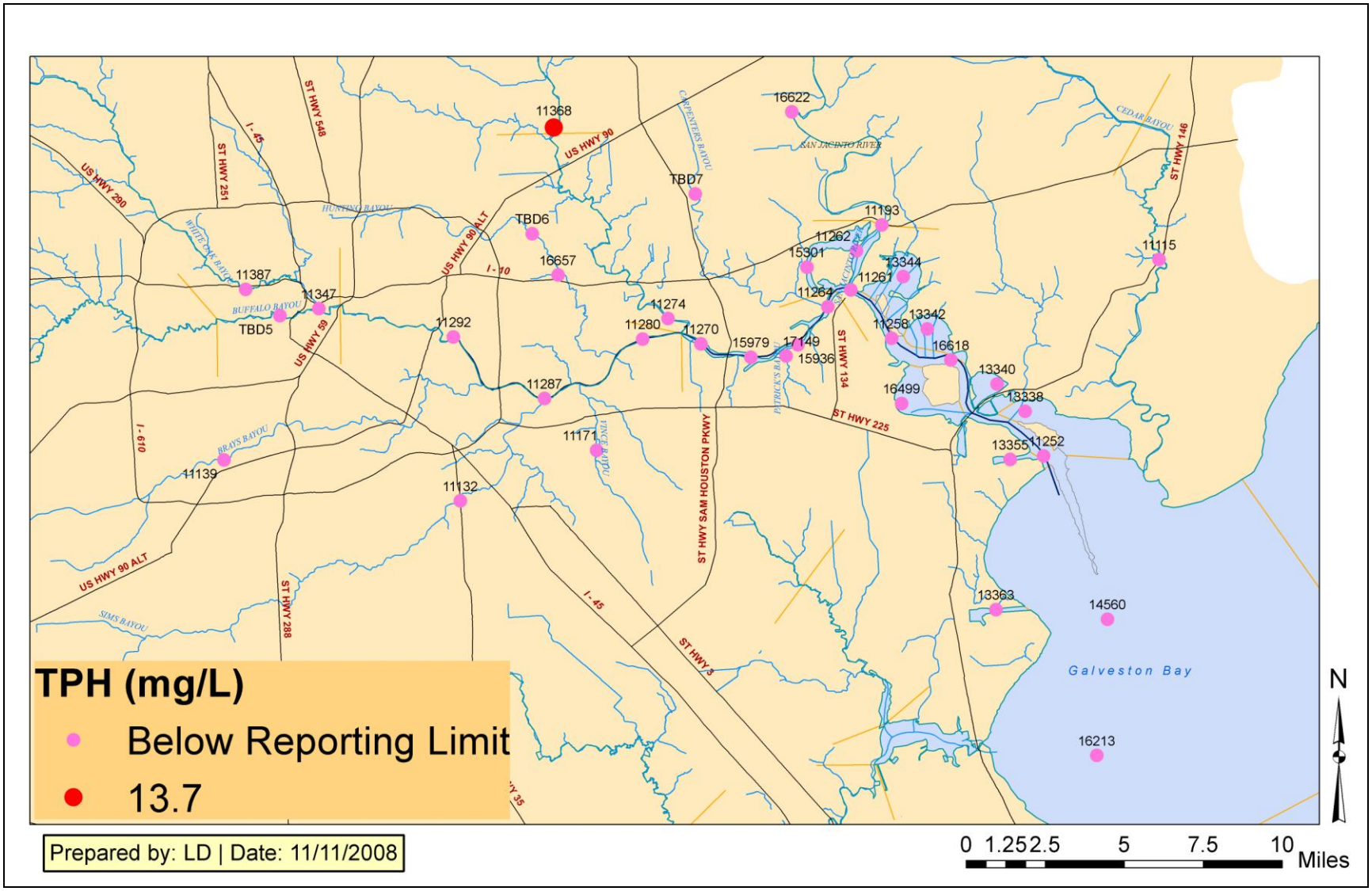


Figure 3.8 Total TPH measurements for Spring-Summer 2008 water samples

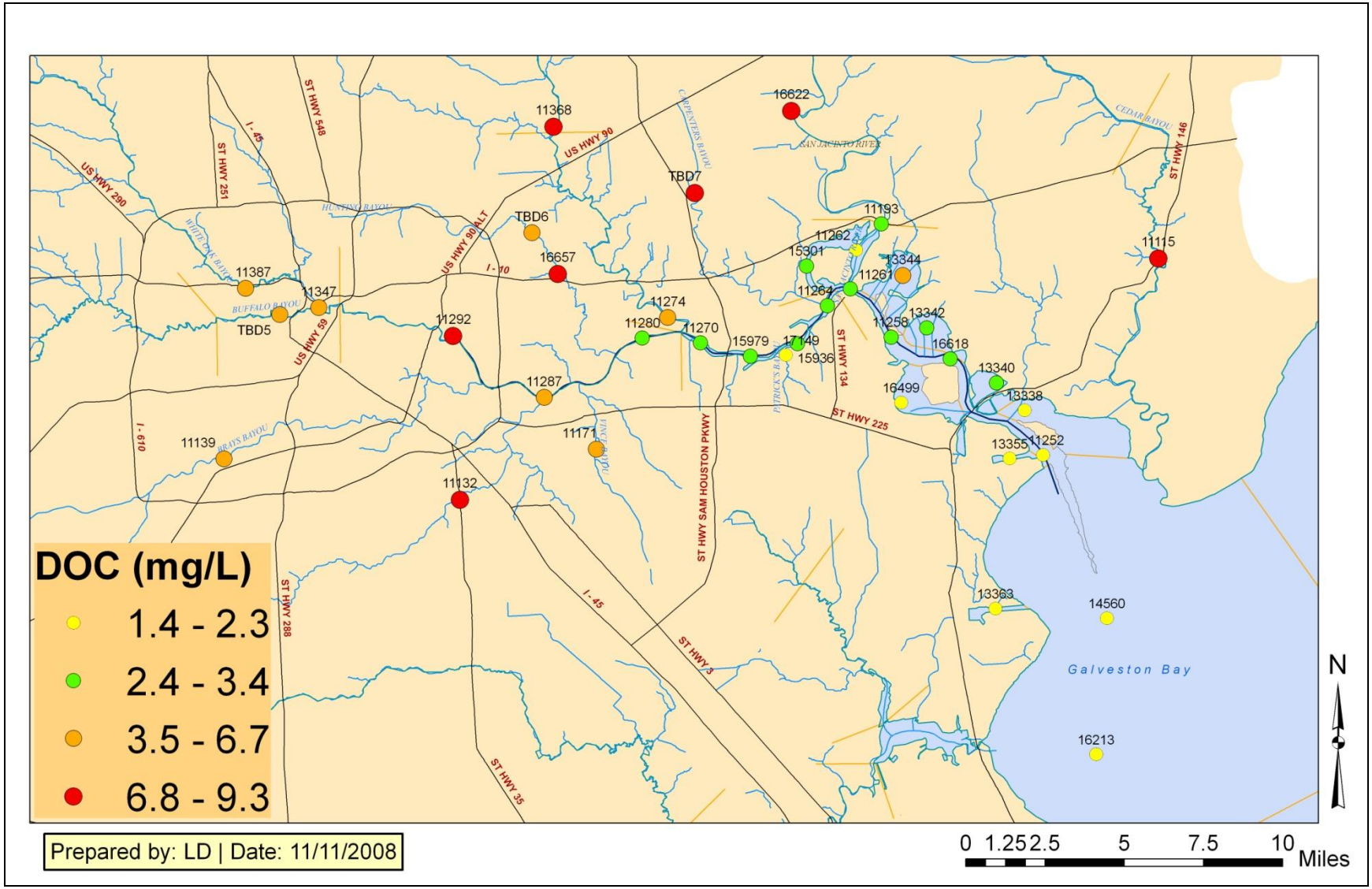


Figure 3.9 DOC measurement in water samples collected in Spring-Summer 2008

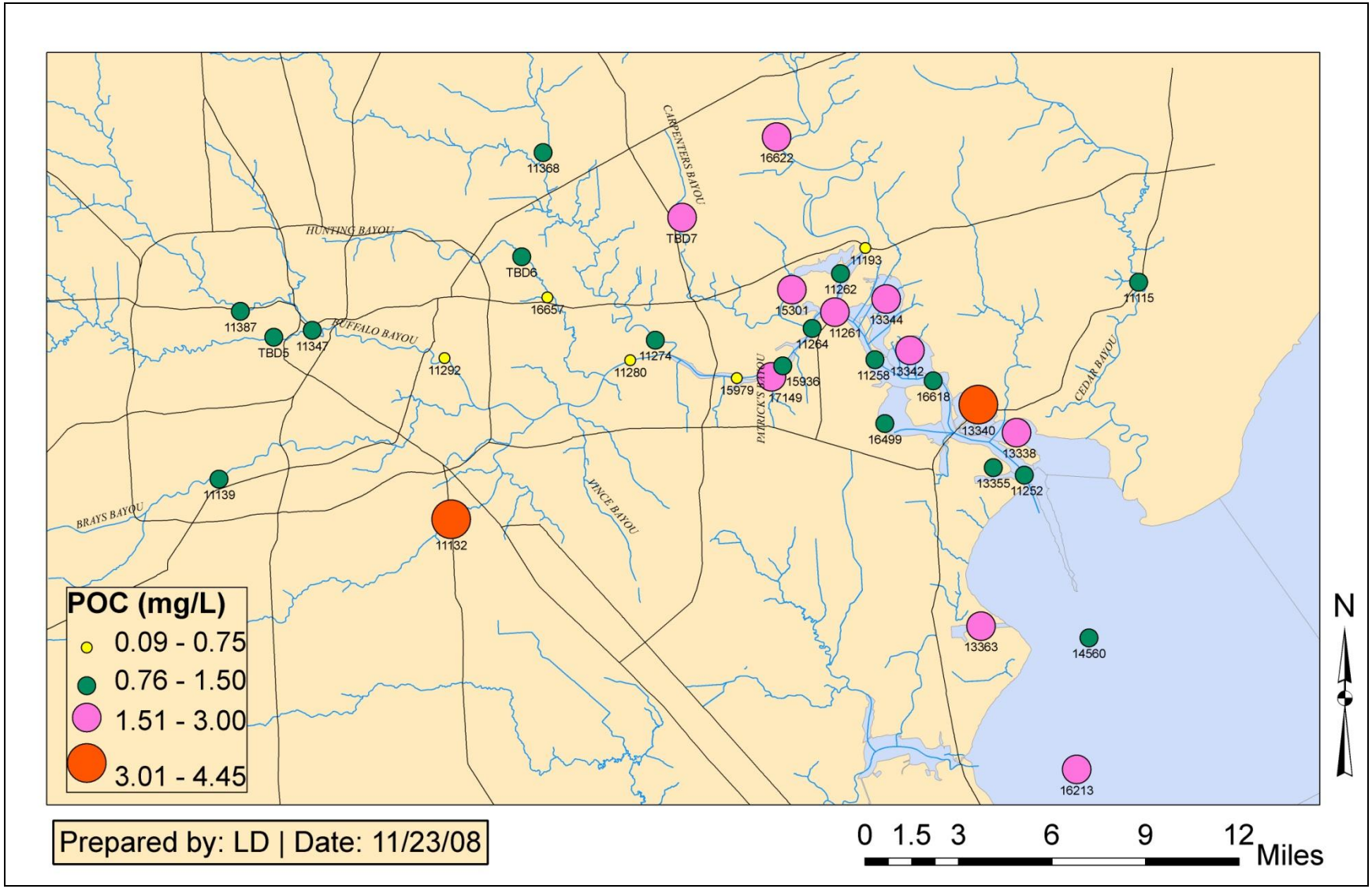


Figure 3.10 POC measurement in water samples collected in Spring-Summer 2008

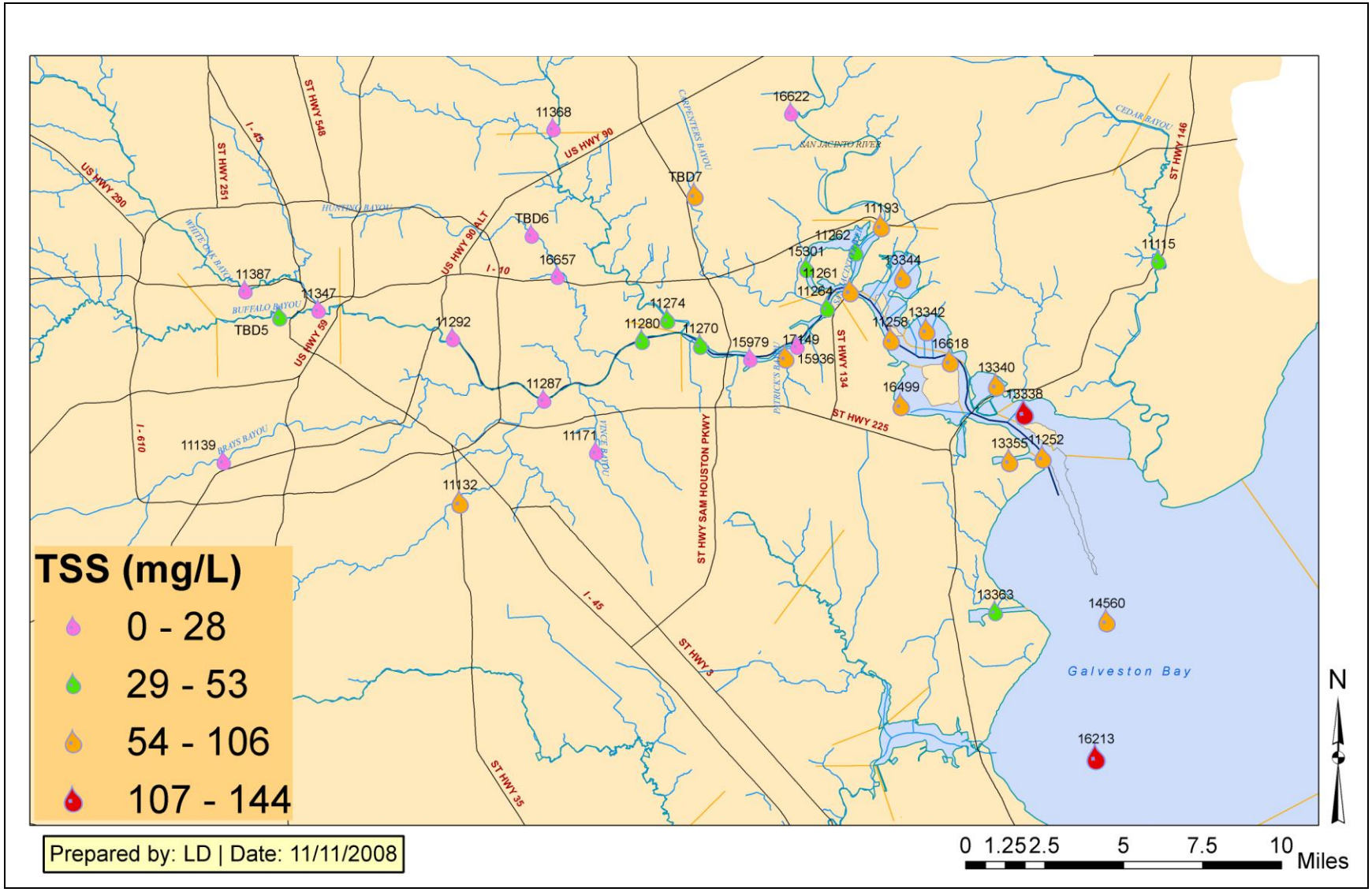
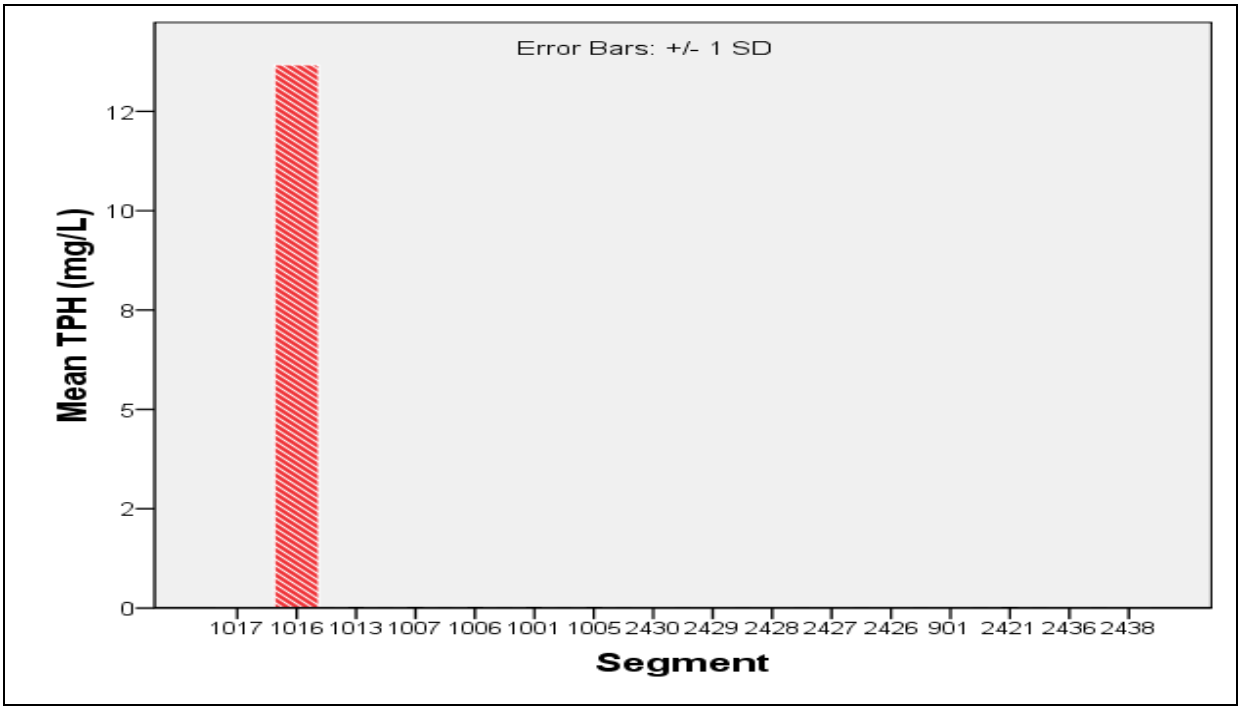


Figure 3.11 TSS measurements in water samples collected in Spring-Summer 2008



* Data for all segments were non-detect

Figure 3.12 Average total TPH values per segment in water

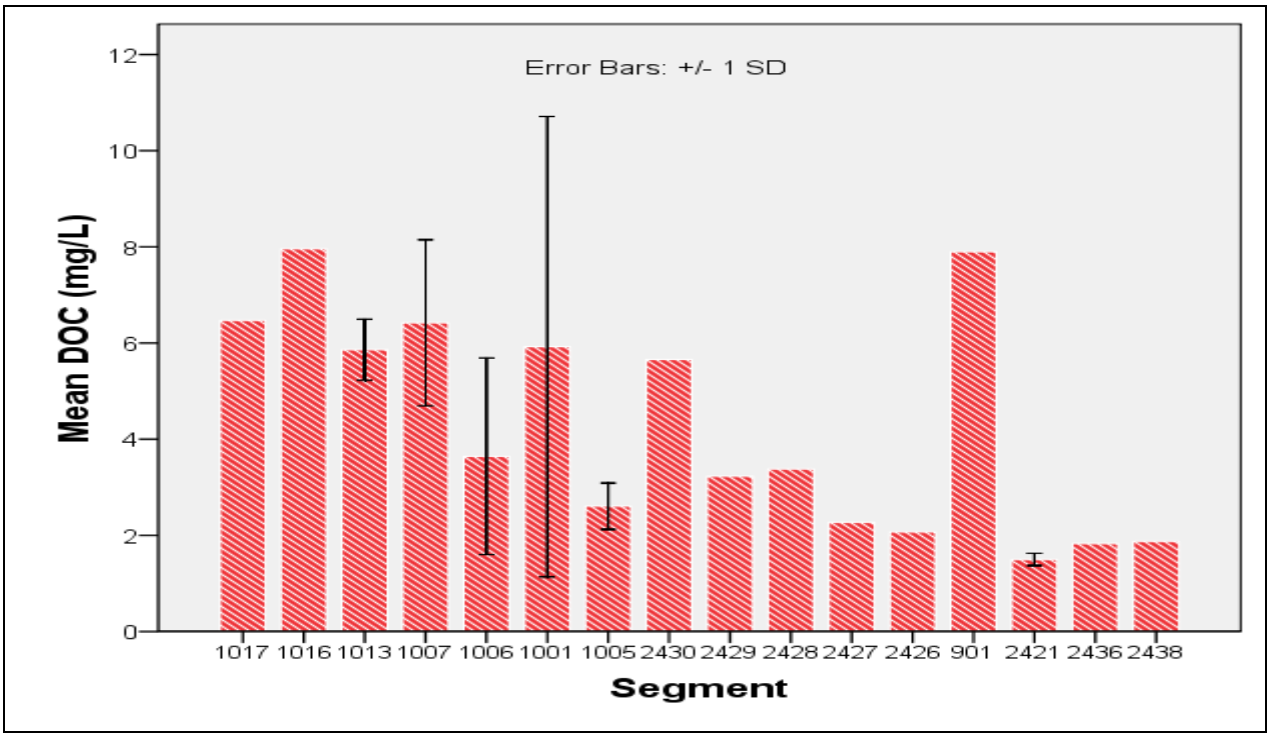


Figure 3.13 Average DOC measurements in water samples per segment

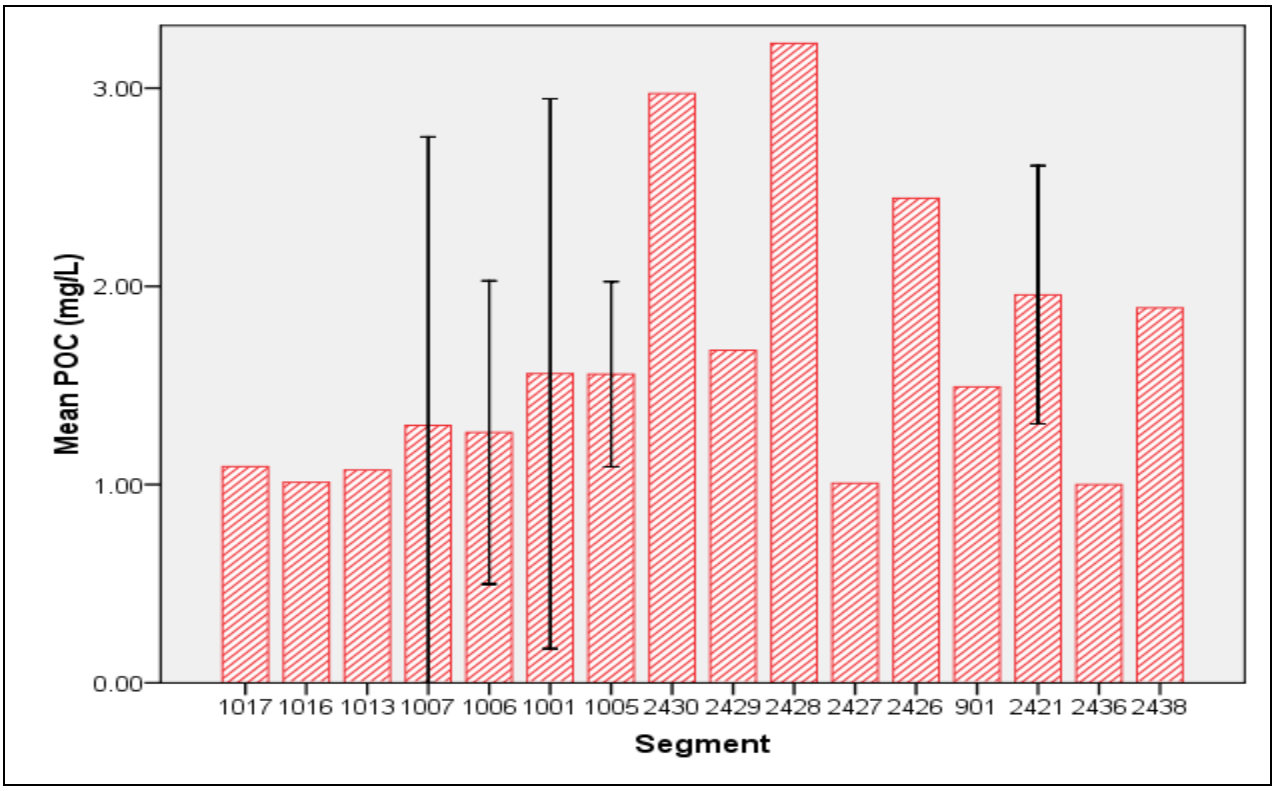


Figure 3.14 Average POC measurements in water samples per segment

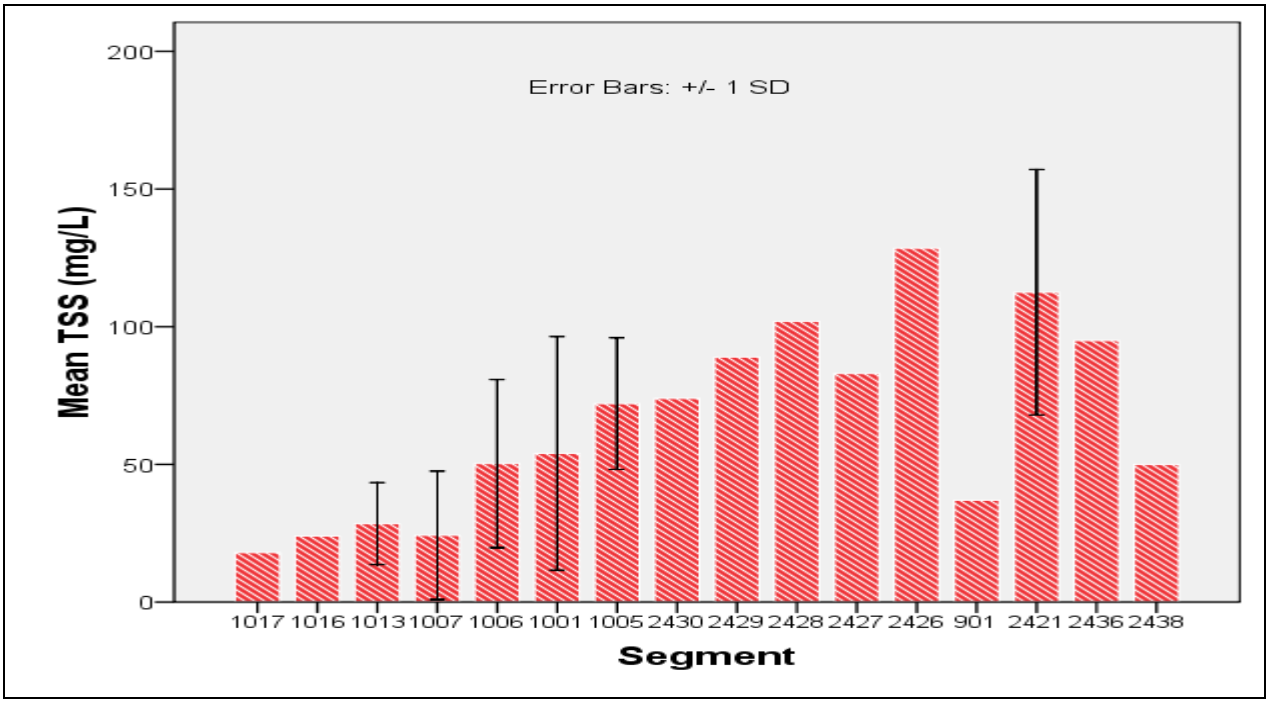


Figure 3.15 Average TSS values in water samples per segment

3.2 In-channel Sediment

Sediment sampling, in addition to PCBs, measured Grain Size, Solids Content, TPH, and TOC (Figures 3.16, 3.17, 3.18, and 3.19, respectively). Table 3.2 summarizes the sediment quality parameters (TOC, TPH 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 a few exceptions that have higher sand fine content. The higher sand content locations are 11347, 11292, 11262, 16622, 11258, and 16499. These locations are in the upper reaches of Buffalo Bayou, San Jacinto River (SJR) and San Jacinto River Tidal, and the Side Bay along the lower reaches of the HSC. Most main channel sediments were smaller in size and more cohesive. TPH results were high in three locations all in the upper bayou reaches of SJR and Buffalo Bayou, but all other locations registered non-detect for TPH. TOC along the HSC did not show any significant spatial pattern and was in the range of 1400-22000 mg/Kg (0.12-2.2%). Figure 3.20 compares the TOC in each segment and it can be seen that there is no considerable difference in TOC along the segments with the exception of segment 1013, Buffalo Bayou.

Table 3.2 Sediment quality measurements by station

Station ID	Moisture (%)	TOC (mg/Kg)	TPH (mg/Kg)
13338	57	9900	<50
11287	53	16000	<50
11274	40	10000	<50
11270	54	12000	<50
15979	48	8400	<50
16622	19	2100	95.3
11280	62	17000	<50
11264	58	10000	<50
11193[a]	72	19000	<50
16213	62	12000	<50
11252	63	11000	<50
14560	57	6000	<50
13363	54	9100	<50
16499	48	8700	<50
16618	74	19000	<50
13355	73	14000	<50
13342	65	13000	<50
11262	16	1400	<50
11261	68	15000	<50
11132	51	12000	<50
11258[a]	53	7700	<50
15301[a]	60	18500	<50
13344	49	8900	<50
11347	17	2600	52.7
11292	50	22000	138

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

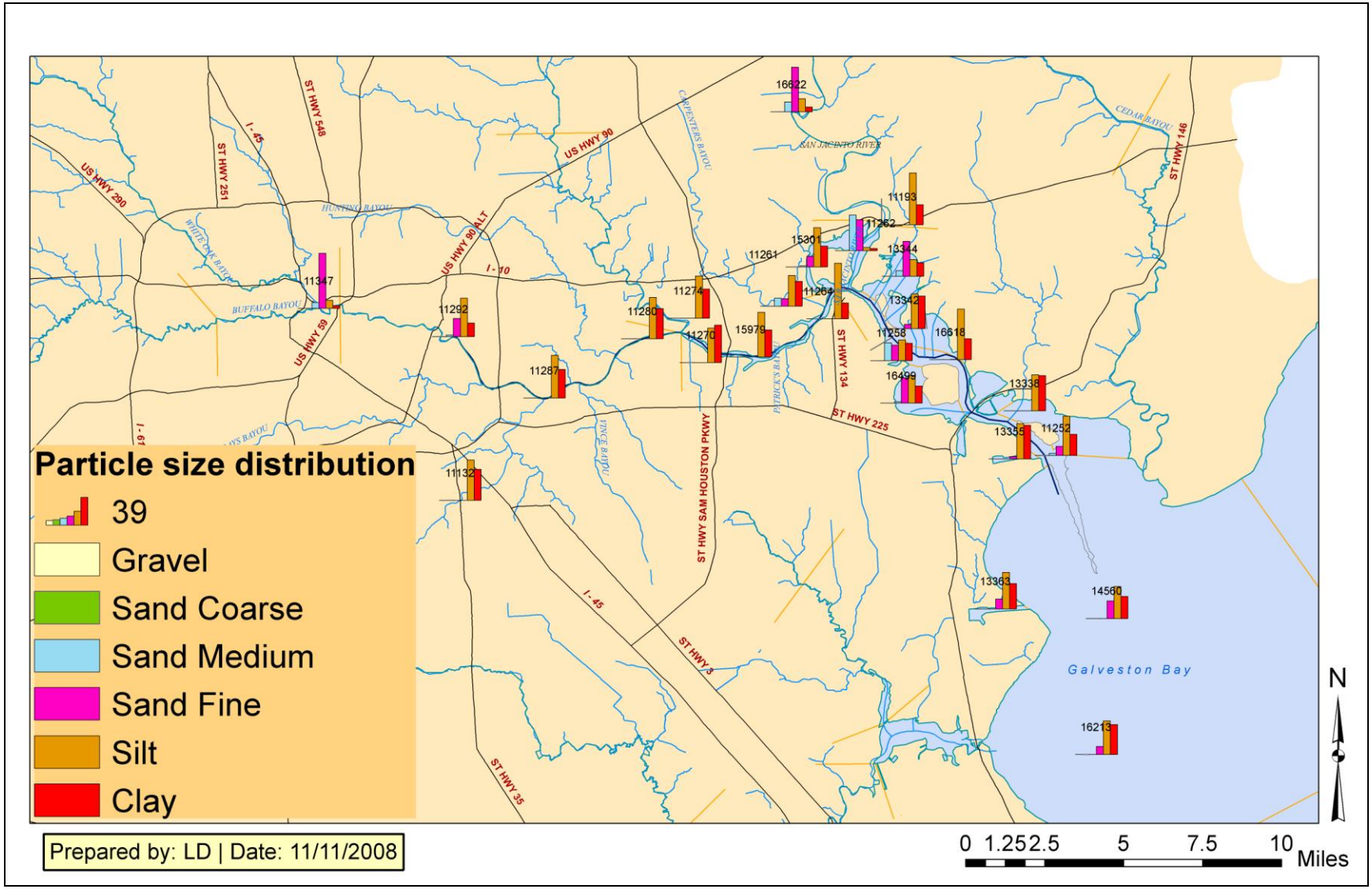


Figure 3.16 Grain size distributions in sediment samples collected in Spring 2008

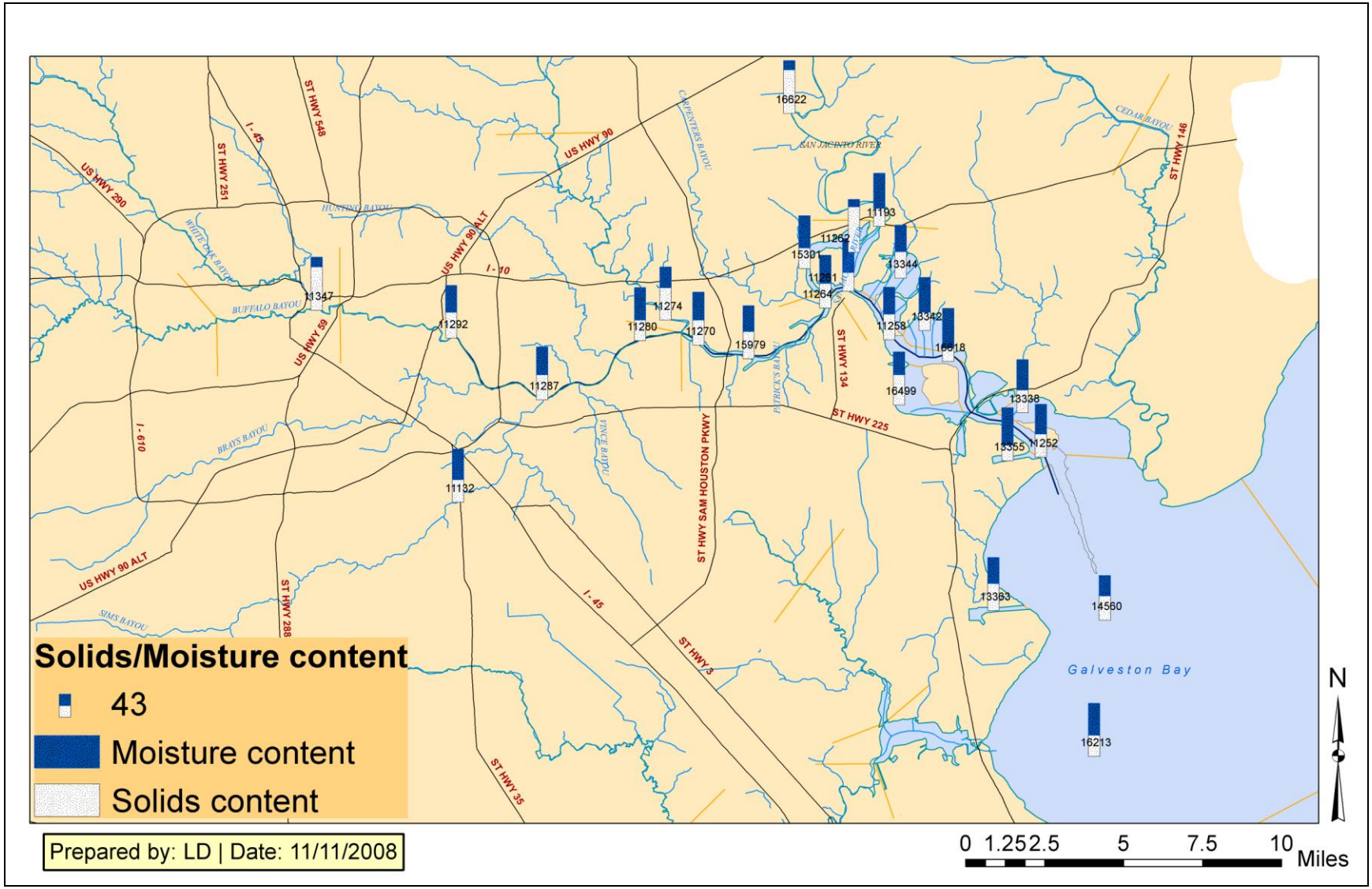


Figure 3.17 Moisture content in sediment samples collected in Spring 2008

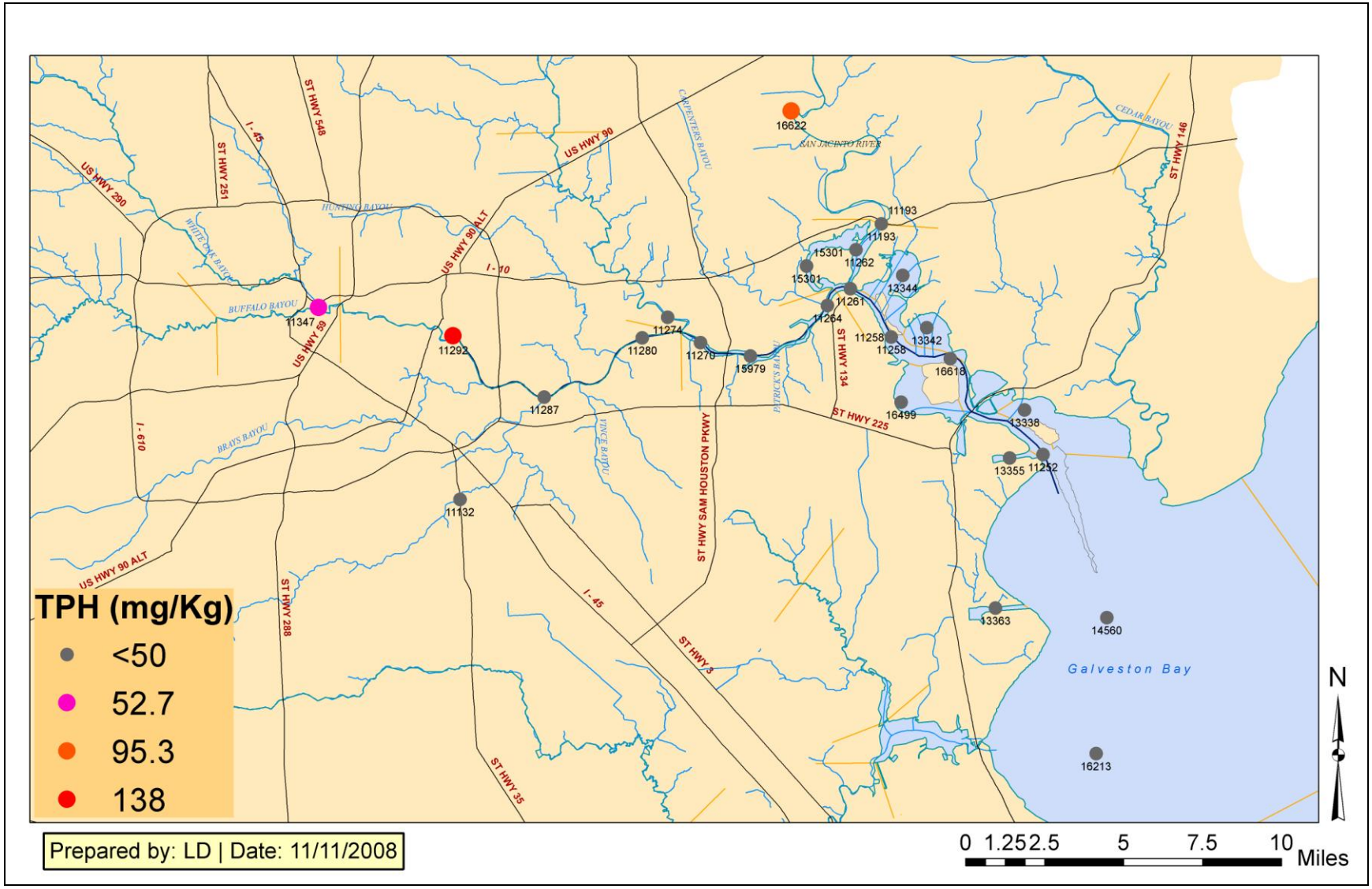


Figure 3.18 Total TPH in sediment samples collected in Spring 2008

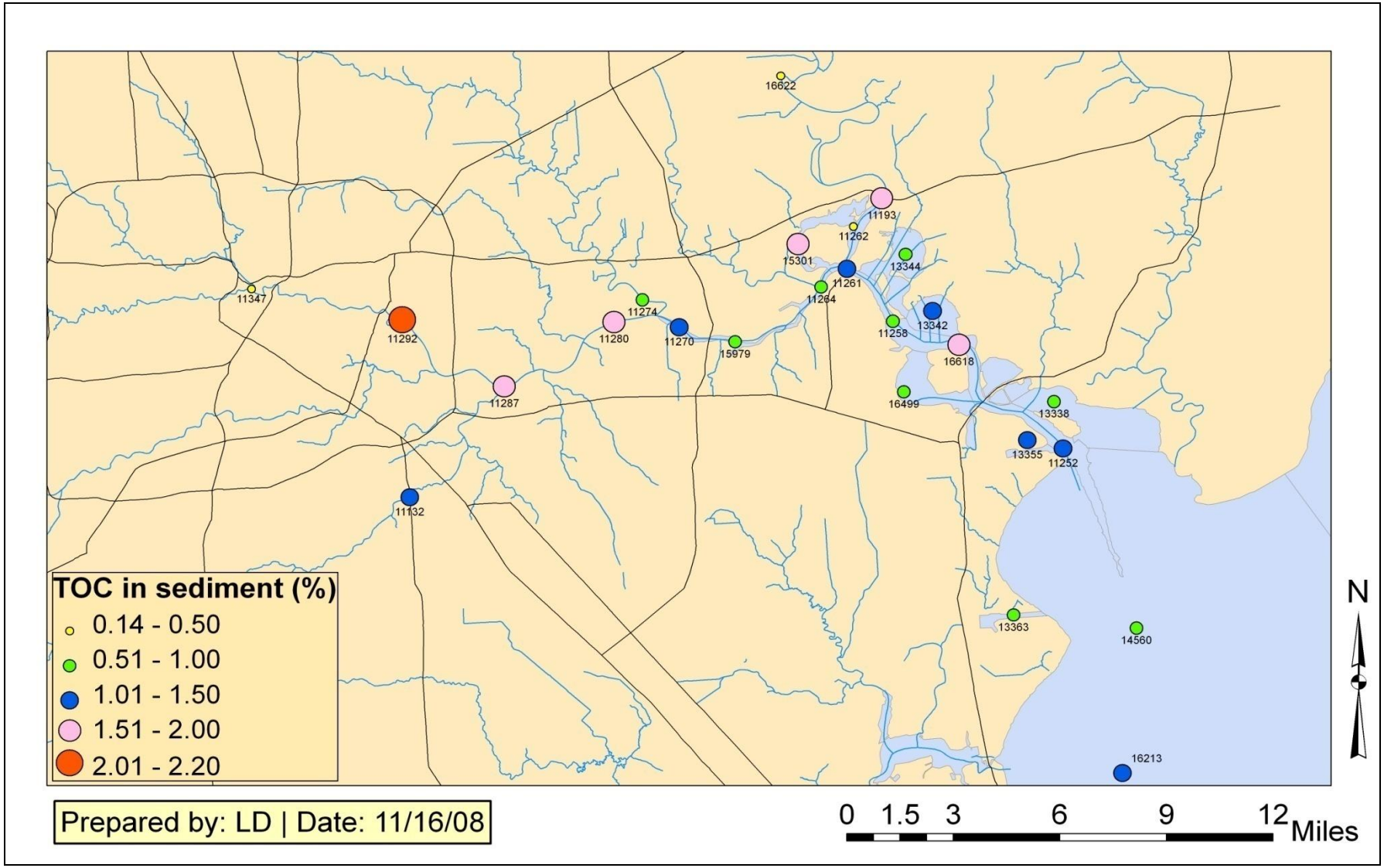


Figure 3.19 TOC in sediment samples collected in Spring 2008

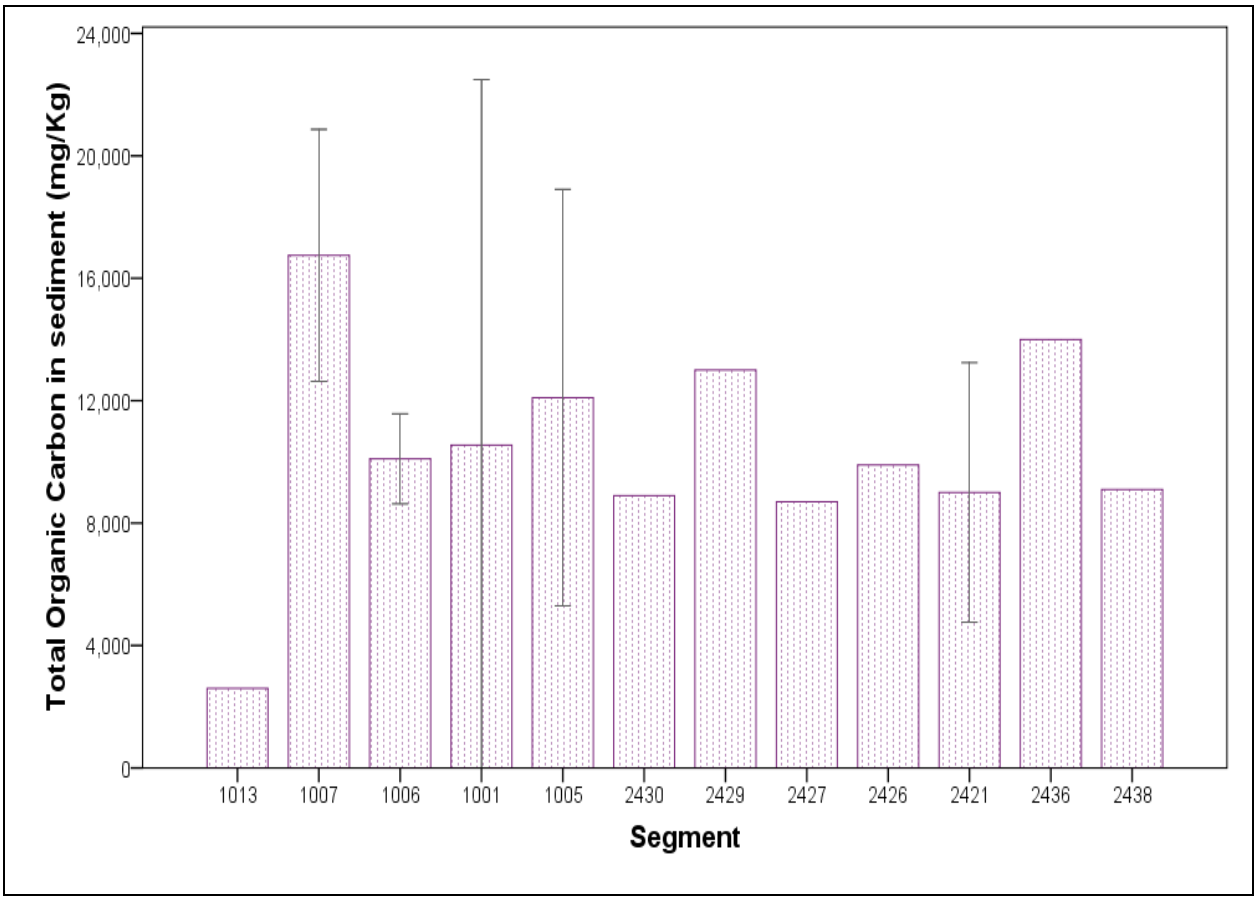


Figure 3.20 Average TOC values in sediment samples per segment

3.3 Intensive sediment sampling

Appendix B provides a summary of field parameters measured during in-channel intensive sediment sampling activities. The pH, salinity, and conductivity averages by station are shown in Figures 3.21, 3.22 and 3.23, respectively. From Figure 3.21 it can be seen that the pH was in the range of 7-8.5. As expected, the salinity and conductivity were relatively low in the tributaries and downstream of the HSC, while both salinity and conductivity increased with the approach of the channel to Galveston Bay understandably due to tidal influence (Figures 3.22 and 3.23).

Intensive sediment sampling, in addition to PCBs, measured Grain Size, Solids Content, TPH, and TOC (Figures 3.24, 3.25, 3.26, and 3.27, respectively). Table 3.3 summarizes the sediment quality parameters (TOC, TPH and moisture content) by station. The sample results shown in Table 3.3 represent the average of duplicates and the average of samples along the transect, if applicable. The moisture content was almost the same or higher than the solids content further downstream compared to the upper reaches of the HSC. In general, grain size data in the channel showed nearly all silts and clays with a few exceptions that have higher sand content. The higher sand content locations are in the upper reaches of Buffalo bayou and Brays bayou. Most main channel sediments were smaller in size and more cohesive. TPH results were non-detect except for one station. TOC along the Main Channel again did show any significant spatial pattern and was in the range of 6400-34000 mg/Kg (0.64-3.4%). However, the TOC near the confluence of Buffalo and Brays bayou showed a higher TOC value than other areas along the HSC.

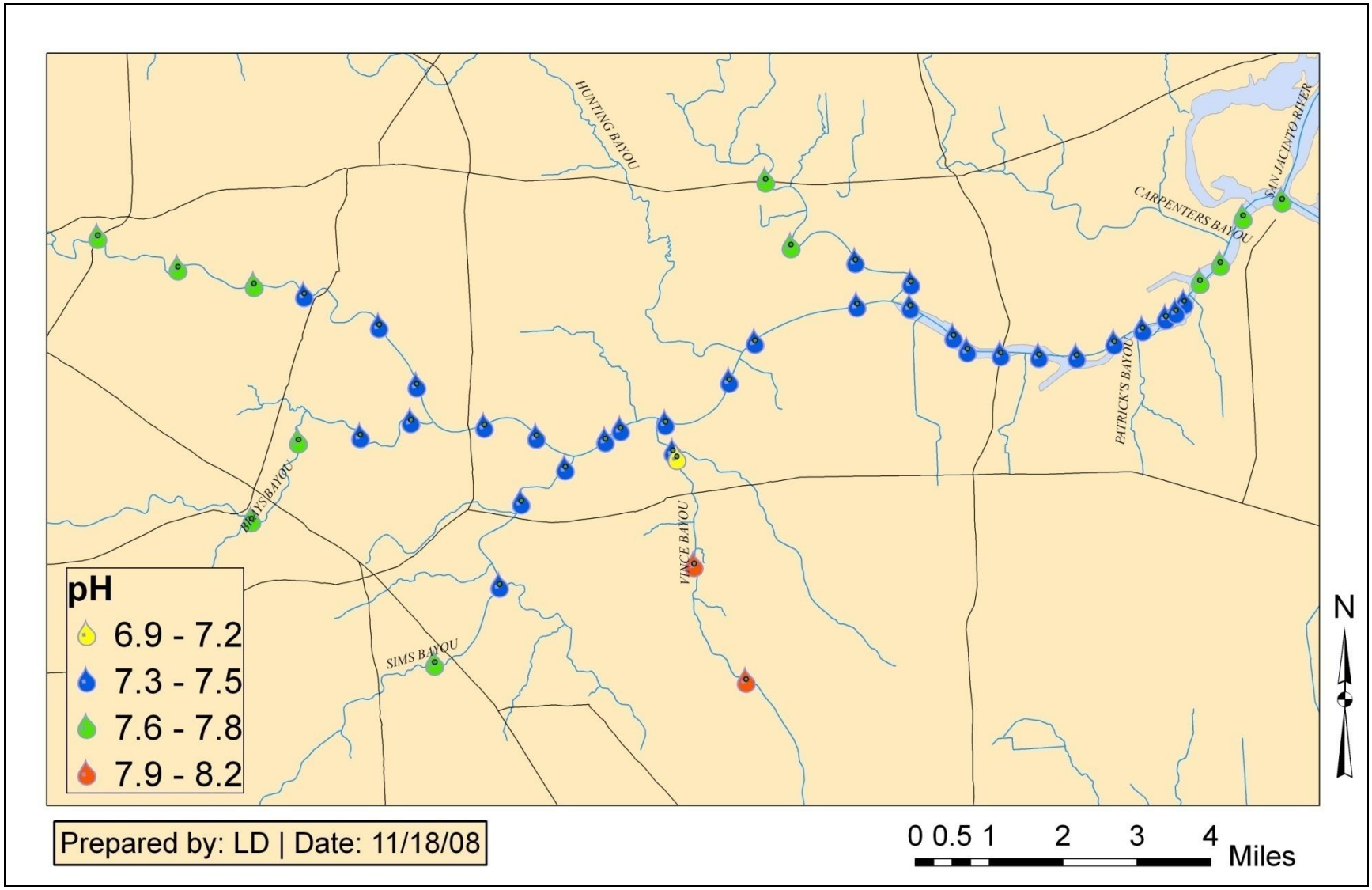


Figure 3.21 Depth and time averaged pH measurements during Intensive sediment sampling

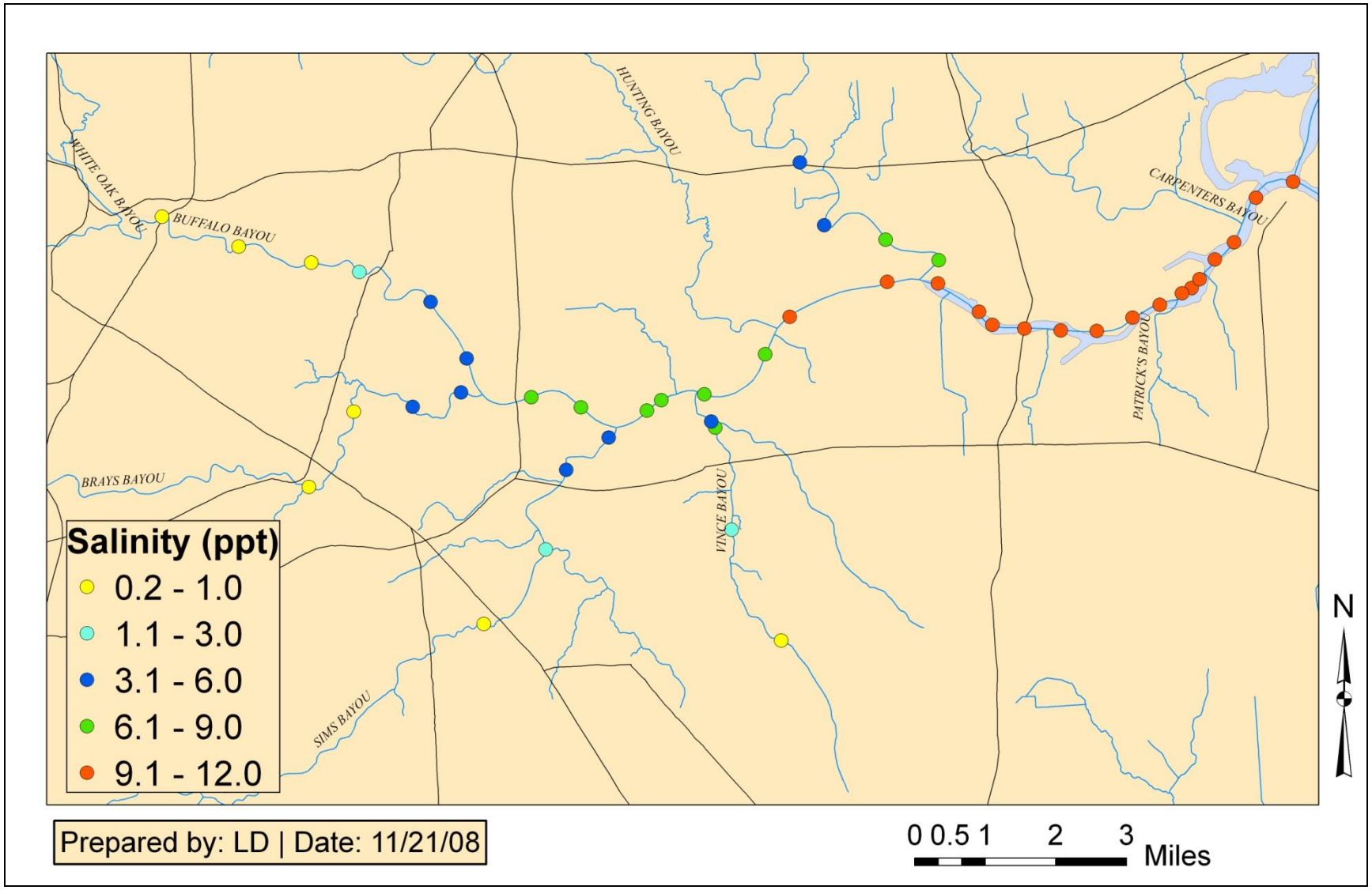


Figure 3.22 Depth and time averaged salinity measurements in part per thousand during Intensive sediment sampling

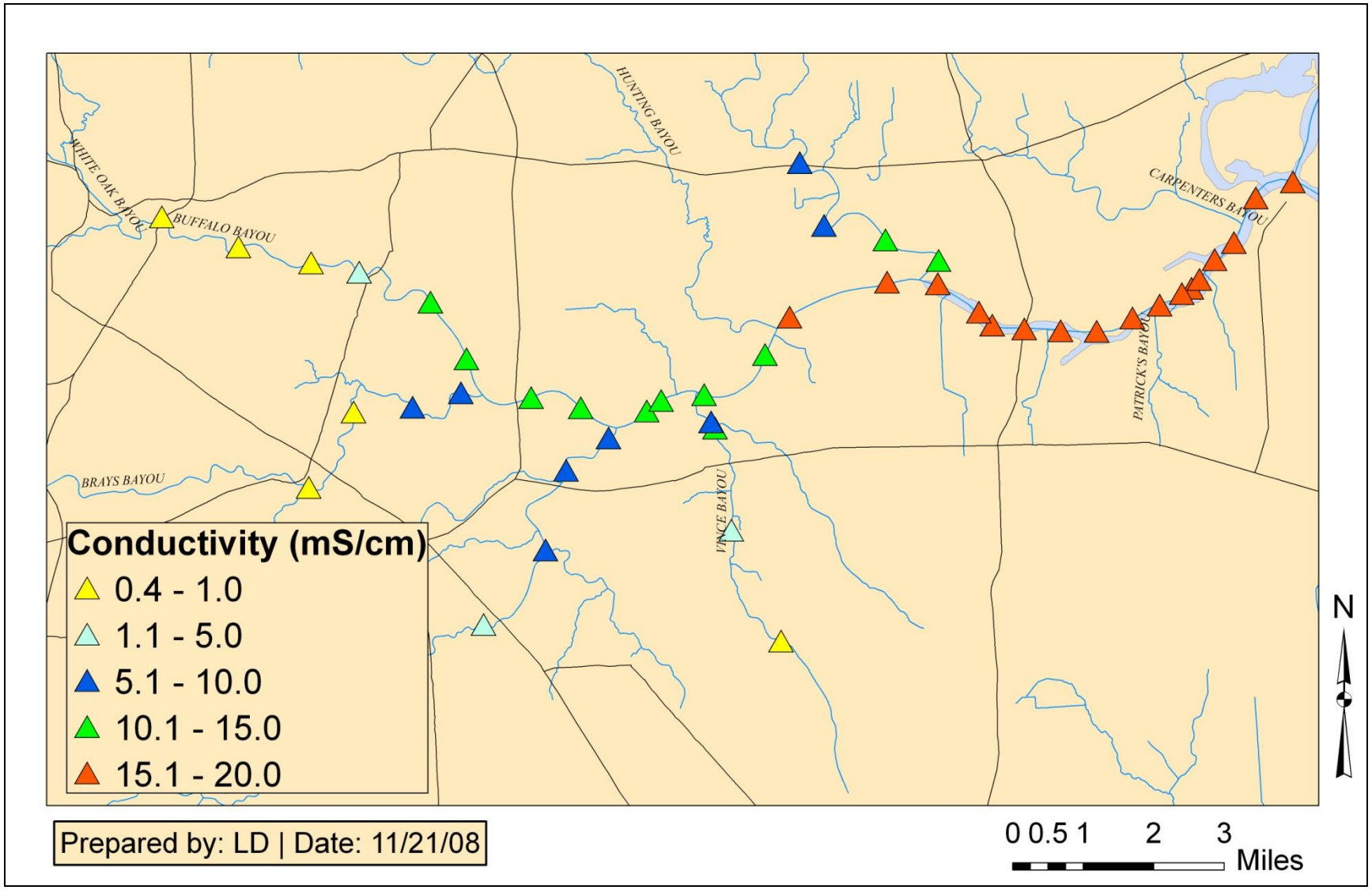
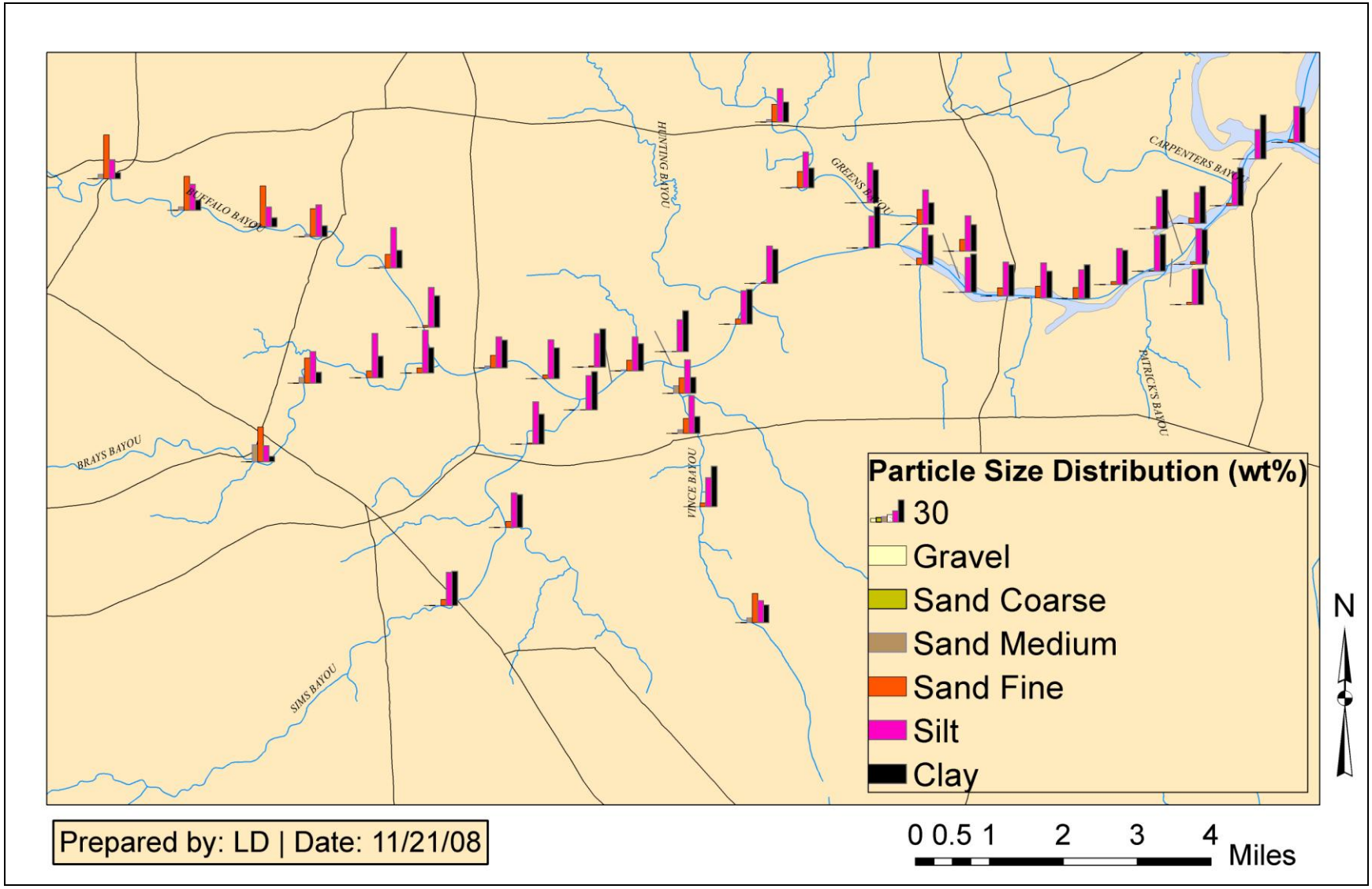
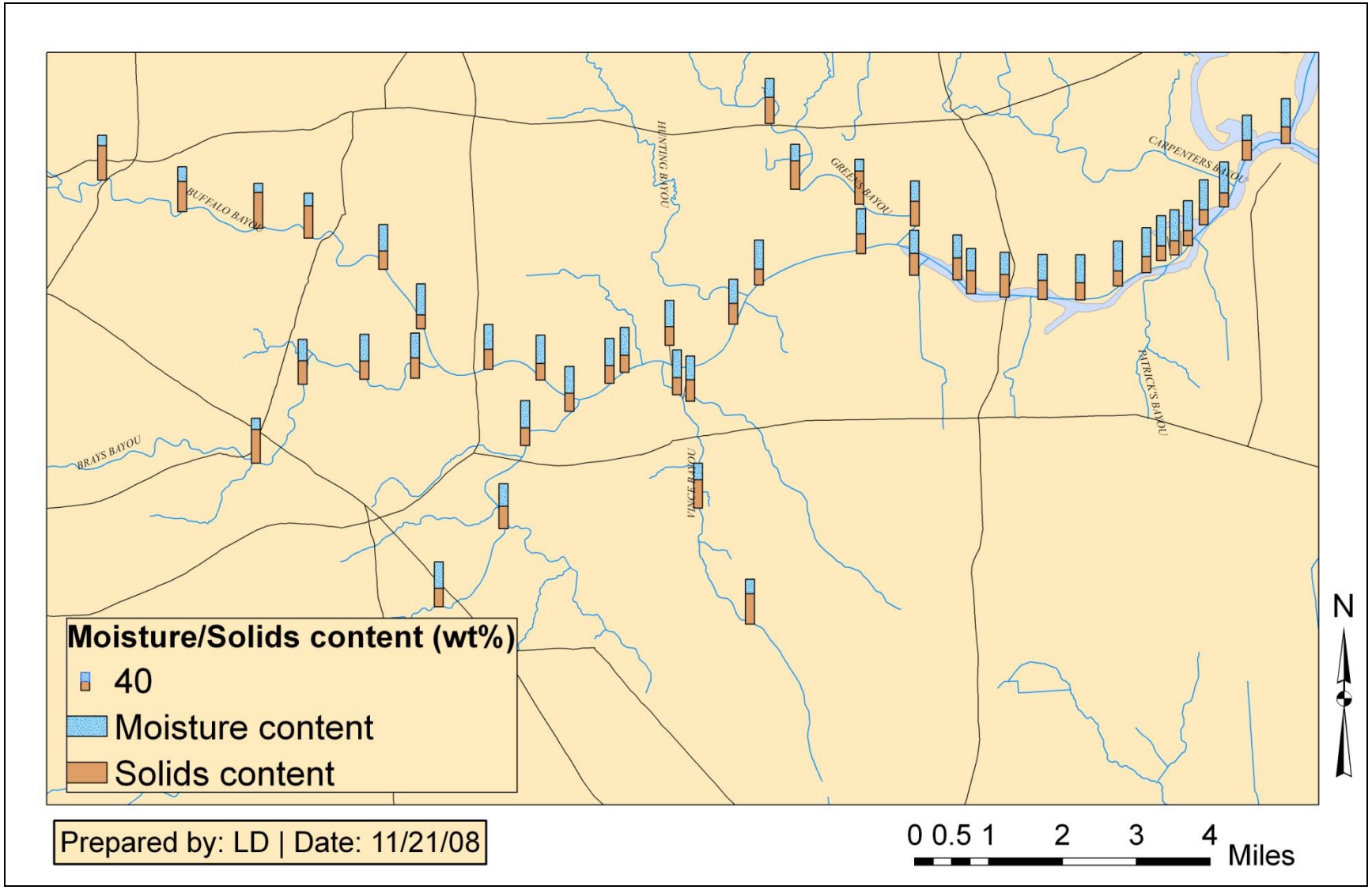


Figure 3.23 Depth and time averaged conductivity measurements during Intensive sediment sampling



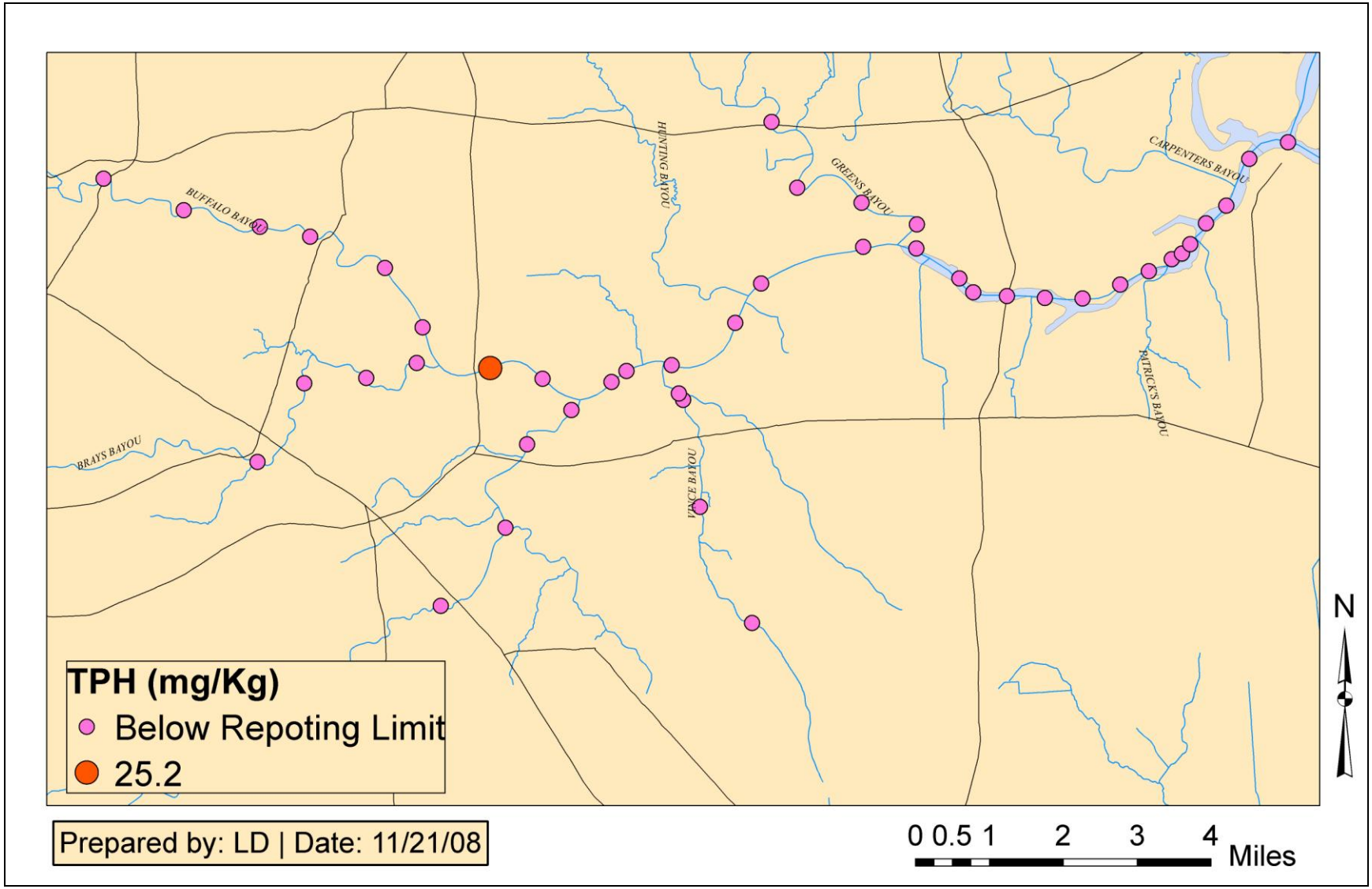
* In case of transects, values are average of sample results

Figure 3.24 Grain size distribution in sediment samples from Intensive sediment sampling



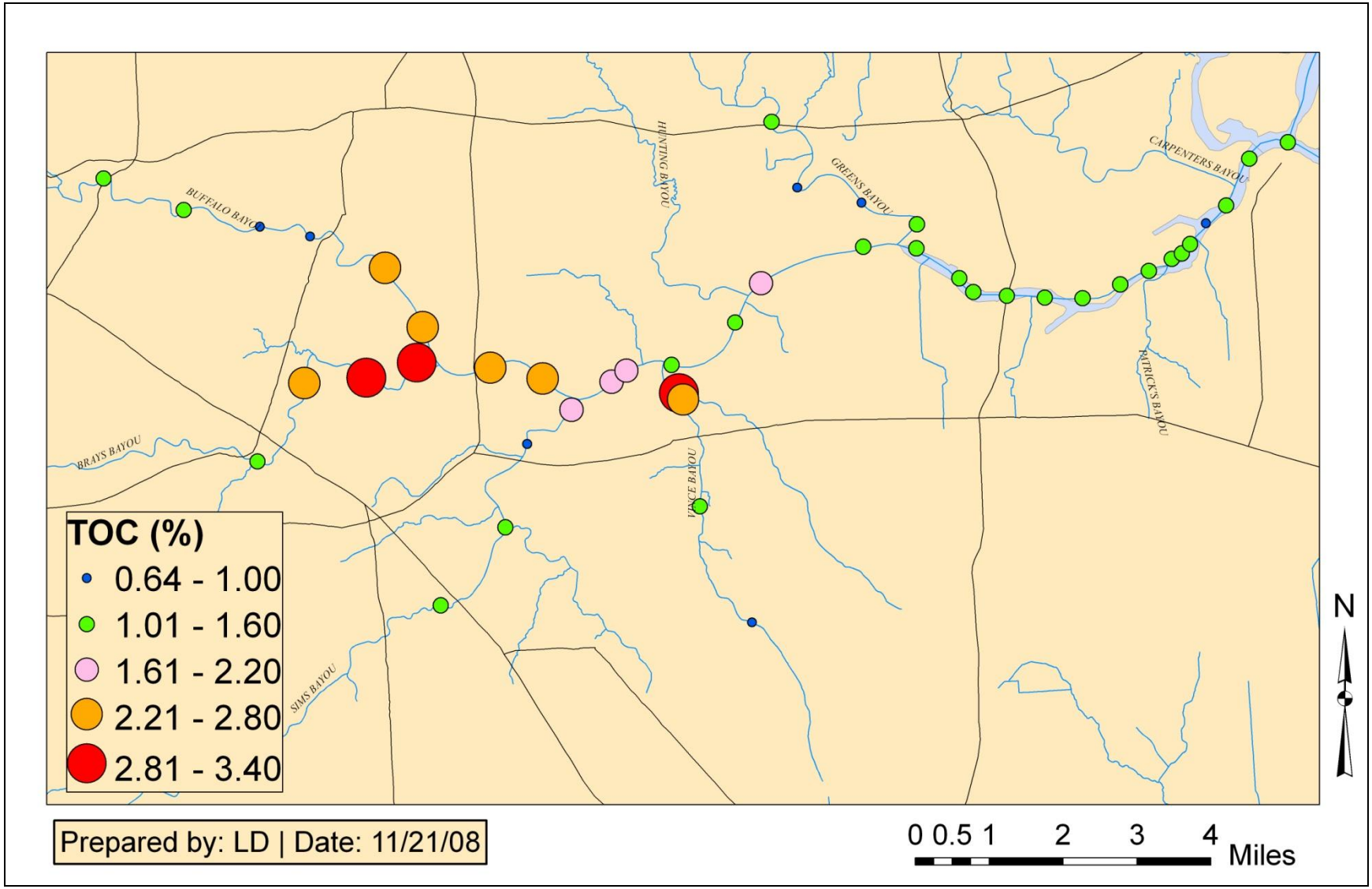
* In case of transects, values are average of sample results

Figure 3.25 Moisture content in sediment samples from Intensive sediment sampling



* In case of transects, values are average of sample results

Figure 3.26 Total TPH in sediment samples from Intensive sediment sampling



* In case of transects, values are average of sample results

Figure 3.27 TOC in sediment samples from Intensive sediment sampling

Table 3.3 Sediment quality measurements from intensive sediment sampling

Station ID	Moisture (%)	TPH (mg/Kg)	TOC (mg/Kg)
C001	60.5	<50	22000
C002	62.0	<50	20000
C003	58.1	<50	15000
C004[b]	54.0	<50	14967
C005	64.5	<50	20000
C006	56.2	<50	15000
E001	51.2	<50	11000
E002	51.1	<50	12000
E003	49.0	<50	12000
E004	49.5	<50	11000
E005	57.8	<50	12000
E006	62.3	<50	14000
E007	66.8	<50	15000
E008	64.3	<50	15000
E009	67.2	<50	16000
E010	68.9	<50	16000
E011[a]	66.6	<50	15500
E012	66.6	<50	9800
E013[ab]	68.8	<50	15125
E014	55.5	<50	13000
E015	62.6	<50	12000
T001[a]	24.9	<50	13500
T002	47.4	<50	23000
T003	59.7	<50	34000
T004	55.1	<50	30000
T005	58.4	<50	12000
T006	50.0	<50	11000

Table 3.3 Sediment quality measurements from intensive sediment sampling

Station ID	Moisture (%)	TPH (mg/Kg)	TOC (mg/Kg)
T007	61.1	<50	9700
T008	59.2	<50	20000
T009[a]	41.7	<50	12500
T010	37.2	<50	8700
T011	26.3	<50	6700
T012	45.2	<50	11000
T013	32.1	<50	7900
T014[a]	36.8	<50	14500
T015	52.5	<50	24000
T016	61.7	<50	29000
W001	23.5	<50	12000
W002[a]	32.8	<50	11350
W003	20.7	<50	6400
W004	28.2	<50	7800
W005	59.1	<50	23000
W006	69.2	<50	28000
W007[b]	55.6	25.17	22500
W008	63.5	<50	26000

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

[b] Average of samples collected along the transect

3.4 Tissue

In addition to PCBs, fish tissue was analyzed for lipid and moisture content. Table 3.4 summarizes the lipid and moisture content results. The results showed a variable fat content in the tissue that ranged from 0.1-4.2% in the case of Catfish to 1.7-8.9% in the case of Seatrout/Atlantic Croaker. The moisture content in tissue was in the range of 62-82%.

Table 3.4 Lipid and Moisture Content in tissue samples by station and species

Station ID	Species type	Lipid (%)	Moisture (%)
11132	Blue Catfish	3.2	79
11193	Hardhead Catfish	0.7	78
11252	Hardhead Catfish	0.2	80
11258[a]	Hardhead Catfish	1.45	79
11261	Hardhead Catfish	0.9	82
11262	Hardhead Catfish	1.2	79
11264	Hardhead Catfish	1.5	79
11270	Hardhead Catfish	2.3	79
11274	Hardhead Catfish	1.3	81
11280	Hardhead Catfish	1.3	80
11287	Blue Catfish	2.7	80
11292	Blue Catfish	0.1	79
11347	Channel Catfish	4.2	77
13338	Hardhead Catfish	1.2	81
13342	Hardhead Catfish	2.3	79
13344	Hardhead Catfish	0.4	80
13355	Hardhead Catfish	0.9	79
13363[a]	Hardhead Catfish	1.05	79.5
14560	Hardhead Catfish	2	78
15301	Hardhead Catfish	0.7	78
15936[a]	Hardhead Catfish	1	77
15979[a]	Hardhead Catfish	1.8	78
16213	Hardhead Catfish	1.6	78
16499	Hardhead Catfish	0.6	81
16618	Hardhead Catfish	2.9	80
16622	Blue Catfish	1	81
11193	Atlantic Croaker	7.6	68

Table 3.4 Lipid and Moisture Content in tissue samples by station and species

Station ID	Species type	Lipid (%)	Moisture (%)
11252	Atlantic Croaker	3.7	69
11258	Atlantic Croaker	4.1	76
11261	Atlantic Croaker	8.7	64
11262	Atlantic Croaker	4.5	75
11264	Speckled Seatrout	3.8	79
11270	Speckled Seatrout	3	76
11280	Atlantic Croaker	8.1	62
13338	Speckled Seatrout	4.1	79
13342	Atlantic Croaker	8.9	66
13344	Atlantic Croaker	8.8	63
13355	Atlantic Croaker	2.7	75
13363	Speckled Seatrout	2.5	76
14560	Atlantic Croaker	3.7	76
14560	Speckled Seatrout	1.9	78
15301	Atlantic Croaker	4.7	65
15936	Atlantic Croaker	6	70
16213	Atlantic Croaker	3	78
16499	Atlantic Croaker	3.8	68
16618	Speckled Seatrout	1.7	76

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

4. SUMMARY OF 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 criteria 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 criteria 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].

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[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 $1x10^{-4}$.

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 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-69, 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 2008, concentrations of the 209 PCB congeners (EPA Method 1668A) were analyzed and results obtained for 37 ambient water locations, 25 in-stream sediment locations, 26 locations for Catfish, and 19 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. 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 0.469 and 69.1 ng/L with an average concentration of 4.02 ng/L for the 37 locations sampled. As can be seen in Table 4.1, 30 out of the 37 locations (81%) sampled in Summer 2008 exceeded the Texas Surface Water Quality Standard (WQS) for human health protection of 0.885 ng/L. In addition, the average concentration was higher than the WQS.

[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.

2) The summation of 43 congeners yielded total PCB concentrations in the range of 0.17 and 26.9 ng/L with an average concentration of 1.71 ng/L for the 37 locations sampled. As can be seen in Table 4.1, 15 out of the 37 locations (41%) sampled in Summer 2008 exceeded the Texas Surface Water Quality Standard (WQS) for human health protection of 0.885 ng/L. In addition, the average concentration was higher than the WQS.
3) The summation of 18 congeners yielded total PCB concentrations in the range of 0.144 and 18.2 ng/L with an average concentration of 1.21 ng/L for the 37 locations sampled. As can be seen in Table 4.1, 10 out of the 37 locations (27%) sampled in Summer 2008 exceeded the Texas Surface Water Quality Standard (WQS) for human health protection of 0.885 ng/L. The average concentration was higher than the WQS.

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	0.726	0.716	0.285	0.285	0.244	0.243
11132	2.464	2.448	1.097	1.095	0.853	0.853
11139	0.475	0.418	0.202	0.195	0.150	0.145
11171	0.484	0.439	0.167	0.159	0.144	0.141
11193	2.120	2.094	0.937	0.933	0.720	0.719
11252	0.730	0.708	0.346	0.342	0.244	0.242
11258	1.642	1.635	0.697	0.697	0.558	0.558
11261	2.059	2.051	1.043	1.043	0.717	0.717
11262	1.819	1.795	0.848	0.845	0.627	0.626
11264	2.765	2.740	1.272	1.269	0.878	0.877
11270	3.943	3.919	1.863	1.860	1.371	1.370
11274	6.173	6.154	2.960	2.958	2.126	2.125
11280	3.856	3.831	1.867	1.864	1.401	1.401
11287	3.357	3.327	1.572	1.569	1.164	1.162
11292	3.340	3.335	1.514	1.513	1.106	1.105
11347	3.765	3.760	1.664	1.664	1.257	1.257
11368	1.166	1.148	0.436	0.433	0.361	0.360
11387	1.057	1.038	0.421	0.418	0.342	0.341
13338	1.118	1.083	0.473	0.467	0.374	0.372
13340	0.739	0.700	0.390	0.383	0.261	0.259
13342	1.403	1.396	0.641	0.640	0.475	0.475
13344	1.389	1.375	0.604	0.603	0.463	0.463
13355	1.019	0.988	0.413	0.408	0.338	0.336
13363	1.148	1.134	0.452	0.450	0.385	0.384
14560	1.284	1.262	0.457	0.454	0.399	0.397
15301	2.838	2.822	1.308	1.306	0.911	0.911

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]
15936	11.185	11.165	5.044	5.043	3.319	3.318
15979	2.243	2.214	1.106	1.102	0.784	0.783
16213	0.605	0.581	0.296	0.292	0.208	0.206
16499	1.661	1.631	0.838	0.835	0.585	0.584
16618	1.638	1.632	0.684	0.683	0.553	0.553
16622	1.181	1.147	0.578	0.573	0.435	0.434
16657	1.937	1.915	0.771	0.768	0.672	0.672
17149	69.170	69.138	26.908	26.908	18.161	18.160
TBD5	1.336	1.315	0.574	0.571	0.468	0.467
TBD6	4.265	4.259	2.188	2.187	1.571	1.571
TBD7	0.469	0.463	0.234	0.233	0.165	0.165

∑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	0.469	0.418	0.167	0.159	0.144	0.141
Max	69.17	69.14	26.91	26.91	18.16	18.16
Average	4.015	3.99	1.71	1.70	1.21	1.21
Stdev	11.19	11.19	4.36	4.36	2.93	2.93
95% Confidence level of mean	0.29 - 7.74	0.26 - 7.72	0.25 - 3.16	0.25 - 3.16	0.23 - 2.19	0.23 - 2.19
% stations that exceed WQS	81		41		27	

∑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 circles in the figures indicate the stations that do not exceed the WQS, while the circles in other colors (yellow, pink, 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.

Figures 4.2a, 4.2b, and 4.2c compare the 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 1013, 1007 and 1006 exceeded the WQS. In addition to the above mentioned segments, segments 1001 and 1005 exceeded the WQS in the case of the ∑43 congener approach. The use of the congener 209 summation approach showed that all segments except 901 and 2428 exceeded the WQS.

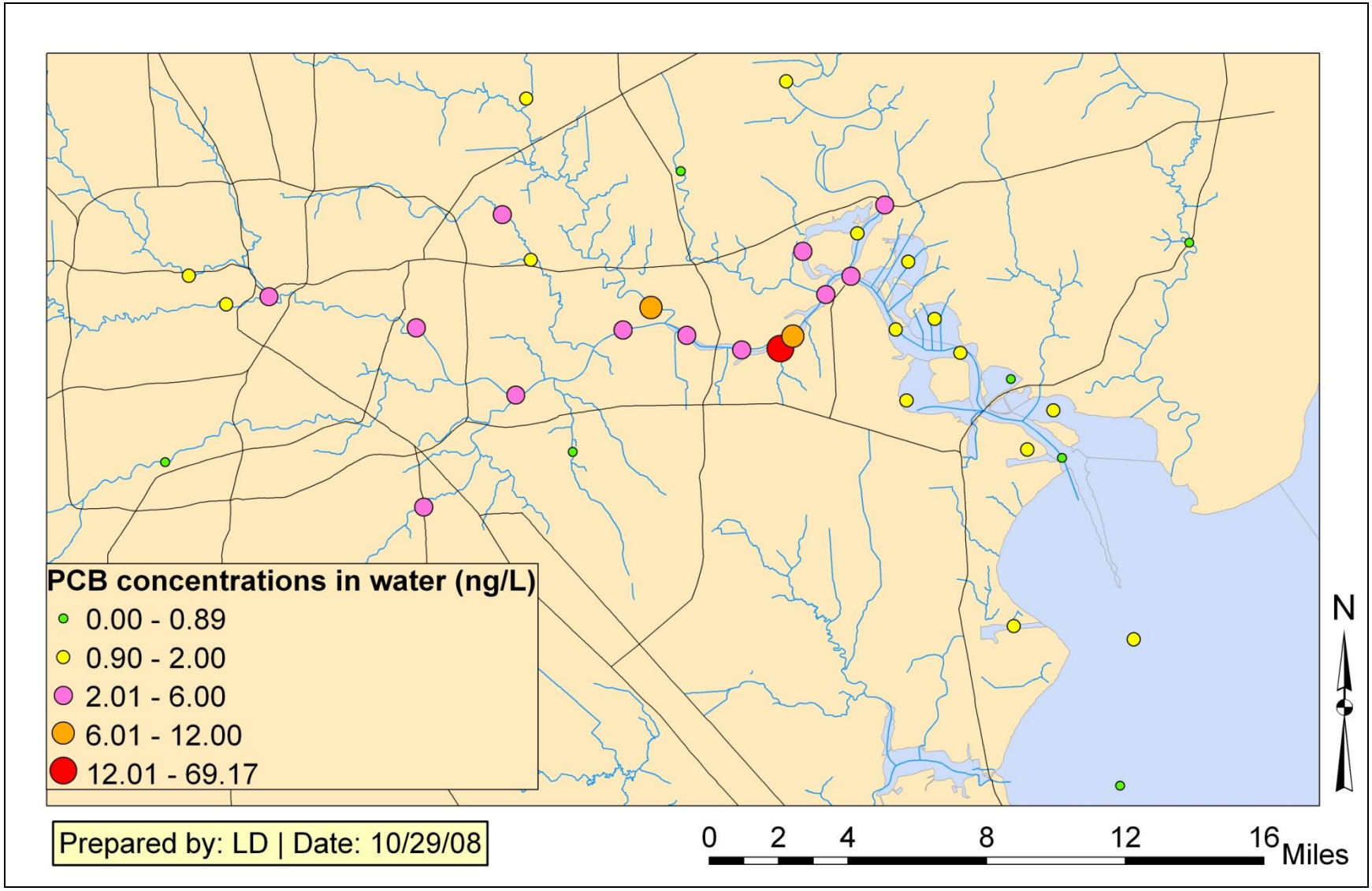


Figure 4.1a Total PCB concentrations in water calculated as sum of 209 congeners

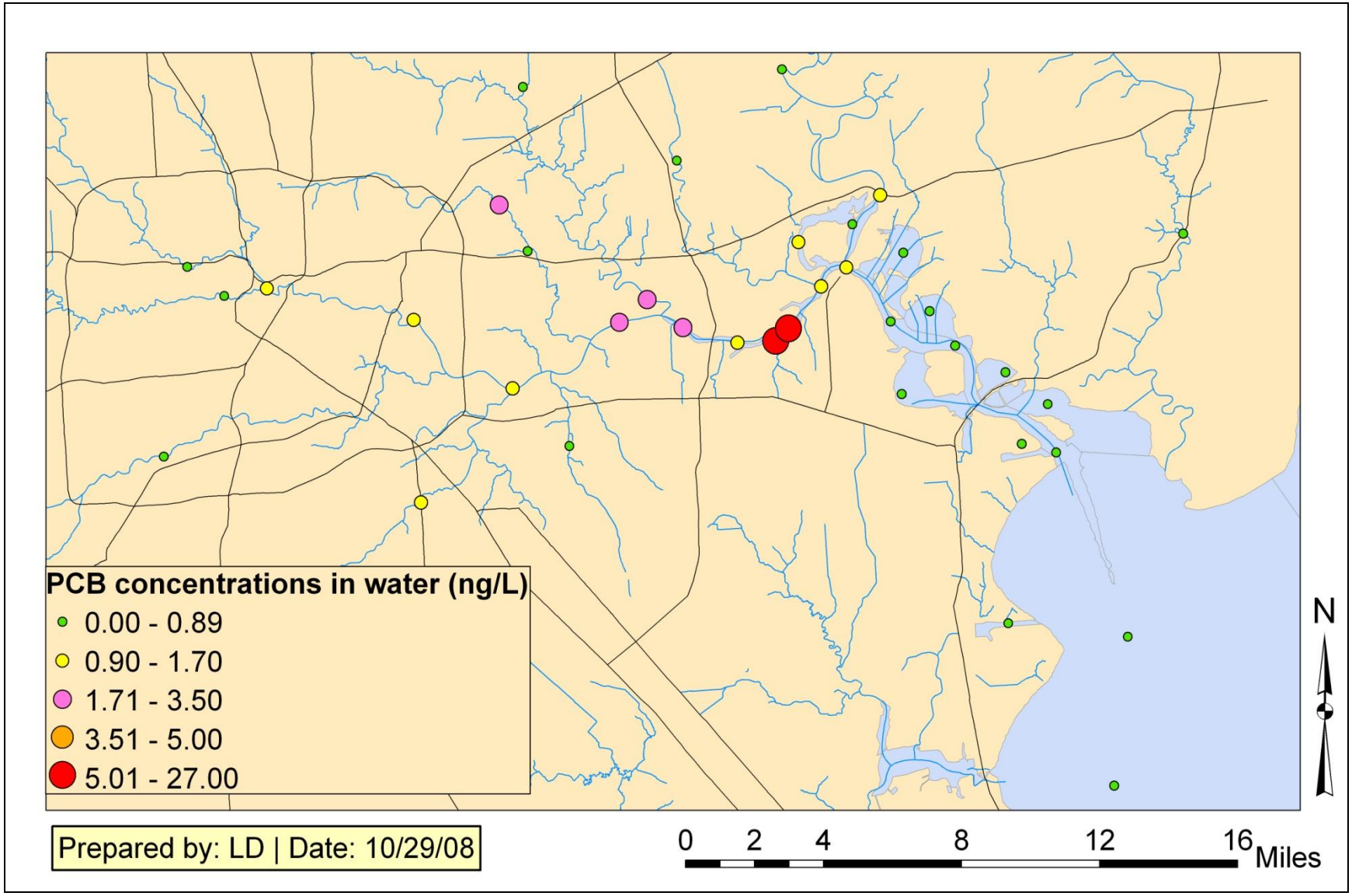


Figure 4.1b Total PCB concentrations in water calculated as sum of 43 congeners

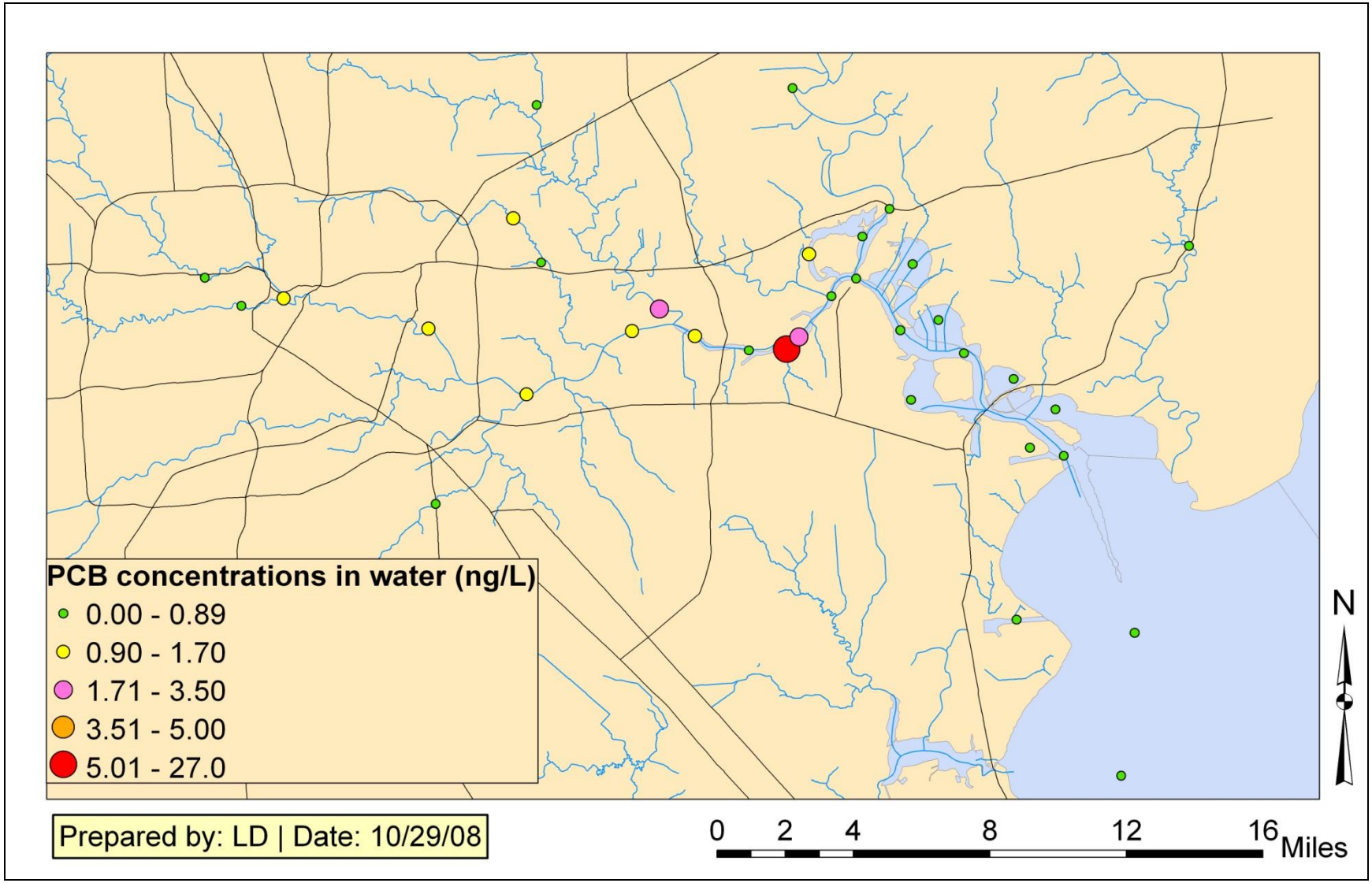


Figure 4.1c Total PCB concentrations in water calculated as sum of 18 congeners

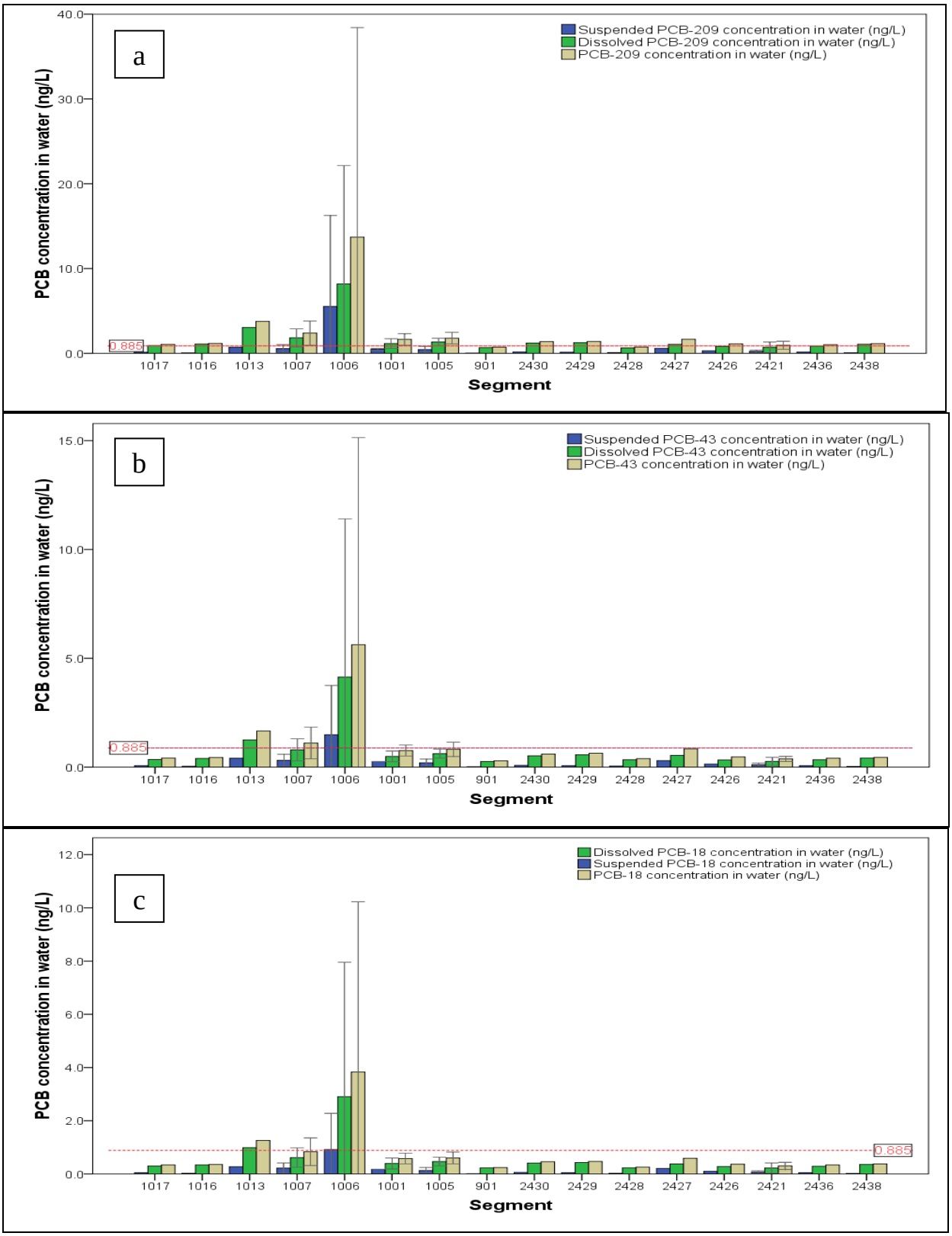


Figure 4.2 Comparison of PCB concentrations in water by segment. (a. ∑ PCB 209 congeners, b. ∑ PCB 43 congeners, c. ∑ PCB 18 congeners)

Figure 4.3 compares the dissolved and suspended phase water PCB concentrations for all congener summation approaches from the 2008 dataset. All the stations except 11139 and 16213 had PCB concentrations higher in the dissolved phase (>50%) than in the suspended phase. Similar higher PCB concentrations in the dissolved phase (> 50%) were observed in the HSC also in the 2002-2003 study (Figure 4.4). 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 and 2008 studies. As can be observed from Table 4.3, approximately 80 and 90% of sampling stations had greater than 50% of the total PCB in the dissolved phase from 2002-2003 and 2008 studies, respectively. The higher PCB concentrations in the dissolved phase are not uncommon and have been reported by other studies around the world (see Table 4.4). Even though theoretically PCB concentrations are expected to be higher in the particulate matter based on partition coefficients, there are many possible reasons why this is not the case for the HSC:

1) Low Organic Carbon content in suspended solids and/or higher organic carbon content in the dissolved phase. The result from the 2008 study in the HSC shows higher DOC than POC content.

2) Small particles of suspended solids (< 1μm) are possible and so the solids can easily pass the 1 um filter and be accounted for in the dissolved concentration thereby resulting in a higher dissolved PCB concentration.

3) Colloidal particles may be present in the HSC that are accounted for in the dissolved solids concentration measurements.

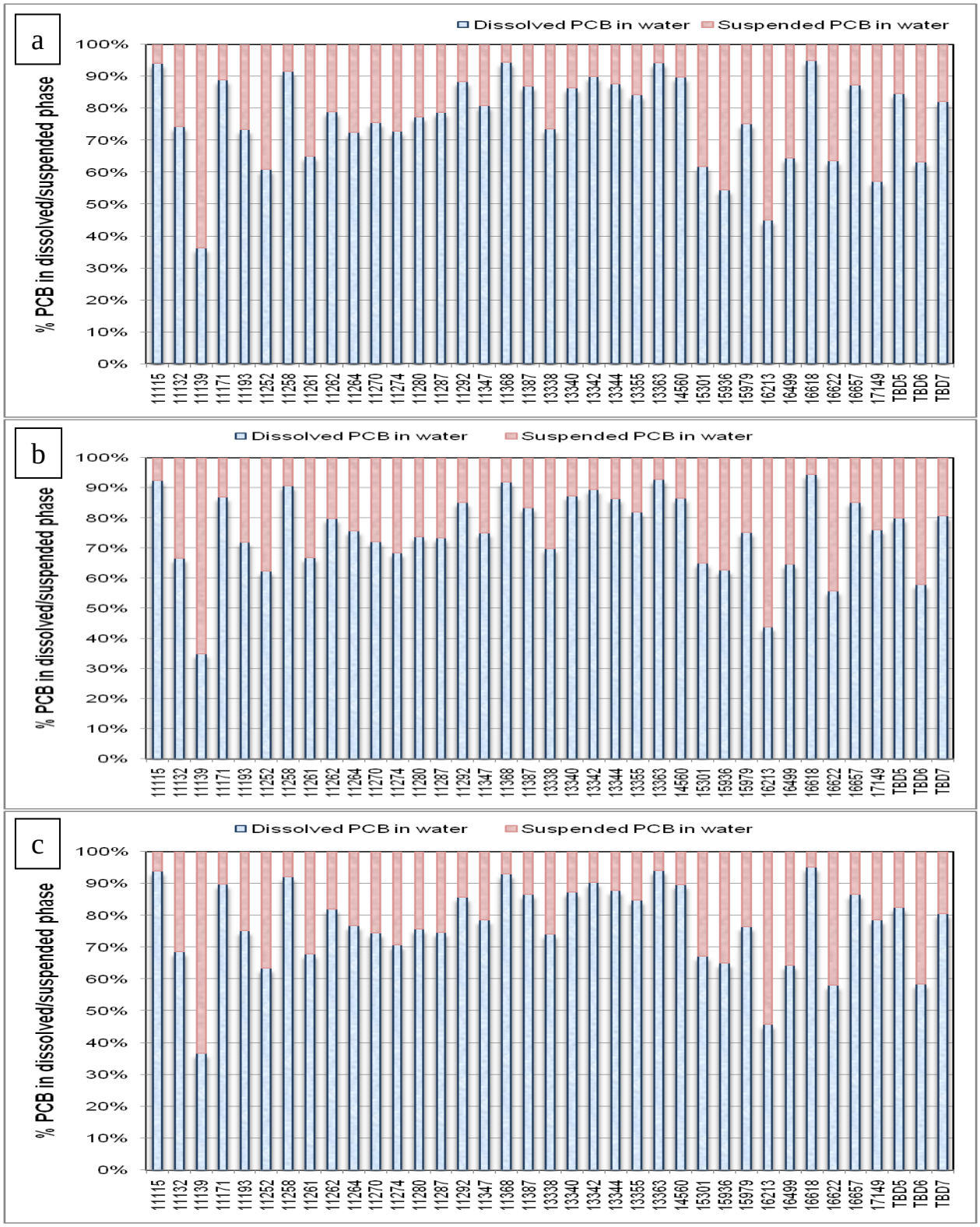


Figure 4.3 Partitioning of PCBs between Dissolved and Suspended Phases in the HSC from 2008 study. (a. ∑ PCB 209 congeners, b. ∑ PCB 43 congeners, c. ∑ PCB 18 congeners)

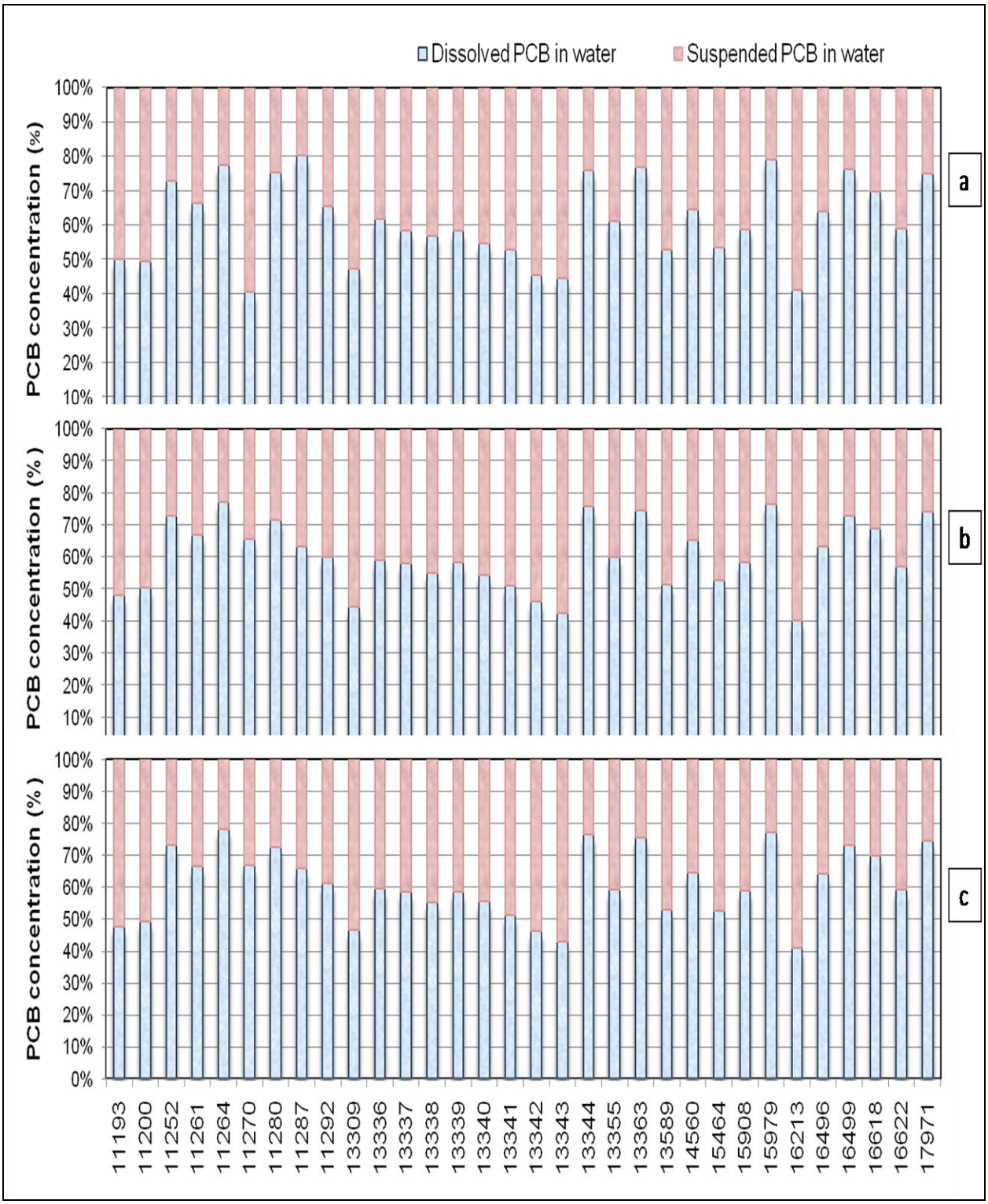


Figure 4.4 Partitioning of PCBs between Dissolved and Suspended Phases in the HSC from 2002-2003 study. (a. ∑ PCB 209 congeners, b. ∑ PCB 43 congeners, c. ∑ PCB 18 congeners)

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	81.25%
	∑43 congeners	32	27	84.38%
	∑18 congeners	32	26	81.25%
2008	∑209 congeners	37	35	94.59%
	∑43 congeners	37	35	94.59%
	∑18 congeners	37	35	94.59%

Table 4.4 Water bodies reported to have PCB water concentrations higher in dissolved phase than in suspended phase

Location	Filter size	Dissolved PCB	Suspended PCB	Reference
Coastal locations in Hong Kong, China	1.6 um	266 - 433.5 pg/L	85.6 - 273 pg/L	Wurl et al., 2006
Yangtse river, China	0.7 um	2 ng/L	0.5-1.3 ng/L	Jiang et al., 2000
Singapore	1 um	60 – 6979 pg/L	38 – 3793 pg/L	Wurl et al., 2006a
Delaware River	0.7 um	1070±573 pg/L *	880±256 pg/L *	Rowe et al., 2007
Barcelona, Spain	0.7 um	1.834 – 45.3 ng/L	0.14 – 10.8 ng/L	Garcıa-Flor et al., 2005
Banyuls-sur-Mer, France	0.7 um	0.447 – 32.5 ng/L	0.09 – 4.62 ng/L	Garcıa-Flor et al., 2005
Lake Michigan	0.7 um	47%	53%	Swackhamer et al., 1987
Green Bay	0.7 um	61%	39%	Swackhamer et al., 1987
Ebro River, Spain	N/A	0.06 ng/L	0.01 ng/L	Dachs et al., 1997
Danube Estuary, Romania	N/A	0.07 – 0.1 ng/L	0.004 – 0.06 ng/L	Maldonado and Bayona, 2002

4.3.2 Sediment PCB Concentrations

PCB results from the in-channel sediment samples collected in Spring-Summer 2008 by station from the three congener summation approaches and the two ND approaches are summarized in Table 4.5, while the statistical summary is given in Table 4.6. The use of non-detects as zero or half the detection limit did not yield significantly different results. Depending on the method of calculation of total PCBs, the sediment PCB concentrations varied significantly. The summation of 209 congeners yielded total PCB concentrations in the range of 1.4 and 108 ng/g with an average concentration of 25 ng/g for the 25 locations sampled. The summation of 43 congeners yielded total PCB concentrations in the range of 0.7 and 62 ng/g with an average concentration of 14 ng/g for the 25 locations sampled. The summation of 18 congeners yielded total PCB concentrations in the range of 0.47 and 41 ng/g with an average concentration of 9.6 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 4.5a, 4.5b, and 4.5c 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.

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 1007 and 1006. The PCB concentrations were significantly lower in Galveston Bay segments compared to other segments.

Table 4.5 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]
11132	21.71	21.49	12.18	12.17	8.60	8.60
11193	22.58	22.02	11.20	11.15	7.48	7.45
11252	1.98	1.91	0.90	0.85	0.65	0.64
11258	3.51	3.44	1.77	1.74	1.18	1.16
11261	9.08	9.01	3.81	3.81	2.53	2.53
11262	1.53	1.43	0.73	0.72	0.49	0.49
11264	20.46	20.38	10.00	9.97	6.51	6.50
11270	58.33	57.93	32.26	32.21	22.02	22.01
11274	108.37	108.12	62.36	62.35	40.85	40.85
11280	69.55	69.24	38.28	38.26	25.99	25.98
11287	65.86	65.18	36.98	36.82	26.00	25.99
11292	96.57	96.06	54.61	54.59	38.01	38.00
11347	15.09	15.01	9.08	9.07	6.43	6.43
13338	8.91	8.85	4.64	4.61	3.10	3.09
13342	19.36	19.27	9.20	9.20	6.16	6.15
13344	6.28	6.23	3.09	3.08	2.08	2.07
13355	1.38	1.32	0.69	0.68	0.47	0.46
13363	2.51	2.43	1.38	1.32	0.93	0.91
14560	2.21	2.13	1.18	1.12	0.89	0.87
15301	36.43	36.37	16.66	16.65	11.10	11.10
15979	46.11	45.99	24.41	24.39	16.49	16.48
16213	2.63	2.55	1.30	1.25	0.82	0.81
16499	24.06	24.00	12.41	12.38	9.42	9.41
16618	2.82	2.78	1.23	1.23	0.84	0.84
16622	1.56	1.46	0.86	0.80	0.64	0.61

∑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 4.6 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	1.377	1.315	0.686	0.682	0.466	0.465
Max	108.374	108.116	62.362	62.347	40.851	40.846
Average	25.955	25.783	14.048	14.017	9.587	9.578
Stdev	31.017	30.898	17.603	17.599	11.927	11.928
95% Confidence level of mean	13.15 - 38.76	13.03 - 38.54	6.78 - 21.31	6.75 - 21.28	4.66 - 14.51	4.65 - 14.5

∑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

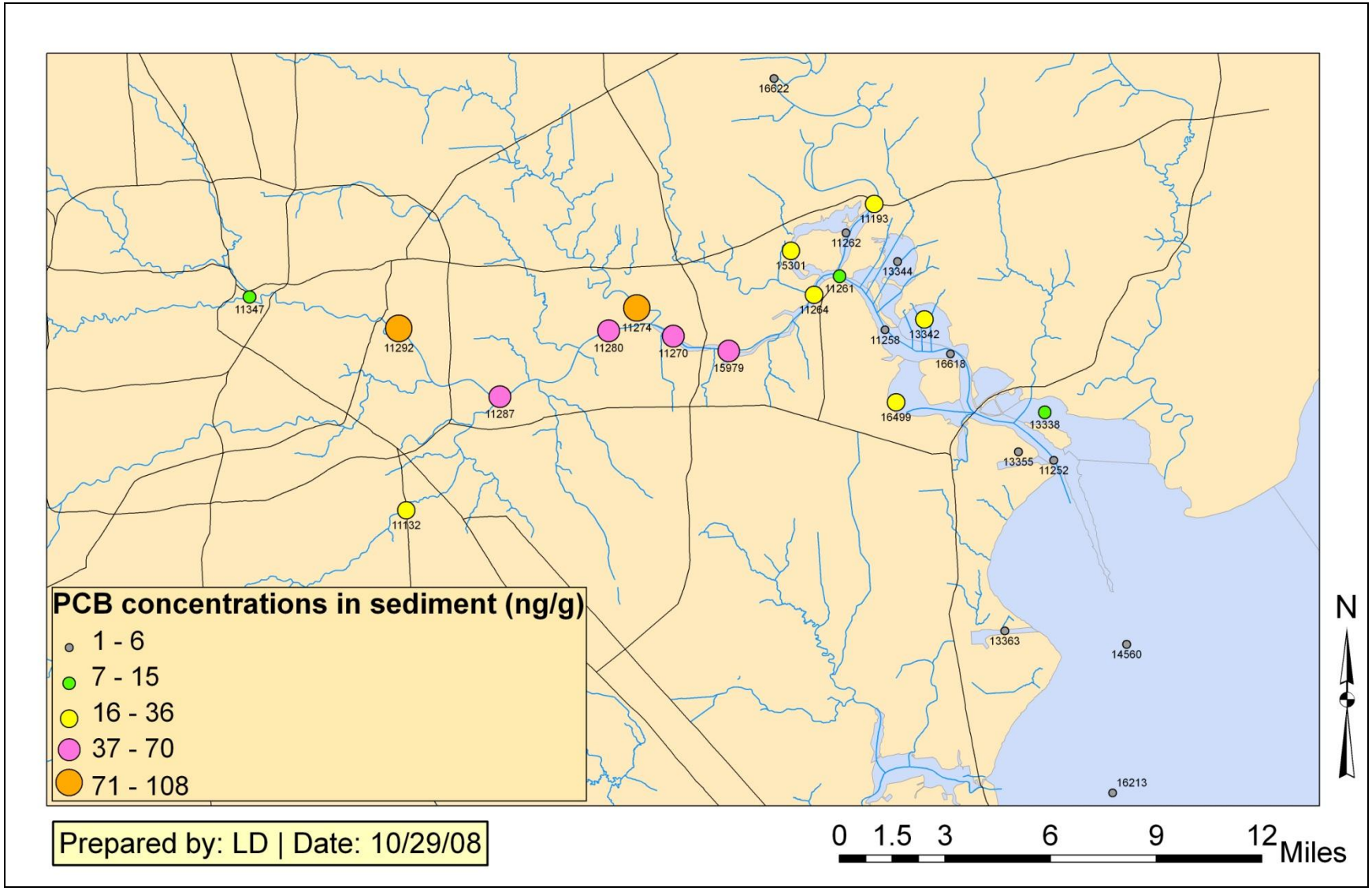


Figure 4.5a Total PCB concentrations in sediment calculated as sum of 209 congeners

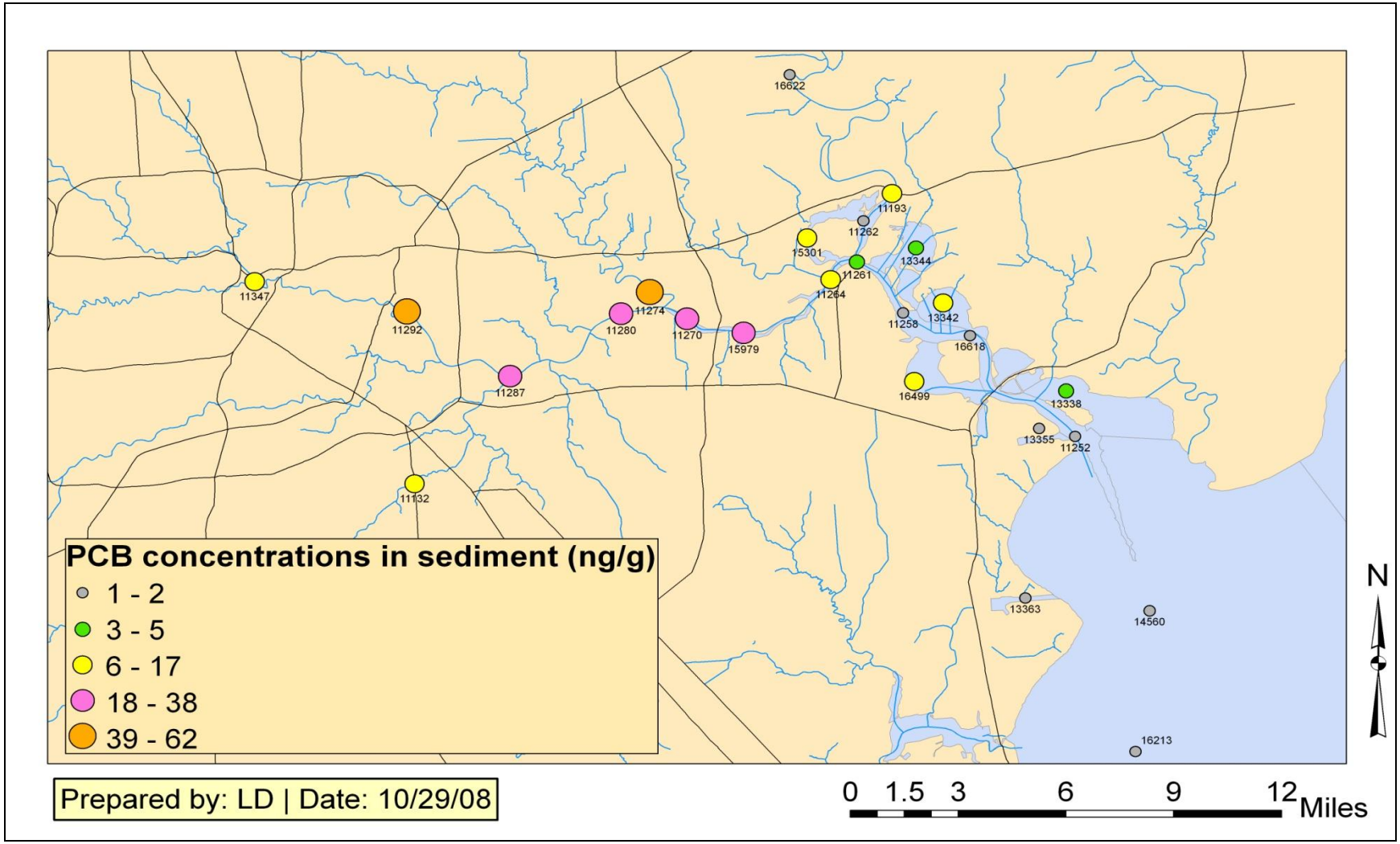


Figure 4.5b Total PCB concentrations in sediment calculated as sum of 43 congeners

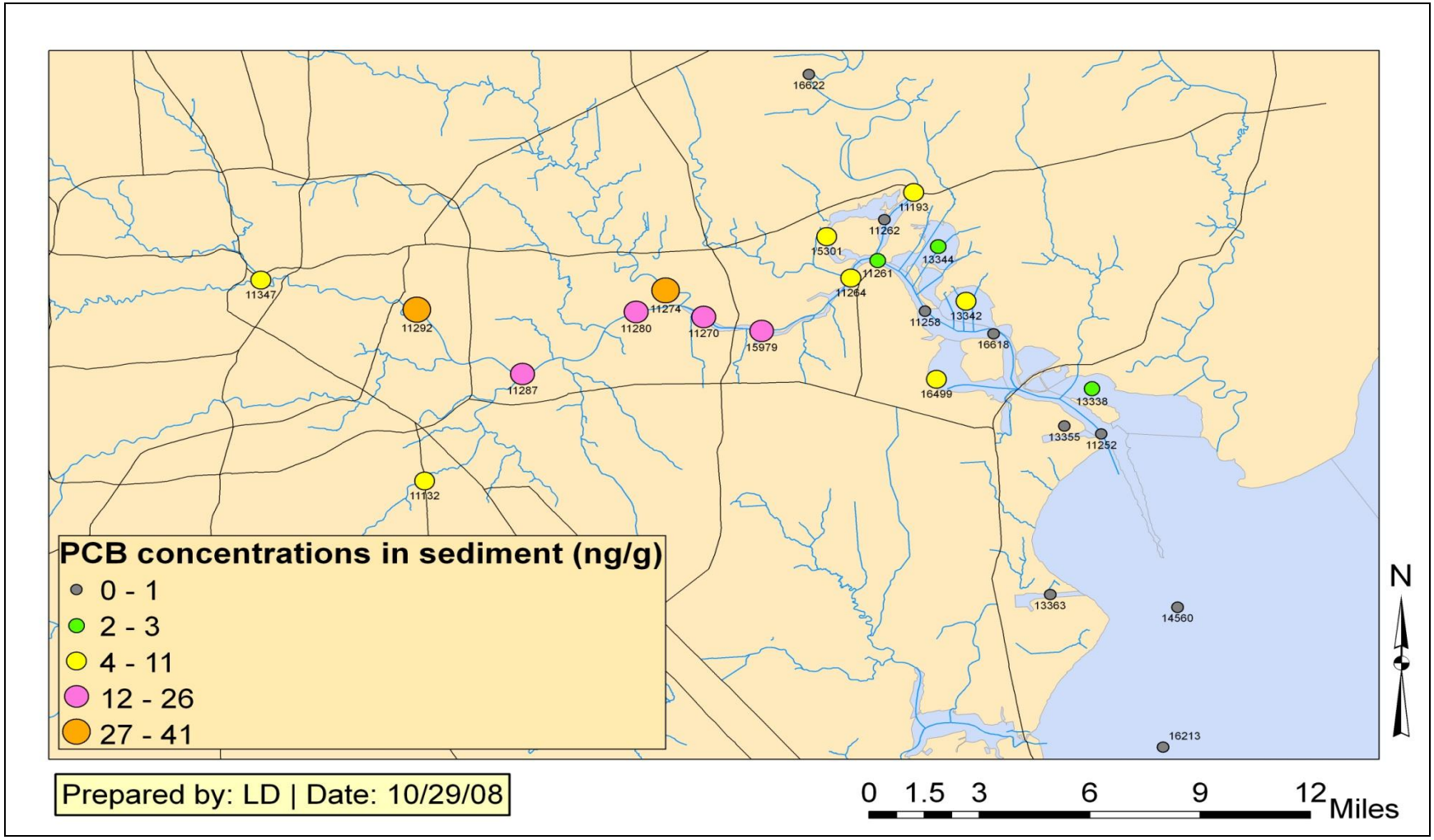


Figure 4.5c Total PCB concentrations in sediment calculated as sum of 18 congeners

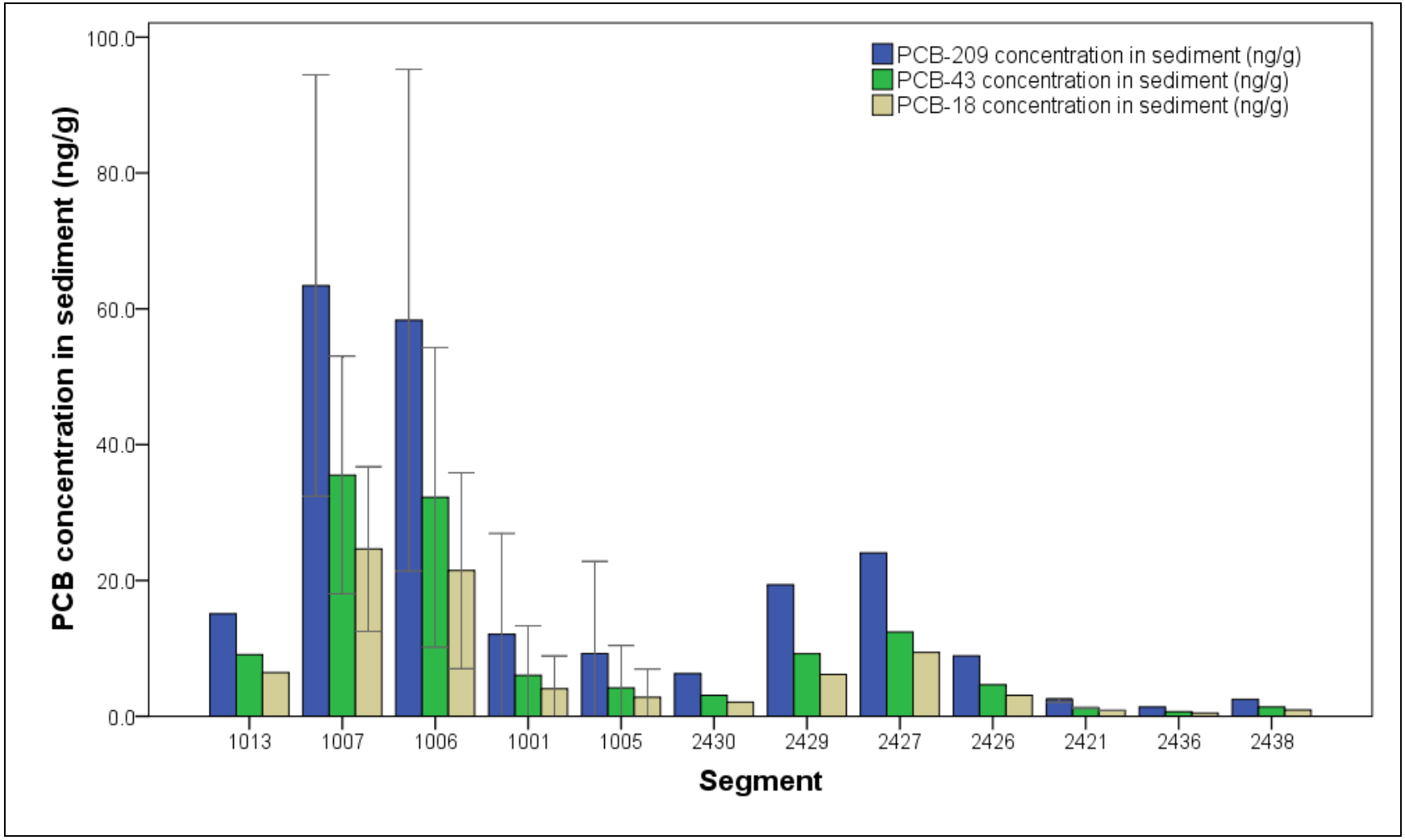


Figure 4.6 Comparison of PCB concentrations in sediment by segment

4.3.3 Tissue PCB Concentrations

The total PCB concentrations in catfish and seatrout/atlantic croaker tissue are included in Table 4.7, while the statistical summary of PCB concentrations in catfish and seatrout/atlantic croaker are given in Tables 4.8 and 4.9, respectively. The PCB concentrations in catfish and seatrout/atlantic croaker for the three summation methods are mapped in Figures 4.7 and 4.8, 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 12-522 ng/g in the case of catfish, and 33-1180 ng/g in the case of seatrout/atlantic croaker. As can be seen in Table 4.7, 22 out of the 26 locations (85%) sampled for catfish and 17 out of 19 locations (90%) sampled for seatrout/atlantic croaker exceeded the DSHS Health Assessment Comparison Value (47 ng/g). In addition, the average concentration of catfish (137 ng/g) and seatrout/atlantic croaker (285 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 7.4-416 ng/g in the case of catfish, and 24-781 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 average

concentration of catfish (105 ng/g) and seatrout/atlantic croaker (189 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 5.4-289 ng/g in the case of catfish, and 18-524 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 average concentration of catfish (77 ng/g) and seatrout/atlantic croaker (131 ng/g) was also higher than the Health Assessment Comparison Value.

Table 4.7 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]
11132	Blue Catfish	184.10	183.99	124.08	124.08	93.69	93.69
11193	Hardhead Catfish	189.46	189.36	145.94	145.93	114.57	114.57
11252	Hardhead Catfish	51.70	51.64	39.89	39.89	30.26	30.26
11258	Hardhead Catfish	143.72	143.48	112.71	112.71	83.12	83.12
11261	Hardhead Catfish	129.43	129.37	100.05	100.04	73.01	73.01
11262	Hardhead Catfish	198.95	198.58	155.01	154.98	119.04	119.04
11264	Hardhead Catfish	151.94	151.42	121.65	121.51	90.04	90.04
11270	Hardhead Catfish	158.22	157.08	124.28	124.19	90.88	90.88
11274	Hardhead Catfish	278.84	278.75	236.35	236.35	168.11	168.11
11280	Hardhead Catfish	130.59	129.46	105.97	105.90	76.95	76.95
11287	Blue Catfish	322.02	321.43	217.72	217.65	157.84	157.84
11292	Blue Catfish	92.31	92.27	62.66	62.66	45.73	45.73
11347	Channel Catfish	124.93	124.82	84.50	84.50	64.07	64.07
13338	Hardhead Catfish	73.39	73.05	57.85	57.83	42.94	42.94
13342	Hardhead Catfish	182.86	182.71	139.93	139.91	106.24	106.24
13344	Hardhead Catfish	78.50	78.41	58.69	58.69	44.05	44.05
13355	Hardhead Catfish	53.06	53.00	41.60	41.60	32.80	32.80
13363	Hardhead Catfish	29.28	29.22	22.58	22.58	16.85	16.85
14560	Hardhead Catfish	57.20	57.00	44.53	44.52	33.55	33.55

Table 4.7 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]
15301	Hardhead Catfish	84.04	83.88	66.30	66.30	49.34	49.34
15936	Hardhead Catfish	521.94	521.84	415.63	415.63	289.08	289.08
15979	Hardhead Catfish	107.95	107.60	86.10	86.08	62.97	62.97
16213	Hardhead Catfish	37.89	37.60	28.77	28.76	22.59	22.59
16499	Hardhead Catfish	120.93	120.90	91.02	91.01	69.63	69.63
16618	Hardhead Catfish	40.38	40.31	31.37	31.37	23.50	23.50
16622	Blue Catfish	12.01	10.11	7.39	7.22	5.36	5.36
11258	Atlantic Croaker	277.69	277.68	185.02	185.02	132.38	132.38
11262	Atlantic Croaker	128.55	128.53	85.77	85.77	60.93	60.93
13355	Atlantic Croaker	42.18	42.14	28.45	28.44	20.74	20.74
14560	Atlantic Croaker	56.55	56.52	39.45	39.45	28.15	28.15
14560	Speckled Seatrout	75.09	75.06	52.91	52.90	39.16	39.16
16213	Atlantic Croaker	33.35	33.22	24.08	24.08	17.93	17.93
16618	Speckled Seatrout	172.11	172.07	117.44	117.44	81.97	81.97
13363	Speckled Seatrout	101.30	101.20	72.23	72.22	54.11	54.11
11280	Atlantic Croaker	910.35	910.29	593.04	593.04	419.07	419.07
11261	Atlantic Croaker	708.78	708.67	468.70	468.70	324.48	324.48
15936	Atlantic Croaker	1179.71	1179.64	780.77	780.77	524.43	524.43
16499	Atlantic Croaker	159.53	159.45	102.28	102.25	72.97	72.97

Table 4.7 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]
11252	Atlantic Croaker	76.12	75.98	50.07	50.06	35.70	35.70
15301	Atlantic Croaker	263.91	263.88	170.47	170.47	120.73	120.73
11193	Atlantic Croaker	314.49	314.47	211.00	211.00	148.60	148.60
13342	Atlantic Croaker	243.68	243.64	155.19	155.18	103.35	103.35
13344	Atlantic Croaker	252.67	252.60	161.52	161.52	110.86	110.861
11270	Speckled Seatrout	226.00	225.08	153.72	153.65	108.02	108.02
11264	Speckled Seatrout	334.34	333.85	221.48	221.37	149.58	149.58
13338	Speckled Seatrout	145.60	144.82	99.30	99.23	67.67	67.67

∑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 4.8 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	12.0	10.1	7.4	7.2	5.4	5.4
Max	521.9	521.8	415.6	415.6	289.1	289.1
Average	136.8	136.4	104.7	104.7	77.2	77.2
Stdev	108.6	108.6	85.1	85.1	59.8	59.8
95% Confidence level of mean	93 - 181	93 - 180	70 - 139	70 - 139	53 - 101	53 - 101
% stations that exceed health standard	85		73		62	

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

b Non-detects assumed to be zero

Table 4.9 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	33.3	33.2	24.1	24.1	17.9	17.9
Max	1179.7	1179.6	780.8	780.8	524.4	524.4
Average	285.1	284.9	188.6	188.6	131.0	131.0
Stdev	303.4	303.5	199.3	199.3	136.0	136.0
95% Confidence level of mean	143 - 427	143 - 427	95 - 282	95 - 282	67 - 195	67 – 195
% stations that exceed health standard	90		84		79	

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

b Non-detects assumed to be zero

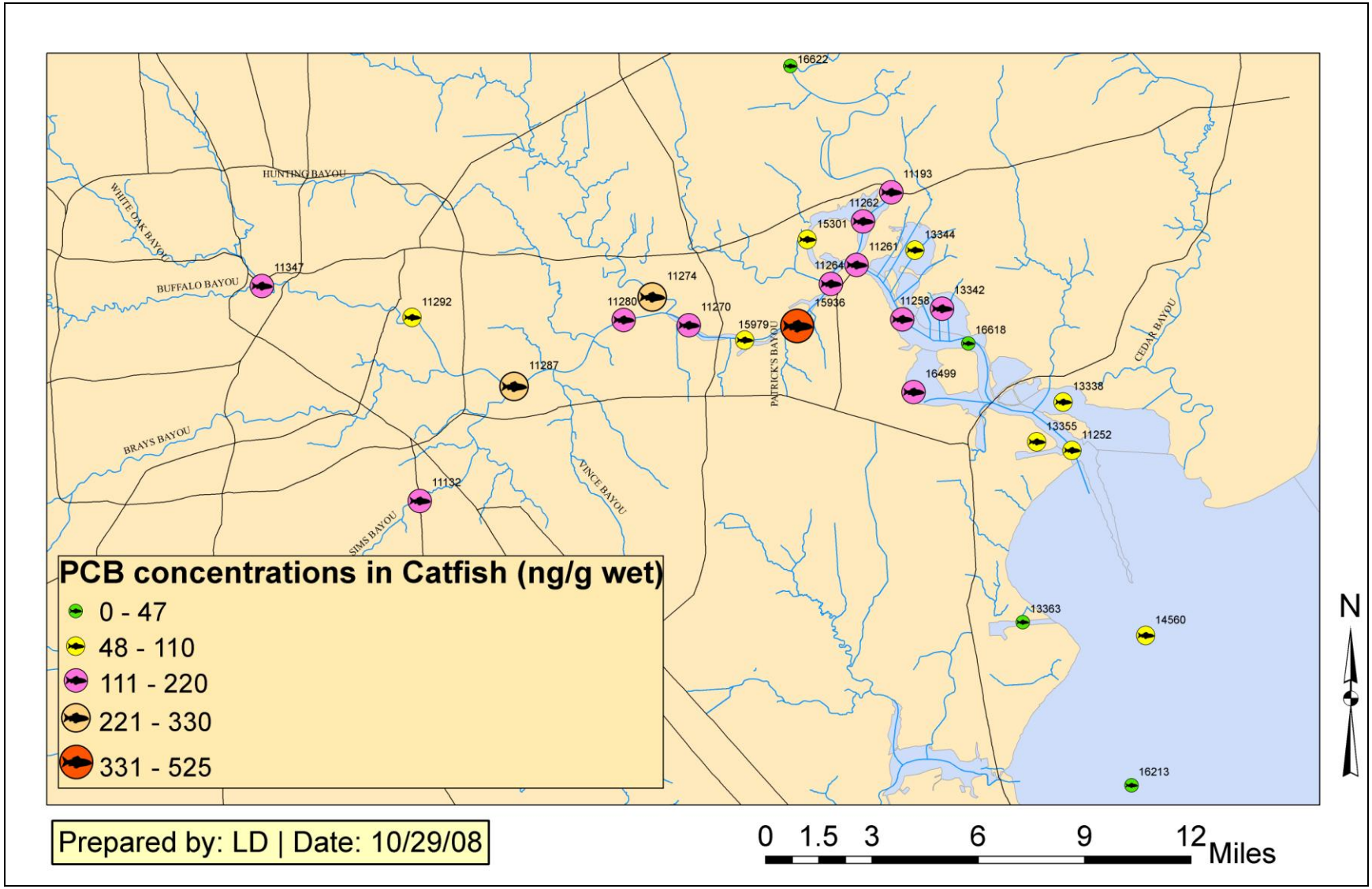


Figure 4.7a Total PCB concentrations in Catfish calculated as sum of 209 congeners

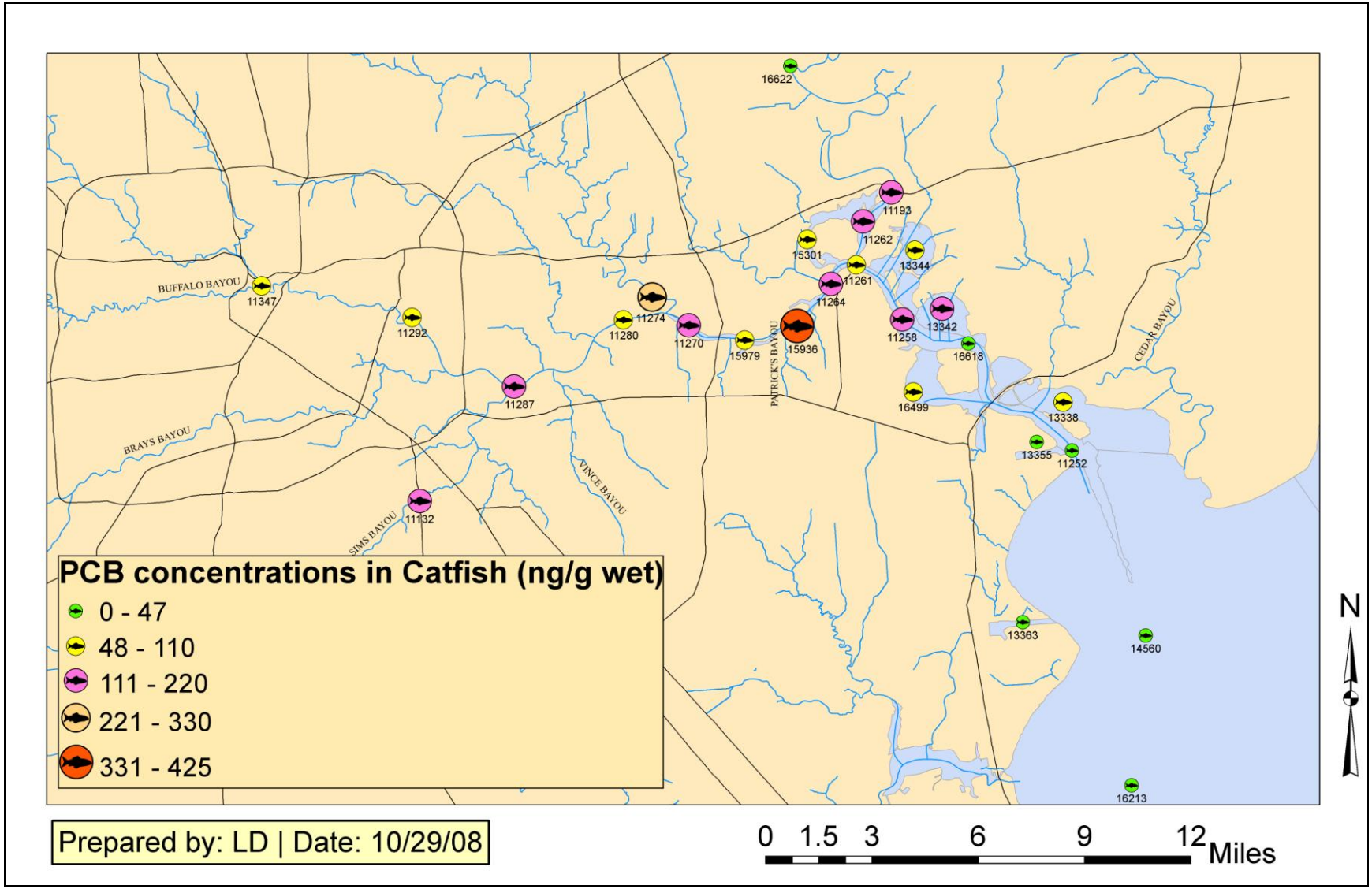


Figure 4.7b Total PCB concentrations in Catfish calculated the sum of 43 congeners

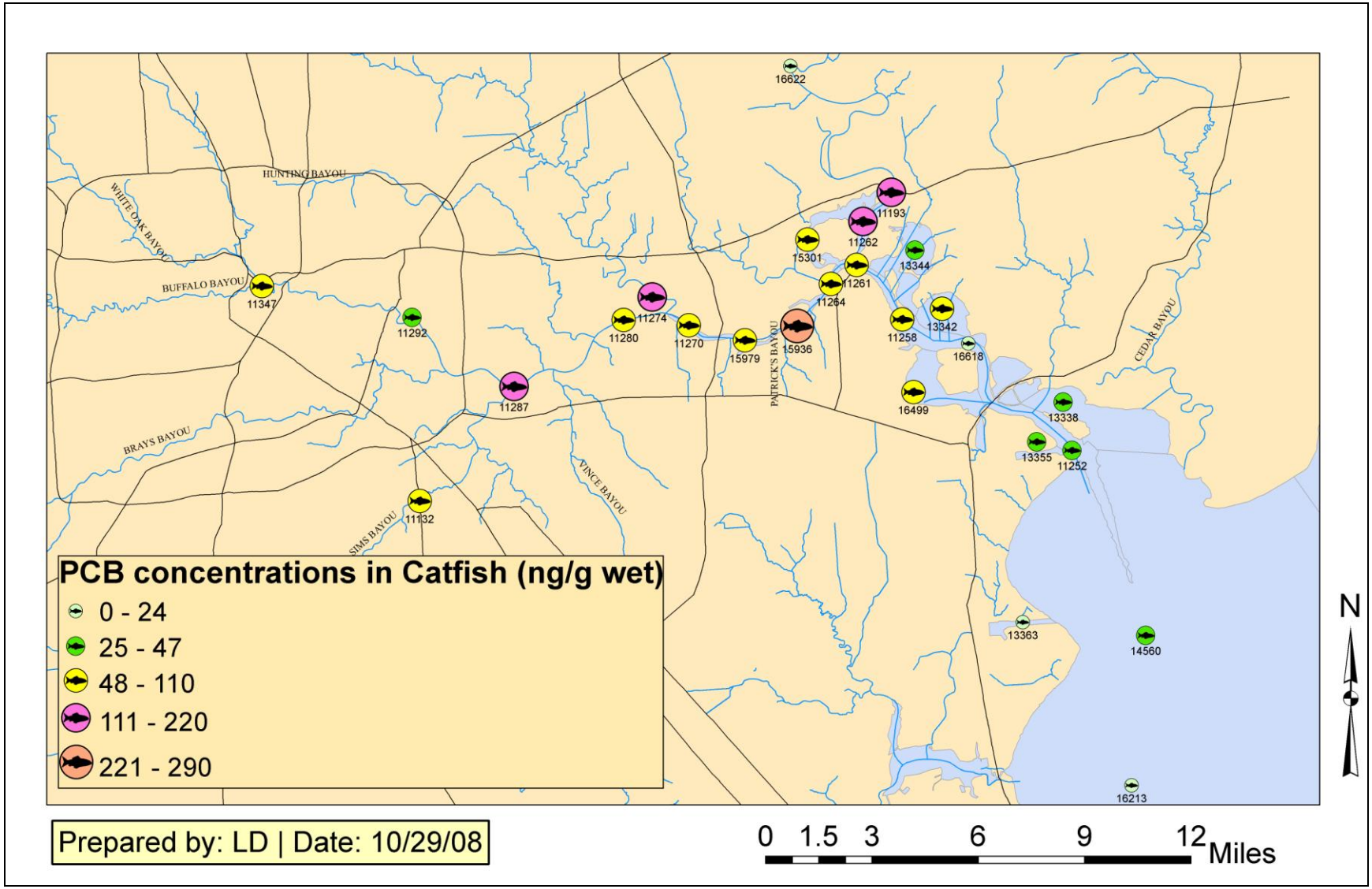


Figure 4.7c Total PCB concentrations in Catfish calculated as sum of 18 congeners

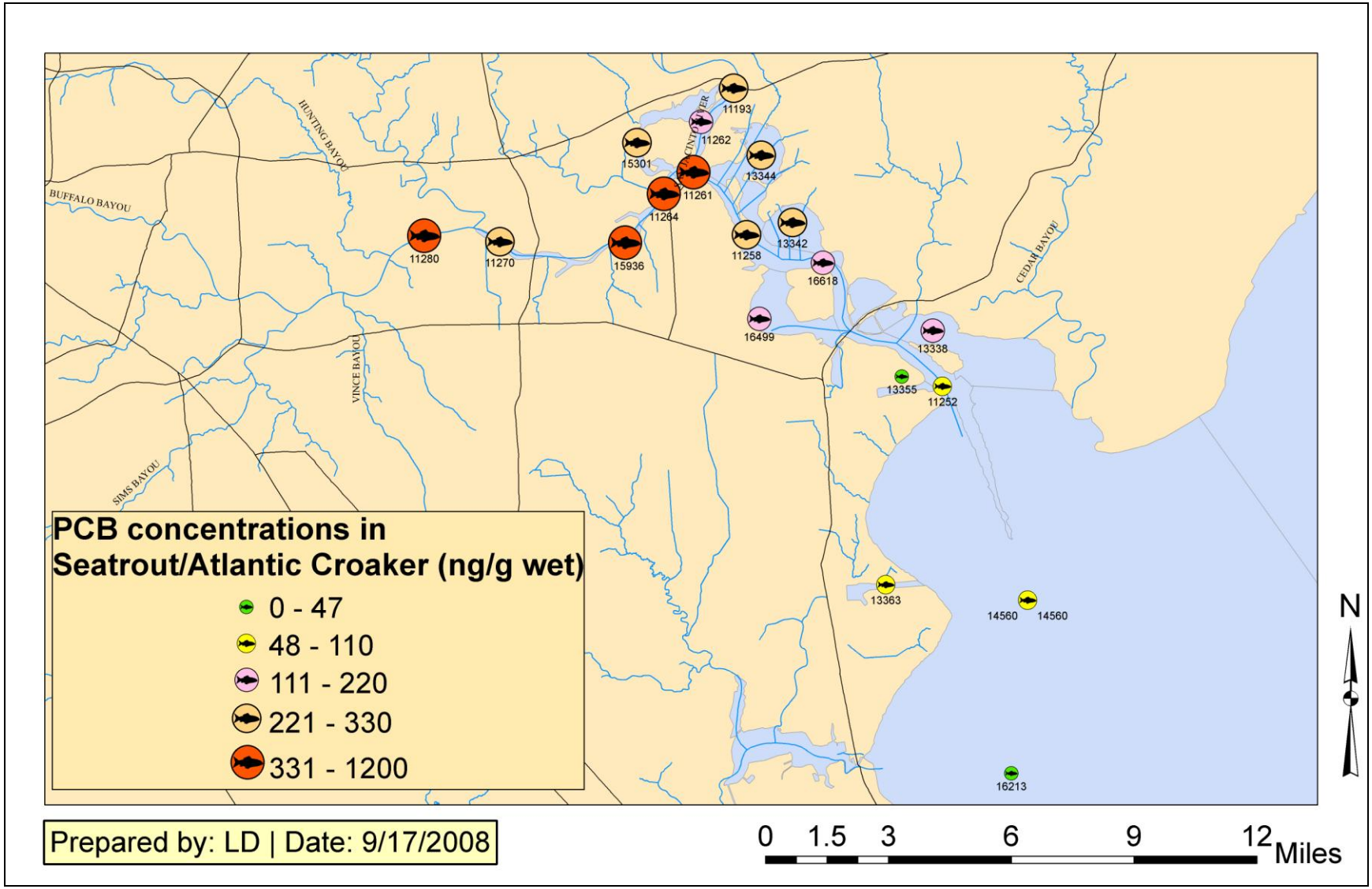


Figure 4.8a Total PCB concentrations in Seatrout/Atlantic croaker calculated as sum of 209 congeners

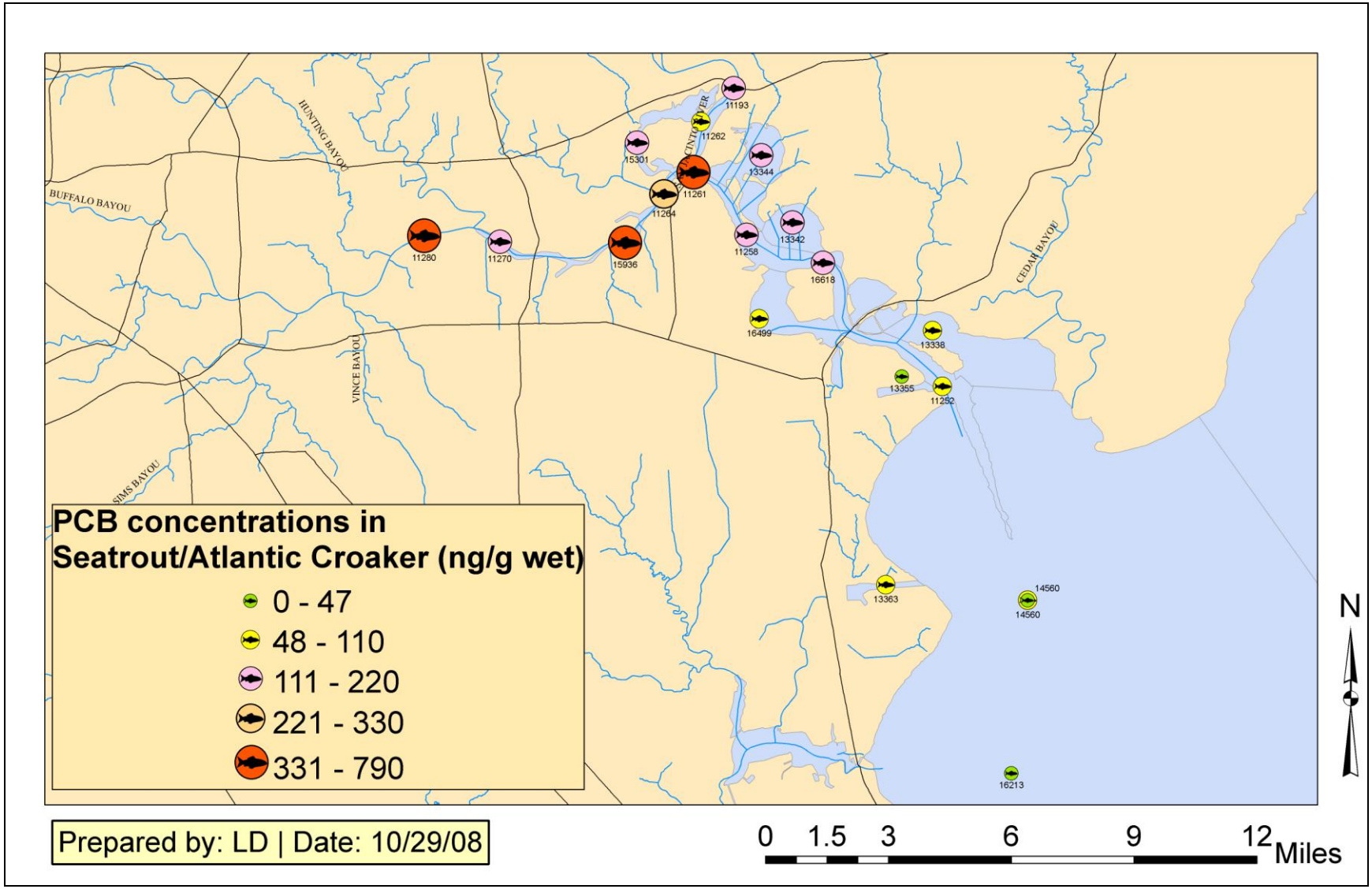


Figure 4.8b Total PCB concentrations in Seatrout/Atlantic croaker calculated as sum of 43 congeners

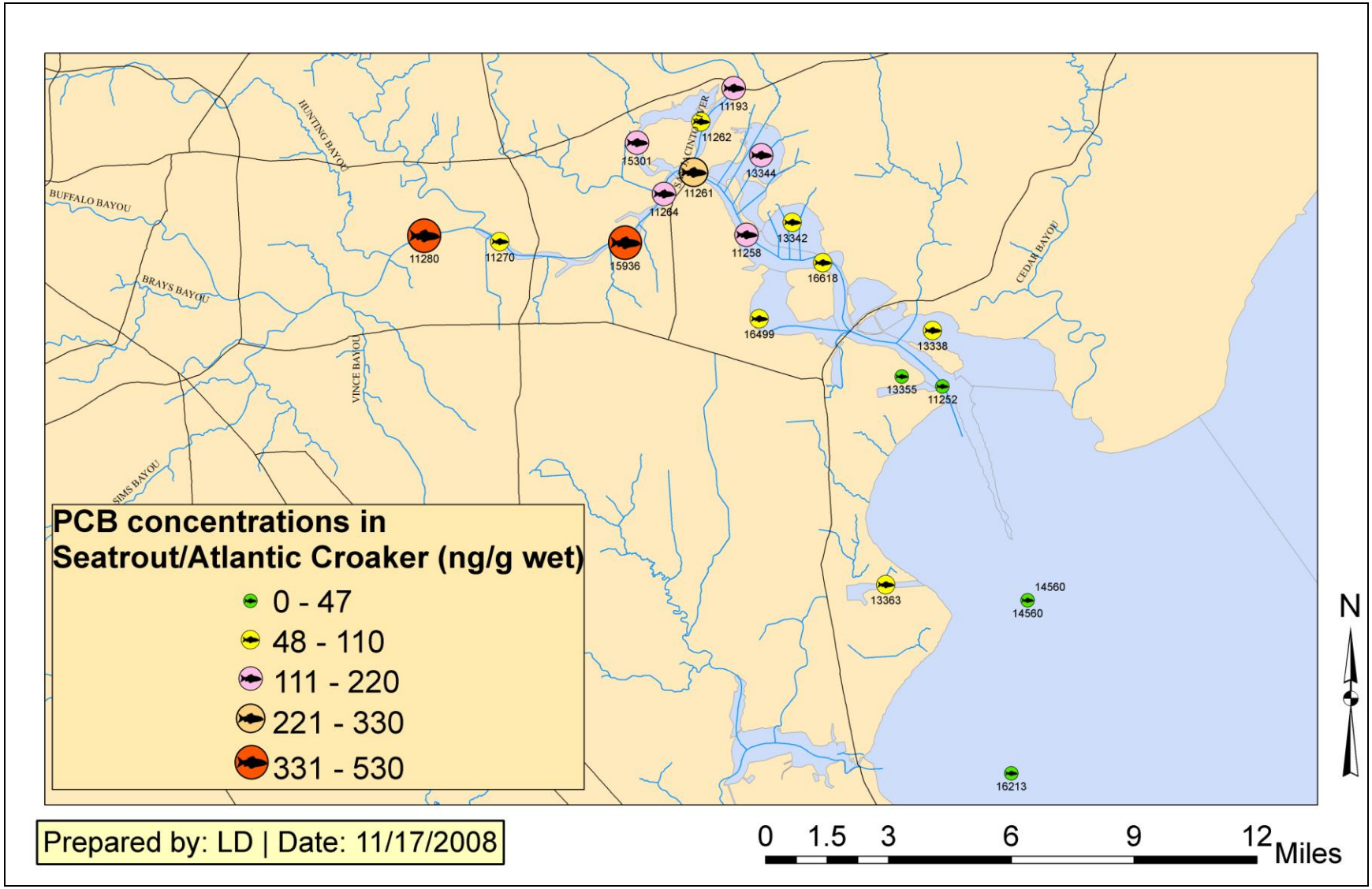


Figure 4.8c Total PCB concentrations in Seatrout/Atlantic croaker calculated as sum of 18 congeners

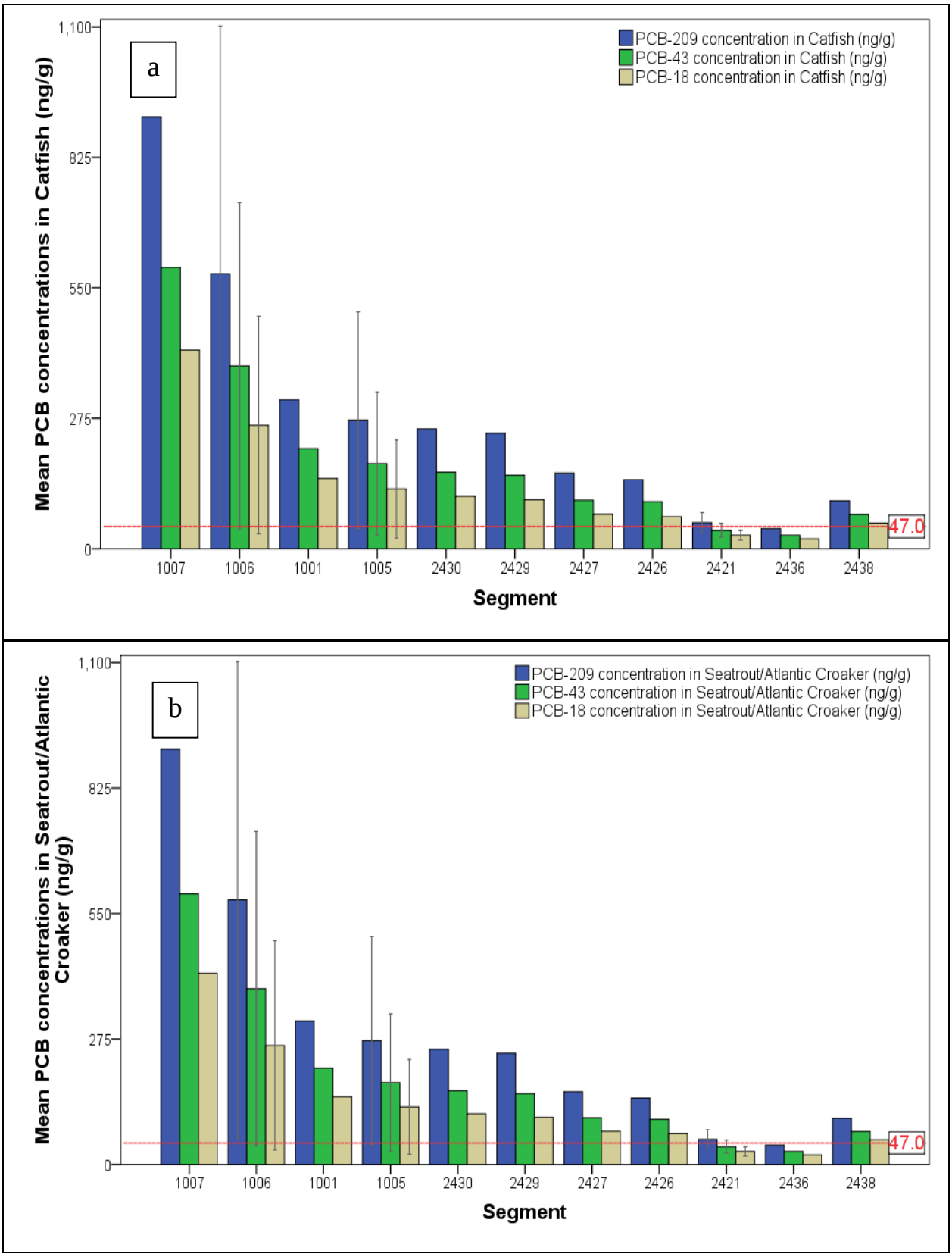


Figure 4.9 Comparison of tissue PCB concentrations by segment

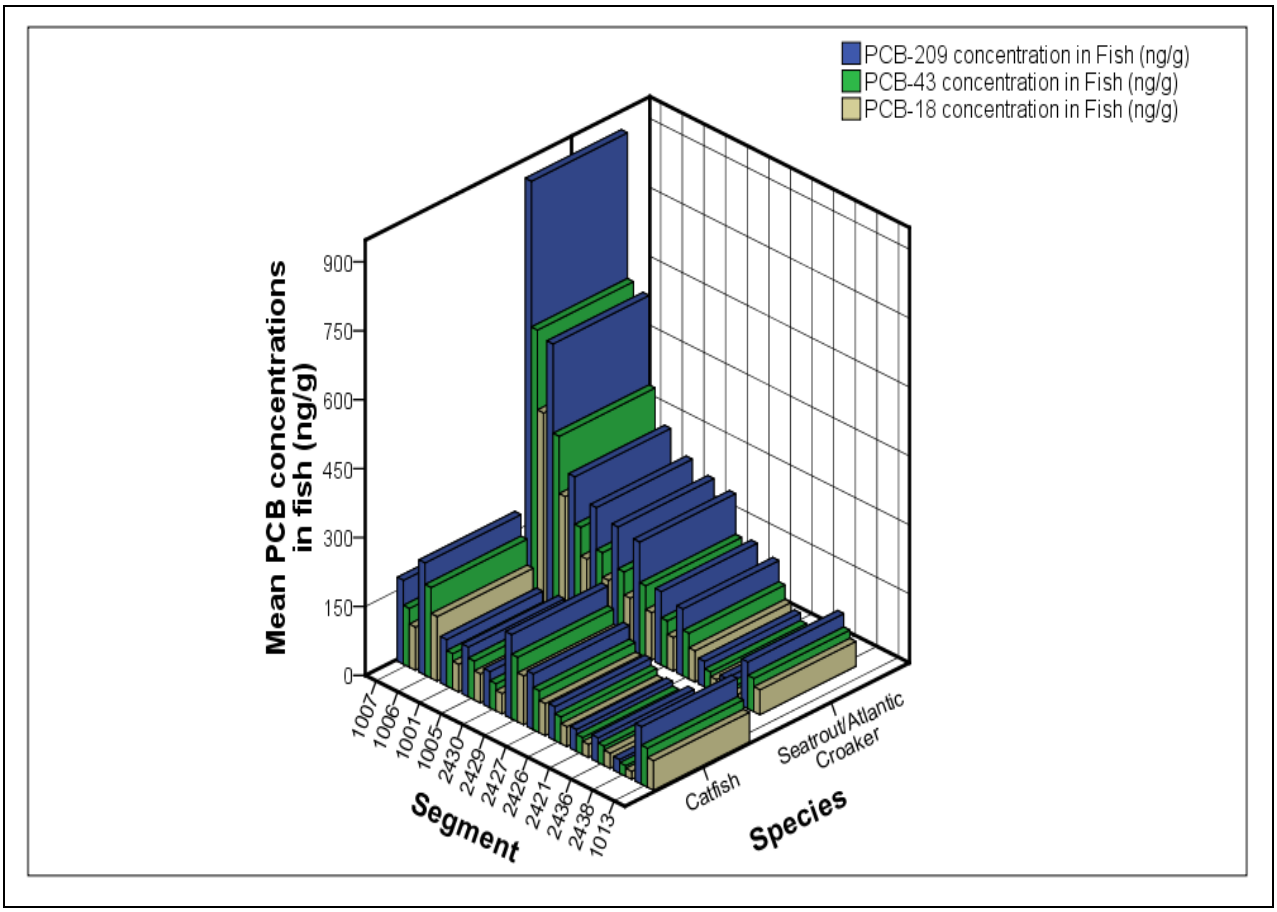


Figure 4.10 Comparison of PCB concentrations by species and segment

Figure 4.9a 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 2430, 2426, 2421, 2436, and 2438 exceeded the standard. All segments except 2421, 2436 and 2438 exceeded the standard in the case of ∑43 congener approach, while only segment 2438 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 4.9b 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 2436 and segment 2421 in a few cases exceeded the health standard criteria of 47 ng/g regardless of the summation approach. The highest concentrations were observed upstream of the HSC in segments 1007 and 1006 and the concentrations decreased significantly as distance increased towards Galveston Bay. Figure 4.10 compares the PCB concentrations by species (Catfish vs Seatrout/Atlantic Croaker) and by segment. 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.

4.3.4 Intensive Sediment PCB Concentrations

Figures 4.11a, 4.11b, and 4.11c show the distribution of total PCBs in sediment in the Houston Ship Channel System from the intensive sampling studies based on calculations using the different congener summation methods. It can be seen that the PCB concentrations in the sediment were found to have no clear pattern in the areas expected to be highly contaminated. Figure 4.12a shows the stations that were sampled for PCB concentrations along the transect. Figure 4.12b compares the sediment PCB concentrations along the transect and it can be seen that all stations sampled at different transects did show considerable difference in PCB concentrations. The PCB concentrations were significantly lower in segments of Galveston Bay compared to other segments.

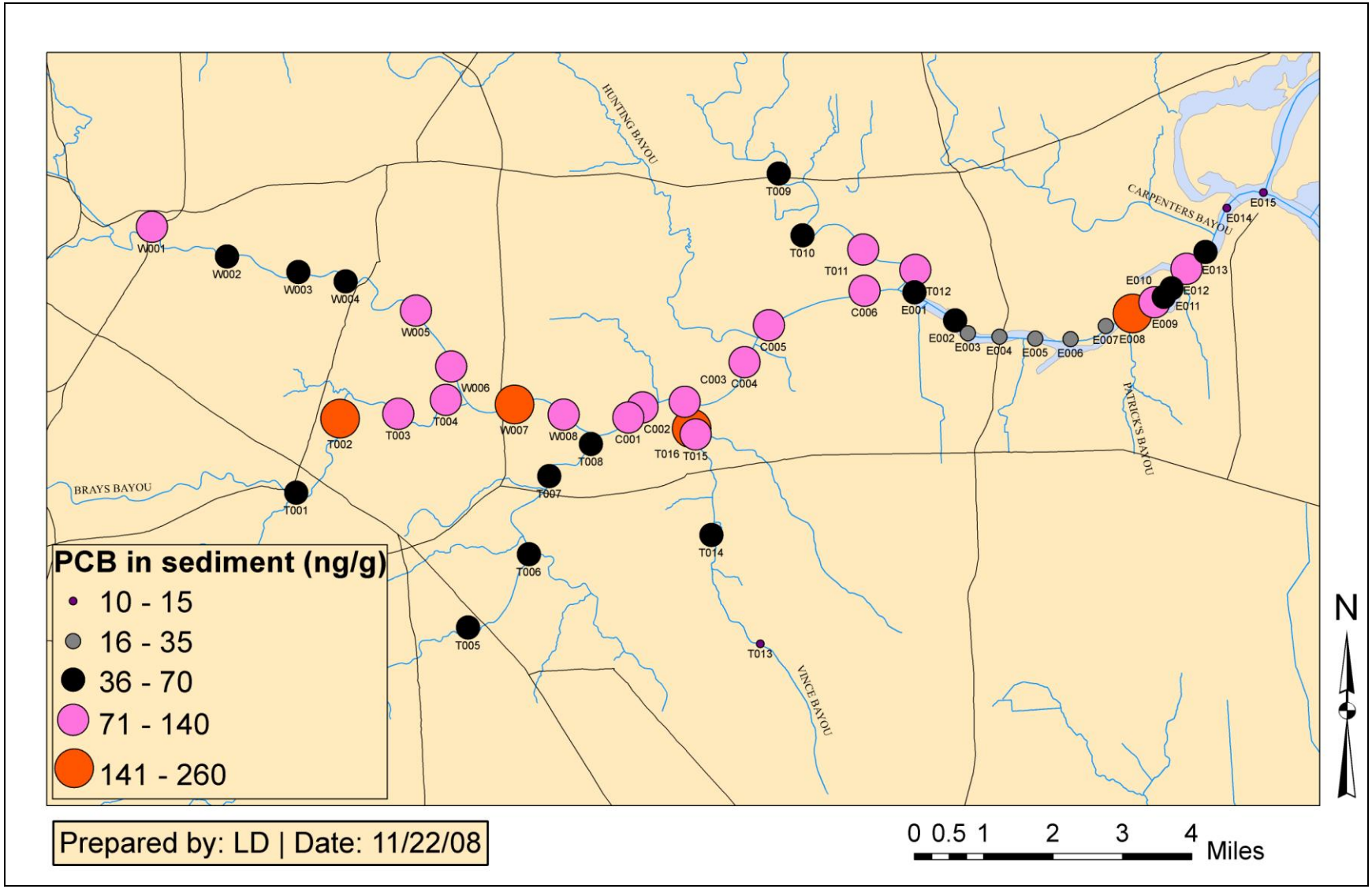


Figure 4.11a Total PCB concentrations in sediment from intensive sediment sampling calculated as sum of 209 congeners

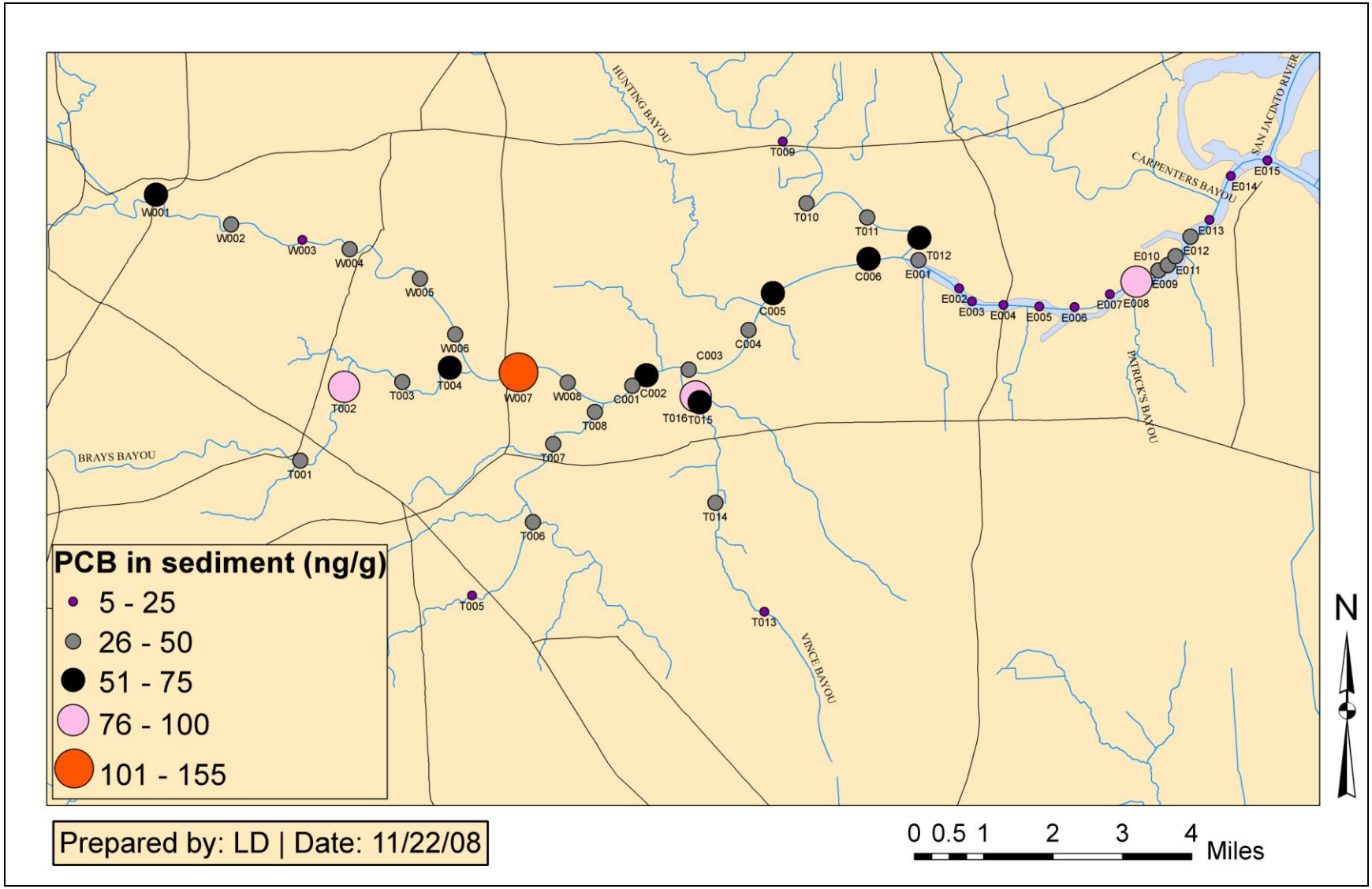


Figure 4.11b Total PCB concentrations in sediment from intensive sediment sampling calculated as sum of 43 congeners

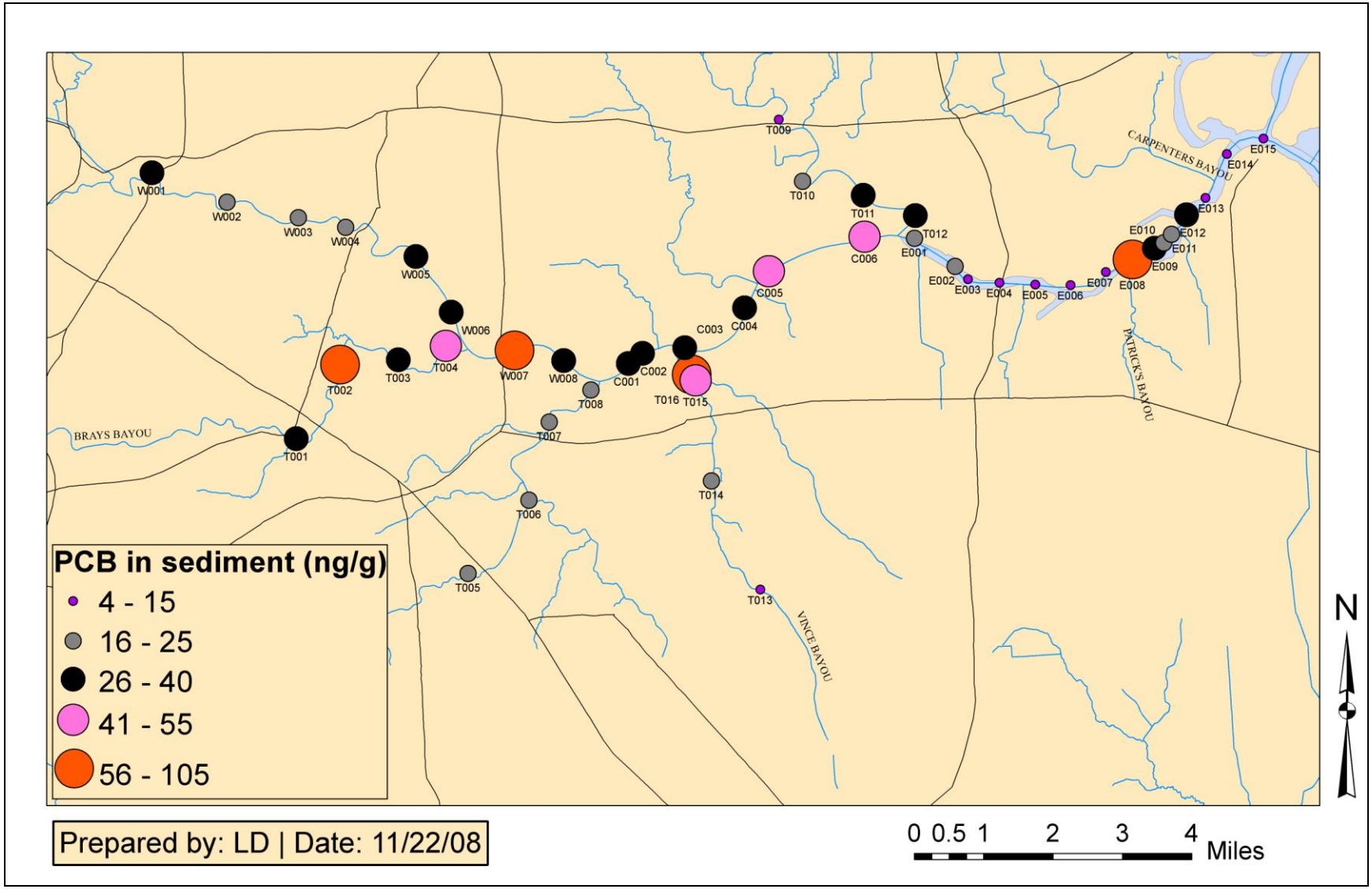
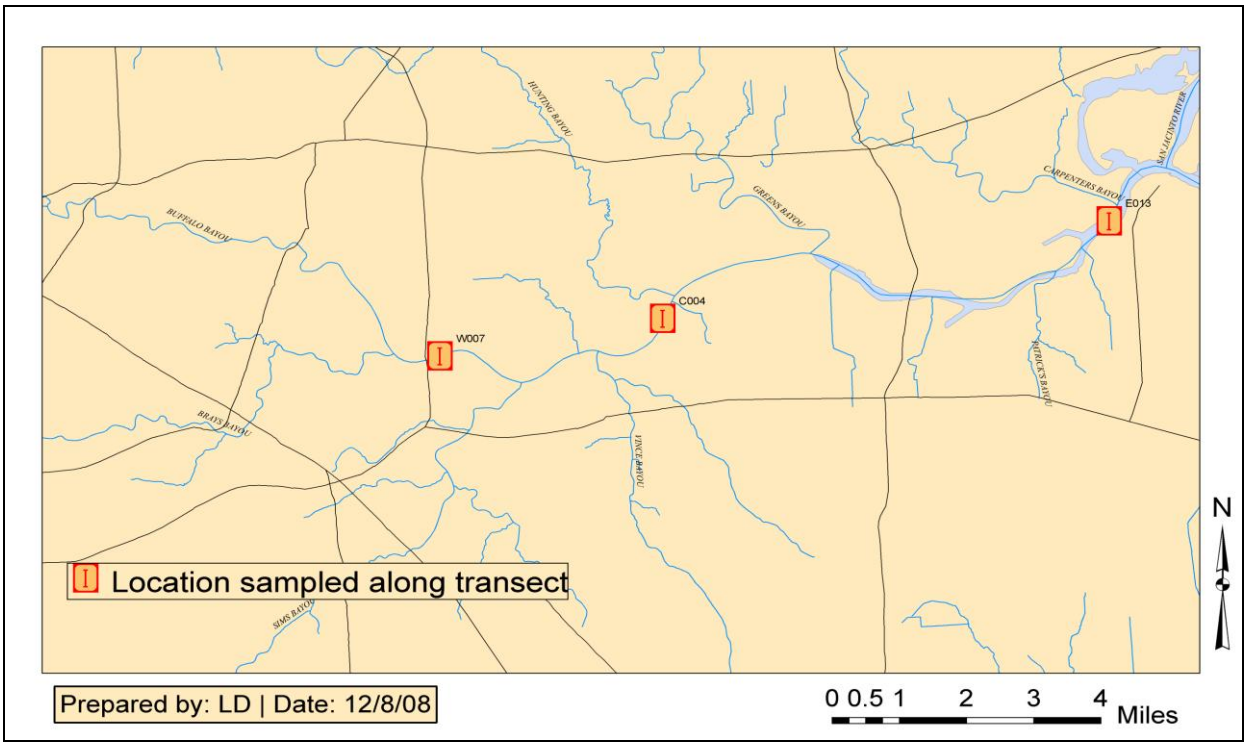


Figure 4.11c Total PCB concentrations in sediment from intensive sediment sampling calculated as sum of 18 congeners



* 5 samples (A, B, C, D, E) were collected along the transect at each location

Figure 4.12a Locations sampled for PCB sediment concentrations along transects

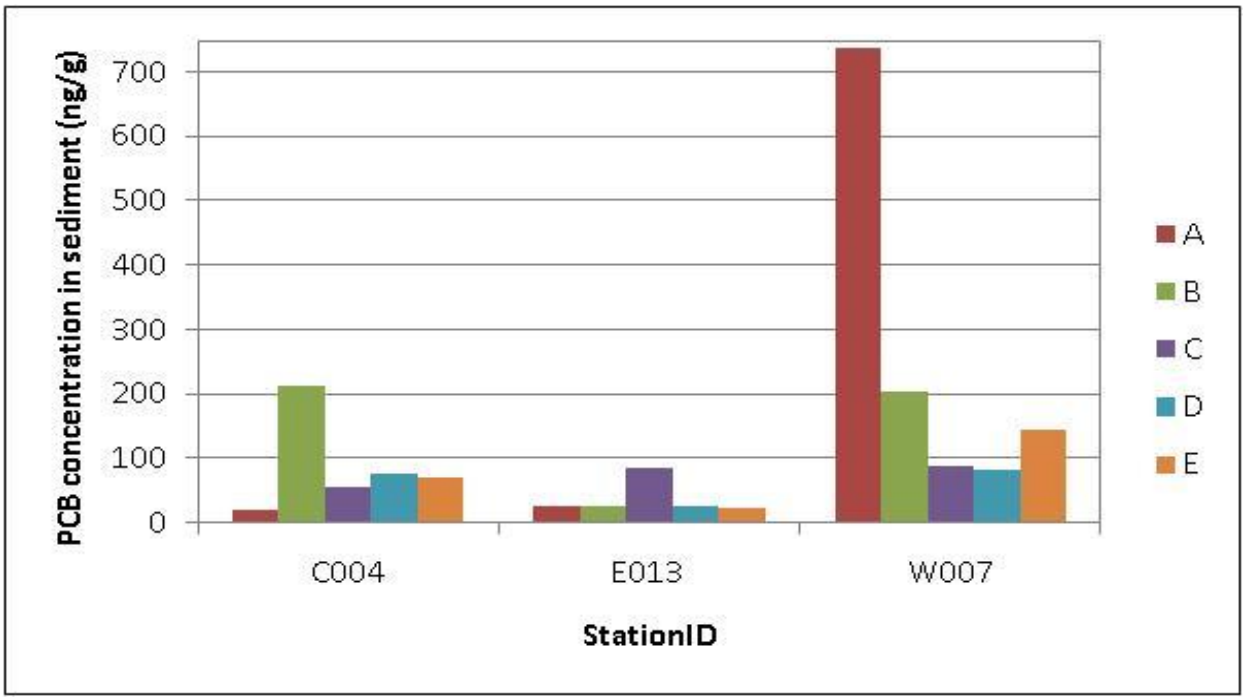
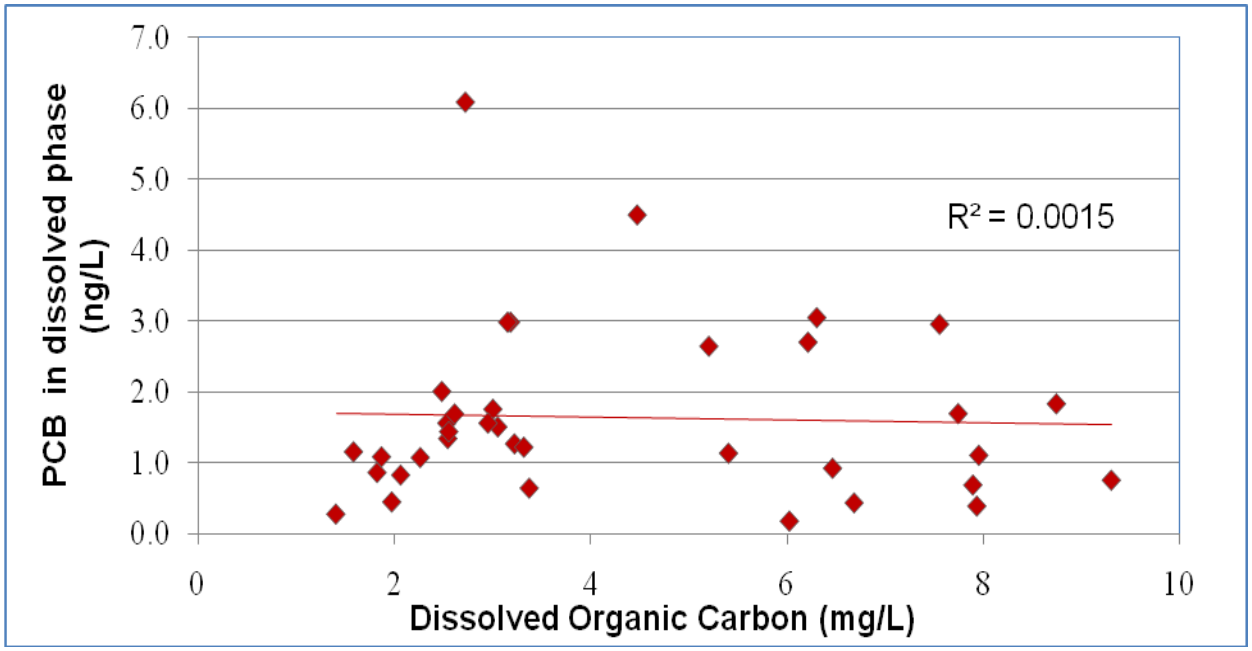


Figure 4.12b Variation in PCB sediment concentrations along the transect of channel

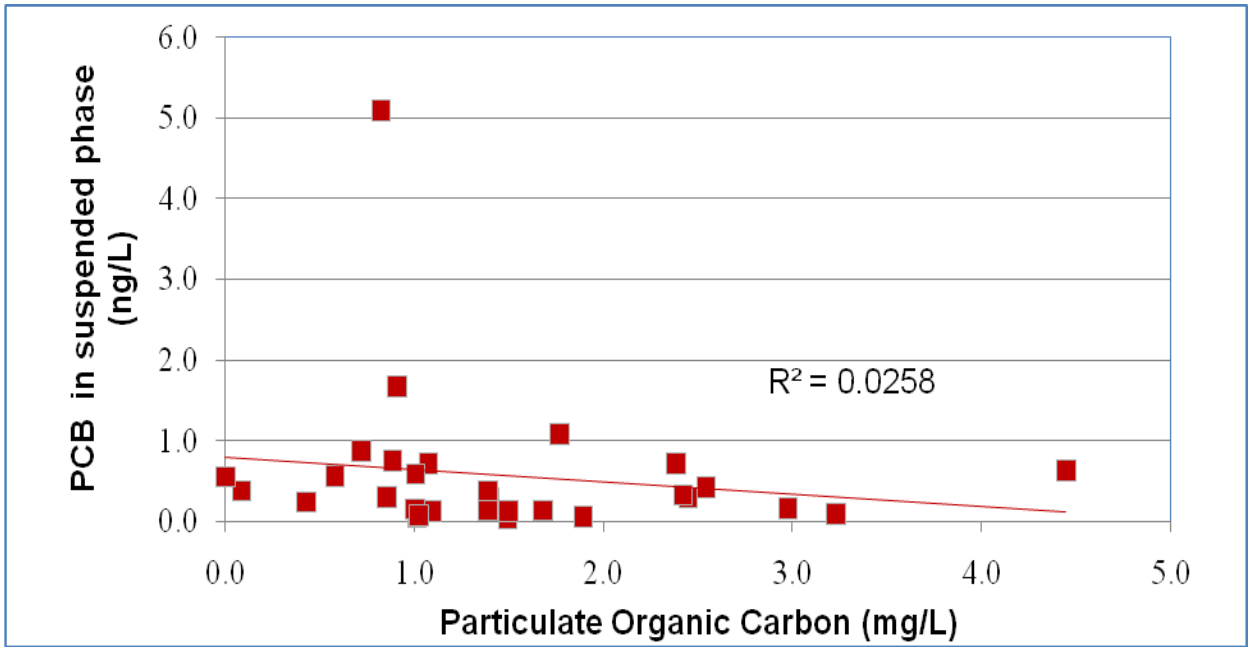
4.4 Data Analysis

The PCB concentrations in the dissolved and suspended phase were correlated with the organic carbon content in the corresponding phases. Since station 17149 had concentrations both in the dissolved and suspended phase that were significantly higher (10 times) compared to other stations, concentrations observed in station 17149 were considered an outlier and not included in the data analysis. Figure 4.13 shows a plot of dissolved PCB concentrations versus dissolved organic carbon and Figure 4.14 shows a plot of suspended PCB versus particulate organic carbon in water. The figures indicate insignificant correlation between the PCB concentrations and the organic carbon both in the dissolved and in the suspended phase. Figure 4.15 shows a plot of PCB concentrations in sediment correlated to the organic carbon in sediment and the plot indicates a weak correlation based on the R^2 value.



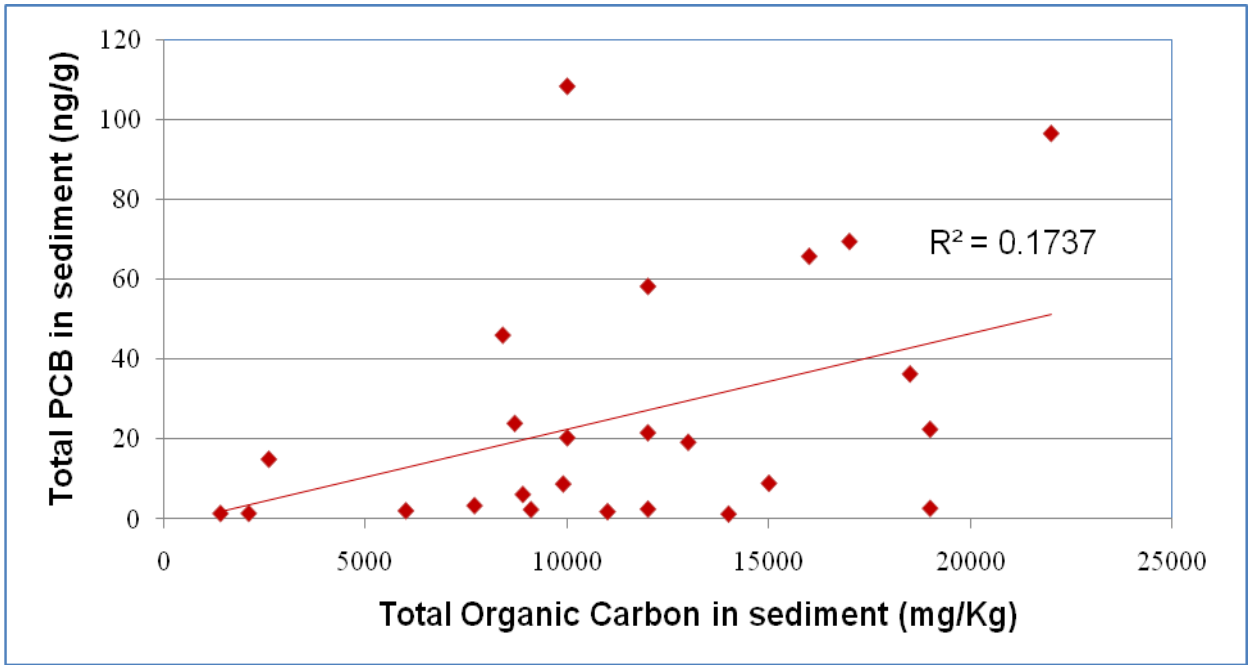
* All concentrations based on 1/2 detection limit treatment of non-detects and ∑209 congeners.

Figure 4.13 Plot of dissolved PCB concentration versus dissolved organic carbon



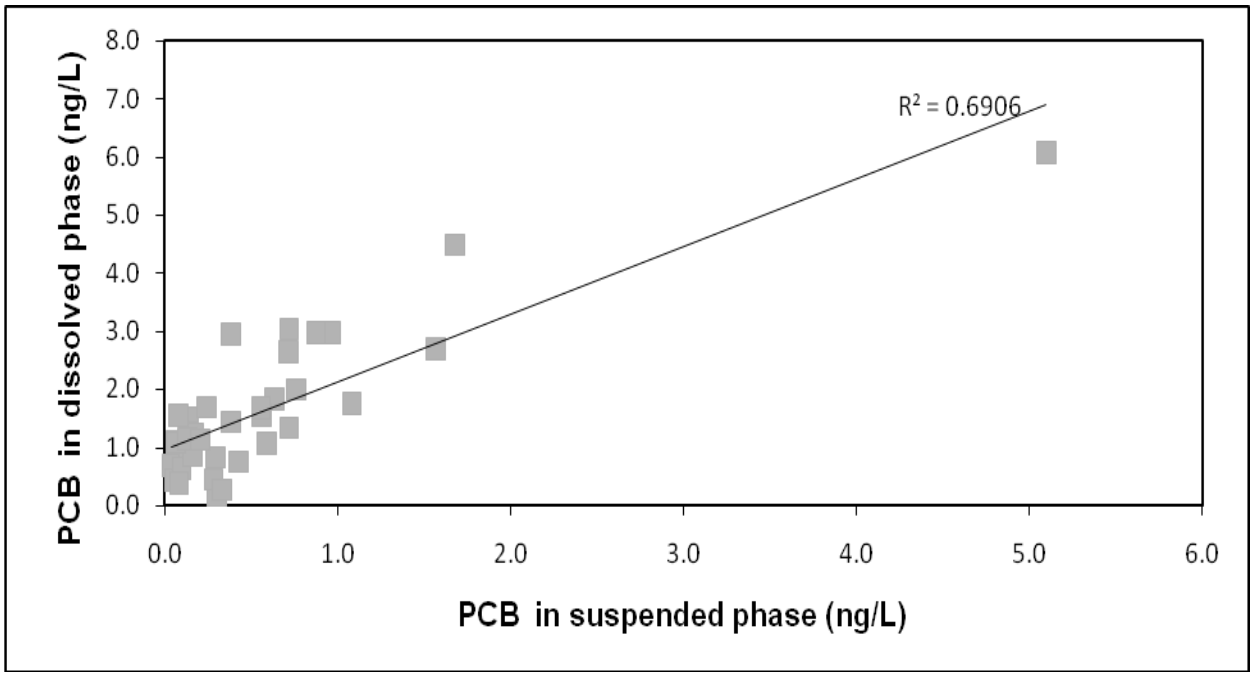
* All concentrations based on 1/2 detection limit treatment of non-detects and ∑209 congeners.

Figure 4.14 Plot of suspended PCB concentration versus particulate organic carbon



* All concentrations based on 1/2 detection limit treatment of non-detects and ∑209 congeners.

Figure 4.15 Plot of PCB concentration versus organic carbon in sediment



* All concentrations based on 1/2 detection limit treatment of non-detects and ∑209 congeners.

Figure 4.16 Partitioning of PCBs between dissolved and suspended Phases in the HSC

A significant correlation was observed between the dissolved PCB concentrations and the suspended PCB concentrations in water (Figure 4.16). This is understandable considering the partitioning that occurs between the dissolved and suspended phases in water. Figure 4.17 shows the correlation that exists between PCB concentrations in sediment to PCB concentrations in water (Dissolved, Suspended and total PCB) and in general the correlation was statistically significant. The correlation was significant for the plots of dissolved PCB in water vs PCB in sediment and total PCB in water vs PCB in sediment. Figure 4.18 shows the correlation between PCB concentrations in sediment to PCB concentrations in fish (Catfish and Seatrout/Atlantic Croaker) and Figure 4.19 shows the correlation between PCB concentrations in water to PCB concentrations in fish (Catfish and Seatrout/Atlantic Croaker). In all cases, the correlation was found to be significant.

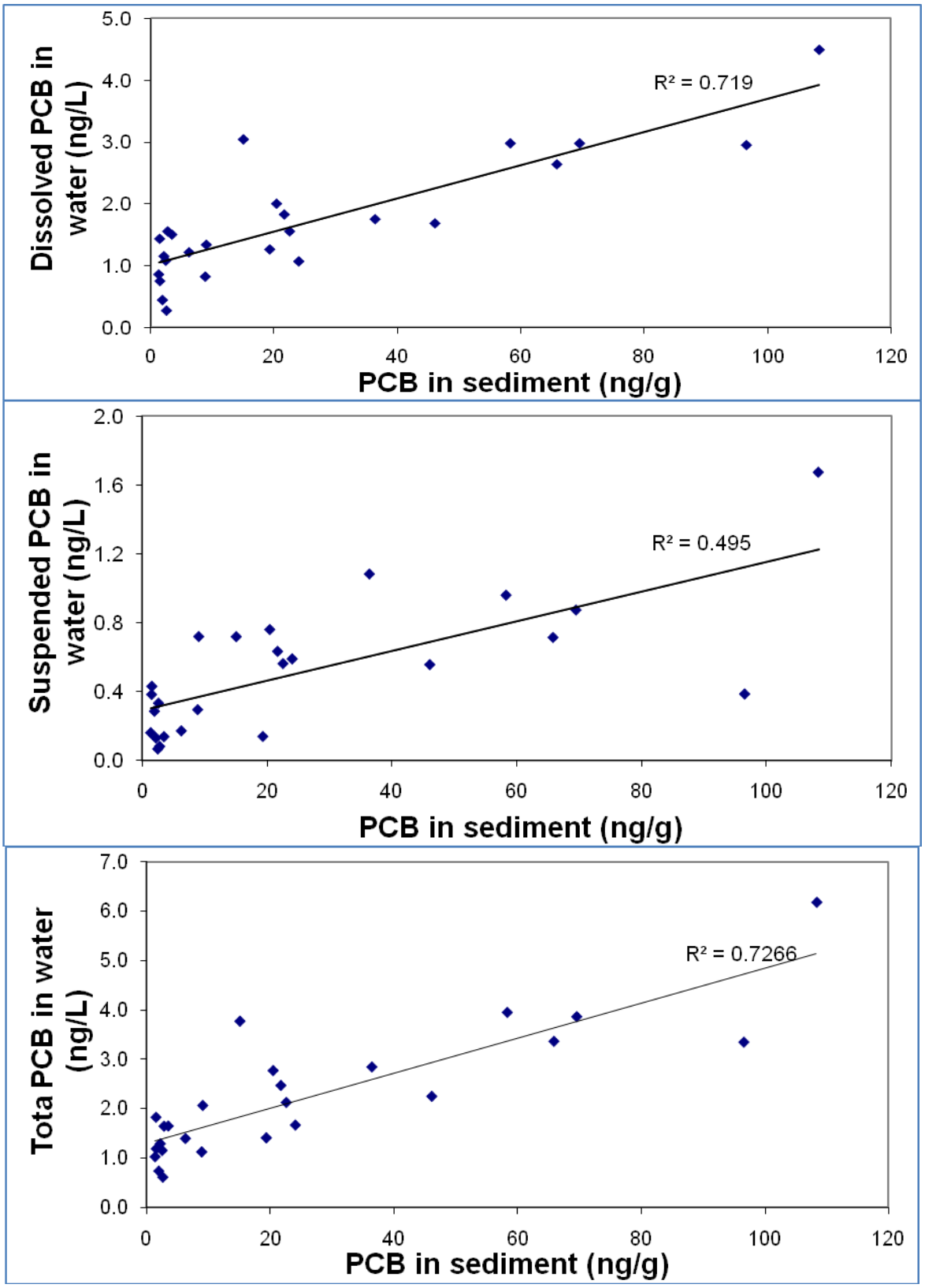


Figure 4.17 Partitioning of PCB between sediment and water in the HSC

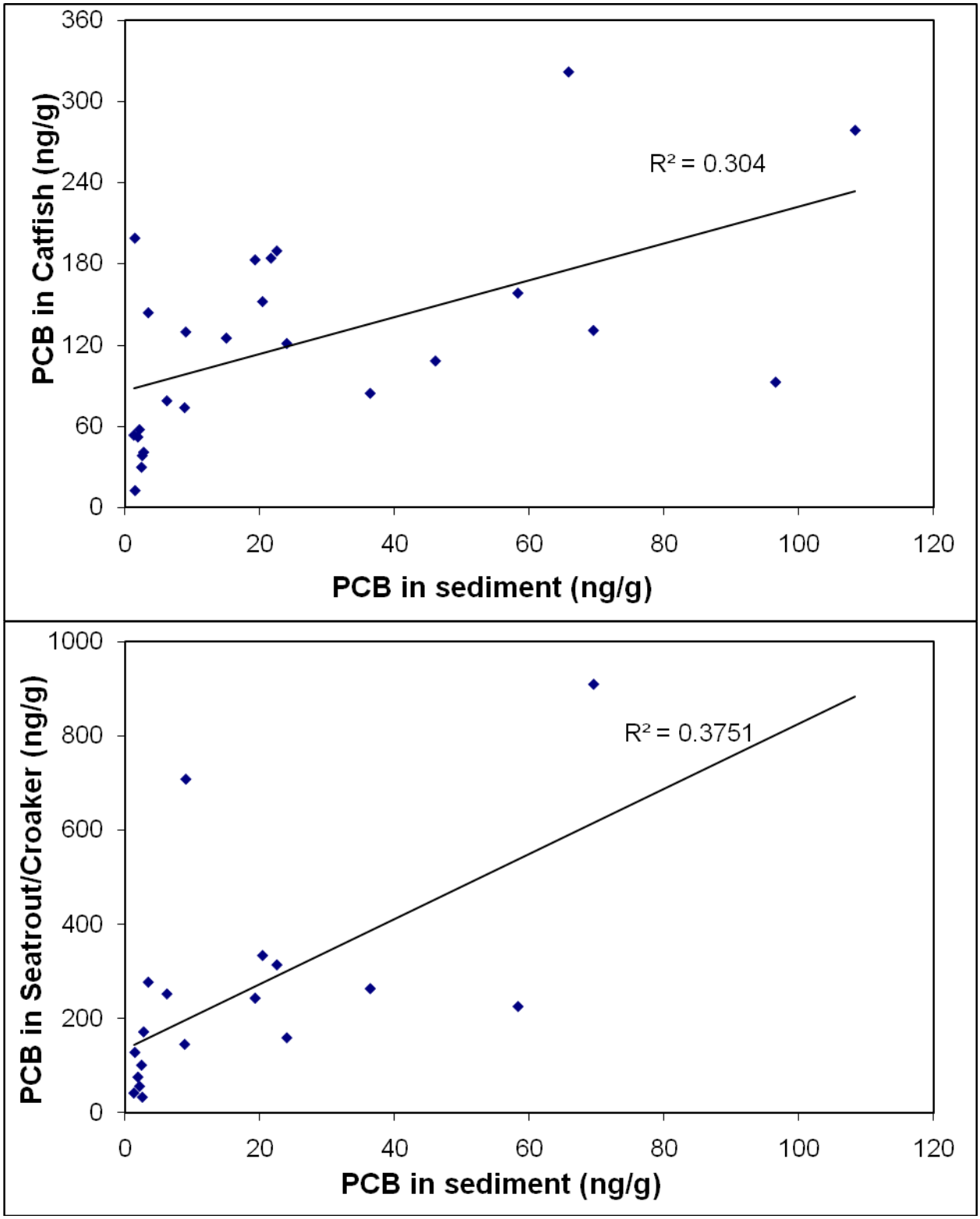


Figure 4.18 Partitioning of PCB between fish and sediment in the HSC

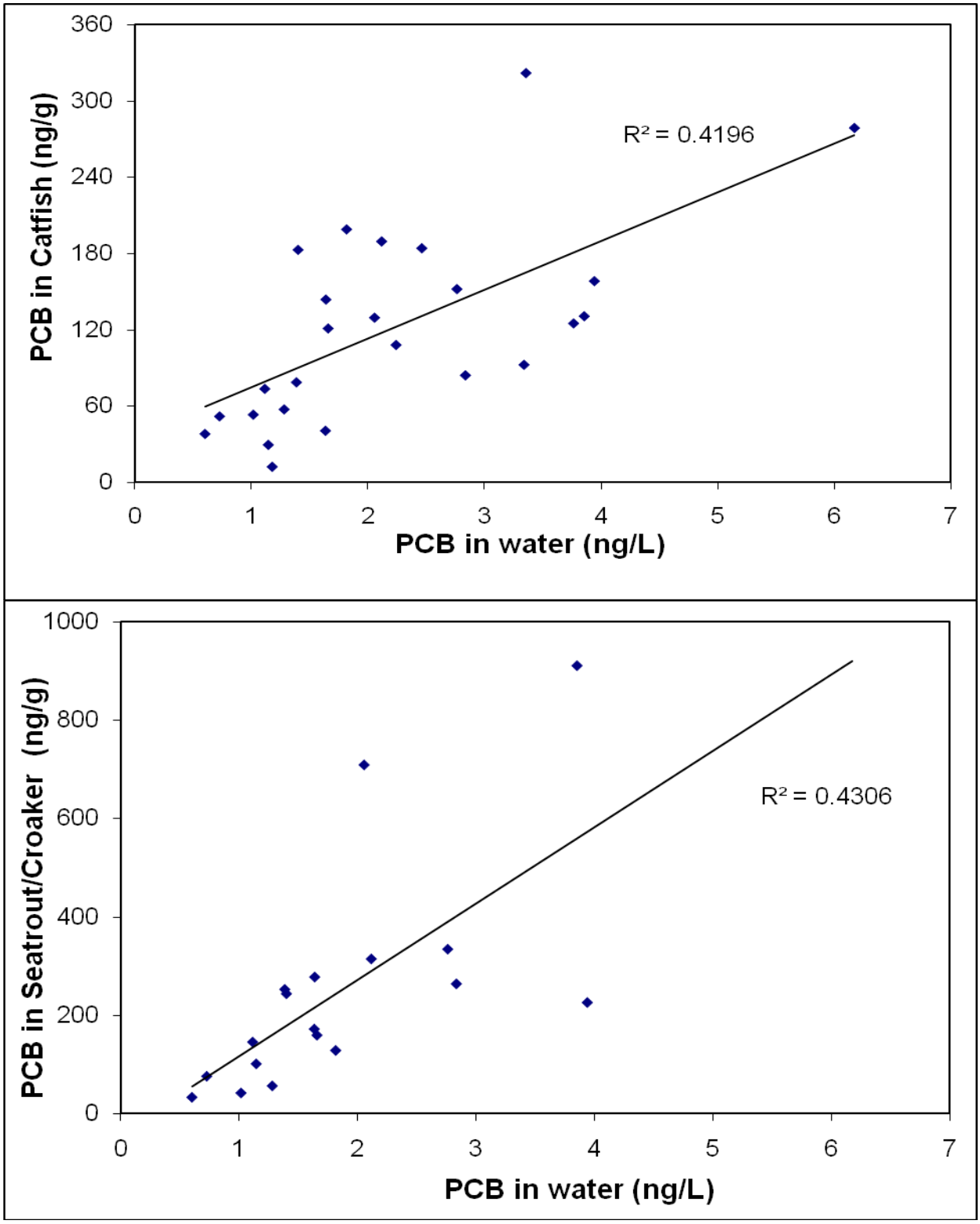


Figure 4.19 Partitioning of PCB between fish and water in the HSC

4.5 Distribution of PCB homologues in water, sediment and tissue

The homologue PCB distributions in water (1-10 chlorine atoms on the biphenyl rings) are shown in Figures 4.20-4.23. Figure 4.20 and 4.21 show the homologue PCB concentration distribution by segment for the suspended and dissolved phases, respectively. It can be observed that the huge spikes in 1006 are due to the high concentrations observed in 17149. Due to huge spikes in 1006, the homologue pattern was not observable in the suspended phase, while in the dissolved phase, the distribution pattern was similar in all segments. The homologue distribution can be better understood through the relative concentrations shown in Figures 4.22 and 4.23 for suspended and dissolved phases, respectively. The suspended phase concentrations were centered around the highly chlorinated congeners such as tetra-, penta-, hexa-, hepta-, and deca-chlorobiphenyls (Figure 4.22). In contrast to the suspended phase concentration being contributed by high chlorinated congeners, the dissolved water phase was contributed by the low chlorinated congeners such as di-, tri-, and tetra- homologue groups (Figure 4.23). It can also be seen that as the chlorination level increased, the relative fraction of PCB decreased in the dissolved phase.

The homologue PCB distributions in sediment (1-10 chlorine atoms on the biphenyl rings) are shown in Figures 4.24 and 4.25. Figure 4.24 shows the homologue distribution in the sediment by segment. As was observed earlier, the highly contaminated areas were in segments 1006 and 1007. The PCB distribution was highly concentrated on the tetra-, penta-, and hexa-chlorobiphenyl in addition to significant amount of decachlorobiphenyl in most segments upstream of Morgans point. The relative sediment PCB chlorobipheyl distribution is shown in Figure 4.25 and it can be seen that the PCB distribution was centered around

pentachlorobiphenyl. The significant amount of decachlorobiphenyls in the sediment could be the reason for high concentrations of decachlorobiphenyls in the suspended phase in water.

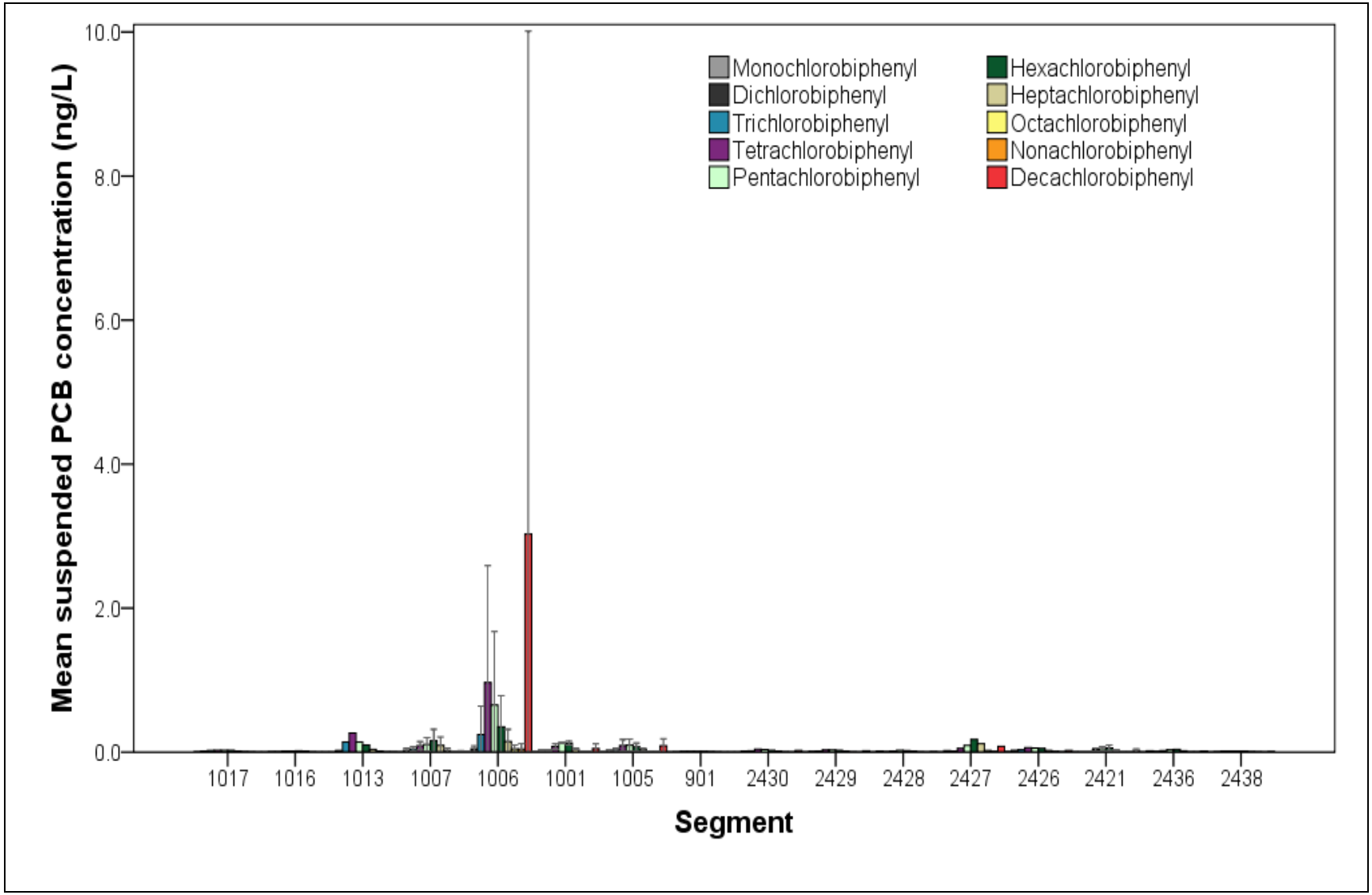


Figure 4.20 Concentration distributions of PCB homologues in the suspended water phase

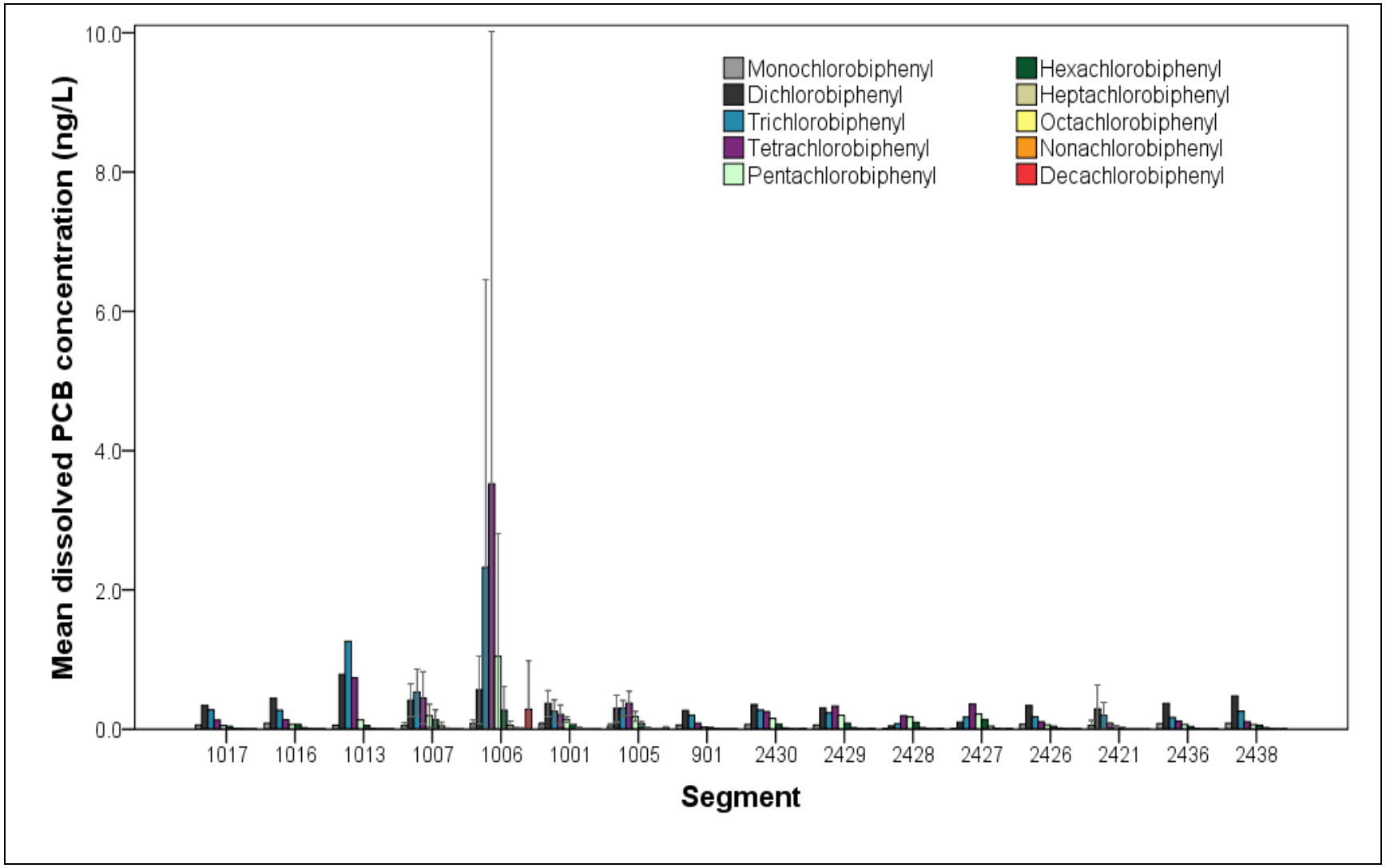


Figure 4.21 Concentration distributions of PCB homologues in the dissolved water phase

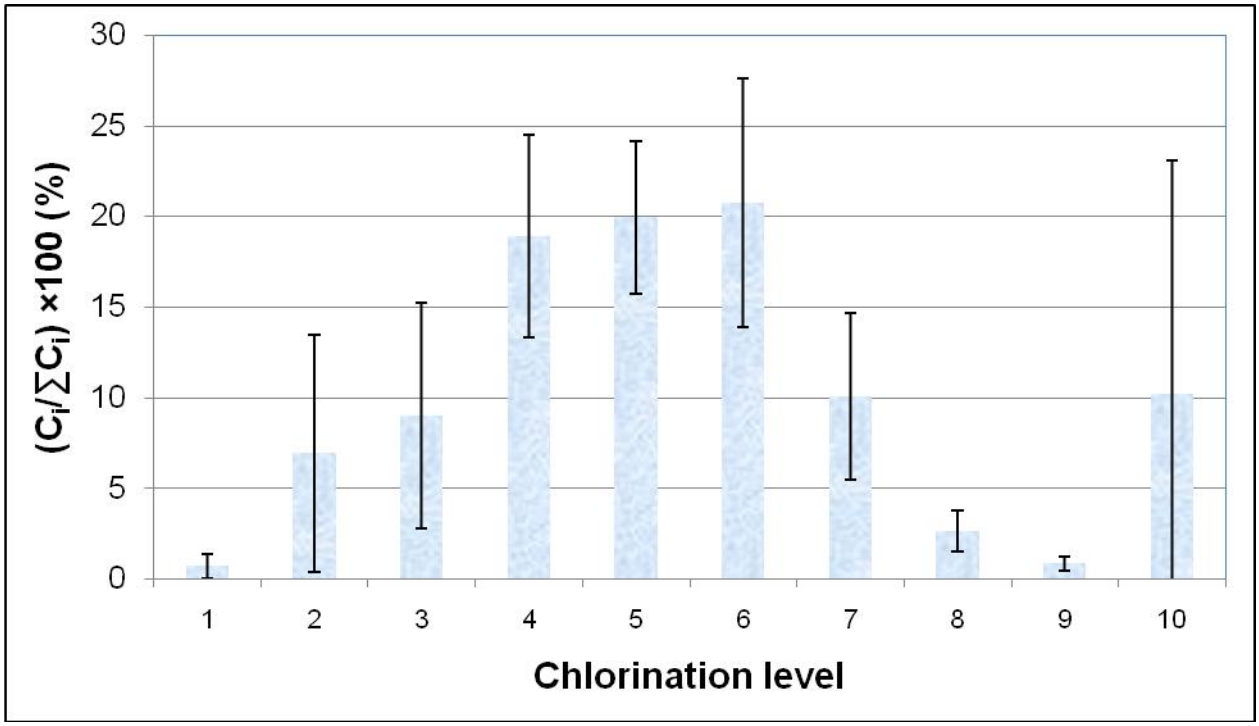


Figure 4.22 Relative concentrations of PCB homologues in the suspended water phase

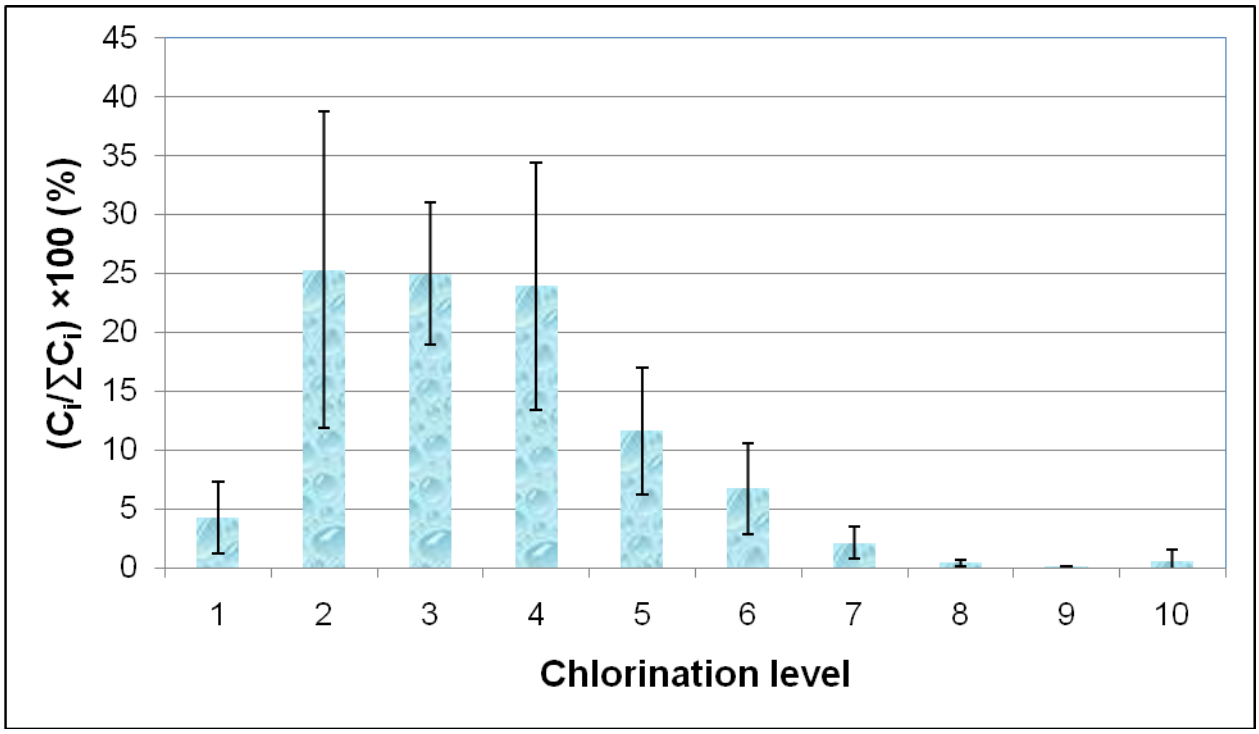


Figure 4.23 Relative concentrations of PCB homologues in the dissolved water phase

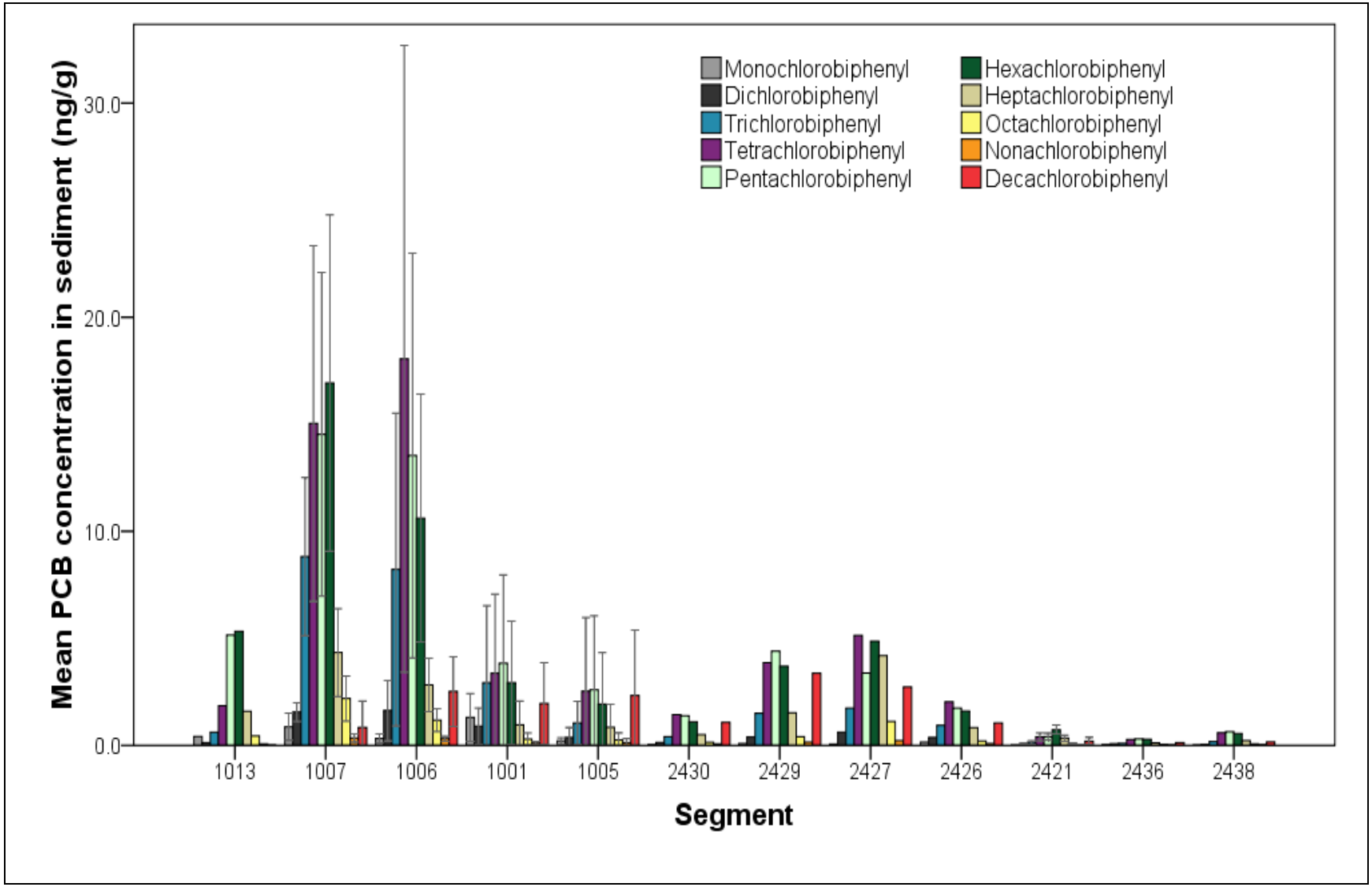


Figure 4.24 Concentration distributions of PCB homologues in the sediment

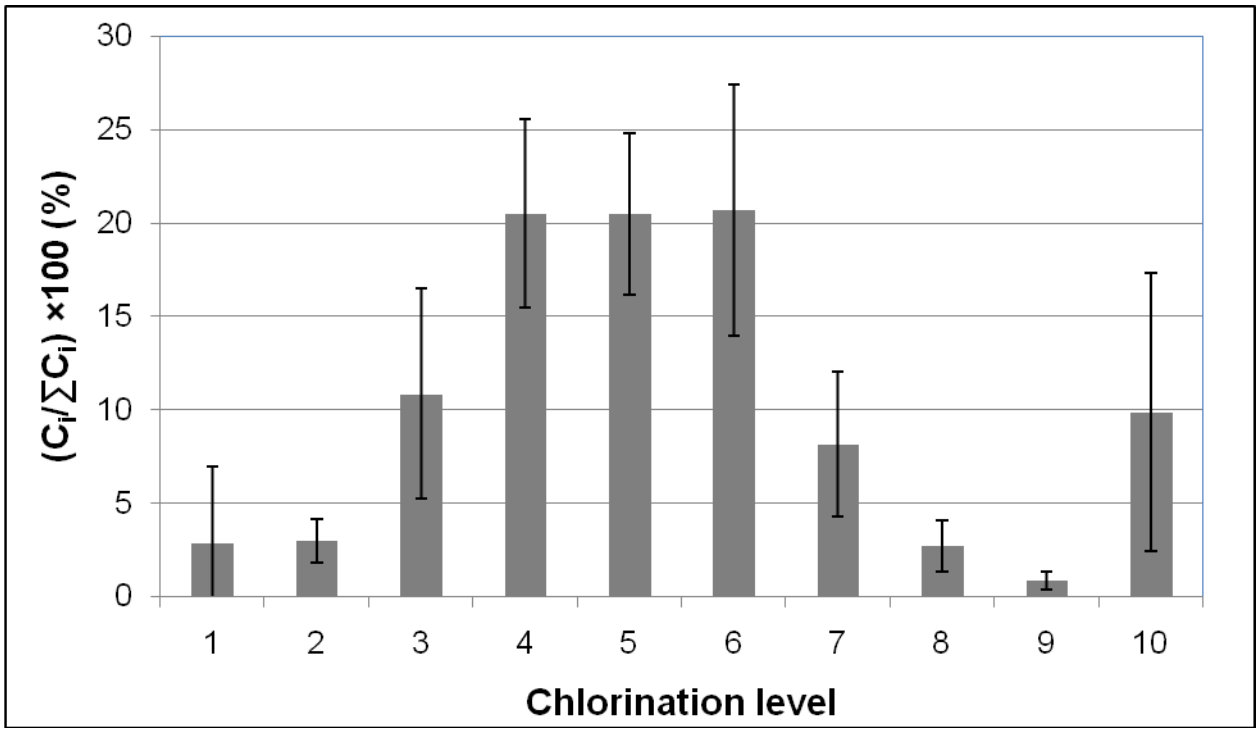


Figure 4.25 Relative concentrations of PCB homologues in the sediment

The homologue PCB distributions in Catfish and Seatrout/Atlantic Croaker (1-10 chlorine atoms on the biphenyl rings) by segment are shown in Figures 4.26 and 4.27, respectively. Even though there was significant difference in the concentrations observed in Catfish and Seatrout/Atlantic Croaker, the chlorination pattern observed was similar in each segment (Figure 4.28). Regardless of the species type, the chlorobiphenyls were centerered around the pentachlorobiphenyl, similar to what was observed in sediment distribution. This is more obvious in the relative fractions shown in Figure 4.29, where the PCB distribution highly concentrated on the tetra-, penta-, and hexa- homologue groups can be clearly observed.

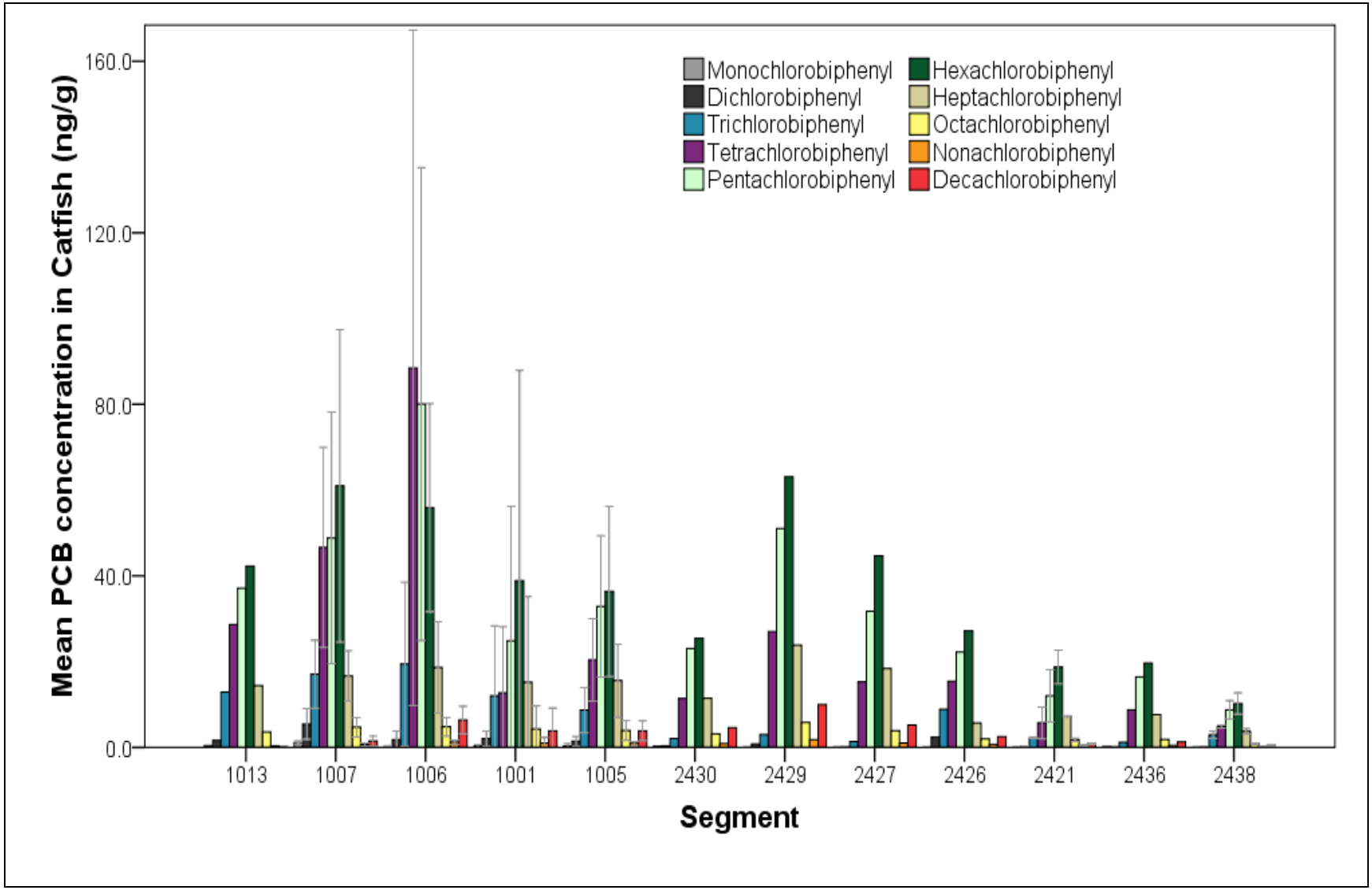


Figure 4.26 Concentration distributions of PCB homologues in the Catfish

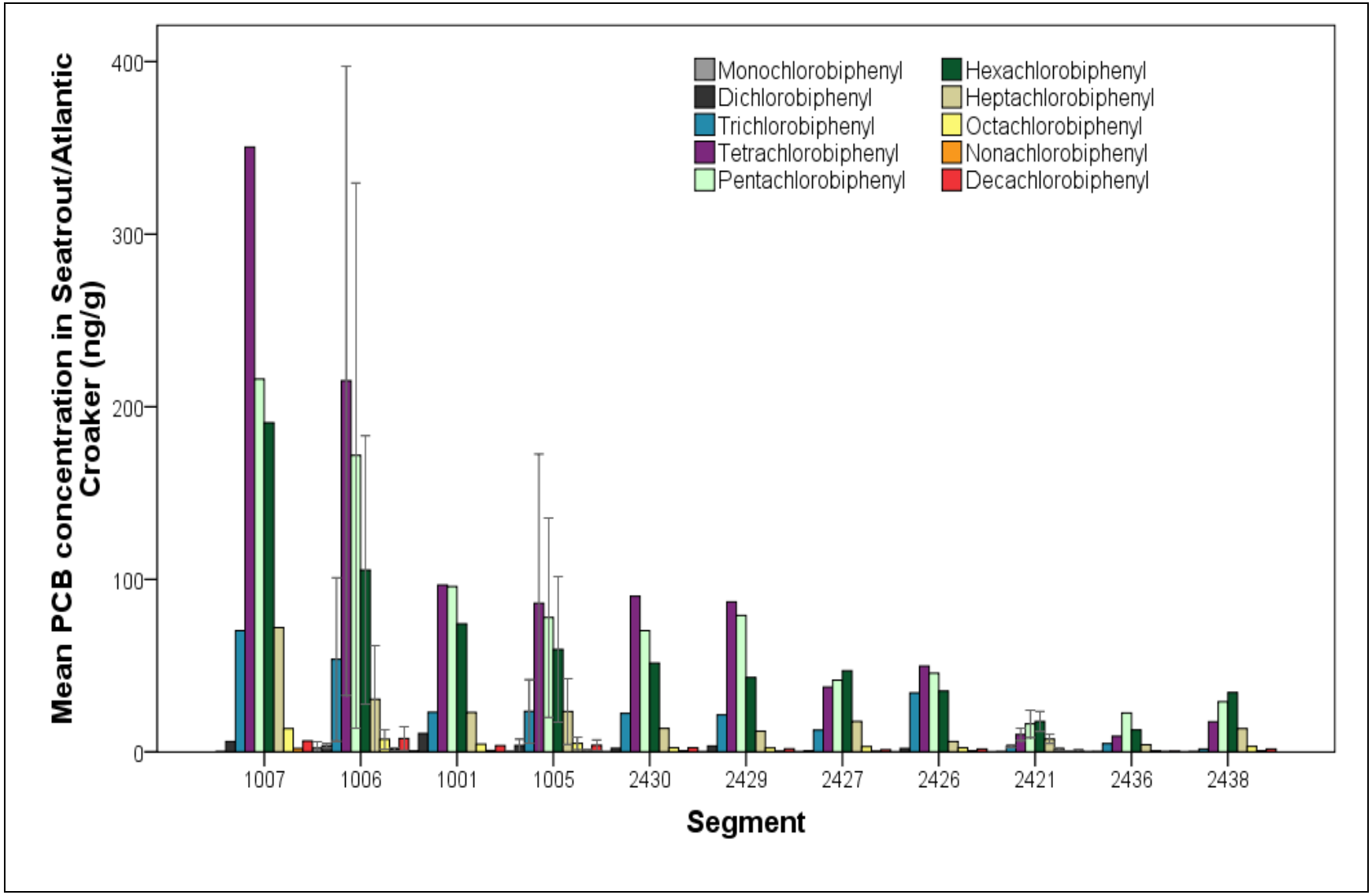


Figure 4.27 Concentration distributions of PCB homologues in the Seatrout/Atlantic Croaker

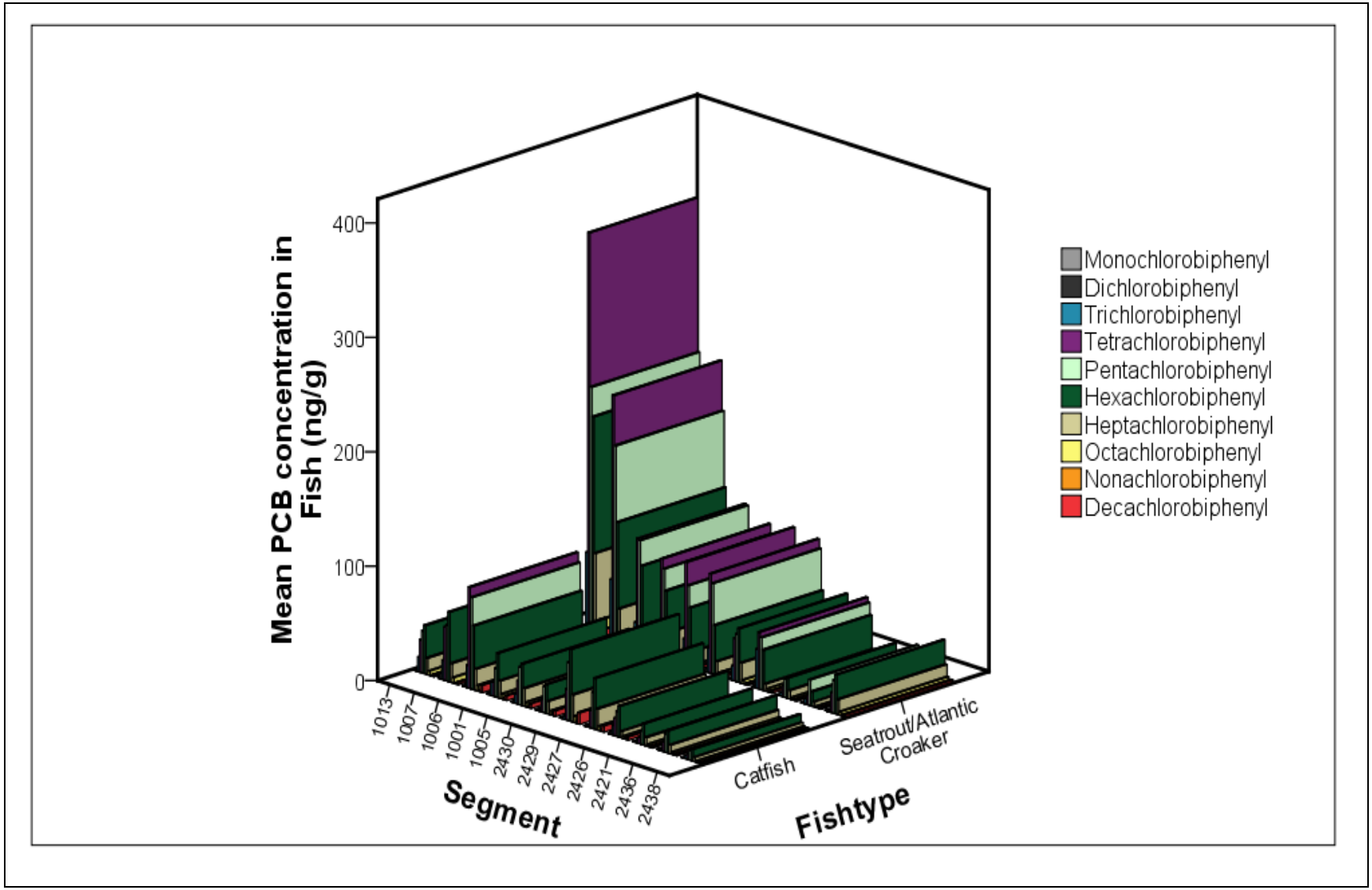


Figure 4.28 Comparison of homologues distribution in the Catfish and Seatrout/Atlantic Croaker

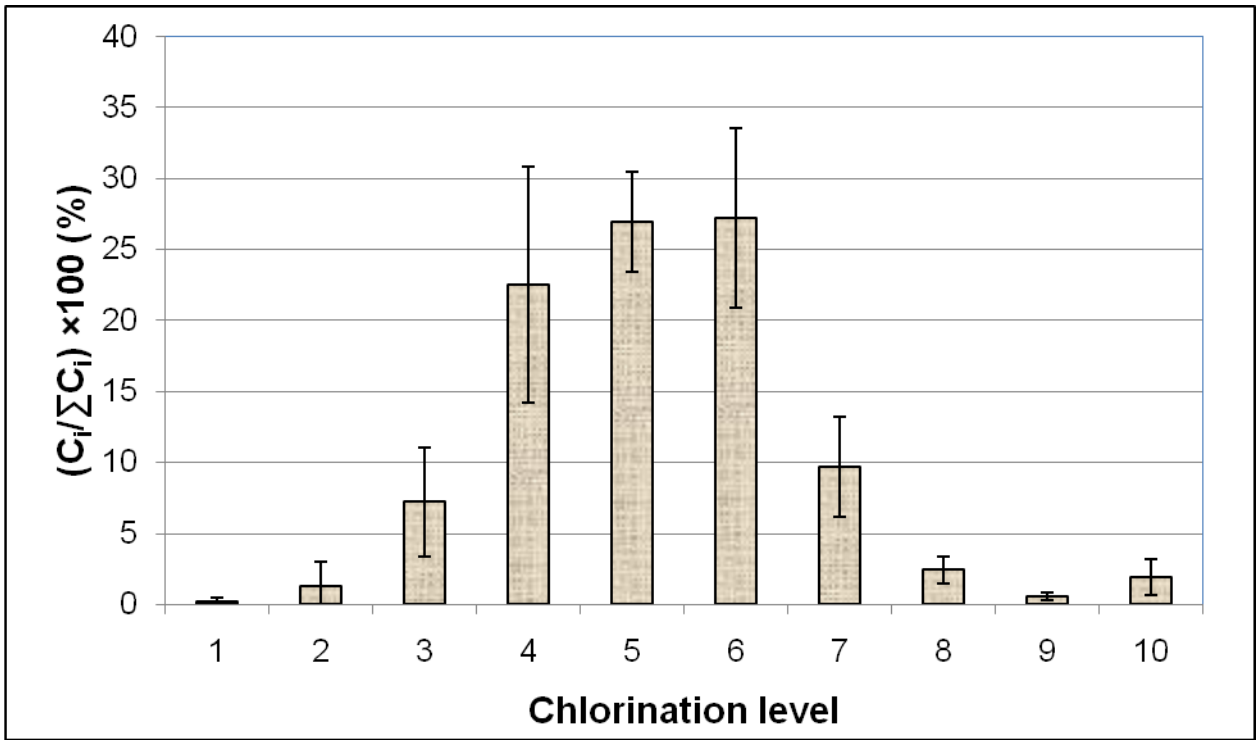


Figure 4.29 Relative fraction of PCB homologues in the fish

The homologue group distribution in water, sediment, and fish are compared in Figure 4.30. It can be observed that the chlorobipheyl distribution is similar for suspended water, sedimnent and fish where the biphenyl distribution is normally distributed around tetra-, penta-, and hexa- chlorobiphenyl. However the dissolved phase water fractions are concentrated on low chlorinated homologues (di-, tri, and tetr- chlorobiphenyls). It can also be observed that the fraction of decachlorobiphenyls in the suspended phase and in the sediment (10%) are significantly greater than in fish (2%) and in dissolved phase (0.5%). The significant amount of decachlorobiphenyls indicates a possible fresh source of PCB in the HSC.

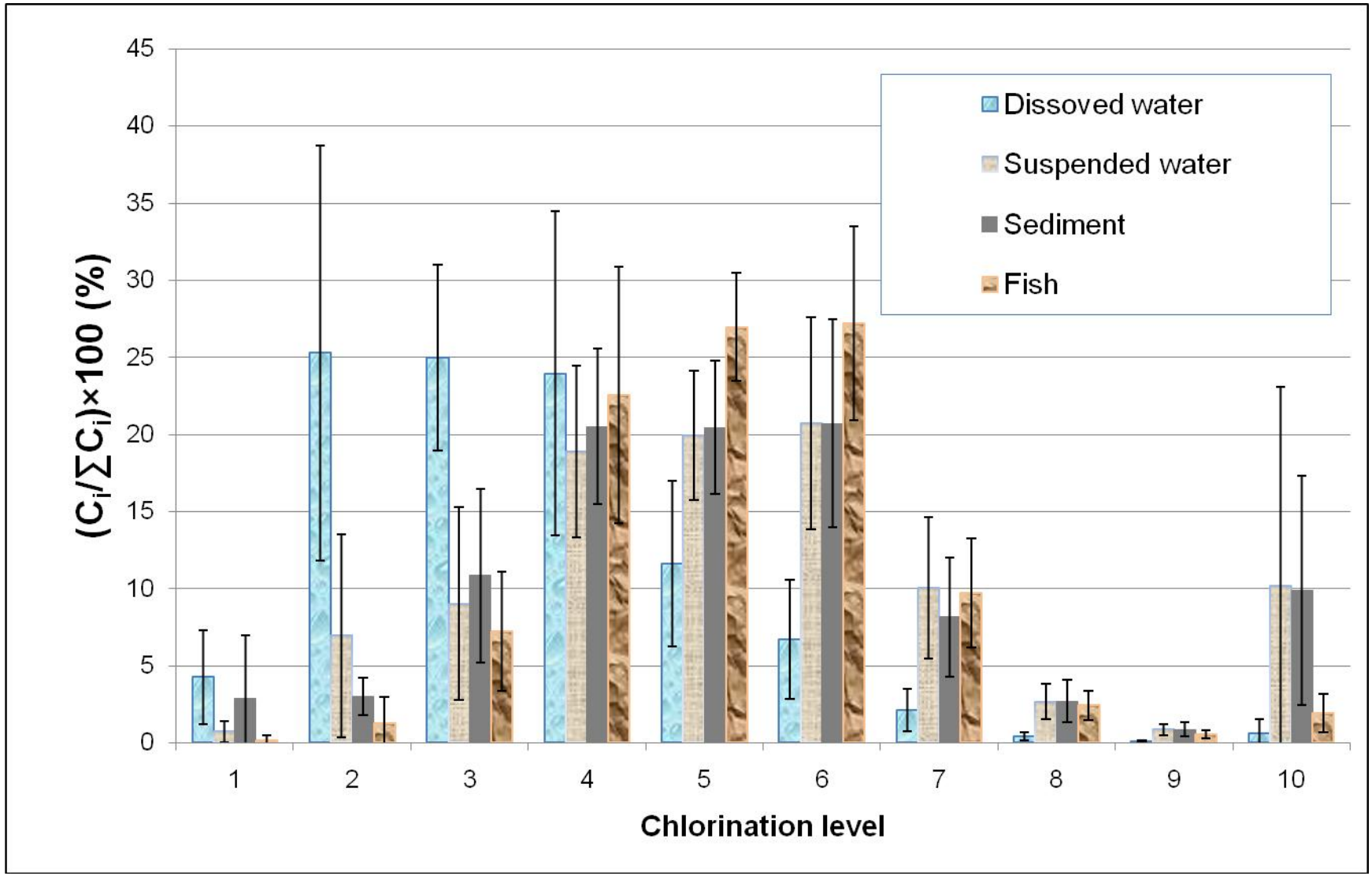


Figure 4.30 Comparison of homologue distribution in the water, sediment, and fish

4.6 Comparison of 2008 PCB results to 2002-2003 results in the HSC

The following is a comparison of data from the 2002-2003 studies and the current studies conducted in Summer 2008. Figure 4.31 shows the PCB concentrations observed in water in 2002-2003 using summation of 43 congeners, while Figure 4.32 compares PCB concentrations in stations sampled both in 2002-2003 and 2008. The green symbols in the figures indicate the stations that do not exceed the WQS of 0.885 ng/L. The 2002-2003 PCB concentrations in water showed water quality exceedance upstream of Morgan's point (Figure 4.29), while comparison of PCB concentrations in the two timeframes indicates possible lowering of PCB concentrations, i.e., the PCB concentrations in 2008 are similar or lower than PCB concentrations in 2002-2003 for most stations. The comparison of PCB concentrations by segment also indicates that the water PCB concentrations in 2008 are lower than in 2002-2003 except for segments 1006 and 1001 (Figure 4.37). Table 4.10 compares the percentage stations that exceeded the WQS in 2002-2003 and in 2008. The percentage of stations that exceeded WQS was similar in both timeframes regardless of the PCB summation approach (e.g 41% vs 38% in 2008 and 2002-2003 respectively using $\sum$43 congeners).

Figure 4.33 shows the PCB concentrations observed in sediment in 2002-2003 using summation of 43 congeners, while Figure 4.34 compares PCB sediment concentrations in stations sampled both in 2002-2003 and 2008. The comparison of PCB concentrations in the two timeframes indicates possible lowering of PCB concentrations in the sediment, i.e., the PCB concentrations in 2008 are same or lower than PCB concentrations in 2002-2003 in most stations. The comparison of PCB concentrations by segment also indicates the sediment PCB concentrations in 2008 are lower than in 2002-2003 (Figure 4.38).

Figure 4.35 shows the PCB concentrations observed in catfish in 2002-2003 using summation of 43 congeners, while Figure 4.36 compares catfish PCB concentrations in stations sampled both in 2002-2003 and 2008. The green colors in the figures indicate that the tissue PCB concentrations did not exceed the DSHS Health Assessment Comparison Value (47 ng/g). The comparison of PCB concentrations by segment also indicates that the tissue PCB concentrations in 2008 are lower than in 2002-2003 in almost all segments (Figure 4.39). Table 4.10 compares the percentage stations that exceeded the Health Assessment Comparison Value in 2002-2003 and in 2008. It was found that the percentage stations that exceeded the Health Assessment Comparison Value were similar in both timeframes regardless of the PCB summation approach (73% vs 80% in 2008 and 2002-2003 respectively using ∑43 congeners). The results from the 2008 tissue concentrations observed in Seatrout/Atlantic Croaker could not be compared since the species was not caught during 2002-2003 sampling. The percentage exceedance with Seatrout/Atlantic Croaker was slightly higher than with Catfish (73% vs 84% in Catfish and Seatrout/Atlantic Croaker respectively using ∑43 congeners).

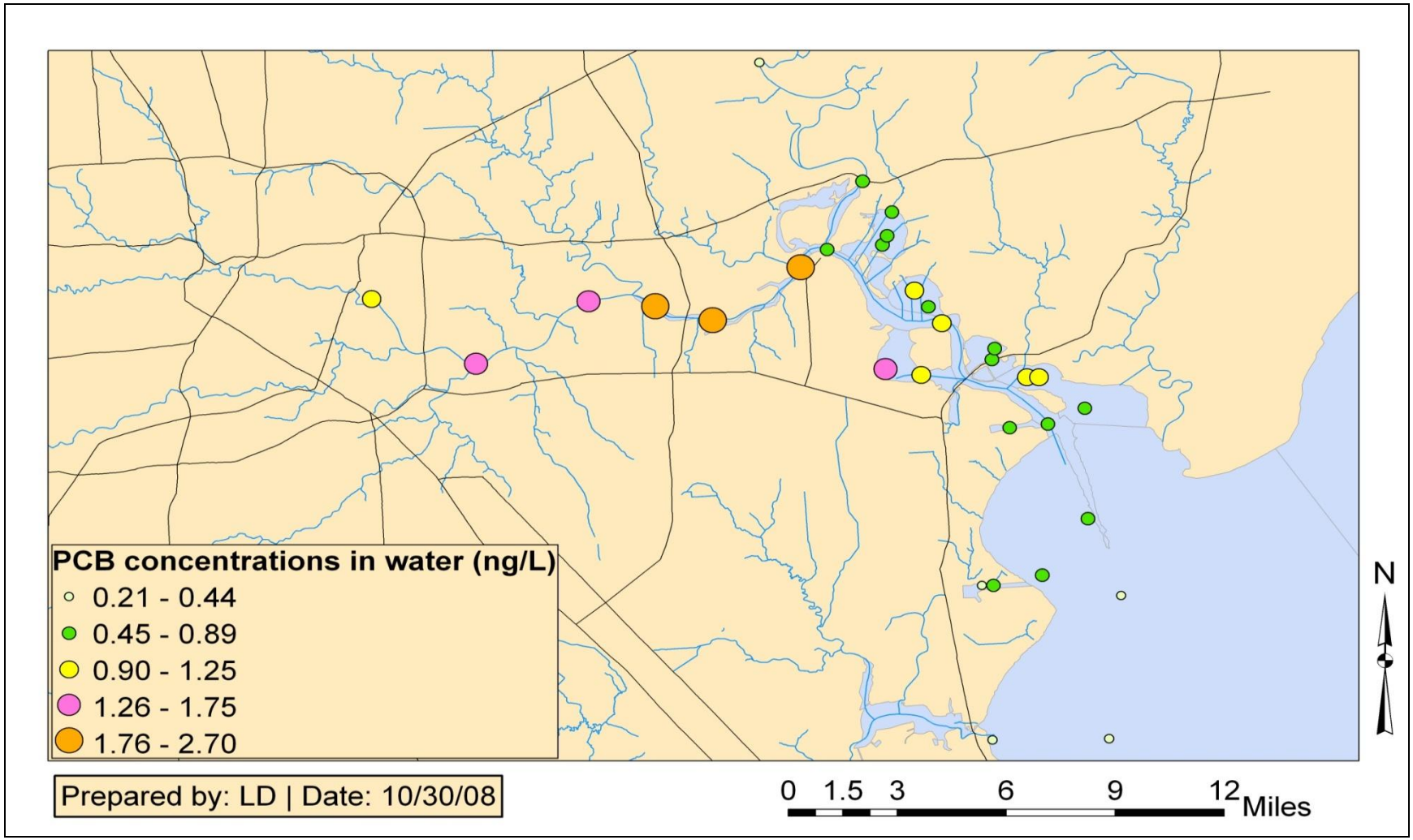
Table 4.10 Comparison of water/tissue quality standard exceedances by media, sample event and congener summation approach

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

* All concentrations based on 1/2 detection limit

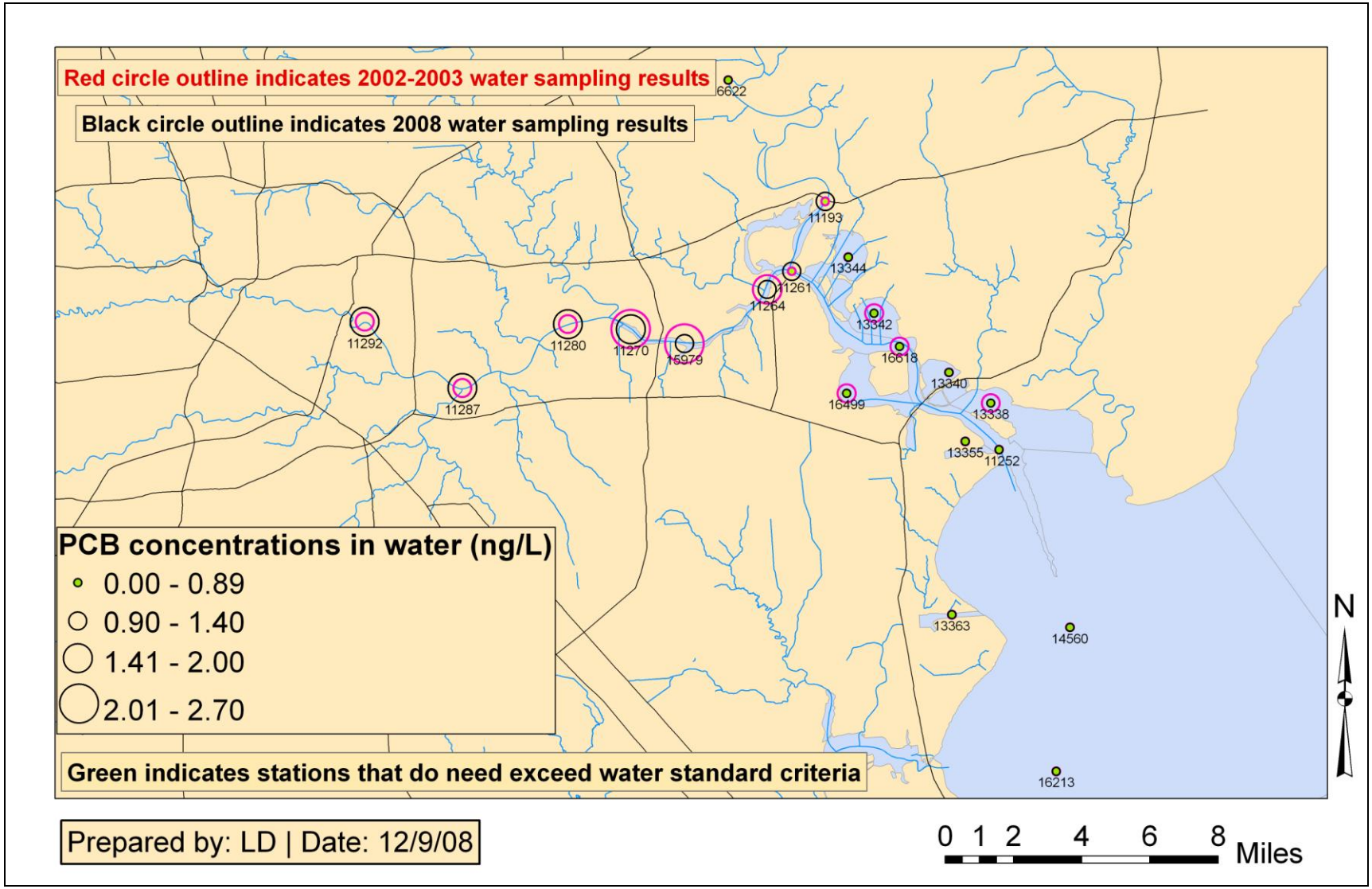
[a] WQS (0.885 ng/L)

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



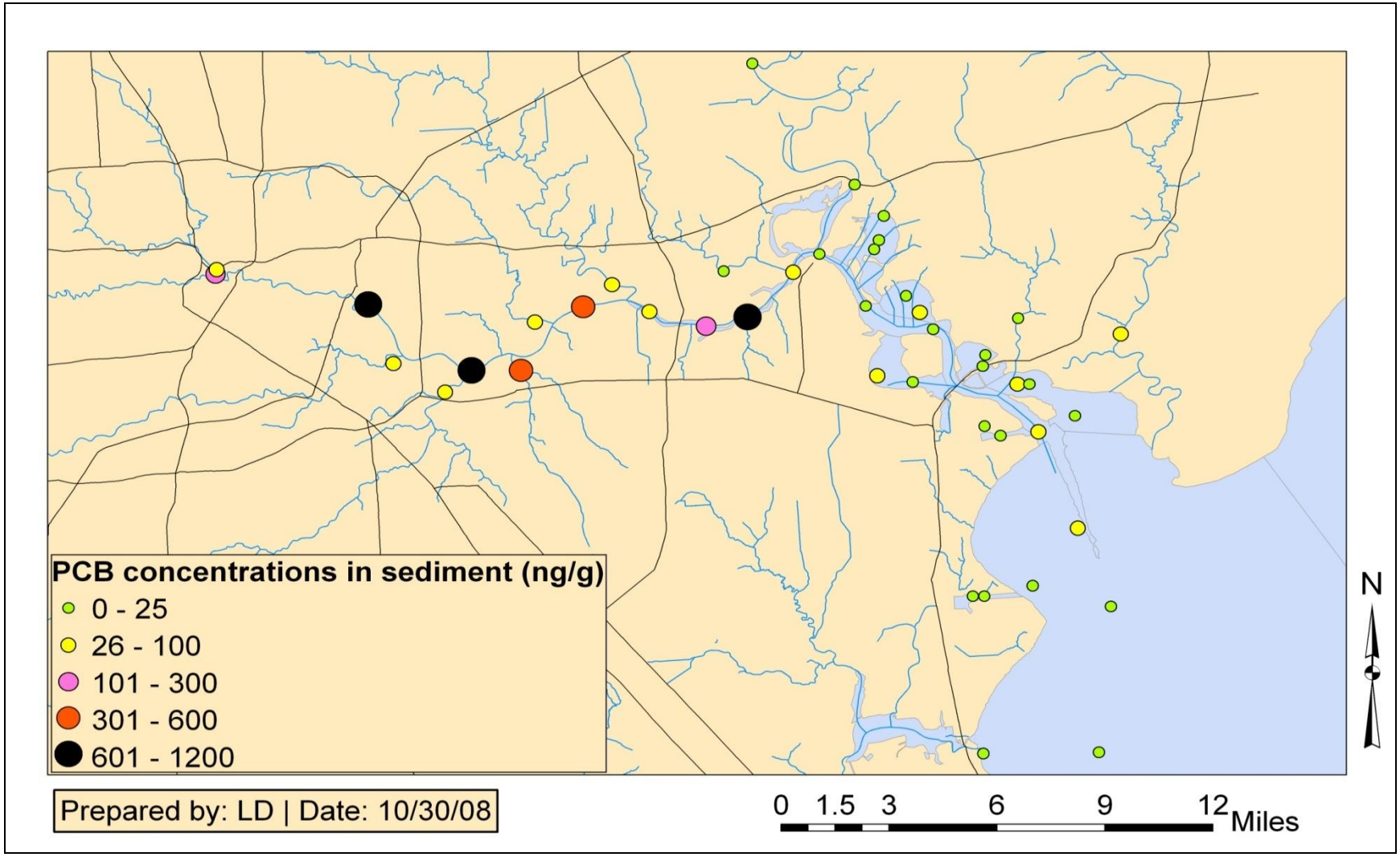
* All concentrations based on 1/2 detection limit for non-detects and ∑43 congeners.

Figure 4.31 Map of PCB water PCB concentrations in 2002-2003



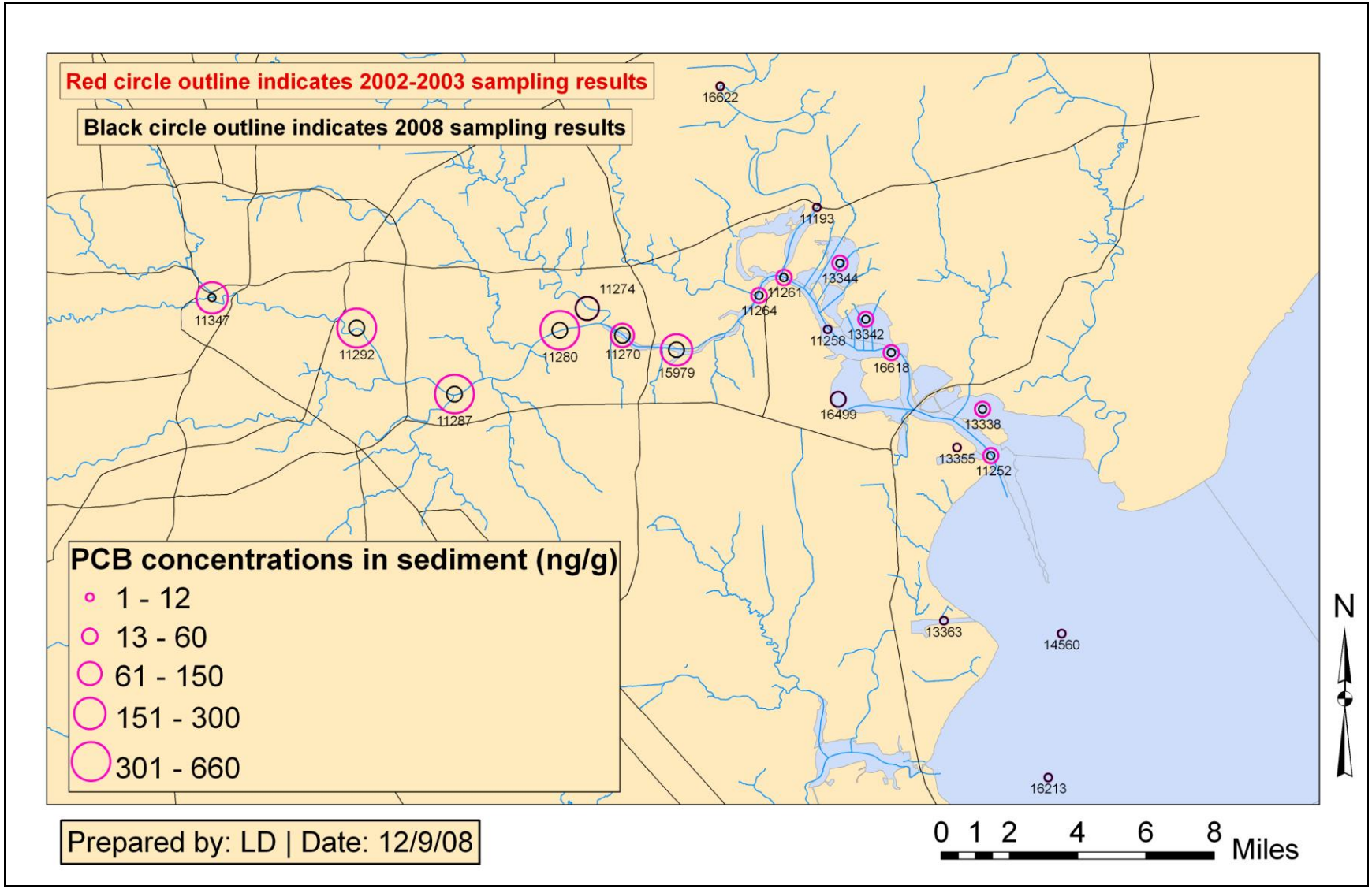
* All concentrations based on 1/2 detection limit for non-detects and ∑43 congeners.

Figure 4.32 Comparison of water PCB concentrations between 2002-2003 and 2008



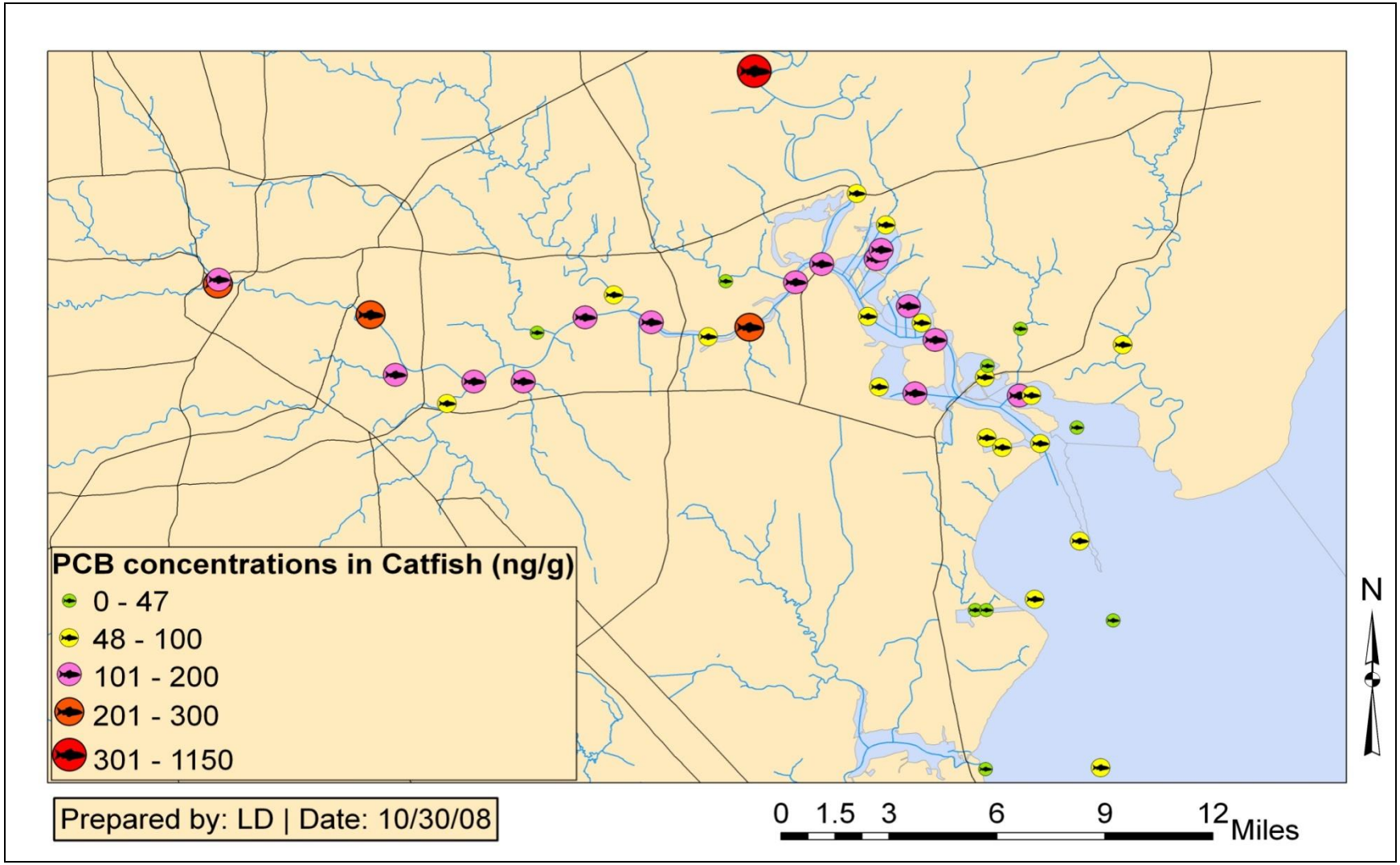
* All concentrations based on 1/2 detection limit for non-detects and ∑43 congeners.

Figure 4.33 Map of PCB sediment PCB concentrations in 2002-2003



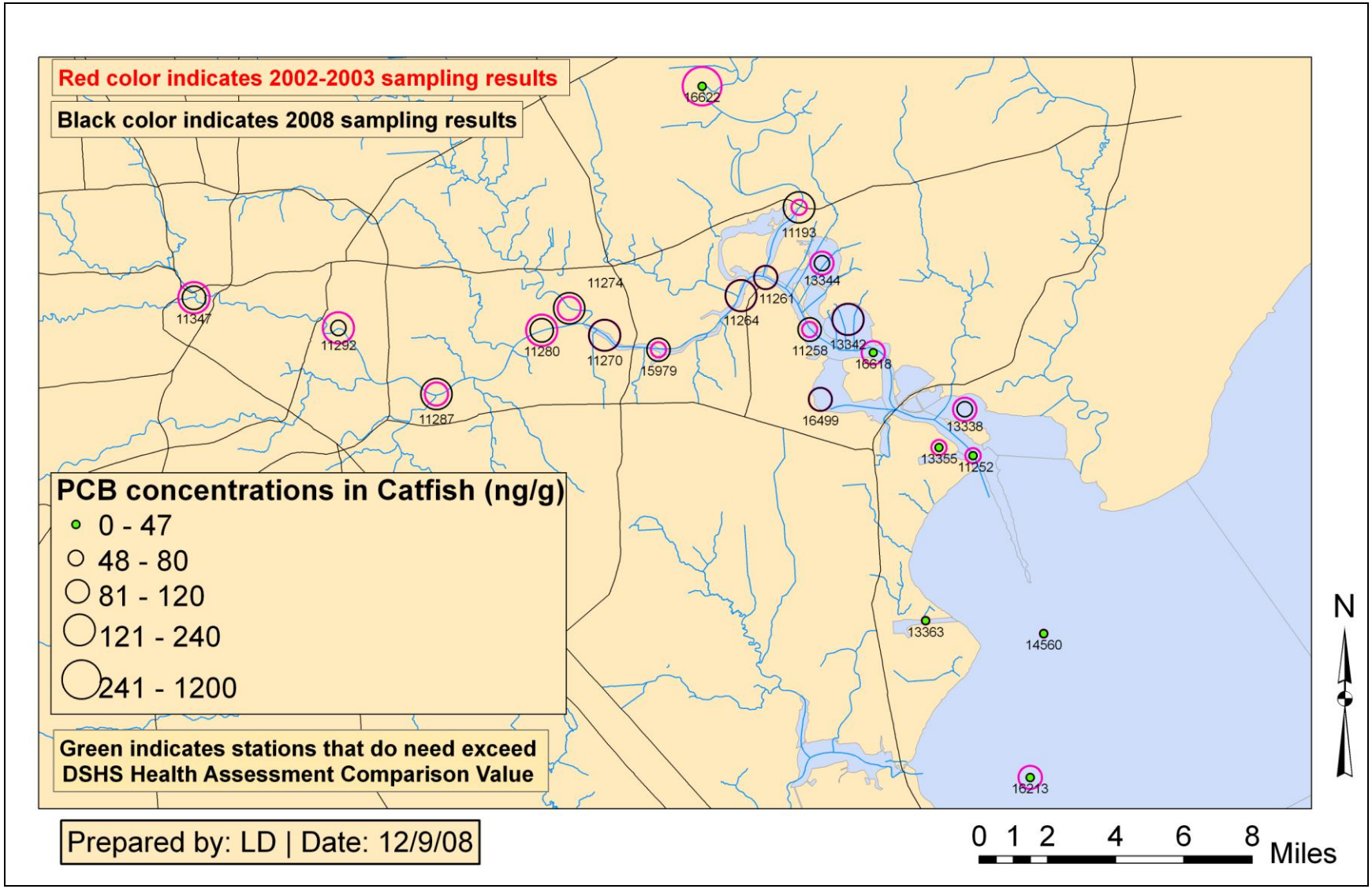
* All concentrations based on 1/2 detection for non-detects and ∑43 congeners.

Figure 4.34 Comparison of sediment PCB concentrations between 2002-2003 and 2008



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

Figure 4.35 Map of PCB catfish tissue concentrations in 2002-2003



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

Figure 4.36 Comparison of PCB concentrations in catfish between 2002-2003 and 2008

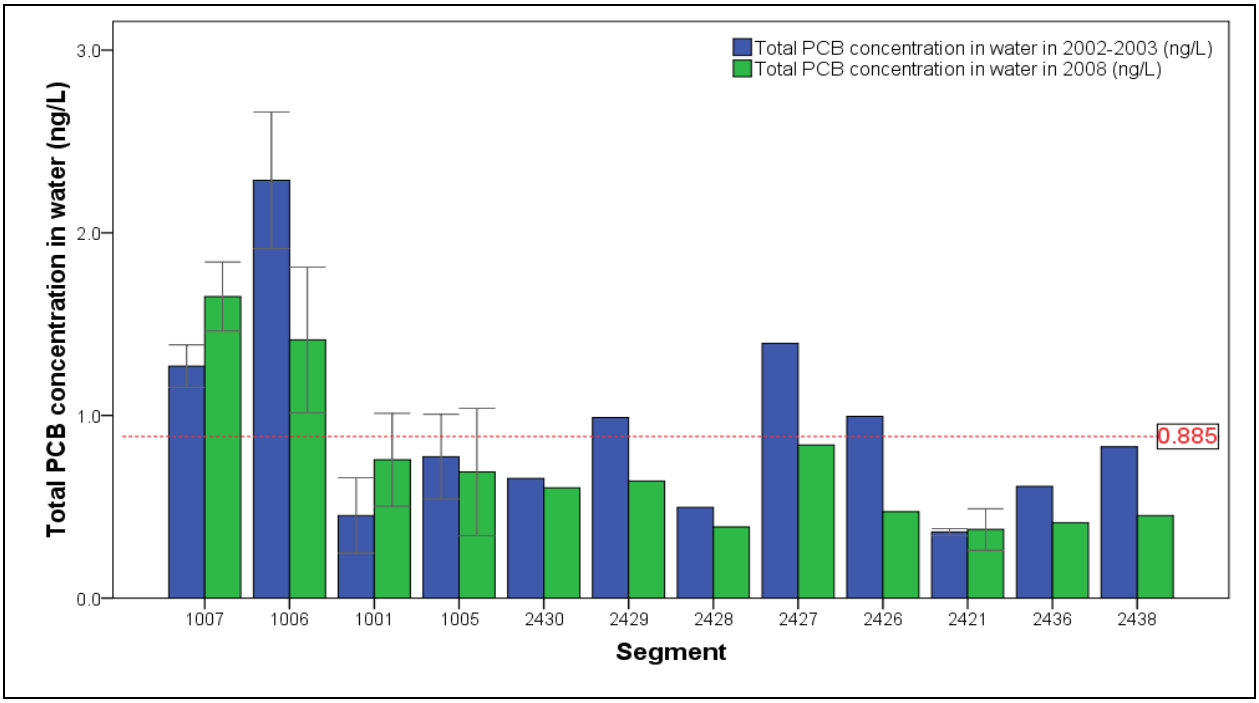


Figure 4.37 PCB water concentration comparisons between 2002-2003 and 2008 by segment

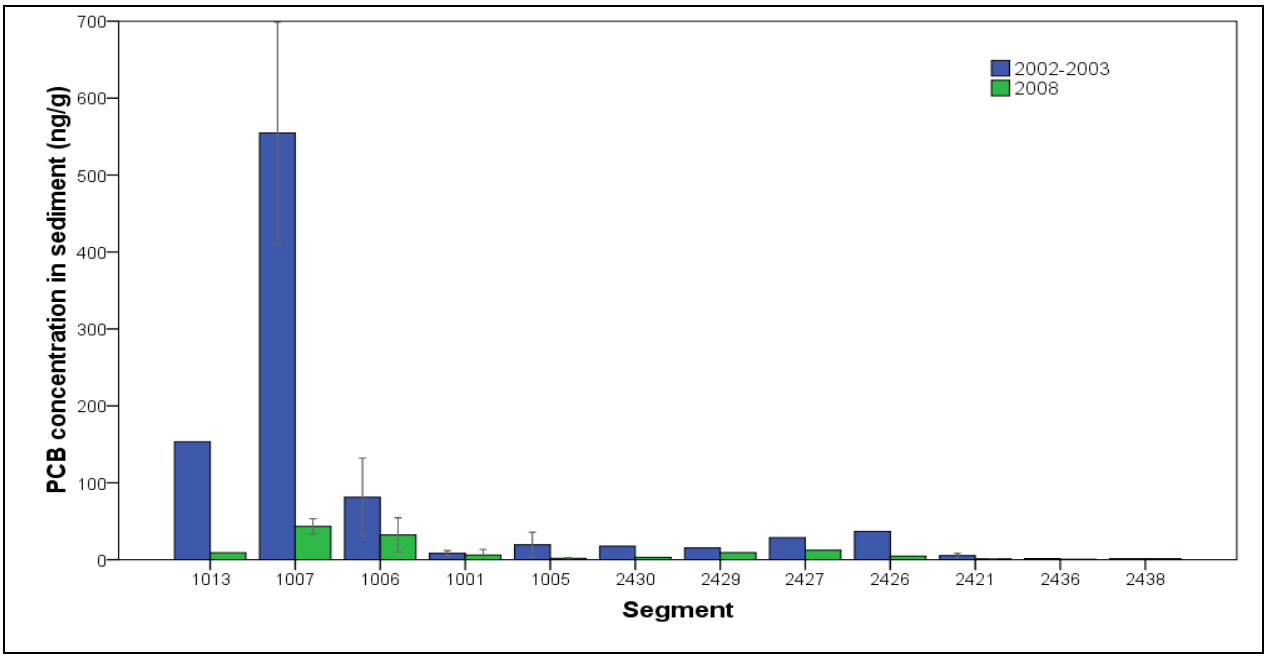


Figure 4.38 PCB sediment concentration comparisons between 2002-2003 and 2008 by segment

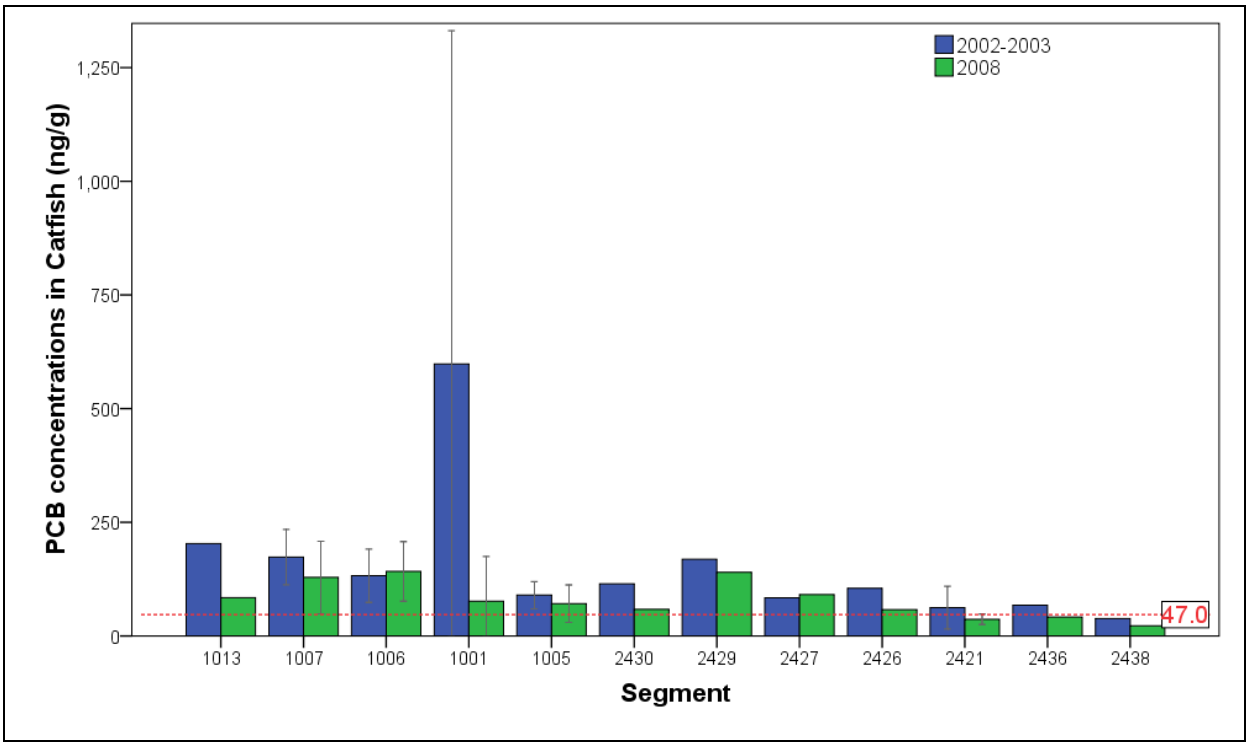


Figure 4.39 PCB catfish tissue concentration comparisons between 2002-2003 and 2008 by segment

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APPENDIX A

Water Quality Parameters - FY 2008 Sampling

Water Quality Parameters - FY 2008 Sampling

Station ID	Sample date	Total depth (ft)	Time	Sample collection depth (ft)	pH	Temperature (^oC)	Conductivity (mS/cm)	Salinity (ppt)
11132	5/13/08	3	10:22	1.5	8.13	26.51	0.88	0.93
			11:30	1.5	8.15	26.73	0.86	0.92
11139	5/13/08	0.6	16:43	0.3	8.53	27.20	0.81	0.39
			17:50	0.3	8.49	25.27	0.72	0.35
11171	4/24/08	0.1	10:45	0.1	9.26	26.54	0.33	0.16
			11:05	0.1	9.32	27.22	0.27	0.13
			13:25	0.1	10.12	30.87	0.67	0.32
			13:55	0.1	10.26	31.87	0.37	0.17
11193	5/1/08	7	17:10	1	7.81	23.47	12.65	7.27
			17:10	3	7.80	23.47	12.67	7.27
			17:10	5	7.80	23.47	12.63	7.25
11252	5/28/08	7	15:00	1	8.12	29.38	13.95	8.01
			15:00	3	8.06	26.59	14.82	8.58
			15:00	5	8.05	28.51	14.85	8.59
			16:25	1	8.10	29.30	14.18	8.15
			16:25	3	8.09	29.23	14.26	8.36
			16:25	5	8.07	28.68	15.27	8.84
11258	6/2/08	10	14:05	2	7.90	29.63	12.47	7.10
			14:05	5	7.84	29.41	12.58	7.17
			14:05	8	7.80	29.18	12.60	7.18
			14:55	2	7.90	29.60	12.34	7.01
			14:55	5	7.79	29.24	12.50	7.11
			14:55	8	7.76	29.19	12.54	7.14
			15:50	2	7.89	29.56	12.36	7.03
			15:50	5	7.86	29.46	12.40	7.06
			15:50	8	7.85	29.34	12.43	7.07
11261	6/4/08	16	8:56	2	7.86	29.13	10.90	6.15
		16	8:56	8	7.85	29.13	10.92	6.15
		16	8:56	14	7.85	29.14	11.00	6.20

Water Quality Parameters - FY 2008 Sampling

Station ID	Sample date	Total depth (ft)	Time	Sample collection depth (ft)	pH	Temperature (^oC)	Conductivity (mS/cm)	Salinity (ppt)
11261	6/4/08	16	10:00	2	7.83	29.02	11.36	6.45
		16	10:00	8	7.82	29.02	11.45	6.47
		16	10:00	14	7.84	29.02	11.55	6.48
		16	10:45	2	7.83	29.05	11.31	6.42
		16	10:45	8	7.85	29.03	11.44	6.49
		16	10:45	14	7.92	29.03	11.48	6.50
11262	6/4/08	12	16:10	2	7.88	29.35	11.08	6.25
		12	16:10	6	7.89	29.36	11.04	6.23
		12	16:10	10	7.91	29.38	11.05	6.23
		12	16:55	2	7.93	29.36	11.06	6.23
		12	16:55	6	7.94	29.36	11.06	6.24
		12	16:55	10	7.95	29.36	11.07	6.24
		12	17:50	2	7.96	29.36	10.90	6.14
		12	17:50	6	7.97	29.37	10.94	6.16
		12	17:50	10	7.98	29.37	11.00	6.20
11264	5/1/08	27	13:00	2	7.50	23.70	12.60	7.23
		27	13:00	12	7.50	23.60	12.67	7.26
		27	13:00	25	7.50	23.60	12.75	7.32
11270	4/29/08	6.5	16:00	1	7.42	24.82	8.22	4.57
		6.5	16:00	3	7.41	24.56	8.29	4.64
		6.5	16:00	5	7.49	23.88	9.21	5.14
		6.5	17:40	1	7.43	24.51	8.54	4.75
		6.5	17:40	3	7.42	24.45	8.59	4.76
		6.5	17:40	5	7.41	24.10	9.01	5.03
11274	4/29/08	10	11:40	1	7.38	24.01	3.52	1.84
		10	11:40	4.5	7.27	23.31	4.09	2.17
		10	11:40	8	7.23	23.48	4.45	2.37
		10	14:00	1	7.30	24.70	4.20	2.10
		10	14:00	4.5	7.09	23.75	5.08	2.73

Water Quality Parameters - FY 2008 Sampling

Station ID	Sample date	Total depth (ft)	Time	Sample collection depth (ft)	pH	Temperature (^oC)	Conductivity (mS/cm)	Salinity (ppt)
		10	14:00	8	7.05	23.75	5.47	2.95
11280	4/23/08	11.9	12:15	1.5	7.35	23.74	8.41	4.68
		11.9	12:15	5	7.35	23.43	8.49	4.73
11280	4/23/08	11.9	12:15	9	7.34	23.09	8.93	4.99
11287	4/21/08	14	14:43	1	7.39	24.65	4.11	2.15
		14	14:43	5	7.19	22.73	6.21	3.39
		14	14:43	11	7.19	22.56	6.30	3.45
11292	6/2/08	16.5	11:01	2	7.21	29.45	2.11	1.07
		16.5	11:01	8.5	7.14	28.81	2.30	1.16
		16.5	11:01	15	7.15	28.62	2.87	1.48
		16.5	11:35	2	7.27	29.64	2.13	1.08
		16.5	11:35	8.5	7.23	29.17	2.16	1.09
		16.5	11:35	15	7.21	28.61	3.00	1.55
		16.5	12:00	2	7.26	29.83	2.13	1.08
		16.5	12:00	8.5	7.19	28.93	2.20	1.11
		16.5	12:00	15	7.13	28.58	3.02	1.56
11347	5/21/08	2.5	10:35	1.25	7.65	27.53	0.73	0.35
		2.5	12:20	1.25	7.78	27.75	0.60	0.29
11368	5/14/08	3	11:15	1.5	7.77	25.63	0.67	0.33
		3	12:25	1.5	7.75	25.73	0.76	0.37
11387	5/12/08	2	11:44	1	8.45	24.53	0.46	0.22
13338	4/22/08	4.5	12:55	2.75	8.51	24.60	12.77	7.28
		4.5	12:58	1	8.52	24.69	12.67	7.27
		4.5	14:15	1	8.39	25.23	12.98	7.45
		4.5	14:15	2.5	8.35	25.22	12.95	7.43
		6.2	15:30	1	8.52	29.85	10.59	5.95
		6.2	15:30	2.5	8.52	29.84	10.60	5.95
		6.2	15:30	4	8.54	29.84	10.59	5.95

Water Quality Parameters - FY 2008 Sampling

Station ID	Sample date	Total depth (ft)	Time	Sample collection depth (ft)	pH	Temperature (^oC)	Conductivity (mS/cm)	Salinity (ppt)
13340	6/3/08	6.2	16:15	1	8.58	29.86	10.62	5.96
		6.2	16:15	2.5	8.58	29.86	10.62	5.96
		6.2	16:15	4	8.59	29.86	10.62	5.96
		6.2	17:00	1	8.55	29.97	10.66	5.99
		6.2	17:00	2.5	8.55	29.97	10.65	5.98
		6.2	17:00	4	8.56	29.97	10.66	5.99
13342	5/30/08	6.5	9:35	1	7.97	27.74	11.65	6.61
		6.5	9:35	3	7.97	27.75	11.67	6.62
		6.5	9:35	5	7.97	27.81	11.94	6.88
		6.5	10:17	1	7.63	27.90	11.71	6.65
		6.5	10:17	3	7.60	27.90	11.80	6.70
		6.5	10:17	5	7.66	27.88	12.08	6.88
		6.5	11:05	1	7.59	27.98	11.69	6.63
		6.5	11:05	3	7.57	28.00	11.73	6.66
		6.5	11:05	5	7.61	27.95	11.75	6.69
13344	6/3/08	8.5	10:40	1	8.25	28.67	11.50	6.51
		8.5	10:40	4	8.24	28.62	11.55	6.55
		8.5	10:40	7	8.21	28.52	11.72	6.63
		8.5	11:35	1	8.37	28.94	11.61	6.58
		8.5	11:35	4	8.37	28.92	11.59	6.56
		8.5	11:35	7	8.37	28.89	11.61	6.57
		8.5	12:50	1	8.19	28.86	11.06	6.24
		8.5	12:50	4	8.19	28.84	11.09	6.26
		8.5	12:50	7	8.19	28.84	11.09	6.26
13355	5/29/08	11.5	13:12	2	8.05	29.74	13.84	7.91
		11.5	13:12	6	8.07	29.62	13.94	8.01
		11.5	13:12	10	8.08	29.18	14.50	8.35
		11.5	14:19	2	8.08	30.02	13.82	7.92
		11.5	14:19	6	8.03	29.47	13.95	8.01

Water Quality Parameters - FY 2008 Sampling

Station ID	Sample date	Total depth (ft)	Time	Sample collection depth (ft)	pH	Temperature (^oC)	Conductivity (mS/cm)	Salinity (ppt)
13355	5/29/08	11.5	14:19	10	7.93	28.60	14.83	8.55
		11.5	15:05	2	8.01	29.18	14.32	8.24
		11.5	15:05	6	7.98	29.24	14.26	8.35
		11.5	15:05	10	7.96	28.89	14.60	8.40
13363	6/11/08	6	10:23	1	8.16	28.92	13.31	8.59
		6	10:23	4	8.10	28.79	15.32	8.94
		6	12:16	1	8.38	29.56	14.67	8.46
		6	12:16	4	8.08	28.97	15.69	9.11
14560	5/28/08	10.5	11:00	8	8.03	28.34	17.78	10.47
		10.5	12:48	1	8.43	28.95	12.80	7.30
		10.5	12:48	4	8.27	28.80	14.75	8.51
		10.5	12:48	8	8.10	28.42	16.53	9.69
		10.5	13:15	1	8.41	29.56	13.05	7.45
		10.5	13:15	4	8.21	28.65	15.50	9.02
		10.5	13:15	8	8.09	28.40	17.07	9.91
15301	6/4/08	6.5	12:25	2	7.86	29.10	5.25	9.44
		6.5	12:25	4	7.94	29.09	5.26	9.45
		6.5	14:14	2	7.89	29.35	9.59	5.33
		6.5	14:14	4	7.93	29.34	9.68	5.36
15936	4/30/08	7	11:45	1	7.55	23.84	10.93	6.20
		7	11:45	3.5	7.40	23.59	11.13	6.32
		7	11:45	5	7.07	23.61	11.13	6.32
		7	12:45	1	7.61	24.07	11.03	6.26
		7	12:45	1	7.61	24.07	11.03	6.26
		7	12:45	3.5	7.58	23.83	11.05	6.28
		7	12:45	3.5	7.58	23.83	11.05	6.28
		7	12:45	5	7.45	23.58	11.55	6.59
		7	12:45	5	7.45	23.58	11.55	6.59
15979	4/30/08	3.5	16:15	1.5	7.60	24.23	10.22	5.77

Water Quality Parameters - FY 2008 Sampling

Station ID	Sample date	Total depth (ft)	Time	Sample collection depth (ft)	pH	Temperature (^oC)	Conductivity (mS/cm)	Salinity (ppt)
15979	4/30/08	3.5	17:30	1.5	7.50	24.03	10.98	6.23
		3.5	17:30	1.5	7.50	24.03	10.98	6.23
16213	5/27/08	10.5	11:11	1	8.22	28.21	18.17	10.69
		10.5	11:11	5	8.21	28.19	18.17	10.69
		10.5	11:11	8	8.20	28.16	18.21	10.71
		10.5	12:46	1	8.25	28.49	18.17	10.69
		10.5	12:46	5	8.22	28.34	18.16	10.68
		10.5	12:46	8	8.21	28.25	18.19	10.72
16499	5/29/08	3.5	9:35	0.5	7.70	29.22	12.05	6.80
		3.5	9:37	2	7.74	29.21	11.99	6.81
		3.5	10:30	0.5	7.76	29.61	11.40	6.45
		3.5	10:30	2	7.73	29.44	12.08	6.86
		3.5	11:30	0.5	7.80	30.02	11.50	6.50
		3.5	11:30	2	7.72	29.47	11.99	6.81
16618	5/30/08	4.5	13:25	2.5	7.81	28.23	13.51	7.75
		4.5	14:28	2.5	7.79	29.00	13.37	7.66
		4.5	15:36	2.5	7.82	28.94	13.59	7.79
16622	5/2/08	6	10:22	1	8.11	24.00	2.00	1.02
		6	10:22	3	8.08	24.00	2.02	1.05
		6	10:22	4	8.08	24.00	2.06	1.06
		14	11:25	1	8.26	24.17	1.70	0.85
		14	11:25	4	8.20	24.08	1.74	0.88
		14	11:25	8	8.10	24.03	1.84	0.94
		14	12:55	1	8.37	24.27	1.35	0.68
		14	12:55	4	8.33	24.23	1.35	0.68
		14	12:55	8	8.30	24.19	1.42	0.71
16657	6/20/08	1.3	9:43	1	7.83	27.86	0.51	0.24
		1.3	10:41	1	7.77	28.18	0.43	0.21
		1.3	11:41	1	7.82	28.73	0.51	0.24

Water Quality Parameters - FY 2008 Sampling

Station ID	Sample date	Total depth (ft)	Time	Sample collection depth (ft)	pH	Temperature (^{o}C)	Conductivity (mS/cm)	Salinity (ppt)
17149	7/29/08	3	10:08	0.67	8.01	24.00	13.48	7.77
		3	12:27	0.67	7.91	23.73	13.94	7.91
11115	5/15/08	2	12:01	1	7.53	25.87	2.81	1.45
		2	13:18	1	7.58	26.22	2.17	1.11
TBD5	5/12/08	3	18:15	1.5	7.72	25.43	0.20	0.08
TBD6	5/14/08	0.5	16:54	0.25	7.66	25.05	1.24	0.58
		0.5	18:17	0.25	7.73	25.18	0.94	0.44
TBD7	5/15/08	2	17:02	1	7.94	29.68	0.46	0.24
		2	18:30	1	8.06	29.78	0.48	0.23

APPENDIX B

Water Quality Parameters during Intensive Sediment Sampling

Water Quality Parameters during Intensive Sediment Sampling

Station ID	Sample date	Total depth (ft)	Time	Sample collection depth (ft)	pH	Temperature (^{o}C)	Conductivity (mS/cm)	Salinity (ppt)
E001	7/8/08	42.2	9:45	38.2	7.35	29.91	18.19	10.92
		42.2	9:45	26	7.30	29.89	16.56	9.67
		42.2	9:45	14	7.29	29.85	15.50	8.99
		42.2	9:45	1	7.29	29.82	15.18	8.77
E002	7/8/08	35.7	10:46	30	7.44	29.91	18.20	10.65
		35.7	10:46	21	7.39	29.87	16.67	9.81
		35.7	10:46	12	7.34	29.86	16.08	9.30
		35.7	10:46	1	7.34	29.91	15.79	9.16
E003	7/8/08	49.1	12:06	43.1	7.46	29.91	20.35	12.02
		49.1	12:06	24.3	7.43	29.88	16.72	9.98
		49.1	12:06	1	7.40	29.85	16.13	9.38
E004	7/8/08	48.1	12:45	43.5	7.44	29.96	20.30	12.06
		48.1	12:45	25	7.36	29.93	17.75	10.60
		48.1	12:45	1	7.36	30.09	16.31	9.50
E005	7/8/08	46	13:25	42.1	7.40	29.57	20.54	12.14
		46	13:25	23	7.36	30.02	17.57	10.34
		46	13:25	1	7.34	30.13	17.06	9.97
E006	7/9/08	48.9	10:35	43	7.40	30.05	20.38	12.18
		48.9	10:35	25.2	7.38	30.07	19.37	11.44
		48.9	10:35	1	7.37	30.08	18.34	10.73
E007	7/9/08	48.6	9:19	43.2	7.36	30.10	20.20	12.01
		48.6	9:19	24.1	7.36	30.02	18.09	10.64
		48.6	9:19	1	7.35	30.01	18.13	10.65
E008	7/9/08	45	10:58	39.2	7.43	30.10	20.12	11.91
		45	10:58	23	7.41	30.08	19.15	11.32
		45	10:58	1	7.41	30.08	18.80	11.05
E009	7/9/08	48.8	11:51	43.4	7.44	30.12	20.49	12.16
		48.8	11:51	24.2	7.42	30.12	19.60	11.58
		48.8	11:51	1	7.42	30.12	19.46	11.48

Water Quality Parameters during Intensive Sediment Sampling

Station ID	Sample date	Total depth (ft)	Time	Sample collection depth (ft)	pH	Temperature (^{o}C)	Conductivity (mS/cm)	Salinity (ppt)
E010	7/9/08	45.2	13:08	40	7.45	30.14	20.44	12.17
		45.2	13:08	27.2	7.41	30.14	20.04	11.88
		45.2	13:08	1	7.42	30.39	19.53	11.57
E011	7/9/08	49.1	14:15	43.4	7.45	30.18	20.38	12.07
		49.1	14:15	25.1	7.43	30.20	19.97	11.82
		49.1	14:15	1	7.44	30.33	19.59	11.52
T007	7/10/08	22.4	9:04	19	7.40	29.92	11.27	5.70
		22.4	9:04	10	7.33	29.93	11.42	6.19
		22.4	9:04	1	7.55	28.01	0.05	0.02
T006	7/10/08	14.9	10:20	12	7.29	29.78	9.58	5.35
		14.9	10:20	7.5	7.46	29.06	5.24	2.66
		14.9	10:20	1	7.71	28.44	0.82	0.37
T005	7/10/08	10.1	11:20	8	7.61	28.89	1.34	0.53
		10.1	11:20	5	7.59	29.14	0.95	0.46
		10.1	11:20	1	7.58	29.39	0.90	0.43
T008	7/10/08	25	12:05	22	7.42	29.90	11.57	6.63
		25	12:05	12.5	7.36	29.79	11.00	6.18
		25	12:05	1	7.44	29.55	5.60	3.42
T001	7/10/08	13.2	14:26	10	7.76	29.46	0.52	0.25
		13.2	14:26	5	7.59	29.55	0.52	0.25
		13.2	14:26	1	7.53	29.54	0.52	0.25
T002	7/10/08	18	15:22	14.8	7.44	29.67	0.59	1.36
		18	15:22	9	7.61	29.69	0.48	0.57
		18	15:22	1	7.53	30.20	0.45	0.21
T003	7/11/08	22.8	9:50	16.8	7.23	29.81	10.20	5.71
		22.8	9:50	10	7.18	29.89	8.52	4.71
		22.8	9:50	1	7.58	29.40	0.95	0.46
T004	7/11/08	23.5	10:31	20	7.22	29.87	11.28	6.37
		23.5	10:31	11	7.22	29.86	9.00	4.99

Water Quality Parameters during Intensive Sediment Sampling

Station ID	Sample date	Total depth (ft)	Time	Sample collection depth (ft)	pH	Temperature (^{o}C)	Conductivity (mS/cm)	Salinity (ppt)
T004	7/11/08	23.5	10:31	1	7.53	29.60	1.23	0.60
W001	7/11/08	23.3	11:19	18	7.72	28.57	0.48	0.23
		23.3	11:19	11.5	7.68	28.56	0.48	0.23
		23.3	11:19	1	7.66	28.93	0.48	0.23
W002	7/11/08	10.8	12:20	8.8	7.84	28.87	0.36	0.17
		10.8	12:20	4.3	7.76	28.96	0.39	0.18
		10.8	12:20	1	7.71	29.34	0.40	0.19
W003	7/11/08	14	13:38	12	7.82	28.52	0.42	0.20
		14	13:38	7	7.74	28.84	0.41	0.20
		14	13:38	1	7.69	30.08	0.45	0.21
W004	7/11/08	17.1	14:10	14.2	7.30	29.65	7.87	4.33
		17.1	14:10	8.5	7.43	28.98	3.25	1.55
		17.1	14:10	1	7.55	29.80	0.71	0.33
W005	7/11/08	37.4	14:40	34	7.28	29.64	13.95	8.01
		37.4	14:40	18	7.24	29.94	12.54	7.07
		37.4	14:40	1	7.41	30.19	3.97	2.06
W007	7/11/08	42.9	15:20	38.1	7.34	29.98	14.22	8.13
		42.9	15:20	21	7.30	30.01	11.26	6.35
		42.9	15:20	1	7.32	30.60	8.13	4.47
W006	7/11/08	41.5	16:42	37.4	7.31	29.94	13.59	7.80
		41.5	16:42	20	7.30	29.92	11.57	6.53
		41.5	16:42	1	7.38	30.75	5.69	3.06
W008	7/12/08	40.7	9:04	37	7.26	30.10	14.00	8.05
		40.7	9:04	20.5	7.28	30.02	10.41	5.86
		40.7	9:04	1	7.27	29.93	9.03	5.01
C001	7/12/08	44	9:41	39	7.36	30.12	14.93	9.05
		44	9:41	20	7.35	30.10	12.82	7.28
		44	9:41	1	7.35	30.00	10.11	5.63
C002	7/12/08	43.9	10:08	39	7.37	30.19	14.66	8.98

Water Quality Parameters during Intensive Sediment Sampling

Station ID	Sample date	Total depth (ft)	Time	Sample collection depth (ft)	pH	Temperature (^{o}C)	Conductivity (mS/cm)	Salinity (ppt)
C002	7/12/08	43.9	10:08	21	7.32	30.06	12.49	7.14
		43.9	10:08	1	7.31	30.08	10.38	5.81
C003	7/12/08	48.3	10:54	44	7.29	30.16	13.98	7.97
		48.3	10:54	24	7.26	30.04	12.19	7.05
		48.3	10:54	1	7.26	30.13	11.10	6.25
C004	7/12/08	42.1	11:28	38.1	7.25	30.18	14.31	8.22
		42.1	11:28	21	7.23	30.17	12.95	7.37
		42.1	11:28	1	7.24	30.47	12.26	6.95
C005	7/12/08	47.7	13:45	45	7.51	30.31	18.99	11.32
		47.7	13:45	27	7.45	30.25	14.38	8.40
		47.7	13:45	1	7.40	30.31	13.98	7.34
C006	7/13/08	42.2	9:20	38.2	7.38	30.40	18.11	10.62
		42.2	9:20	22.1	7.38	30.29	15.86	9.26
		42.2	9:20	1	7.37	30.13	13.58	7.76
T009	7/13/08	27.5	9:39	25	7.45	29.79	11.66	6.59
		27.5	9:39	13	7.39	29.97	10.44	5.84
		27.5	9:39	1	7.76	30.03	2.14	1.08
T010	7/13/08	21.5	10:47	18.2	7.50	30.22	13.18	7.53
		21.5	10:47	9.1	7.47	30.35	10.75	6.01
		21.5	10:47	1	7.76	30.45	3.60	1.88
T011	7/13/08	18.5	11:15	15.5	7.47	30.29	13.66	7.83
		18.5	11:15	11	7.45	30.21	11.88	6.74
		18.5	11:15	1	7.58	30.35	6.98	3.79
T012	7/13/08	35.3	11:43	30.4	7.51	30.36	17.22	10.10
		35.3	11:43	17.1	7.44	30.33	13.52	7.73
		35.3	11:43	1	7.44	30.61	12.74	7.26
E012	7/13/08	50.3	12:54	48	7.63	30.60	20.92	11.21
		50.3	12:54	25	7.57	30.38	18.72	11.02
		50.3	12:54	1	7.51	30.56	16.84	10.45

Water Quality Parameters during Intensive Sediment Sampling

Station ID	Sample date	Total depth (ft)	Time	Sample collection depth (ft)	pH	Temperature (^{o}C)	Conductivity (mS/cm)	Salinity (ppt)
E013	7/13/08	42.1	14:48	45	7.77	30.52	19.50	11.56
		42.1	14:48	24	7.61	30.54	17.10	10.98
		42.1	14:48	1	7.55	30.57	18.39	10.81
E014	7/13/08	50	16:02	44	7.68	30.61	19.63	11.80
		50	16:02	25	7.62	30.64	18.97	11.17
		50	16:02	1	7.58	30.66	18.88	11.11
E015	7/13/08	50	16:30	47.2	7.66	30.58	21.12	12.52
		50	16:30	25.3	7.63	30.70	11.76	11.75
		50	16:30	1	7.66	30.72	19.00	11.19
T015	7/15/08	8	7:54	6	6.78	30.46	11.73	6.63
		8	7:54	1	6.97	30.44	10.20	5.75
T016	7/15/08	13	8:51	12	7.26	30.45	11.98	6.79
		13	8:51	6	7.20	30.45	11.79	6.68
		13	8:51	1	7.33	29.37	6.01	3.33
T014	7/15/08	4	9:58	3	7.78	30.73	2.81	1.45
		4	9:58	1	7.84	31.05	1.39	0.69
T013	7/15/08	3	11:24	1	8.15	30.07	0.96	0.47