Sourcing of Dioxins from the San Jacinto Waste Pit Superfund Site into the Galveston Bay System

A Thesis

Presented to

the Faculty of the Department of Civil and Environmental Engineering

University of Houston

In Partial Fulfillment

of the Requirements for the Degree

Master of Science

in Environmental Engineering

by

Taft Yerger Tucker

August 2012

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ABSTRACT

In 1965 and 1966, dioxin laden paper mill wastes were disposed of in the San Jacinto River Waste Pits (SJWP) on the banks of the San Jacinto River (SJR). Regional land subsidence has caused submergence of portions of the waste pits, directly exposing the wastes to the SJR. This thesis is aimed at quantifying the contribution of the SJWP to the observed dioxin pollution in water, sediment, and tissue samples collected from the Galveston Bay System (GBS).

A qualitative investigation of dioxin fingerprints in sediments identified 3 primary source profiles most likely representing dioxins from a) SJWP (paper mill), b) the Houston Ship Channel (HSC) upstream of its confluence with the SJR, and c) Houston's urban air. A quantitative source apportionment model, positive matrix factorization (PMF), identified similar source profiles and indicated that industrial point sources have a significant impact on nearby sediment quality within the HSC and SJR; however, atmospheric deposition is the dominant source of dioxins observed in the more open waters of Galveston and Trinity Bays. PMF results also indicate the locations within the GBS where the SJWP affected sediment quality. An EFDC model of the GBS was used to aid in the understanding of the complex hydrodynamics of the system. Model results provide supporting evidence of SJWP dioxin laden sediment transport and deposition within the GBS.

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NOMENCLATURE

DOC	dissolved organic carbon
EFDC	Environmental Fluid Dynamics Code
EM	End member
GBS	Galveston Bay System
GFF	Glass fiber filter
HSC	Houston Ship Channel
LCL	Lower confidence limit
M-PVA	Modified polytopic vector analysis
MSL	Mean sea level
NPL	National Priorities List
PAH	Polycyclic aromatic hydrocarbon
PC	Principal component
PCA	Principal component analysis
PCB	polychlorinated biphenyl
PCDD	Polychlorinated dibenzo-p-dioxin
PCDF	Polychlorinated dibenzofurans
PCP	Polychlorinated phenoxyphenols
PMF	Positive Matrix Factorization
POP	Persistent Organic Pollutant
ppt	Parts per trillion
PVA	Polytopic vector analysis
SJR	San Jacinto River
SJWP	San Jacinto River Waste Pit Superfund Site
TCRA	Time Critical Removal Action

TDSHS	Texas Department of State Health Services
TEF	Toxicity equivalence factor
TEQ	Toxicity equivalent
TMDL	Total maximum daily load
TPWD	Texas Parks and Wildlife Department
TSS	Total suspended sediment
UCL	Upper confidence limit
USEPA	United States Environmental Protection Agency
USGS	United States Geological Survey
WHO	World Health Organization

CHAPTER 1 – INTRODUCTION

Persistent organic pollutants (POPs) are a group of man-made compounds known for their hydrophobicity, lipophilicity, recalcitrance, and toxicity to humans and other organisms. POPs (e.g., dioxins[1], polychlorinated biphenyls or PCBs, and many insecticides) have become ubiquitous in the modern industrialized urban setting and can be found all over the world in various environmental media (Van den Berg, Birnbaum et al., 2006). Their stability allows them to travel considerable distances from sources and, when combined with their propensity to dissolve into lipids, leads to the accumulation and magnification of POPs in food chains (Jones and de Voogt 1999). This thesis focuses on dioxins and furans in sediment at a Superfund site and their role as a source affecting the surrounding estuarine environment.

Polychlorinated dibenzo-*p*-dioxins (PCDDs) and polychlorinated dibenzofurans (PCDFs) can be present as one of 210 congeners, depending on the number and location of attached chlorine atoms. Of these congeners, only 17 are considered to exhibit "dioxin-like" toxicity; however, 2,3,7,8-tetrachlorodibenzo-*p*-dioxin is often given the dubious distinction of being the "most toxic man-made chemical" (Hites 2011), though toxicity varies significantly among the different congeners (Schwetz, Norris et al., 1973). Due to their high toxicity and persistence in the environment, dioxins have received a significant amount of regulatory interest in recent years.

Unlike most other contaminants, which are typically desired end products of some industrial process, dioxins are only present as unintended byproducts of industrial

[1] Throughout this thesis, the term dioxin(s) will be used to refer to the chemically similar polychlorinated dibenzo-*p*-dioxins (PCDDs) and polychlorinated dibenzofurans (PCDFs or furans).

processes or combustion. Generally, any process which combines chlorination and heat may result in trace levels of dioxins. In 1988, prompted by findings of elevated 2378-TCDD concentrations in fish downstream of several paper mills, the United States Environmental Protection Agency (USEPA) in conjunction with the paper industry released data proving that dioxins are formed during the paper bleaching process. These findings prompted a more comprehensive study, commonly known as the 104 Mill study, quantifying dioxin in wastes emanating from paper mills. The results showed that about 0.64 kg/yr of 2378-TCDD and 5.1 kg/yr of 2378-TCDF were formed in paper mill wastes during the late 1980s, (Whittemore, LaFleur et al., 1990). Formation of dioxins in paper mill wastes has steadily declined since then (USEPA 2006), unfortunately impacted media, particularly sediments, can act as long term sources in the environment due to the persistent nature of dioxins. Thus, despite regulating dioxins in paper mill effluent, a number of natural water systems in the US exhibit elevated levels of dioxins in their water, sediment, and biota.

In the 1960s, paper mill solid and liquid wastes were disposed of in the San Jacinto River Waste Pits (SJWP), bermed impoundments on the banks of the San Jacinto River (See Figure 1-1). Since then, land subsidence in the area has exacerbated erosion of the waste pit berms and partial inundation of the pits allowing direct, constant contact between the San Jacinto River (SJR) and the dioxin laden wastes in the pits. Elevated levels of dioxins in water, fish tissue, and sediment observed to date throughout the Houston Ship Channel (HSC) system and in sediment samples collected near the waste pits indicate that the waste pits are a probable current source of dioxin into the San Jacinto River (Suarez, Rifai et al., 2006). Subsequently, the SJWP site was added to the EPA's National Priorities List (NPL), and interim remedial actions have been implemented to limit the release of dioxin from the site while permanent remedial actions are considered.

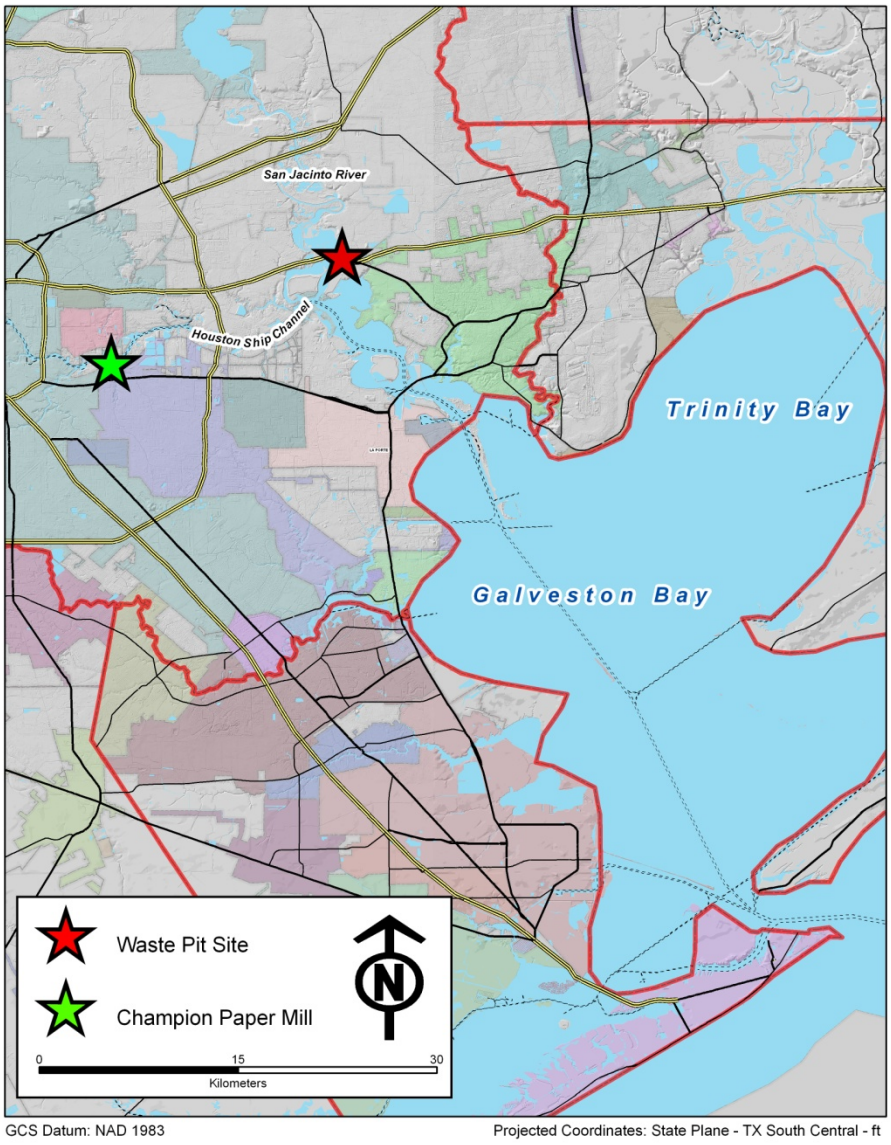


Figure 1-1: SJWP Location Map

While it is clear that the SJWP site has contributed to dioxin contamination in the San Jacinto River and downstream water bodies; the magnitude and extent of its contribution has yet to be quantified. This thesis attempts to characterize the extent to which that the SJWP site has contributed to the dioxin pollution in the Galveston Bay system (GBS). The focus of the thesis will be on contaminated sediment and waste sludges that would have been released into the GBS from the pits since the 60s.

Because of the widespread nature of the dioxin contamination in the Houston Ship Channel and Galveston Bay, this is a critical issue that affects the nature and extent of remedial activities at the SJWP Superfund site and within the GBS.

The following chapter, Chapter 2, will outline the specific objectives of this research. Chapter 3 includes a detailed description of dioxins in paper mill wastes, and a review of existing studies attempting to pinpoint the source of dioxin contamination in sediments. Chapter 4 describes the history of the SJWP and gives an overview of the dataset investigated in this research and dioxin levels in the SJWP. Chapter 5 presents the investigation of the SJWP historical aerial photos as well as the details and results of the source fingerprinting analysis. Chapter 6 presents the results of the EFDC modeling. Chapter 7 presents the conclusions that were drawn from this research.

CHAPTER 2 – OBJECTIVES

The overall goal of this research is to characterize the extent to which the San Jacinto Waste Pit Superfund Site (SJWP) has contributed to the dioxin pollution in the Galveston Bay system. Specifically, this thesis delineates the extent to which dioxin contaminated sediments originating from SJWP have migrated into downstream portions of the Galveston Bay system. To this end, several supporting lines of qualitative and quantitative evidence will be studied as described in the following paragraphs.

Available historical aerial photographs of the SJWP and San Jacinto River will be examined in an effort to better understand the changes in the San Jacinto River and the Waste Pit site over time. In particular, land subsidence due to groundwater pumping has significantly lowered ground surface elevations in the highly industrialized area near the site causing many low lying areas, including portions of the waste pits, to be inundated by the San Jacinto River. Sand mining activities in the vicinity of the site have also played a significant role in altering the flow paths of the San Jacinto River around the waste pits. Historical aerials will be important in helping determine approximately when elevations around the site declined enough to cause full breach of the waste pit berms allowing direct, constant contact between the San Jacinto River and the dioxin laden wastes in the pits. The development of a site timeline will be important in determining the time periods for model runs, and, perhaps more importantly, it will aid in the development of a sound conceptual model of the SJWP and its interaction with the San Jacinto River.

Datasets generated during previous sediment sampling events will be used to “fingerprint” dioxin contamination originating from the SJWP and to delineate the extent of contaminated sediments attributable to the SJWP. A qualitative fingerprint analysis will be performed to identify, if possible, any dominant dioxin fingerprints in the system.

This will be combined with a geospatial analysis to identify potential source areas with identifiable fingerprints. Positive Matrix Factorization (PMF), a quantitative source apportionment model, will be used to identify the relative contribution that each fingerprint source has contributed to sediments within the GBS.

Sediment transport in the San Jacinto River will be modeled using an existing Environmental Fluid Dynamics Code (EFDC) model of the Houston Ship Channel and Upper Galveston Bay estuary (Howell 2012). EFDC is a robust 3-D modeling program with the capability of simulating channel hydrodynamics, sediment and contaminant transport, and water quality in a surface water system. Additionally, it can be used to model drying and wetting of low lying areas as well as sediment resuspension and deposition. EFDC will be used to model the transport and fate of sediments from the San Jacinto River and SJWP into the Galveston Bay system.

As outlined in the preceding paragraphs, this thesis examines the San Jacinto Waste Pit Superfund Site as a source of dioxin contamination by modeling transport and deposition of SJWP sediments and statistically linking dioxin concentration profiles in sediments downstream of the SJWP with dioxin profiles of wastes still present in the SJWP.

CHAPTER 3 – BACKGROUND

3.1 Persistent Organic Pollutants

As discussed in Chapter 1, persistent organic pollutants (POPs) are a group of hydrophobic, highly toxic, recalcitrant, and bioaccumulative environmental pollutants which are found in environmental media throughout the world. In particular, POPs affecting sediments can act as long term contaminant sources due to long half-lives (Rawn, Lockhart et al., 2001). Their stability allows them to travel considerable distances from sources and, when combined with their propensity to dissolve into lipids, leads to the accumulation and magnification of POPs in food chains (Jones and de Voogt 1999). POPs have been recognized as a global problem capable of impacting all corners of the globe, and in May 2001, the United Nations issued the Stockholm Protocol calling on the reduction or elimination of releases of 12 POPs (see Table 1), including dioxins and furans, to the environment (USEPA 2011). This thesis focuses on dioxins and furans emanating from a former paper mill waste disposal facility and its effects on the surrounding estuary.

3.2 Dioxins and Furans

Polychlorinated dibenzo-*p*-dioxins (PCDDs) and polychlorinated dibenzofurans (PCDFs) can be present as one of 210 congeners, but typically only the 17 toxic congeners are measured in environmental samples. Due to their high toxicity, persistence in the environment, and prevalence within industrialized settings (Wenning, Paustenbach et al., 1993), dioxins have received a significant amount of regulatory interest in recent years.

Table 3-1: "Dirty Dozen" Persistent Organic Pollutants

POP	Source
aldrin & dieldrin	**Insecticide:** Commonly used on corn, cotton, and for termite control
chlordane	**Insecticide:** Used on a variety of crops and for termite control. Also used on home lawn and garden pests.
DDT	**Insecticide:** Used on agricultural crops, primarily cotton. Used to control insect vectors of diseases like malaria and typhus.
endrin	**Insecticide & Rodenticide:** Used on cotton, grains, and to control rodents.
mirex	**Insecticide:** Used to control fire ants, termites, mealybugs. **Fire retardent:** Used in plastics, rubber, and electrical products
heptachlor	**Insecticide:** Primarily used agains soil insects and termites.
hexachlorobenzene	**Fungicide:** Used in seed treatment **Industrial chemical:** Used to make fireworks, synthetic rubber, and other substances. **Unintentional byproduct:** produced during combustion, impurity in certain pesticides,
PCBs	**Industrial chemical:** Used for a variety of processes and purposes. **Unintentional byproduct:** Also unintentionally produced during combustion
toxaphene	**Insecticide:** Used to control pests on crops and livestock and to control unwanted fish in lakes
dioxins and furans	**Unintentional byproduct:** Unintentionally produced during most forms of combustion and during some industrial processes. Found as trace contaminants in certain herbicides, wood preservatives, and in PCB mixtures.

Notes: Modified from “Dirty Dozen Table” (USEPA 2011)

3.2.1 Dioxin Toxicity Equivalence

Dioxins and furans are often found as complex mixtures of individual congeners in impacted environmental media. For simplicity, concentrations of the toxic dioxin congeners present in a sample are often reported as 2378-TCDD toxicity equivalence (TEQ). Dioxins and furan congeners are considered to be toxic if chlorines are present in the 2, 3, 7, and 8 positions at a minimum (see Figure 3-1).

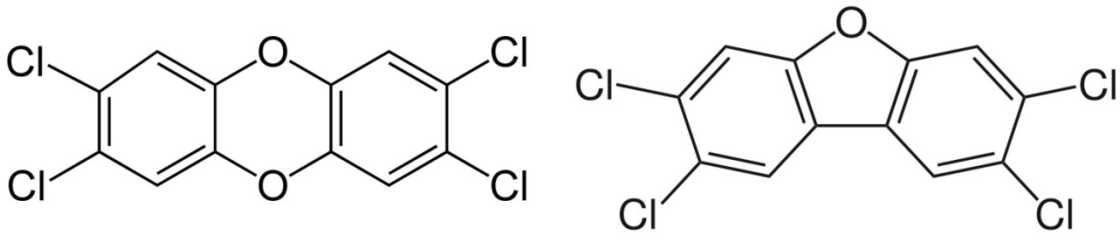


Figure 3-1: 2378-TCDD & 2378-TCDF showing chlorines in the 2, 3, 7, & 8 positions

The 17 toxic dioxin congeners are multiplied by their respective toxicity equivalence factor (TEF) and summed to calculate a sample's dioxin TEQ, i.e.,

$$TEQ = \sum_{i=1}^{n} Concentration_{Cong_i} \cdot TEF_{Cong_i}. \quad (3.1)$$

In this thesis, all TEQ values are calculated using the TEFs outlined during the World Health Organization's (WHO) 2005 International Programme on Chemical Safety, shown in Table 3-2 (Van den Berg, Birnbaum et al., 2006).

Table 3-2: WHO-2005 Toxic Equivalency Factors for PCDDs and PCDFs

PCDDs	TEF (WHO, 2005)
2378-TCDD	1
12378-PeCDD	1
123478-HxCDD	0.1
123678-HxCDD	0.1
123789-HxCDD	0.1
1234678-HpCDD	0.01
OCDD	0.0003

PCDFs	TEF (WHO, 2005)
2378-TCDF	0.1
12378-PeCDF	0.03
23478-PeCDF	0.3
123478-HxCDF	0.1
123678-HxCDF	0.1
123789-HxCDF	0.1
234678-HxCDF	0.1
1234678-HpCDF	0.01
1234789-HpCDF	0.01
OCDF	0.0003

3.2.2 Dioxins in Paper Mill Effluents and Wastes

Unlike most other contaminants, which are typically the desired end products of some industrial process, dioxins are only present as unintended byproducts of industrial processes or combustion. Generally, any process which combines chlorination and heat may result in trace levels of dioxins.

In 1988, prompted by findings of elevated 2378-TCDD concentrations in fish downstream of several paper mills, the United States Environmental Protection Agency (USEPA) in conjunction with the paper industry released data proving that dioxins are

formed during the chlorine bleaching process. These findings prompted a more comprehensive study, commonly known as the 104 Mill study, quantifying dioxin in wastes emanating from paper mills. The results showed that about 0.64 kg/yr of 2378-TCDD and 5.1 kg/yr of 2378-TCDF were formed in paper mill wastes during the late 1980s, (Whittemore, LaFleur et al., 1990). Dioxins are primarily generated by direct chlorination of dibenzofurans and dibenzo-p-dioxins during pulp bleaching or due to condensation of polychlorinated phenoxyphenols (PCPs), a common wood preservative, during pulp digestion (Dimmel, Riggs et al., 1993). As a result, paper mills began phasing out the use of molecular chlorine (Cl_2) as a bleaching agent, among other process improvements (Santl, Gruber et al., 1994), and formation and subsequent release of dioxins due to paper mill activities has steadily declined (USEPA 2006). Reductions of dioxin levels in paper mill wastes and effluents has led to an apparent reduction in dioxin levels in fish tissue (Gillespie and Abbott 1998).

Evaluation of dioxin profiles in paper mill wastes and effluents has shown that particular congener patterns tend to emerge during the paper mill pulp bleaching process, particularly elevated levels of 2378-TCDF and 2378-TCDD (Ehrlich, Wenning et al., 1994). Crab and sediment samples near a paper mill in Sweden also showed similar dioxin profiles (Rappe, Andersson et al., 1987). Additionally, isomer profiles of tetra-chlorinated homologue groups can be useful in identifying contamination associated with paper mill wastes and effluents (Swanson, Rappe et al., 1988). As shown in Figure 3-2 (Figure 4 from Swanson, Rappe et al., 1988), the 2378-TCDD and 2378-TCDF isomers typically dominate the homologue profile in paper mill effluents, making the profile readily discernible from the typical incineration isomer profile.

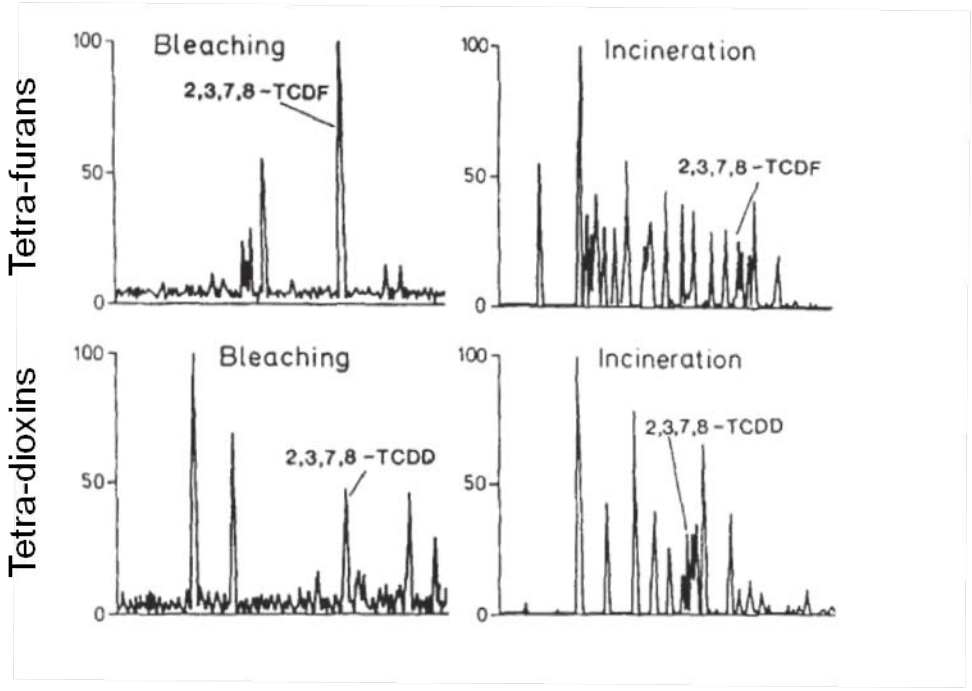


Figure 3-2: Chromatographs of TCDD and TCDF levels formed during bleaching and incineration. Figure 4 from (Swanson, Rappe et al., 1988).

3.2.3 Environmental Impacts of Paper Mills on Receiving Water Bodies

As mentioned above, degradations in biota and sediment quality have been documented in water bodies receiving paper mill effluents. Reductions in PCDD/F levels in effluent have led to decreases in dioxin concentrations in fish (Kovacs, Martel et al., 2002) and shellfish (Hagen, Colodey et al., 1997; Yunker, Cretney et al., 2002) tissue samples. Sediments, on the other hand, have been slower to respond to reductions in paper mill emissions. Shellfish are a particularly good indicator of the bioavailability of dioxin contamination from paper mill impacts, as they are more likely to uptake the lower chlorinated dioxins (e.g., TCDD and TCDF) which dominate paper mill wastes and effluents (Oehme, Bartonova et al., 1990). More recent sampling in British Columbia showed that the decrease in shellfish contamination demonstrated up to 1997 (Hagen, Colodey et al., 1997) seems to have stalled, and contaminated sediments are now the

primary source providing dioxin bioavailability (Yunker, Cretney et al., 2002). In the case of the SJWP site, where layers of waste sludges were laid adjacent to the main river channel, contaminated sediments are likely to be a long term source of dioxins into the estuarine ecosystem.

3.3 Source Identification and Apportionment for Dioxins and Furans

Identification of the source of a contaminant or contaminant class that is present in an impacted medium is a fundamental goal of nearly all environmental investigations. When multiple sources of a complex contaminant class are present, which is the case for dioxins in the HSC system, parsing out individual sources and their contribution to the system is a non-trivial task. This section explores the theory and application of various chemometric methods that can be applied to multivariate environmental data to assist in source identification and apportionment.

3.3.1 Principal Component Analysis

Principal component analysis (PCA) is a pattern recognition technique applied to a complex, multivariate dataset to reduce the dimensionality and identify relationships between samples that may not be readily apparent (Einax and Zwanziger 1997). When applied to environmental datasets, such as media analyzed for dioxin contamination, it decomposes the dataset of many samples and analytes into a set of linear combinations of the original variables, called principal components (PCs), while maintaining most of the information within the original dataset (Zitko 1994). PCA is often applied as an exploratory technique to dioxin data to help determine the number and congener pattern of sources that have contributed to a contaminated medium (Okeefe, Smith et al., 1994). In theory, the original dataset, represented by matrix *X,* is completely described by a linear combination of PCs in matrix *A* with factor scores in matrix *F*, as given by

$$X = A \cdot F + E. \quad (3.2)$$

Here, matrix *E* is the residuals generated during the PCA due to the reduction in dimensionality of the data.

The loading scores represent the coordinates for each sample within the dimensionally reduced PC space. Samples which appear near one another within this PC space are considered to be similar to one another (Schwartz and Stalling 1991). PCA combined with cluster analysis can be used to identify similarity among samples and, therefore, identify samples which may have come from the same source (Wenning, Harris et al., 1992). Wenning et al. (1992) demonstrated PCA's applicability to dioxin datasets by using PCA on 2378-TCDD substituted concentrations in sediments collected from several industrial waterways around the world. Their analysis showed that samples thought to be impacted by similar sources generally clustered together regardless of the geographic origin of the sample (Wenning, Harris et al., 1992). While PCA is a useful technique for exploring patterns between samples and aiding in the identification of potential source patterns, its results are not quantitative, thus its value as a standalone analysis technique is somewhat limited. PCA was attempted on the SJWP data set; however, since only 17 of the 210 dioxin congeners were measured in most of the samples, the results were not conclusive.

3.3.2 Source Apportionment Models for Dioxins

Multivariate receptor models, such as polytopic vector analysis (PVA) and positive matrix factorization (PMF) can be employed on multivariate datasets to determine the fingerprint of individual sources, called end-members (EMs). Each EM is then quantitatively apportioned to samples within the dataset. In this way environmental investigators can quantitatively model source apportionment in complex systems where many individual sources have contributed to observed concentrations.

In PVA, results from an iterative PCA algorithm are used to determine EM patterns which are used to determine a source's contribution to observed dioxin contamination (Full, Ehrlich et al., 1982), with varying degrees of success. Wenning et al. (1993) applied PVA to concentrations of 2378-TCDD substituted congeners in surface sediments from Newark Bay, New Jersey, but the researchers were unable to strongly link the fingerprints of known sources to EMs generated during the PVA analysis (Wenning, Paustenbach et al., 1993). Ehrlich et al. (1994) was able to resolve contributing EMs in the Newark Bay estuary system that more strongly resembled known sources of dioxins (Ehrlich, Wenning et al., 1994). Bright et al. (1999) applied PVA to sediment core samples analyzed for 2378-TCDD substituted congeners and also homologue groups and was able to resolve a pulp mill effluent EM, among other EMs, and apportion the EMs historical contribution to sediment concentrations based on sedimentation rates (Bright, Cretney et al., 1999).

Typically, EM values are positively constrained such that observed concentrations can only be linear additions of EMs. However, a modified PVA (M-PVA) technique has been developed which removes the positivity constraint for one of the EMs, which represents dechlorination, and allows for the characterization of reductive dechlorination processes on dioxin contamination (Barabas, Adriaens et al., 2004a; Barabas, Goovaerts et al., 2004b). The dechlorination end member will have negative scores for the higher chlorinated congeners, representing degradations, and positive scores for the lower chlorinated congeners that are generated during dechlorination. However, when M-PVA was applied to sediment data from the Passaic River in New Jersey, the resulting dechlorination EM accounted for less than 5% of the overall variance in the dataset (Barabas, Goovaerts et al., 2004b), suggesting that dechlorination may not be an important process for dioxin contaminated sediments.

In contrast with PVA, PMF calculates the fingerprint of the EMs and the EMs contribution simultaneously (Paatero and Tapper 1994). PMF can also be used to incorporate uncertainty of measured concentrations, which Paatero and Tapper argue is more appropriate than traditional PCA for environmental data (Paatero and Tapper 1993). In recent years, PMF has become the most commonly used multivariate receptor model applied to environmental datasets (Sundqvist, Tysklind et al., 2010).

In PMF, the contribution of *p* independent sources to the original data matrix, X_{ij}, is modeled by,

$$X_{ij} = \sum_{k=1}^{p} F_{ik} G_{kj} + E_{ij}, \tag{3.3}$$

where F_{ik} is the concentration of the *i*th analyte, e.g., congener or homologue group, in the *k*th factor, G_{kj} is the contribution of the *k*th factor to the *j*th sample, and E_{ij} is the model residual for the *i*th congener in the *j*th sample. The "object function", *Q*, is minimized to obtain an optimal solution and is represented explicitly as a weighted least squares problem by,

$$Q(E) = \sum_{i=1}^{m} \sum_{j=1}^{n} \left[\frac{E_{ij}}{s_{ij}} \right]^2, \tag{3.4}$$

where s_{ij} is the uncertainty of the concentration of the *i*th congener in the *j*th sample of the original dataset containing *m* congeners analyzed *n* samples (Paatero 1997). Unlike in PVA, the number of factors, *p,* is an input into the model, and the determination of the optimal number of contributing sources is an iterative process. For environmental datasets, *Q* typically decreases with increasing number of factors; however, when the number of factors exceeds the number of actual contributing sources, the model becomes unstable causing source profiles to vary between model runs (Sundqvist, Tysklind et al., 2010).

Recent studies have shown that PMF can be successfully applied to estuarine sediment datasets. Rodenburg et al. (2011) applied PMF to a substantial PCB dataset from the Hudson River Estuary. The PMF analysis produced source profiles and apportionments in general agreement with a mass balance study previously conducted (Totten 2005), but PMF was also able to identify potential important sources of high molecular weight PCBs that the mass balance study overlooked (Rodenburg, Du et al., 2011).

Sundqvist et al. (2010) applied PMF to sediment samples collected throughout the Baltic Sea. The researchers were able to identify industrial sources likely to have contributed to localized dioxin "hot spots." The PMF model was used successfully to extract 2 separate end members representing air deposition of dioxins which were identified to be representative of global background air and more recent regional dioxin emissions (Sundqvist, Tysklind et al., 2010).

3.3.3 Data Pretreatment

One of the strengths of PMF is its ability to consider the uncertainty, s_{ij}, associated with the concentration of each data point in the original data matrix. This allows the model to place less weight on concentrations of congeners near or below the detection limit while still including them in the model. For the PMF analyses run for this research, the following uncertainty values, based off of recommendations of (Polissar, Hopke et al., 1998) with minor changes as applied by (Sundqvist, Tysklind et al., 2010), were assigned, as follows:

$$s_{ij} = \frac{5}{6} MDL \qquad \text{for values below the MDL,} \qquad (3.5)$$

$$s_{ij} = MDL + 0.1 C_{ij} \qquad \text{for quantified concentrations,} \qquad (3.6)$$

$$s_{ij} = 4\,\overline{C_i} \qquad \text{for missing values,} \qquad (3.5)$$

where, *MDL* is the method detection limit, C_{ij} is the measured concentration of the *i*th congener in sample *j*, and $\overline{C_i}$ is the average concentration of the *i*th congener from the sample dataset. Values missing from the dataset were replaced with $\overline{C_i}$ and values below the *MDL* were replaced with ½ *MDL* prior to PMF analysis. For values where the *MDL* was not reported, a value of 0.5 ng/kg was substituted in equation 3.6.

CHAPTER 4 – DIOXIN CONTAMINATION IN THE SAN JACINTO WASTE PIT SUPERFUND SITE

4.1 Site History

In the mid 1960s, a set of waste impoundments were constructed along the western banks of the San Jacinto River, just north of the IH-10 crossing of the San Jacinto River (see Figure 5-3: 1966 Aerial Photograph. Solid and liquid wastes originating from the Champion Paper Mill in Pasadena, Texas, were transported by barge and disposed of within the waste pits. Wastes within the pits are now known to contain high levels of dioxins due to the use of elemental chlorine as a bleaching agent at the Champion Paper Mill (Figure 1-1). The site consists of two main waste pits separated by a central berm. The two pits were connected via a drain line that ran through the central berm allowing excess fluids to accumulate in the eastern pit which was then pumped into barges and taken off-site (Anchor and Integral 2010). By the end of 1966, the pits had been filled to capacity and were no longer used for disposal of wastes, and it is unclear whether management of the fluids that accumulated within the eastern pit continued. It is clear, however, that the site maintenance was neglected at some point following the cessation of waste disposal.

Regional land subsidence has been a significant issue in the industrialized area near the SJWP. Figure 4-1 and Figure 4-2, present data collected using extensometers located near the site in Northeast Houston and Baytown, respectively (HGSD 2012). As shown in Figures 4-1 and 4-2, subsidence in recent years has stabilized due to reductions in groundwater extraction, but subsidence during the 1970s and 1980s was roughly 0.7 to 0.8 ft. Using this data, land subsidence near the site since the installation of the waste pits (c. 1965) is estimated to be on the order of 1.5 to 2 ft (~0.5 to 0.6 m).

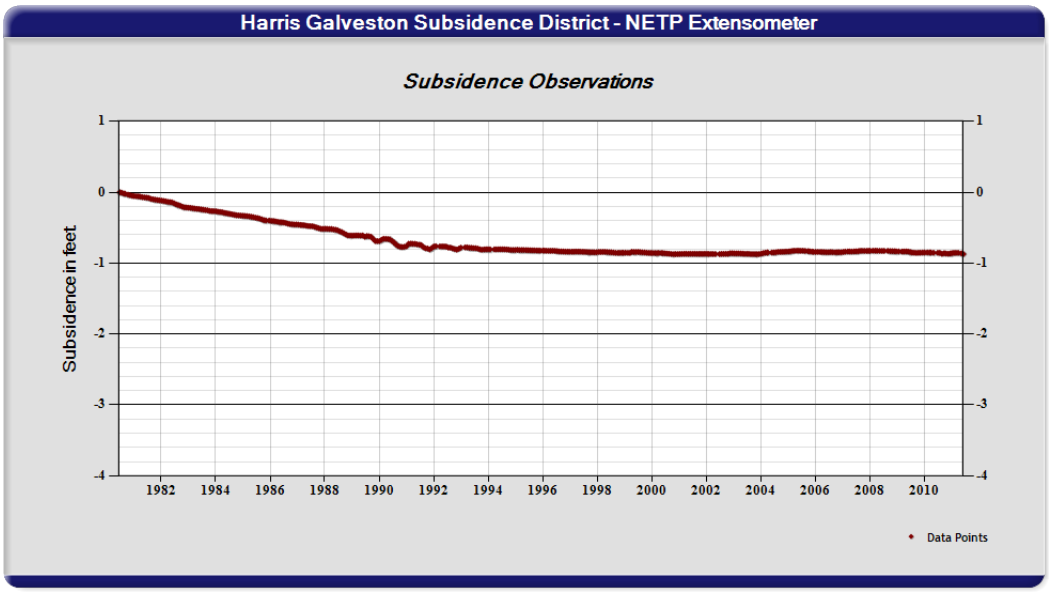


Figure 4-1: Northeast Houston Extensometer Observations

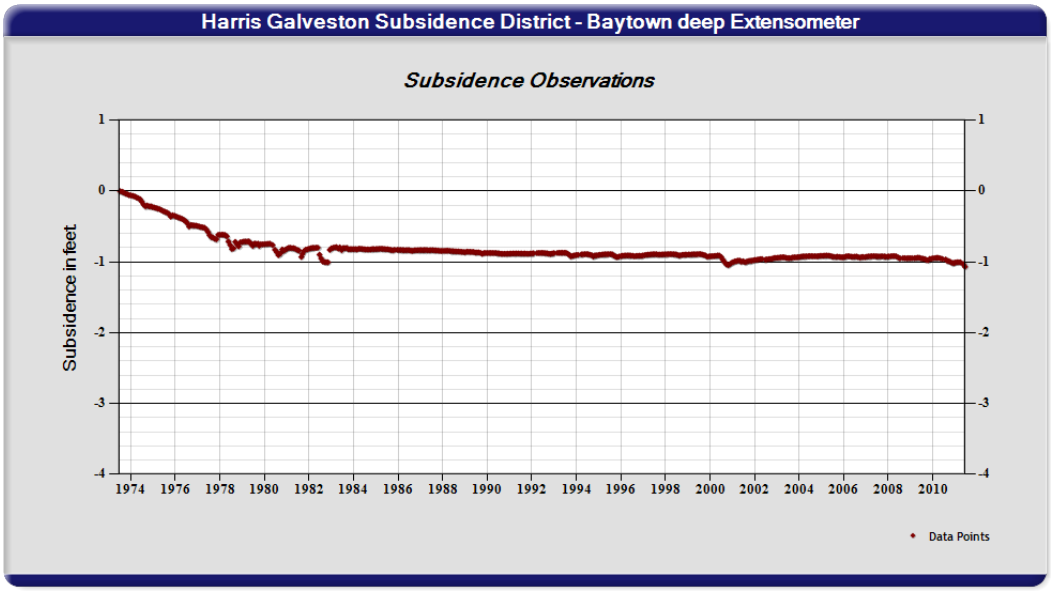


Figure 4-2: Baytown Extensometer Observations

Sand mining in the immediate vicinity of the site has also induced localized physical changes at the site, as outlined in following chapter. The combination of subsidence and sand mining has subjected the site to increased water levels and water

velocities. These factors caused the northern berm to become submerged during high flow events, and the berm was completely breached by the mid 1990s, allowing direct, constant contact between the San Jacinto River wastes within the pits. Prior to loss of integrity of the waste pit berms, interaction between the San Jacinto River and wastes in the pits was limited to flow events which were high enough to overtop the waste pit berms. As shown in Figure 4-3, the present day elevation of the central berm is approximately 2.0 m MSL, while the portion of the western berm still intact is roughly 1.0 m MSL. Given the estimated regional subsidence of 0.5 m, it is likely that flows with water level elevations greater than 1.5 m MSL and almost certain that water levels above 2.5 m MSL would have overtopped the SJWP berms.

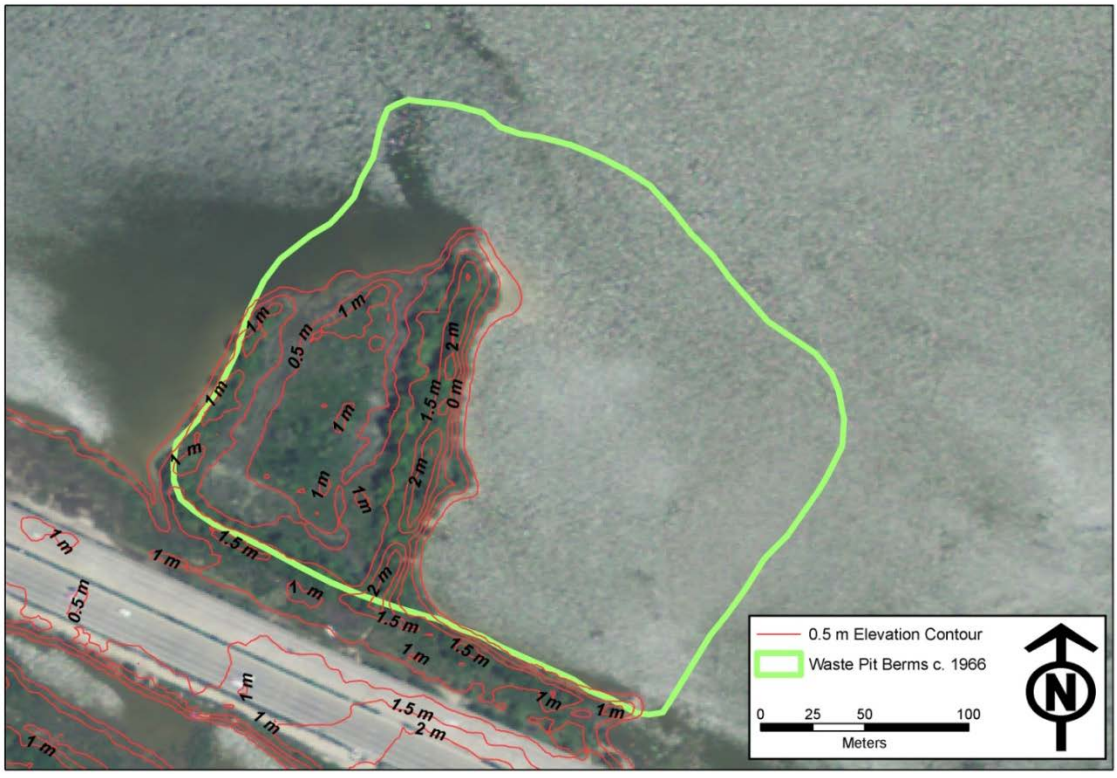


Figure 4-3: Elevations near SJWP

Data for mean daily water surface elevation between 17-Aug-96 and 1-Nov-12, were obtained for USGS station 08072050, located upstream of the SJWP where US Highway 90 crosses the San Jacinto River. The data from this time frame indicated that the SJWP berms were overtopped between two and seven times per year, submerging the pits and exposing the SJR to dioxin wastes in the pits, see Table 4-1. While a relatively small number per year, this translates to more than 100 times over a 30 year period. It should also be kept in mind that rainfall over the pits has the potential to fill the pits to capacity and allow their content to spill over directly into the SJR.

Table 4-1: SJWP Inundation Frequency

Year	# of Readings	# > 1.5 m	% > 1.5 m	# > 2.5 m	% > 2.5 m
1996	136	0	0.00%	0	0.00%
1997	365	9	2.47%	0	0.00%
1998	362	27	7.46%	13	3.59%
1999	365	0	0.00%	0	0.00%
2000	366	1	0.27%	0	0.00%
2001	359	13	3.62%	5	1.39%
2002	365	17	4.66%	7	1.92%
2003	365	7	1.92%	2	0.55%
2004	359	18	5.01%	0	0.00%
2005	361	3	0.83%	0	0.00%
2006	365	9	2.47%	3	0.82%
2007	362	2	0.55%	0	0.00%
2008	364	9	2.47%	4	1.10%
2009	365	8	2.19%	2	0.55%
2010	361	0	0.00%	0	0.00%
2011	303	0	0.00%	0	0.00%
	Avg % of days inundated		**2.1%**		**0.62%**
	Avg # days/yr inundated		**7.7**		**2.3**

4.2 Sampling Events and Site Database

Beginning in the early 1990s, state and local agencies began collecting samples from environmental media, including fish and crab samples, from the HSC system for dioxin toxicity analysis. In 1990, the Texas Department of State Health Services

(TDSHS) issued its first seafood consumption advisory for Upper Galveston Bay and the Houston Ship Channel due to elevated dioxin levels in blue crab and catfish (Lester, Gonzalez et al., 2011). As a result, the HSC system was placed on the list of impaired water bodies under §303(d) of the Clean Water Act and a Total Maximum Daily Load (TMDL) study was initiated.

High concentrations of dioxins have been observed in samples collected from sampling station 11193 (see Figure 4-7), immediately downstream of the SJWP. In 2005, the Texas Parks and Wildlife Department (TPWD) identified the waste pits as a possible source of contamination which prompted the TCEQ to conduct a complete site assessment (TCEQ 2007). The results of TCEQ's investigation prompted a TCEQ request to the EPA that the SJWP site be included on the National Priorities List (NPL). The EPA concurred, and in 2007, the SJWP site became a Superfund Site.

Numerous sampling events have been conducted since 1990, and a substantial dataset of dioxin concentrations in samples of various environmental media collected near the site as well as throughout the GBS has been generated. These data have been compiled in a site database accessible through the EPA Region 6 SJWP website. Figure 4-4 through Figure 4-6 show the locations where dioxin samples have been collected in the vicinity of the SJWP site. Overall, the SJWP database consists of 421 surface sediment samples, 142 surface water samples (Figure 4-4), 247 blue crab tissue samples, and 166 hardhead catfish tissue samples (Figure 4-5) collected throughout the HSC/GBS system and analyzed for dioxins. Additionally, dioxin concentrations with depth were obtained from 57 locations where sediment cores were collected (Figure 4-6).

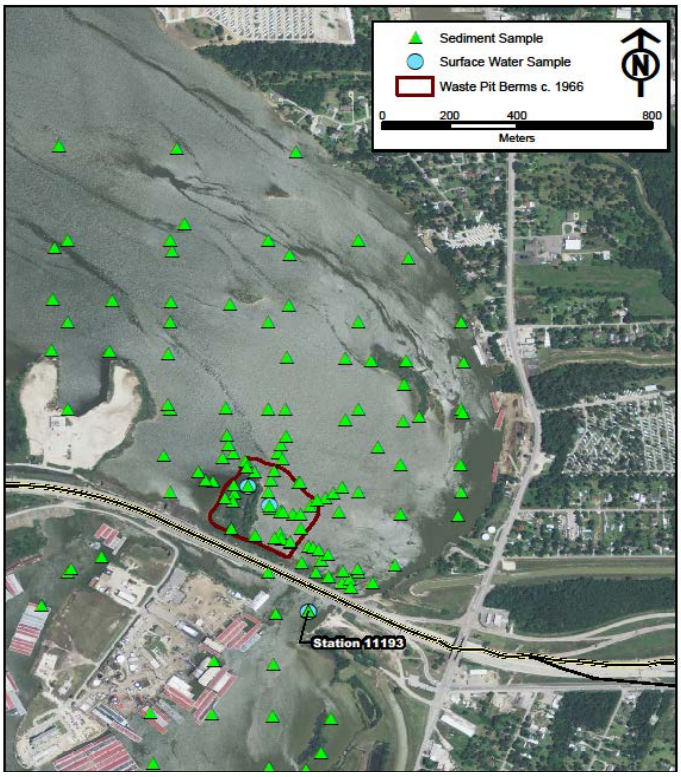


Figure 4-4: Sediment and Surface Water Sampling Locations near SJWP

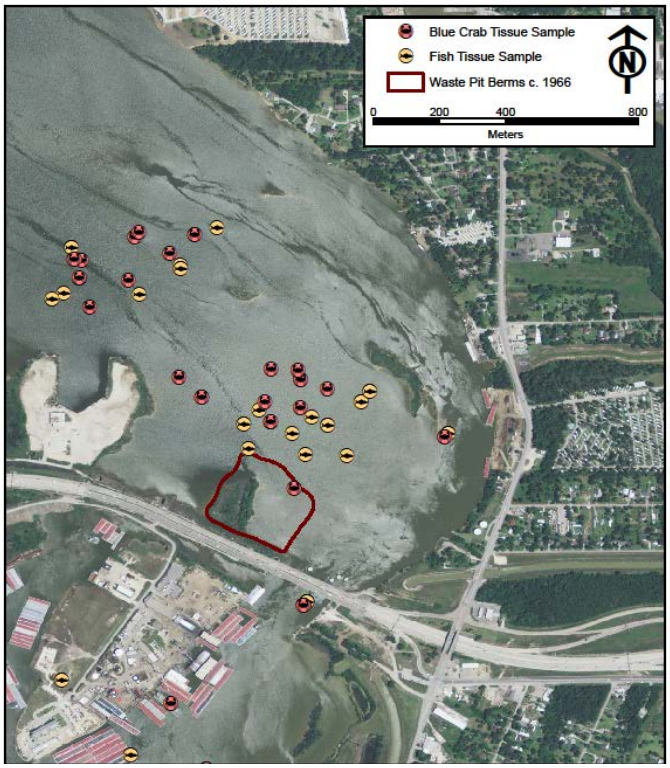


Figure 4-5: Crab and Fish Tissue Sampling Locations near SJWP

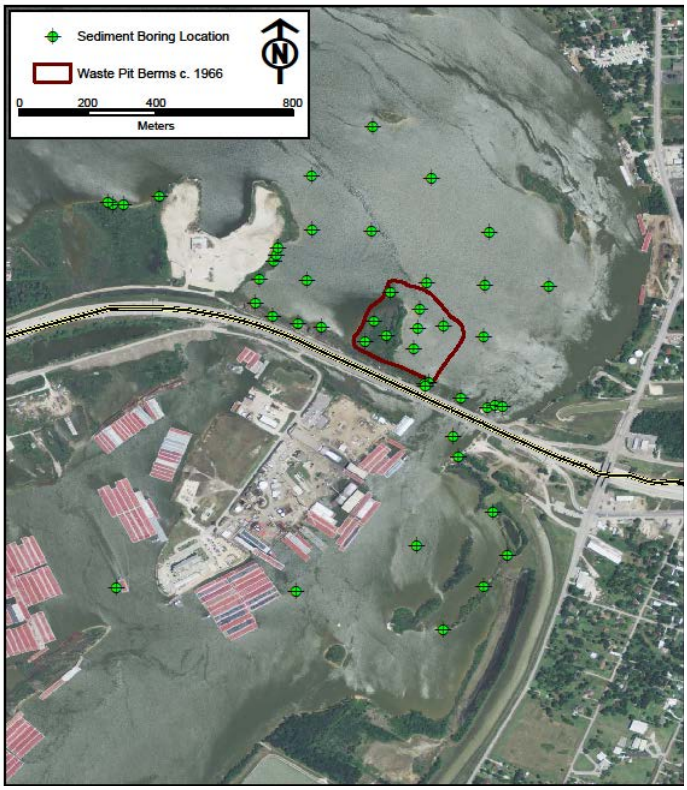


Figure 4-6: Sediment Boring Locations

4.3 Dioxins in the Houston Ship Channel/Galveston Bay System

Due to the industrial setting surrounding the HSC, elevated levels of dioxins are found in environmental media and biota samples collected throughout the HSC/GBS system.

4.3.1 Dioxins in HSC/GBS Sediments

Figure 4-7 shows TEQ results for sediment samples collected during 1993 and 1994. Samples collected from the HSC (stations 015 & 016) and immediately downstream of the SJWP site (station 11193) show TEQ concentrations well above the concentration observed in sediments further upstream in the San Jacinto River. While elevated dioxins were observed directly downstream of the SJWP site, during this sampling event, the highest dioxin TEQ concentration, 344.38 ng/kg or parts per trillion

(ppt), was observed in Patrick Bayou, Station 015, an industrialized tributary to the Houston Ship Channel. A portion of Patrick Bayou was been placed on EPA's NPL due to sediments contaminated with metals, PAHs, PCBs, and pesticides.

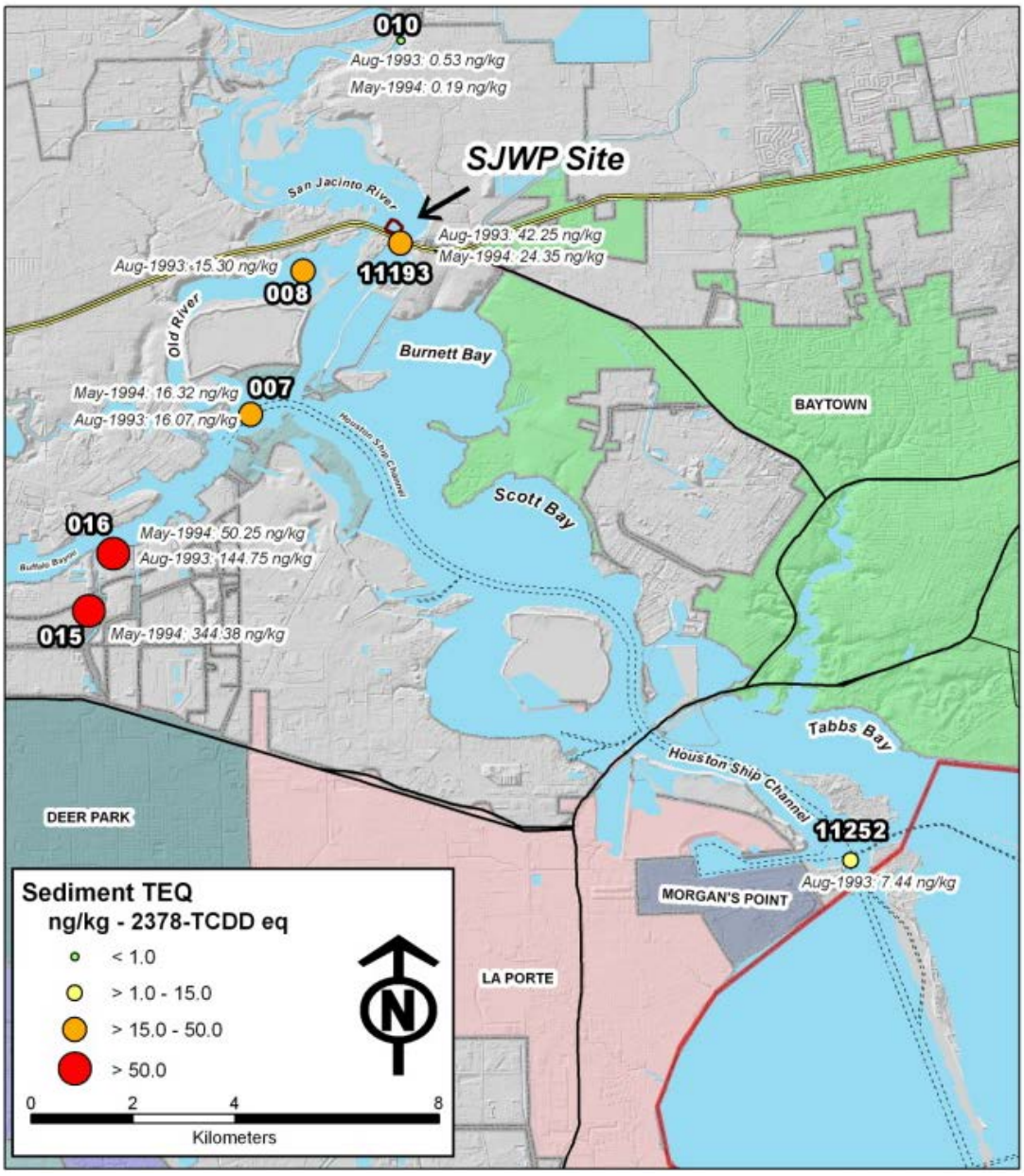


Figure 4-7: Sediment TEQ results from samples collected in 1993 & 1994

More comprehensive sampling of the HSC system was conducted during 2002, 2003, 2004, 2005, and 2011, following the initiation of the dioxin Total Maximum Daily Load (TMDL) for the HSC. Figure 4-8 through Figure 4-14, presented below, show the TEQ results for samples collected during these events. Generally, these results suggest that the SJWP site and industries along the Buffalo Bayou portion of the HSC are major contributors of dioxin toxicity in the HSC/GBS system. The highest TEQ concentrations are, for the most part, seen upstream of the Houston Ship Channel/SJR confluence and concentrations gradually decrease as sampling locations move into Galveston Bay. These datasets show that there are several significant sources of dioxins into the HSC/GBS system; however, as discussed in Chapter 3, dioxin profiles vary depending upon the process by which they are generated which may allow observed profiles to be attributed to a particular source. The main objective of this thesis, as stated in Chapter 2, is to determine to what degree dioxin contamination from the SJWP has contributed to the dioxin contamination present in the HSC/GBS.

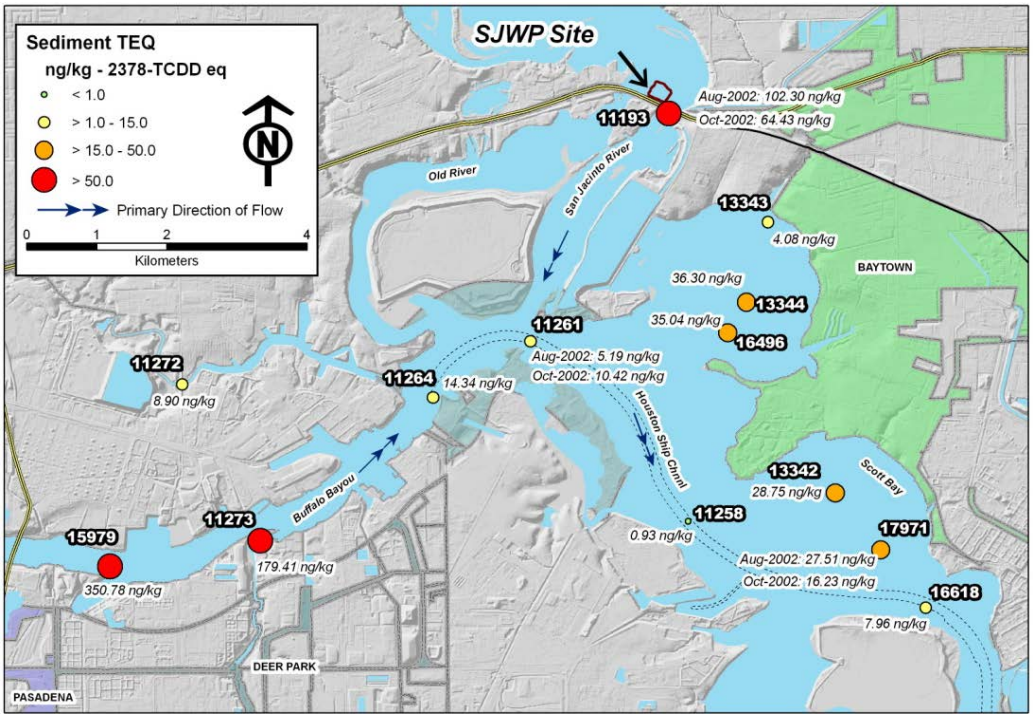


Figure 4-8: Sediment TEQ 2002 near Confluence of HSC & SJR

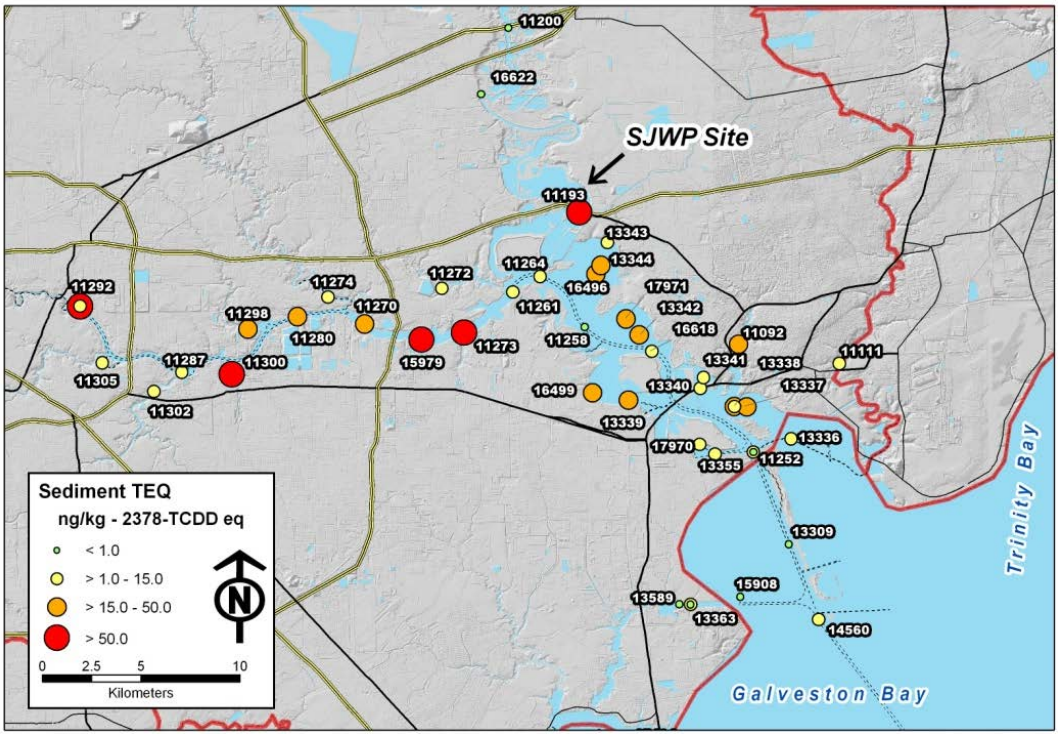


Figure 4-9: Sediment TEQ 2002: HSC to Upper Galveston Bay

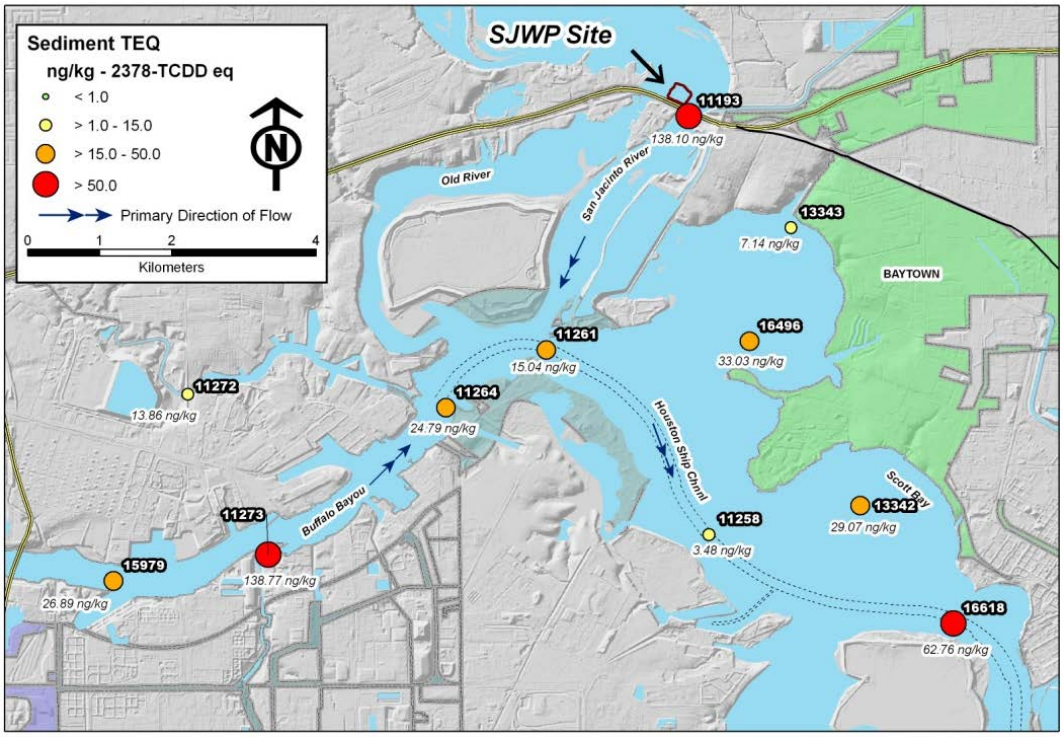


Figure 4-10: Sediment TEQ 2003 near Confluence of HSC & SJR

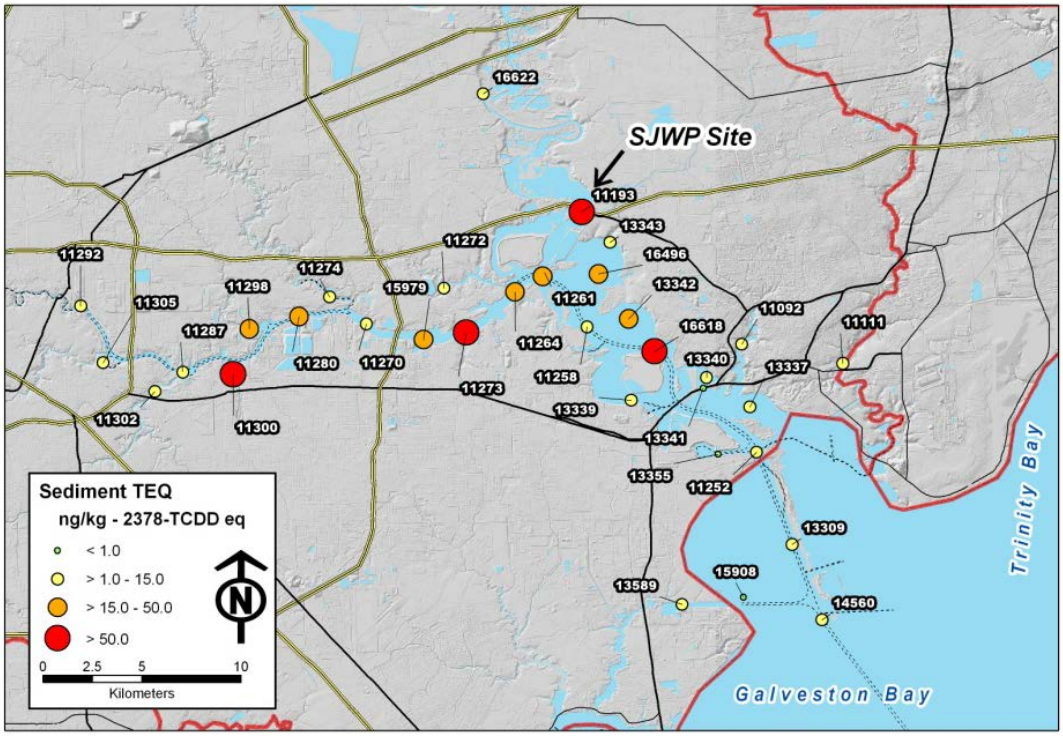


Figure 4-11: Sediment TEQ 2003: HSC to Upper Galveston Bay

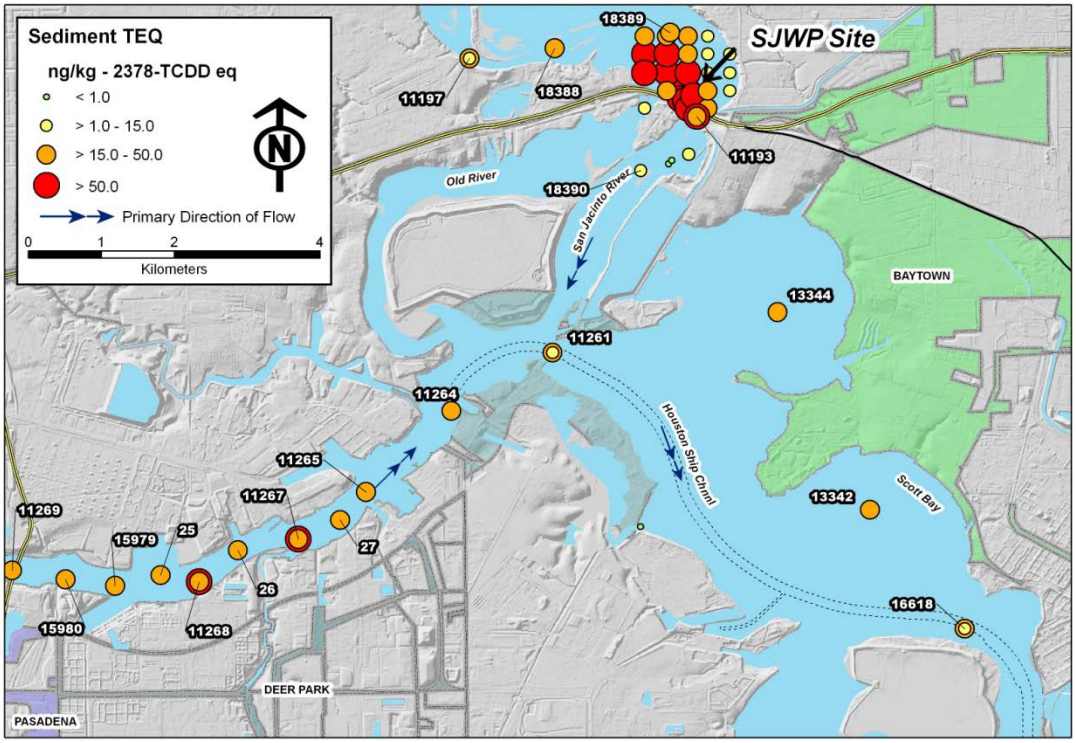


Figure 4-12: Sediment TEQ 2004 & 2005 near Confluence of HSC

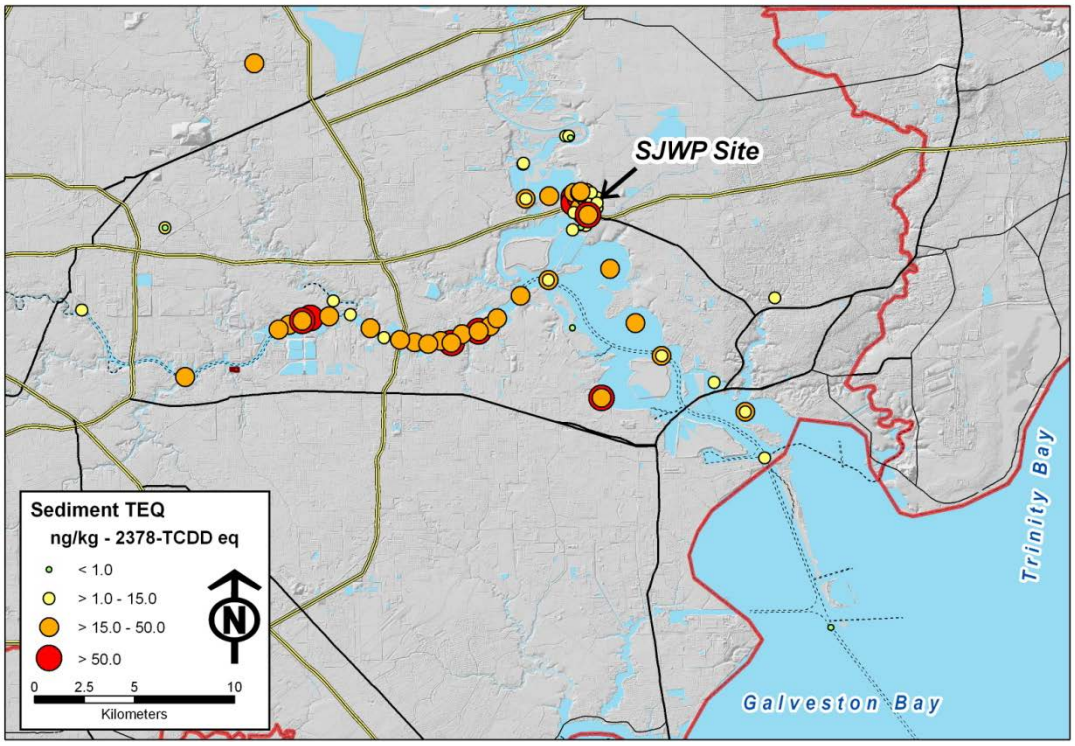


Figure 4-13: Sediment TEQ 2004 & 2005: HSC to Upper Galveston Bay

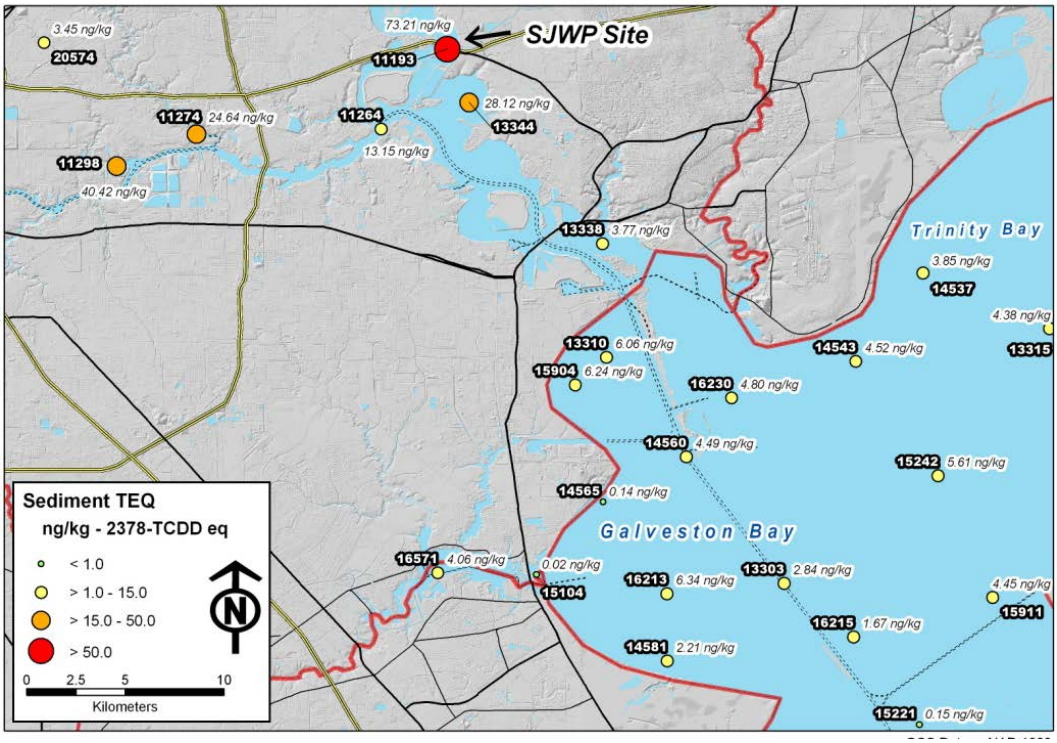


Figure 4-14: Sediment TEQ 2011

4.3.2 Dioxins in HSC/GBS Blue Crabs

Edible tissue samples collected from blue crabs during the 1990s (Figure 4-15) showed similar spatial distributions to dioxins measured in sediments. During the 1990s, the highest TEQ was observed in a sample collected at station 007 near the confluence of the Houston Ship Channel and the San Jacinto River. TEQ seems to progressively decrease in the samples collected downstream of the confluence into upper Galveston Bay. In these figures, the smallest sample marker represents the Texas Department of Health tissue screening sample of 0.47 ng/kg 2378-TCDD equivalent, which has recently been reduced to 0.41 ng/kg.

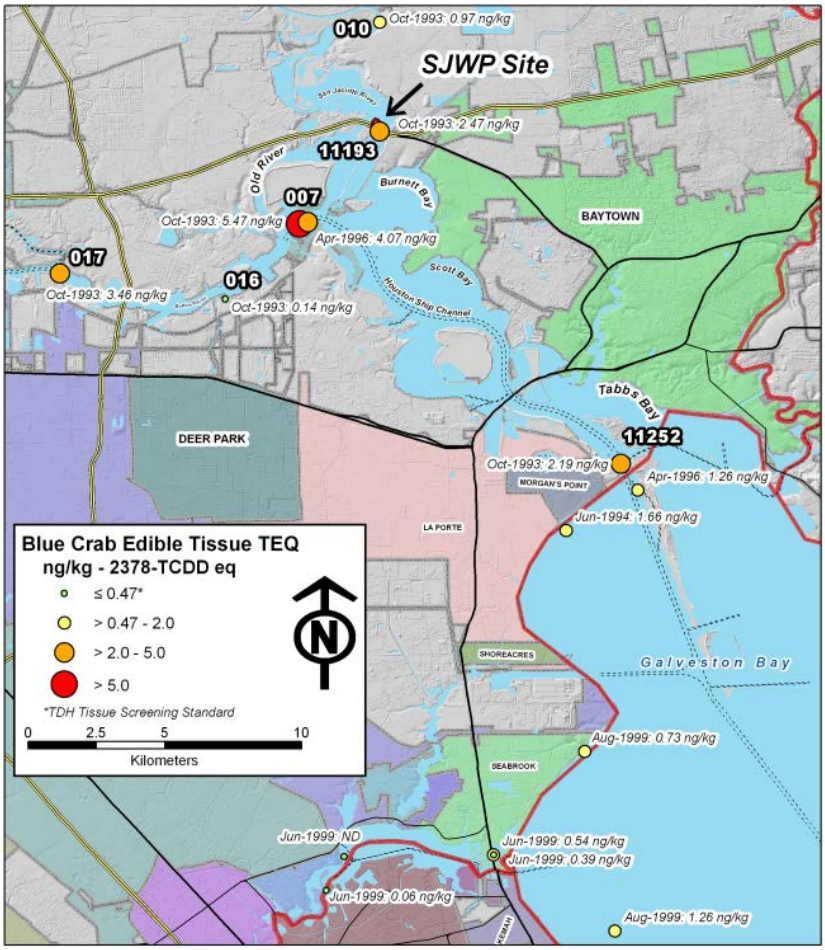


Figure 4-15: Blue Crab TEQ results from samples collected during the 1990s

Blue crab samples collected during 2002, 2003, and 2004 (shown in Figure 4-16, Figure 4-17, and Figure 4-18, respectively) reveal the highest concentrations in crabs collected from GBS waters upstream of Morgan's Point. While the concentrations decrease as sample locations progress downstream, even samples collected from Upper Galveston Bay indicate levels of dioxins in crab tissue that exceed health based standards.

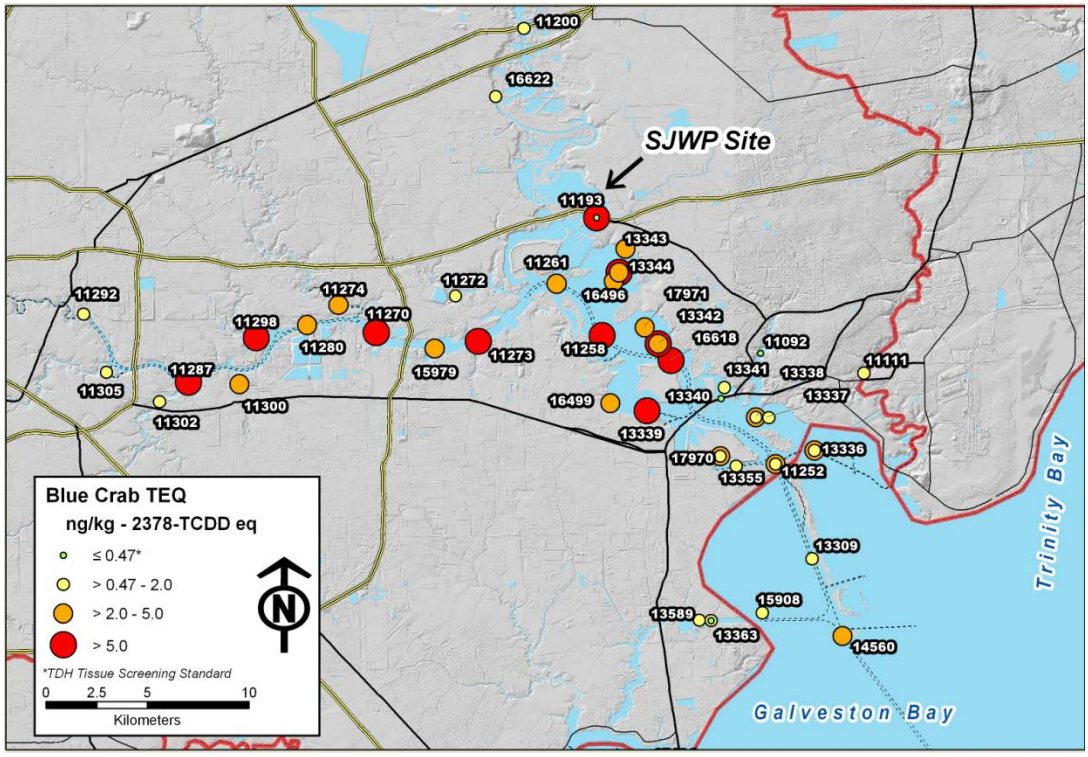


Figure 4-16: 2002 Blue Crab TEQ results

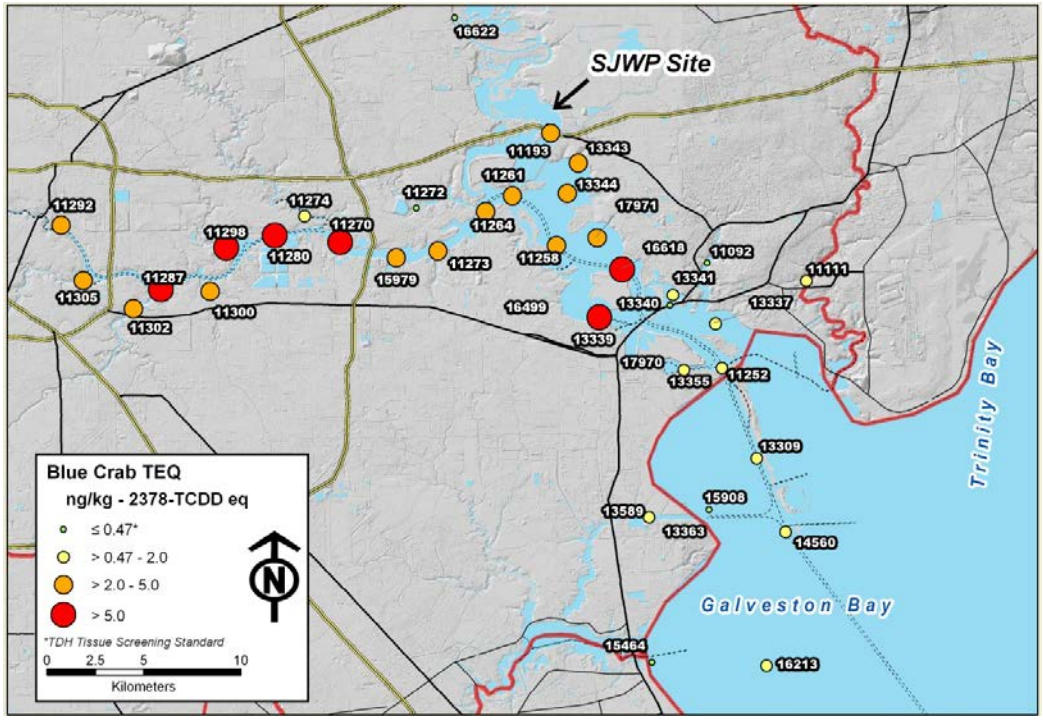


Figure 4-17: 2003 Blue Crab TEQ

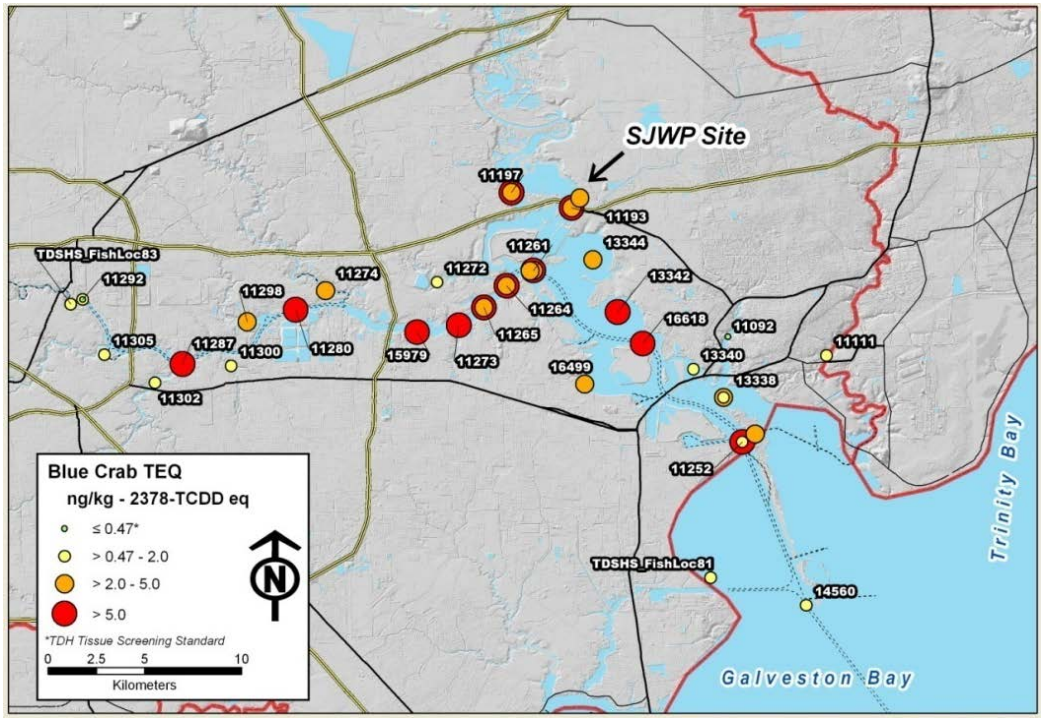


Figure 4-18: 2004 Blue Crab TEQ

In contrast, blue crab tissue collected from near shore areas in Galveston and Trinity Bays during 2006 revealed only very low dioxin concentrations in crab tissue; subsequently, the consumption advisory for crabs harvested from the waters south of Morgan's point has been lifted.

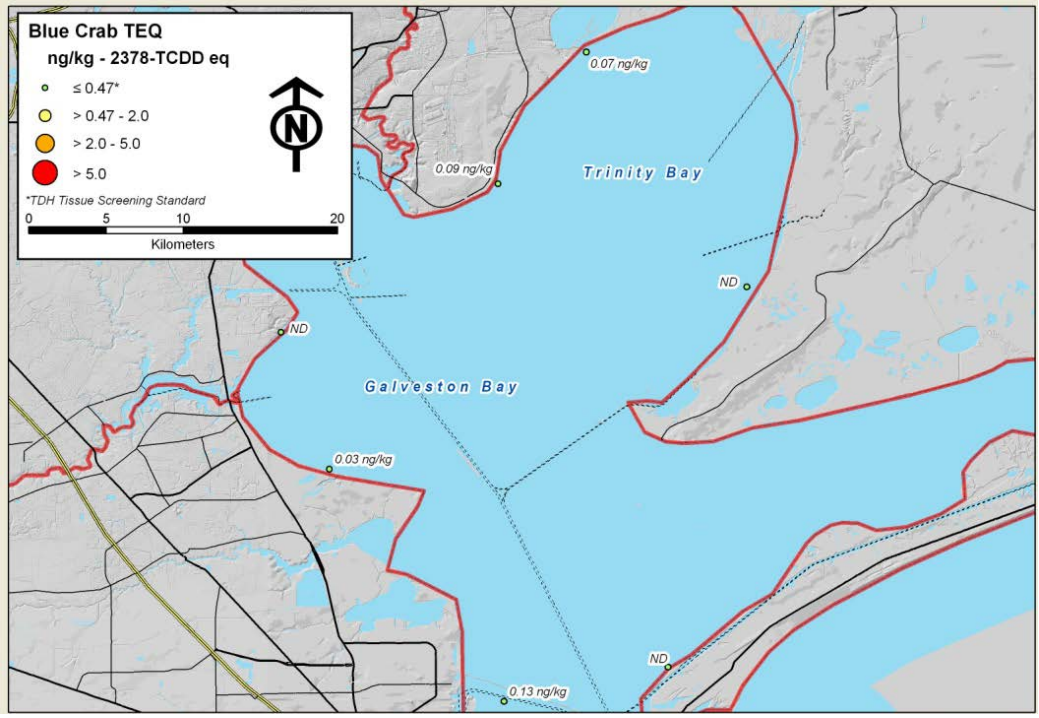


Figure 4-19: 2006 Blue Crab TEQ

4.3.3 Dioxin Contamination in HSC/GBS Fish Tissue

Figure 4-20 through Figure 4-25 present dioxin TEQ concentrations measured in tissues from catfishes, most often hardhead but sometimes gafftopsail, blue, and channel, and game fishes, typically speckled trout or Atlantic croaker, collected throughout the GBS. As in the crab TEQ figures, the smallest sample marker represents the TDH tissue screening level, 0.47 ng/kg. Nearly all samples collected throughout the bay are well above the health standard, often by an order of magnitude or more. Similar to other environmental matrices, the most heavily impacted tissues were observed near the waste pits and within the Buffalo Bayou portion of the HSC.

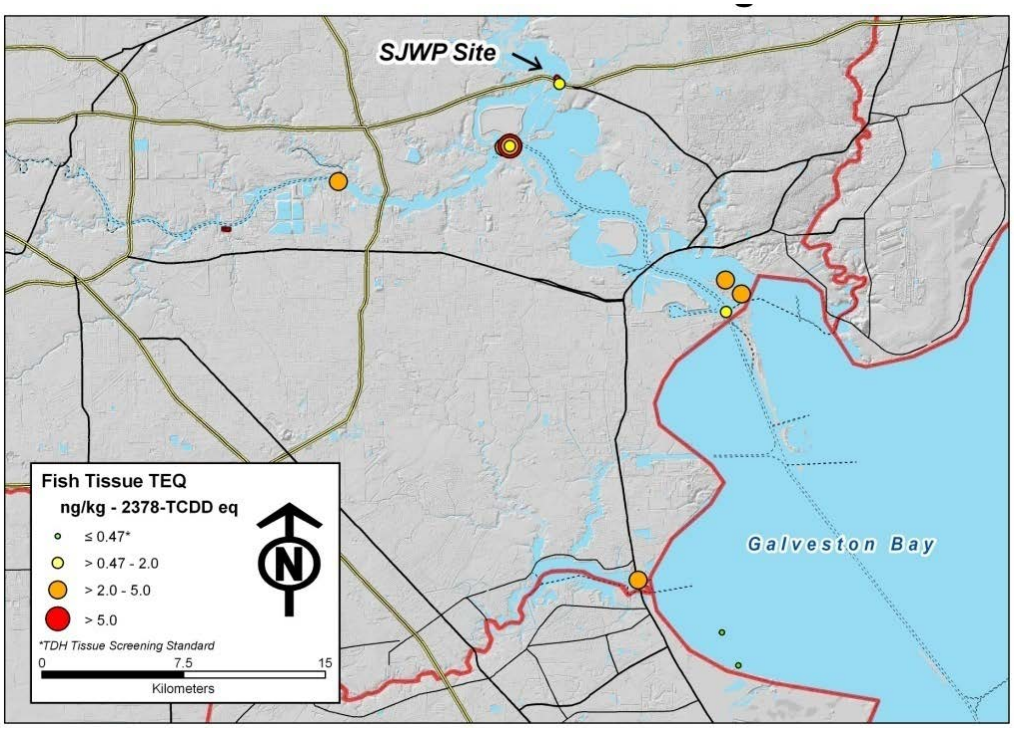


Figure 4-20: Fish Tissue TEQ: 1992 through 1999

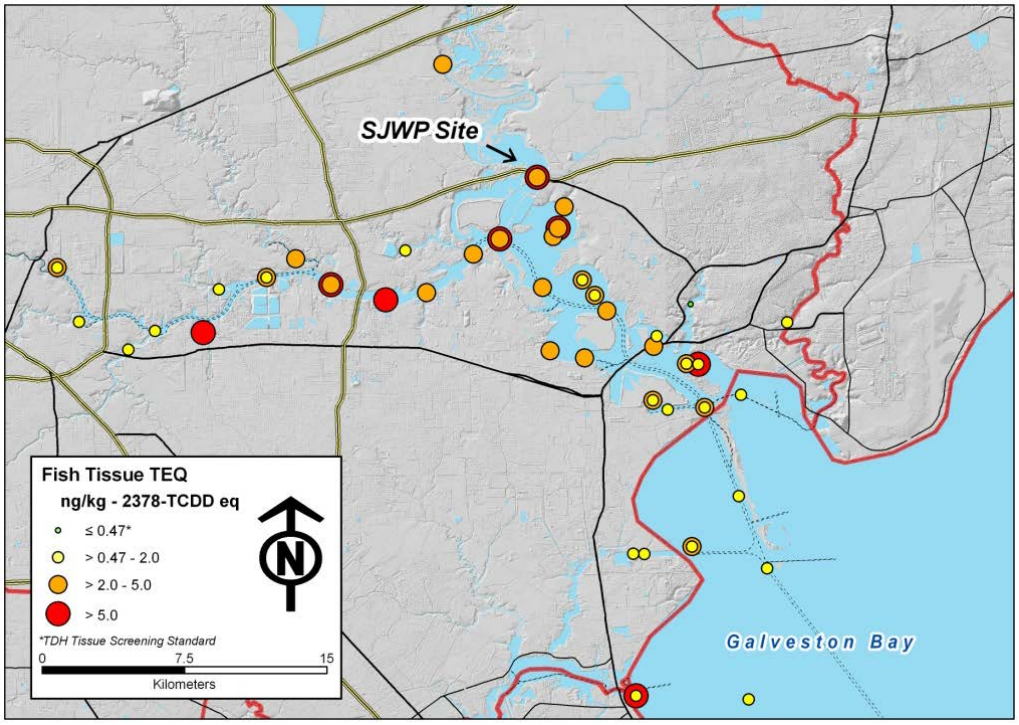


Figure 4-21: Fish Tissue TEQ: 2002

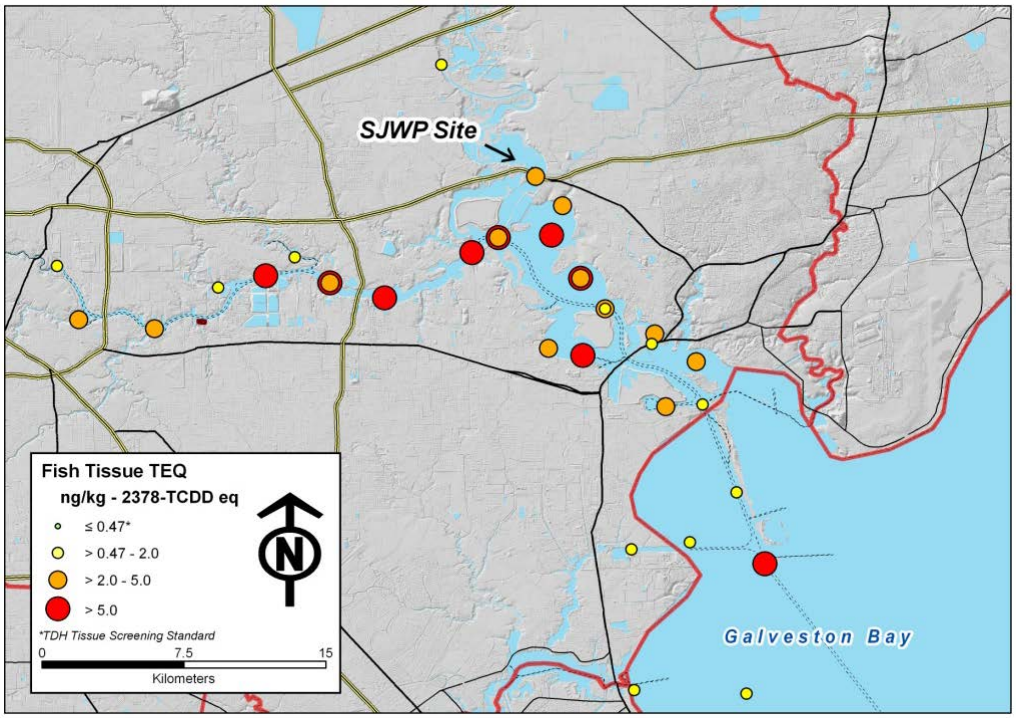


Figure 4-22: Fish Tissue TEQ: 2003

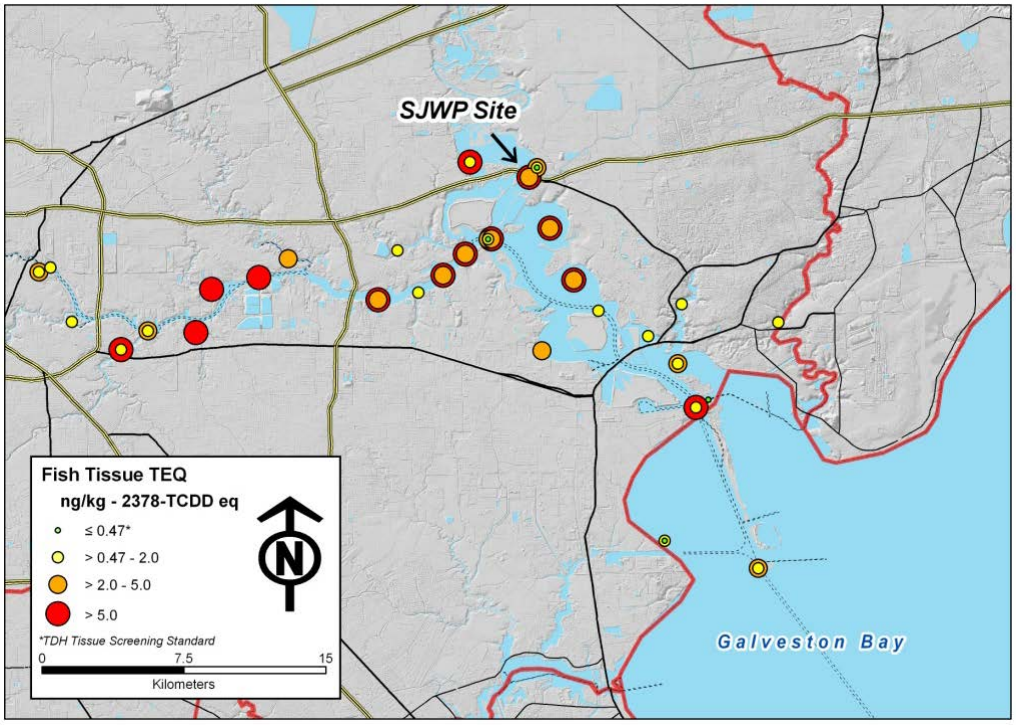


Figure 4-23: Fish Tissue TEQ: 2004

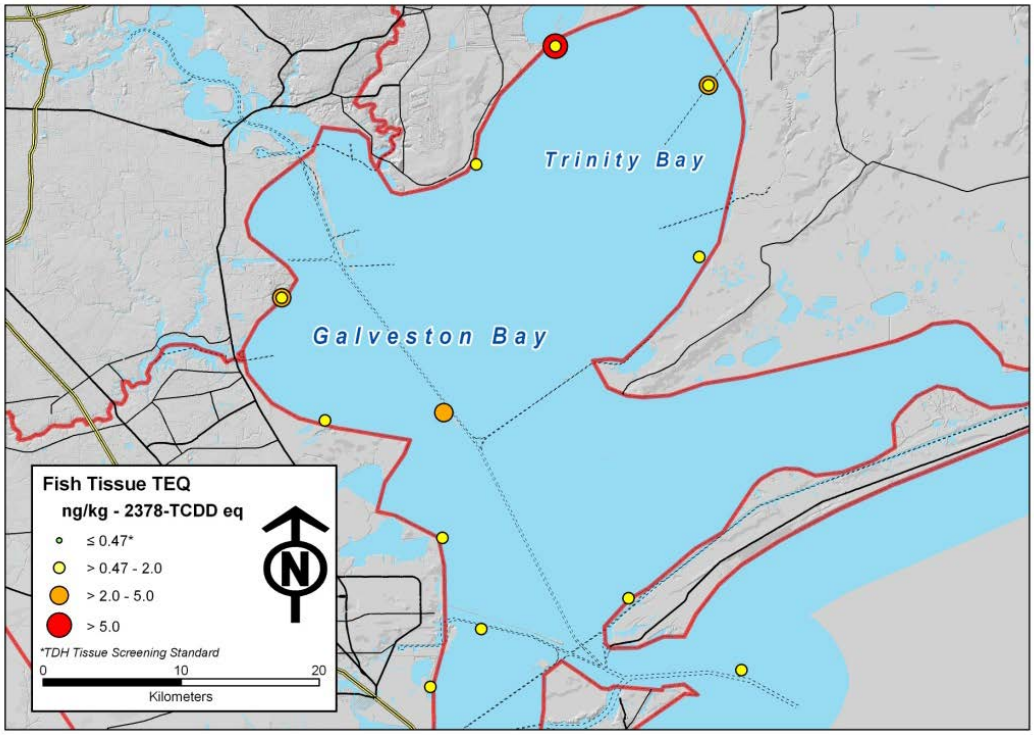


Figure 4-24: Fish Tissue TEQ: 2006 & 2007

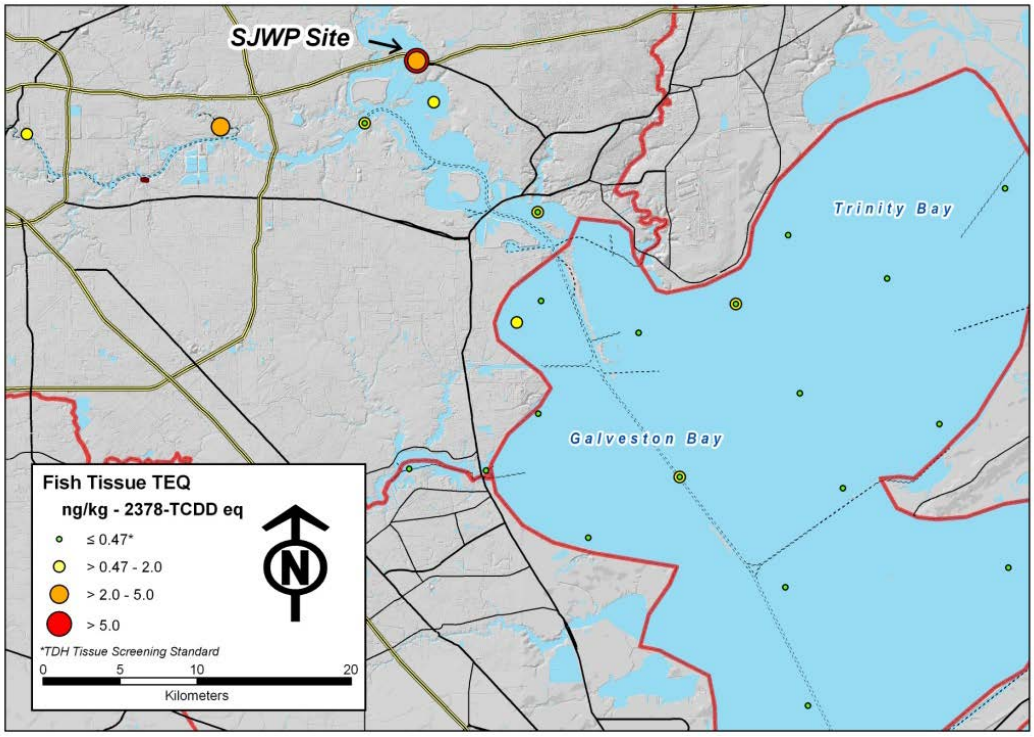


Figure 4-25: Fish Tissue TEQ: 2011

4.3.4 Dioxin Contamination in HSC/GBS Surface Waters

Figure 4-26 through Figure 4-29 show TEQ values for total recoverable dioxins measured in surface waters of the GBS during sampling events conducted in 2002, 2003, 2004, and 2011. Surface water samples are collected using a high volume sampling method due to the extremely low detection limits required to resolve the trace dioxin levels present in the water column. Approximately 500 to 700 L are pumped first through a 1 µm glass fiber filter (GFF), which collects all suspended sediments greater than 1 µm in diameter. The filtered water is then pumped through a recovery column filled with hydrophobic XAD-2 resin, to which the remaining dissolved dioxin mass preferentially sorbs. The XAD-2 resin also scavenges dioxin mass associated with dissolved organic carbon (DOC), for this reason the mass measured on the resin is often referred to as “operationally dissolved” as opposed to “truly dissolved.” The mass on each sampling media is extracted and quantified separately. The total recoverable dioxin TEQs presented here is simply the sum of concentration present in the sorbed and dissolved phase. Even though nearly all samples collected exceed the Texas TEQ water quality standard, 0.0933 pg/L; TEQ levels are significantly elevated in samples collected near the SJWP and the HSC.

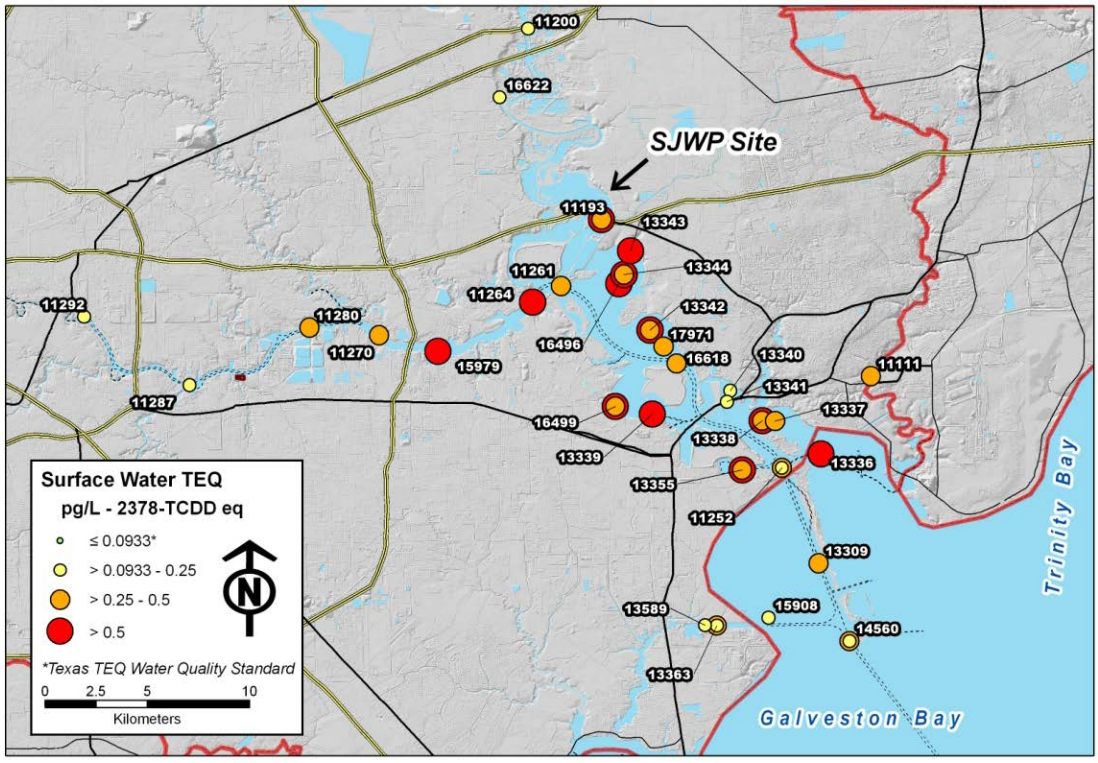


Figure 4-26: 2002 Surface Water TEQ

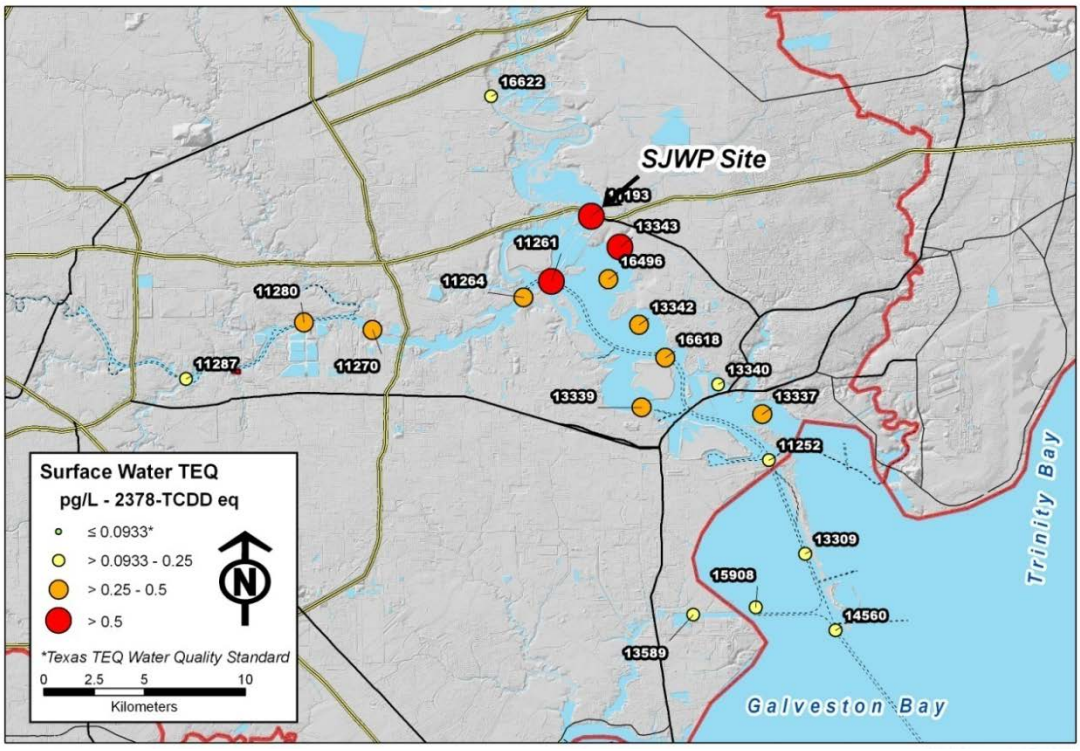


Figure 4-27: 2003 Surface Water TEQ

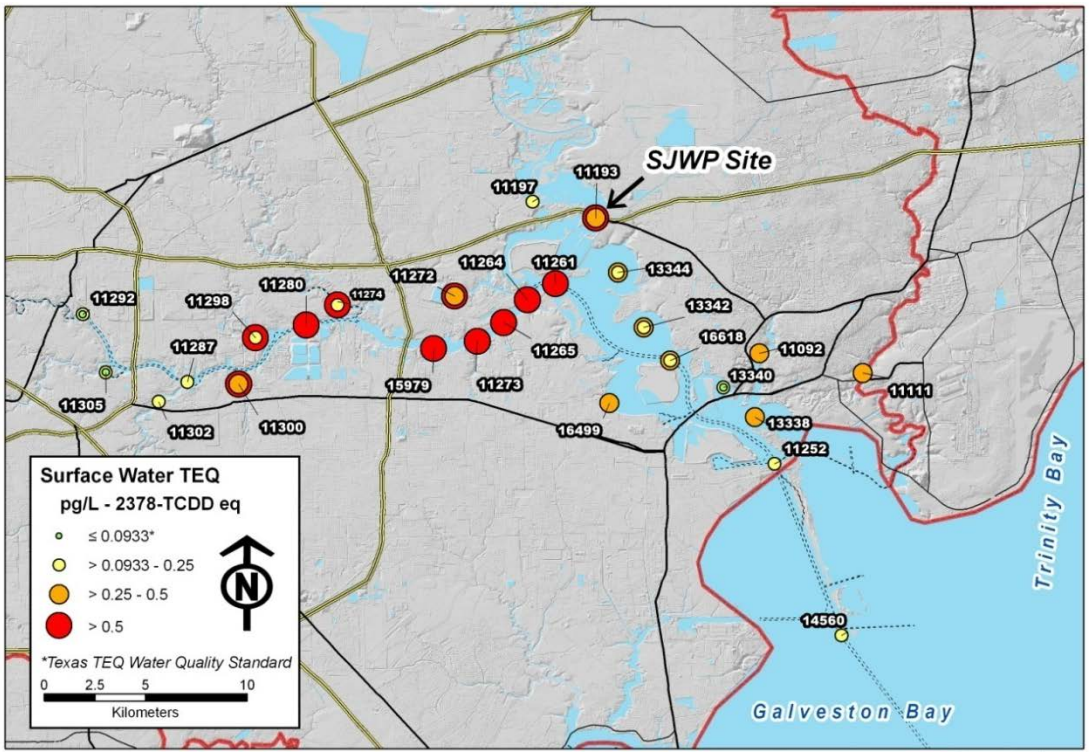


Figure 4-28: 2004 Surface Water TEQ

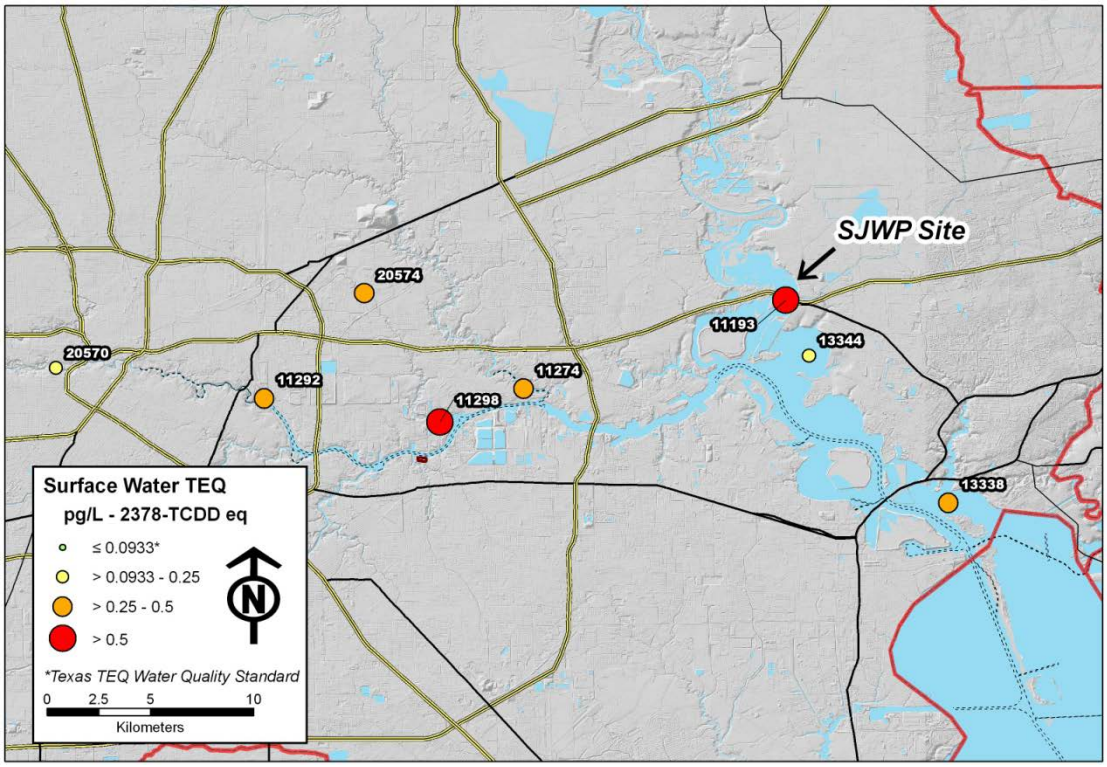
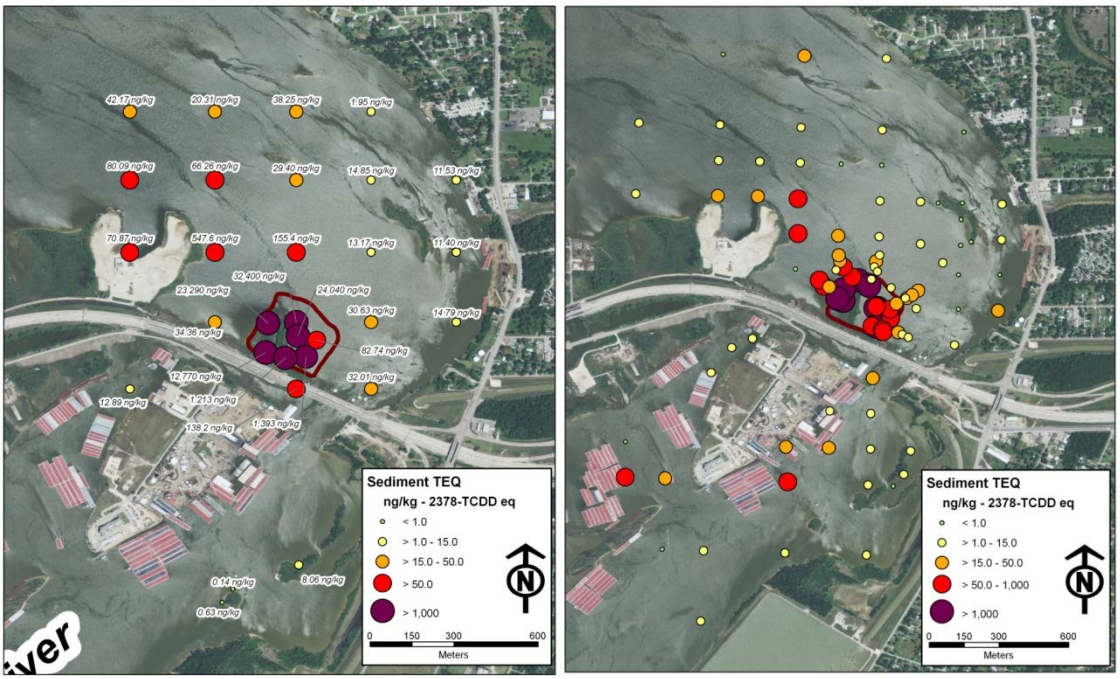


Figure 4-29: 2011 Surface Water TEQ

4.4 Dioxins in the San Jacinto Waste Pits

Following the TPWD's identification of the waste pits as a probable source of contamination into the estuarine ecosystem, intensive sampling events were conducted focused specifically on the SJWP site and the surrounding area. TEQ results from the 2005 and 2010 intensive sampling are presented in Figure 4-30. Not surprisingly, dioxin levels are orders of magnitude higher in samples collected from within the perimeter of the original waste pit berms. The highest concentration observed within the berm boundary was 32,400 ng/kg, while the highest concentration observed outside of the pits was 547.6 ng/kg, measured in a sample collected northwest of the waste pits. Interestingly, dioxin levels are higher upstream (northwest) rather than downstream of the site. This is most likely due to upstream transport during high tide, as tidal flow velocities would be slower than velocities due to a storm event, leading to more rapid and more concentrated deposition of wastes eroded from the pits. Additionally, sand mining in the immediate upstream vicinity of the site may have helped distribute impacted material from within and around the pits to a broader area upstream of the pits.

Sediment samples, collected in 2010 following SJWP's listing on the NPL, show similar results to those collected in 2005 (see Figure 4-30). TEQ concentrations are highest within the bounds of the waste pit berms and gradually decrease with increasing distance from the waste pits. Elevated dioxin levels in nearby areas outside of the original waste pit berms confirm that the SJWP have contributed considerable amounts of dioxins into SJR system.



a) 2005 b) 2010

Figure 4-30: Sediment TEQ near SJWP Site a) 2005 b) 2010

CHAPTER 5 – DATA ANALYSIS

5.1 Analysis of Historical Aerial Photographs

Historical aerial photographs of the SJWP and San Jacinto River serve as an important qualitative line of evidence helping to characterize the changes in the San Jacinto River and the site over time. Land subsidence due to groundwater pumping has significantly lowered ground surface elevations in the highly industrialized area near the site as mentioned previously causing many low lying areas, including portions of the waste pits, to be inundated by the San Jacinto River. Sand mining activities in the vicinity of the site have also played a significant role in altering the flow paths of the San Jacinto River around the waste pits. This section presents select aerial photographs that were chosen because they give the most insight into the historical interaction between the SJWP site and the San Jacinto River.

Figure 5-1, taken in 1953, is indicative of conditions prior to most industrial development in the area. As can be seen in the figure, the land mass where the SJWP site is located was continuous and connected to the northwest landmass. The SJR channel in the figure is well defined, and appears to be relatively narrower and deeper with clear water. All base aerial photographs were obtained from the Earth Resources Observations and Science Center courtesy of the U.S. Geological Survey (USGS 2010).

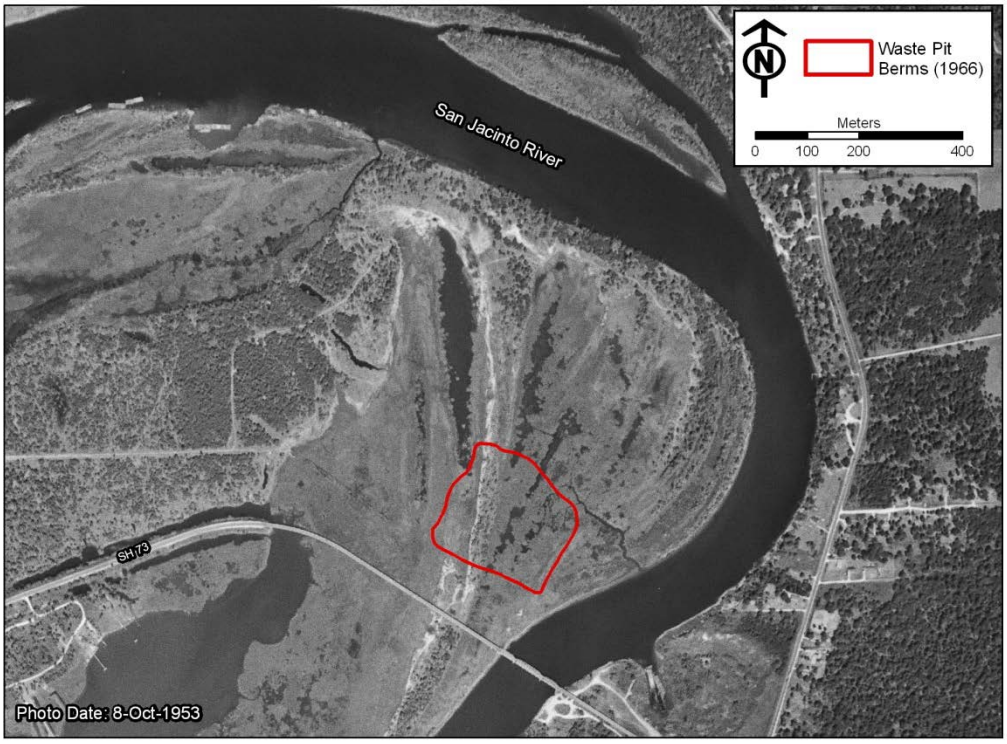


Figure 5-1: 1953 Aerial Photograph

As shown in Figure 5-2 and Figure 5-3, the waste pits were constructed and put into use sometime between 1962 and 1966. Note the apparent sand mining activities to the north and northwest of the site that have begun to erode the northwest landmass potentially leading to an avulsion or forking of the SJR into a dual flow channel. Also note the newly constructed IH-10 that is visible in the 1962 aerial; it is possible that sand mined from the areas near the site was used during the construction of the interstate. Additionally, a recently identified second pit is visible in Figure 5-3.

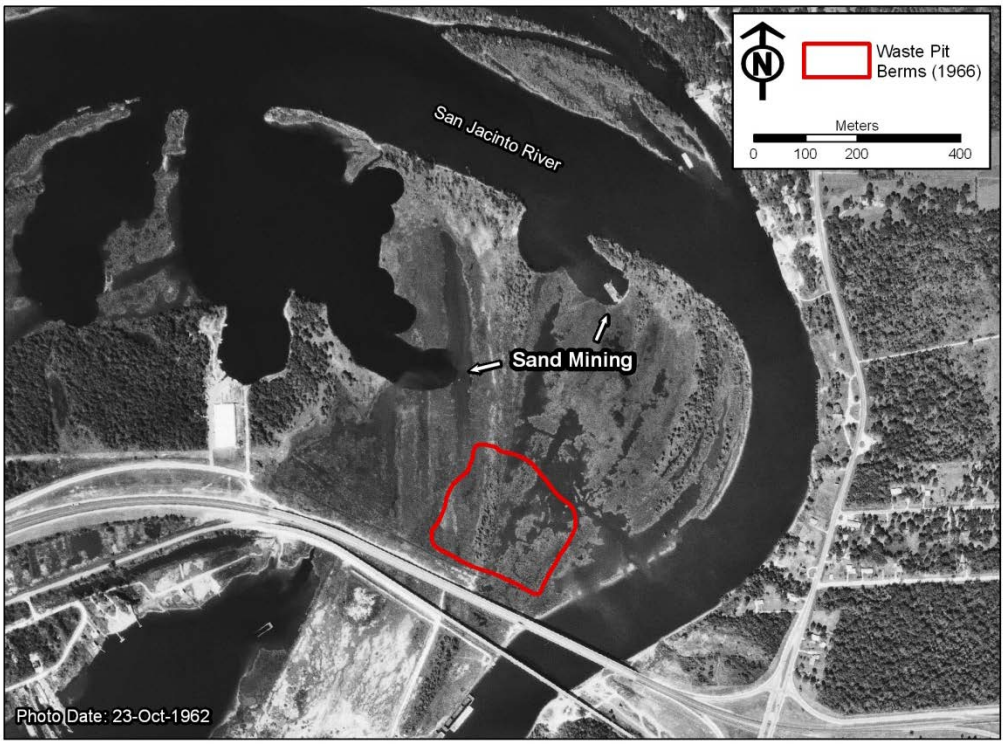


Figure 5-2: 1962 Aerial Photograph

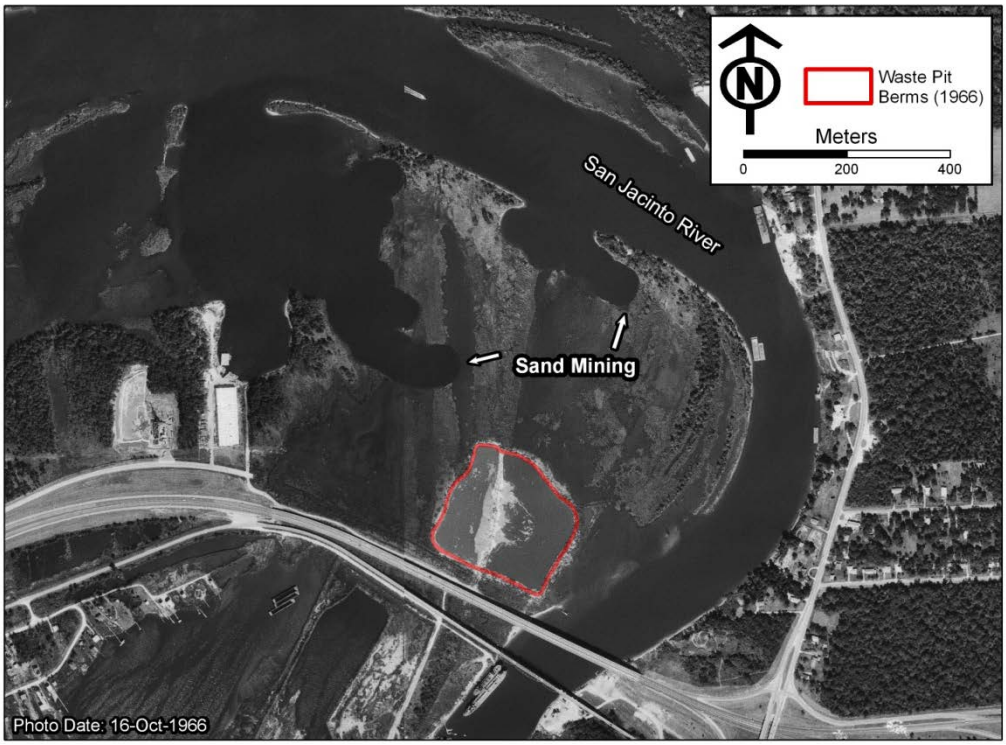


Figure 5-3: 1966 Aerial Photograph

By the 1970s, there is some periodic contact between the waste pits and waters from the San Jacinto River during high water events. Figure 5-4 (1976) shows a period of relatively low water, respectively. It appears that during high water, San Jacinto River waters enter the eastern pit, and by 1976, a small portion of the northeastern berm has been eroded, probably due to cyclical inundation and subsequent draining of the pits during high water events.

Figure 5-4: 1976 Aerial Photograph

Figure 5-5, taken during relatively low water in 1995, shows that the integrity of the northern berm has been compromised in at least two locations, and San Jacinto river water is clearly visible within the waste pits. A sub-channel appears to have developed on the northern edge of the site. It is likely that the sand mining operations, which cut into the San Jacinto River's banks to the northwest of the waste pits, provided a pathway allowing a portion of the river's flow to bypass the meander in the channel north of the SJWP. Conceptually, this sub-channel would have subjected the waste pit berms to increased flow velocities and accelerated the erosion and weakening of the berms.

Figure 5-5: 1995 Aerial Photograph

Between 1995 and 2002 (Figure 5-6), the percentage of the waste pits visible above water is drastically reduced.

Figure 5-6: 2002 Aerial Photograph

The entire northern berm appears to have been breached, along with most of the eastern berm. The sub-channel to the north of the site seems more defined, and the San Jacinto River is in constant contact with the dioxin contaminated wastes. Interestingly, the site conditions do not degrade as significantly between 2002 and 2010 (Figure 5-7). It is possible that Tropical Storm Allison, which inundated Houston in June 2001, caused a significant portion of the deterioration observed between 1995 and 2002.

Figure 5-7: 2010 Aerial Photograph

5.2 Estimating Mass Flux from SJWP into GBS prior to 1995

5.2.1 High Water Releases: 1965 through 1995

As discussed in Chapter 4, prior to loss of integrity of the waste pit berms, the primary mode of dioxin release from the pits into the SJR would have been during storm events from overtopping of the berms and rainfall directly on the pits. When water elevations were high enough to overtop the berms, a portion of the SJRs flow would have been directed through the pits, exposing the flow to the contaminated wastes within the berms. As shown in Section 4.1, it was estimated that water levels high enough to

overtop the containment berms occur between 2.3 and 7.7 days per year. To estimate the dioxin mass that would likely be mobilized by the SJR flood waters, a relationship was derived relating the sediment concentration observed in a sample to the total recoverable concentration measured in a concurrent water sample, such that,

$$C_w = rC_s, \tag{5.1}$$

where C_s is the dioxin concentration measured in the sediment, r is the coefficient derived relating the 2378-TCDD/F concentrations present in the sediment to concentrations observed in the water column, and C_w is the total concentration present in the water column. C_w is simply

$$C_w = C_d^m + C_p, \tag{5.2}$$

where, C_d^m is the operationally dissolved dioxin concentration and C_p is the dioxin concentration that is sorbed to suspended particulates in the water column, expressed by

$$C_p = \frac{mass\ dioxin\ sorbed\ to\ particls}{mass\ of\ particles} \cdot SSC, \tag{5.3}$$

where SSC is the suspended sediment concentration.

This relationship is not meant to describe an equilibrium partitioning relationship; it is simply a means to relate the sediment concentration present in the pits to what would be expected to be mobilized in some way during the relatively high flow events. It is simply a means by which to predict the dioxin mass which will likely enter the water column, regardless of phase, since C_w was found to be significantly correlated to C_s ($p < 0.05$). Values for r were estimated using results from station 11193, immediately downstream of the waste pits, and samples collected within the waste pit berms, as shown in Table 5-1. For this analysis, only 2378-TCDD and 2378-TCDF concentrations were used, since they are the primary components by mass and primary drivers of toxicity of the SJWP dioxin signature as explained is Section 5.3.

Table 5-1: Relationship between observed sediment concentrations and water concentrations

Sampling Station	Sampling Event	Dioxin Congener	C_s (ng/kg)	C_d (ng/L)	C_p (ng/L)	Total Water Column (ng/L)	C_s/C_w (L_{water}/kg_{sed})
11193	Summer 2002	2378-TCDD	6.90E+01	*2.75E-05*	2.86E-04	3.13E-04	2.20E+05
11193	Summer 2002	2378-TCDF	2.90E+02	2.42E-04	8.35E-04	1.08E-03	2.69E+05
11193	Fall 2002	2378-TCDD	4.40E+01	6.52E-05	1.84E-03	1.91E-03	2.31E+04
11193	Fall 2002	2378-TCDF	1.60E+02	2.83E-04	5.95E-03	6.23E-03	2.57E+04
11193	Summer 2003	2378-TCDD	9.40E+01	1.71E-04	1.99E-03	2.16E-03	4.35E+04
11193	Summer 2003	2378-TCDF	3.90E+02	5.83E-04	6.97E-03	7.55E-03	5.16E+04
11193	Spring 2004	2378-TCDD	6.10E+01	**1.35E-04**	**7.56E-04**	8.91E-04	6.85E+04
11193	Spring 2004	2378-TCDF	2.30E+02	**4.42E-04**	**2.21E-03**	2.65E-03	8.67E+04
11193	Summer 2004	2378-TCDD	**3.55E+01**	1.92E-04	1.42E-03	1.61E-03	2.21E+04
11193	Summer 2004	2378-TCDF	**1.58E+02**	7.08E-04	4.87E-03	5.58E-03	2.82E+04
11193	Fall 2004	2378-TCDD	**2.90E+01**	**2.62E-05**	**1.89E-04**	2.16E-04	1.34E+05
11193	Fall 2004	2378-TCDF	**1.10E+02**	**1.07E-04**	**5.54E-04**	6.61E-04	1.66E+05
11193	Summer 2011	2378-TCDD	4.50E+01	1.35E-04	6.03E-04	7.39E-04	6.09E+04
11193	Summer 2011	2378-TCDF	2.10E+02	4.54E-04	1.88E-03	2.33E-03	9.00E+04
Pit Samples							
SE-01/SW-01	Summer 2009	2378-TCDD	1.30E+03	NA	NA	7.50E-03	1.73E+05
SE-01/SW-01	Summer 2009	2378-TCDF	3.70E+03	NA	NA	3.00E-02	1.23E+05
SE-02/SW-02	Summer 2009	2378-TCDD	1.10E+03	NA	NA	7.00E-03	1.57E+05
SE-02/SW-02	Summer 2009	2378-TCDF	3.20E+03	NA	NA	2.70E-02	1.19E+05
SE-03/SW-03	Summer 2009	2378-TCDD	6.80E+02	NA	NA	1.90E-03	3.58E+05
SE-03/SW-03	Summer 2009	2378-TCDF	2.70E+03	NA	NA	9.10E-03	2.97E+05
						95th UCL of Mean	1.72E+05
						95th LCL of Mean	8.02E+04

Notes:

1) Concentrations shown in italics were not detected and are represented as one half of the sample detection limit

2) Bold concentrations represent the average concentration measured between 2 duplicate samples

The 95th upper and lower confidence limits (UCL and LCL, respectively) of the mean, were used to estimate upper and lower bound estimates of mass flux from the pits when inundated by storm water. The UCL and LCL for the sediment concentration were calculated using surface and near surface samples of sediment and soil collected within the original boundaries of the waste pit berms. The contaminated depth of flow was assumed to be between 0.5 and 1.0 m, and the projected pit cross sectional length perpendicular the flow is estimated to be 250 m. The flow velocity was estimated based on results from an EFDC model developed by Anchor QEA for USEPA during the design of the Time Critical Removal Action (TCRA) implemented at the SJWP in conjunction with superfund activities at the site (Anchor 2010). The flux calculations are presented in Table 5-2, below.

Table 5-2: Estimation of Dioxin Flux from SJWP Due to Berm Overtopping

	2378-TCDD Mass Flux		2378-TCDF Mass Flux	
	Lower Estimate	**Upper Estimate**	**Lower Estimate**	**Upper Estimate**
Concentrations in Pit Sed (ng/kg)	3.05E+03	6.47E+03	8.62E+03	2.07E+04
C_{sed}/C_{water}	1.72E+05	8.02E+04	1.72E+05	8.02E+04
Cwater during storm (ng/L)	1.78E-02	8.07E-02	5.03E-02	2.59E-01
Impacted Flow Depth (m)	0.5	1.0	0.5	1.0
Water Velocity (m/s)	0.5	1.5	0.5	1.5
Contaminated Flow (m^3/sec)	6.25E+01	3.75E+02	6.25E+01	3.75E+02
Mass Flux from SJWP (ng/sec)	1.11E+03	3.02E+04	3.14E+03	9.70E+04
Mass Flux from SJWP (g/day)	9.61E-02	2.61E+00	2.71E-01	8.38E+00
Days/yr Inundation	2.3	7.7	2.3	7.7
Flux/yr From 1965 through 1995 (g/yr)	0.221	20.1	0.624	64.5

Lower Estimate TEQ Flux (g/yr)	**0.28**
Upper Estimate TEQ Flux (g/yr)	**26.6**

Notes:
1) Pit sediment concentrations based 95th UCL & LCL of the mean based on pit samples
2) Flow based on cross sectional length of 250 m

It is estimated that between 0.28 and 26.6 g TEQ per year were released between the years of 1965 and 1995, prior to complete loss of berm containment. Water quality monitoring conducted for the TCEQ in conjunction with TMDL activities concluded that the HSC/GBS could assimilate approximately 1.49 g TEQ/year without

applicable water quality standards. The calculations performed here indicate that even if the SJWP were the only source of dioxins to the GBS, dioxins would most likely be present in the system at levels above health based standards. This calculation does not, however, indicate where the dioxin would be found since it does not take into account the hydrodynamics or the fate and transport aspects of dioxin in the estuary. The distribution of dioxin emanating from the SJWP into the GBS will be addressed in subsequent sections of the thesis using additional calculations and modeling with EFDC.

5.2.2 Sediment Accumulation Rates in GBS

Sediment cores were collected in 2005 from sampling locations throughout the GBS. The cores were used to piece together the historical sediment depositional, as well as dioxin flux patterns in the bay (Yeager, Santschi et al., 2007). Figure 5-8, presents the sediment deposition rates calculated by the authors, which have been converted from mass rates per cm^2 per year to depth deposited per year, assuming a uniform sediment bulk density of 1.7 g/cm^3.

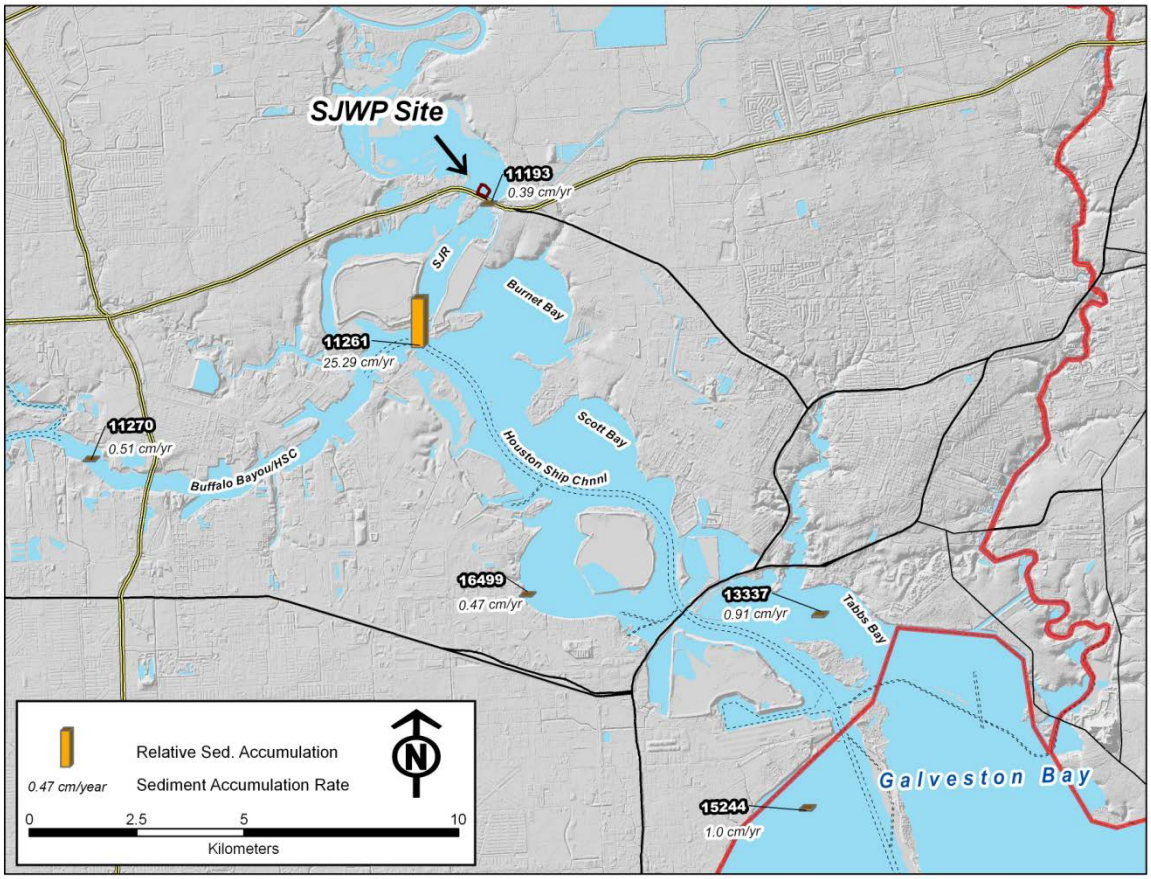


Figure 5-8: Sediment Deposition Rates (interpreted from Yeager et al., 2007)

Sediment deposition at sampling station 11261, located at the confluence of the SJR and HSC, is much higher than at any other location sampled. There are likely several factors which contribute to the rapid deposition of sediments being carried by the SJR and HSC: 1) channel widening & deepening, with respect to SJR, likely causes a decrease in flow velocities relative to those found in the SJR 2) flow velocities from the HSC & SJR are often orthogonal which would serve to enhance mixing and flocculation of fine grained sediments and 3) the increase in salinity at the confluence relative to the SJR also aids in flocculation of fine grained sediments.

As would be expected, historical dioxin fluxes at station 11261 were also higher than at other locations throughout the bay (see Table 5-3). Dioxin flux at most stations within the HSC range between 66.8 ng/m^2/yr and 133.8 ng/m^2/yr, but flux at station 11261 is much higher at 1465 ng/m^2/yr. These results imply that most of the sediment dioxin load originating from the HSC and SJR upstream of their confluence is deposited at or near the HSC/SJR confluence.

Table 5-3: Sediment and Dioxin Fluxes at Coring Locations (modified from Yeager et al., 2007)

LocationID	2378-TCDD Flux (ng/m^2/yr)	2378-TCDF Flux (ng/m^2/yr)	TEQ Flux (ng/m2/yr)	Sed Mass Accumulation (g/cm2/yr)	Sed Depth Accumulation (cm/yr)
11261	1160	3050	1465	43	25.3
15244	53.8	130	66.8	1.63	1.0
11193	107	268	133.8	0.67	0.4
11270	13.8	33.5	17.15	0.86	0.5
FW1	0.504	2.52	0.756	0.21	0.1
16499	73.6	192	92.8	0.8	0.5
13337	71.3	217	93	1.55	0.9

Notes:
1) TEQ is based on 2378-TCDD and 2378-TCDF concentrations only.

Dioxin concentrations with depth from were used to construct a dioxin deposition timeline at each coring location. As seen in Figure 5-9, taken from Fig 3 in (Yeager, Santschi et al., 2007), dioxin deposition seems to have varied over time, but several of the coring locations seem to show increasing dioxin flux in recent years, possibly due to the increased dioxin flux from the SJWP site.

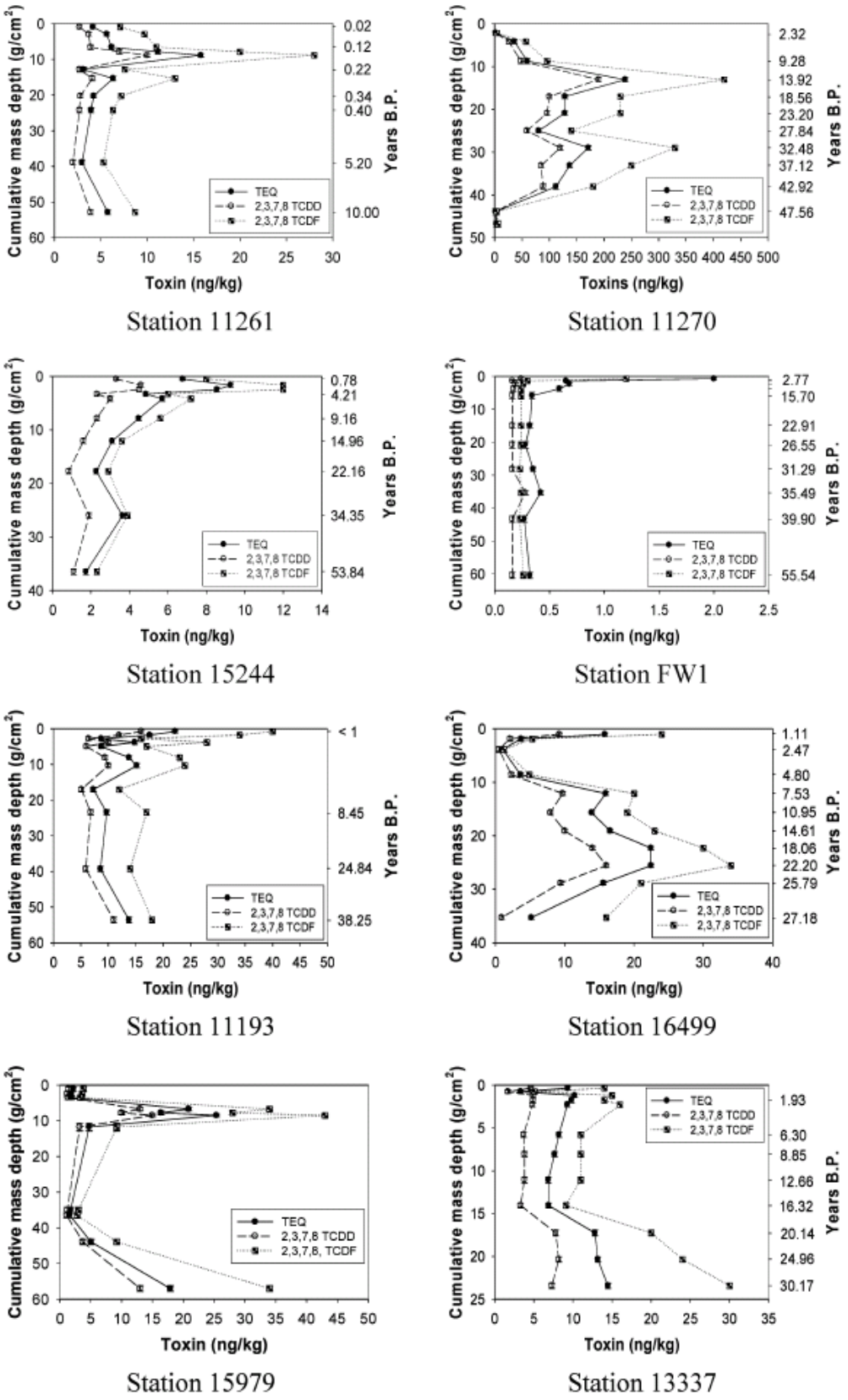


Figure 5-9: Dioxin TEQ history based on 2005 Corings. Taken from Yeager et al., 2007.

5.2.3 Examining 2378-TCDD/F Partitioning near the SJWP site

Organic carbon portioning coefficients, for dissolved (K_{poc}) and sorbed (K_{doc}) organic carbon can be estimated via a three phase partitioning model where the bulk water concentration C_w (Equation 5.2) is modeled by (Howell 2012)

$$C_w = C_d + C_d K_{doc} DOC + C_d K_{poc} f_{oc} TSS, \quad (5.4)$$

where, C_d is the truly dissolved dioxin concentration, DOC is the dissolved organic carbon concentrations, K_{doc} is the partitioning coefficient between truly dissolved dioxins and dioxins associated with dissolved organic carbon, K_{poc} is the partitioning coefficient between dissolved dioxins and dioxins sorbed to particulate organic carbon, and f_{oc} is the fraction organic carbon of the suspended sediment. The truly dissolved dioxin is related to the measured operationally dissolved concentration by

$$C_d^m = C_d + C_d K_{doc} DOC. \quad (5.5).$$

Thus, the dioxin concentration sorbed to suspended sediments, C_s, is modeled by

$$C_s = C_d K_{poc} f_{oc} TSS. \quad (5.6).$$

In a two phase model, no distinction is made between operationally and truly dissolved concentrations, so partitioning is modeled by

$$C_w = C_d^m + C_d^m K_{poc} f_{oc} TSS. \quad (5.7).$$

A two-phase model was used to calculate partitioning coefficients for 2378-TCDD (Table 5-4) and 2378-TCDF (Table 5-5). The mean calculated K_{poc} value for 2378-TCDD is 6.72 and for 2378-TCDF is 6.77.

Table 5-4: 2378-TCDD K_{poc} Calculation – Station 11193

Sample Date	DOC (mg/L)	TOC (mg/L)	POC (mg/L)	TSS (mg/L) (mg/L)	f_{oc}	2378-TCDD-Susp (ng/L)	2378-TCDD-Susp (ng/kg-dry)	2378-TCDD-Diss (ng/L)	log K_{oc} TCDD
08/07/2002	28.6	28.9	0.3	23.2	1.29%	2.86E-04	12.32	*ND*	NA
11/20/2002	23.3	25.4	2.1	25.0	8.40%	1.84E-03	73.65	6.52E-05	7.13
06/04/2003	22.1	25.1	3.0	23.0	13.0%	6.97E-03	303.05	5.83E-04	6.60
03/23/2004	20.85	22.6	1.75	19.5	8.97%	7.56E-04	38.79	1.35E-04	6.51
08/03/2004	29.2	30.95	1.75	19.0	9.21%	1.42E-03	74.52	1.92E-04	6.63
11/03/2004	7.365	7.455	0.09	7.4	1.22%	1.84E-04	24.92	*ND*	NA
08/18/2011	6.35	7.21	0.86	24.7	3.48%	6.03E-04	24.43	1.35E-04	6.72

1) DOC = Dissolved organic carbon, TOC = Total organic carbon, TSS = Suspended Sed Concentration
POC = Particulate organic carbon, calculated TOC - DOC

Table 5-5: 2378-TCDF K_{poc} Calculation – Station 11193

Sample Date	DOC (mg/L)	TOC (mg/L)	POC (mg/L)	TSS (mg/L) (mg/L)	f_{oc}	2378-TCDF-Susp (ng/L)	2378-TCDF-Susp (ng/kg-dry)	2378-TCDF-Diss (ng/L)	log Koc TCDF
08/07/2002	28.6	28.9	0.3	23.2	1.29%	8.35E-04	33.81	*2.42E-04*	7.03
11/20/2002	23.3	25.4	2.1	25.0	8.40%	5.95E-03	240.85	2.83E-04	7.01
06/04/2003	22.1	25.1	3.0	23.0	13.0%	6.97E-03	282.19	5.83E-04	6.57
03/23/2004	20.85	22.6	1.75	19.5	8.97%	2.21E-03	89.56	4.42E-04	6.35
08/03/2004	29.2	30.95	1.75	19.0	9.21%	4.87E-03	197.05	7.08E-04	6.48
11/03/2004	7.365	7.455	0.09	7.4	1.22%	5.54E-04	22.44	*1.07E-04*	7.24
08/18/2011	6.35	7.21	0.86	24.7	3.48%	1.88E-03	76.06	4.54E-04	6.68

1) DOC = Dissolved organic carbon, TOC = Total organic carbon, TSS = Suspended Sed Concentration
POC = Particulate organic carbon, calculated TOC - DOC

An expected range of theoretical values were calculated based on log K_{ow} values for 2378-TCDD and 2378-TCDF (6.49 and 6.46, respectively) using methodology presented in (Seth, Mackay et al., 1999). The 95% upper and lower confidence limits for expected 2378-TCDD values are 5.61 and 6.60, respectively. Likewise, for 2378-TCDF the expected log K_{poc} ranges from 5.59 to 6.57. The calculated mean Kpoc values for both compounds in Tables 5-4 and 5-5 are higher than the expected 95% confidence levels. This suggests that equilibrium has not been reached, and that suspended sediment in the water column is contributing dioxin mass to the dissolved phase via desorption. This provides further evidence that the dioxins in the suspended sediments

at station 11193 were recently suspended from the SJWP area and, when deposited, will continue to release dissolved concentrations into the HSC/GBS. Since a three phase model would further increase K_{poc} values, the two phase partitioning model was sufficient in supporting this conclusion.

5.3 Dioxins in the HSC and Qualitative Fingerprinting Analysis

Results from historical sediment sampling events were analyzed to establish a link between source zone wastes and dioxin concentrations within the GBS. Data from numerous sampling events conducted throughout the GBS have been compiled by others within a geodatabase that is publically accessible through the SJWP site website, as mentioned in Section 4.2. The data in the geodatabase (accessed on January 4, 2012) was combined with data generated during the sampling conducted for the TCEQ by the University of Houston (U of H) during the summer of 2011 to serve as the base dataset for analyses in this research.

5.3.1 Source Zone Characterization

Qualitative comparisons of dioxin sources can be made by evaluating the relative contribution each congener makes to the overall dioxin TEQ concentration in a sample. Concentrations and distributions of the individual dioxin congeners present in typical paper mill wastes vary depending on a number of factors related to conditions present during the manufacturing process; however, elevated levels of specific congeners, particularly 2378-TCDF and 2378-TCDD, can be used as markers of paper mill impacts(Ehrlich, Wenning et al., 1994). Figure 5-10 depicts the congener distribution observed in waste sludges sampled in EPA's 104 Mill Study (Whittemore, LaFleur et al., 1990; USEPA 2006). The congeners OCDD and 2378-TCDF make up more than 80% of the total dioxins present, 2378-TCDD and trace levels of penta-chlorinated furans and hepta-chlorinated dioxins and furans make up most of the remainder.

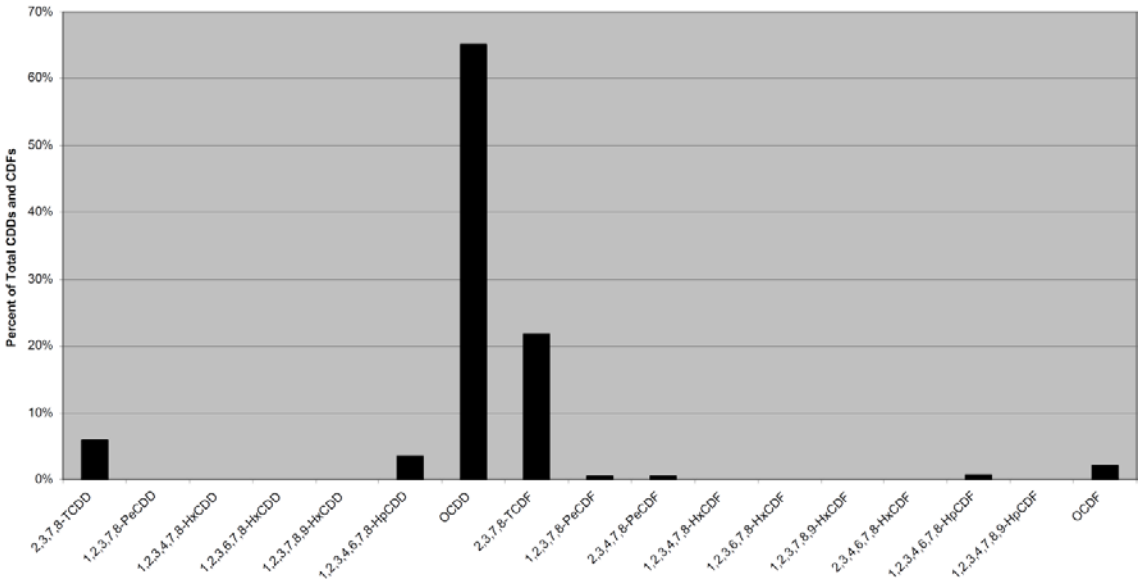


Figure 5-10: Distribution of Dioxin Congeners Present in Paper Mill Waste Sludges taken from USEPA 2006

The SJWP source zone, defined as the area within the historical waste pit berms, has been well characterized during the NPL site investigation process. Roughly 69 surface and core sediment samples have been collected within the boundaries of the waste pit berms. Not surprisingly, source zone sediment samples exhibit high levels of 2378-TCDF and 2378-TCDD, see Figure 5-11. Similarly, the homologue mass (Figure 5-12: Median Homologue Distribution of Source Zone Samples is predominantly TCDF, with TCDF and TCDD making approximately 70% of the total dioxin mass in source zone samples. In comparison, sediments from other parts of the Galveston Bay System are dominated by OCDD, as shown in Figure 5-13 and Figure 5-14.

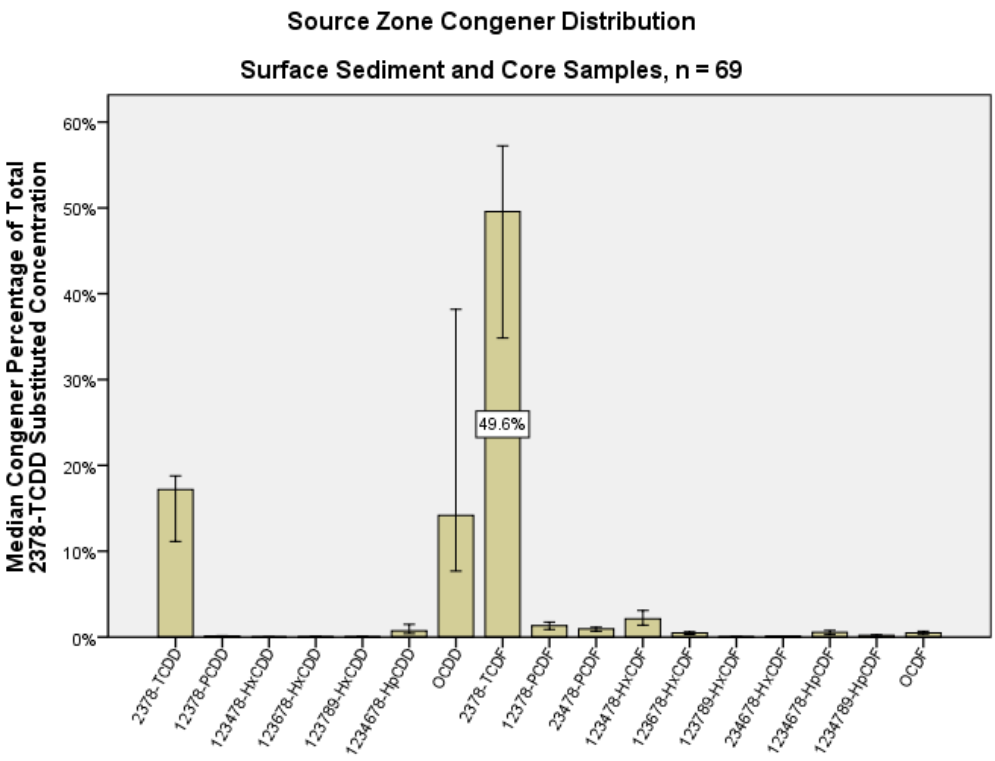


Figure 5-11: Median Congener Distribution of Source Zone Samples

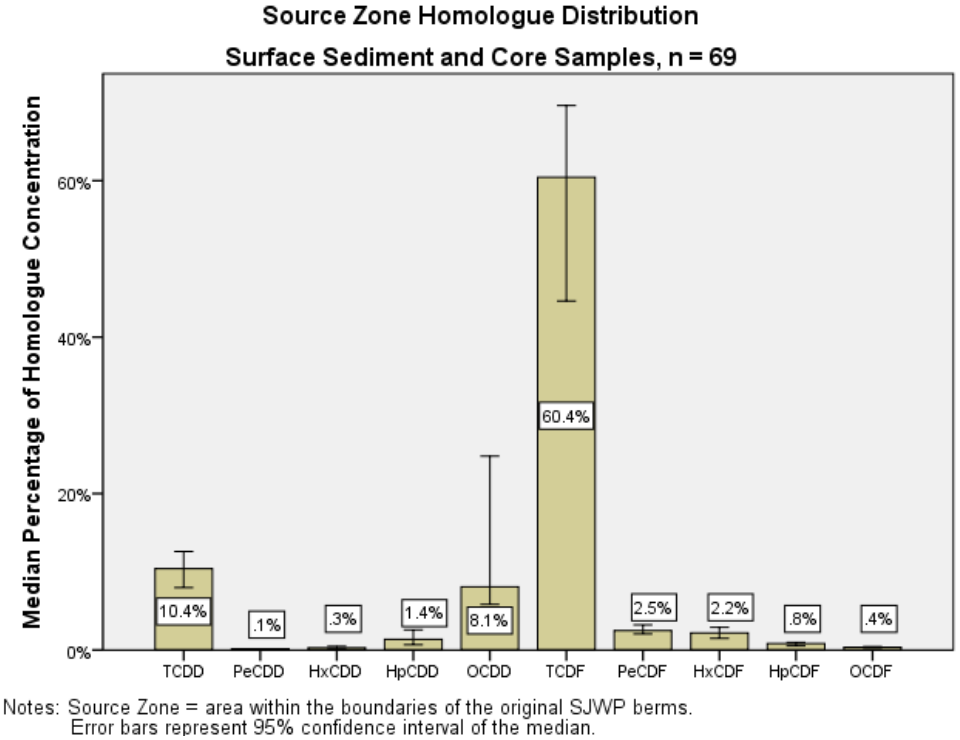


Figure 5-12: Median Homologue Distribution of Source Zone Samples

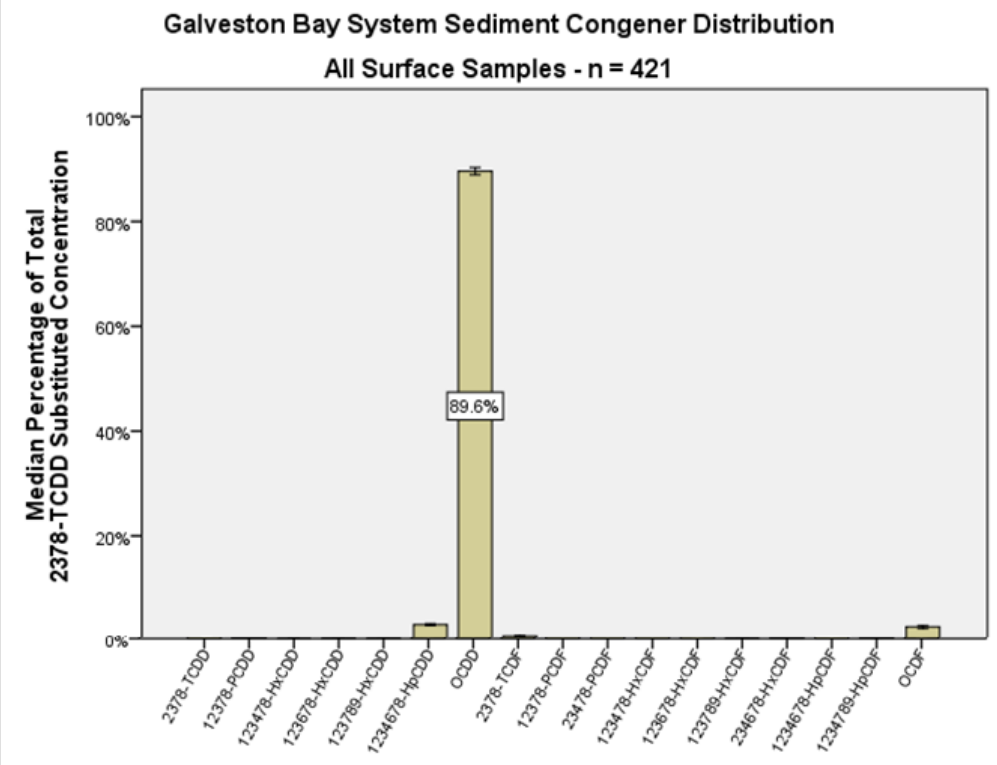


Figure 5-13: Median Congener Distribution of Galveston Bay System Sediments

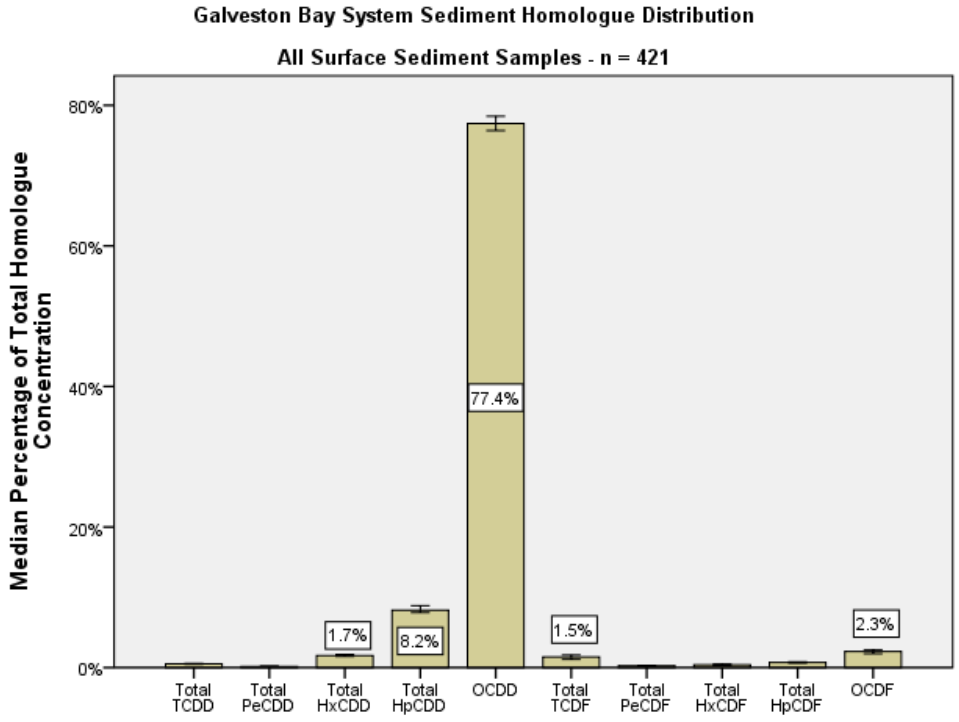


Figure 5-14: Median Homologue Distribution of Galveston Bay System Sediments

Dioxin homologue profiles from samples collected at Station 11193 in 1994 exhibit slightly higher proportions of TCDF and TCDD congener groups, markers for paper mill dioxin wastes and SJWP wastes, than samples collected further downstream, but higher chlorinated homologues still dominate the dioxin concentration present in the sample (see Figure 5-15). In the sample collected during August 2002, TCDF's and TCDD's contribution to total dioxin concentration have increased to approximately 30% and 4.4%, respectively. The sediment sample collected near the SJR's confluence with the Houston Ship Channel also shows a slight, although less marked, increase in TCDF's contribution to dioxin concentration (see Figure 5-16). The increase in TCDF and TCDD homologue concentrations between the mid 1990s and 2002 provide further evidence that the SJWP site released dioxins at a higher rate following full breach of the waste pit berms, which, according to aerial photography, occurred sometime between 1995 and 2002, as discussed in Section 5.1 Analysis of Historical Aerial Photographs.

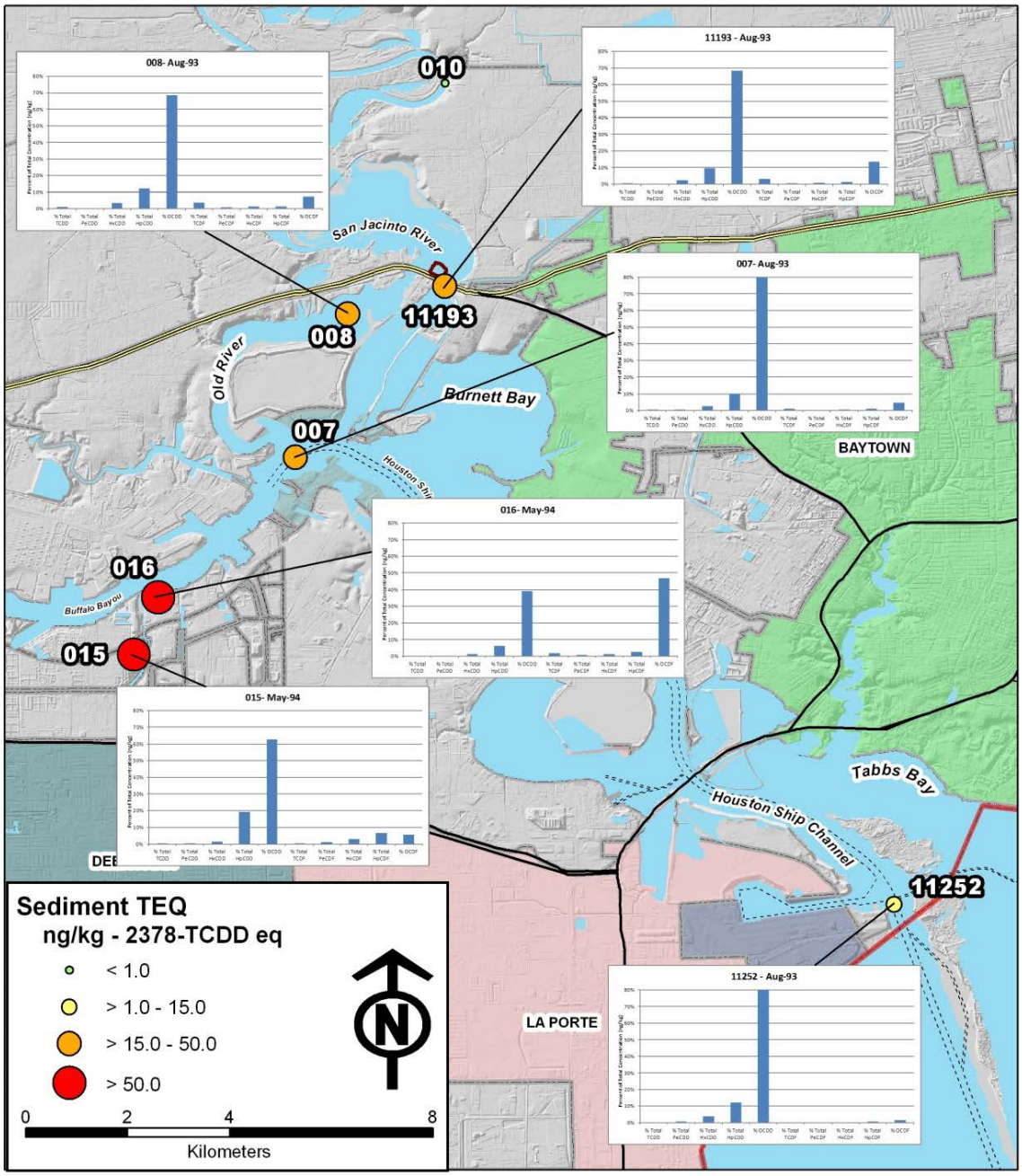


Figure 5-15: Sediment Sample Homologue Distribution 1993 & 1994

Note the similarities in profile among stations 11193, 007, and 008 and how they differ from the other samples, particularly 016 and 11252.

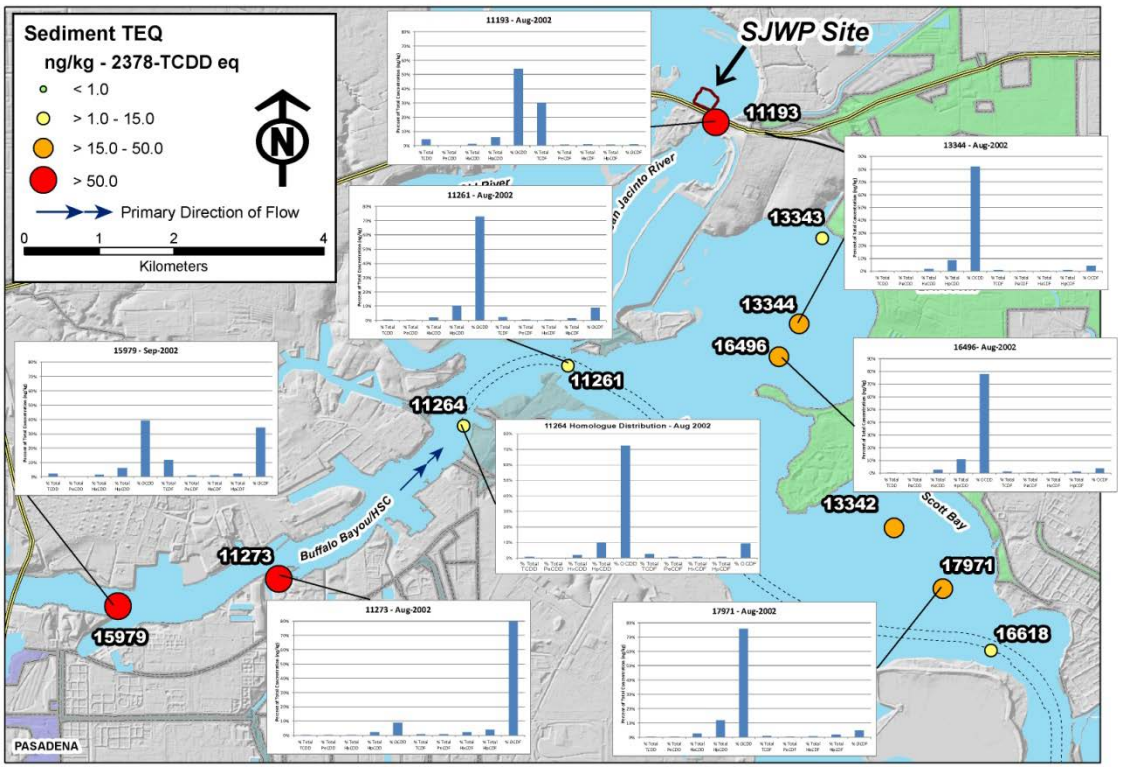


Figure 5-16: Sediment Sample Homologue Distribution 2002

The samples collected during the 2003 and 2004 sampling, shown in Figure 5-17 and Figure 5-18, respectively, show similar distributions. The pit's influence is evident in the elevated TEQ and in the increased proportions of TCDF and TCDD. During 2004, samples were collected immediately upstream of the SJWP site and the elevated TCDF/TCDD signature is not readily apparent; however, the samples did exhibit elevated TEQ probably due to contributions of TCDF and TCDD from the waste in the pits. Since 2378-TCDF and 2378-TCDD are among the most toxic dioxin congeners, even small amounts have the potential to significantly raise the toxicity of sediments within the system.

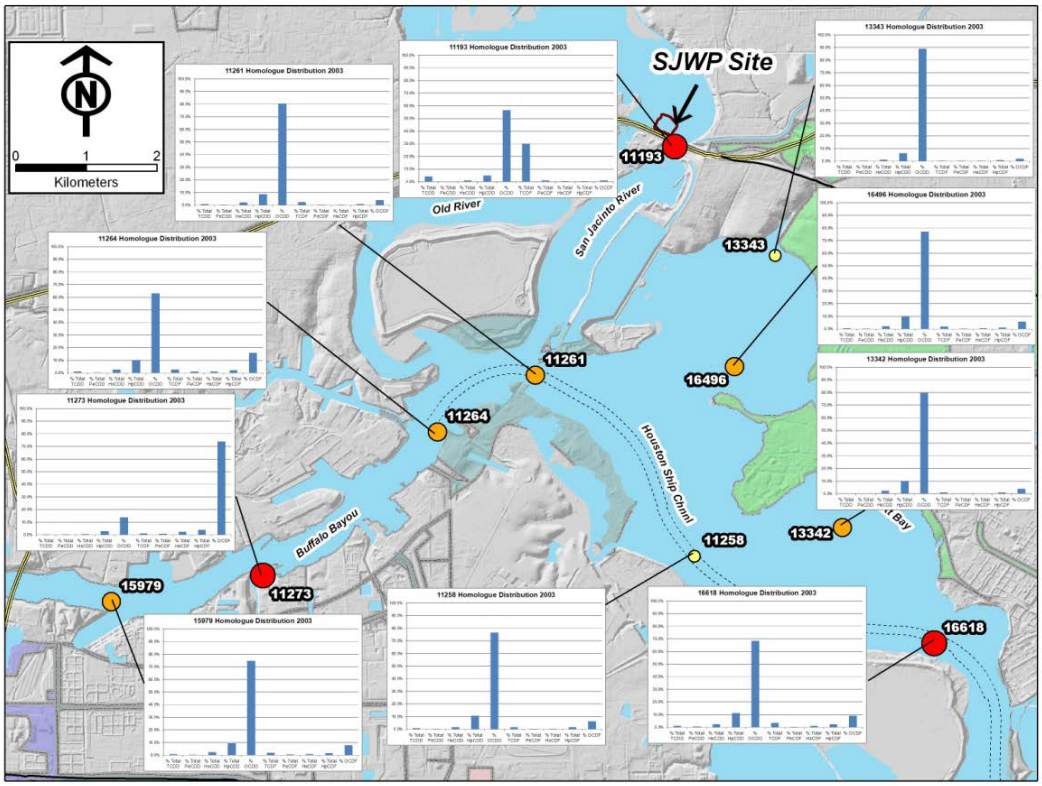


Figure 5-17: Sediment Homologue Distribution 2003

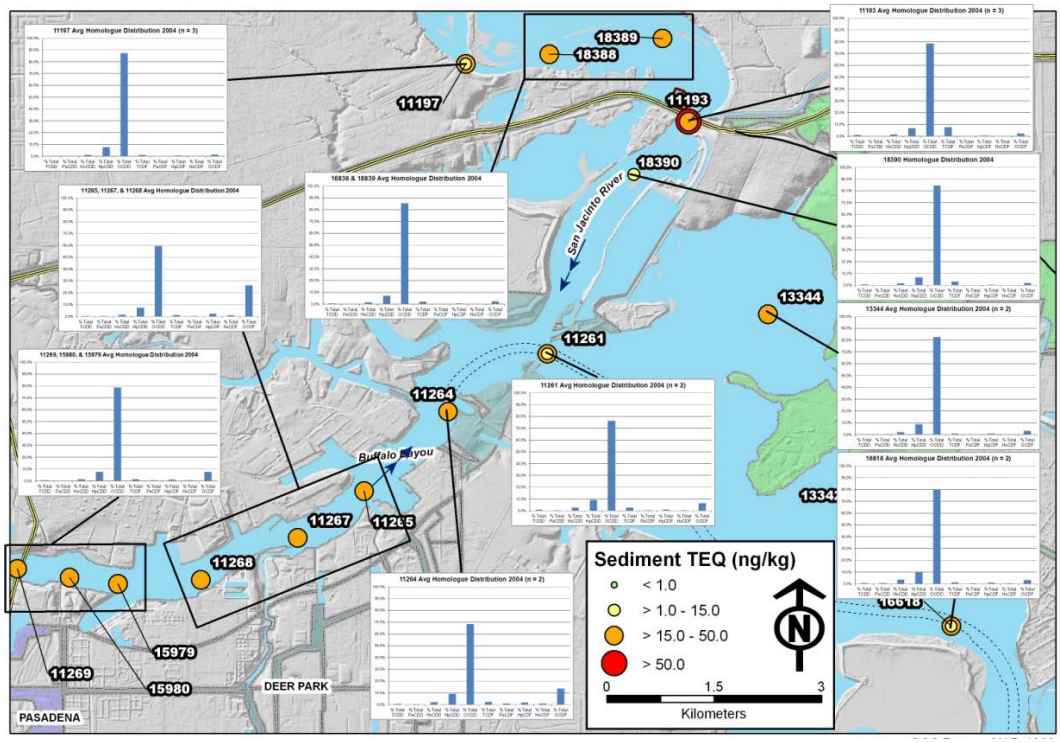


Figure 5-18: Sediment Homologue Distribution 2004

5.3.2 Dioxins within the HSC Main Channel

Inspection of the dioxin fingerprint from samples collected within the Buffalo Bayou portion of the HSC, prior to its confluence with the San Jacinto River reveals another, non-OCDD dominated, dioxin signature. Many of the sediment samples collected from this portion of the HSC have higher concentrations of the higher chlorinated furans, particularly OCDF. This fingerprint is most noticeable in sediments collected near the confluence of Patrick Bayou, known to have contaminated sediments, and the HSC, e.g., Station 016 (1994), Station 11273 (2002 and 2003) and Station 11267 (2004) with industries along its banks producing effluent that is particularly enriched with furans as opposed to dioxins. It should also be noted that the Pasadena paper mill, the originator of the wastes disposed of in the SJWP pits, discharged treated liquid effluents directly to HSC waters for at least a portion of its operating history (Hoover, Peoples et al., 1973). Legacy contamination resulting from these discharges, not mass emanating from the pits, is the most likely culprit for elevated TCDF and TCDD levels seen in some of the samples from within HSC (e.g., Station 15979 - 2002) upstream of the confluence with the SJR. It should be kept in mind, however, that the flow patterns at the confluence are tidally influenced with some level of mixing due to negative flows during high tide (i.e., flows from the estuary into the channel) that potentially serve to push dioxins present at the confluence into the HSC. This component has not been examined in detail in this research. The sediment samples collected during 2005, shown in Figure 5-19, clearly illustrate that, in particular, Patrick Bayou appears to be a localized dioxin source whose profile is dominated by OCDF. Other local sources may also subtly alter the overall dioxin distribution on a small scale, but the source signature characterized by a high percentage of OCDF has had the most noticeable widespread impact on dioxin distributions within Buffalo Bayou portion of the HSC.

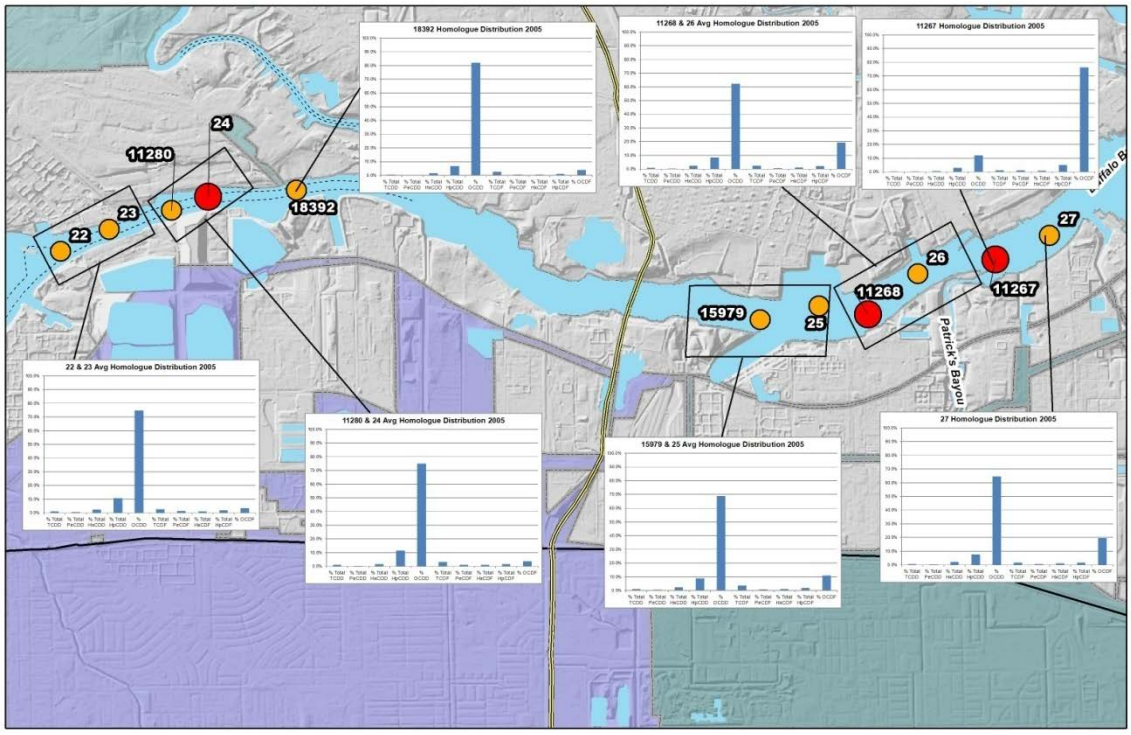


Figure 5-19: Sediment Homologue Distribution 2005

5.3.3 Dioxins in the Galveston Bay System

In the summer of 2011, UH collected surface sediment samples from select areas of the HSC and SJR and in many distributed locations throughout Galveston and Trinity Bays. Figure 5-20 shows the homologue distribution for samples collected in the highly industrialized areas near the confluence of the SJR with the HSC, and Figure 5-21 shows the homologue distribution for sample locations distributed throughout Galveston and Trinity Bays. Impacts from the local HSC and SJWP sources, as evidenced by increased OCDF and TCDF/TCDD fractions, respectively, are evident in the HSC, SJR, and, to some degree, in the side bays adjacent to the HSC downstream of its confluence with the SJR. However, as the sampling locations progress downstream from the confluence and out into the open bays, it appears that a single profile dominates the dioxins detected in the sediments, one that is OCDD enriched mostly. Furthermore, the dioxin concentrations appear to be evenly distributed throughout the bays indicating that

there is likely a widespread, relatively evenly distributed source of dioxins, whose signature is dominated by OCDD and the more highly chlorinated dioxins, which is contributing mass to the GBS.

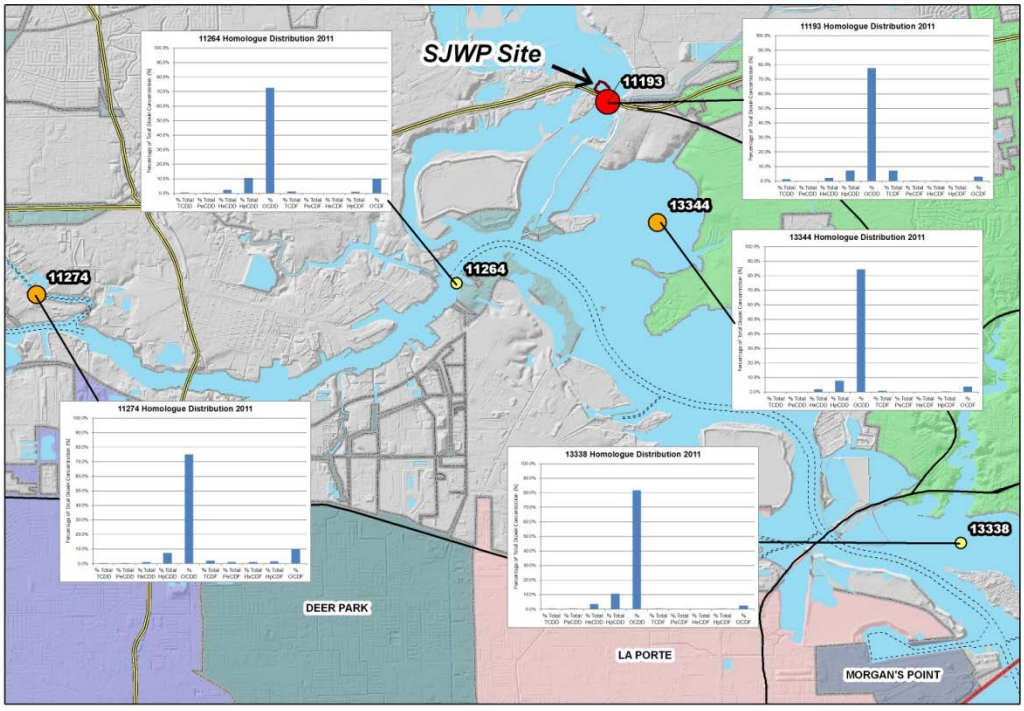


Figure 5-20: Sediment Homologue Distribution 2011: HSC SJR Confluence

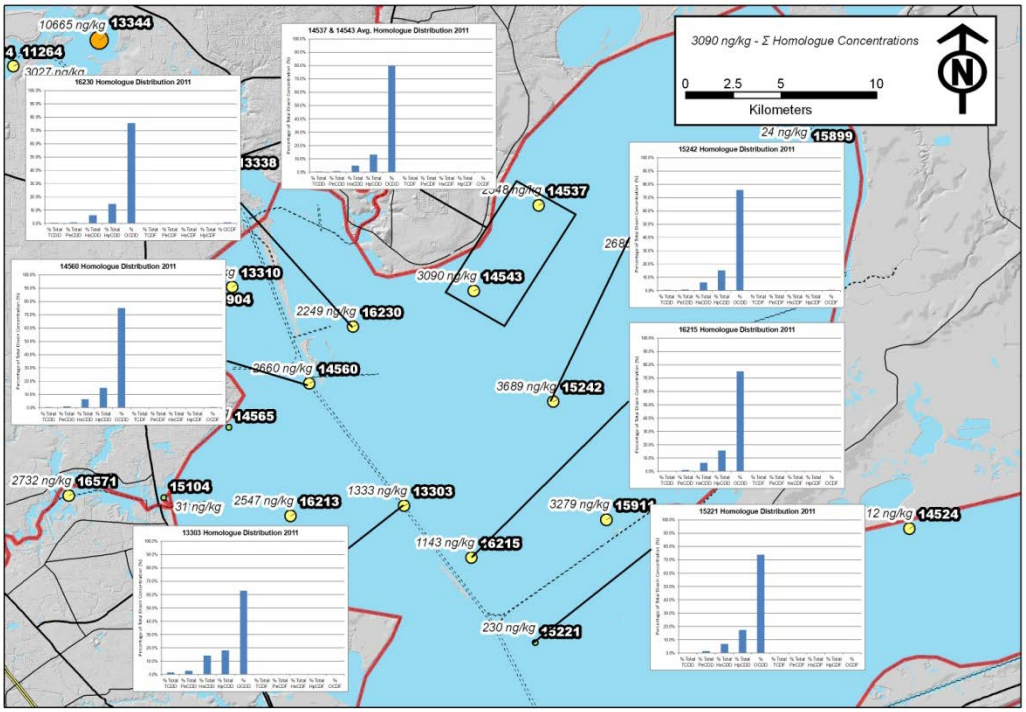


Figure 5-21: Sediment Homologue Distribution 2011 – Galveston Bay System

This signature closely resembles the dioxin homologue distribution that was measured sorbed to suspended particles in runoff samples collected during 2002 and 2003 (see Figure 5-22). The profile observed in the runoff samples was found to be correlated to ambient air, particle phase concentrations (Correa, Raun et al., 2006) collected during the same period (Correa, Rifai et al., 2004) suggesting entrainment of dioxin on airborne particulates into runoff combined with direct deposition of particles into the GBS during dry weather as the source.

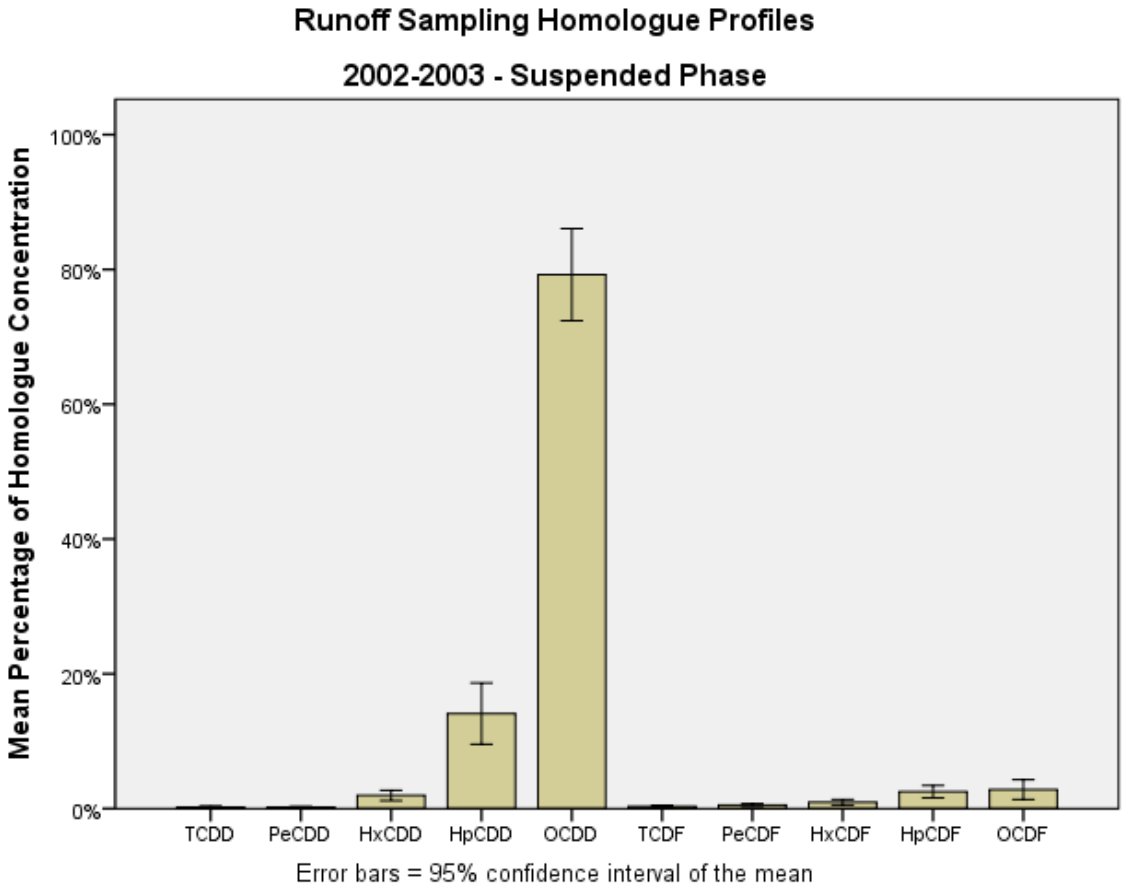


Figure 5-22: Runoff Sampling Homologue Profile - Suspended Phase 2002-2003

5.3.4 Dioxin Profiles Identified by a Qualitative Dioxin Fingerprint Analysis

As presented in the preceding paragraphs, there appears to be three dominant contributors to dioxins observed within the Galveston Bay System:

1. The San Jacinto River Waste Pits – This profile is characterized by high levels of tetra-furan and tetra-dioxin, particularly 2378-TCDF and 2378-TCDD, which are typically present in a roughly 2.5-3 to 1 ratio.
2. HSC Industry – OCDF is the dominant congener in this signature. Patrick Bayou appears to be a major contributor of this dioxin profile.
3. Houston Regional Air – This profile is predominantly OCDD along with other dioxins that decrease in concentration with decreasing chlorination level. Runoff

likely delivers this profile to a certain degree, but the uniform distribution of this profile suggests that air deposition also plays an important role in delivering this profile to the system.

While other sources with profiles differing from those presented above are present in the system, they appear to be minor in relation to the profiles above and have not been investigated in this research.

5.3 Results of Positive Matrix Factorization Source Apportionment

Prior to PMF analysis, outliers and samples with detections in fewer than 50% of 2378-TCDD substituted congeners were removed from the dataset. A PMF model defining 3 major sources was found to adequately represent the data, and the source profiles generated where in general agreement with the qualitative fingerprinting analysis described above. Factor profiles returned by the PMF model are presented in Figure 5-23, below.

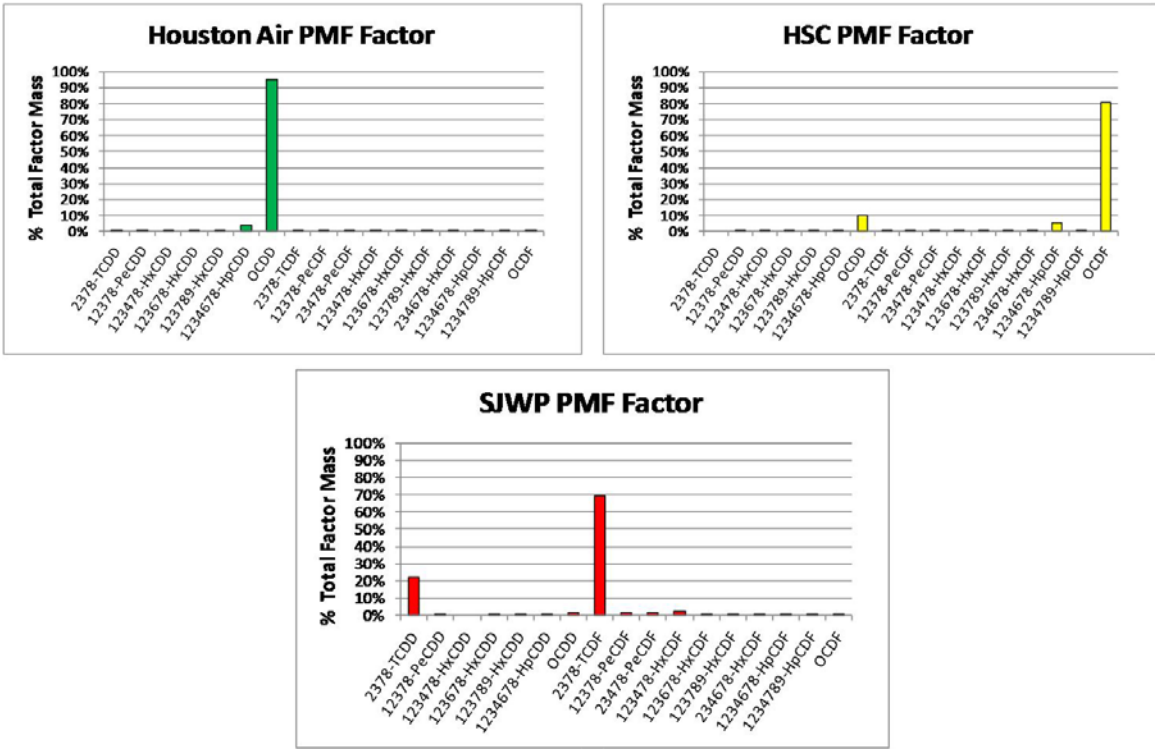


Figure 5-23: PMF Factor Congener Profiles

The ability of the model to predict observed concentrations was analyzed on a congener by congener basis using the coefficient of determination (R^2), where a value of 1.0 indicates a perfect fit to all data points. The three factor model fit the data very well ($R^2 > 0.9$) for 9 of the 17 congeners and adequately ($R^2 > 0.6$) for all 17 2378-TCDD substituted congeners (See Table 5-6).

Table 5-6: Coefficient of Determination for the 2378-TCDD substituted congeners

Species	R^2
2378-TCDD	0.9994452
12378-PeCDD	0.9879228
123478-HxCDD	0.6258385
123678-HxCDD	0.8841823
123789-HxCDD	0.6757804
1234678-HpCDD	0.8879126
OCDD	0.7293263
2378-TCDF	0.9734722
12378-PeCDF	0.9678237
23478-PeCDF	0.983047
123478-HxCDF	0.917576
123678-HxCDF	0.9181218
123789-HxCDF	0.9370941
234678-HxCDF	0.8364098
1234678-HpCDF	0.8717881
1234789-HpCDF	0.832221
OCDF	0.9947744

Generally, the model reproduces the observed sediment concentration well and returns source profiles very similar to those hypothesized based on the qualitative fingerprint analysis. As shown in Figure 5-24, Figure 5-25, and Figure 5-26, the contribution of the SJWP source profile dominates the samples collected in the immediate vicinity of the SJWP site. Likewise, the HSC Industry profile dominates mass contribution near suspected dioxin “hot spots.” The Houston air profile dominates the mass contribution in sediment samples collected upstream of localized dioxin sources and within the open areas of Galveston and Trinity Bays. However, while the Houston air profile dominates mass contribution in nearly every sample, the SJWP profile, which is dominated by two of the more toxic congeners, contributes a much higher toxicity relative to its mass contribution.

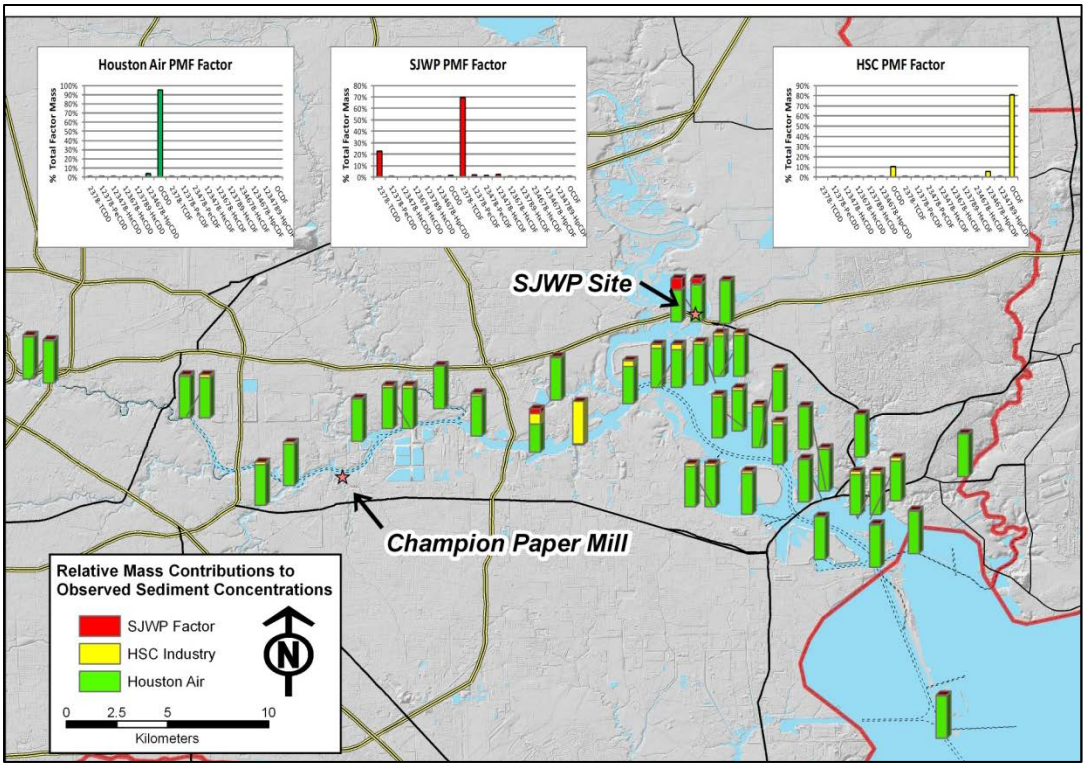


Figure 5-24: 2002 PMF Source Apportionment

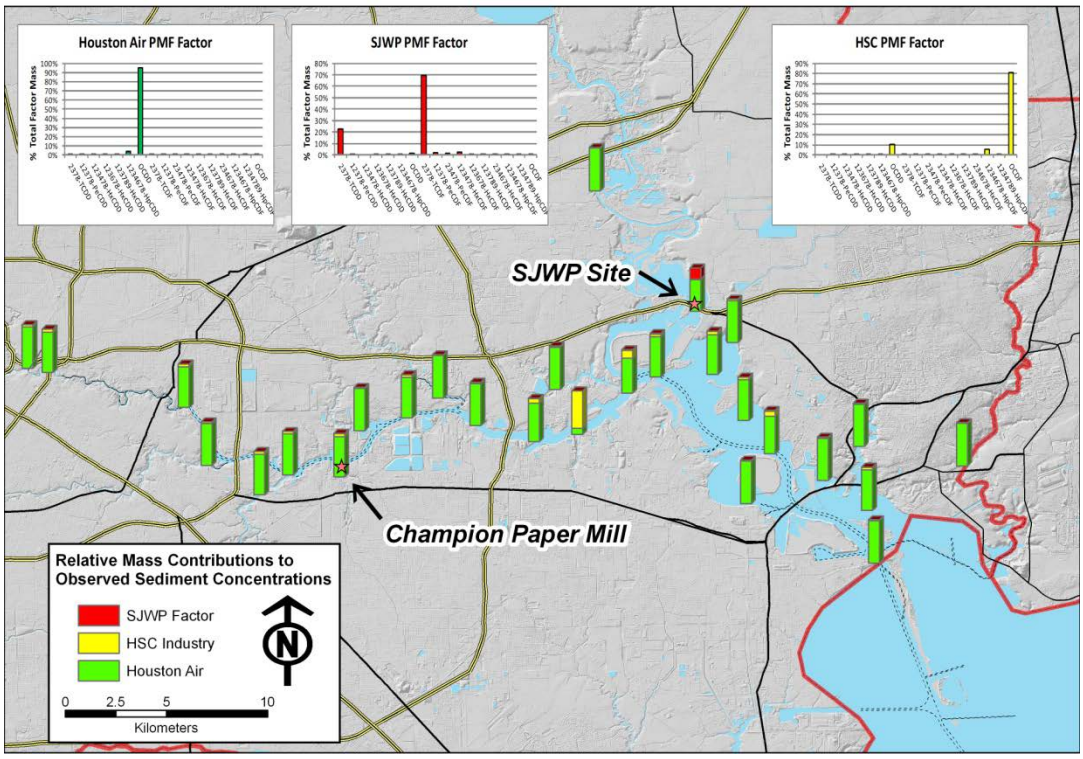


Figure 5-25: 2003 PMF Source Apportionment

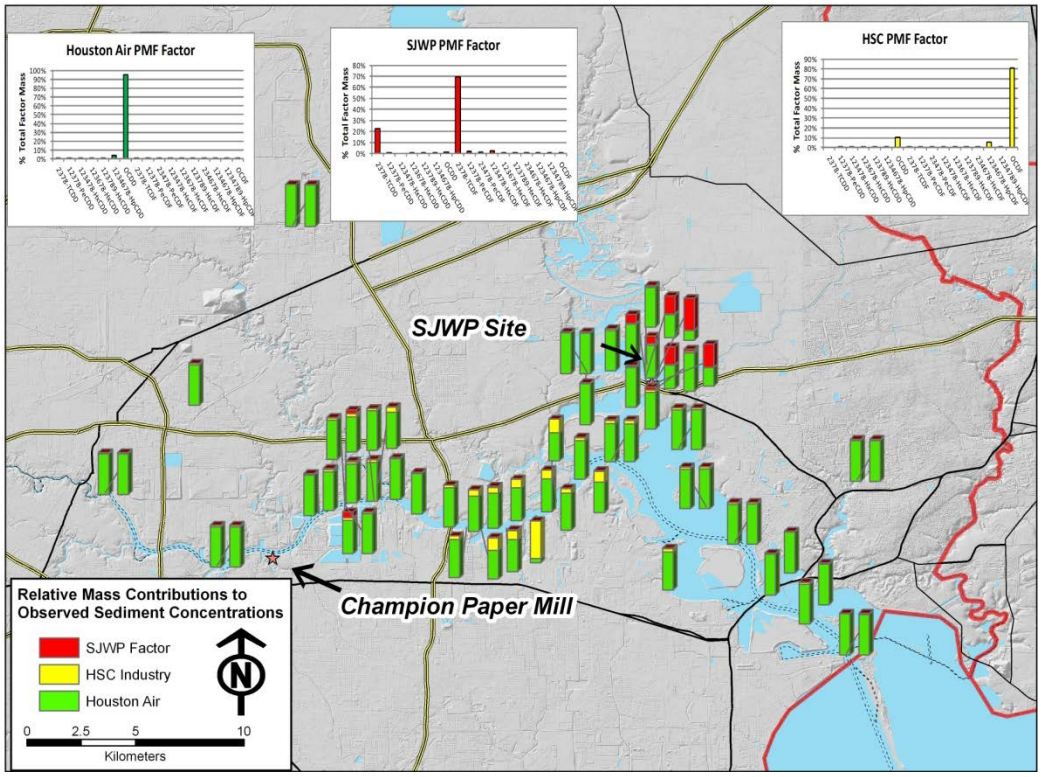


Figure 5-26: 2004 PMF Source Apportionment

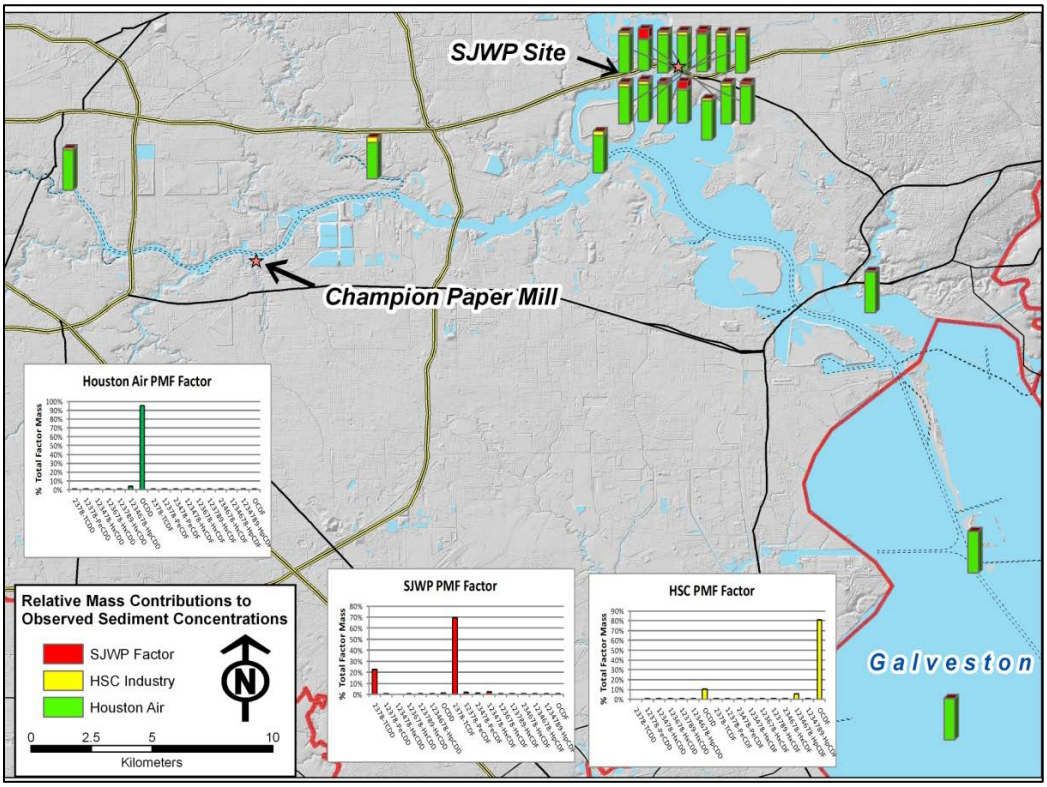


Figure 5-27: 2006 through 2008 PMF Source Apportionment

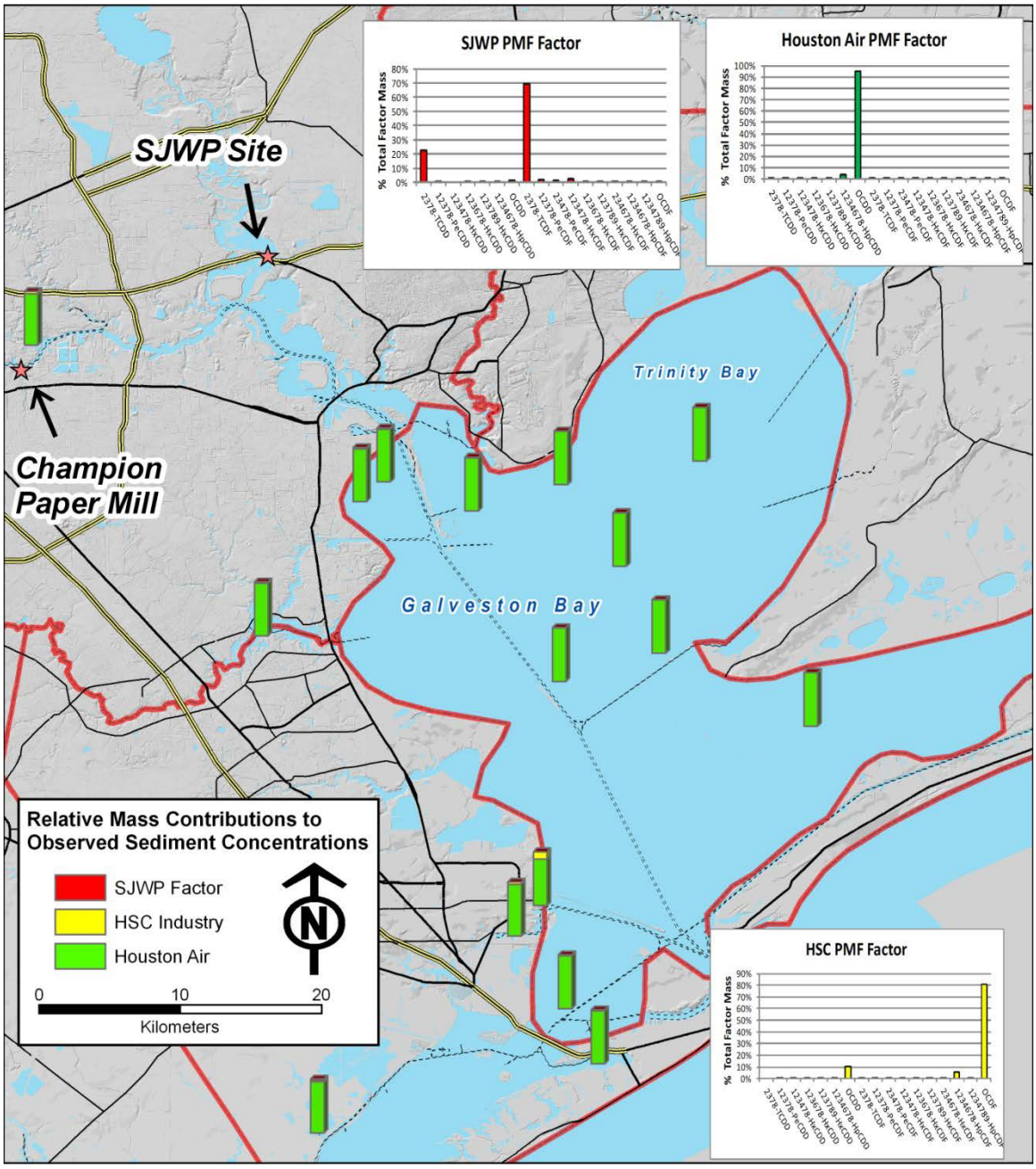


Figure 5-28: 2011 PMF Source Apportionment

CHAPTER 6 – EFDC MODELING

6.1 EFDC Model Overview

An Environmental Fluid Dynamics Code (EFDC) model, developed by Howell 2012, was used to aid in understanding the complex hydrodynamics of the GBS and to provide additional evidence that SJWP sediments would be mobilized from the pits. The model, developed by Howell 2012, extends from upstream boundaries in the HSC and SJR, the turning basin and Lake Houston Dam, respectively, to Morgan's Point (see Figure 6-1). The model was set up to run multi-year simulations to help fill the gap between major sampling events. The model simulates the historical time period between November 2, 2002 and March 24, 2004. For a more detailed description of the model, refer to Howell 2012.

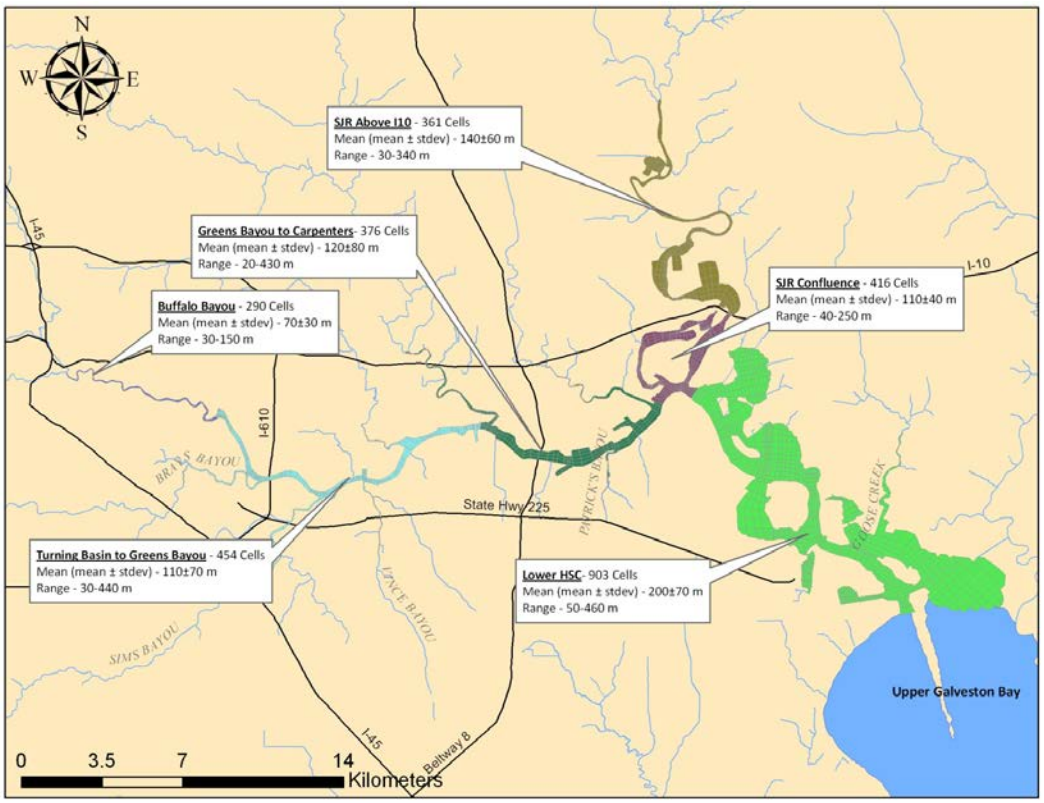


Figure 6-1: Model Grid Layout taken from Howell (2012)

6.2 Shear Stress Analysis near SJWP

Shear stresses for the cells in the immediate vicinity of the SJWP were analyzed to determine the frequency that sediments would be mobilized from the areas around the pits. Grain size distributions for the pit sediments was determined based on results from surface and near surface sediment and soil samples collected within the boundaries of the former waste pits. As shown in Figure 6-2, the material in the pits is primarily silty clay to clayey silt with minor very fine to fine grained sand content with nearly all samples containing >10% clay, suggesting the material from the pits would behave as cohesive sediment.

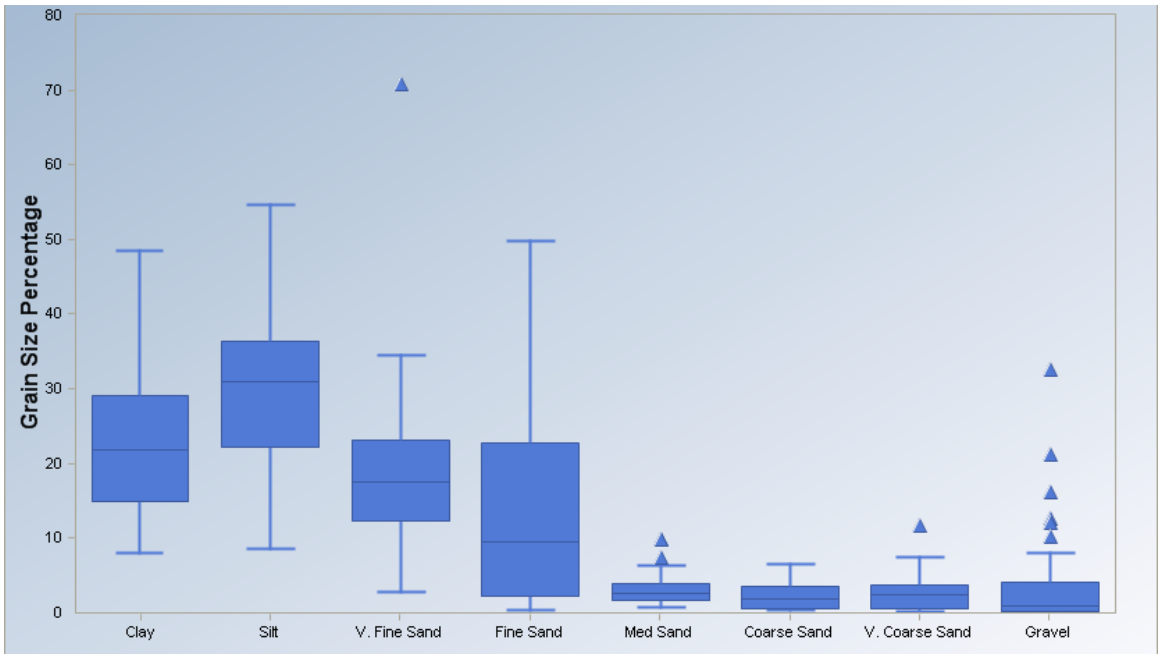


Figure 6-2: Source Zone Grain Size Distribution

Critical erosive shear stress (τ_e) values were estimated to be 0.15 N/m^2 based on measurements collected from side bays just downstream of the SJR/HSC confluence (Salehi and Strom 2012). As shown in Figure 6-3, the critical shear stress is exceeded often in the grid cells near the SJWP, and the maximum shear stress values modeled in the cells near the pit exceed the critical shear value by more than an order of magnitude.

These results support the idea that wastes from the pits would be mobilized from the pits on a regular basis.

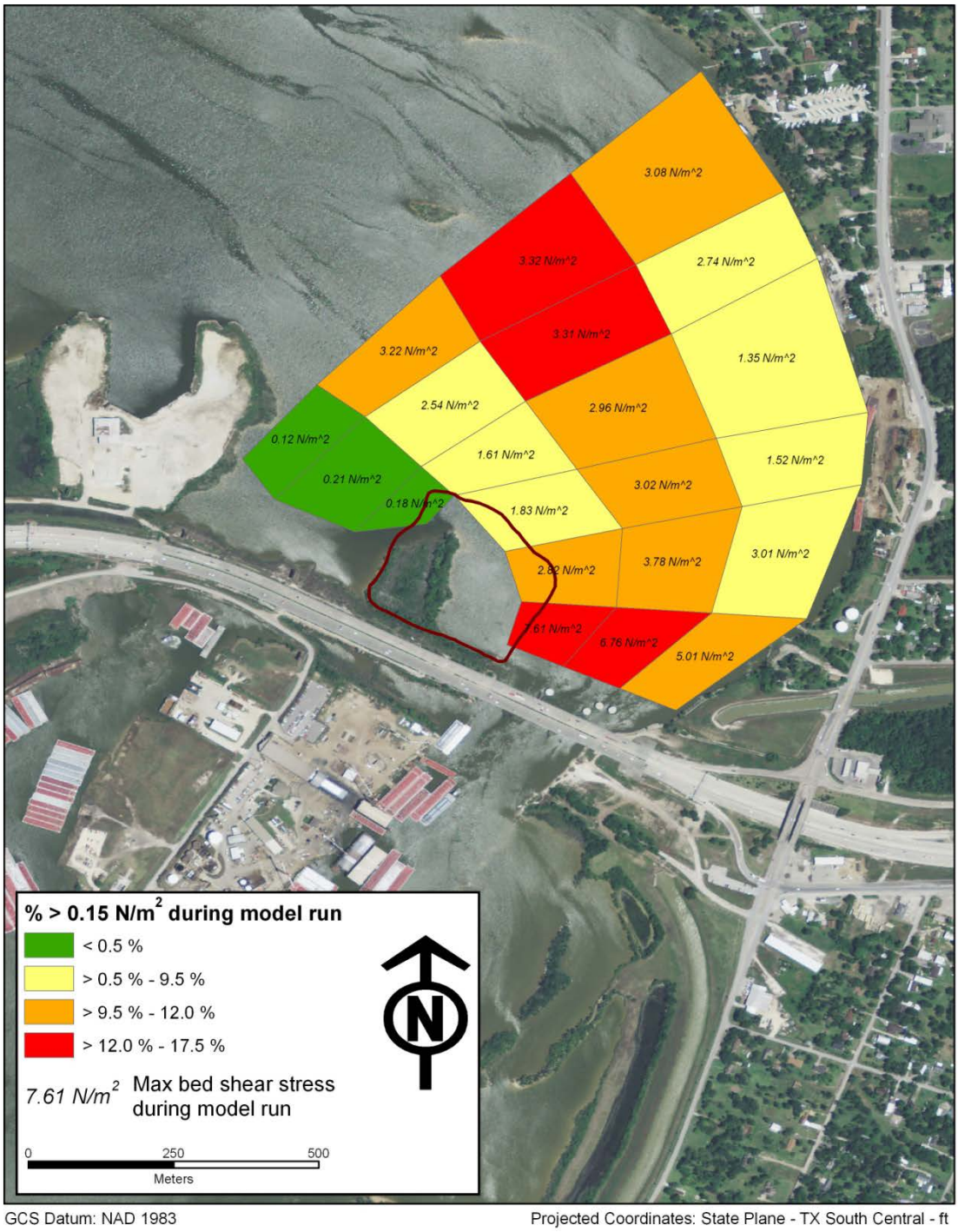


Figure 6-3: Critical Shear Stress Exceedance Frequency

6.3 Estimation of Flux Based on Modeled TSS Concentrations

The dioxin load exiting the SJWP area sorbed to mobilized sediments was estimated using total suspended sediment (TSS) concentrations generated during the model run. During most model time steps, there was net sediment deposition within the cells adjacent to the SJWP; however, water samples collected at station 11193 during dry weather events indicate a non-trivial dioxin load in suspended sediments, even during relatively quiescent flows. It is likely that even though there is net sediment deposition near the pits, most likely in the tranquil areas to the northwest of the pits, some contaminated sediments are still mobilized and moved downstream. The dioxin TEQ sorbed to suspended sediment, on a typical day was based on the average 2378-TCDD and 2378-TCDF concentrations, on a dry weight basis, measured in the suspended sediment samples collected at station 11193 from 2002 through 2004, see Table 6-1.

Table 6-1: Calculation of Typical TSS Load

Sample	TSS (mg/L)	2378-TCDD-Susp	2378-TCDD-Susp	2378-TCDF-Susp	2378-TCDF-Susp
Date	(mg/L)	(ng/L)	(ng/kg-dry)	(ng/L)	(ng/kg-dry)
08/07/2002	23.2	2.86E-04	12.32	8.35E-04	33.81
11/20/2002	25.0	1.84E-03	73.65	5.95E-03	240.85
06/04/2003	23.0	6.97E-03	303.05	6.97E-03	282.19
03/23/2004	19.5	7.56E-04	38.79	2.21E-03	89.56
08/03/2004	19.0	1.42E-03	74.52	4.87E-03	197.05
11/03/2004	7.4	1.84E-04	24.92	5.54E-04	22.44
		Avg	87.87	Avg	144.32

Avg. TEQ (ng/kg)	102.3

Using TSS load values generated by the model, the dioxin flux ($M_{out,i}$) emanating from the SJWP and surrounding areas during a typical model time steps was calculated using the following,

$$M_{out,i} = SSC_i \, C_p \sum Q_{out,i}, \tag{6.1}$$

where, SSC_i is the suspended sediment concentration from the model during time step i, $\sum Q_{out,i}$ is the cumulative volumetric SJR flow out of the SJWP area during time step i, and C_p is the dioxin concentration sorbed to suspended sediments. C_p is equal to 102.3 ng/kg-dry for this calculation.

Additionally, during higher flow events when the SJWP cells experienced a net loss of sediment, it was assumed that the net sediment lost from the SJWP area was significantly more contaminated and was modeled with a C_p equal to 500 ng/kg-dry.

Based on these assumptions, the total dioxin mass which was transported out of the SJWP system during the model run was calculated to be 36.0 g TEQ, which represents a mass flux of 0.0930 g TEQ/day or 33.9 g TEQ/year. This is ~27% greater than the upper end flux estimate for high water events only.

6.4 Evaluation of Flow Paths using a Conservative Dye Model

To better understand the transport of mass from the site into the HSC/GBS a conservative dye tracer simulation was undertaken in EFDC. A dye was released from the cells adjacent to the waste pits when water levels rose above 1.5 m, simulating transport from the site during full inundation. As this is a conservative dye, it is not meant to simulate sediment depositional processes; therefore, only hydrodynamic transport conclusions can be made.

Figure 6-4 through Figure 6-10 depict the progression of dye through the system. As shown in Figure 6-4, the dye has reached the confluence after about 2 hours and is beginning to spread into Old River. As shown in Figure 6-7, some dye from the SJWP has travelled into the Buffalo Bayou portion of the HSC, upstream of its confluence with the SJR. This helps explain some of the PMF model's attribution of dioxin mass in these sediments.

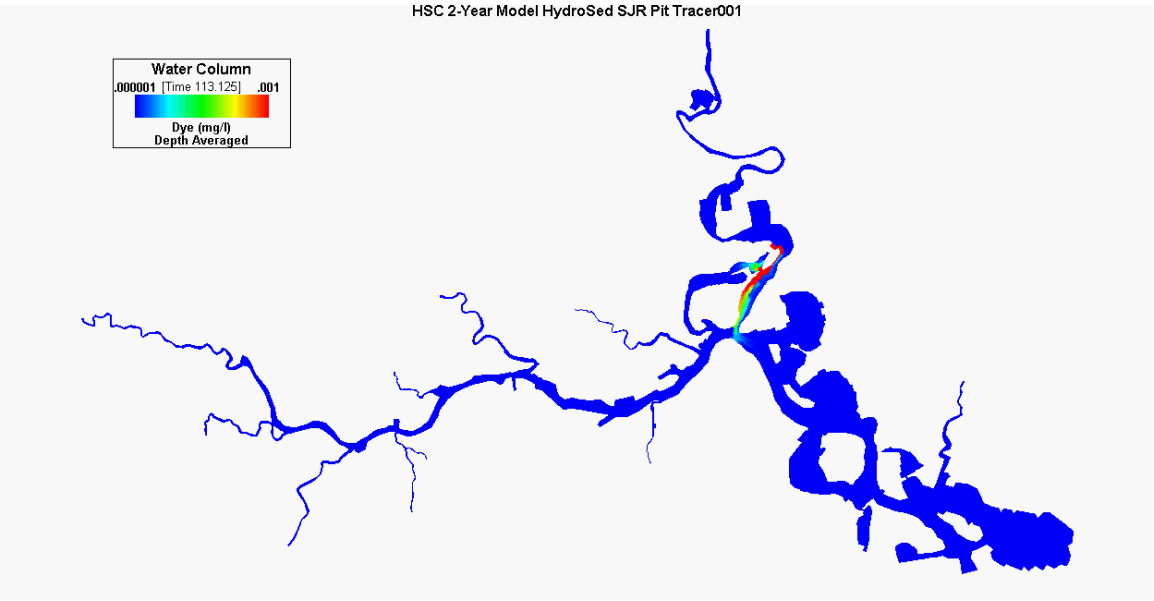


Figure 6-4: Dye Distributions t = 2 hr After Dye Release Initiation

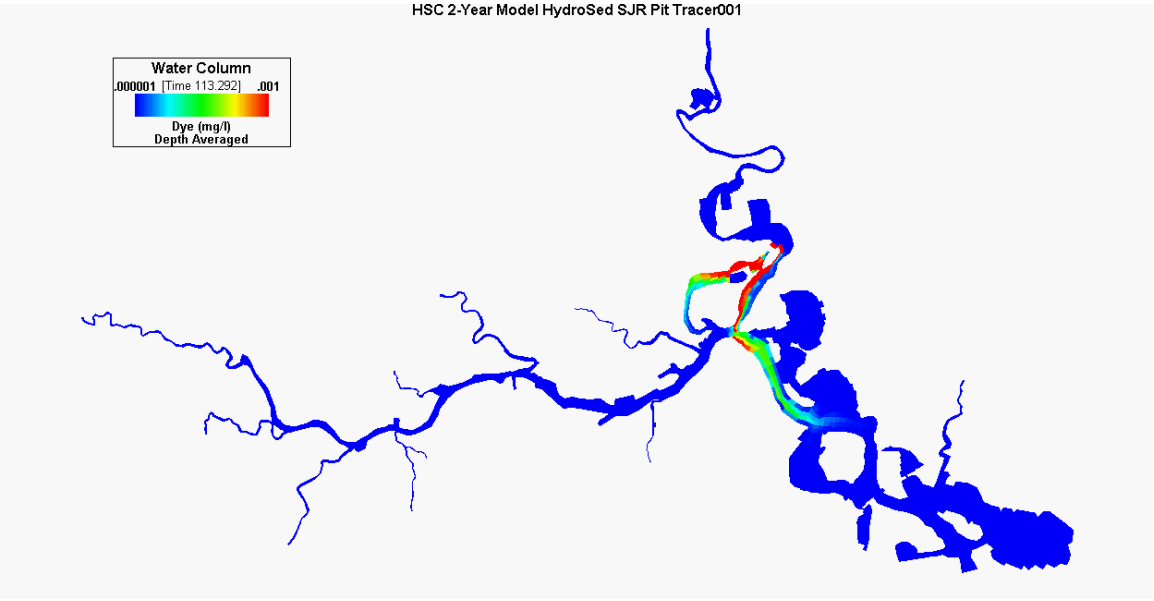


Figure 6-5: Dye Distributions t = 6 hrs

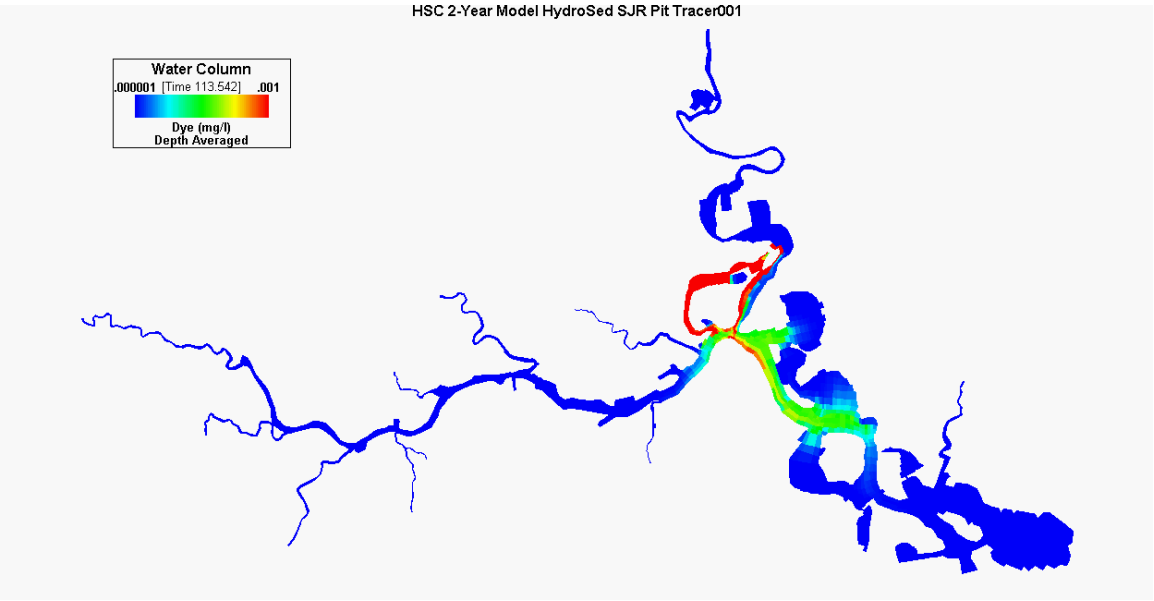


Figure 6-6: Dye Distributions t = 12 hrs

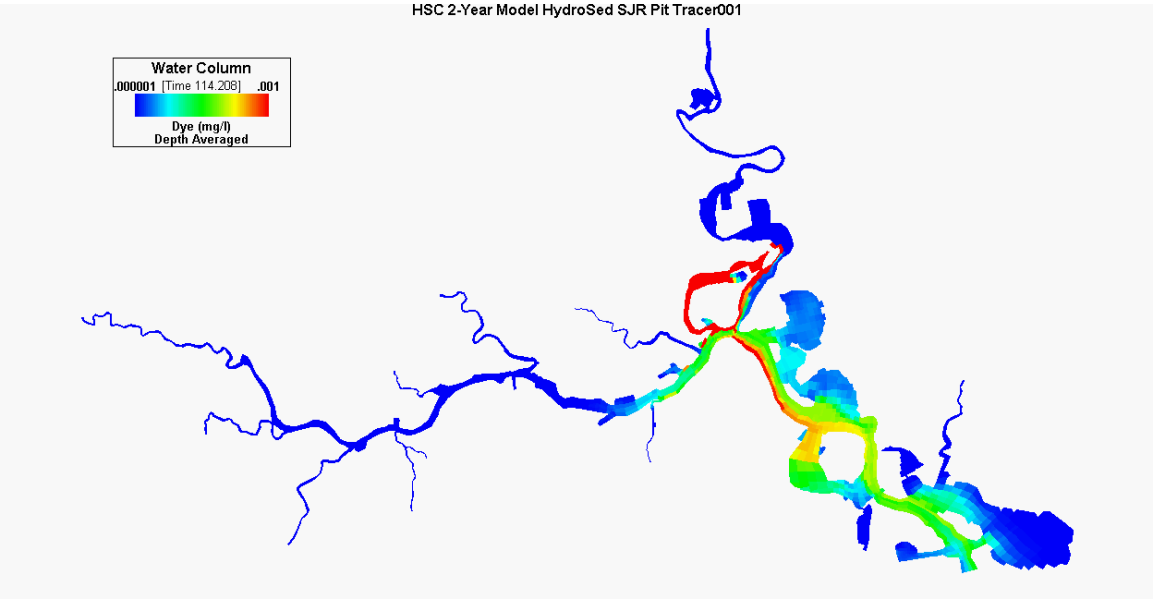


Figure 6-7: Dye Distributions t = 28 hrs

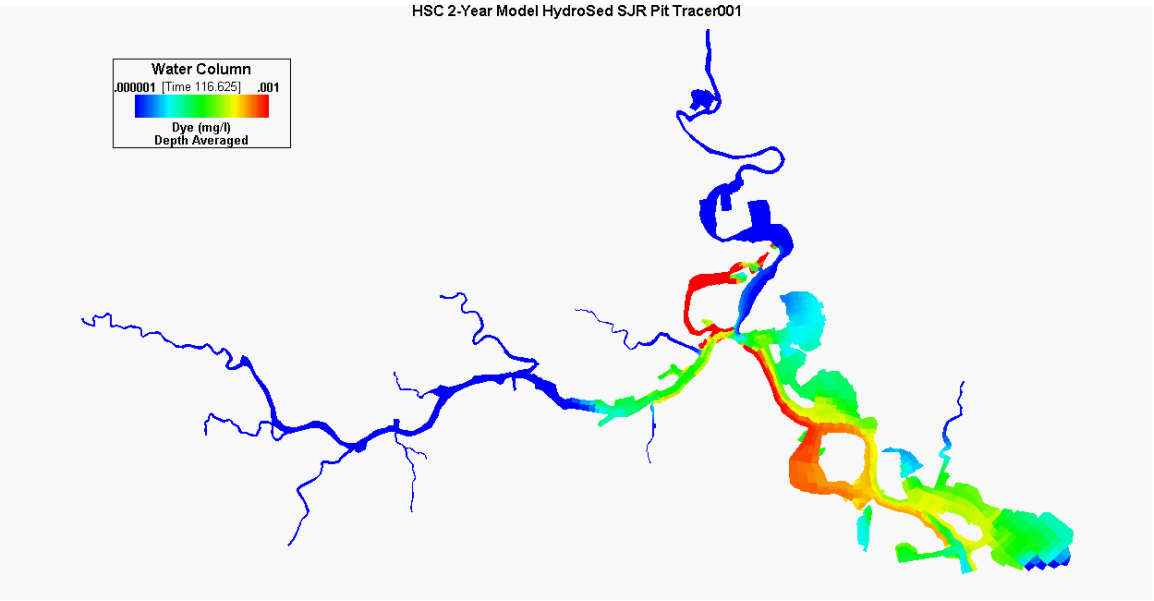


Figure 6-8: Dye Distributions Immediately after Release Halted

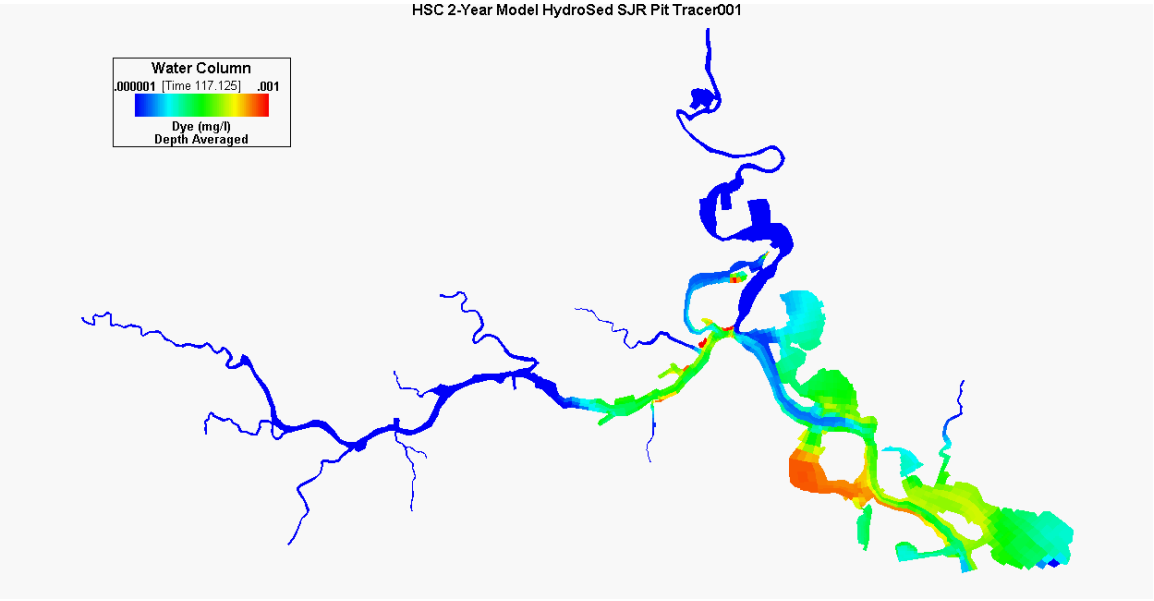


Figure 6-9: Dye being flushed from System

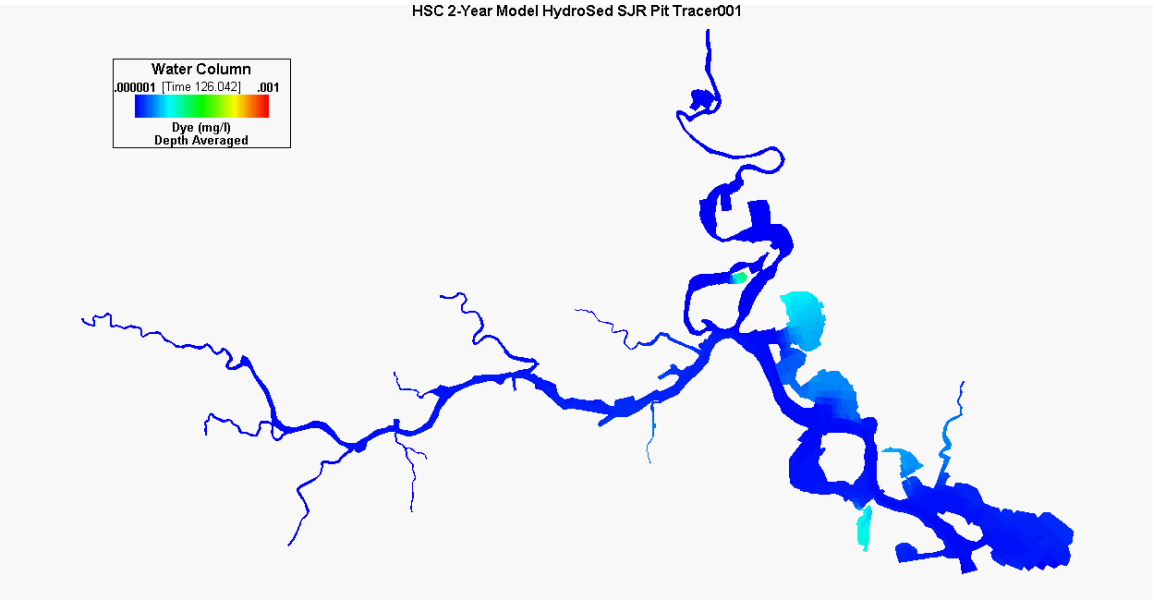


Figure 6-10: Most Dye Flushed from System

As can be seen in Figure 6-10, some of the dye has remained in side bays even after most of the dye has been flushed from the system. If these were dioxin concentrations sorbed to sediments, they would eventually deposit, explaining some of the SJWP mass apportioned to these areas by the PMF modeling.

CHAPTER 7 CONCLUSIONS

This thesis examined the contribution of dioxins from the San Jacinto Waste River Waste Pit Superfund Site to the widespread dioxin contamination observed in sediment, water, and biota in the Houston Ship Channel and Galveston Bay system. Examination of historical aerials indicated that complete, constant inundation of portions of the original SJWP occurred between 1995 and 2002. However, intermittent exposure due to overtopping of the berms during storm events likely released significant dioxins into the SJR prior to 1995. Flux calculations indicate that between 0.28 and 26.6 g TEQ per year were released from the waste pits during this period. Partitioning calculations suggest that sediments suspended from the SJWP area are sourcing dioxins into the dissolved phase.

A qualitative fingerprint analysis of dioxin homologue distributions in GBS sediments revealed three primary dioxin profiles attributable to the following sources:

1. The San Jacinto River Waste Pits – This profile is characterized by high levels of tetra-furan and tetra-dioxin, particularly 2378-TCDF and 2378-TCDD, which are typically present in a roughly 2.5-3 to 1 ratio.
2. HSC Industry – OCDF is the dominant congener in this signature. Patrick Bayou appears to be a major contributor of this dioxin profile.
3. Houston Regional Air – This profile is predominantly OCDD along with other dioxins that decrease in concentration with decreasing chlorination level. Runoff likely delivers this profile to a certain degree, but the uniform distribution of this profile suggests that air deposition also plays an important role in delivering this profile to the system.

A PMF model was applied to the observed sediment concentration distributions, and returned similar source profiles to the three listed above. The source apportionment

of the profiles resolved that localized dioxin sources, i.e., HSC and SJWP, have significant impact on sediment and therefore water quality upstream of Morgan's Point, and the Houston Regional Air profile dominates mass contributions in the open waters of Galveston and Trinity Bays downstream of Morgan's Point. This is in agreement with sedimentation results presented in (Yeager, Santschi et al., 2007).

An EFDC model of the HSC/SJR estuary, developed by Howell, 2012, provided supporting evidence for erosion of SJWP wastes and their subsequent transport downstream. Dioxin fluxes after partial inundation of the waste pits was estimated to be 33.9 g TEQ per year, based on suspended sediment loads generated by the model. Not surprisingly, this is considerably higher than the flux estimated prior to loss of berm integrity. This is consistent with the increasing dioxin concentrations in more recent sediment depositions observed in cores analyzed by (Yeager, Santschi, et al., 2007). When compared to maximum daily load allowable concentrations for dioxin in the HSC-GBS, both pre and post breach fluxes were most likely high enough to cause exceedance of dioxin water quality standards, even in the absence of other dioxin sources to the system.

An EFDC conservative tracer dye simulation provided support for the distributions of concentrations observed in sediments throughout the system, including the dioxins attributed to the SJWP in sediments upstream of the HSC/SJR confluence. The tracer dye simulation suggests that areas potentially impacted by SJWP include the side bays, the area downstream of the confluence with the HSC to Morgan's Point, and an area into the Buffalo Bayou portion of the HSC extending almost to the confluence of Greens Bayou. Further study and modeling would be required to quantify the relative contribution of these simulated impacts and the uncertainties associated with model estimates.

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APPENDIX A –VALUES USED IN PMF MODELING

TABLES

TABLE A.1: Concentration Values Used for PMF Modeling (ng/kg - for all samples)

Sample ID	Station ID	Sample Date	2378-TCDD	12378-PeCDD	123478-HxCDD	123678-HxCDD	123789-HxCDD	1234678-HpCDD	OCDD	2378-TCDF	12378-PeCDF	23478-PeCDF	123478-HxCDF	123678-HxCDF	123789-HxCDF	234678-HxCDF	1234678-HpCDF	1234789-HpCDF	OCDF
050817SE1	001	8/17/2005	54	1.1	1.2	3	3.2	83	2800	200	5.1	4.5	5.1	2.4	0.93	1.2	8.2	1.6	58
050830SE10	010	8/30/2005	110	0.125	0.96	2.3	2.4	68	2700	380	11	9.2	15	3.5	1.8	1.1	11	2.3	89
050818SE11	011	8/18/2005	360	3.7	1.1	2	1.8	75	2700	1400	35	30	47	13	4.7	2.7	18	5.3	65
020801SE11092	11092	8/1/2002	1.5	2.6	5.4	20	10	810	13000	3.2	0.215	1.9	3.1	0.115	0.53	2.4	51	4.2	140
030430SE11092	11092	4/30/2003	0.91	3	3.5	9.1	5.2	250	6500	2.1	0.55	2.6	4.8	2.3	0.42	3.8	48	3	140
020731SE11111	11111	7/31/2002	2.5	0.55	3	4.4	5.6	130	3300	5.7	0.78	0.88	1.2	0.95	0.25	0.98	9.4	1.2	57
030501SE11111	11111	5/1/2003	2.1	1.8	3.4	5.9	6.2	130	4200	3.7	0.67	0.78	0.3	0.375	0.385	0.94	9.2	1.8	44
020808SE11193	11193	8/8/2002	69	0.455	0.4	0.6	1	34	1000	290	5.1	6.3	10	1.8	1.1	1.1	6	1.4	20
021031SE11193	11193	10/31/2002	44	0.8	0.71	1.8	1.7	51	1500	160	3.9	4.1	4.9	1.9	0.62	0.81	6.4	0.84	32
030513SE11193	11193	5/13/2003	94	0.335	0.53	1.2	1.5	42	1500	390	7.5	7.5	9.9	2.1	0.87	0.61	6.4	1.3	25
040324SE11193	11193	3/24/2004	61	2.3	1.05	1.8	5.5	160	5200	230	6.6	6.2	11	3.6	1.7	2.2	19	2.8	160
040811SE11193	11193	8/11/2004	11	0.46	0.45	0.89	1.1	31	1400	55	1	1.4	0.7	0.49	0.105	0.32	2.7	0.19	17
041104SE11193	11193	11/4/2004	31	0.84	0.7	1.5	1.9	57	2000	120	2.5	2.6	3.2	1.1	0.1	0.6	8.1	1	100
040324SE11197	11197	3/24/2004	5.9	0.72	0.305	1.7	0.7	67	2600	16	0.32	0.98	0.7	0.62	0.37	0.56	6	0.64	39
040811SE11197	11197	8/11/2004	17	1.5	2.3	4.9	5.5	190	7300	53	2.6	2.4	4.5	2.9	0.89	1.4	15	2.1	100
041109SE11197	11197	11/9/2004	8.8	0.69	1.1	2.7	2.9	100	3800	26	1.1	1.2	2	0.71	0.135	0.82	9.2	1.1	72
021024SE11252	11252	10/24/2002	3.4	2.2	3.2	5.3	7.3	170	3800	7.7	0.79	1	1.3	1	0.255	1.1	13	1.3	86
030528SE11252	11252	5/28/2003	3.5	1.5	1.6	4	3.9	94	2300	8.1	0.62	0.63	1.4	0.63	0.25	0.205	7.7	0.73	51
040311SE11252	11252	3/11/2004	2.6	0.92	0.5	1.9	2.6	69	1400	6.9	0.53	0.26	1.5	0.39	0.29	0.38	2.4	0.265	44
041108SE11252	11252	11/8/2004	1.4	1	1.6	2.9	4.1	96	2000	3.1	0.31	0.52	0.72	0.16	0.225	0.41	5.3	0.19	27
020819SE11261	11261	8/19/2002	3.4	0.335	0.35	0.6	1	27	640	8.4	0.69	0.65	0.26	0.54	0.25	0.205	5.4	0.66	78
021026SE11261	11261	10/26/2002	6.5	0.34	0.89	1.8	2	57	1500	16	1	1.2	1.6	0.72	0.255	0.66	8.8	0.83	140
030511SE11261	11261	5/11/2003	9.5	0.85	0.73	1.9	1.7	53	1700	26	0.255	1.2	1.4	0.135	0.255	0.21	8	0.77	85
040324SE11261	11261	3/24/2004	5.5	0.225	0.365	1.4	1.3	36	1000	17	0.81	0.73	1.2	0.16	0.33	0.42	4.9	0.68	83
041109SE11261	11261	11/9/2004	12	0.63	1.3	2.4	3.1	79	2000	36	1.3	1.5	2.5	0.7	0.62	0.83	11	1.5	170
020819SE11264	11264	8/19/2002	9.4	0.335	0.77	2.7	1.5	62	1300	21	1.3	1.8	2.5	1.3	0.54	1	15	1.6	170
030529SE11264	11264	5/29/2003	16	0.34	1.8	3.8	4.1	100	2100	33	3.3	4.2	6.2	2.1	1.5	0.92	26	3.9	530
040324SE11264	11264	3/24/2004	10	0.93	1.3	3.4	1.8	84	1700	39	16	10	10	2.3	1.8	1.8	32	3.5	610
041104SE11264	11264	11/4/2004	11	1	1.3	3	3.3	100	2600	28	2.1	2	3.1	1.1	0.67	1.2	13	2.1	190
040401SE11265	11265	4/1/2004	15	1.4	2.6	6.6	4.6	180	4100	40	6.9	6.7	8	5.6	4.9	4.1	100	14	2100
041104SE11265	11265	11/4/2004	17	1.2	1.8	3.7	3.9	110	2700	42	2.4	0.145	4.3	1.4	0.95	1.6	20	2.8	370
040811SE11267	11267	8/11/2004	16	1.9	3.7	8.3	6.4	230	5700	0.12	20	14	29	5.6	10	7	270	30	6500
050816SE11267	11267	8/16/2005	14	1.6	2.7	6.6	4.1	140	1900	58	29	29	54	0.9	16	10	460	62	12000
050816SE11268	11268	8/16/2005	36	1.7	2.4	6.4	5.5	150	3600	96	5.1	4.7	7.1	3.1	3.3	2.7	49	8.8	1300
040810SE11269	11269	8/10/2004	8.5	1.3	1.3	3.1	3	93	3100	20	1.3	1.6	1.7	1.6	0.6	1.2	15	2	170
020828SE11270	11270	8/28/2002	24	0.335	1.5	2.9	1.6	78	2000	49	3.1	3.5	0.26	0.285	0.25	1.3	13	1.1	92
030506SE11270	11270	5/6/2003	2.3	0.34	0.81	1.3	0.97	37	1400	5.5	0.255	0.91	1.1	0.51	0.255	0.69	6.8	0.23	33
040810SE11270	11270	8/10/2004	6.2	1.3	2	5.1	4	160	6600	16	1.8	2.6	0.09	2.4	0.97	2	28	2.8	130

TABLE A.1: Concentration Values Used for PMF Modeling (ng/kg - for all samples)

Sample ID	Station ID	Sample Date	2378-TCDD	12378-PeCDD	123478-HxCDD	123678-HxCDD	123789-HxCDD	1234678-HpCDD	OCDD	2378-TCDF	12378-PeCDF	23478-PeCDF	123478-HxCDF	123678-HxCDF	123789-HxCDF	234678-HxCDF	1234678-HpCDF	1234789-HpCDF	OCDF
040810SE11271	11271	8/10/2004	5.3	0.195	1.4	3.1	2.8	98	4700	13	1.2	1.8	2.1	1.5	0.66	1.5	16	1.7	82
020725SE11272	11272	7/25/2002	3.8	0.65	2	3.9	3.1	110	4000	13	0.5	1.2	2.35	0.375	0.5	0.96	12	0.7	74
030430SE11272	11272	4/30/2003	3.8	2.3	2.4	4.4	5.6	160	10000	7.9	0.3	1.2	2	1.4	0.29	1.9	18	2	140
020828SE11273	11273	8/28/2002	17	0.6	0.26	0.6	0.39	390	4700	110	170	170	370	110	84	48	1500	160	42000
030503SE11273	11273	5/3/2003	23	0.8	8.4	18	11	430	6400	100	82	120	210	76	76	22	1100	140	34000
020730SE11274	11274	7/30/2002	2.2	0.65	2.2	6.6	3.6	170	5600	7.4	1.6	3.3	3.9	1.7	0.495	2.7	28	0.75	73
030501SE11274	11274	5/1/2003	1.5	0.345	1.5	3	3.3	72	2900	3.6	0.53	1.3	1.8	0.61	0.25	1.2	10	0.96	32
040518SE11274	11274	5/18/2004	1.3	0.76	1.1	2.1	2.2	83	220	4.2	0.57	1.1	1.5	0.96	0.38	0.98	10	0.92	26
020829SE11280	11280	8/29/2002	18	1.8	4.1	9.4	5.6	250	4100	43	3.9	6.7	6	0.135	1.5	4.6	49	4.5	220
021202SE11280	11280	12/2/2002	27	0.35	6.6	18	8.1	480	7700	65	6.9	11	11	9.1	2.5	4.6	100	7.4	510
030506SE11280	11280	5/6/2003	27	0.455	4.3	10	7.1	330	5600	62	3	6.7	9.6	3.9	2.3	3.5	59	5.5	290
040401SE11280	11280	4/1/2004	330	6.8	9.7	28	15	720	9000	810	22	39	40	26	2.9	42	160	15	740
040810SE11280	11280	8/10/2004	25	3	3.6	9.6	6.5	310	6200	63	6.7	6.8	12	6.5	2.6	5.1	50	4.7	230
041104SE11280	11280	11/4/2004	650	13	9.2	30	16	680	9500	1600	27	34	30	12	5.1	12	130	15	760
050816SE11280	11280	8/16/2005	14	1.1	1.8	4.7	3.5	130	2500	38	3.4	3.1	6.3	2.4	1	1.3	23	2.3	120
020826SE11287	11287	8/26/2002	1.3	0.8	1.6	3.1	2.3	82	1300	3.5	0.19	1.1	1.5	1	0.5	1.3	20	1.3	64
030505SE11287	11287	5/5/2003	1.6	0.425	1.5	3.2	2.3	88	1200	3.3	0.25	1.1	2	1	0.395	1.3	17	0.65	60
040402SE11287	11287	4/2/2004	8.5	2	3.3	8.4	5.3	260	3500	22	2.1	3.2	5.8	2.7	1.4	3.5	46	3.9	150
041104SE11287	11287	11/4/2004	10	1.8	3.5	8	5.8	230	3800	27	2.4	3.7	3.7	3.4	1	3.8	44	3.9	140
020905SE11292	11292	9/5/2002	1.9	1.7	4.4	11	6.2	290	4300	11	4.9	8.7	5.5	0.65	3.4	6	47	5.6	300
021210SE11292	11292	12/10/2002	25	4.55	12	71	24	2100	41000	48	14	23	49	24	9.4	13	460	29	1400
030506SE11292	11292	5/6/2003	0.405	0.395	2.2	6	3.5	190	2600	1.7	0.25	3	2.2	2.4	0.68	2.9	40	3.8	160
040402SE11292	11292	4/2/2004	0.64	2.4	3.3	8.9	6.3	270	3900	2.7	1.1	2.7	2.5	2.7	1.1	3.6	41	3.2	120
041104SE11292	11292	11/4/2004	1.2	2	3.4	9.1	5.8	250	3800	4.9	1.1	2.9	6.5	2.7	0.96	3.5	44	3.5	120
020729SE11298	11298	7/29/2002	10	1.05	4	10	6.5	290	6800	33	3	4.8	4.7	3.4	1.4	4.2	48	1.7	130
030502SE11298	11298	5/2/2003	6.4	0.365	2.9	7.6	5.2	210	4600	20	0.305	3.3	3.9	2.5	0.82	3.3	33	3	82
020905SE11300	11300	9/5/2002	12	0.33	2.5	8.7	4.8	200	3500	100	170	74	330	67	28	19	130	36	160
030529SE11300	11300	5/29/2003	13	0.33	5.6	16	8.6	390	4600	64	58	22	93	19	12	5.6	100	17	320
020826SE11302	11302	8/26/2002	0.125	0.335	1.1	3.3	2.2	100	1600	1	0.25	1.3	1.7	0.135	0.8	1.3	16	1.5	100
030501SE11302	11302	5/1/2003	2.5	1.3	4.1	8.7	6	230	2900	4.4	0.65	2.3	0.8	0.85	0.7	5.4	51	1.25	190
030504SE11305	11305	5/4/2003	0.455	0.7	1.9	4.3	2.4	88	1100	1.4	0.415	1.9	2.1	1.2	0.325	2	14	2.1	39
020812SE11347	11347	8/12/2002	0.125	0.335	0.7	1.8	1.2	41	610	0.4	0.25	0.62	0.26	1.35	0.25	0.77	11	0.55	18
030504SE11347	11347	5/4/2003	0.135	0.335	0.97	2.7	1.7	75	960	0.55	0.25	0.13	0.78	0.57	0.25	0.91	14	0.465	65
020812SE11382	11382	8/12/2002	0.135	1.1	2	5.6	3.4	140	2000	0.9	0.91	2.3	1.9	1.6	0.72	3.3	28	0.85	81
030505SE11382	11382	5/5/2003	0.25	0.38	1.4	3.5	2.5	120	1700	0.78	0.325	1.5	0.26	1.2	0.315	2	21	0.5	78
050830SE12	12	8/30/2005	35	0.92	6.2	15	5.3	1300	11000	130	3.9	3.7	6	2.4	0.9	1.7	52	3.8	390
050817SE13	13	8/17/2005	8	0.3	0.42	0.94	1.2	26	730	29	2.5	1.3	2.8	0.97	0.63	0.046	3.6	0.57	33
021022SE13336	13336	10/22/2002	3.7	1.5	4.2	7.6	7.1	220	5300	8.9	1.3	1.9	3.3	2	0.29	2.9	27	1.7	130

TABLE A.1: Concentration Values Used for PMF Modeling (ng/kg - for all samples)

Sample ID	Station ID	Sample Date	2378-TCDD	12378-PeCDD	123478-HxCDD	123678-HxCDD	123789-HxCDD	1234678-HpCDD	OCDD	2378-TCDF	12378-PeCDF	23478-PeCDF	123478-HxCDF	123678-HxCDF	123789-HxCDF	234678-HxCDF	1234678-HpCDF	1234789-HpCDF	OCDF
020814SE13337	13337	8/14/2002	10	0.295	2.6	6.2	5.3	150	3000	23	2.8	3	5	0.115	0.97	2.2	24	2.7	260
030528SE13337	13337	5/28/2003	8.3	0.36	1.9	3.3	3.3	100	2000	20	1.5	1.6	2.3	1.2	0.6	0.85	12	1.5	110
020822SE13338	13338	8/22/2002	15	0.33	2.6	7.4	7.1	190	4400	37	0.245	4.5	12	4.1	2.1	2.8	29	3.1	330
021022SE13338	13338	10/22/2002	4.4	0.29	1.3	2.6	3.1	77	1800	11	1.3	1	3	1.3	0.36	0.66	10	1	150
040319SE13338	13338	3/19/2004	8.9	0.93	1.9	3.4	3.7	93	2000	29	1.5	1.3	2.3	1.9	0.5	0.98	9.6	1.2	88
041108SE13338	13338	11/8/2004	5	0.165	2.4	4.3	5.6	150	3900	14	0.89	1.2	2.2	0.97	0.31	0.79	18	1.6	95
020822SE13339	13339	8/22/2002	13	0.31	2.5	6	6.8	160	3600	29	0.235	2.6	3.7	1.8	1.1	1.9	24	2.5	190
030504SE13339	13339	5/4/2003	2.8	0.335	0.98	2.2	2.3	190	2700	3.8	0.54	0.14	0.55	0.6	0.25	0.89	6.5	0.34	47
020806SE13340	13340	8/6/2002	3	1.5	2.8	5.4	6.1	150	3200	7.1	0.245	1.7	1.8	1.7	0.245	1.1	17	2	73
021023SE13340	13340	10/23/2002	5.7	1	2	4	5	120	3100	14	1	1.4	2.1	1	0.255	1.2	13	1.3	120
030529SE13340	13340	5/29/2003	2.7	1.4	2.2	4.2	4.8	140	2700	6.3	0.25	1.6	2	1.3	0.55	0.69	17	1.3	68
040311SE13340	13340	3/11/2004	4	0.5	3.3	5.6	7.6	220	4500	9.3	0.46	0.7	1.7	1.8	0.53	1.5	25	1.9	100
041109SE13340	13340	11/9/2004	2.9	1.2	1.7	3.9	4.3	120	2400	7.4	0.96	1.4	1.3	1.1	0.46	1	12	1.3	49
020806SE13341	13341	8/6/2002	5	1.8	3	6.5	6.6	170	4200	12	2.9	1.5	2.1	0.12	0.225	1.6	20	0.31	100
020821SE13342	13342	8/21/2002	15	2.3	3.7	6.8	7.3	200	5500	35	1.6	3.1	5.1	2.1	1.5	2.3	32	3	290
021028SE13342	13342	10/28/2002	14	1.5	2.3	5.9	6.3	190	5400	33	2.5	2.8	4.2	2	0.92	2.1	27	2.9	280
030511SE13342	13342	5/11/2003	15	2.3	3.6	6.5	8.3	250	6300	30	0.25	3	5.6	2.3	1.3	2.4	35	3.5	310
040311SE13342	13342	3/11/2004	17	0.8	2.6	5.6	6.3	190	4500	43	3.1	3.1	3.3	2.5	0.43	2.2	27	3.1	220
041109SE13342	13342	11/9/2004	15	1.4	3.3	7.1	7.8	220	7900	49	2.9	3.1	3.1	2.5	1	2.1	33	3.6	300
020820SE13343	13343	8/20/2002	1	0.35	1.2	2.3	2.3	67	3700	2.1	0.25	0.78	0.26	0.91	0.25	0.92	8.5	0.39	27
030511SE13343	13343	5/11/2003	2.6	0.71	1.3	2.5	2.5	85	3800	5.1	0.54	0.69	1.4	0.9	0.25	0.9	12	0.8	80
020821SE13344	13344	8/21/2002	15	2	3.1	7.1	7.7	230	7100	29	0.25	3.2	5.8	2.9	1.7	2.9	42	3.6	350
021027SE13344	13344	10/27/2002	21	1.8	3.5	7.6	7.9	240	7400	40	3.4	3.5	5.3	2.7	1.3	3.1	41	4.3	460
040319SE13344	13344	3/19/2004	11	1.1	2.1	4.5	4.9	150	4800	28	2.5	2.6	3.05	1.7	1.2	2	22	1.15	170
041108SE13344	13344	11/8/2004	15	1.7	3.2	6.7	6.4	240	6900	38	2.9	3.2	5.3	2.5	1.5	2.4	35	3.8	290
050818SE14	14	8/18/2005	24	0.34	0.19	0.049	0.43	13	450	85	2.5	2	3.4	0.92	0.33	0.27	2	0.55	7.5
020830SE14560	14560	8/30/2002	3	3.7	7.2	11	7.4	150	3100	6.9	1.1	0.61	1.4	1	0.73	0.95	10	1.4	68
050818SE15	15	8/18/2005	21000	240	3.5	8.2	2.25	95	1200	82000	2800	2200	3900	1100	410	210	1100	440	390
020904SE15979	15979	9/4/2002	310	8.5	5.4	20	10	360	6300	950	26	25	26	28	5.5	7	140	16	5500
030529SE15979	15979	5/29/2003	16	0.34	2.5	6.8	6.4	150	3900	36	0.255	4.3	7	2.8	1.8	1.3	30	4.8	410
040402SE15979	15979	4/2/2004	9.8	0.67	0.76	0.75	1.2	50	1100	26	1.2	1.3	2	0.92	1	0.84	24	3.6	510
040518SE15979	15979	5/18/2004	12	1.4	1.7	4.3	3.6	130	380	32	1.8	2.3	3.3	1.8	0.74	1.7	26	2.8	54
040810SE15979	15979	8/10/2004	12	1.3	2.1	4.6	3.5	150	4400	29	2.4	2.6	3.8	2	1.4	1.8	29	3.8	310
A	15979	8/10/2004	4.8	0.65	1.2	2.5	2.1	71	2100	12	1	1.6	2	1.2	0.5	1.1	12	1.7	110
B	15979	8/10/2004	12	1.2	1.9	5	3.7	150	4200	30	2.6	2.9	0.21	2.3	1.4	2.1	27	3.8	290
C	15979	8/10/2004	11	0.85	1.6	3.9	3.2	110	3100	35	3.5	3	0.55	2	1.1	1.8	25	4.5	360
D	15979	8/10/2004	11	1.2	1.7	4.3	3.1	110	2900	27	2.4	2.8	0.16	1.9	1.1	1.9	23	2.1	210
041104SE15979	15979	11/4/2004	12	1.4	2	5	4	150	5100	29	2	2.7	4	2	0.93	2.3	26	2.6	210

TABLE A.1: Concentration Values Used for PMF Modeling (ng/kg - for all samples)

Sample ID	Station ID	Sample Date	2378-TCDD	12378-PeCDD	123478-HxCDD	123678-HxCDD	123789-HxCDD	1234678-HpCDD	OCDD	2378-TCDF	12378-PeCDF	23478-PeCDF	123478-HxCDF	123678-HxCDF	123789-HxCDF	234678-HxCDF	1234678-HpCDF	1234789-HpCDF	OCDF
050816SE15979	15979	8/16/2005	19	1.5	0.26	5.6	4.8	150	3100	52	3.5	3.5	0.325	3.6	2.6	2.5	39	7.8	520
040810SE15980	15980	8/10/2004	12	1.7	2.3	5.8	4.3	160	5000	30	2.6	3.3	8.1	3.1	1.5	2.3	32	4.2	360
050818SE16	16	8/18/2005	89	1.1	0.055	0.79	0.86	21	590	440	7.6	7.3	7.2	2.3	0.91	0.66	2.9	0.95	8.7
020821SE16496	16496	8/21/2002	20	0.335	0.145	9.7	10	270	6600	46	0.345	4.8	8.3	3.2	3.1	3.4	40	4.9	330
030511SE16496	16496	5/11/2003	21	0.335	2.5	5.3	5.3	180	4600	50	0.25	3.3	6	2	0.96	2	32	3.2	340
020822SE16499	16499	8/22/2002	16	2.2	2.5	6.9	6.4	150	3300	36	1.2	2.6	4.6	1.8	1.4	1.8	28	2.6	210
021024SE16499	16499	10/24/2002	9.9	1.3	2.6	7	5.5	140	3200	20	1.6	1.9	4.1	1.9	0.78	2.1	26	3	170
040319SE16499	16499	3/19/2004	29	2.2	2.9	9.6	6.3	160	2700	55	2.7	2.5	7.4	3.4	0.75	2	29	3.9	210
041109SE16499	16499	11/9/2004	56	5.7	5.5	28	18	360	5100	110	4	4.4	0.09	3.9	1.6	3.8	64	5.7	360
020819SE16618	16618	8/19/2002	5.3	0.35	0.17	1.6	1.2	27	670	15	0.245	0.66	0.95	0.52	0.27	0.23	5.2	0.37	46
030506SE16618	16618	5/6/2003	41	3.1	3.5	8	6.3	230	4100	100	0.355	4.5	5.9	2.4	1.6	3.1	47	6.4	540
040319SE16618	16618	3/19/2004	3.3	0.285	1.1	1.7	2	58	1400	7.3	0.55	0.51	1.3	0.48	0.28	0.38	6.4	1	53
041109SE16618	16618	11/9/2004	12	0.84	1.7	3.5	4.5	110	3500	31	1.2	1.3	0.085	0.87	0.41	0.76	12	1.3	150
030529SE16622	16622	5/29/2003	0.55	0.315	1.7	4.3	4.4	150	6600	1.2	0.235	0.82	1.3	1.1	0.235	0.195	13	1.3	44
050817SE17	17	8/17/2005	21	0.55	0.81	1.9	2.3	66	2400	73	2.2	2	3.1	0.86	0.3	0.65	8.1	1.2	86
021024SE17970	17970	10/24/2002	1	0.32	0.74	1.2	1.7	49	1500	3.8	1.3	0.81	0.77	0.34	0.24	0.195	2.6	0.185	16
020824SE17971	17971	8/24/2002	14	0.335	4.7	10	7.8	340	6200	32	0.25	2.7	5	1.8	0.86	3	49	4	390
021028SE17971	17971	10/28/2002	8.3	1.2	1.6	4.1	4.6	120	3500	21	1.6	1.5	3	1.4	0.64	1.2	16	1.5	170
050817SE18	18	8/17/2005	25	0.97	1.7	3.8	4	120	3700	63	5.1	3.6	4.7	2.8	2.6	1.6	19	3.1	310
040802SE18388	18388	8/2/2004	10	0.87	1.6	4.1	3.6	140	4800	28	2	1.6	2.7	1.4	0.63	1.4	14	2.5	140
040811SE18389	18389	8/11/2004	11	0.6	0.76	1.6	1.7	59	2100	33	0.1	1.2	1.8	0.77	0.36	0.55	5.6	0.68	56
040811SE18390	18390	8/11/2004	8	0.49	0.62	1.1	1.4	39	1500	26	0.82	0.71	0.125	0.61	0.165	0.175	4.6	0.41	36
040810SE18392	18392	8/10/2004	18	2.1	2.9	6.7	5.2	200	5200	50	0.165	4.3	5.7	3.2	1.5	3.2	34	4.2	220
050816SE18392	18392	8/16/2005	12	0.41	0.295	4	0.34	88	3100	36	2.8	3.5	0.255	1.8	1.5	0.24	16	2.7	140
050817SE19	19	8/17/2005	13	0.38	0.76	1.7	1.9	62	2700	41	1.8	1.4	2.3	0.75	0.41	0.51	6.8	0.96	58
050817SE2	2	8/17/2005	45	0.94	1.5	3	3.7	96	3600	150	4.8	4	5.8	2	0.92	1.1	9.9	1.7	63
050818SE20	20	8/18/2005	1.2	0.041	0.15	0.28	0.33	8.8	330	3.8	0.2	0.14	0.25	0.12	0.0345	0.13	0.85	0.07	6.6
050817SE21	21	8/17/2005	27	0.97	1.4	3.3	3.8	100	3900	94	3	2.8	4	1.3	0.78	1.1	10	1.4	68
050816SE22	22	8/16/2005	15	1	3.7	7.5	10	260	3900	38	0.21	4.9	5.2	2.3	1.6	1.4	25	2.7	140
050816SE23	23	8/16/2005	23	1.4	1.8	5.3	3.8	120	2700	72	2.7	6.7	4.6	2.5	1.1	1.6	29	2.3	150
050816SE24	24	8/16/2005	41	1.9	2.7	8.2	5.7	220	4500	110	6.4	6.1	8.5	3.5	1.9	1.8	38	4.3	230
050816SE25	25	8/16/2005	22	0.74	1.2	2.6	2.5	64	1800	50	1.9	2.2	4.3	1.5	0.65	1.2	14	2.3	270
050817SE26	26	8/17/2005	13	0.84	1.6	3.2	3	92	1800	29	1.9	2	3.6	1.7	1.4	1.3	28	4.7	480
050817SE27	27	8/17/2005	12	1.1	1.7	4.3	3.4	110	3100	31	3.4	3.4	5.1	2.3	0.76	2	37	5.4	940
050818SE3	3	8/18/2005	19	0.59	1	2.3	2.7	77	3200	63	2	1.8	2.7	0.92	0.27	0.69	8.6	1.3	93
050817SE4	4	8/17/2005	8.1	0.35	0.56	1.4	1.7	46	1800	28	0.98	0.87	1.4	0.8	0.27	0.38	4.7	0.68	41
050817SE5	5	8/17/2005	6.8	0.41	0.81	1.5	1.6	52	1700	23	0.83	0.86	1.3	0.43	0.26	0.42	5.7	0.68	54
050815SE6	6	8/15/2005	7.4	0.185	0.9	0.185	1.4	40	1500	24	0.83	0.8	1.3	0.64	0.16	0.105	4.7	0.6	35

TABLE A.1: Concentration Values Used for PMF Modeling (ng/kg - for all samples)

Sample ID	Station ID	Sample Date	2378-TCDD	12378-PeCDD	123478-HxCDD	123678-HxCDD	123789-HxCDD	1234678-HpCDD	OCDD	2378-TCDF	12378-PeCDF	23478-PeCDF	123478-HxCDF	123678-HxCDF	123789-HxCDF	234678-HxCDF	1234678-HpCDF	1234789-HpCDF	OCDF
050815SE7	7	8/15/2005	9.7	0.38	0.54	1.1	1.3	33	1300	31	0.95	0.92	1.8	0.05	0.075	0.41	4.8	0.65	65
050818SE8	8	8/18/2005	20	0.59	0.78	1.9	2.2	58	2000	71	2.1	1.9	3	1.1	0.56	0.61	7.3	1.3	90
050818SE9	9	8/18/2005	7.8	0.49	0.76	1.3	1.8	58	2900	25	0.99	0.84	1.4	0.06	0.3	0.38	4.3	0.54	36
D1_20060511	D1	5/11/2006	14.9	0.482	0.507	0.99	2	43.8	1290	46.4	1.61	1.06	2.28	0.76	0.0435	0.323	6.72	0.841	97.4
D2a_20060602	D2	6/2/2006	8.63	0.301	0.344	0.827	1.42	32.3	948	25.1	1.02	0.677	1.71	0.642	0.334	0.241	5.83	0.839	60.7
D3_20060511	D3	5/11/2006	3.33	0.144	0.096	0.284	0.476	11	308	9.54	0.371	0.249	0.522	0.206	0.0155	0.0135	2.25	0.203	22
SE-04	Point#4	8/20/2009	15	0.34	0.65	1.1	1.5	32	1000	49	1.3	1.3	1.4	0.51	0.32	0.32	2.1	0.195	16
SE-05	Point#5	8/20/2009	360	4	2	3.8	4.6	130	4600	1300	32	28	40	13	4.1	1.9	22	5.1	110
S10-0-1	S10	5/11/2006	10.566	0.339	0.477	1.085	1.774	43.382	1278.16	36.825	1.291	0.682	1.96	0.747	0.0165	0.255	7.529	0.843	82.467
S11-0-1	S11	5/11/2006	7.171	0.234	0.201	0.522	0.881	21.93	651.596	28.174	0.805	0.439	1.029	0.38	0.028	0.0245	4.198	0.467	46.893
S12-0-1	S12	5/11/2006	7.912	0.243	0.274	0.649	1.165	26.773	778.922	29.293	0.8	0.58	1.196	0.408	0.0415	0.036	5.164	0.462	54.215
S5-0-1	S5	5/11/2006	8.133	0.125	0.01	0.154	0.221	5.369	131.246	40.628	0.743	0.474	0.687	0.197	0.0095	0.0085	0.461	0.107	3.546
S6-0-1	S6	5/11/2006	4.692	0.0115	0.053	0.128	0.227	6.463	100.255	18.941	0.445	0.292	0.403	0.153	0.009	0.0075	0.673	0.11	4.648
S200-0-1	S7	5/11/2006	10.766	0.235	0.208	0.72	1.054	33.42	1161.14	55.367	1.231	0.805	1.179	0.416	0.009	0.13	2.231	0.267	21.783
S7-0-1	S7	5/11/2006	18.582	0.275	0.279	0.798	1.205	34.733	1157.62	84.144	1.722	1.089	2.013	0.604	0.025	0.152	3.564	0.509	34.289
S8-0-1	S8	5/11/2006	8.065	0.257	0.368	0.798	1.464	37.723	1019.35	26.515	0.871	0.598	1.413	0.511	0.0425	0.215	6.012	0.535	63.152
S9-0-1	S9	5/11/2006	4.371	0.0175	0.146	0.352	0.638	14.464	439.858	15.195	0.541	0.306	0.769	0.276	0.0155	0.099	2.774	0.292	30.037
F1NE1	SE-04	7/12/2005	908	12.4	1.215	3	3.94	128	4850	4210	107	89	129	31.3	13	7.15	39.8	11.3	34
F1NE2	SE-05	7/12/2005	814	9.74	1.195	1.49	1.5	43.8	1410	3530	71.7	61.8	99.1	26.3	8.57	5.09	26.2	8.36	34.3
F1NE4	SE-07	7/12/2005	51.2	1.16	1.24	3.21	4.87	147	6090	246	3.7	3.6	4.84	1.24	1.24	1.24	1.24	0.398	2.72
F1NE5	SE-08	7/12/2005	18500	182	3.55	11	5.74	188	3200	41300	1900	1290	5560	1390	440	222	962	354	475
F1NE6	SE-09	7/13/2005	5710	363	4.83	27.9	10.2	658	3980	8430	2400	1480	5220	1360	451	229	1300	531	1060
F1NE7	SE-09	7/13/2005	12900	349	4.71	26.9	10.1	591	6480	20600	3770	2330	8660	2290	656	349	2360	878	990
F1NE8	SE-11	7/13/2005	17900	323	4.2	15.9	7.03	367	4860	36700	2710	2030	4940	1270	403	216	1290	477	517
SJA1-SL-N	SJA1	4/15/2010	9970	102	2.13	8.75	4.4	200	2980	26900	1240	802	2510	603	28.3	73.5	788	282	514
SJA2-SL-N	SJA2	4/15/2010	2710	21.1	0.4085	3.27	2.12	91.6	1790	8980	8880	3360	9650	1790	80.7	478	1000	327	402
SJA3-SG-N	SJA3	4/13/2010	35.3	0.457	0.196	0.519	0.132	15.8	534	118	2.84	2	4.26	1.28	0.0535	0.275	2.83	0.599	18.2
SJA4-SG-N	SJA4	4/13/2010	61.7	0.778	0.327	0.942	0.877	32	1130	203	5.07	3.91	9.89	1.26	0.169	0.172	2.74	0.555	40.3
SJA5-SG-N	SJA5	4/13/2010	36.5	0.473	0.31	0.966	0.3625	29.1	972	119	2.64	2.2	4.52	1.34	0.06	0.4	3.98	0.805	32.2
SJB1-SG-N	SJB1	4/15/2010	15400	133	2.54	18.3	4.85	290	4870	41200	1500	990	3160	731	16.1	72.4	993	364	650
SJB2-SG-N	SJB2	4/15/2010	269	2.66	0.27	2.62	1.85	68.7	2230	898	49.7	25.5	74.9	19.9	1.5	2.66	24	8.23	86.2
SJB3-SG-N	SJB3	4/13/2010	65.3	0.936	0.607	1.75	2.08	51.3	1790	220	5.16	3.87	8.86	2.54	0.243	0.798	8	1.64	67.2
SJB4-SG-N	SJB4	4/13/2010	31.3	0.1765	0.1035	0.248	0.145	20.1	674	102	2.48	1.8	3.73	1.14	0.0276	0.04595	3.23	0.513	32.3
SJB5-SG-N	SJB5	4/13/2010	14	0.254	0.0735	0.691	0.2625	24.6	1020	45.9	1.31	1	2.28	0.684	0.02505	0.11	2.6	0.421	20.7
SJC1-SG-N	SJC1	4/15/2010	9720	90.9	0.65	1.98	3.14	74.9	1420	35900	732	618	1110	283	14.3	34.7	351	118	231
SJC3-SG-N	SJC3	4/14/2010	6.58	0.03415	0.266	0.609	0.249	19.4	706	21.6	0.768	0.55	1.25	0.1975	0.066	0.057	2.28	0.1635	21.1
SJC4-SG-N	SJC4	4/14/2010	12.1	0.0765	0.393	0.927	0.976	36.2	1340	45.7	0.55	1.04	2.11	0.3145	0.068	0.307	3.91	0.55	0.147
SJC5-SG-N	SJC5	4/14/2010	9.3	0.244	0.385	1.03	1.19	38.4	1500	34	0.4385	0.663	1.72	0.605	0.0555	0.229	4.13	0.589	39.3

TABLE A.1: Concentration Values Used for PMF Modeling (ng/kg - for all samples)

Sample ID	Station ID	Sample Date	2378-TCDD	12378-PeCDD	123478-HxCDD	123678-HxCDD	123789-HxCDD	1234678-HpCDD	OCDD	2378-TCDF	12378-PeCDF	23478-PeCDF	123478-HxCDF	123678-HxCDF	123789-HxCDF	234678-HxCDF	1234678-HpCDF	1234789-HpCDF	OCDF
SJD1-SG-N	SJD1	4/14/2010	552	5.15	0.2535	1.57	1.91	51.2	1590	1800	41.6	30.8	59.4	15.9	0.292	2.51	23	6.72	82
SJD2-SG-N	SJD2	4/14/2010	13.9	0.37	0.161	0.954	1.78	37	1350	48.2	1.12	0.372	2.03	0.633	0.051	0.0775	2.04	0.174	17.9
SJD3-SG-N	SJD3	4/14/2010	31.8	0.487	0.214	1.81	1.99	57.6	1860	80.5	1.65	1.57	2.22	0.758	0.04885	0.387	5.32	0.589	67
SJD4-SG-N	SJD4	4/14/2010	12.6	0.096	0.329	0.885	0.968	31.7	1110	42.4	0.945	0.922	1.52	0.46	0.0595	0.219	3.54	0.53	41.3
SJD5-SG-N	SJD5	4/14/2010	14	0.16	0.472	1.42	1.64	50.7	1750	43.2	1.46	0.996	2.31	0.827	0.0304	0.117	5.01	0.573	62.6
SJE1-SG-N	SJE1	4/14/2010	1020	8.3	0.296	0.4675	0.334	22.7	636	3590	73.4	59.7	95.3	23.7	0.944	3.53	25.7	8.97	36.5
SJE2-SG-N	SJE2	4/14/2010	360	2.77	0.162	0.381	1.2	32.9	897	1370	20.3	19.1	24.4	6.41	0.296	0.4205	10.7	1.125	38.1
SJE3-SG-N	SJE3	4/14/2010	16.4	0.0475	0.183	0.2275	0.25	15.5	484	66.2	1.27	0.885	1.47	0.457	0.03845	0.03465	1.18	0.073	7.66
SJGB004-GR1	SJGB004	5/17/2010	7.53	0.073	0.271	0.761	0.803	37.9	1460	38.7	0.618	0.531	1.1	0.155	0.03675	0.0341	1.34	0.04135	10.7
SJGB005-GR1	SJGB005	5/23/2010	6.61	0.061	0.0995	0.578	0.933	19.1	633	27.4	0.761	0.268	1.04	0.308	0.0545	0.0675	1.67	0.091	17.8
SJGB007-GR1	SJGB007	5/23/2010	644	6.54	0.16	0.796	0.44	17.6	476	1520	56	38.4	65.9	16.6	1.6	2.18	21	7.82	69.2
SJGB008-GR1	SJGB008	5/23/2010	111	1.14	0.0444	0.112	0.402	7.87	259	638	9.07	7.28	18	4.29	0.154	0.1595	8.83	3.15	12.7
SJNE004-GR1	SJNE004	5/23/2010	3.49	0.0555	0.1185	0.545	0.555	20.1	760	17.6	0.524	0.405	0.611	0.118	0.1255	0.073	2.17	0.158	31.5
SJNE007-GR1	SJNE007_Grab	5/12/2010	33.8	0.315	0.0775	0.1485	0.355	13.9	473	138	2.31	1.9	3.21	0.4665	0.0963	0.074	1.77	0.507	11
SJNE008-GR1	SJNE008_Grab	5/11/2010	32.8	0.494	0.2455	1.42	1.88	50.6	1520	138	3.33	2.17	12	3.26	0.0271	0.659	12.1	2.62	66.8
SJNE011-GR1	SJNE011	5/11/2010	10.3	0.0825	0.1915	1.53	0.51	56.8	1220	41.2	0.834	0.618	1.56	0.457	0.1325	0.118	4.75	0.1765	63.6
SJNE019-GR1	SJNE019	5/12/2010	4.98	0.02495	0.168	0.58	0.144	17.2	442	12.3	0.1465	0.309	0.702	0.24	0.0323	0.182	2.3	0.0825	27.4
SJNE022-GR1	SJNE022-1	5/17/2010	126	1.02	0.03045	0.044	0.0371	1.01	25.7	425	11.6	7.73	40.5	8.07	0.0675	1.22	9.57	7.09	9.04
SJNE022-GR2	SJNE022-2	5/17/2010	1600	10.2	0.151	1.18	0.829	28	650	4930	177	104	247	63	3.12	8.76	63.1	25.2	49
SJNE022-GR3	SJNE022-3	5/17/2010	1760	13.3	0.234	1.39	0.327	18.1	293	4190	193	104	347	82.7	3.57	14.6	85.8	35.1	51.7
SJNE023-GR1	SJNE023_Grab	5/14/2010	9.13	0.057	0.0625	0.799	0.914	23.7	598	32.5	0.2515	0.481	1.23	0.345	0.1095	0.0725	1.82	0.122	18.6
SJNE027-GR1	SJNE027	5/14/2010	9.87	0.04495	0.0373	0.185	0.0685	6.83	242	36.2	0.871	0.629	1.23	0.303	0.02465	0.0235	0.853	0.03605	6.38
SJNE032-GR1	SJNE032_Grab	5/14/2010	111	0.819	0.079	1.15	1.03	40	1190	362	7.73	5.83	12.6	1.575	0.0885	0.428	8.78	1.57	45.5
SJNE033-GR1	SJNE033_Grab	5/14/2010	17.5	0.289	0.1135	0.58	1.36	37.1	1210	46.9	1.21	1.04	2.05	0.2985	0.189	0.214	5.68	0.217	79.8
SJNE039-GR1	SJNE039	5/14/2010	18	0.0705	0.0985	1.75	1.68	62.7	2210	60.7	1.95	0.66	3.59	1.06	0.292	0.265	7.32	0.3105	67.7
SJNE049-GR1	SJNE049	5/13/2010	9.45	0.089	0.108	1.09	0.695	37.8	1410	10.4	0.3865	0.637	1.27	0.571	0.0845	0.371	3.75	0.1645	42.5
SJNE052-GR1	SJNE052	5/12/2010	2.95	0.0483	0.316	0.692	0.726	24.4	784	9.38	0.338	0.272	0.555	0.109	0.063	0.055	1.95	0.306	17.4
SJNE053-GR1	SJNE053	5/13/2010	5.08	0.0366	0.323	0.918	0.353	35	1390	16.8	0.563	0.216	1.1	0.183	0.1095	0.1095	3.46	0.174	39
SJNE059-GR1	SJNE059	5/12/2010	3.25	0.0595	0.26	0.912	0.984	32.3	1110	10.7	0.377	0.052	0.328	0.267	0.0805	0.1345	3.13	0.317	23.1
SJSH057-GR1	SJSH057	5/23/2010	1.53	0.0387	0.123	0.301	0.442	10.6	393	5.92	0.206	0.0319	0.245	0.09	0.0645	0.03995	1	0.0393	12.2
SJVS001-GR1	SJVS001	5/21/2010	8770	67.4	0.928	5.67	2.1	140	3370	34400	736	468	1020	226	13.8	35.9	264	122	194
SJVS016-GR1	SJVS016	5/20/2010	525	4.65	0.04815	0.489	0.573	13.8	478	2890	52	38.7	62.2	13.9	0.3425	1.86	11.5	5.09	19.5
10	SS-10	12/16/2004	0.27	0.6	1.6	4.4	3.6	85	1000	1.4	0.5	1.2	1.1	0.8	0.55	2.1	15	1.75	34
108	SS-108	9/30/2004	0.11	0.185	0.6	1.6	0.165	36	480	0.44	0.09	0.36	0.56	0.16	0.69	0.39	4.3	0.14	15
13	SS-13	10/1/2004	0.195	1	2	4.4	2.9	130	1900	0.12	0.35	0.145	0.96	0.74	0.125	0.97	18	1.1	58
13	SS-13	1/12/2005	0.08	0.42	1	2.4	2	58	670	0.12	0.1	0.115	0.6	0.99	0.105	1.3	18	0.96	21
14	SS-14	3/2/2005	0.08	0.69	1.1	2.3	2	53	800	0.5	0.3	0.41	0.8	0.115	0.105	0.13	9.3	0.93	23
20041001sdSS-7	SS-7	10/1/2004	0.235	0.55	0.62	1.6	0.93	47	840	0.43	0.085	0.7	0.16	0.165	0.24	0.8	6.2	0.6	22

TABLE A.1: Concentration Values Used for PMF Modeling (ng/kg - for all samples)

Sample ID	Station ID	Sample Date	2378-TCDD	12378-PeCDD	123478-HxCDD	123678-HxCDD	123789-HxCDD	1234678-HpCDD	OCDD	2378-TCDF	12378-PeCDF	23478-PeCDF	123478-HxCDF	123678-HxCDF	123789-HxCDF	234678-HxCDF	1234678-HpCDF	1234789-HpCDF	OCDF
20041001sdSS-9	SS-9	10/1/2004	0.33	2.6	4.7	7.5	12	390	31000	0.26	0.165	0.095	0.125	0.44	0.47	0.41	3.6	0.14	13
20050127sdSS-9	SS-9	1/27/2005	0.08	0.57	1.2	2.2	2.7	110	4800	0.12	0.1	0.115	0.42	0.26	0.105	0.3	2.4	0.24	5.2
11193-SE-1	11193	8/11/2011	45	1.3	1.3	2.6	3.5	120	4200	210	4.2	4.1	7.8	2.5	0.135	1.3	13	1.4	170
11264-SE-1	11264	8/23/2011	7.4	0.68	1.2	2.3	2.7	92	2200	19	1	1.1	1.9	1	0.13	0.72	14	1.3	310
11274-SE-1	11274	8/19/2011	8.9	0.89	2.9	12	10	250	5200	28	2.7	5.6	18	4.9	2.9	3.4	52	8.4	700
11292-SE-1	11292	8/12/2011	5.6	1.7	3.5	9	5.3	290	5000	17	9	4.5	5.2	3.5	2.9	5.1	47	4.4	190
11298-SE-1	11298	8/23/2011	19	2.3	3.5	11	7	390	7400	63	2.7	5.1	7.4	9.5	1.3	3.1	67	5.1	300
11421-SE-1	11421	6/23/2011	6.1	0.83	0.93	1.3	2.1	38	430	18	1.2	0.77	1.6	0.56	0.12	0.06	1.8	0.145	3.9
13310-SE-1	13310	6/15/2011	2.3	0.57	1.2	2.2	3	85	2000	7	0.065	0.49	1.1	0.7	0.105	0.095	5.9	0.245	45
13315-SE-1	13315	7/5/2011	0.59	0.84	2.1	2.6	4.8	92	2100	1.9	0.41	0.34	0.51	0.62	0.032	0.0445	2.6	0.065	7
13322-SE-1	13322	6/22/2011	0.55	3	3.9	7.8	10	260	3400	2	1.8	1.2	1.1	1.4	1.2	2.7	21	1.7	51
13338-SE-1	13338	8/9/2011	1.3	0.52	0.83	1.4	2.2	49	1400	3.7	0.125	0.4	0.19	0.59	0.205	0.205	3.7	0.32	40
13344-SE-1	13344	8/9/2011	13	1.8	3.4	6.2	7.8	250	9000	38	2.2	2.8	4.5	4.4	0.235	2.6	36	4.5	410
13361-SE-1	13361	8/13/2011	0.135	0.16	1.3	2.6	2.9	110	1400	1.3	0.055	0.95	1.6	0.98	0.115	0.1	12	0.26	59
13561-SE-1	13561	6/28/2011	0.215	0.215	0.91	1.7	2.2	68	1200	0.9	0.77	0.48	2.1	0.94	0.34	0.195	17	2.3	130
14543-SE-1	14543	7/6/2011	0.46	1.1	1.7	2.3	4.8	96	2500	1.8	0.12	0.24	0.41	0.49	0.145	0.16	2.4	0.23	12
14560-SE-1	14560	7/8/2011	0.68	0.75	1.9	2.7	4.7	98	2000	2	0.08	0.48	0.85	0.71	0.14	0.085	4.6	0.145	19
15215-SE-1	15215	6/23/2011	0.065	0.59	1.5	2	3.6	81	1100	0.75	0.055	0.47	0.86	0.52	0.048	0.042	4.5	0.105	21
15242-SE-1	15242	6/8/2011	0.86	0.8	2.6	3.4	6.4	140	2800	2.3	0.06	0.45	0.042	0.5	0.065	0.05	4.9	0.14	17
15904-SE-1	15904	6/14/2011	1.9	0.64	1.3	2.4	3.2	110	2900	5.8	0.65	0.58	1.2	0.52	0.085	0.0495	8	0.145	60
15911-SE-1	15911	6/8/2011	0.105	0.9	2.4	3.3	5.8	130	2400	1.5	0.065	0.38	0.76	0.065	0.085	0.065	4.1	0.14	13
15916-SE-1	15916	6/28/2011	0.58	0.68	1.5	1.9	3.7	75	1300	1.5	0.065	0.48	0.055	0.07	0.095	0.08	2.6	0.13	6.6
16213-SE-1	16213	7/7/2011	1.7	1.2	1.9	2.3	4.2	96	1900	4.8	0.66	0.6	1.2	0.99	0.08	0.85	6.3	0.95	32
16215-SE-1	16215	7/8/2011	0.06	0.32	0.55	1.2	2.1	47	860	1	0.0275	0.19	0.36	0.28	0.043	0.0285	1.9	0.095	3.5
16230-SE-1	16230	6/30/2011	1.2	0.72	1.9	2.7	3.6	79	1700	3.6	0.71	0.54	0.84	0.88	0.195	0.245	4.1	0.3	22
16548-SE-1	16548	6/28/2011	0.16	0.6	0.97	2.2	2.9	85	1400	1.1	0.63	0.48	3.4	1.4	0.09	0.07	25	3.2	190
16571-SE-1	16571	6/16/2011	0.085	0.64	1	3.1	3.1	88	2200	1.6	0.82	0.76	2	1.5	0.145	1.9	18	1.7	43
20574-SE-1	20574	8/26/2011	0.075	0.48	0.8	2.4	1.8	91	1900	1.1	0.46	1.1	1.2	0.92	0.055	1.3	17	1.2	51

TABLE A.2: Uncertainty Values Used for PMF Modeling (ng/kg - for all samples)

Sample ID	Station ID	Sample Date	2378-TCDD	12378-PeCDD	123478-HxCDD	123678-HxCDD	123789-HxCDD	1234678-HpCDD	OCDD	2378-TCDF	12378-PeCDF	23478-PeCDF	123478-HxCDF	123678-HxCDF	123789-HxCDF	234678-HxCDF	1234678-HpCDF	1234789-HpCDF	OCDF
050817SE1	001	8/17/2005	5.9	0.61	0.62	0.8	0.82	8.8	280.5	20.5	1.01	0.95	1.01	0.74	0.593	0.62	1.32	0.66	6.3
050830SE10	010	8/30/2005	11.5	0.20833	0.596	0.73	0.74	7.3	270.5	38.5	1.6	1.42	2	0.85	0.68	0.61	1.6	0.73	9.4
050818SE11	011	8/18/2005	36.5	0.87	0.61	0.7	0.68	8	270.5	140.5	4	3.5	5.2	1.8	0.97	0.77	2.3	1.03	7
020801SE11092	11092	8/1/2002	0.65	0.76	1.04	2.5	1.5	81.5	1300.5	0.82	0.35833	0.69	0.81	0.19167	0.553	0.74	5.6	0.92	14.5
030430SE11092	11092	4/30/2003	0.781	0.94	1.35	2.11	1.52	26.7	652.2	1.02	0.91667	0.96	1.47	1.05	0.7	1.17	6.4	1.9	16.3
020731SE11111	11111	7/31/2002	0.75	0.91667	0.8	0.94	1.06	13.5	330.5	1.07	0.578	0.588	0.62	1.58333	0.41667	0.598	1.44	0.62	6.2
030501SE11111	11111	5/1/2003	1.03	1.14	1.23	1.79	1.38	14.4	423.6	0.77	0.667	0.438	0.5	0.625	0.64167	0.634	1.84	1.58	6.8
020808SE11193	11193	8/8/2002	7.4	0.75833	0.54	1	0.6	3.9	100.5	29.5	1.01	1.13	1.5	0.68	0.61	0.61	1.1	0.64	2.5
021031SE11193	11193	10/31/2002	4.9	0.58	0.571	0.68	0.67	5.6	150.5	16.5	0.89	0.91	0.99	0.69	0.562	0.581	1.14	0.584	3.7
030513SE11193	11193	5/13/2003	9.73	0.55833	0.253	1.32	0.74	4.56	151.1	39.38	1.25	1.02	1.51	0.48	0.587	0.481	0.84	0.53	4.9
040324SE11193	11193	3/24/2004	6.62	1.33	1.75	3	1.2	17.2	522.4	23.31	1.35	1.28	1.61	0.8	0.54	0.72	2.5	0.96	16.69
040811SE11193	11193	8/11/2004	1.62	0.266	0.275	0.269	0.31	3.56	144.1	5.75	0.3	0.37	0.25	0.279	0.175	0.292	0.58	0.31667	2.49
041104SE11193	11193	11/4/2004	3.33	0.294	0.36	0.48	0.56	6.65	203.9	12.28	0.44	0.48	0.54	0.34	0.16667	0.31	1.11	0.46	10.75
040324SE11197	11197	3/24/2004	1.36	0.462	0.50833	0.84	1.16667	8.1	263.2	2.01	0.53333	0.368	1.16667	0.382	0.387	0.356	1.03	0.454	4.39
040811SE11197	11197	8/11/2004	2.15	0.39	0.49	0.75	1	19.6	734.1	5.79	0.67	0.49	0.83	0.69	0.519	0.53	2.01	0.99	10.78
041109SE11197	11197	11/9/2004	1.2	0.329	0.74	0.98	1.08	10.65	384	2.84	0.31	0.35	0.48	0.301	0.225	0.342	1.23	0.65	7.98
021024SE11252	11252	10/24/2002	0.84	0.72	0.82	1.03	1.23	17.5	380.5	1.27	0.579	0.6	0.63	0.6	0.425	0.61	1.8	0.63	9.1
030528SE11252	11252	5/28/2003	0.59	0.81	0.42	1.6	0.98	9.81	231.1	0.98	0.562	0.323	0.66	0.323	0.41667	0.34167	0.97	0.463	7.4
040311SE11252	11252	3/11/2004	0.96	0.632	0.83333	0.63	0.58	7.79	141.8	1.07	0.213	0.43333	0.4	0.359	0.249	0.218	4	0.44167	4.8
041108SE11252	11252	11/8/2004	0.47	0.49	0.45	0.63	0.72	10.34	204	0.55	0.231	0.282	0.342	0.26667	0.375	0.301	0.84	0.31667	3.48
020819SE11261	11261	8/19/2002	0.84	0.55833	0.535	1	0.6	3.2	64.5	1.34	0.569	0.565	0.43333	0.554	0.41667	0.34167	1.04	0.566	8.3
021026SE11261	11261	10/26/2002	1.15	0.56667	0.589	0.68	0.7	6.2	150.5	2.1	0.6	0.62	0.66	0.572	0.425	0.566	1.38	0.583	14.5
030511SE11261	11261	5/11/2003	1.2	0.765	0.233	1.39	0.77	5.66	171.1	2.77	0.425	0.39	0.67	0.225	0.425	0.35	1.09	0.477	10.9
040324SE11261	11261	3/24/2004	1.04	0.375	0.60833	0.57	0.56	4.38	101.3	1.98	0.461	0.393	0.38	0.26667	0.263	0.232	0.78	0.368	8.84
041109SE11261	11261	11/9/2004	1.74	0.363	0.41	0.49	0.61	8.55	204	3.9	0.6	0.37	0.49	0.32	0.392	0.333	1.4	0.66	17.77
020819SE11264	11264	8/19/2002	1.44	0.55833	0.577	0.77	0.65	6.7	130.5	2.6	0.63	0.68	0.75	0.63	0.554	0.6	2	0.66	17.5
030529SE11264	11264	5/29/2003	1.93	0.56667	0.52	1.58	1.01	10.36	211.1	3.52	0.84	0.71	1.15	0.58	0.66	0.512	3.01	0.79	55.4
040324SE11264	11264	3/24/2004	1.57	0.453	0.75	1.06	0.8	9.18	171.8	4.21	2	1.36	1.44	0.58	0.55	0.52	3.8	1.04	61.74
041104SE11264	11264	11/4/2004	1.4	0.38	0.39	0.48	0.53	10.55	264.1	3.04	0.44	0.43	0.62	0.4	0.347	0.38	1.61	0.52	19.79
040401SE11265	11265	4/1/2004	1.84	0.68	0.62	1.01	0.88	18.79	413.9	4.28	1.2	1.09	13.3333	0.9	1.08	0.97	10.4	2.11	210.74
041104SE11265	11265	11/4/2004	1.92	0.34	0.64	0.64	0.65	11.48	274.1	4.44	0.56	0.24167	0.67	0.58	0.335	0.42	2.31	0.5	37.79
040811SE11267	11267	8/11/2004	2.19	1	0.64	1.38	1.1	23.5	574.1	0.2	2.26	1.72	3.22	0.93	1.68	1.06	27.91	3.46	650.9
050816SE11267	11267	8/16/2005	1.9	0.66	0.77	1.16	0.91	14.5	190.5	6.3	3.4	3.4	5.9	1.5	2.1	1.5	46.5	6.7	1200.5
050816SE11268	11268	8/16/2005	4.1	0.67	0.74	1.14	1.05	15.5	360.5	10.1	1.01	0.97	1.21	0.81	0.83	0.77	5.4	1.38	130.5
040810SE11269	11269	8/10/2004	1.24	0.45	0.48	0.55	0.76	10.13	314	2.32	0.55	0.48	0.42	0.42	0.43	0.5	1.8	0.74	18.2
020828SE11270	11270	8/28/2002	2.9	0.55833	0.65	0.79	0.66	8.3	200.5	5.4	0.81	0.85	0.43333	0.475	0.41667	0.63	1.8	0.61	9.7
030506SE11270	11270	5/6/2003	0.6	0.56667	0.581	1.33	0.697	4.38	141.5	0.84	0.425	0.451	0.64	0.401	0.425	0.489	1.19	0.38333	5.7
040810SE11270	11270	8/10/2004	0.96	0.47	0.48	0.8	0.64	16.58	664.1	1.84	0.46	0.49	0.15	0.47	0.307	0.46	3.14	0.64	13.84
040810SE11271	11271	8/10/2004	0.81	0.325	0.54	0.7	0.64	10.43	473.8	1.56	1	0.46	0.48	0.66	0.366	0.53	2.25	0.83	9.01
020725SE11272	11272	7/25/2002	0.88	1.08333	0.7	0.89	0.81	11.5	400.5	1.8	0.83333	0.62	3.91667	0.625	0.83333	0.596	1.7	1.16667	7.9
030430SE11272	11272	4/30/2003	1.23	0.96	1.1	1.64	1.16	18.4	1001.6	1.44	0.5	0.6	0.72	0.61	0.48333	0.6	2.58	1.1	16.3
020828SE11273	11273	8/28/2002	2.2	1	0.43333	1	0.65	39.5	470.5	11.5	17.5	17.5	37.5	11.5	8.9	5.3	150.5	16.5	4200.5
030503SE11273	11273	5/3/2003	3.9	1.33333	2.34	4.1	3.2	44.9	644.3	11.5	9.5	12.92	23.1	9.4	11.8	5	111.9	17.5	3402.4
020730SE11274	11274	7/30/2002	0.72	1.08333	0.72	1.16	0.86	17.5	560.5	1.24	0.66	0.83	0.89	0.67	0.825	0.77	3.3	1.25	7.8
030501SE11274	11274	5/1/2003	0.78	0.575	1.15	1.5	0.97	9.2	294	0.93	0.603	0.74	0.78	0.671	0.41667	0.67	1.77	1.096	5.5

TABLE A.2: Uncertainty Values Used for PMF Modeling (ng/kg - for all samples)

Sample ID	Station ID	Sample Date	2378-TCDD	12378-PeCDD	123478-HxCDD	123678-HxCDD	123789-HxCDD	1234678-HpCDD	OCDD	2378-TCDF	12378-PeCDF	23478-PeCDF	123478-HxCDF	123678-HxCDF	123789-HxCDF	234678-HxCDF	1234678-HpCDF	1234789-HpCDF	OCDF
040518SE11274	11274	5/18/2004	0.28	0.246	0.33	0.38	0.41	8.69	22.39	0.65	0.247	0.33	0.32	0.316	0.238	0.348	1.3	0.362	2.85
020829SE11280	11280	8/29/2002	2.3	0.68	0.91	1.44	1.06	25.5	410.5	4.8	0.89	1.17	1.1	0.225	0.65	0.96	5.4	0.95	22.5
021202SE11280	11280	12/2/2002	3.2	0.58333	1.16	2.3	1.31	48.5	770.5	7	1.19	1.6	1.6	1.41	0.75	0.96	10.5	1.24	51.5
030506SE11280	11280	5/6/2003	3.65	0.75833	1.37	2.2	1.54	35.4	562.8	7.03	1.5	1.35	1.93	1.2	0.97	1.27	6.9	1.65	31.4
040401SE11280	11280	4/1/2004	33.65	1.36	1.44	3.31	1.82	73.3	904	81.71	2.43	4.14	4.35	2.94	0.69	4.58	17.1	2.45	74.77
040810SE11280	11280	8/10/2004	3.06	0.86	1.23	1.81	1.25	32.5	624.1	6.78	1.49	1.24	1.85	1.29	1.03	1.34	5.58	2.47	26.1
041104SE11280	11280	11/4/2004	65.45	1.72	1.18	3.45	1.94	68.67	954.1	160.46	2.94	3.68	3.22	1.43	0.85	1.86	13.4	1.96	76.78
050816SE11280	11280	8/16/2005	1.9	0.61	0.68	0.97	0.85	13.5	250.5	4.3	0.84	0.81	1.13	0.74	0.6	0.63	2.8	0.73	12.5
020826SE11287	11287	8/26/2002	0.63	0.58	0.66	0.81	0.73	8.7	130.5	0.85	0.31667	0.61	0.65	0.6	0.55	0.63	2.5	0.63	6.9
030505SE11287	11287	5/5/2003	0.93	0.70833	0.81	1.52	0.97	10.3	122	1.19	0.41667	0.54	0.79	0.78	0.65833	0.95	2.62	1.08333	8.4
040402SE11287	11287	4/2/2004	1.72	0.68	0.71	1.36	0.89	26.74	354	2.62	0.54	0.58	0.99	0.62	0.55	0.61	5.07	0.91	15.77
041104SE11287	11287	11/4/2004	1.31	0.56	0.58	1.03	0.79	23.41	384.1	2.94	0.49	0.6	0.55	0.57	0.31	0.64	4.71	0.82	14.78
020905SE11292	11292	9/5/2002	0.69	2.83333	0.94	1.6	1.12	29.5	430.5	1.6	0.99	1.37	1.05	1.08333	0.84	1.1	5.2	1.06	30.5
021210SE11292	11292	12/10/2002	3	7.58333	1.7	7.6	2.9	210.5	4100.5	5.3	1.9	2.8	5.4	2.9	1.44	1.8	46.5	3.4	140.5
030506SE11292	11292	5/6/2003	0.675	0.65833	0.94	1.8	0.94	20.1	264.4	0.6	0.41667	0.76	0.81	0.75	0.568	0.7	5.1	1.68	18.4
040402SE11292	11292	4/2/2004	0.534	0.75	0.77	1.23	0.97	27.56	394	0.66	0.42	0.66	0.55	0.55	0.41	0.69	4.77	0.89	12.77
041104SE11292	11292	11/4/2004	0.44	0.43	0.74	1.57	0.78	25.4	384	0.73	0.31	0.52	0.83	0.5	0.426	0.61	4.7	0.84	12.78
020729SE11298	11298	7/29/2002	1.5	1.75	0.9	1.5	1.15	29.5	680.5	3.8	0.8	0.98	0.97	0.84	0.64	0.92	5.3	2.83333	13.5
030502SE11298	11298	5/2/2003	1.52	0.60833	1.05	1.96	1.3	22.5	464.2	2.6	0.50833	0.85	0.97	0.95	0.692	1	4.6	1.7	10.5
020905SE11300	11300	9/5/2002	1.7	0.55	0.75	1.37	0.98	20.5	350.5	10.5	17.5	7.9	33.5	7.2	3.3	2.4	13.5	4.1	16.5
030529SE11300	11300	5/29/2003	1.75	0.55	1.32	2.8	1.47	40.5	463.2	6.63	6.29	2.75	9.81	2.19	1.69	0.97	10.91	2.8	34.3
020826SE11302	11302	8/26/2002	0.20833	0.55833	0.61	0.83	0.72	10.5	160.5	0.6	0.41667	0.63	0.67	0.225	0.58	0.63	2.1	0.65	10.5
030501SE11302	11302	5/1/2003	1.35	2.16667	2.71	2.87	2	26.3	296.4	1.42	1.08333	1.18	1.33333	1.41667	1.16667	1.74	6.6	2.08333	24.3
030504SE11305	11305	5/4/2003	0.75833	1.16667	0.8	1.63	0.84	10.2	112.2	0.82	0.69167	0.95	0.74	0.58	0.54167	0.74	2.12	0.98	6.3
020812SE11347	11347	8/12/2002	0.20833	0.55833	0.57	0.68	0.62	4.6	61.5	0.54	0.41667	0.562	0.43333	2.25	0.41667	0.577	1.6	0.555	2.3
030504SE11347	11347	5/4/2003	0.225	0.55833	0.407	1.47	0.76	7.89	97.1	0.325	0.41667	0.21667	0.598	0.317	0.41667	0.501	1.76	0.775	8.8
020812SE11382	11382	8/12/2002	0.225	0.61	0.7	1.06	0.84	14.5	200.5	0.59	0.591	0.73	0.69	0.66	0.572	0.83	3.3	1.41667	8.6
030505SE11382	11382	5/5/2003	0.41667	0.63333	0.89	1.55	1.09	13.1	171.1	0.518	0.54167	0.54	0.43333	0.47	0.525	0.66	2.88	0.83333	10.2
050830SE12	12	8/30/2005	4	0.592	1.12	2	1.03	130.5	1100.5	13.5	0.89	0.87	1.1	0.74	0.59	0.67	5.7	0.88	39.5
050817SE13	13	8/17/2005	1.3	0.53	0.542	0.594	0.62	3.1	73.5	3.4	0.75	0.63	0.78	0.597	0.563	0.07667	0.86	0.557	3.8
021022SE13336	13336	10/22/2002	0.87	0.65	0.92	1.26	1.21	22.5	530.5	1.39	0.63	0.69	0.83	0.7	0.48333	0.79	3.2	0.67	13.5
020814SE13337	13337	8/14/2002	1.5	0.49167	0.76	1.12	1.03	15.5	300.5	2.8	0.78	0.8	1	0.19167	0.597	0.72	2.9	0.77	26.5
030528SE13337	13337	5/28/2003	1.1	0.6	0.49	1.63	0.97	10.51	201.2	2.21	0.69	0.48	0.79	0.41	0.6	0.535	1.62	0.57	13.5
020822SE13338	13338	8/22/2002	2	0.55	0.76	1.24	1.21	19.5	440.5	4.2	0.40833	0.95	1.7	0.91	0.71	0.78	3.4	0.81	33.5
021022SE13338	13338	10/22/2002	0.94	0.48333	0.63	0.76	0.81	8.2	180.5	1.6	0.63	0.6	0.8	0.63	0.536	0.566	1.5	0.6	15.5
040319SE13338	13338	3/19/2004	1.09	0.443	0.62	0.65	0.71	9.72	200.89	3.19	0.48	0.3	3.83333	0.52	0.28	0.448	1.31	0.58	9.22
041108SE13338	13338	11/8/2004	0.88	0.275	0.58	0.83	1.56	15.88	394	1.68	0.349	0.35	0.53	0.417	0.51667	0.479	2.28	1.11	10.28
020822SE13339	13339	8/22/2002	1.8	0.51667	0.75	1.1	1.18	16.5	360.5	3.4	0.39167	0.76	0.87	0.68	0.61	0.69	2.9	0.75	19.5
030504SE13339	13339	5/4/2003	1.28	0.55833	0.718	1.42	0.88	20.4	272.7	1.1	0.554	0.23333	0.575	0.65	0.41667	0.659	1.22	0.56667	7.1
020806SE13340	13340	8/6/2002	0.8	0.65	0.78	1.04	1.11	15.5	320.5	1.21	0.40833	0.67	0.68	0.67	0.40833	0.61	2.2	0.7	7.8
021023SE13340	13340	10/23/2002	1.07	0.6	0.7	0.9	1	12.5	310.5	1.9	0.6	0.64	0.71	0.6	0.425	0.62	1.8	0.63	12.5
030529SE13340	13340	5/29/2003	0.59	0.81	0.49	1.62	1.07	14.35	271.1	0.85	0.41667	0.43	0.72	0.4	0.555	0.479	1.9	0.52	9.2
040311SE13340	13340	3/11/2004	0.62	0.83333	1.21	1.3	1.1	22.88	453.4	1.17	0.76667	1.16667	2.83333	0.51	0.283	0.34	2.74	0.6	10.45
041109SE13340	13340	11/9/2004	0.54	0.37	1.1	1.01	1.73	12.64	244.1	0.98	0.356	0.37	0.42	0.37	0.366	0.4	1.51	0.61	5.68
020806SE13341	13341	8/6/2002	1	0.68	0.8	1.15	1.16	17.5	420.5	1.7	0.79	0.65	0.71	0.2	0.375	0.66	2.5	0.51667	10.5

TABLE A.2: Uncertainty Values Used for PMF Modeling (ng/kg - for all samples)

Sample ID	Station ID	Sample Date	2378-TCDD	12378-PeCDD	123478-HxCDD	123678-HxCDD	123789-HxCDD	1234678-HpCDD	OCDD	2378-TCDF	12378-PeCDF	23478-PeCDF	123478-HxCDF	123678-HxCDF	123789-HxCDF	234678-HxCDF	1234678-HpCDF	1234789-HpCDF	OCDF
020821SE13342	13342	8/21/2002	2	0.73	0.87	1.18	1.23	20.5	550.5	4	0.66	0.81	1.01	0.71	0.65	0.73	3.7	0.8	29.5
021028SE13342	13342	10/28/2002	1.9	0.65	0.73	1.09	1.13	19.5	540.5	3.8	0.75	0.78	0.92	0.7	0.592	0.71	3.2	0.79	28.5
030511SE13342	13342	5/11/2003	1.82	0.9	0.66	1.85	1.42	25.63	631.1	3.32	0.41667	0.57	1.08	0.5	0.63	0.65	4.04	0.85	33.4
040311SE13342	13342	3/11/2004	2.01	1.33333	0.72	1.04	1.01	20.1	452.6	4.62	0.59	0.46	5.5	0.57	0.71667	0.4	3.15	1.13	22.56
041109SE13342	13342	11/9/2004	1.66	0.32	0.56	0.89	1.06	22.4	794	5.14	0.49	0.54	0.49	0.48	0.31	0.47	3.6	0.56	30.78
020820SE13343	13343	8/20/2002	0.6	0.58333	0.62	0.73	0.73	7.2	370.5	0.71	0.41667	0.578	0.43333	0.591	0.41667	0.592	1.35	0.65	3.2
030511SE13343	13343	5/11/2003	0.74	0.731	0.49	1.45	0.84	9.8	383.3	0.83	0.554	0.329	0.66	0.46	0.41667	0.5	1.64	0.59	10.3
020821SE13344	13344	8/21/2002	2	0.7	0.81	1.21	1.27	23.5	710.5	3.4	0.41667	0.82	1.08	0.79	0.67	0.79	4.7	0.86	35.5
021027SE13344	13344	10/27/2002	2.6	0.68	0.85	1.26	1.29	24.5	740.5	4.5	0.84	0.85	1.03	0.77	0.63	0.81	4.6	0.93	46.5
040319SE13344	13344	3/19/2004	1.37	0.75	0.66	0.86	0.96	15.46	481	3.04	0.56	0.48	5.08333	0.5	0.35	0.52	2.68	1.91667	17.41
041108SE13344	13344	11/8/2004	1.89	0.63	0.6	1.12	0.92	24.62	694.1	4.1	0.63	0.63	0.83	0.6	0.52	0.59	3.99	0.99	29.79
050818SE14	14	8/18/2005	2.9	0.534	0.519	0.08167	0.543	1.8	45.5	9	0.75	0.7	0.84	0.592	0.533	0.527	0.7	0.555	1.25
020830SE14560	14560	8/30/2002	0.8	0.87	1.22	1.6	1.24	15.5	310.5	1.19	0.61	0.561	0.64	0.6	0.573	0.595	1.5	0.64	7.3
050818SE15	15	8/18/2005	2100.5	24.5	0.85	1.32	3.75	10	120.5	8200.5	280.5	220.5	390.5	110.5	41.5	21.5	110.5	44.5	39.5
020904SE15979	15979	9/4/2002	31.5	1.35	1.04	2.5	1.5	36.5	630.5	95.5	3.1	3	3.1	3.3	1.05	1.2	14.5	2.1	550.5
030529SE15979	15979	5/29/2003	1.89	0.56667	0.76	1.88	1.24	15.95	392	3.97	0.425	0.7	1.38	0.67	0.69	0.55	3.56	1.09	43.4
040402SE15979	15979	4/2/2004	1.31	0.407	0.496	1.25	0.59	5.41	114	2.87	0.44	0.41	0.44	0.352	0.39	0.334	2.91	1.07	51.76
040518SE15979	15979	5/18/2004	1.38	0.41	0.4	0.73	0.58	13.74	38.41	3.44	0.45	0.46	0.51	0.41	0.284	0.43	2.99	0.78	5.65
040810SE15979	15979	8/10/2004	1.69	0.56	0.63	0.91	0.89	15.83	444.1	3.2	0.96	0.54	0.67	0.5	0.56	0.55	3.58	1.68	32.7
040810SE15979-A	15979	8/10/2004	0.97	0.615	0.93	0.88	0.95	8.2	214.1	1.51	0.53	0.41	0.5	0.46	0.39	0.37	1.83	1.01	12.6
040810SE15979-B	15979	8/10/2004	1.75	0.75	0.78	1.27	1.3	16.4	424.1	3.47	0.8	0.96	0.35	0.7	0.72	0.7	3.37	1.38	30.3
040810SE15979-C	15979	8/10/2004	1.89	0.865	1.66	2.69	1.62	13.2	316.9	4.17	1.85	1.7	0.91667	1.4	1.03	0.86	4	2.75	38.6
040810SE15979-D	15979	8/10/2004	1.53	0.39	0.4	0.64	0.55	11.41	294.1	3.01	0.64	0.51	0.26667	0.42	0.32	0.51	2.65	0.64	21.99
041104SE15979	15979	11/4/2004	1.36	0.37	0.57	0.78	0.6	15.4	514	3.14	0.4	0.5	0.58	0.43	0.303	0.49	2.92	0.68	21.78
050816SE15979	15979	8/16/2005	2.4	0.65	0.43333	1.06	0.98	15.5	310.5	5.7	0.85	0.85	0.54167	0.86	0.76	0.75	4.4	1.28	52.5
040810SE15980	15980	8/10/2004	1.5	0.6	0.66	0.97	0.98	16.61	503.5	3.31	0.6	1.27	1.26	0.78	0.49	0.85	3.69	1.26	37.3
050818SE16	16	8/18/2005	9.4	0.61	0.09167	0.579	0.586	2.6	59.5	44.5	1.26	1.23	1.22	0.73	0.591	0.566	0.79	0.595	1.37
020821SE16496	16496	8/21/2002	2.5	0.55833	0.24167	1.47	1.5	27.5	660.5	5.1	0.575	0.98	1.33	0.82	0.81	0.84	4.5	0.99	33.5
030511SE16496	16496	5/11/2003	2.45	0.55833	0.58	1.73	1.12	18.72	461.1	5.26	0.41667	0.63	1.12	0.46	0.596	0.61	3.85	1.03	36.4
020822SE16499	16499	8/22/2002	2.1	0.72	0.75	1.19	1.14	15.5	330.5	4.1	0.62	0.76	0.96	0.68	0.64	0.68	3.3	0.76	21.5
021024SE16499	16499	10/24/2002	1.49	0.63	0.76	1.2	1.05	14.5	320.5	2.5	0.66	0.69	0.91	0.69	0.578	0.71	3.1	0.8	17.5
040319SE16499	16499	3/19/2004	3.47	0.92	0.71	1.23	0.96	16.78	271.1	5.74	0.63	0.57	1	0.66	0.305	0.49	3.25	0.89	21.59
041109SE16499	16499	11/9/2004	5.76	0.75	0.78	3.03	2.1	36.4	514	11.24	0.6	0.67	0.15	0.62	0.37	0.63	6.79	0.84	36.77
020819SE16618	16618	8/19/2002	1.03	0.58333	0.28333	0.66	0.62	3.2	67.5	2	0.40833	0.566	0.595	0.552	0.45	0.38333	1.02	0.61667	5.1
030506SE16618	16618	5/6/2003	5.8	0.98	1.07	2	1.22	24.1	412.5	10.57	0.59167	1.28	1.19	0.78	0.97	0.87	5.44	1.57	56.3
040319SE16618	16618	3/19/2004	0.54	0.475	0.53	0.75	0.65	6.34	140.65	0.97	0.225	0.201	0.39	0.378	0.258	0.278	1.02	0.63	5.72
041109SE16618	16618	11/9/2004	1.35	0.254	0.39	0.52	0.64	11.39	353.9	3.33	0.31	0.35	0.14167	0.307	0.241	0.326	1.49	0.32	15.75
030529SE16622	16622	5/29/2003	0.285	0.525	0.3	1.53	1	15.33	661	0.28	0.39167	0.332	0.62	0.36	0.39167	0.325	1.49	0.5	6.6
050817SE17	17	8/17/2005	2.6	0.555	0.581	0.69	0.73	7.1	240.5	7.8	0.72	0.7	0.81	0.586	0.53	0.565	1.31	0.62	9.1
021024SE17970	17970	10/24/2002	0.6	0.53333	0.574	0.62	0.67	5.4	150.5	0.88	0.63	0.581	0.577	0.534	0.4	0.325	0.76	0.30833	2.1
020824SE17971	17971	8/24/2002	1.9	0.55833	0.97	1.5	1.28	34.5	620.5	3.7	0.41667	0.77	1	0.68	0.586	0.8	5.4	0.9	39.5
021028SE17971	17971	10/28/2002	1.33	0.62	0.66	0.91	0.96	12.5	350.5	2.6	0.66	0.65	0.8	0.64	0.564	0.62	2.1	0.65	17.5
050817SE18	18	8/17/2005	3	0.597	0.67	0.88	0.9	12.5	370.5	6.8	1.01	0.86	0.97	0.78	0.76	0.66	2.4	0.81	31.5
040802SE18388	18388	8/2/2004	1.25	0.567	0.57	0.8	0.84	14.51	484.1	3.04	0.66	0.55	0.47	0.46	0.513	0.4	1.94	0.68	14.79
040811SE18389	18389	8/11/2004	1.48	0.3	0.306	0.38	0.37	6.31	214.1	3.58	0.16667	0.35	0.36	0.307	0.246	0.315	0.87	0.268	6.38

TABLE A.2: Uncertainty Values Used for PMF Modeling (ng/kg - for all samples)

Sample ID	Station ID	Sample Date	2378-TCDD	12378-PeCDD	123478-HxCDD	123678-HxCDD	123789-HxCDD	1234678-HpCDD	OCDD	2378-TCDF	12378-PeCDF	23478-PeCDF	123478-HxCDF	123678-HxCDF	123789-HxCDF	234678-HxCDF	1234678-HpCDF	1234789-HpCDF	OCDF
040811SE18390	18390	8/11/2004	1.4	0.419	0.432	0.68	0.95	4.41	153.9	2.83	0.382	0.451	0.20833	0.281	0.275	0.29167	0.79	0.68333	4.35
040810SE18392	18392	8/10/2004	2.57	1.01	0.66	1.32	1.17	20.69	524.1	5.88	0.275	0.86	1.13	0.77	0.93	0.75	4.15	2.12	23.3
050816SE18392	18392	8/16/2005	1.7	0.68333	0.49167	0.9	0.56667	9.3	310.5	4.1	0.78	0.85	0.425	0.68	0.65	0.4	2.1	0.77	14.5
050817SE19	19	8/17/2005	1.8	0.538	0.576	0.67	0.69	6.7	270.5	4.6	0.68	0.64	0.73	0.575	0.541	0.551	1.18	0.596	6.3
050817SE2	2	8/17/2005	5	0.594	0.65	0.8	0.87	10.1	360.5	15.5	0.98	0.9	1.08	0.7	0.592	0.61	1.49	0.67	6.8
050818SE20	20	8/18/2005	0.62	0.06833	0.515	0.528	0.533	1.38	33.5	0.88	0.52	0.514	0.525	0.512	0.0575	0.513	0.585	0.11667	1.16
050817SE21	21	8/17/2005	3.2	0.597	0.64	0.83	0.88	10.5	390.5	9.9	0.8	0.78	0.9	0.63	0.578	0.61	1.5	0.64	7.3
050816SE22	22	8/16/2005	2	0.6	0.87	1.25	1.5	26.5	390.5	4.3	0.35	0.99	1.02	0.73	0.66	0.64	3	0.77	14.5
050816SE23	23	8/16/2005	2.8	0.64	0.68	1.03	0.88	12.5	270.5	7.7	0.77	1.17	0.96	0.75	0.61	0.66	3.4	0.73	15.5
050816SE24	24	8/16/2005	4.6	0.69	0.77	1.32	1.07	22.5	450.5	11.5	1.14	1.11	1.35	0.85	0.69	0.68	4.3	0.93	23.5
050816SE25	25	8/16/2005	2.7	0.574	0.62	0.76	0.75	6.9	180.5	5.5	0.69	0.72	0.93	0.65	0.565	0.62	1.9	0.73	27.5
050817SE26	26	8/17/2005	1.8	0.584	0.66	0.82	0.8	9.7	180.5	3.4	0.69	0.7	0.86	0.67	0.64	0.63	3.3	0.97	48.5
050817SE27	27	8/17/2005	1.7	0.61	0.67	0.93	0.84	11.5	310.5	3.6	0.84	0.84	1.01	0.73	0.576	0.7	4.2	1.04	94.5
050818SE3	3	8/18/2005	2.4	0.559	0.6	0.73	0.77	8.2	320.5	6.8	0.7	0.68	0.77	0.592	0.527	0.569	1.36	0.63	9.8
050817SE4	4	8/17/2005	1.31	0.535	0.556	0.64	0.67	5.1	180.5	3.3	0.598	0.587	0.64	0.58	0.527	0.538	0.97	0.568	4.6
050817SE5	5	8/17/2005	1.18	0.541	0.581	0.65	0.66	5.7	170.5	2.8	0.583	0.586	0.63	0.543	0.526	0.542	1.07	0.568	5.9
050815SE6	6	8/15/2005	1.24	0.30833	0.59	0.30833	0.64	4.5	150.5	2.9	0.583	0.58	0.63	0.564	0.26667	0.175	0.97	0.56	4
050815SE7	7	8/15/2005	1.47	0.538	0.554	0.61	0.63	3.8	130.5	3.6	0.595	0.592	0.68	0.08333	0.125	0.541	0.98	0.565	7
050818SE8	8	8/18/2005	2.5	0.559	0.578	0.69	0.72	6.3	200.5	7.6	0.71	0.69	0.8	0.61	0.556	0.561	1.23	0.63	9.5
050818SE9	9	8/18/2005	1.28	0.549	0.576	0.63	0.68	6.3	290.5	3	0.599	0.584	0.64	0.1	0.53	0.538	0.93	0.554	4.1
D1_20060511	D1	5/11/2006	1.99	0.5482	0.5507	0.599	0.7	4.88	129.5	5.14	0.661	0.606	0.728	0.576	0.0725	0.5323	1.172	0.5841	10.24
D2a_20060602	D2	6/2/2006	1.363	0.5301	0.5344	0.5827	0.642	3.73	95.3	3.01	0.602	0.5677	0.671	0.5642	0.5334	0.5241	1.083	0.5839	6.57
D3_20060511	D3	5/11/2006	0.833	0.5144	0.5096	0.5284	0.5476	1.6	31.3	1.454	0.5371	0.5249	0.5522	0.5206	0.02583	0.0225	0.725	0.5203	2.7
SE-04	Point#4	8/20/2009	2	0.534	0.565	0.61	0.65	3.7	100.5	5.4	0.63	0.63	0.64	0.551	0.532	0.532	0.71	0.325	2.1
SE-05	Point#5	8/20/2009	36.5	0.9	0.7	0.88	0.96	13.5	460.5	130.5	3.7	3.3	4.5	1.8	0.91	0.69	2.7	1.01	11.5
S10-0-1	S10	5/11/2006	1.5566	0.5339	0.5477	0.6085	0.6774	4.8382	128.316	4.1825	0.6291	0.5682	0.696	0.5747	0.0275	0.5255	1.2529	0.5843	8.7467
S11-0-1	S11	5/11/2006	1.2171	0.5234	0.5201	0.5522	0.5881	2.693	65.6596	3.3174	0.5805	0.5439	0.6029	0.538	0.04667	0.04083	0.9198	0.5467	5.1893
S12-0-1	S12	5/11/2006	1.2912	0.5243	0.5274	0.5649	0.6165	3.1773	78.3922	3.4293	0.58	0.558	0.6196	0.5408	0.06917	0.06	1.0164	0.5462	5.9215
S5-0-1	S5	5/11/2006	1.3133	0.5125	0.01667	0.5154	0.5221	1.0369	13.6246	4.5628	0.5743	0.5474	0.5687	0.5197	0.01583	0.01417	0.5461	0.5107	0.8546
S6-0-1	S6	5/11/2006	0.9692	0.01917	0.5053	0.5128	0.5227	1.1463	10.5255	2.3941	0.5445	0.5292	0.5403	0.5153	0.015	0.0125	0.5673	0.511	0.9648
S200-0-1	S7	5/11/2006	1.5766	0.5235	0.5208	0.572	0.6054	3.842	116.614	6.0367	0.6231	0.5805	0.6179	0.5416	0.015	0.513	0.7231	0.5267	2.6783
S7-0-1	S7	5/11/2006	2.3582	0.5275	0.5279	0.5798	0.6205	3.9733	116.262	8.9144	0.6722	0.6089	0.7013	0.5604	0.04167	0.5152	0.8564	0.5509	3.9289
S8-0-1	S8	5/11/2006	1.3065	0.5257	0.5368	0.5798	0.6464	4.2723	102.435	3.1515	0.5871	0.5598	0.6413	0.5511	0.07083	0.5215	1.1012	0.5535	6.8152
S9-0-1	S9	5/11/2006	0.9371	0.02917	0.5146	0.5352	0.5638	1.9464	44.4858	2.0195	0.5541	0.5306	0.5769	0.5276	0.02583	0.5099	0.7774	0.5292	3.5037
F1NE1	SE-04	7/12/2005	91.3	1.74	2.025	0.8	0.894	13.3	485.5	421.5	11.2	9.4	13.4	3.63	1.8	1.215	4.48	1.63	3.9
F1NE2	SE-05	7/12/2005	81.9	1.474	1.99167	0.649	0.65	4.88	141.5	353.5	7.67	6.68	10.41	3.13	1.357	1.009	3.12	1.336	3.93
F1NE4	SE-07	7/12/2005	5.62	0.616	2.06667	0.821	0.987	15.2	609.5	25.1	0.87	0.86	0.984	2.06667	2.06667	2.06667	2.06667	0.5398	0.772
F1NE5	SE-08	7/12/2005	1850.5	18.7	0.855	1.6	1.074	19.3	320.5	4130.5	190.5	129.5	556.5	139.5	44.5	22.7	96.7	35.9	48
F1NE6	SE-09	7/13/2005	571.5	36.8	0.983	3.29	1.52	66.3	398.5	843.5	240.5	148.5	522.5	136.5	45.6	23.4	130.5	53.6	106.5
F1NE7	SE-09	7/13/2005	1290.5	35.4	0.971	3.19	1.51	59.6	648.5	2060.5	377.5	233.5	866.5	229.5	66.1	35.4	236.5	88.3	99.5
F1NE8	SE-11	7/13/2005	1790.5	32.8	0.92	2.09	1.203	37.2	486.5	3670.5	271.5	203.5	494.5	127.5	40.8	22.1	129.5	48.2	52.2
SJA1-SL-N	SJA1	4/15/2010	1067.4	10.484	0.614	1.433	0.888	20.643	298.388	2719.3	124.34	80.594	251.924	61.209	3.89	8.45	79.307	28.844	51.797
SJA2-SL-N	SJA2	4/15/2010	275.23	2.342	0.68083	0.898	0.694	9.54	179.343	901.36	891.71	336.584	972.83	179.752	8.934	48.664	100.954	33.93	40.473
SJA3-SG-N	SJA3	4/13/2010	3.6024	0.1171	0.1516	0.2359	0.22	1.747	53.608	12.015	0.3156	0.2346	0.5026	0.2059	0.08917	0.1183	0.429	0.2629	1.964
SJA4-SG-N	SJA4	4/13/2010	6.2396	0.1421	0.1637	0.2762	0.2437	3.402	113.133	20.566	0.5544	0.4444	1.0727	2.1	0.1209	0.28667	4.56667	0.925	4.196

TABLE A.2: Uncertainty Values Used for PMF Modeling (ng/kg - for all samples)

Sample ID	Station ID	Sample Date	2378-TCDD	12378-PeCDD	123478-HxCDD	123678-HxCDD	123789-HxCDD	1234678-HpCDD	OCDD	2378-TCDF	12378-PeCDF	23478-PeCDF	123478-HxCDF	123678-HxCDF	123789-HxCDF	234678-HxCDF	1234678-HpCDF	1234789-HpCDF	OCDF
SJA5-SG-N	SJA5	4/13/2010	3.7223	0.1049	0.161	0.2736	0.60417	2.9966	97.34	12.107	0.3525	0.3184	0.5449	0.2254	0.1	0.141	0.605	0.3635	3.353
SJB1-SG-N	SJB1	4/15/2010	1615	13.673	0.618	2.352	0.897	29.647	487.476	4156.1	150.458	99.5	317.06	74.13	26.8333	8.42	100.024	37.276	65.564
SJB2-SG-N	SJB2	4/15/2010	27.449	0.677	0.45	0.822	0.671	7.394	223.705	90.405	5.372	3.028	7.778	2.27	0.494	0.586	2.773	1.343	9.395
SJB3-SG-N	SJB3	4/13/2010	6.5876	0.1721	0.1518	0.303	0.317	5.324	179.169	22.192	0.5716	0.4491	1.016	0.382	0.1873	0.2238	1.021	0.453	6.844
SJB4-SG-N	SJB4	4/13/2010	3.1681	0.29417	0.1725	0.41333	0.24167	2.0935	67.506	10.367	0.2973	0.2349	0.4171	0.1577	0.046	0.07658	0.432	0.1893	3.333
SJB5-SG-N	SJB5	4/13/2010	1.4257	0.0736	0.1225	0.1336	0.4375	2.5567	102.064	4.7	0.166	0.1387	0.2676	0.1071	0.04175	0.18333	0.3182	0.1177	2.1104
SJC1-SG-N	SJC1	4/15/2010	1018.8	9.302	1.08333	3.3	0.529	7.807	142.268	3602.4	73.403	62.01	111.388	28.682	1.855	3.916	35.478	12.305	23.336
SJC3-SG-N	SJC3	4/14/2010	0.789	0.05692	0.1326	0.2049	0.415	2.113	70.828	2.461	0.1287	0.1125	0.227	0.32917	0.11	0.095	0.398	0.2725	2.374
SJC4-SG-N	SJC4	4/14/2010	1.365	0.1275	0.1348	0.2287	0.2126	3.791	134.142	5.93	0.91667	0.1615	0.325	0.52417	0.11333	0.1597	0.565	0.275	0.245
SJC5-SG-N	SJC5	4/14/2010	1.052	0.0774	0.1445	0.249	0.244	3.92	150.183	3.659	0.73083	0.1208	0.2592	0.1469	0.0925	0.1219	0.573	0.2689	4.093
SJD1-SG-N	SJD1	4/14/2010	55.377	0.5863	0.4225	0.373	0.371	5.292	159.265	183.47	4.271	3.216	6.0088	1.6574	0.48667	0.331	2.491	0.916	8.403
SJD2-SG-N	SJD2	4/14/2010	1.532	0.183	0.26833	0.3974	0.44	3.964	135.156	5.128	0.1835	0.62	0.2906	0.1505	0.085	0.12917	0.345	0.29	2.004
SJD3-SG-N	SJD3	4/14/2010	3.287	0.108	0.35667	0.32	0.317	5.924	186.104	8.378	0.2222	0.2266	0.3049	0.1585	0.08142	0.1321	0.6175	0.1659	6.836
SJD4-SG-N	SJD4	4/14/2010	1.3506	0.16	0.1167	0.2045	0.1961	3.355	111.167	4.374	0.1488	0.1471	0.254	0.149	0.09917	0.1259	0.483	0.209	4.324
SJD5-SG-N	SJD5	4/14/2010	1.4913	0.26667	0.1379	0.274	0.275	5.302	175.159	4.4099	0.1845	0.1391	0.2822	0.1341	0.05067	0.195	0.617	0.1983	6.397
SJE1-SG-N	SJE1	4/14/2010	102.117	0.8889	0.1149	0.77917	0.55667	2.502	63.765	361.56	7.3833	6.0158	9.6223	2.4607	0.194	0.4494	2.719	1.076	3.797
SJE2-SG-N	SJE2	4/14/2010	36.345	0.523	0.27	0.635	0.397	3.792	90.117	138.96	2.198	2.083	2.597	0.797	0.2086	0.70083	1.31	1.875	4.243
SJE3-SG-N	SJE3	4/14/2010	1.793	0.07917	0.1293	0.37917	0.41667	1.797	48.632	7.01	0.254	0.2145	0.212	0.108	0.06408	0.05775	0.234	0.12167	0.973
SJGB004-GR1	SJGB004	5/17/2010	0.871	0.12167	0.107	0.1739	0.1643	4.015	146.141	3.99	0.1487	0.1381	0.1735	0.25833	0.06125	0.05683	0.2002	0.06892	1.246
SJGB005-GR1	SJGB005	5/23/2010	0.7601	0.10167	0.16583	0.1461	0.1825	2.022	63.436	3.117	0.1781	0.44667	0.1648	0.0889	0.09083	0.1125	0.254	0.15167	1.949
SJGB007-GR1	SJGB007	5/23/2010	64.606	0.916	0.26667	0.1866	0.158	1.99	47.8	157.79	5.779	4.038	6.757	1.821	0.376	0.401	2.225	0.965	7.121
SJGB008-GR1	SJGB008	5/23/2010	11.1693	0.1606	0.074	0.18667	0.09	0.8245	25.9842	67.79	0.9465	0.7713	1.8329	0.4612	0.07	0.26583	0.9366	0.3873	1.3412
SJNE004-GR1	SJNE004	5/23/2010	0.501	0.0925	0.1975	0.2075	0.2025	2.459	76.217	2.046	0.1694	0.1675	0.1871	0.19667	0.20917	0.12167	0.395	0.26333	3.405
SJNE007-GR1	SJNE007_Grab	5/12/2010	3.4163	0.0775	0.12917	0.2475	0.0837	1.4299	47.3728	13.8675	0.2573	0.2192	0.3707	0.7775	0.08343	0.12333	0.2589	0.1667	1.1579
SJNE008-GR1	SJNE008_Grab	5/11/2010	3.435	0.13	0.40917	0.293	0.316	5.262	152.189	13.911	0.449	0.344	1.2465	0.3709	0.04517	0.1185	1.334	0.422	6.848
SJNE011-GR1	SJNE011	5/11/2010	1.301	0.1375	0.31917	0.342	0.85	6.087	122.397	4.43	0.2634	0.2468	0.368	0.2517	0.22083	0.19667	0.733	0.29417	6.759
SJNE019-GR1	SJNE019	5/12/2010	0.606	0.04158	0.0788	0.1496	0.24	1.853	44.256	1.333	0.24417	0.0999	0.1243	0.0779	0.05383	0.0678	0.342	0.1375	2.853
SJNE022-GR1	SJNE022-1	5/17/2010	12.6827	0.1555	0.05075	0.07333	0.06183	0.1649	2.6398	43.478	1.2053	0.8293	4.1374	0.8948	0.1125	0.2138	1.0565	0.864	1.021
SJNE022-GR2	SJNE022-2	5/17/2010	161.15	1.146	0.25167	0.267	0.2079	2.915	65.145	496.46	17.7611	10.4639	24.845	6.444	0.473	1.033	6.433	2.682	5.117
SJNE022-GR3	SJNE022-3	5/17/2010	177.86	1.3794	0.1069	0.26	0.545	1.912	29.3632	423.84	19.3831	10.4933	34.7816	8.3542	0.4481	1.5478	8.697	3.67	5.28
SJNE023-GR1	SJNE023_Grab	5/14/2010	1.05	0.095	0.10417	0.2489	0.2394	2.626	59.965	3.3421	0.41917	0.1351	0.25	0.1615	0.1825	0.12083	0.343	0.20333	2.073
SJNE027-GR1	SJNE027	5/14/2010	1.092	0.07492	0.06217	0.1003	0.11417	0.789	24.341	3.694	0.1445	0.1164	0.1693	0.0747	0.04108	0.03917	0.146	0.06008	0.763
SJNE032-GR1	SJNE032_Grab	5/14/2010	11.1774	0.1669	0.13167	0.33	0.29	4.277	119.259	36.608	0.8329	0.6552	1.375	2.625	0.1475	0.71333	1.319	0.801	4.823
SJNE033-GR1	SJNE033_Grab	5/14/2010	1.871	0.1136	0.18917	0.96667	0.34	3.887	121.133	5.237	0.227	0.221	0.435	0.4975	0.315	0.35667	0.854	0.36167	8.229
SJNE039-GR1	SJNE039	5/14/2010	1.912	0.1175	0.16417	0.426	0.393	6.593	221.463	6.246	0.312	1.1	0.687	0.434	0.48667	0.44167	1.101	0.5175	6.878
SJNE049-GR1	SJNE049	5/13/2010	1.059	0.14833	0.18	0.412	1.15833	4.167	145.1	1.168	0.64417	0.2227	0.256	0.1801	0.14083	0.1721	0.622	0.27417	4.6
SJNE052-GR1	SJNE052	5/12/2010	0.478	0.0805	0.1228	0.1822	0.1688	2.624	78.58	1.057	0.1438	0.1402	0.1514	0.18167	0.105	0.09167	0.355	0.2416	1.945
SJNE053-GR1	SJNE053	5/13/2010	0.625	0.061	0.1923	0.3088	0.58833	3.5449	139.136	1.7596	0.1521	0.1197	0.26	0.305	0.1825	0.1825	0.558	0.29	4.03
SJNE059-GR1	SJNE059	5/12/2010	0.506	0.09917	0.128	0.2152	0.2054	3.495	111.214	1.258	0.1467	0.08667	0.54667	0.1467	0.13417	0.22417	0.422	0.1847	2.575
SJSH057-GR1	SJSH057	5/23/2010	0.231	0.0645	0.1114	0.1288	0.1372	1.171	39.413	0.704	0.0818	0.05317	0.0962	0.0763	0.1075	0.06658	0.1476	0.0655	1.329
SJVS001-GR1	SJVS001	5/21/2010	882.35	6.843	0.1893	0.6628	0.3062	14.194	337.043	3448.68	73.742	46.93	102.234	22.818	1.829	3.834	26.543	12.402	19.4463
SJVS016-GR1	SJVS016	5/20/2010	52.627	0.5619	0.08025	0.136	0.1426	1.562	47.932	293.6	5.273	3.9522	6.3032	1.471	0.57083	0.2771	1.27	0.704	2.052
20041216sdSS-10	SS-10	12/16/2004	0.45	1	1.76	2.24	1.56	12.8	106.3	0.87	0.83333	0.98	0.82	0.86	0.91667	1.41	3.5	2.91667	7.5
20040930sdSS-108	SS-108	9/30/2004	0.18333	0.30833	0.47	0.5	0.275	3.94	48.63	0.274	0.15	0.226	0.306	0.26667	0.289	0.239	0.77	0.23333	1.92

TABLE A.2: Uncertainty Values Used for PMF Modeling (ng/kg - for all samples)

Sample ID	Station ID	Sample Date	2378-TCDD	12378-PeCDD	123478-HxCDD	123678-HxCDD	123789-HxCDD	1234678-HpCDD	OCDD	2378-TCDF	12378-PeCDF	23478-PeCDF	123478-HxCDF	123678-HxCDF	123789-HxCDF	234678-HxCDF	1234678-HpCDF	1234789-HpCDF	OCDF
20041001sdSS-13	SS-13	10/1/2004	0.325	0.52	0.63	0.83	0.7	13.92	191.2	0.2	0.285	0.24167	0.386	0.404	0.20833	0.317	2.17	0.56	6.8
20050112sdSS-13	SS-13	1/12/2005	0.13333	0.222	0.33	0.42	0.4	6.21	71.1	0.2	0.16667	0.19167	0.24	0.329	0.175	0.39	2.11	0.456	2.89
20050302sdSS-14	SS-14	3/2/2005	0.13333	0.249	0.34	0.49	0.42	5.71	84.1	0.29	0.23	0.271	0.26	0.19167	0.175	0.21667	1.24	0.293	3.09
20041001sdSS-7	SS-7	10/1/2004	0.39167	0.345	0.482	0.46	0.433	5.07	84.66	0.283	0.14167	0.24	0.26667	0.275	0.254	0.33	0.86	0.35	2.66
20041001sdSS-9	SS-9	10/1/2004	0.263	0.96	0.89	0.98	1.53	39.3	3100.64	0.256	0.275	0.15833	0.20833	0.364	0.267	0.271	0.59	0.23333	1.71
20050127sdSS-9	SS-9	1/27/2005	0.13333	0.237	0.35	0.4	0.47	11.76	484.1	0.2	0.16667	0.19167	0.222	0.256	0.175	0.29	0.55	0.224	1.31
11193-SE-1	11193	8/11/2011	4.92	0.51	0.53	0.8	0.7	12.92	421.4	21.32	0.54	0.54	0.99	0.43	0.225	0.37	1.7	0.7	18.6
11264-SE-1	11264	8/23/2011	0.96	0.308	0.36	0.42	0.45	9.71	220.26	2.16	0.28	0.205	0.46	0.25	0.21667	0.252	1.61	0.38	31.27
11274-SE-1	11274	8/19/2011	1.03	0.159	0.49	1.4	1.16	25.13	520.19	3.01	0.39	0.69	1.889	0.586	0.43	0.46	5.39	1.09	70.14
11292-SE-1	11292	8/12/2011	0.69	0.545	0.855	1.715	1.165	30.885	516.4	1.54	1.455	0.61	0.805	0.655	0.79	0.855	5.175	1.52	20.75
11298-SE-1	11298	8/23/2011	2.01	0.327	0.425	1.32	0.96	39.18	740.31	6.54	0.4	0.605	0.832	1.06	0.28	0.42	7.02	0.93	30.3
11421-SE-1	11421	6/23/2011	0.81	0.343	0.413	0.5	0.41	4.32	43.62	2.09	0.32	0.267	0.32	0.186	0.2	0.1	0.36	0.24167	0.99
13310-SE-1	13310	6/15/2011	0.46	0.327	0.48	0.53	0.61	9.48	200.88	0.95	0.10833	0.179	0.24	0.26	0.175	0.15833	0.9	0.40833	5.49
13315-SE-1	13315	7/5/2011	0.179	0.204	0.41	0.41	0.65	9.73	210.15	0.29	0.12	0.104	0.148	0.149	0.05333	0.07417	0.4	0.10833	0.8
13322-SE-1	13322	6/22/2011	0.455	0.7	0.74	1.07	1.64	26.3	341.2	0.68	0.43	0.4	0.52	0.39	0.76	0.72	2.6	1.07	5.95
13338-SE-1	13338	8/9/2011	0.42	0.362	0.393	0.44	0.47	5.5	140.59	0.72	0.20833	0.25	0.31667	0.409	0.34167	0.34167	0.75	0.53333	5
13344-SE-1	13344	8/9/2011	1.59	0.57	0.93	1.19	1.39	26.2	901.6	4.21	0.65	0.52	0.84	0.74	0.39167	0.63	4	1.65	42.8
13361-SE-1	13361	8/13/2011	0.225	0.26667	0.49	0.57	0.59	11.62	140.77	0.46	0.09167	0.245	0.37	0.288	0.19167	0.16667	1.57	0.43333	6.6
13561-SE-1	13561	6/28/2011	0.3	0.35867	0.5655	0.725	0.68	6.37	110.965	0.53	0.449	0.274	0.35917	0.36367	0.375	0.2625	1.305	0.70833	7.485
14543-SE-1	14543	7/6/2011	0.246	0.32	0.4	0.58	0.73	9.97	250.61	0.4	0.2	0.164	0.291	0.219	0.24167	0.26667	0.54	0.38333	1.8
14560-SE-1	14560	7/8/2011	0.288	0.355	0.57	0.67	0.82	10.48	200.49	0.49	0.13333	0.178	0.275	0.221	0.23333	0.14167	0.72	0.24167	2.41
15215-SE-1	15215	6/23/2011	0.10833	0.219	0.31	0.39	0.6	8.74	110.25	0.245	0.09167	0.144	0.168	0.131	0.08	0.07	0.57	0.175	2.55
15242-SE-1	15242	6/8/2011	0.376	0.35	0.54	0.49	0.89	14.59	280.52	0.46	0.1	0.13	0.07	0.16	0.10833	0.08333	0.64	0.23333	2.2
15904-SE-1	15904	6/14/2011	0.3	0.264	0.47	0.56	0.63	11.77	290.66	0.85	0.215	0.168	0.23	0.242	0.14167	0.0825	1.03	0.24167	6.58
15911-SE-1	15911	6/8/2011	0.175	0.26	0.68	0.59	0.88	13.87	240.35	0.33	0.10833	0.138	0.216	0.10833	0.14167	0.10833	0.57	0.23333	1.6
15916-SE-1	15916	6/28/2011	0.328	0.368	0.45	0.49	0.72	8.09	130.44	0.3	0.10833	0.168	0.09167	0.11667	0.15833	0.13333	0.43	0.21667	1.25
16213-SE-1	16213	7/7/2011	0.27	0.24	0.39	0.46	0.75	10.09	190.35	0.68	0.158	0.157	0.27	0.249	0.13333	0.215	0.82	0.455	3.55
16215-SE-1	16215	7/8/2011	0.1	0.152	0.195	0.29	0.32	5.05	86.11	0.23	0.04583	0.088	0.127	0.081	0.07167	0.0475	0.269	0.15833	0.51
16230-SE-1	16230	6/30/2011	0.53	0.402	0.5	1.05	0.85	8.73	170.73	0.76	0.301	0.254	0.384	0.528	0.325	0.40833	0.75	0.5	2.6
16548-SE-1	16548	6/28/2011	0.26667	0.45	0.417	0.51	0.58	9.6	140.47	0.4	0.343	0.328	0.56	0.31	0.15	0.11667	2.71	0.89	19.6
16571-SE-1	16571	6/16/2011	0.14167	0.234	0.33	0.54	0.64	9.63	220.57	0.37	0.202	0.196	0.35	0.31	0.24167	0.42	2.15	0.73	4.87
20574-SE-1	20574	8/26/2011	0.125	0.12	0.25	0.37	0.35	9.39	190.21	0.188	0.156	0.23	0.205	0.202	0.09167	0.26	1.84	0.29	5.38