Public Health Assessment

Public Comment Draft

For

**San Jacinto River Waste Pits,
Channelview, Harris County, Texas**

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Prepared for ATSDR by the
Texas Department of State Health Services

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Agency for Toxic Substances and Disease Registry
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ATSDR
AGENCY FOR TOXIC SUBSTANCES AND DISEASE REGISTRY

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Foreword

The Agency for Toxic Substances and Disease Registry (ATSDR) was established under the mandate of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) of 1980. This act, also known as the "Superfund" law, authorized the U. S. Environmental Protection Agency (EPA) to conduct clean-up activities at hazardous waste sites. EPA was directed to compile a list of sites considered potentially hazardous to public health. This list is termed the National Priorities List (NPL). Under the Superfund law, ATSDR is charged with assessing the presence and nature of health hazards to communities living near Superfund sites, helping prevent or reduce harmful exposures, and expanding the knowledge base about the health effects that result from exposure to hazardous substances [1].

In 1984, amendments to the Resource Conservation and Recovery Act of 1976 (RCRA) – which provides for the management of hazardous waste storage, treatment, and disposal facilities – authorized ATSDR to conduct public health assessments at these sites when requested by the EPA, states, tribes, or individuals. The 1986 Superfund Amendments and Reauthorization Act (SARA) broadened ATSDR's responsibilities in the area of public health assessments and directed ATSDR to prepare a public health assessment (PHA) document for each NPL site. ATSDR also conducts public health assessments or public health consultations when petitioned by concerned community members, physicians, state or federal agencies, or tribal governments [1]. [Note: Appendix A provides a list of abbreviations and acronyms used in this report.]

The aim of a PHA is to determine if people are being exposed to hazardous substances and, if so, whether that exposure is potentially harmful and should be eliminated or reduced. Public health assessments are carried out by environmental health scientists from ATSDR and from the states with which ATSDR has cooperative agreements. Because each NPL site has a unique set of circumstances surrounding it, the public health assessment process allows flexibility in document format when ATSDR and cooperative agreement scientists present their findings about the public health impact of the site. The flexible format allows health assessors to convey important public health messages to affected populations in a clear and expeditious way, tailored to fit the specific circumstances of the site.

Comments:

If you have any questions, comments, or unanswered concerns after reading this report, we encourage you to send them to us.

Letters should be addressed as follows:

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Summary

INTRODUCTION

The San Jacinto River Waste Pits (SJRWP) site consists of a series of three surface impoundments (pits) that were constructed on the west bank of the San Jacinto River (SJR) near the Interstate Highway-10 (IH-10) bridge sometime between October 8, 1964 and February 15, 1973. Paper mill waste containing elevated levels of polychlorinated dibenzodioxins (PCDDs) and polychlorinated dibenzofurans (PCDFs) were offloaded from barges into these pits some time in the 1960s and 1970s. Since the pits were constructed, the pit area has subsided causing two of the pits to become partially submerged under a few inches to a few feet of water.

A sand mining operation northwest of the site (also now submerged) may have transported dioxin[1]-contaminated sand to unknown locations for unknown uses. High water flow events during past flooding may have transported dioxin-contaminated sediments downstream to the Houston Ship Channel (HSC) and Upper and Lower Galveston Bay (UGB & LGB). Dioxin levels in blue catfish and blue crab were found to exceed the DSHS reference standard of 2.33 picograms per gram (pg/g) by factors of 2.6 and 1.3 respectively. The maximum sediment dioxin level found on site was over 680 times higher than the ATSDR's screening level for dioxins in residential soil (50 pg/g). The site is easily accessible by boat and relatively accessible by land. A trail leading across the site terminates at a well-beaten-down point overlooking the waters of the SJR. The presence of trash and debris at this point tends to indicate that this is a fairly popular fishing location.

An exposure pathway analysis identified three potential pathways of exposure to site contaminants: oral ingestion of sediments through hand contact and subsequent hand-to-mouth activities, dermal absorption of site contaminants through skin contact with sediments, and ingestion of fish or crabs caught near the site. Six exposure scenarios were constructed to evaluate a potential range of exposures that might occur at the site: three scenarios involving adult fishermen and three scenarios involving children of fishermen visiting the site with different frequencies and eating fish or crabs caught near the site.

This PHA presents conclusions about whether a health threat is present for each of the three routes of exposure and under each of the six hypothetical exposure scenarios. Health outcome data for the surrounding neighborhoods were not evaluated because the airborne and water-borne routes were not considered significant pathways that may have exposed a larger, geographically circumscribed population. Also, individuals who live in more distant areas (and who may routinely visit the site) could not be differentiated from those who do not visit the site among the general entries in the cancer registry or birth defect registry databases.

[1] In this document, the terms "dioxin" or "dioxins" refer to the entire family of (PCDDs) and/or (PCDFs).

CONCLUSIONS	After review of the available data, the Texas Department of State Health Services (DSHS) and ATSDR have reached the following seven conclusions with regard to contact with dioxin-contaminated sediments from the SJRWP site and consumption of fish from the SJR, the HSC, and UGB:

Conclusion 1

DSHS and ATSDR conclude that frequent and/or regular sediment exposures by mouth and/or through skin contact with sediments from the SJRWP site for both adults and children for periods of 1 year or longer could harm people's health by increasing theoretical risks for cancer and non-cancer adverse health effects.

Basis for Conclusion

PCDDs/PCDFs have been detected in sediments at the SJRWP site at levels that would cause unacceptably high theoretical risks for cancer (greater than 10^{-4}) and unacceptably high hazard quotients (greater than 1.00) for non-cancer effects for children and adults under the subsistence fisherman exposure scenario (260 days per year for 47/30 years respectively) and under the child-of-a-weekend-fisherman exposure scenario (52 days per year for 47 years) for either oral and/or dermal exposures.

Current Progress

The following actions have been taken:

- The SJRWP site was proposed to the EPA's NPL on September 19, 2007, and was officially added to the NPL by final rule in 40 CFR Part 300 as published in the Federal Register on March 19, 2008.
- Pamphlets have been distributed in and around Channelview warning residents to avoid visiting or fishing at the SJRWP site and to avoid eating any fish or blue crab caught near the site.
- The EPA has posted warning signs and erected a fence to restrict access to the SJRWP site.
- The EPA has formulated a Remedial Investigation/Feasibility Study (RI/FS) work plan and has begun the field sampling sediment study, the fate & transport modeling assessment, & the bioaccumulation assessment.

Next Steps

Once the RI/FS has been completed, dioxins and other hazardous materials should be removed from the SJRWP site according to standard EPA protocol.

Conclusion 2

DSHS and ATSDR conclude that the consumption of fish or crabs caught near the SJRWP site for periods of one year or longer could harm people's health by increasing theoretical risks for cancer.

Basis for Conclusion

PCDDs/PCDFs have been detected in fish and crabs caught near the SJRWP site at levels that would cause unacceptably high theoretical risks for cancer (greater than 10^{-4}) under all but the sporadic-fishermen-and-their-children exposure scenarios.

Current Progress	The following actions have been taken: • The SJRWP site was proposed to the EPA's NPL on September 19, 2007, and was officially added to the NPL by final rule in 40 CFR Part 300 as published in the Federal Register on March 19, 2008. • Pamphlets have been distributed in and around Channelview warning residents to avoid visiting or fishing at the SJRWP site and to avoid eating fish caught near the site. • Under a project to develop Biota-Sediment Accumulation Factors (BSAFs) funded by the Texas Environmental Health Institute (TEHI), Baylor University has begun collecting benthic samples in the vicinity of the SJRWP site to more completely characterize PCDD/PCDF concentrations in fish, crabs, and shellfish caught near the site.
Next Steps	The following actions should be pursued: • DSHS should continue to periodically collect fish and crab samples from the SJR near the IH-10 Bridge and test for dioxins and other contaminants found at the site. • If samples are found to contain elevated levels of contaminants, fishing advisories or bans should be issued or revised as necessary.
Conclusion 3	DSHS and ATSDR conclude that exposures to groundwater near the SJRWP site are not expected to contribute to people's overall risks from contaminants coming from the SJRWP site.
Basis for Conclusion	Groundwater near the site is brackish and is not being used for drinking water purposes, and the nearest residence is approximately ½ mile from the site. Also, dioxins have relatively low solubility, are tightly bound to sediments, and are not likely to travel freely in groundwater.
Current Progress	EPA has included a groundwater sampling plan in the RI/FS for the SJRWP site, and sampling is expected to begin in December 2010.
Next Steps	Once the RI/FS has been completed, any groundwater issues at the SJRWP site should be addressed according to standard EPA protocol.
Conclusion 4	DSHS and ATSDR conclude that exposures to surface water near the SJRWP site are not expected to contribute to people's overall risks from contaminants coming from the SJRWP site.
Basis for Conclusion	Surface water near the site is brackish and is not being used for drinking water purposes, and the nearest residence is approximately ½ mile from the site. Also, dioxins have relatively low solubility, are tightly bound to sediments, and are not likely to travel freely in surface water.

Next Steps	None required.
Conclusion 5	DSHS and ATSDR conclude that exposures to ambient air at the SJRWP site are not expected to contribute to people's overall risk from contaminants coming from the SJRWP site.
Basis for Conclusion	Because of the nature of the contaminants, their low volatility, their high affinity for soil particles, and the high vegetation coverage on the site – leading to low likelihood of wind blown dust – the airborne route was not considered a significant pathway of exposure at this site.
Next Steps	None required.
Conclusion 6	DSHS and ATSDR cannot conclude whether or not past or present exposures to sand coming from sand mining activities near the SJRWP site could harm people's health.
Basis for Conclusion	PCDDs and PCDFs were detected in off-site sediments at the location of a former sand mining operation immediately northwest of the SJRWP site. At present, we do not know the TCDD TEQ[2] concentrations in the sand that has been mined or where the mined sand has been distributed.
Next Steps	The following actions need to be pursued: • The sand mining operation needs to be investigated by the EPA and/or TCEQ, and attempts need to be made to determine where the mined sand has been distributed. • Samples of mined sand should be tested by the EPA and/or TCEQ for PCDDs/PCDFs and other hazardous contaminants. • If mined sand is found to be in areas where human exposure might occur and if TCDD TEQ or other hazardous contaminants are found to exceed EPA soil standards for the particular type of area, contaminated sand should be removed and disposed of according to EPA guidelines.
Conclusion 7	DSHS and ATSDR cannot conclude whether or not past or present off-site migration of dioxin-contaminated sediments could harm people's health.
Basis for Conclusion	Although two of the surface impoundments are inundated with water from the SJR and site contaminants are likely being washed downstream to some extent during high water flow periods, sediment samples collected downstream (under the Dioxin Total Maximum Daily Load Project) have not shown any clear evidence of significant off-site migration of PCDDs/PCDFs from the SJRWP site. However, the extent of transport of dioxin-contaminated sediments off-site has not yet been

2 In this document, the term "TCDD TEQ" refers to 2,3,7,8-tetrachlorodibenzo-p-dioxin toxic equivalency, the calculation of which is explained in Appendix D.

adequately evaluated.

Current Progress EPA has included an extensive sediment sampling plan in the RI/FS for the SJRWP site that will include both upstream and downstream sediment samples.

Next Steps The following actions need to be pursued:

- The water flow patterns of the SJR as it passes under the IH-10 Bridge should be studied by the EPA and/or TCEQ in order to predict where sediments from the SJRWP site may have migrated.
- Sediment samples should be systematically obtained throughout the likely distribution area and tested by the EPA and/or TCEQ for PCDDs/PCDFs and other site-related contaminants.
- If distributed sediments are found to contain excessive amounts of PCDDs/PCDFs or other hazardous materials, contaminated sediments should be removed and disposed of according to EPA guidelines.

Additional Public Health Action Plan for Site DSHS and ATSDR propose the following public health action plan with regard to the SJRWP site:

- The SJRWP PHA technical review document was submitted to the Texas Commission on Environmental Quality (TCEQ) and the EPA for their comments. This version of the PHA document addresses the suggested comments received from the TCEQ and EPA.
- After the ATSDR reviews these minor modifications, this PHA document will then be made available for public review and comment.
- Any comments received during the public review period will be appropriately addressed, the document will be updated as necessary, and the final HA document will then be released.
- DSHS staff will participate in EPA or TCEQ availability sessions or other community meetings to collect and address any community health concerns related to the SJRWP site.
- Follow-up with individuals living in the surrounding neighborhoods was not recommended because the airborne and water-borne routes were not considered significant pathways that may have exposed a larger, geographically circumscribed population.
- Likewise, it was not considered feasible to attempt follow-up of individuals who have routinely visited the site because such individuals are unknown and they may live anywhere in the greater Houston area.

FOR MORE INFORMATION	If you have any questions or concerns about this Public Health Assessment or about theoretical dioxin risks from exposures to sediments from the SJR-HSC-UGB, you should contact Richard A. Beauchamp, M.D., from DSHS at 1-512-458-7269. A copy of this Public Health Assessment document will be made available on the DSHS website at http://www.dshs.state.tx.us/epitox/assess.shtm You can also call the ATSDR at 1-800-CDC-INFO and ask for information on dioxins. The ATSDR's toxicological profile on dioxins is available on the ATSDR's website under the name "Chlorinated Dibenzo-p-Dioxins" at http://www.atsdr.cdc.gov/toxpro2.html.

Purpose and Health Issues

This PHA was prepared for the San Jacinto River Waste Pits (SJRWP) site in accordance with the Interagency Cooperative Agreement between ATSDR and DSHS. The aim of this evaluation is to determine if people are being exposed to hazardous substances and, if so, whether that exposure is potentially harmful and should be eliminated or reduced. In preparing this PHA, no independent sediment, fish, or other samples were collected and/or analyzed. Instead, DSHS and ATSDR have used sediment sample data previously collected on-site by the Texas Commission on Environmental Quality (TCEQ), fish and crab sample data collected near the SJRWP site by the DSHS Seafood and Aquatic Life Group (SALG), and sediment sample data collected from the San Jacinto River (SJR), Houston Ship Channel (HSC), and Upper Galveston Bay (UGB) by the University of Houston under the Dioxin TMDL Project.

Exposure Routes and Scenarios

The SJRWP PHA evaluates three primary and secondary routes of exposure to contaminants from the site: 1) inadvertent oral ingestion of contaminated sediments; 2) dermal absorption of contaminants through skin contact with sediments; and 3) ingestion of fish or crabs containing elevated levels of contaminants from the site. Six exposure scenarios were developed to cover the range of likely or at least plausible exposures: 1) The subsistence fisherman, fishing on-site 5 days per week, 52 weeks per year for 30 years; 2) The weekend fisherman, fishing on-site 1 day per week, 52 weeks per year for 30 years; 3) The sporadic fisherman, fishing on-site 12 times per year for 15 years; 4) The child of a subsistence fisherman, who starts exposure at age 3 and continues through age 50 (47 years, as in scenario 1 above); 5) The child of a weekend fisherman, starting exposure at age 3 and continuing through age 50 (47 years, as in scenario two above); and 6) The child of a sporadic fisherman, starting exposure at age 3 and continuing through age 35 (32 years, as in scenario three above).

Eliminated Pathways

Because of the nature of the contaminants, their low volatility, their high affinity for soil particles, and the high vegetation coverage on the site – leading to low likelihood of wind-blown dust – the airborne route was not considered a significant pathway of exposure for this PHA. Additionally, the groundwater pathway was not considered because groundwater in the area is brackish and non-potable, and there are no groundwater wells in the immediate vicinity of the site. Surface water samples were not collected and reported in the hazard ranking system (HRS) documentation, and the probability of regular ingestion of surface water from the SJR, HSC, or UGB is low because these waters are brackish and non-potable; therefore, surface water was not considered to be a significant pathway of exposure at this site.

Health Outcome Data

Health outcome data for the surrounding neighborhoods were not evaluated because the airborne and water-borne routes were not considered significant pathways that may have exposed a larger, geographically circumscribed population. Also, individuals who live in other areas (and who may routinely visit the site) could not be differentiated from those who do not visit the site among the general entries in the cancer registry or birth defect registry databases.

Background

Site Description

The SJRWP site is located in eastern Harris County, Texas, between the cities of Channelview and Baytown (See Figures 1, 2, 3, and 4; Appendix B). The site occupies a 20 acre tract of land currently owned by Virgil C. McGinnis, Trustee. The property lies on the western bank of the SJR immediately north of the IH-10 Bridge. The pits consist of a series of three surface impoundments that were constructed sometime between October 8, 1964 and February 15, 1973. Surface areas (converted to acres) for pits A, B, and C are approximately 3.04, 1.11, and 4.33 acres, respectively (see Figure 5, Appendix B for approximate surface areas in square feet). No information is available regarding the construction details of the three surface impoundments. Because of gradual subsidence in the area over the years, most of two of the waste pits (pits B and C) are now submerged under approximately a foot or more of water from the SJR. The third waste pit (pit A) is on slightly higher ground and is separated from the other two submerged pits by an approximately 6 foot high berm [2].

Site History

The SJRWP are believed to have been used from the mid-1960s to the mid-1970s for the disposal of paper mill waste. A witness, previously employed as a marine surveyor who inspected barges, has reported seeing tugboats pushing barges filled with waste sludge from the Champion Paper Co. in Pasadena, Texas, to the pits for offloading and storage. He further reported witnessing sludge from these barges being discharged into the pits on the site [2]. Since paper mill waste from the 1960s and 1970s is known to contain high levels of dioxins and other chemicals as a result of the chlorine bleaching process then in use, the waste pits are thought to be a contributing source of the elevated levels of dioxins found in fish, crabs, and sediments in the SJR, HSC, and UGB [3].

The DSHS SALG routinely collects fish, crabs, and other aquatic life samples from bodies of water across the state and analyzes them for various contaminants of potential public health concern, such as mercury, polychlorinated biphenyls (PCBs), pesticides, and, occasionally, dioxins. As part of this monitoring program, the Texas Department of Health (TDH – the predecessor agency for DSHS) collected fish and crab samples from the SJR, HSC, and UGB. In September 1990, as a result of excessive dioxin concentrations found in these samples (greater than 2.33 pg/g), TDH issued a seafood consumption advisory for catfish and blue crabs caught from these waters. The advisory recommended that men should consume no more than one 8-ounce meal of catfish or blue crabs from this area per month and, furthermore, that women of child-bearing age and children should not consume any catfish or blue crabs from the HSC or the UGB [4]. Since 1990, TDH/DSHS has conducted five additional health consultations/risk characterizations for the consumption of seafood from the HSC and UGB, all of which have recommended the continuance of the previously issued advisory on the consumption of catfish and/or blue crabs [5,6,7,8,9]. The two most recent health consultations/risk characterizations [8,9] have lifted the advisory on blue crabs but have added an advisory on spotted seatrout from the UGB and LGB.

In July 1995, the Houston Ship Channel Toxicity Study reported unexplained high concentrations of dioxins in sediment samples in the vicinity of the SJR where it flows under the IH-10 Bridge [10]. Section 303(d) of the Clean Water Act requires all states to identify waters that do not meet, or are not expected to meet, applicable water quality standards. For each listed water body that does not meet a standard, states must develop a Total Maximum Daily Load (TMDL) for each pollutant that has been identified as contributing to the impairment of water quality in that water body. The TCEQ is responsible for ensuring that TMDLs are developed for impaired surface waters in Texas. The ultimate goal of these TMDLs is to restore the quality of the impaired water bodies [11].

Because of the elevated levels of dioxins found in fish and crabs, the HSC system was placed on the §303(d) impaired surface waters list, and a TMDL study was initiated by the TCEQ [11]. In carrying out the Dioxin TMDL Project, the University of Houston has collected hundreds of sediment, water, fish, and other aquatic life samples and analyzed them for various congeners of PCDDs/PCDFs over the time period from 2002 through 2005 [11]. These data are available from TCEQ's website in pdf format. The University of Houston reported evidence of a sand mining operation in the area immediately northwest of the SJRWP site [11]. (See the circled area in Figure 6, Appendix B). However, documentation and details of the sand mining operation were not presented in the University of Houston's Dioxin TMDL Project report.

In 2005, the Texas Parks and Wildlife Department (TPWD) became aware of the presence of what appeared to be a number of waste pits located in a sandbar in the SJR immediately north of the IH-10 Bridge. TPWD contacted the TCEQ in April of 2005 and asked that the area be evaluated as a potential threat to aquatic resources and human health [12].

In the summer of 2005, TCEQ began sampling from the waste pits site under their Preliminary Assessment/Site Inspection (PA/SI) program. The site inspection report, including sampling data analysis and other background information, was completed by early 2007. Figure 3, Appendix B, shows the approximate locations where the site sediment samples were obtained, and Figure 4a, Appendix B shows the approximate locations where background sediment samples were collected. Both the PA/SI study and the Dioxin TMDL Project have shown very high levels of dioxin in the waste pits on-site, and the Dioxin TMDL Project has shown scattered elevated levels of dioxin over a much larger area in the SJR, HSC, and UGB [3,11].

The SJRWP site was proposed to the EPA's NPL on September 19, 2007 [13] and was officially added to the NPL by Final Rule in 40 CFR Part 300 as published in the Federal Register on March 19, 2008 [14]. In January 2010, the EPA released the Remedial Investigation/Feasibility Study (RI/FS) work plan and began the field sampling sediment study, the fate and transport modeling assessment, and the bioaccumulation assessment. In April 2010, the EPA posted warning signs and erected a fence to restrict access to the SJRWP site. Under a project to develop Biota-Sediment Accumulation Factors (BSAFs) funded by the Texas Environmental Health Institute (TEHI), Baylor University has begun collecting benthic samples in the vicinity of the SJRWP site to more completely characterize PCDD/PCDF concentrations in fish, crabs, and shellfish caught near the site.

Land and Natural Resource Use

The SJRWP site is located on the west bank of the SJR. This area is near what is referred to as the Port of Houston. The Port of Houston is 25 miles long and includes both public and private facilities. This port is connected to a vast array of interstate highways and railroads, and 150 trucking lines connect the Port to the continental United States, Canada, and Mexico. The SJR and Galveston Bay offer recreational anglers and commercial shrimpers opportunities for boating and fishing access. One such example would be San Jacinto Battleground-Monument State Historic Site where individuals can fish without purchasing a fishing license (see TPWD's website http://www.tpwd.state.tx.us/fishboat/fish/programs/familyfish).

Demographics

The City of Baytown comprises an area of approximately 32.7 square miles and had a population of 73,491, according to the 2006 Census estimate. The City of Channelview comprises an area of approximately 16.2 square miles and had a population of 29,685, according to the 2000 Census (no estimate was available for 2006) [16]. The nearest residential population (Channelview, Texas) is located approximately ½ mile or more west of the SJRWP site. Additional residential areas in the communities of Lynchburg and Highlands are located approximately ½ mile southeast and ½ mile northeast of the site respectively (on the other side of the river from the site). Approximately 1,155 people live within 1 mile of the site and most of these are on the east side of the SJR [17]. Of these, 108 were children aged 6 and younger, 134 were adults aged 65 or older, and 221 were females aged 15-44 (See Figure 1, Appendix B).

Site Visits

DSHS, along with representatives from the TCEQ and the EPA, visited the SJRWP site on December 18, 2007. The site was unfenced and easily accessible from the SJR by small boat. Land access also was relatively unlimited as evidenced by the dirt road paralleling IH-10 on the north side that gave way to a well traveled foot trail leading across the site and continuing out to a point at the north end of the site overlooking the SJR. This area and the trails leading to it were well beaten-down and were littered with trash, soft drink cans, beer bottles, charcoal briquettes, fishing line in the trees, and even an old wire crab trap left behind on the bank. By its well-beaten-down appearance and the presence of the afore-mentioned trash, this point appeared to be a popular fishing location. Figures 6-13, Appendix B, show various features of the site and the surrounding areas.

On October 14, 2009, a team from DSHS traveled to Channelview, Texas, in order to distribute educational materials regarding the fish consumption advisory and other exposure hazards related to the SJRWP and to meet with staff from TCEQ and Baylor University for a tour of the SJRWP site. After the initial site visit, DSHS talked with a number of families who were fishing and wading in the SJR near the IH-10 bridge (some actually on the site, some immediately south of the site, and others across the river). Brochures were distributed, explaining the dangers of eating fish caught from the HSC and SJR, especially for small children and women of child bearing age. The DSHS team proceeded to the area across the river from the site and distributed small stacks of 20-30 brochures at R.V. parks, bait houses, and restaurants along South Main Street in Highlands, TX.

The following day, DSHS met with Gail Miller, Assistant Harris County Commissioner, Pct. 2, informing her of our plans to distribute informational brochures in the Channelview area and leaving a box of 1,000 brochures for her to distribute through her office. The team also visited the Baytown Health Department, Environmental Health Division, and left a stack of approximately 150 brochures for them to distribute through their clinics. Later, the team went door-to-door and disseminated brochures in five neighborhoods located to the west, southwest, northeast, and southeast of the site. DSHS also met with TPWD staff at the San Jacinto Battleground State Park, where park visitors can (and frequently do) fish without having to obtain a fishing license. DSHS left approximately 750 brochures with TPWD rangers who agreed to distribute the brochures to visitors planning to fish in the park. In total, the DSHS team distributed approximately 3,000 brochures, receiving positive feedback from citizens, business owners, and County officials regarding our efforts to inform the public.

Community Health Concerns

The TPWD was instrumental in doing the research that initiated the process resulting in the site being proposed to the NPL. U.S. Representatives Gene Green (D-Houston) and Ted Poe (R-Humble) have offered valuable bipartisan legislative support encouraging the EPA to begin a cleanup of the site [3]. After the SJRWP site was proposed to the NPL, the EPA received a number of comments favoring listing and cleanup. One of the comments urged EPA not only to list the site but also to “consider environmental targets which were not used in scoring the site.” EPA will change the HRS scoring record to indicate environmental targets were not scored but should be considered when EPA performs more extensive investigation under the remedial investigation/feasibility study (RI/FS) [14]. However, it is not clear from the Federal Register article what “environmental targets” were not scored.

Methods Used in this Public Health Assessment

Chemicals of Concern for the Site

The chief chemicals of concern for the SJRWP site (those that led to its being ranked as a Superfund site) are PCDDs and PCDFs [2]. Other hazardous chemicals may be identified in the pits along with the PCDDs and PCDFs once the site has been more thoroughly characterized during the RI/FS phase of the Superfund process.

Quality Assurance/Quality Control (QA/QC)

In preparing this report, DSHS and ATSDR relied on the data provided to us by the TCEQ in the HRS Documentation Record for the SJRWP NPL site (sediment samples) [2]. All sediment samples were collected according to the EPA-approved FY 2004-2005 TCEQ Quality Assurance Project Plan. We also relied on data collected by the DSHS SALG as part of their routine seafood and shellfish monitoring activities (fish and crab samples) [4,5,6,7,8,9]. The SALG outlines their QA/QC methods in their most recent risk characterization of adverse health effects associated with the consumption of fish or blue crab from the lower Galveston Bay [9]. Finally, the University of Houston carefully follows what appear to be appropriate QA/QC methods in their conduct of their Dioxin TMDL Project for the evaluation of dioxins in the SJR, HSC, and UGB waterway system [11]. Thus, we have assumed adequate QA/QC procedures were followed with regard to data collection, chain of custody, laboratory procedures, and data reporting.

SJRWP Pathway Analysis

High concentrations of PCDDs and PCDFs from paper mill waste have been found in soil and sediments contained in three large surface impoundments at the SJRWP site. The land on which the pits are located has subsided over the years since the waste was impounded, and two of the pits are partially submerged under a few inches to a few feet of water from the SJR. The SJRWP site was unfenced and there was clear evidence that people have been frequenting the site for years for fishing and wading. Consequently, on-site oral and dermal contacts with contaminated sediments were considered to be significant pathways for exposure. During high water flow events, it is anticipated that some of the contaminants from the site have been washed downstream. Thus, off-site oral and dermal contacts with contaminated sediments from the site were also considered to be potential pathways for exposure. Dioxin concentrations exceeding fish comparison values by a factor of 1.3 to 2.6 have been measured in blue crabs and blue catfish caught near the SJRWP site and fishing advisories have been issued by DSHS over the years. Consequently, fish and crab consumption were also considered to be potential pathways for exposure to SJRWP site contaminants.

Because of the nature of the contaminants, their low volatility, their high affinity for soil particles, and the high vegetation coverage on the site – leading to low likelihood of wind-blown dust – the airborne route was not considered a significant pathway of exposure at this site. Additionally, the groundwater pathway was not considered because groundwater near the site is brackish and non-potable and there are no groundwater wells in the immediate vicinity. Surface water samples were not collected and reported in the HRS documentation, and the probability of regular ingestion of surface water from the SJR, HSC, or UGB is low because these waters are brackish and non-potable; therefore, surface water was not considered to be a significant pathway of exposure at this site. Tables 1 and 2, Appendix C, identify the various pathways of significance for exposures to contaminants at or from the SJRWP site.

SJRWP Exposure Scenarios

The SJRWP PHA evaluates three primary or secondary routes of exposure to contaminants from the site: 1) inadvertent oral ingestion of contaminated sediments; 2) dermal absorption of contaminants through skin contact with sediments; and 3) ingestion of fish or crabs containing elevated levels of contaminants from the site. For comparison purposes, we looked at the PCDD/PCDF concentrations measured at other locations in the SJR/HSC/UGB waterway system by the University of Houston under the Dioxin TMDL Project and estimated the risks from oral and dermal sediment exposures and fish or crab consumption at these additional locations.

Oral and dermal exposure levels for individuals fishing at the SJRWP site and other locations in the SJR/HSC/UGB waterway system are unknown; however, on the basis of the pathway analysis, we made a number of conservative assumptions about possible oral and dermal exposures and set up six scenarios describing a range of possible exposures.

The first scenario is that of the **subsistence fisherman** who may fish at the site 5 days per week, 52 weeks per year, for 30 years (from ages 20 through 50) and who may, in the process, get contaminated sediments on his or her hands and forearms, leading to both dermal and oral exposures. This scenario assumes an average daily sediment ingestion rate 100 mg/day, sediment dermal exposures affecting 2,056 cm^2 of skin per day, and an average daily fish consumption rate of 163 g/day for a 70.58 kg adult.

The second scenario is that of the **weekend fisherman** who may fish at the site 1 day per week, 52 weeks per year, for 30 years (from ages 20 through 50) and who may, in the process, get contaminated sediments on his or her hands and forearms, leading to both dermal and oral exposures. This scenario assumes an average daily sediment ingestion rate 100 mg/day, sediment dermal exposures affecting 2,056 cm^2 of skin per day, and an average daily fish consumption rate of 32.6 g/day for a 70.58 kg adult (roughly comparable to the 30 g/day rate and 70 kg weight used by the DSHS SALG for determining the need for fish consumption advisories).

The third scenario is that of the **sporadic fisherman** who may fish at the site 12 times per year, for 15 years (from ages 20 through 35) and who may, in the process, get contaminated sediments on his or her hands and forearms, leading to both dermal and oral exposures. This scenario assumes an average daily sediment ingestion rate 100 mg/day, sediment dermal exposures affecting 2,040 cm^2 of skin per day, and an average daily fish consumption rate of 7.37 g/day for a 69.05 kg adult.

The fourth scenario is that of the **child of a subsistence fisherman** who (starting at age 3) may accompany the fishing parent to the site 5 days per week, 52 weeks per year and who may, in the process, get contaminated sediments on his or her hands and forearms, leading to both dermal and oral exposures. For this scenario the child is assumed to grow into a subsistence fisherman who continues the same frequency of exposure up until age 50 (a total of 47 years of exposure). This scenario assumes an average daily sediment ingestion rate 120 mg/day, sediment dermal exposures affecting 1,816 cm^2 of skin per day, and an average daily fish consumption rate of 143 g/day for a child/adult weighing an average of 60.1 kg over the 47 year period.

The fifth scenario is that of the **child of a weekend fisherman** who (starting at age 3) may accompany the fishing parent to the site 1 day per week, 52 weeks per year and who may, in the process, get contaminated sediments on his or her hands and forearms, leading to both dermal and oral exposures. For this scenario the child is assumed to grow into a weekend fisherman who continues the same frequency of exposure up until age 50 (a total of 47 years of exposure). This scenario assumes an average daily sediment ingestion rate 120 mg/day, sediment dermal exposures affecting 1,816 cm^2 of skin per day, and an average daily fish consumption rate of 28.6 g/day for a child/adult weighing an average of 60.1 kg over the 47 year period.

The sixth scenario is that of the **child of a sporadic fisherman** who (starting at age 3) may accompany the fishing parent to the site 12 times per year and who may, in the process, get contaminated sediments on his or her hands and forearms, leading to both dermal and oral exposures. For this scenario the child is assumed to grow into a sporadic fisherman who continues the same frequency of exposure up until age 35 (a total of 32 years of exposure). This scenario assumes an average daily sediment ingestion rate 130 mg/day, sediment dermal exposures affecting 1,696 cm^2 of skin per day, and an average daily fish consumption rate of 6.09 g/day for a child/adult weighing an average of 54.5 kg over the 32 year period.

Under all six scenarios it is assumed that potentially contaminated fish are caught during each visit, leading to additional oral exposures to dioxins from ingestion of fish or crabs. The assumptions employed in calculating the various risk estimates for this health assessment should be considered to range from "typical" to "very conservative" for fishermen and children of fishermen visiting the site and should not be construed to represent actual or likely risks for casual visitors to the site.

Toxic Equivalency (TEQ) for Mixed Dioxins

The PCDD/PCDF congeners with dioxin-like toxicity are often found in complex mixtures. For the purpose of this risk assessment, we have calculated the total TCDD TEQ for each specific mixture of PCDDs and PCDFs. This procedure involves multiplying the concentration of each congener by its individual toxicity equivalency factor (TEF) and summing these products for the entire sample (see Table 3, Appendix C, for a list of the various PCDD/PCDF congeners and their respective TEFs. Also, see Appendix D for a more thorough description of the method for calculating the TCDD TEQ for a mixed dioxin sample).

Cancer Risk Estimates and Exposed Population Calculations

In this PHA document, cancer risk estimates are presented in scientific notation, with values rounded to three significant digits (e.g., calculated value = $1.25384534528542\times10^{-5}$; displayed value = 1.25×10^{-5}). The tables in Appendix C, showing theoretical cancer risk estimates, have additional columns labeled "CA Odds" (which actually represent the odds against getting cancer) and are calculated as the reciprocals of the un-rounded cancer risk estimates. These "CA Odds" values (rounded to the nearest integer and occasionally appearing in the text of the document) represent the size of the exposed population necessary to see one additional cancer case over background. Thus, in the above risk estimate example, the size of the exposed population necessary to see one additional cancer case over background would be displayed as 79,755 (the reciprocal of $1.25384534528542\times10^{-5}$) and not 80,000 (the reciprocal of 1.25×10^{-5}) (see Appendix D for descriptions of the methods used for calculating cancer risk estimates for the various exposure scenarios).

Health Assessment Comparison (HAC) Values

To simplify the health assessment process, ATSDR, EPA, Oak Ridge National Laboratories (ORNL), and some of the individual states have compiled lists of chemical substances that have been evaluated in a consistent, scientific manner in order to derive toxicant doses (health guidelines) and/or toxicant concentrations (environmental guidelines), exposures to which, are confidently felt to be without significant risk of adverse health effects, even in sensitive sub-populations.

Health Guidelines

Health guidelines for chemical exposures are derived from the toxicologic or epidemiologic literature with many uncertainty or safety factors applied to insure that they are amply protective of human health. They are generally derived for specific routes of exposure (e.g., inhalation, oral ingestion, or dermal absorption) and are expressed in terms of dose, with units of milligrams per kilogram per day (mg/kg/day).

Media-specific HAC values for non-cancer health effects under oral exposure routes are generally based on ATSDR's chronic oral minimal risk levels (MRLs) or EPA's oral reference doses (RfDs). Chronic oral MRLs and RfDs are based on the assumption that there is an identifiable exposure dose (with units of mg/kg/day) for individuals, including sensitive subpopulations (such as pregnant women, infants, children, the elderly, or individuals who are immunosuppressed), that is likely to be without appreciable risk for non-cancer health effects over a specified duration of exposure.

RfDs and MRLs are derived for contaminant-specific critical effects (such as poor weight gain, increased liver enzymes, decreased performance on some neurological or psychological test, altered social behavior, decreased resistance to infection, decreased lung function, respiratory irritation, skin rash, or any number of other physiological effects) observed in human or animal studies at a specified contaminant dose. The lowest dose at which the critical effect is observed is called the Lowest Observed Adverse Effect Level (LOAEL) and the next lower dose (at which no adverse effects are observed) is called the No Observed Adverse Effects Level (NOAEL).

Generally, one or more uncertainty factors are applied to the LOAEL or NOAEL to arrive at a lower exposure dose that is felt to be protective of human health, including sensitive sup-populations. Each uncertainty factor is usually in the range of 3-10 (e.g., 3 or 10 for extrapolation from animals to humans, 3 for sensitive sub-populations, 3 or 10 for the use of a minimal LOAEL instead of a NOAEL, 10 for human variability, 3 or 10 for database deficiencies, 5 for potential increased susceptibility in children, etc.). Total uncertainty factors for MRLs or RfDs (all uncertainties combined) generally range from 3 up to 2,000 or more, depending on the substance and the apparent reliability of the study upon which the MRL or RfD was based.

Thus, RfDs or MRLs represent exposure doses that are felt to be unlikely to cause adverse health effects for the specified duration of exposure, even in sensitive sub-populations. When the hazard quotient (HQ) or hazard index[3] (HI) is greater than or equal to the uncertainty factor used in deriving the health guideline dose, exposures are in the same range as those that were observed to produce the critical effect in the original study. Therefore, it is reasonable to anticipate a higher probability of adverse effects in exposed individuals (particularly, if the MRL or RfD was based on the study LOAEL).

Environmental Guidelines

Environmental guidelines for specific media (e.g., air, soil/sediment, food, drinking water, etc.) are often derived from health guidelines after making certain assumptions about 1) the average quantities of the specific media that a person may assimilate into the body per day (i.e., inhale, eat, absorb through the skin, or drink) and 2) the person's average body weight during the exposure period. Environmental guidelines are expressed as chemical concentrations in a specific medium with units such as micrograms per cubic meter ($\mu g/m^3$), milligrams per kilogram (mg/kg), micrograms per liter (µg/L), parts per million (ppm), or parts per billion (ppb). If these values are based on ATSDR's oral MRLs, they are known as environmental media evaluation guides (EMEGs); if they are based on EPA's RfDs, they are called reference dose media evaluation guides (RMEGs).

For airborne contaminants, ATSDR health assessors frequently use ATSDR's inhalation minimal risk levels (inhalation MRLs) or EPA's inhalation reference concentrations (RfCs). Inhalation MRLs and RfCs are all based on the assumption that there is an identifiable exposure concentration in air [with units of micrograms per cubic meter ($\mu g/m^3$) or parts per billion by volume (ppbv)] for individuals, including sensitive subpopulations, that is likely to be without appreciable risk for non-cancer health effects over a specified duration of exposure. Since it is already in the form of a concentration in a particular medium, the inhalation MRL is also called the EMEG for air exposures.

These environmental guidelines are frequently referred to as "screening values" or "comparison values" since the contaminant concentrations measured at a Superfund or other hazardous waste site are frequently "compared" to their respective environmental guidelines in order to "screen" for those substances that require a more in-depth evaluation. Since comparison values are health-based (i.e., derived so as to be protective of public health) and they are frequently employed in conducting public health assessments, they are commonly referred to as health assessment comparison values or HAC values.

Other HAC value acronyms have been developed by the various EPA Regions or other state or federal agencies including EPA Region 3's "risk-based concentrations" (RBCs), EPA Region 6's "contaminant screening levels" (CSLs), EPA Region 9's "risk evaluation guides" (REGs), EPA's health effects assessment summary tables (HEAST) "dose-response values" (DRVs),

3 The hazard quotient in this context is defined as the ratio of the calculated exposure dose for the scenario to the MRL or RfD. When hazard quotients from multiple exposure routes are summed together, the resulting value is called the hazard index. Hazard quotients or hazard indices less than 1.0 imply that the exposure dose(s) are below the comparison value and thus are not expected to be a public health concern. If the HQ or HI is greater than or equal to 1.0, the exposure dose(s) exceed the comparison value and may or may not be a public health concern depending on the magnitude of the HQ or HI and the magnitude of the uncertainty factors used in the original study.

California's "reference exposure levels" (RELs), and TCEQ's "effects screening levels" (ESLs). These values are occasionally used when there are no published MRLs, RfDs, or RfCs for a given contaminant.

HAC values for non-cancer effects (specifically ATSDR's oral and/or inhalation MRLs) may be available for up to three different exposure durations: acute (13 days or less), intermediate (14 to 364 days), or chronic (365 days or more). As yet, EPA calculates RfD or RfC HAC values only for chronic exposure durations.

HACs for Cancer Effects

When a substance has been identified as a carcinogen, the lowest available HAC value usually proves to be the cancer risk evaluation guide (CREG). For oral exposures, the CREG (with units of mg/kg or ppm) is based on EPA's chemical-specific cancer slope factor (CSF) (also referred to as oral slope factor or OSF) and represents the concentration that would result in a daily exposure dose (expressed in units of mg/kg/day) that would produce a theoretical lifetime cancer risk of 1×10^{-6} (one additional cancer case in one million people exposed over a 70 year lifetime) [1]. For dust, soil, or sediment exposures, the CREG is generally based on the assumptions that a person ingests an average of 100 mg of dust/soil/sediment per day and that their average body weight is 70 kg over their lifetime. The theoretical risk from such exposures is calculated as Risk = Concentration (mg/kg) $\times 10^{-6}$ kg/mg (units conversion factor) $\times$ 100 mg/day $\div$ 70 kg $\times$ OSF. The CREG concentration is calculated by setting the Risk = 10^{-6} and solving for the Concentration. Thus, the CREG = $10^{-6} \times 70 \div 10^{-6} \div 100 \div$ OSF = $0.7 \div$ OSF.

For inhalation exposures, the CREG (expressed in units of $\mu g/m^3$) is based on the EPA's inhalation unit risk (IUR) value and is calculated as CREG = $10^{-6} \div$ IUR. The inhalation CREG represents the ambient air concentration that, if inhaled continuously over a lifetime, would produce a theoretical excess lifetime cancer risk of 1×10^{-6} (one additional cancer case in one million people exposed over a 70 year lifetime).

Imputed or Derived HAC Values

The science of environmental health and toxicology is still developing, and sometimes, scientific information on the health effects of a particular substance of concern is not available. In these cases, ATSDR scientists will occasionally look to a structurally similar compound, for which health effects data are available, and assume that similar health effects can reasonably be anticipated on the basis of their similar structures and properties. Occasionally, some of the contaminants of concern may have been evaluated for one exposure route (e.g., the oral route) but not for another route of concern (e.g., the inhalation route) at a particular NPL site or other location with potential air emissions. In these cases, ATSDR scientists may do what is called a route-to-route extrapolation and calculate the inhalation RfD, which represents the air concentration (in $\mu g/m^3$) that would deliver the same dose (in mg/kg/day) to an individual as the published oral RfD for the substance. This calculation involves making certain assumptions about the individual's inhalation daily volume in cubic meters per day (m^3/day) and the individual's body weight (in kg). It also assumes a similarity in the oral and inhalation absorption fraction, meaning that once the contaminant has been absorbed into the bloodstream, it behaves similarly whether it came through the gastrointestinal (GI) tract or the lungs. Because of these assumptions, route-to-route extrapolations are employed only when there are no available HAC values for one of the likely routes of exposure at the site.

Use of HAC Values

When assessing the potential public health significance of the environmental sampling data collected at a contaminated site, the first step is to identify the various plausible site-specific pathways and routes of exposure based on the media that is contaminated (e.g., dust, soil, sediment, sludge, ambient air, groundwater, drinking water, food product, etc.). Once this is done, maximum values for measured contaminant concentrations are generally compared to the most conservative (i.e., lowest) published HAC value for each contaminant. If the maximum contaminant concentration is below the screening HAC value, then the contaminant is eliminated from further consideration, but if the maximum concentration exceeds the screening HAC, the contaminant is identified as requiring additional evaluation. However, since the screening HAC value is almost always based on a chronic exposure duration (or even a lifetime exposure duration, in the case of comparisons with CREG values) and the maximum contaminant concentration represents a single point in time (which would translate to an acute duration exposure), one cannot conclude that a single exceedance (or even several exceedances) of a HAC value necessarily constitutes evidence of a public health hazard. That conclusion can be reached only after it has been determined that peak concentrations are exceeding acute-exposure-duration HAC values, intermediate-term average concentrations are exceeding intermediate-exposure-duration HACs, or long-term average concentrations are exceeding chronic-exposure-duration HACs.

Health Assessment Comparison Values for the SJRWP Site

The following HAC values have been established (or calculated) by the EPA, ATSDR, and/or the Oak Ridge National Laboratories (Risk Assessment Information System or RAIS) for oral and/or dermal exposures to 2,3,7,8-TCDD:

- Soil/Sed CREG (calculated) 4.67×10^{-6} ppm = 4.67 pg_{TEQ}/g_{Sed}
- Chronic Soil/Sed $EMEG_{Adult}$ 8.4×10^{-4} ppm = 840 pg_{TEQ}/g_{Sed}
- Intermediate Soil/Sed $EMEG_{Adult}$ 1.63×10^{-2} ppm = 16,300 pg_{TEQ}/g_{Sed}
- Acute Soil/Sed $EMEG_{Adult}$ 1.17×10^{-1} ppm = 117,000 pg_{TEQ}/g_{Sed}
- Chronic Soil/Sed $EMEG_{Child}$ 6.0×10^{-5} ppm = 60.0 pg_{TEQ}/g_{Sed}
- Intermediate Soil/Sed $EMEG_{Child}$ 1.67×10^{-3} ppm = 1,670 pg_{TEQ}/g_{Sed}
- Acute Soil/Sed $EMEG_{Child}$ 8.33×10^{-3} ppm = 8,330 pg_{TEQ}/g_{Sed}
- ATSDR's Chronic Oral MRL 1.2×10^{-9} mg_{TEQ}/kg_{BW}/day
- ATSDR's Intermediate Oral MRL 2.33×10^{-8} mg_{TEQ}/kg_{BW}/day
- ATSDR's Acute Oral MRL 1.67×10^{-7} mg_{TEQ}/kg_{BW}/day
- (Est.) Chronic Dermal MRL 1.2×10^{-9} mg_{TEQ}/kg_{BW}/day
- (Est.) Intermediate Dermal MRL 2.33×10^{-8} mg_{TEQ}/kg_{BW}/day
- (Est.) Acute Dermal MRL 1.67×10^{-7} mg_{TEQ}/kg_{BW}/day

- RAIS's Oral Slope Factor 150,000 $(mg_{TEQ}/kg_{BW}/day)^{-1}$
- RAIS's Dermal Slope Factor 300,000 $(mg_{TEQ}/kg_{BW}/day)^{-1}$

Children's Health Considerations

ATSDR and DSHS recognize that fetuses, infants, and children may be uniquely susceptible to adverse effects from exposure to toxic chemicals and that exceptional susceptibilities demand special attention [25,26]. Windows of vulnerability or "critical periods" exist during development – particularly during early gestation (weeks 0 through 8) – but can occur at any time during pregnancy, infancy, childhood, or adolescence. Indeed, there are numerous times during development when toxicants can impair or alter the structure or function of susceptible systems [27]. A growing body of evidence demonstrates that children may suffer disproportionately from environmental health risks.

Children exposed to toxicants in various environmental media (food, water, air, soil, etc.) may receive higher exposure doses than adults exposed to the same media, because children eat more food, drink more fluids, and breathe more air in proportion to their body weights than do adults. Also, children are likely to ingest higher quantities of soil or sediment from the environment, because they have a greater tendency to handle contaminated objects and to put their hands or said objects in their mouths. Children tend to absorb a higher percentage of many toxicants from the GI tract than do adults. A child's smaller body and organ size and weight, combined with a higher exposure dose, results in a higher concentration of toxicant at the target organ. Children may also experience toxicity at lower exposure doses than adults because a child's organs may be more sensitive to the effects of toxicants, and their systems could respond more extensively, or with greater severity, to a given dose than would an adult organ exposed to an equivalent toxicant dose [28].

Infants can ingest toxicants passed on from the mother through breast milk – an exposure pathway that may go unrecognized. Nonetheless, the advantages of breastfeeding generally outweigh the probability of significant exposure to infants through breast milk, so women are encouraged to continue breastfeeding while limiting exposure of their infants through limitation of their intake of contaminated foodstuffs.

If a chemical appears more toxic to fetuses, infants, or children than to adults, federal risk assessors adjust RfDs, MRLs, or other non-cancer HAC values to assure protection of the immature system [29]. This comes in the form of an additional uncertainty factor (typically 10) being applied during the development of the HAC value. Although comparison values used for assessing the probability of cancer do not contain uncertainty factors as such, conclusions drawn from those probability determinations do contain substantial safety margins by virtue of the models used to derive the factors. Furthermore, in their *Supplemental Guidance for Assessing Cancer Susceptibility from Early-Life Exposure to Carcinogens* [30], the EPA recommends applying a 10-fold adjustment factor to the published CSF, for exposures before 2 years of age, when the carcinogen has been determined to have a mutagenic mode of action. For exposures during ages 2 through 15 years, the adjustment factor is reduced to 3, and for exposures after age 15 (or for carcinogens not having a mutagenic mode of action, such as dioxins), no adjustment is applied. Additionally, in accordance with the ATSDR's *Child Health Initiative* [31] and the

EPA's *National Agenda to Protect Children's Health from Environmental Threats* [32], the DSHS further seeks to protect children from the possible negative effects of toxicants in fish by suggesting that this potentially sensitive subgroup consume smaller quantities of contaminated fish or shellfish than adults ordinarily consume. In this HA, DSHS has scaled the fish consumption rates for children in proportion to the 3/4 power of the body weight of the child with respect to the 3/4 power of the body weight of the adult (child consumption rate = adult consumption rate × $[\text{child body weight}]^{3/4} \div [\text{adult body weight}]^{3/4}$).

In making recommendations regarding the maximum quantity of a potentially contaminated fish species a person should consume, the DSHS SALG calculates a HAC value representing a fish-tissue concentration for each contaminant of concern (usually expressed as milligrams contaminant per kilogram fish). This HAC value amounts to an EMEG for the contaminant in fish tissues. For carcinogenic contaminants, a fish tissue concentration is calculated which would produce a theoretical cancer risk of 10^{-4}, assuming an individual eats an average of 30 grams of the contaminated fish per day for a period of 30 years and that the individual's average body weight over the exposure period is 70 kg. For non-carcinogenic effects, the fish tissue concentration is calculated which would result in an exposure dose (in mg/kg/day) that would just equal the RfD or MRL for that contaminant, assuming a 70 kg adult, eating an average of 30 grams of contaminated fish per day (approximately one 8 oz. meal per week) for a period of longer than a year. To account for the lower body weights of children (and correspondingly higher exposure dose per unit of fish consumed), the DSHS SALG recommends that children weighing 35 kg or less and/or who are 11 years of age or younger limit their exposure to the contaminated species of fish or shellfish by eating no more than 15 grams per day of the contaminated species (i.e., no more than approximately one 4-ounce meal per week). The DSHS also recommends that consumers spread these meals over time. Since fish EMEGs are based on the assumption that an individual adult or child would be eating fish at a rate of 30 g/day or 15 g/day, respectively, these EMEGs are not appropriate for evaluating a potential subsistence-fishing scenario. Thus, for this PHA, DSHS has used a risk-based approach to appropriately evaluate the various potential fish consumption rates anticipated under the worst-case subsistence fishing scenarios for this site (see Appendix D for the exposure dose and risk calculations used in this PHA).

We also evaluated the scenario of the inadvertent ingestion of – and dermal contact with – sediment by a child of a subsistence fisherman, a weekend fisherman, and a sporadic fisherman who accompanies the fisher parent and who subsequently carries on the respective fishing activity as an older child and later as an adult. We allowed the exposure to start at age 3 years and to continue through age 50 (age 35 for the child of a sporadic fisherman). Sediment ingestion rates were set at 200 mg/day for ages 3 through 5 years; after age 5, rates decreased linearly to 100 mg/day by age 20; rates remained at 100 mg/day from ages 20 through 50 years.

Results and Discussion

Toxicologic Evaluation of PCDDs/PCDFs

Sources and Production

Dioxins and dioxin-like compounds inadvertently released into the environment generally originate as minor by-products of various industrial processes, such as metal smelting and refining, manufacture of chlorinated chemicals, and paper bleaching. They are also generated through various natural or man-made combustion activities such as forest fires, brush fires, house fires, and medical or municipal waste incineration. Dioxins also can enter the environment through natural biological and photochemical processes, or can transfer from one medium to another through mobilization from environmental reservoirs (e.g., stirred sediments mobilized to the water column). Dioxins can be found throughout the world at low levels in air, soil, water, sediment, and in foods such as meat, dairy products, fish, and shellfish. Dioxins are found at their highest levels in soil, sediment, and in the fatty tissues of animals. When dioxins are released into surface waters, some are broken down by sunlight while others (primarily those with 1, 2, or 3 chlorines, i.e., the mono-, di-, or trichlorodibenzo-p-dioxins) may evaporate into the air. The more highly chlorinated congeners, however, are less volatile, and most will attach to suspended organic particulate matter in the water which gradually settles to the bottom; thus dioxins tend to accumulate in the sediments [18,33].

Exposure Sources and Pathways

Possible routes of human exposure to dioxins and dioxin-like compounds include but are not limited to exposure through food, ambient air, drinking water, and contact with contaminated soil or sediment. Occasionally, exposures may occur through occupational contacts or through contacts at hazardous waste sites [18,33].

For most individuals, consumption of food containing low levels of dioxins and dioxin-like compounds is by far the most important pathway for exposure, accounting for more than 95% of the intake of dioxins in the human population [which generally averages 120 picograms (pg) TEQ/day]. Foods that contribute most to the total daily dietary intake of dioxins include pork, beef, chicken, and eggs (66.1 pg TEQ/day); dairy products (42 pg TEQ/day); and fish (7.8 pg TEQ/day). However, for certain subpopulations (e.g., recreational and subsistence fishermen), fish consumption may be the single most important source of dioxin exposure. For example, residents of the Great Lakes region, who regularly consume fish from the Great Lakes, may have dioxin intakes that range from 390 to 8,400 pg TEQ/day. Other minor sources of exposure for the general population would include breathing ambient air containing low levels of dioxins (2.2 pg TEQ/day), ingesting small amounts of soil containing low levels of dioxins (0.8 pg TEQ/day), and drinking water containing low levels of dioxins (0.008 pg TEQ/day). For some individuals, additional exposures to dioxins may occur through skin contact with herbicides and pesticides (e.g., 2,4,5-T and 2,4-D); living near a hazardous waste site containing dioxins; and occupational exposure at paper and pulp mills, municipal or hazardous waste incinerators, or wood treatment facilities using pentachlorophenol (PCP) [18].

Absorption, Distribution, & Elimination

Dioxins present in food items are generally almost completely absorbed (up to 95%). However, the absorption of TCDD from oily soil at Times Beach, Missouri, was found to be approximately 50% and the absorption from non-oily New Jersey soil was measured at less than 1% [34]. Once dioxins are absorbed into the body, they will be distributed to various organs based on the organ's lipid content. Over time, dioxins will accumulate in an individual's body fat. Seventy-six percent of adipose tissue samples collected from the general population in the U.S. contained measurable quantities of 2,3,7,8-TCDD that averaged 6.2±3.3 pg TEQ/g of fat. The median concentration of PCDDs/PCDFs in adipose tissues of the general population was 31.3 pg TEQ/g adipose tissue (range, 6.01-75.0 pg TEQ/g adipose tissue) [18].

In many animal species, the metabolism of dioxins has been found to take place in the liver through various detoxification processes, including oxidation and reductive dechlorination and/or oxygen bridge cleavage. Once dioxin is broken down into its various metabolites, it will be excreted in the bile and urine. Bile is then excreted in the feces, thus eliminating the toxicant from the body. Women who are breastfeeding infants also have the ability to excrete dioxins in their breast milk. Dioxin has been found to have a half-life of approximately 8.7 years in the human body (range, 7 to 12 years) [18].

Toxicological Effects of Exposure

The most frequently noted health effect in people exposed to excessive amounts of the most toxic member of the dioxin family [2,3,7,8-tetrachlorodibenzo-p-dioxin (2,3,7,8-TCDD)] is chloracne, a severe skin rash characterized by acne-like lesions that occur mainly on the face, neck, and upper body. Other skin effects noted in people exposed to high doses of 2,3,7,8-TCDD include other skin rashes, skin discoloration, and excessive body hair. Another non-cancer health effect caused by high dioxin exposure is transient mild hepatotoxicity (liver damage). Peripheral neuropathy (a form of peripheral nerve damage) has been reported in some individuals exposed to elevated levels of dioxins. Lastly, exposure to high concentrations of PCDDs may induce long-term alterations in glucose metabolism and subtle changes in hormonal levels [18].

In certain animal species, such as Hartley guinea pigs, 2,3,7,8-TCDD is especially harmful and can cause death after a single, relatively low-dose exposure [i.e., LD_{50} doses[4] of 0.6 to 2.1 microgram per kilogram (µg/kg)]. Other animal species, such as Syrian hamsters (with LD_{50} doses of 1,157 to 5,051 µg/kg), appear to be far more resistant to the acute toxic effects of 2,3,7,8-TCDD. Most other animal species fall between these extremes, with LD_{50} doses ranging from 22 to 360 µg/kg. Exposure to sub-lethal levels can cause a variety of effects in animals, such as weight loss, liver damage, and disruption of the endocrine system. Some animals exposed to dioxins at doses of 0.5 to 10 microgram per kilogram per day (µg/kg/day) during pregnancy had higher rates of miscarriages, and the offspring of animals exposed to 2,3,7,8-TCDD during pregnancy often had severe birth defects including skeletal deformities and kidney defects. In some species, a single dose of 2,3,7,8-TCDD at 0.01 µg/kg has been found to weaken the immune system, causing a decrease in the animal's ability to fight viral infections. Other

[4] The lethal dose 50% written as LD_{50} represents the dose that was found to be lethal for 50% of the animals tested.

studies have shown an adverse effect on the development of the thymus in animals exposed for 90 days to diets containing 2,3,7,8-TCDD at 0.005 µg/kg/day. Chronic exposure (for periods of over 16 months) to diets containing 2,3,7,8-TCDD at 0.0012 µg/kg/day has caused altered social behavior in the offspring of exposed mothers [18].

Other non-cancer health effects that are suspected, but not yet confirmed, to be associated with dioxin exposures, include porphyria cutanea tarda (characterized by liver dysfunction and photosensitive skin lesions), type 2 diabetes, and neurobehavioral development effects in infants. Also, men in populations that are highly exposed to dioxins appear to be less likely to father boys [18].

It should be noted that none of the preceding adverse health effects have been reported – or are suspected to have actually occurred – in individuals as a result of contact with contaminants that came from the SJRWP Superfund site.

Carcinogenicity

Several studies in humans have been performed evaluating 2,3,7,8-TCDD exposures and potential cancer effects. These studies suggest that exposure to 2,3,7,8-TCDD increases the risk of several types of cancer in humans. A major weakness in many of these studies is the lack of adequate exposure data. In many cases, body burdens of 2,3,7,8-TCDD were not measured, surrogates of exposure were used to identify subjects who were likely to have been exposed, and/or there was concomitant exposure to other carcinogenic compounds. Cancer health effects that are suspected (but not yet confirmed to be associated with dioxin exposures) include all cancers combined, rectal cancer, pleural cancer, lymphohemopoietic cancer, leukemia, respiratory cancers, prostate cancer, and multiple myeloma (a malignant tumor of plasma cells affecting the bone marrow) [18].

Numerous animal studies have also suggested that exposure to 2,3,7,8-TCDD increases the risk of cancer in animals. Oral exposures of rats to 2,3,7,8-TCDD by gavage or in the feed have significantly increased the incidence of thyroid follicular cell adenoma, ear duct carcinoma, lymphocytic leukemia, kidney adenocarcinoma, peritoneal malignant histiocytoma, skin angiosarcoma, Leydig cell adenoma, hepatocellular carcinoma, and squamous cell carcinoma of the lungs in exposed animals. Mice exposed to 2,3,7,8-TCDD by gavage also developed significantly higher rates of hepatoma, hepatocellular carcinoma, thyroid follicular cell adenoma, and histiocytic lymphoma [18].

The Department of Health and Human Services (DHHS) and the National Toxicology Program (NTP) have determined that 2,3,7,8-TCDD may reasonably be anticipated to cause cancer in humans and thus have listed it as a Class 1 carcinogen (known human carcinogen).

The International Agency for Research on Cancer (IARC) concluded that there is limited evidence in humans for the carcinogenicity of 2,3,7,8-TCDD; however, data from studies involving experimental animals provided sufficient evidence of carcinogenicity. Thus, IARC and the World Health Organization (WHO) currently list 2,3,7,8-TCDD as a Class 1 carcinogen [i.e., carcinogenic to humans (sufficient human evidence)].

The EPA concludes that there is sufficient evidence that 2,3,7,8-TCDD is an animal carcinogen but inadequate evidence that it is a human carcinogen and thus classifies it as a B2 carcinogen [18].

Environmental Samples Collected

TCEQ HRS Samples

On July 12-13, 2005, seven sediment samples were collected just below the surface layer (1 to 8 feet below the surface of the water for submerged locations) from the SJRWP site by the TCEQ as reported in the HRS Documentation Record [2] (see Table 4, Appendix C). For comparison purposes, an additional four sediment samples were collected off-site (two from approximately 3 miles up-stream and two from approximately 4 miles down-stream) (See Tables 4, 5, 6, 7, and 8; Appendix C for sample results and qualifiers) (See Figures 3 and 4, Appendix B, for site sample and background sample locations, respectively). Each TCEQ sediment sample was measured for 15 of the 17 PCDD/PCDF congeners thought to have 2,3,7,8-TCDD-like toxicity or carcinogenicity [the octachlorodibenzo-p-dioxin (OCDD) and octachlorodibenzofuran (OCDF) concentrations were not reported].

University of Houston TMDL Samples

As part of the TMDL study of dioxins in the SJR, HSC, and UGB, the University of Houston collected 210 sediment samples from 84 different locations throughout the SJR, HSC, and UGB from 2002 through 2005. Two of these samples (SE-15 and SE-15dup) were collected on the SJRWP site between pits B and C and close to the northwest extreme of pit B (See Figures 5 and 6, Appendix B). The remaining 208 sediment samples were collected throughout the SJR, HSC, and UGB waterway system. The 210 TMDL samples were measured for all 17 of the PCDD/PCDF congeners having TCDD-like toxicity.

Grouping of Samples for Analysis

For the purpose of this analysis, the samples were grouped into five geographical categories: 1) those that were collected on the SJRWP site (the two TMDL samples were grouped with the seven TCEQ HRS samples); 2) those that are down-stream from the SJRWP site in the SJR, HSC, or UGB (59 samples); 3) those that are in the SJR in the immediate vicinity of the SJRWP site (31 samples); 4) those that are in the HSC above (west) of its confluence with the SJR (62 samples); and 5) those that are up-stream from the SJRWP site or are up various tributaries to the SJR, HSC, or UGB (56 samples).

TCDD TEQ Concentrations at the SJRWP Site & Background Locations

Of the nine samples collected on the SJRWP site, only one sample (SE-07) had a TCDD TEQ concentration of less than 1,000 picograms per gram (pg/g) (See Appendix D for the method for calculating the TCDD TEQ concentration for a sample with mixed PCDDs and PCDFs). The average TCDD TEQ concentration for the nine samples from the site was 15,594 pg/g (range: 80.9 – 34,028 pg/g). TCEQ's upstream and downstream "background" sediment TCDD TEQ concentrations for the four samples averaged 1.85 pg/g (range 1.27 – 2.77 pg/g). (See Tables 5, 6, 7, 8, and 9, Appendix C, for individual congener concentrations and averages). (Also, see Figures 2, 3, and 6, Appendix B for on-site sample locations and Figure 4a for background sample locations).

TCDD TEQ Concentrations at Other Locations in the SJR/HSC/UGB Waterways

For comparison purposes, we looked at TCDD TEQ concentrations measured at other locations in the SJR/HSC/UGB waterway system by the University of Houston under the TMDL Project. Downstream TMDL samples were found to have an average TCDD TEQ concentration of 13.8 pg/g (range: 0.739 – 86.2 pg/g), site vicinity TMDL samples averaged 82.2 pg/g (range: 2.00 – 573 pg/g), HSC TMDL samples averaged 65.7 pg/g (range: 4.90 – 857 pg/g), and upstream or tributary TMDL samples averaged 16.0 pg/g (range: 0.759 – 103 pg/g) (See Table 9, Appendix C, for average, minimum, and maximum values in each sample group). (See Figures 4b and 6, Appendix B, for some of the elevated off-site sample locations).

Public Health Implications

Details of the cancer and non-cancer risk assessment calculations employed in this section can be found in Appendix D. The assumptions employed in calculating the various risk estimates for this health assessment should be considered to range from “typical” to “very conservative” and should not be construed to represent actual or likely risks for casual visitors to the site. Since theoretical risks are directly proportional to the lifetime average daily exposure dose, cutting the average exposure dose in half (by halving the sediment intake rate, halving the number of days per year a person visits the site, or halving the number of years a person is exposed) will cut the resulting theoretical risk in half as well.

Carcinogenic Health Effects Evaluation

a. Oral Sediment Exposures

The oral slope factor for 2,3,7,8-TCDD is generally taken to be 150,000 $(mg/kg/day)^{-1}$ [22]. Using parameters for the oral sediment exposure scenarios shown in Tables 10a and 10b, Appendix C, we calculated the theoretical increased lifetime cancer risks for oral ingestion exposures to the average and maximum values for each of the six groupings of sediment samples and each of the six exposure scenarios. Regular oral exposure to sediments from the SJRWP site was found to pose unacceptably high theoretical risks for cancer (greater than 10^{-4}) for both adults and children under the subsistence fisherman exposure scenario and for children under the weekend fisherman exposure scenario. The highest risk (8.16×10^{-4}) would be for the child of a subsistence fisherman with oral exposure to on-site sediments at the maximum sample TCDD TEQ concentration of 34,028 pg/g. Exposure at the average TCDD TEQ concentration (15,594 pg/g) produced a theoretical lifetime cancer risk of 3.74×10^{-4} for the child of a subsistence fisherman. This means that if 2,674 people were exposed to the average levels of TCDD TEQ found at the SJRWP site, 260 days per year, for 47 years (starting at age 3), theoretically, we would predict that one additional person might get cancer as a result of that exposure. Qualitatively, we would describe a risk of this magnitude as posing a **moderate increased lifetime risk** for cancer (See Tables 11 and 12, Appendix C). It should be noted, however, that the preceding estimate is based on a very conservative, worst-case scenario and that it is unlikely that any individuals are actually being orally exposed to sediments with these levels of TCDDs for such an extended period of time.

All off-site sediment samples were low enough to produce theoretical lifetime cancer risk estimates of less than 10^{-4} for the child of a subsistence fisherman (average risk, all samples, 9.60×10^{-7}, range $1.77\times10^{-8} – 2.05\times10^{-5}$). Qualitatively, we would describe risks of this range of magnitudes as posing **no increased lifetime risk** to a **low increased lifetime risk** for cancer.

The highest off-site sample (sediment sample number 11280), collected from the HSC approximately 7 miles upstream from its confluence with the SJR (by the University of Houston under the Dioxin TMDL Project) had a TCDD TEQ concentration of 857 pg/g, producing a cancer risk estimate of 2.05×10^{-5} for the child of a subsistence fisherman (see Figure 4b, Appendix B, for the approximate sample collection location). This means that if 48,666 people were exposed to the levels of TCDD TEQ found at this location in the HSC, 260 days per year, for 47 years (starting at age 3), theoretically, we would predict that one additional person might get cancer as a result of that exposure. Qualitatively, we would describe a risk of this magnitude as posing a **low increased lifetime risk** for cancer (See Tables 11 and 12, Appendix C).

Sediment sample numbers 11 and 11d collected under the Dioxin TMDL Project in the area of a former sand mining operation northwest of the SJRWP site (see Figure 6, Appendix B, for approximate sample collection location) had TCDD TEQ concentrations of 523 and 572 pg/g, producing cancer risk estimates for oral sediment exposures of 1.25×10^{-5} and 1.37×10^{-5}, respectively for the child of a subsistence fisherman. This means that if 72,832 to 79,755 people were exposed to the levels of TCDD TEQ found at this location near the SJRWP site, 260 days per year, for 47 years (starting at age 3), theoretically, we would predict that one additional person might get cancer as a result of that exposure. Qualitatively, we would describe a risk of this magnitude as posing a **low increased lifetime risk** for cancer. (See Tables 11 and 12, Appendix C, for risk estimates and odds for other off-site oral sediment exposures).

More realistic risks for oral exposures to sediments, such as in the sporadic-fisherman and child-of-a-sporadic-fisherman scenarios, range from 3.99×10^{-6} to 3.05×10^{-5} for on-site exposures and 1.02×10^{-8} to 7.69×10^{-7} for off-site exposures. These values would be categorized as **low** to **no apparent increased lifetime risk** for cancer for on-site exposures and **no increased lifetime risk** for cancer for off-site exposures (See Tables 11 and 12, Appendix C).

b. Dermal Sediment Exposures

The dermal slope factor for 2,3,7,8-TCDD is generally taken to be 300,000 $(mg/kg/day)^{-1}$ [22]. Using parameters for the dermal sediment exposure scenarios shown in Tables 13a and 13b, Appendix C, we calculated the theoretical increased cancer risks for dermal contact exposures to the average and maximum values for each of the six groupings of sediment samples and each of the six exposure scenarios. Regular dermal exposure to maximum sediments from the SJRWP site was found to pose unacceptably high (greater than 10^{-4}) theoretical risks for cancer for both adults and children under the subsistence fisherman and the weekend fisherman exposure scenarios.

The highest risk (1.48×10^{-3}) would be for the child of a subsistence fisherman with dermal exposure to on-site sediments at the site maximum concentration of 34,028 pg/g. Exposure at the average TCDD TEQ concentration of 15,594 pg/g would produce a theoretical lifetime risk of 6.78×10^{-4}. This means that if 1,475 people were exposed to the average concentration of TCDD TEQ found at the SJRWP site, 260 days per year, for 47-years (starting at age 3), theoretically, we would predict that one additional person might get cancer as a result of that exposure. Qualitatively, we would describe a risk of this magnitude as posing a **moderate increased lifetime risk** for cancer (see Tables 14 and 15, Appendix C). Again, the preceding estimate is based on a very conservative, worst-case scenario and that it is unlikely that any individuals are actually being dermally exposed to sediments with these levels of TCDDs for such an extended period of time. Because of the considerable uncertainties in calculating excess cancer risks from dermal exposures, our confidence in the accuracy of these risk values is low.

Only five sediment samples from off-site locations were high enough to produce theoretical cancer risks from dermal exposures of greater than 10^{-5} for the child of a subsistence fisherman (average risk, all samples, 1.74×10^{-6}, range $3.21\times10^{-8} – 3.72\times10^{-5}$). Dermal exposure at the maximum off-site concentration of 857 pg/g from TMDL sample 11280 would produce a theoretical lifetime risk of 3.72×10^{-5}. This means that if 26,846 people were exposed to the concentration of TCDD TEQ found at TMDL sample location 11280, 260 days per year, for 47 years (starting at age 3), theoretically, we would predict that one additional person might get cancer as a result of that exposure. Qualitatively, we would describe a risk of this magnitude as posing a **low increased lifetime risk** for cancer. (See Tables 14 and 15, Appendix C, for risk estimates and odds for off-site dermal sediment exposures).

Dermal exposure to sediments from the area of the former sand mining operation (TMDL samples 11 and 11dup with TCDD TEQ concentrations of 523 and 572 pg/g, respectively) (see Figure 6, Appendix B, for the approximate location of sediment samples 11 and 11dup) would produce theoretical excess lifetime cancer risks of 2.27×10^{-5} and 2.49×10^{-5}, respectively, for the child of a subsistence fisherman. This means that if 40,177 to 43,996 people were exposed to the levels of TCDD TEQ found at this location near the SJRWP site, 260 days per year, for 47 years (starting at age 3), theoretically, we would predict that one additional person might get cancer as a result of that exposure. Qualitatively, we would describe a risk of this magnitude as posing a **low increased lifetime risk** for cancer.

More realistic risks for dermal exposures to sediments, such as in the sporadic-fisherman and child-of-a-sporadic-fisherman scenarios, range from 9.76×10^{-6} to 4.79×10^{-5} for on-site exposures and 2.51×10^{-8} to 1.21×10^{-6} for off-site exposures. These values would be categorized as **low** to **no apparent increased lifetime risk** for cancer for on-site exposures and **no apparent** to **no increased lifetime risk** for cancer for off-site exposures (see Tables 14 and 15, Appendix C).

c. Fish and Crab Consumption Exposures

Using the parameters for the fish and crab exposure scenarios shown in Tables 16a and 16b, Appendix C, we calculated the theoretical increased cancer risks for fish and crab consumption exposures to the average TCDD TEQ concentrations for each fish or crab species and each of the six exposure scenarios (See Table 17, Appendix C). The fish consumption rates shown in Tables 16a and 16b represent the quantities of fish eaten only on fishing days and must be multiplied by the fishing frequencies (5/7, 1/7, and 12/365, respectively) to arrive at the average daily fish consumption rate. Thus, the effective average daily fish consumption rates for Subsistence, Weekend, and Sporadic fishermen were 163, 32.6 and 7.37 g/day, respectively. At these rates, regular consumption of the fish and crab species caught near the SJRWP site was found to pose unacceptably high theoretical risks for cancer under all but the sporadic-fisherman and the child-of-a-sporadic-fisherman exposure scenarios.

The highest risk (1.37×10^{-3}) would be for the child of a subsistence fisherman eating only blue catfish (with an average TCDD TEQ concentration of 6.04 pg/g) caught near the site. Consumption of approximately 163 g/day of a variety of fish and crabs containing the average TCDD TEQ concentration of 2.28 pg/g would produce a theoretical lifetime risk of 5.18×10^{-4}. This means that if 1,931 people were routinely consuming fish and crabs containing TCDD TEQ at the average levels found near the SJRWP site, 260 days per year, for 47-years (starting at age 3), theoretically, we would predict that one additional person might get cancer as a result of that exposure. Qualitatively, we would describe a risk of this magnitude as posing a **moderate increased lifetime risk** for cancer (See Table 17, Appendix C). As before, the preceding estimate is based on a very conservative, worst-case scenario and that it is unlikely that any individuals are actually consuming such large quantities of fish and crabs with these levels of TCDDs for such an extended period of time.

More realistic risks for fish and crab consumption exposures (where fish consumption rates are assumed to be 32.6 g/day), such as in the weekend-fisherman and child-of-a-weekend-fisherman scenarios, range from 2.73×10^{-6} to 2.75×10^{-4} for fish caught near the SJRWP site. These values would be categorized as **no apparent increased lifetime risk** for cancer and **moderate increased lifetime risk** for cancer, respectively (See Table 17, Appendix C).

The lower end of theoretical risks from fish and crab consumption exposures (where fish consumption rates are assumed to be 7.37 g/day), such as in the sporadic-fisherman and child-of-a-sporadic-fisherman scenarios, range from 3.17×10^{-7} to 4.41×10^{-5} for fish caught near the SJRWP site. These values would be categorized as **no increased lifetime risk** for cancer and **low increased lifetime risk** for cancer, respectively (See Table 17, Appendix C).

d. All Exposure Routes Combined

For the cumulative risk for all exposure routes combined, we assumed that individuals fishing at the site would consume a variety of fish and crabs caught near the site, thus we used the risk estimates based on the average TCDD TEQ for all species. The highest theoretical cancer risk for all exposure routes combined (2.81×10^{-3}) was seen in the child of a subsistence fisherman exposed regularly to sediments at the maximum concentration found on the site (34,028 pg/g). The theoretical increased lifetime cancer risks associated with oral and dermal sediment exposures to site average TCDD TEQ concentrations (15,594 pg/g) plus fish and crab consumption of species having an average TCDD TEQ concentration of 2.28 pg/g were found to be 1.57×10^{-3}. This means that if 637 people were routinely exposed to the average contaminant level from the site and were consuming fish and crabs containing TCDD TEQ at the average levels found near the SJRWP site, 260 days per year, for 47-years (starting at age 3), theoretically, we would predict that one additional person might get cancer as a result of that exposure. Qualitatively, we would describe a risk of this magnitude as posing a **high increased**

lifetime risk for cancer (See Tables 18 and 19, Appendix C). As before, the preceding estimate is based on a very conservative, worst-case scenario and that it is unlikely that many individuals are actually being exposed to TCDDs at these high levels for such an extended period of time.

For off-site fishing locations, the cumulative risk for oral, dermal, and fish/crab exposures were found to be driven primarily by the fish consumption risks and were relatively consistent at values ranging from 5.19×10^{-4} to 5.76×10^{-4} for the child of a subsistence fisherman. These risks would be categorized as **moderate increased lifetime risks** for cancer. (See Tables 18 and 19, Appendix C, for risk estimates and odds for off-site exposures to sediments and consumption of fish and crabs with TCDD TEQ concentrations similar to those found near the SJRWP site).

More realistic cumulative risks, such as in the weekend-fisherman and child-of-a-weekend-fisherman scenarios (where fish consumption rates are assumed to be 32.6 g/day), range from 1.81×10^{-4} to 5.63×10^{-4} for on-site exposures and 6.43×10^{-5} to 1.15×10^{-4} for off-site exposures. These values would be categorized as **moderate increased lifetime risk** for cancer for on-site exposures and **low** to **moderate increased lifetime risk** for cancer for off-site exposures (See Tables 18 and 19, Appendix C).

Typical cumulative risks, such as in the sporadic-fisherman and child-of-a-sporadic-fisherman scenarios (where fish consumption rates are assumed to be 7.37 g/day), range from 2.12×10^{-5} to 9.50×10^{-5} for on-site exposures and 7.46×10^{-6} to 1.86×10^{-5} for off-site exposures. These values would be categorized as **low increased lifetime risk** for cancer for on-site exposures and **low** to **no apparent increased lifetime risk** for cancer for off-site exposures (See Tables 18 and 19, Appendix C).

Non-Carcinogenic Health Effects Evaluation:

a. Acute Duration Exposures

The acute oral MRL for 2,3,7,8-TCDD is based on an animal study in which there was a statistically significant increase in mortality in the influenza-A-infected female B6C3F1 mice exposed to a single gavage dose of 0.01 (or higher) µg/kg 2,3,7,8-TCDD in corn oil. No significant effects were observed at lower doses (0.001 or 0.005 µg/kg). Thus 0.005 and 0.01 µg/kg are the NOAEL and LOAEL, respectively, for impaired resistance to influenza A infection in female B6C3F1 mice. The acute oral MRL of 1.67×10^{-7} mg/kg/day was derived by dividing the NOAEL of 5.0×10^{-6} mg/kg by an uncertainty factor of 30 (3 for extrapolation from animals to humans and 10 for human variability) [18].

For the SJRWP site, the HQs for acute duration exposures to TCDD TEQ through oral ingestion of soil/sediments, dermal absorption from skin contact with soil/sediment, fish & crab consumption, and all three exposure routes combined were all less than 1.00 under all six exposure scenarios (See Figures 15-18, Appendix B, and Tables 20-26, Appendix C). With a maximum HI of 0.442 and an uncertainty factor of 30, the actual combined exposure dose for a 3-year old child would be over 67 times lower than the study NOAEL upon which the acute MRL was based. Qualitatively, we would describe HIs of this magnitude as posing **no apparent increased risk** for impaired resistance to infection as a result of acute-duration exposures to contaminants from the SJRWP site.

b. Intermediate Duration Exposures

The intermediate oral MRL for 2,3,7,8-TCDD is based on an animal study in which there was a statistically significant decrease in thymus weight in weanling Hartley guinea pigs fed a diet containing 76 parts per trillion (ppt) (or higher) of 2,3,7,8-TCDD for 90 days (for the animals in the study, this was equivalent to a dose of 0.005 µg/kg/day). No significant effects were observed at the lower doses (i.e., 0.0001 or 0.0007 µg/kg/day). Thus 0.0007 and 0.005 µg/kg/day are the NOAEL and LOAEL, respectively, for decreased thymus weight in weanling Hartley guinea pigs. The intermediate oral MRL of 2.33×10^{-8} mg/kg/day was derived by dividing the NOAEL of 7.0×10^{-7} mg/kg/day by an uncertainty factor of 30 (3 for extrapolation from animals to humans and 10 for human variability) [18].

For the SJRWP site, the HQs for intermediate duration exposures through soil/sediment ingestion (in the child-of-a-subsistence-fisherman scenario) exceeded 1.00 by a very small margin (HQ = 1.04) only for exposures to site-average TCDD TEQ concentrations of 15,594 pg/g starting at age 3. Qualitatively, we would describe an HQ of this magnitude as posing a **low increased risk** for altered development of the thymus. The HQs for intermediate duration exposures through soil/sediment ingestion in the other childhood exposure scenarios were both less than 1.00 for all ages (See Figure 15, Appendix B, and Tables 27 and 28, Appendix C). With maximum HQs of 0.0480 and 0.208 and an uncertainty factor of 30, the actual exposure dose for an exposed child would be from 144-625 times lower than the study NOAEL upon which the intermediate MRL was based. Qualitatively, we would describe HQs of this magnitude as posing **no** to **no apparent increased risk** for altered development of the thymus. Consequently, intermediate-duration oral exposures to sediments are not expected to be a problem at the SJRWP site.

The HQs for intermediate duration exposures to TCDD TEQ through dermal absorption in all six exposure scenarios were less than 1.00 in all age ranges (See Figure 16, Appendix B, and Tables 29 and 30, Appendix C). The maximum HQ in the child of a subsistence fisherman exposed to site-average TCDD TEQ concentrations (15,594 pg/g) was 0.224. Qualitatively, we would describe HQs of this magnitude as posing **no apparent increased risk** for altered development of the thymus. With an HQ of 0.224 and an uncertainty factor of 30, the actual exposure dose for a 3-year-old child would be 134 times lower than the study NOAEL upon which the intermediate MRL was based. Consequently, intermediate-duration dermal exposures to sediments are not expected to be a problem at the SJRWP site.

The HQs for intermediate duration exposures to TCDD TEQ through fish or crab consumption (all species combined) was less than 1.00 in all age ranges (the maximum HQ of 0.314 occurred at age 3 years for the child of a subsistence fisherman) (See Figure 17, Appendix B, and Table 31, Appendix C). Qualitatively, we would describe HQs of this magnitude as posing **no apparent increased risk** for altered development of the thymus.

The HI for intermediate duration exposures, all exposure routes combined (in the child-of-a-subsistence-fisherman scenario) was greater than 1.00 for children up to the age of 7.5 years (the maximum HI of 1.58 occurred at age 3 years). With a maximum HI of 1.58 and an uncertainty factor of 30, the actual combined exposure dose for the child would still be 19 times lower than the study NOAEL upon which the intermediate MRL was based. The maximum HIs (at age 3) for intermediate duration exposures, all exposure routes combined, were 0.316 and 0.0728 for the child-of-a-weekend-fisherman and the child-of-a-sporadic-fisherman, respectively (See Figure 18, Appendix B, and Tables 32 and 33, Appendix C). Qualitatively, we would describe HIs of this magnitude as posing **no apparent** to **no increased risk** for altered development of the thymus. Considering the uncertainty factors built in to the intermediate MRL, it is unlikely that individual children would experience altered development of the thymus as a result of intermediate-duration oral, dermal, and fish consumption exposures at the SJRWP site.

c. Chronic Duration Exposures

The chronic oral MRL for 2,3,7,8-TCDD is based on an animal study involving rhesus monkeys in which there was altered social behavior in the offspring of mothers fed diets containing 5 ppt 2,3,7,8-TCDD for 16.2 months (for the animals in the study, this was equivalent to an oral dose of 1.2×10^{-4} µg/kg/day of 2,3,7,8-TCDD). Thus 1.2×10^{-4} µg/kg/day was the LOAEL for altered social behavior in rhesus monkeys whose mothers were fed diets containing 2,3,7,8-TCDD. The chronic oral MRL of 1.2×10^{-9} mg/kg/day was derived by dividing the LOAEL of 1.2×10^{-7} mg/kg by an uncertainty factor of 100 (3 for the use of a minimal LOAEL, 3 for extrapolation from animals to humans, and 10 for human variability) [18].

The HQs for chronic duration oral exposures to TCDD-contaminated soil/sediment (at site-average TCDD TEQ concentrations of 15,594 pg/g) exceeded 1.00 for the subsistence fisherman (child or adult) and for the child of the weekend fisherman. The maximum HQ of 19.5 occurred at age 3 years for the child of a subsistence fisherman, and the HQs remained elevated at 2.14-2.35 for all ages from 20-50 years for subsistence fishermen (See Figure 15, Appendix B, and Tables 34 and 35, Appendix C). Qualitatively, we would describe HQs of this magnitude as posing a **moderate** to **low increased risk** for altered social behavior in children.

The HQs for chronic duration dermal exposures to TCDD-contaminated soil/sediment (at site-average TCDD TEQ concentrations of 15,594 pg/g) were greater than 1.00 in all age ranges under the subsistence fisherman scenario. The maximum HQ of 4.35 occurred at age 3 years for the child of a subsistence fisherman, and the HQs remained elevated at 2.66-2.80 for all ages from 20-50 years for subsistence fishermen (See Figure 16, Appendix B, and Tables 36 and 37, Appendix C). Qualitatively, we would describe HQs of this magnitude as posing a **low increased risk** for altered social behavior in children. Realistically, with an HQ of 4.35 and an uncertainty factor of 100, the actual exposure dose for a child would be 23 times lower than the study LOAEL upon which the chronic MRL was based. Consequently, it is unlikely that any children of subsistence fishermen would actually experience altered social behavior as a result of the exposures of their mothers.

The HQs for chronic duration exposures to TCDD TEQ through fish or crab consumption (at the all-species-average concentration of 2.28 pg/g) was greater than 1.00 in all ages for the subsistence fisherman scenarios and for the child of the weekend fisherman scenario. The maximum HQ of 6.05 occurred at age 3 years for the child of a subsistence fisherman (see Figure 17, Appendix B, and Table 38, Appendix C). Qualitatively, we would describe HQs of this magnitude as posing a **low increased risk** for altered social behavior in children of mothers exposed during pregnancy.

The maximum HI for chronic duration exposures, all exposure routes combined was greater than 1.00 in all childhood scenarios and in the adult subsistence and weekend fisherman scenarios. The maximum HI of 29.9 occurred at age 3 years, and the HIs remained elevated at approximately 8.93-9.37 from ages 20-50 for subsistence fishermen (see Figure 18, Appendix B, and Tables 39 and 40, Appendix C). Qualitatively, we would describe HIs of this magnitude as posing a **moderate** to **low increased risk** for altered social behavior in children of mothers exposed during pregnancy. This exposure falls into a gray zone because the chronic oral MRL is based on a study LOAEL and the maximum HI is only 3.34 times lower than that study LOAEL. If pregnant subsistence fishermen were actually being exposed orally, dermally, and through fish consumption 260 days per year, and if the children of these mothers respond similarly to rhesus monkeys, we might actually expect to see altered social behavior in some of these children as a result of the combined exposures of their mothers.

Conclusions

After review of the available data, DSHS and ATSDR have reached the following seven conclusions with regard to contact with dioxin-contaminated sediments from the SJRWP site and consumption of fish from the SJR, the HSC, and UGB:

1. PCDDs and PCDFs were detected in sediments at the SJRWP site at concentrations that would cause unacceptably high theoretical risks for cancer (greater than 10^{-4}) and non-cancer adverse health effects (HQ or HI greater than 1.00) for both adults and children under the subsistence fisherman exposure scenario and for children under the weekend fisherman scenario for both oral and dermal exposures. Therefore, ATSDR concludes that recurring oral and/or dermal exposures to sediments from this site for periods of one year or longer could harm people's health.
2. PCDDs and PCDFs have been detected in fish and crabs caught near the SJRWP site at concentrations that would cause unacceptably high theoretical risks for cancer (greater than 10^{-4}) under all but the sporadic-fishermen-and-their-children exposure scenarios. Therefore ATSDR concludes that dioxin exposures through eating fish and crabs caught near the SJRWP site for periods of one year or longer could harm people's health.
3. Because groundwater near the site is brackish and is not being used for drinking water purposes, and the nearest residence is approximately ½ mile from the site, contamination of shallow groundwater (if it has occurred) is not likely to pose a health hazard. Therefore, ATSDR concludes that exposures to groundwater near the SJRWP site are not expected to harm people's health.
4. Surface water near the site is brackish and is not being used for drinking water purposes, and the nearest residence is approximately ½ mile from the site. Furthermore, since dioxins have relatively low solubility and are tightly bound to sediments, contamination of surface water is not likely to pose a significant health hazard. Therefore, ATSDR concludes that exposures to surface water near the SJRWP site are not expected to harm people's health.
5. Because of the nature of the contaminants, their low volatility, their high affinity for soil particles, and the high vegetation coverage on the site – leading to low likelihood of wind blown dust – the airborne route was not considered a significant pathway of exposure at this

site. Therefore, ATSDR concludes that exposures to ambient air near the SJRWP site are not expected to harm people's health.

6. PCDDs and PCDFs were detected in off-site sediments at the location of a former sand mining operation. Since we do not know the TCDD TEQ concentrations in the sand that has been mined, ATSDR cannot conclude whether or not past or present exposures to sand coming from sand mining activities near the SJRWP site could harm people's health.
7. Although two of the surface impoundments are inundated with water from the SJR and site contaminants are likely being washed downstream to some extent during high water flow periods, sediment samples collected downstream (under the Dioxin TMDL Project) have not shown any clear evidence of significant off-site migration of PCDDs/PCDFs from the SJRWP site. However, the extent of transport of dioxin-contaminated sediments off-site has not yet been adequately evaluated. Therefore, ATSDR cannot conclude whether or not past or present off-site migration of dioxin-contaminated sediments could harm people's health.

Recommendations

ATSDR makes the following recommendations with regard to the SJRWP site:

1. The SJRWP site should remain securely fenced to reduce, if not eliminate, unauthorized access to the site by individuals who do not understand the issues with the contaminated sediments.
2. Signs posted around the area of the pits, warning individuals to avoid contact with soil or sediments from the site, should be checked periodically, and should be replaced if they disappear or become defaced.
3. The current fishing advisory issued by the SALG at DSHS should be continued in order to minimize exposures to potentially hazardous levels of PCDDs/PCDFs in fish or crabs caught near the SJRWP site.
4. The EPA should continue their thorough evaluation of the SJRWP site to determine the full extent of the contamination, not only for PCDDs/PCDFs but also for other potentially hazardous contaminants.
5. Off-site sediments in downstream locations should be more thoroughly evaluated to determine the extent of off-site migration of contaminants from the site.
6. Efforts should be made to determine greater details of the sand mining operation, including when sands were mined from the area adjacent to the pits with respect to when wastes were disposed of in the pits, where mined sands have been distributed, and if possible, obtain sand samples for PCDD/PCDF measurements.
7. All sediments at the SJRWP site with significant levels of PCDDs/PCDFs or other hazardous contaminants should be removed and disposed of properly.

Public Health Action Plan

Actions Completed

1. The SJRWP site was proposed to the EPA's National Priorities List on September 19, 2007.

2. The SJRWP site was officially added to the NPL by Final Rule in 40 CFR Part 300 as published in the Federal Register on March 19, 2008.

3. DSHS reissued the fish and crab consumption advisory for the SJR, the Houston Ship Channel, and Upper Galveston Bay on July 8, 2008, adding spotted seatrout from Galveston Bay to list of species for limited consumption.

4. Pamphlets have been distributed in and around Channelview warning residents to avoid visiting or fishing at the SJRWP site and to avoid eating fish or crabs caught near the site.

5. The SJRWP PHA initial release document was submitted to the Texas Commission on Environmental Quality (TCEQ) and the EPA for their comments and technical review. This version of the PHA document addresses the suggested comments received from the TCEQ and EPA.

6. The site has been fenced and signs have been posted warning people to stay off the site and avoid contact with sediments in the area and to refrain from fishing in the area.

7. The EPA has formulated a Remedial Investigation/Feasibility Study (RI/FS) work plan and has begun the field sampling sediment study, the fate and transport modeling assessment, and the bioaccumulation assessment.

8. Under a project to develop BSAFs funded by TEHI, Baylor University has begun collecting benthic samples in the vicinity of the SJRWP site to more completely characterize PCDD/PCDF concentrations in fish, crabs, and shellfish caught near the site.

9. On July 28, 2010, the EPA issued a Time Critical Removal Action in order to stabilize the contaminated sediments in the pits most likely to be affected by high water flow events.

Actions Planned

1. After the ATSDR reviews this updated PHA document, it will then be made available for public review and comment.

2. Any comments received during the public review period will be appropriately addressed, the document will be updated as necessary, and the final HA document will then be released.

3. DSHS staff will participate in EPA or TCEQ availability sessions or other community meetings to collect and address any community health concerns related to the SJRWP site and to educate the public regarding the fish possession ban and the potential health effects associated with eating fish from this area.

4. Follow-up of individuals living in the surrounding neighborhoods was not recommended because the airborne and water-borne routes were not considered significant pathways that may have exposed a larger, geographically circumscribed population.

5. Likewise, it was not considered feasible to attempt follow-up of individuals who have routinely visited the site because such individuals are unknown, most would likely be unwilling to admit that they had been fishing at a site that was posted as "no fishing," they may live anywhere in the Greater Houston area, and it is not possible to predict the likelihood of an individual getting cancer or other adverse health effects even if serum and/or tissue dioxin levels were determined.

6. Work with the SJRWP Community Advisory Committee to plan and carry out local educational activities pertaining to the site.

7. Follow up with DSHS SALG to insure that signs remain posted near the site warning the public not to eat fish or blue crab caught near the site.

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Certification

This public health assessment for the San Jacinto River Waste Pitts in Channelview, Harris County, Texas (EPA Facility ID: TXN000606611) was prepared by the Texas Department of State Health Services (DSHS) under a cooperative agreement with the Agency for Toxic Substances and Disease Registry (ATSDR). It is in accordance with methods and procedures approved at the time the investigation was initiated. Editorial review was completed by the Cooperative Agreement partner.

Technical Project Officer, Cooperative Agreement Team, SPAB, DHAC, ATSDR

The Division of Health Assessment and Consultation, ATSDR, has reviewed this public health consultation and concurs with its findings.

Cooperative Agreement Team Leader, SPAB, DHAC, ATSDR

Appendices

Appendix A: Acronyms and Abbreviations

Appendix B: Figures

Appendix C: Tables

Appendix D: Health Assessment Calculations

Appendix A – Acronyms and Abbreviations

Acronyms and Abbreviations

ATSDR	Agency for Toxic Substances and Disease Registry
BSAFs	Biota-Sediment Accumulation Factors
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
cm^2	Square Centimeters
CREG	Cancer Risk Evaluation Guide
CRQL	Contract Required Quantitation Limit
CSF	Cancer Slope Factor
CSL	Contaminant Screening Levels
D	Democrat
DHHS	US Department of Health and Human Services
DRV	Dose-Response Value
DSHS	Texas Department of State Health Services
EDL	Estimated Detection Limit
EMEG	Environmental Media Evaluation Guide
EPA	US Environmental Protection Agency
ESL	Effects Screening Level
ft^2	Square Feet
GI	Gastrointestinal
HAC Value	Health Assessment Comparison Value
HEAST	Health Effects Assessment Summary Tables
HI	Hazard Index
HQ	Hazard Quotient
HRS	Hazard Ranking System
HSC	Houston Ship Channel
HSDB	Hazardous Substance Data Bank
IARC	International Agency for Research on Cancer
IDL	Instrument Detection Limit
IH-10	Interstate Highway 10
IRIS	EPA Integrated Risk Information System
IUR	Inhalation Unit Risk
J	Result is estimated.
kg	Kilogram
L	Reported concentration is between the IDL and the CRQL
LD_{50}	Lethal dose for 50% of animals tested
LGB	Lower Galveston Bay
LOAEL	Lowest Observed Adverse Effect Level
mg/kg	Milligrams per kilogram
mg/kg/day	Milligrams per kilograms per day
MRL	Minimal Risk Level
ND	Non-Detect
NLM	National Library of Medicine
NOAEL	No Observed Adverse Effect Level
NPL	National Priorities List

OCDD	Octachlorodibenzo-p-dioxin
OCDF	Octachlorodibenzofuran
ORNL	Oak Ridge National Laboratories
OSF	Oral Slope Factor
PASI	Preliminary Assessment/Site Inspection
PCB	Polychlorinated biphenyl
PCDD	Polychlorinated dibenzodioxin
PCDF	Polychlorinated dibenzofuran
pg	Picogram (1 pg = 10^{-12} g)
pg/g	Picograms per gram
PHA	Public Health Assessment
ppb	Parts per billion
ppbv	Parts per billion by volume
ppm	Parts per million
ppt	Parts per trillion
PRP	Potentially Responsible Party
QA/QC	Quality Assurance/Quality Control
R	Republican
RAIS	Risk Assessment Information System
RBC	Risk-Based Concentration
RCRA	Resource Conservation Recovery Act
REG	Risk Evaluation Guide
REL	Reference Exposure Level
RfC	Reference Concentration
RfD	Reference Dose
RI/FS	Remedial Investigation/Feasibility Study
RMEG	Reference Dose Media Evaluation Guide
SALG	Seafood and Aquatic Life Group
SARA	Superfund Amendments and Reauthorization Act
SJR	San Jacinto River
SJRWP	San Jacinto River Waste Pits
TCDD	Tetrachlorodibenzo-p-dioxin
TCDF	Tetrachlorodibenzofuran
TCEQ	Texas Commission on Environmental Quality
TDH	Texas Department of Health
TEF	Toxic Equivalency Factor
TEHI	Texas Environmental Health Institute
TEQ	Toxic Equivalency
TMDL	Total Maximum Daily Load
TPWD	Texas Parks and Wildlife Department
µg/kg/day	Micrograms per kilogram per day
µg/L	Micrograms per liter
µg/m^3	Micrograms per cubic meter
UGB	Upper Galveston Bay
WHO	World Health Organization

Appendix B – Figures

Figure 1. San Jacinto River Waste Pits, General Location & Population Demographics.

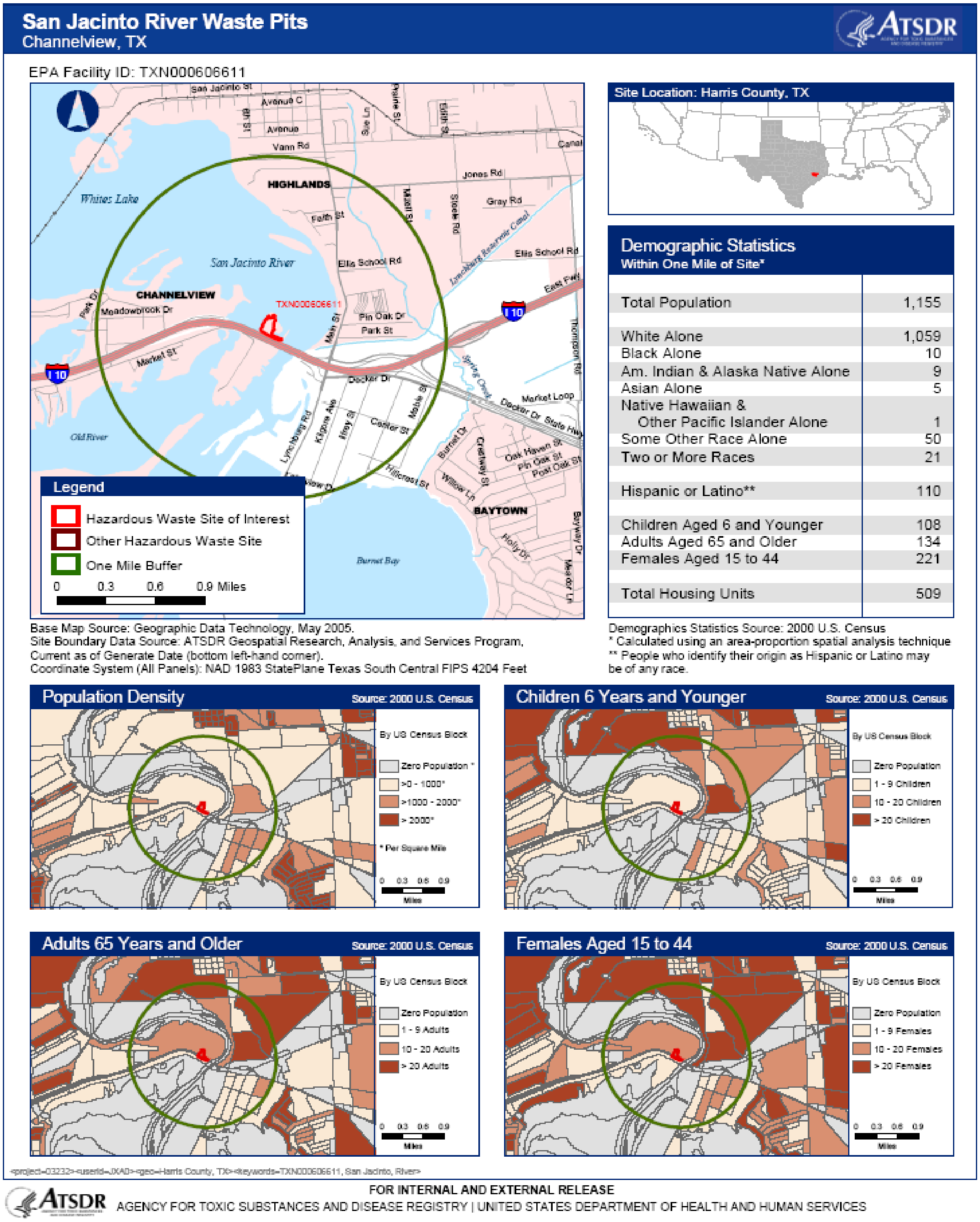


Figure 2. Aerial Photo of San Jacinto River Waste Pits Showing General Location

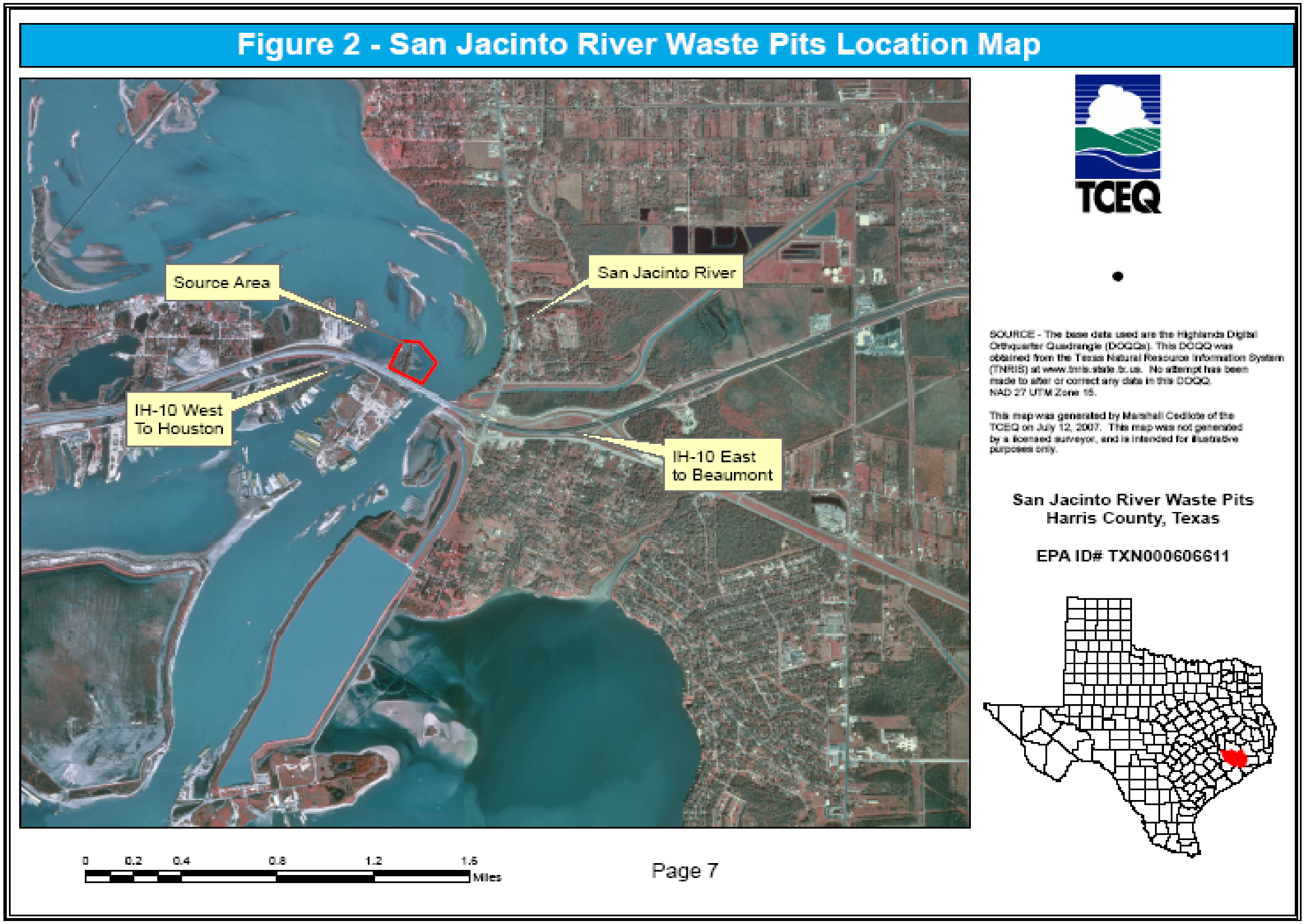


Figure 3. Aerial Photo of San Jacinto River Waste Pits, Sediment Sample Locations

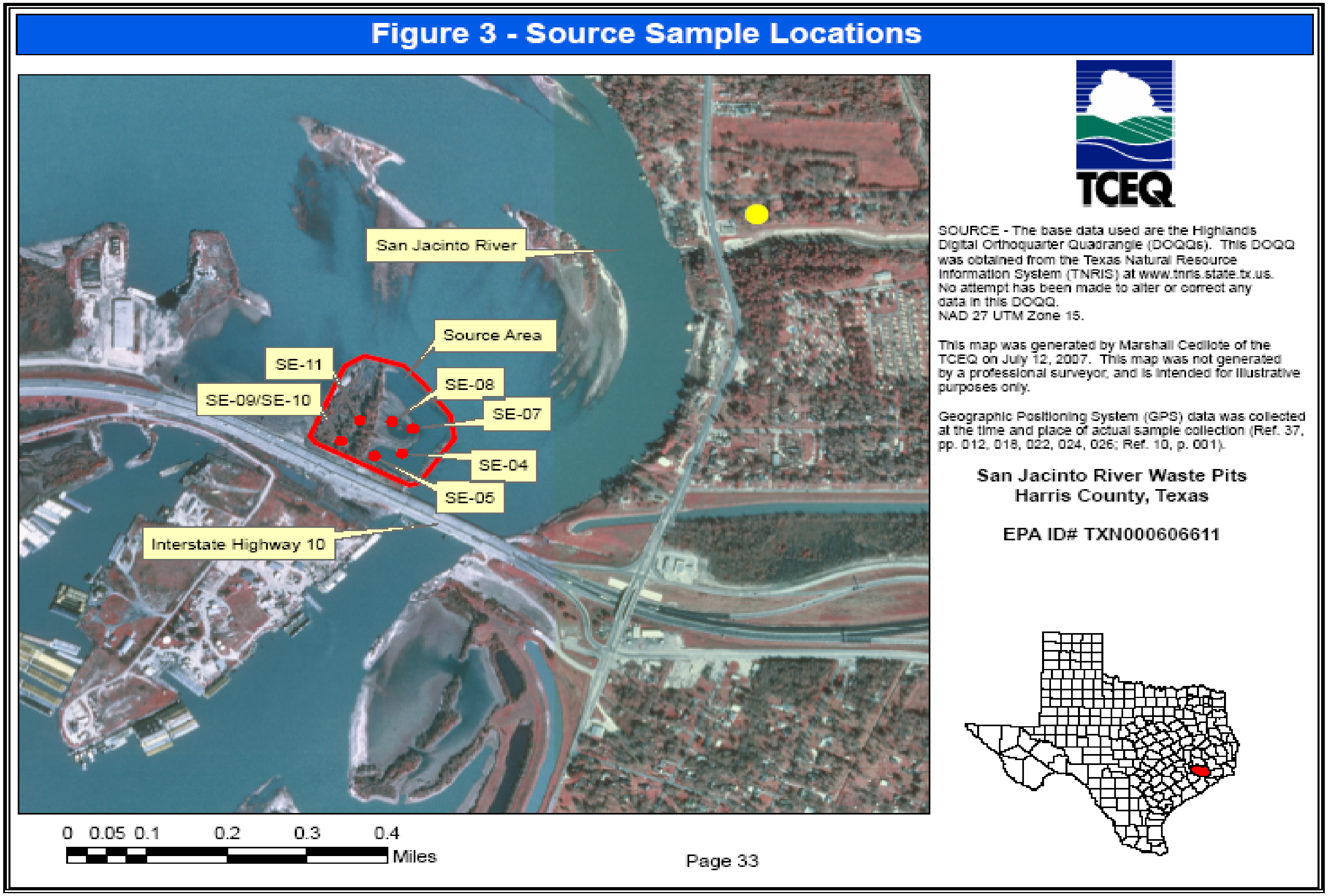


Figure 4a. Aerial Photo, San Jacinto River Waste Pits, Background Sample Locations.

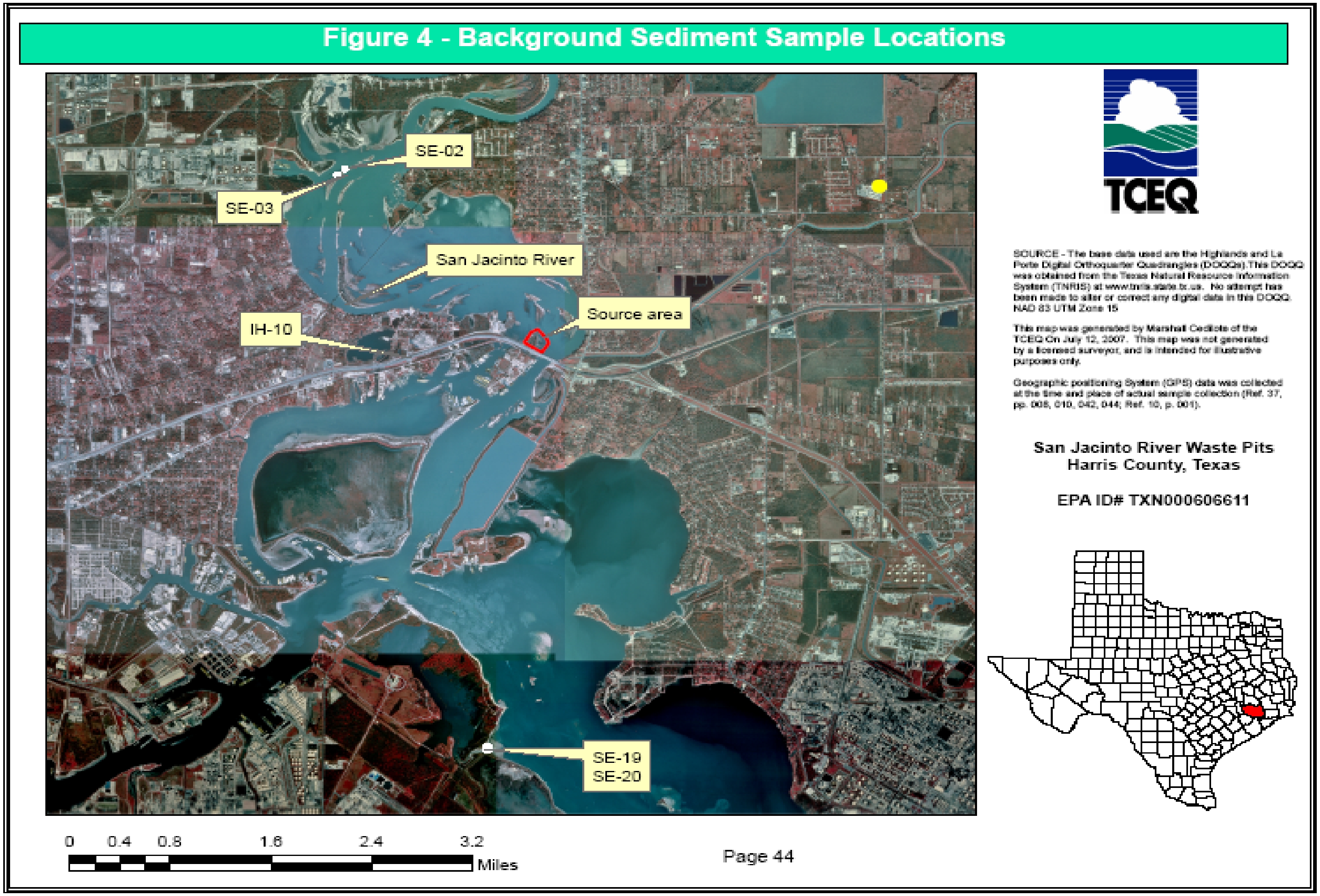


Figure 4b. Aerial Photo, Houston Ship Channel TMDL Sample Locations.

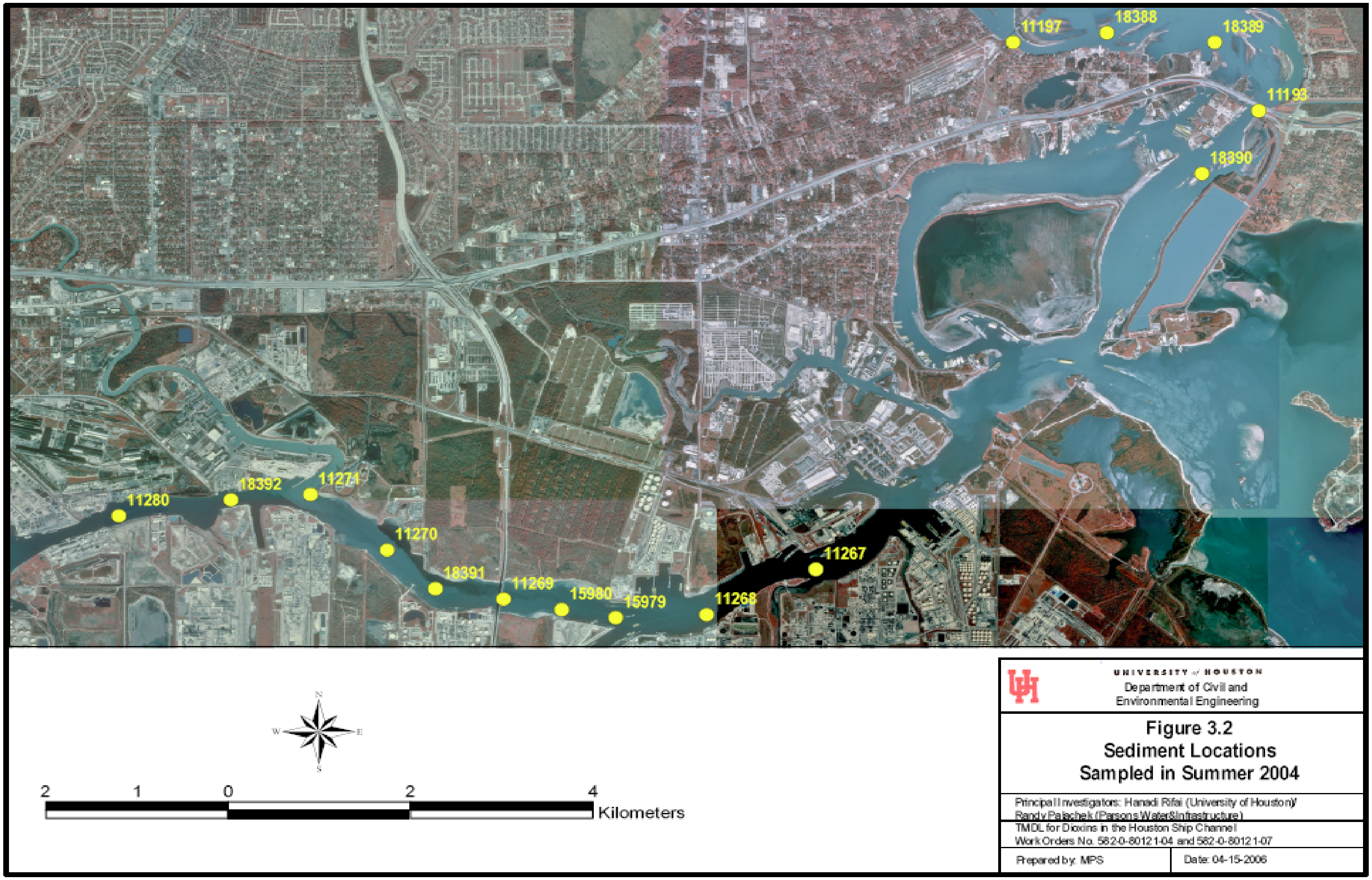


Figure 5 - Calculation of Source Area

Figure 6. TMDL Project Sample Locations, Collected by the University of Houston

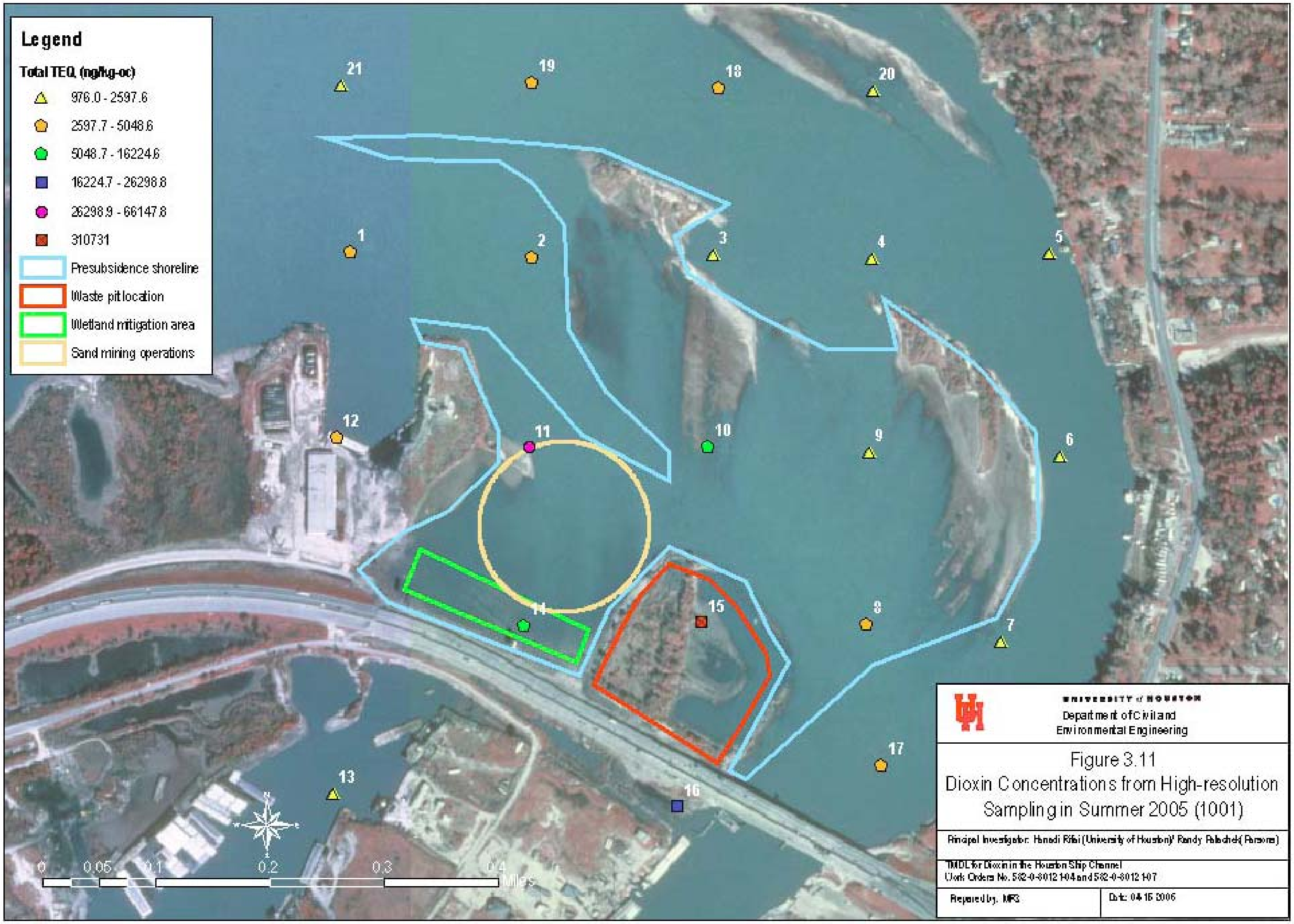


Figure 7. Pit A from Berm Trail, Camera Looking Southwest

Figure 8. Sump Tubing along Berm Trail, Camera Looking Southeast

Figure 9. Crab Trap & Litter at Fishing Point, Camera Looking South

Figure 10. Fishing Point Viewed from River, Camera Looking South

Figure 11. Well Beaten Down Fishing Point, Camera Looking North

Figure 12. Fishing Health Advisory Sign, Houston Ship Channel

Figure 13. Dirt Road to Site, North Side IH-10, Camera Looking East

Figure 14. Fishermen Across River from Site, Camera Looking East

Figure 15. Hazard Quotients for TCDD TEQ, Oral Sediment Route

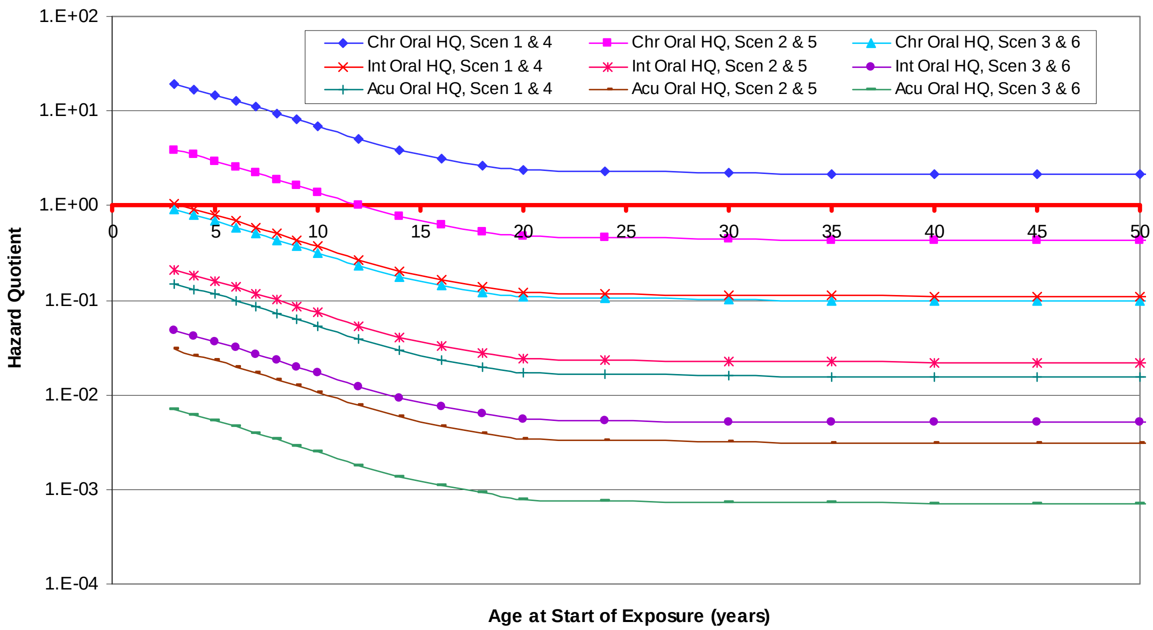
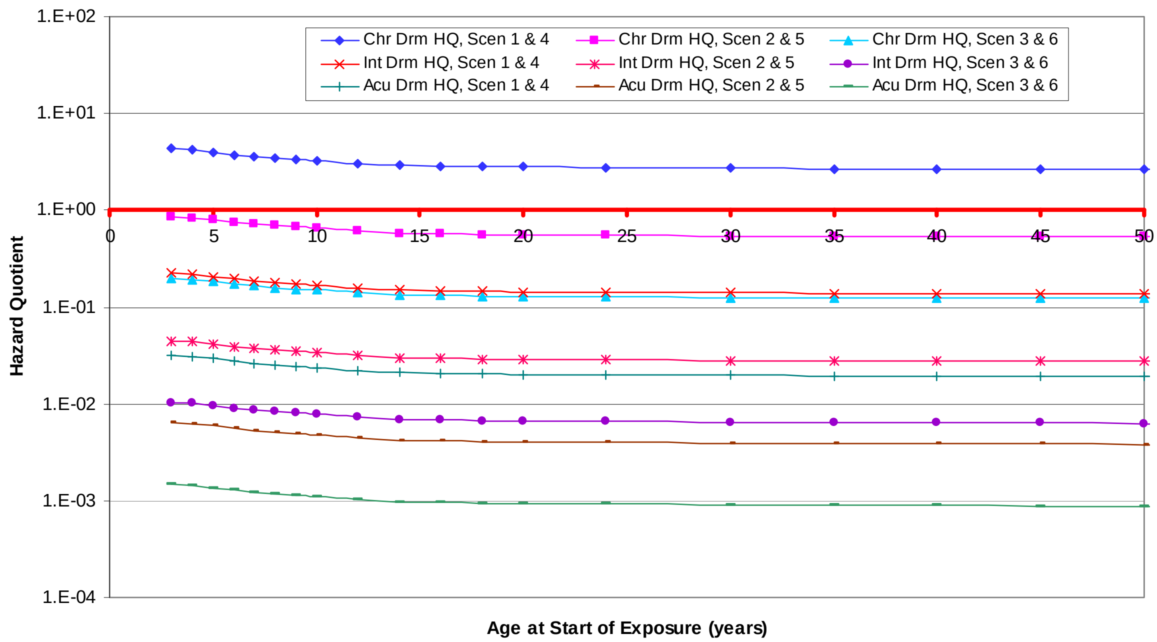


Figure 16. Hazard Quotients for TCDD TEQ, Dermal Absorption Route



Abbreviations: TCDD TEQ = tetrachlorodibenzo-p-dioxin toxicity equivalents; Chr = chronic; Int = intermediate; Acu = acute; Drm = dermal route, HI = Hazard Index; HQ = hazard quotient; Scen = scenario.

Figure 17. Hazard Quotients for TCDD TEQ, Fish/Crab Consumption Route

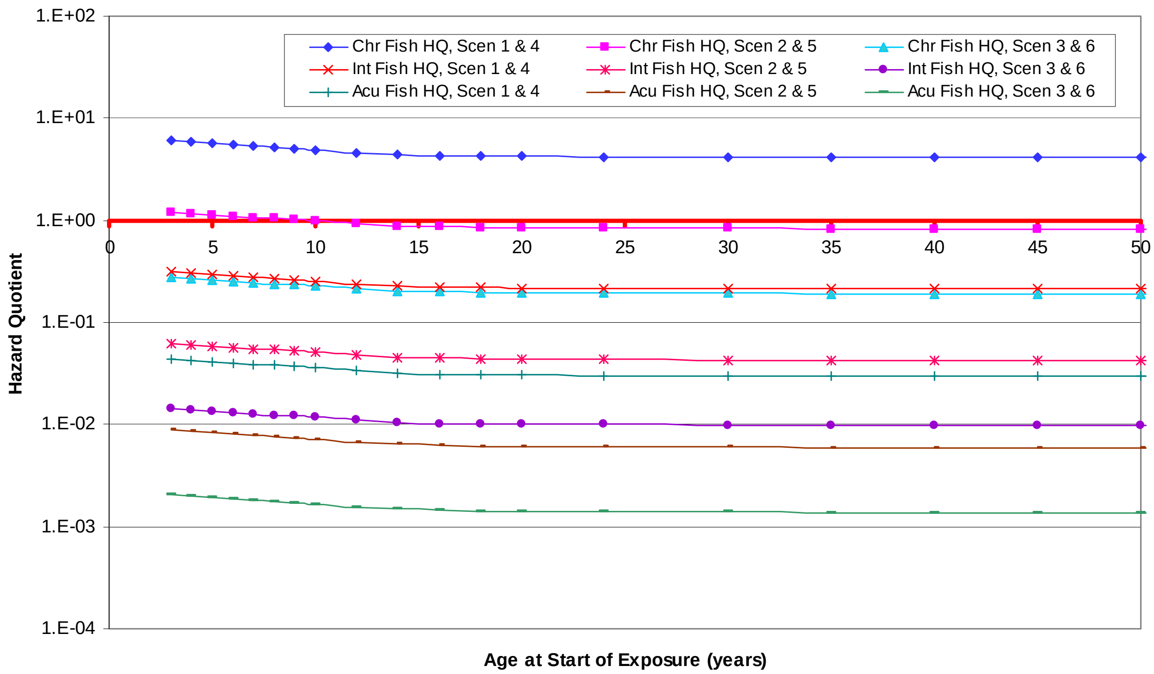
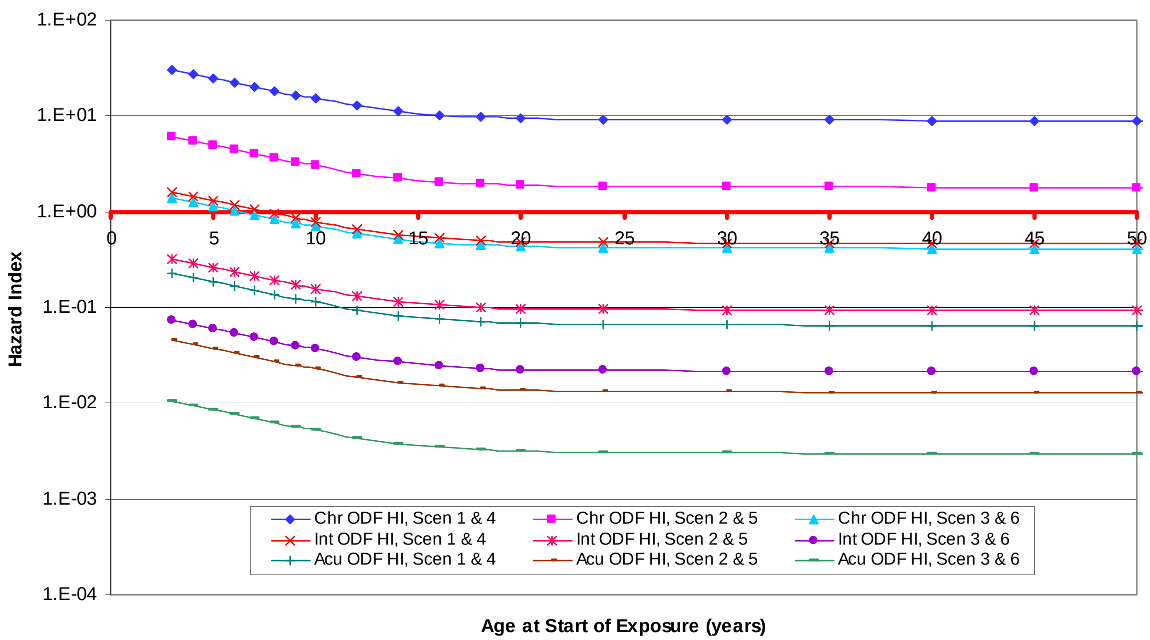


Figure 18. Hazard Indices for TCDD TEQ, Oral, Dermal, & Fish Routes



Abbreviations: TCDD TEQ = tetrachlorodibenzo-p-dioxin toxicity equivalents; Chr = chronic; Int = intermediate; Acu = acute; ODF = oral, dermal, and fish combined, HQ = hazard quotient; HI = hazard index; Scen = scenario.

Appendix C – Tables

Table 1. SJRWP Exposure Pathway Analysis, Sediment Pathway

Pathway Name	Contaminant of Concern	Exposure Pathway Elements: Contaminant Source – Source	Contaminant Source – Status	Transport Medium – Medium	Transport Medium – Status	Point of Exposure – Point	Point of Exposure – Status	Route of Exposure – Route	Route of Exposure – Status	Exposed Population – Population	Exposed Population – Status	Time	Comments and Pathway Status
Soil/ Sediment	PCDDs and PCDFs	Surface Impoundment of Papermill Waste		Soil/ Sediment		On-Site		Ingestion		Subsistence Fisherman		Past Present Future	**Complete** - Significant levels of TCDD TEQ contaminants found in on-site sediment.
										Weekend Fisherman			
										Sporadic Fisherman			
								Dermal Contact		Subsistence Fisherman		Past Present Future	**Complete** - Significant levels of TCDD TEQ contaminants found in on-site sediment.
										Weekend Fisherman			
										Sporadic Fisherman			
						Nearby Yards and Commercial Properties		Ingestion		Nearby Residents		Past Present Future	No data available to evaluate pathway; however, not considered to be a significant pathway of exposure, because no means of sediments getting to distant yards.
										Employees at Nearby Businesses			
								Dermal Contact		Nearby Residents		Past Present Future	
										Employees at Nearby Businesses			
						Downstream Sediment		Ingestion		Subsistence Fisherman		Past Present Future	**Potential** - Significant TCDD TEQ contaminants found in on-site sediments that could move downstream. Some TCDD TEQ found in sediments from numerous other locations in the Houston Ship Channel & Galveston Bay
										Weekend Fisherman			
										Sporadic Fisherman			
								Dermal Contact		Subsistence Fisherman		Past Present Future	**Potential** - Significant TCDD TEQ contaminants found in on-site sediments that could move downstream.. Some TCDD TEQ found in sediments from numerous other locations in the Houston Ship Channel & Galveston Bay
										Weekend Fisherman			
										Sporadic Fisherman			
						Passing Boats		Ingestion		Passing Boaters		Past Present Future	No data available to evaluate pathway; however, not considered to be a significant pathway of exposure.
								Dermal Contact		Passing Boaters			

Table 2. SJRWP Exposure Pathway Analysis, Other Pathways

Pathway Name	Contaminant of Concern	Exposure Pathway Elements: Source		Transport Medium		Point of Exposure		Route of Exposure		Exposed Population		Time	Comments and Pathway Status
		Source	Status	Medium	Status	Point	Status	Route	Status	Population	Status		
Biota	PCDDs and PCDFs	Surface Impoundment of Papermill Waste		Fish and Crabs		Caught Near Site		Ingestion		Subsistence Fisherman		Past Present Future	**Complete** - Significant TCDD TEQ contaminants found in fish and crabs caught near site.
										Weekend Fisherman			
										Sporadic Fisherman			
						Caught Downstream from Site		Ingestion		Subsistence Fisherman		Past Present Future	**Complete** - Significant TCDD TEQ contaminants found in fish and crabs caught further down in Galveston Bay.
										Weekend Fisherman			
										Sporadic Fisherman			
Ground Water	No Data	Surface Impoundment of Papermill Waste		Ground Water		Shallow Ground Water Wells		Ingestion		Nearby Residents		Past Present Future	No data available to evaluate pathway; however, shallow ground water not considered to be a significant pathway of exposure because no wells in immediate vicinity and shallow ground water is brackish. PCDDs & PCDFs very low solubility & volatility, so evaporation from water not expected to occur.
										Employees at Nearby Businesses			
								Inhalation		Nearby Residents		Past Present Future	
										Employees at Nearby Businesses			
								Dermal Contact		Nearby Residents		Past Present Future	
										Employees at Nearby Businesses			
Surface Water	No Data	Surface Impoundment of Papermill Waste		Surface Water		On-Site Surface Water		Ingestion		Nearby Residents		Past Present Future	No data available to evaluate pathway; however, surface water not considered to be a significant pathway of exposure because surface water is brackish & drinking of surface water not expected to occur. PCDDs & PCDFs have very low solubility & volatility, so evaporation from water not expected to occur.
										Employees at Nearby Businesses			
								Inhalation		Nearby Residents		Past Present Future	
										Employees at Nearby Businesses			
								Dermal Contact		Nearby Residents		Past Present Future	
										Employees at Nearby Businesses			
Ambient Air	No Data	Surface Impoundment of Papermill Waste		Ambient Air		On-Site Air		Inhalation		Nearby Residents		Past Present Future	No data available to evaluate pathway; however, ambient air not considered to be a significant pathway of exposure because PCDDs & PCDFs have very low volatility and are tightly bound to sediments.
										Employees at Nearby Businesses			
						Off-Site Air		Inhalation		Nearby Residents			
										Employees at Nearby Businesses			

Table 3. Toxicity Equivalency Factors (TEFs) for PCDDs/PCDFs

Item#	PCDD/PCDF Congener	Texas TEF [11]	WHO_{98} TEF [11]	WHO_{05} TEF [19]
1	2,3,7,8-TCDD	1	1	1
2	1,2,3,7,8-PeCDD	0.5	1	1
3	1,2,3,4,7,8-HxCDD	0.1	0.1	0.1
4	1,2,3,6,7,8-HxCDD	0.1	0.1	0.1
5	1,2,3,7,8,9-HxCDD	0.1	0.1	0.1
6	1,2,3,4,6,7,8-HpCDD		0.01	0.01
7	OCDD		0.0001	0.0003
8	2,3,7,8-TCDF	0.1	0.1	0.1
9	1,2,3,7,8-PeCDF	0.05	0.05	0.03
10	2,3,4,7,8-PeCDF	0.5	0.5	0.3
11	1,2,3,4,7,8-HxCDF	0.1	0.1	0.1
12	1,2,3,6,7,8-HxCDF	0.1	0.1	0.1
13	1,2,3,7,8,9-HxCDF	0.1	0.1	0.1
14	2,3,4,6,7,8-HxCDF	0.1	0.1	0.1
15	1,2,3,4,6,7,8-HpCDF		0.01	0.01
16	1,2,3,4,7,8,9-HpCDF		0.01	0.01
17	OCDF		0.0001	0.0003

Abbreviations: PCDDs/PCDFs = polychlorinated dibenzo-p-dioxins / polychlorinated dibenzofurans; TCDD = tetrachlorodibenzo-p-dioxin; PeCDD = pentachlorodibenzo-p-dioxin; HxCDD = hexachlorodibenzo-p-dioxin; HpCDD = heptachlorodibenzo-p-dioxin; OCDD = octachlorodibenzo-p-dioxin; TCDF = tetrachlorodibenzofuran; PeCDF = pentachlorodibenzofuran; HxCDF = hexachlorodibenzofuran; HpCDF = heptachlorodibenzofuran, OCDF = octachlorodibenzofuran; WHO = World Health Organization

Table 4. San Jacinto River Waste Pits, Sediment Sample Descriptions

On-Site/ Off-Site	Sample Number	Sample Date	Sample Location	Sample Depth
On-Site	D02009	7/12/2005	SE-04	Approximately 7 feet below water surface
On-Site	D02008	7/12/2005	SE-05	Approximately 7-8 feet below water surface
On-Site	D02007	7/12/2005	SE-07	Approximately 5.5 feet below water surface
On-Site	D02006	7/12/2005	SE-08	Approximately 6 feet below water surface
On-Site	D02012	7/13/2005	SE-09	Approximately 1-6 inches below soil/sed surface
On-Site	D02013	7/13/2005	SE-10	Approximately 1-6 inches below soil/sed surface
On-Site	D02014	7/13/2005	SE-11	Approximately 1-6 inches below soil/sed surface
On-Site	TMDL15	8/18/2005	SE-15	Approximately 1-6 inches below soil/sed surface
On-Site	TMDL15d	8/18/2005	SE-15dup	Approximately 1-6 inches below soil/sed surface
Off-Site	D02010	7/13/2005	SE-02	Approximately 3.5 feet below water surface
Off-Site	D02011	7/13/2005	SE-03	Approximately 3.5 feet below water surface
Off-Site	D02002	7/12/2005	SE-19	Approximately 1 foot below water surface
Off-Site	D02003	7/12/2005	SE-20	Approximately 1 foot below water surface

Abbreviations: dup = duplicate sample; sed = sediment

Table 5. San Jacinto River Waste Pits Sediment PCDD/PCDF Results

PCDD/PCDF Congener	SE-04 7/12/05 (pg/g)	SE-05 7/12/05 (pg/g)	SE-07 7/12/05 (pg/g)	SE-08 7/12/05 (pg/g)	SE-09 7/13/05 (pg/g)	SE-10 7/13/05 (pg/g)	SE-11 7/13/05 (pg/g)	SE-15 8/18/05 (pg/g)	SE-15dup 8/18/05 (pg/g)	Average (pg/g)
2,3,7,8-TCDD	908	814	51.2	18,500 J	5,710	12,900 J	17,900 J	21,000	23,000	8,111.89
1,2,3,7,8-PeCDD	12.4	9.74	1.16 LJ	182	363	349	323	240	290	177.19
1,2,3,4,7,8-HxCDD	1.215 ND	1.195 ND	1.24 ND	3.55	4.83	4.71	4.2	3.5	1.75 ND	2.99
1,2,3,6,7,8-HxCDD	3	1.49 LJ	3.21	11	27.9	26.9	15.9	8.2	8.1	12.77
1,2,3,7,8,9-HxCDD	3.94	1.5 LJ	4.87	5.74	10.2	10.1	7.03	2.25 ND	2.25 ND	6.20
1,2,3,4,6,7,8-HpCDD	128	43.8	147	188	658	591	367	95	90	303.26
OCDD	-	-	-	-	-	-	-	1,200	1,200	1,200
2,3,7,8-TCDF	4,210	3,530	246	41,300 J	8,430 J	20,600 J	36,700 J	82,000	93,000	16,430.86
1,2,3,7,8-PeCDF	107	71.7	3.7	1,900	2,400	3,770	2,710	2,800	2,900	1,566.06
2,3,4,7,8-PeCDF	89	61.8	3.6	1,290	1,480	2,330	2,030	2,200	2,300	1,040.63
1,2,3,4,7,8-HxCDF	129	99.1	4.84	5,560	5,220	8,660	4,940	3,900	4,600	3,516.13
1,2,3,6,7,8-HxCDF	31.3	26.3	1.24 ND	1,390	1,360	2,290	1,270	1,100	1,200	909.83
2,3,4,6,7,8-HxCDF	7.15	5.09	1.24 ND	222	229	349	216	210	210	147.07
1,2,3,7,8,9-HxCDF	13	8.57	1.24 ND	440	451	656	403	410	390	281.83
1,2,3,4,6,7,8-HpCDF	39.8	26.2	1.24 ND	962	1,300	2,360	1,290	1,100	1,300	854.18
1,2,3,4,7,8,9-HpCDF	11.3	8.36	0.398 LJ	3.54	531	878	477	440	520	272.80
OCDF	-	-	-	-	-	-	-	390	450	420
TCDD TEQ (pg/g)	1,391.96	1,212.5	81.43	24,030.8	8,187.18	17,359.06	23,290.25	30,764	34,028	10,793.31

Abbreviations: CRQL = contract required quantitation limit; EDL = estimated detection limit; IDL = instrument detection limit; J = result is estimated; L = reported concentration is between the IDL and the CRQL; ND = not detected at the laboratory reported IDL. (Values for ND results represent sample EDL ÷ 2); pg/g = picograms per gram; TCDD = tetrachlorodibenzo-p-dioxin; PeCDD = pentachlorodibenzo-p-dioxin; HxCDD = hexachlorodibenzo-p-dioxin; HpCDD = heptachlorodibenzo-p-dioxin, OCDD = octachlorodibenzo-p-dioxin; TCDF = tetrachlorodibenzofuran; PeCDF = pentachlorodibenzofuran; HxCDF = hexachlorodibenzofuran; HpCDF = heptachlorodibenzofuran, OCDF = octachlorodibenzofuran

Table 6. SJRWP Site Sample PCDD/PCDF Quantitation & Detection Limits

PCDD / PCDF Congener	SE-04 CRQL or [EDL] (pg/g)	SE-05 CRQL or [EDL] (pg/g)	SE-07 CRQL or [EDL] (pg/g)	SE-08 CRQL or [EDL] (pg/g)	SE-09 CRQL or [EDL] (pg/g)	SE-10 CRQL or [EDL] (pg/g)	SE-11 CRQL or [EDL] (pg/g)	SE-15 CRQL or [EDL] (pg/g)	SE-15dup CRQL or [EDL] (pg/g)
2,3,7,8-TCDD	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
1,2,3,7,8-PeCDD	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
1,2,3,4,7,8-HxCDD	[2.43]	[2.39]	[2.48]	5.0	5.0	5.0	5.0	5.0	[3.50]
1,2,3,6,7,8-HxCDD	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
1,2,3,7,8,9-HxCDD	5.0	5.0	5.0	5.0	5.0	5.0	5.0	[4.50]	[4.50]
1,2,3,4,6,7,8-HpCDD	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
OCDD	-	-	-	-	-	-	-	5.0	5.0
2,3,7,8-TCDF	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
1,2,3,7,8-PeCDF	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
2,3,4,7,8-PeCDF	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
1,2,3,4,7,8-HxCDF	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
1,2,3,6,7,8-HxCDF	5.0	5.0	[2.48]	5.0	5.0	5.0	5.0	5.0	5.0
2,3,4,6,7,8-HxCDF	5.0	5.0	[2.48]	5.0	5.0	5.0	5.0	5.0	5.0
1,2,3,7,8,9-HxCDF	5.0	5.0	[2.48]	5.0	5.0	5.0	5.0	5.0	5.0
1,2,3,4,6,7,8-HpCDF	5.0	5.0	[2.48]	5.0	5.0	5.0	5.0	5.0	5.0
1,2,3,4,7,8,9-HpCDF	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
OCDF	-	-	-	-	-	-	-	5.0	5.0

Abbreviations: pg/g = picograms per gram; CRQL = contract required quantitation limit; EDL = estimated detection limit; TCDD = tetrachlorodibenzo-p-dioxin; PeCDD = pentachlorodibenzo-p-dioxin; HxCDD = hexachlorodibenzo-p-dioxin; HpCDD = heptachlorodibenzo-p-dioxin, OCDD = octachlorodibenzo-p-dioxin; TCDF = tetrachlorodibenzofuran; PeCDF = pentachlorodibenzofuran; HxCDF = hexachlorodibenzofuran; HpCDF = heptachlorodibenzofuran, OCDF = octachlorodibenzofuran

Table 7. San Jacinto River Waste Pits, Background Sample Results

Item#	PCDD/PCDF Congener	SE-02 (pg/g)	SE-03 (pg/g)	SE-19 (pg/g)	SE-20 (pg/g)	Average (pg/g)
1	2,3,7,8-TCDD	0.47	0.92	0.14 ND	0.105 ND	0.409
2	1,2,3,7,8-PeCDD	0.0575 ND	0.196 LJ	0.263 LJ	0.0484 ND	0.141
3	1,2,3,4,7,8-HxCDD	1.175 ND	1.215 ND	1.2 ND	1.2 ND	1.198
4	1,2,3,6,7,8-HxCDD	0.457 LJ	0.844 LJ	0.192 LJ	0.106 LJ	0.400
5	1,2,3,7,8,9-HxCDD	0.581 LJ	0.98 LJ	0.234 LJ	0.14 LJ	0.484
6	1,2,3,4,6,7,8-HpCDD	15.8	27.9	1.2 ND	1.2 ND	11.525
7	OCDD					
8	2,3,7,8-TCDF	1.11	1.6	0.5	0.24 ND	0.863
9	1,2,3,7,8-PeCDF	1.175 ND	1.215 ND	1.2 ND	1.2 ND	1.198
10	2,3,4,7,8-PeCDF	1.175 ND	1.215 ND	1.2 ND	1.2 ND	1.198
11	1,2,3,4,7,8-HxCDF	1.175 ND	1.215 ND	1.2 ND	1.2 ND	1.198
12	1,2,3,6,7,8-HxCDF	1.175 ND	1.215 ND	1.2 ND	1.2 ND	1.198
13	2,3,4,6,7,8-HxCDF	1.175 ND	1.215 ND	1.2 ND	1.2 ND	1.198
14	1,2,3,7,8,9-HxCDF	0.65 ND	1.215 ND	1.2 ND	1.2 ND	1.066
15	1,2,3,4,6,7,8-HpCDF	1.175 ND	2.24 LJ	1.2 ND	4.67	2.321
16	1,2,3,4,7,8,9-HpCDF	0.122 LJ	0.281 LJ	0.343 LJ	1.29 LJ	0.509
17	OCDF					
18	TCDD TEQ (pg/g)	1.836	2.771	1.519	1.270	1.849

Abbreviations: pg/g = picograms per gram; CRQL = Contract Required Quantitation Limit; EDL = Estimated Detection Limit; IDL = Instrument Detection Limit; ND = Undetected at the laboratory reported IDL. (Values for ND results represent sample EDL ÷ 2); L = Reported concentration is between the IDL and the CRQL; J = Result is estimated; TCDD = tetrachlorodibenzo-p-dioxin; PeCDD = pentachlorodibenzo-p-dioxin; HxCDD = hexachlorodibenzo-p-dioxin; HpCDD = heptachlorodibenzo-p-dioxin, OCDD = octachlorodibenzo-p-dioxin; TCDF = tetrachlorodibenzofuran; PeCDF = pentachlorodibenzofuran; HxCDF = hexachlorodibenzofuran; HpCDF = heptachlorodibenzofuran, OCDF = octachlorodibenzofuran.

Table 8. Background PCDD/PCDF Quantitation & Detection Limits

Item#	PCDD/ PCDF Congener	SE-02 *CRQL or [EDL]* (pg/g)	SE-03 *CRQL or [EDL]* (pg/g)	SE-19 *CRQL or [EDL]* (pg/g)	SE-20 *CRQL or [EDL]* (pg/g)
1	2,3,7,8-TCDD	*1.0*	*1.0*	*[0.280]*	*1.0*
2	1,2,3,7,8-PeCDD	*[0.115]*	*5.0*	*5.0*	*5.0*
3	1,2,3,4,7,8-HxCDD	*[2.35]*	*[2.43]*	*[2.40]*	*[2.40]*
4	1,2,3,6,7,8-HxCDD	*5.0*	*5.0*	*5.0*	*5.0*
5	1,2,3,7,8,9-HxCDD	*5.0*	*5.0*	*5.0*	*5.0*
6	1,2,3,4,6,7,8-HpCDD	*5.0*	*5.0*	*[2.40]*	*[2.40]*
7	OCDD	-	-	-	-
8	2,3,7,8-TCDF	*1.0*	*1.0*	*1.0*	*[0.48]*
9	1,2,3,7,8-PeCDF	*[2.35]*	*[2.43]*	*[2.40]*	*[2.40]*
10	2,3,4,7,8-PeCDF	*[2.35]*	*[2.43]*	*[2.40]*	*[2.40]*
11	1,2,3,4,7,8-HxCDF	*[2.35]*	*[2.43]*	*[2.40]*	*[2.40]*
12	1,2,3,6,7,8-HxCDF	*[2.35]*	*[2.43]*	*[2.40]*	*[2.40]*
13	2,3,4,6,7,8-HxCDF	*[2.35]*	*[2.43]*	*[2.40]*	*[2.40]*
14	1,2,3,7,8,9-HxCDF	*[1.30]*	*[2.43]*	*[2.40]*	*[2.40]*
15	1,2,3,4,6,7,8-HpCDF	*[2.35]*	*5.0*	*[2.40]*	*5.0*
16	1,2,3,4,7,8,9-HpCDF	*5.0*	*5.0*	*5.0*	*5.0*
17	OCDF	-	-	-	-

Abbreviations: pg/g = picograms per gram; CRQL = contract required quantitation limit; EDL = estimated detection limit; PCDD/PCDF = polychlorinated dibenzo-p-dioxin / polychlorinated dibenzofuran; TCDD = tetrachlorodibenzo-p-dioxin; PeCDD = pentachlorodibenzo-p-dioxin; HxCDD = hexachlorodibenzo-p-dioxin; HpCDD = heptachlorodibenzo-p-dioxin; OCDD = octachlorodibenzo-p-dioxin; TCDF = tetrachlorodibenzofuran; PeCDF = pentachlorodibenzofuran; HxCDF = hexachlorodibenzofuran; HpCDF = heptachlorodibenzofuran, OCDF = octachlorodibenzofuran.

Table 9. Average TCDD TEQ Concentrations (pg/g), On-Site & Off-Site Locations

Sediment Sample Collection Location	Count	Average (pg/g)	Minimum (pg/g)	Maximum (pg/g)	Standard Deviation
SJRWP, On-Site Samples	9	15,594	80.92	34,028	13,264
Down-Stream from SJRWP, SJR, HSC, & UGB	59	13.75	0.739	86.16	15.5
SJRWP Site-Vicinity, SJR Near SJRWP	31	82.24	1.997	572.5	131
Houston Ship Channel, Above/West of SJR	62	65.69	4.904	856.8	134
Up-Stream & Tributaries to SJR, HSC, or UGB	56	15.97	0.759	102.9	20.4
All Off-Site Samples	208	40.04	0.739	856.8	93.7

Abbreviations: pg/g = picograms per gram; SJRWP = San Jacinto River Waste Pits; SJR = San Jacinto River; HSC = Houston Ship Chanel; UGB = Upper Galveston Bay, TCDD TEQ = tetrachlorodibenzo-p-dioxin toxic equivalent.

Table 10a. Parameters for Oral Sediment Exposure Scenarios, Adults

Parameters for Oral Exposures to TCDD TEQ in Sediments while Fishing at the SJRWP Site, Adults	Subsistence Fisherman	Weekend Fisherman	Sporadic Fisherman
Avg SIR over entire exp period (Ca) (mg_{sed}/day)	100.00	100.00	100.00
SIR for Acu, Int, & Chr dur exp (Non-Ca) (mg_{sed}/day)	100.00	100.00	100.00
Conversion Factor 1 (10^{-9} mg_{TEQ}/pg_{TEQ})	1.00E-09	1.00E-09	1.00E-09
Conversion Factor 2 (10^{-3} g_{sed}/mg_{sed})	1.00E-03	1.00E-03	1.00E-03
Oral Absorption Factor for TCDD in sediments (unitless)	0.50	0.50	0.50
Oral Ca Slope Factor for TCDD $(mg/kg/day)^{-1}$	150,000	150,000	150,000
Acute Oral MRL for TCDD (mg/kg/day)	1.67E-07	1.67E-07	1.67E-07
Intermediate Oral MRL for TCDD (mg/kg/day)	2.33E-08	2.33E-08	2.33E-08
Chronic Oral MRL for TCDD (mg/kg/day)	1.20E-09	1.20E-09	1.20E-09
Avg BW over entire exposure period (Ca) (kg)	70.58	70.58	69.05
Avg BW for Acu dur exp (7 day, Non-Ca) (kg)	65.61	65.61	65.61
Avg BW for Int dur exp (182 day, Non-Ca) (kg)	65.77	65.77	65.77
Avg BW for Chr dur exp (365 day, Non-Ca) (kg)	65.95	65.95	65.95
Exposure Duration Factors for Less Than Daily (24-7-52-70) Exposures	**Subsistence Fisherman**	**Weekend Fisherman**	**Sporadic Fisherman**
Age at beginning of exposure period	20	20	20
Age at ending of exposure period	50	50	35
Number of hours exposed per day	8	8	8
Number of days exposed per week	5	1	1
Number of weeks exposed per year	52	52	12
Number of years of lifetime exposed	30	30	15
Number of hours in a day	24	24	24
Number of days in a week	7	7	7
Number of weeks in a year	52	52	52
Number of years in a standard lifetime	70	70	70
Exposure factor for Ca scenarios (unitless)	0.102041	0.020408	0.002355
Exposure factor for Non-Ca scenarios (unitless)	0.238095	0.047619	0.010989

Abbreviations: **TCDD** = tetrachlorodibenzo-p-dioxin; **TEQ** = toxic equivalent concentration; **SJRWP** = San Jacinto River Waste Pits; **SIR** = Sediment Ingestion Rate; **Ca** = Cancer; **mg_{sed}/day** = milligrams sediment per day; **mg_{TEQ}/pg_{TEQ}** = milligrams toxicity equivalents per picogram toxicity equivalents; **g_{sed}/mg_{sed}** = grams sediment per milligram sediment; **mg/kg/day** = milligrams per kilogram per day; **kg** = kilogram; **MRL** = Minimal Risk Level; **Avg** = average; **BW** = body weight; **Acu** = acute; **Int** = intermediate; **Chr** = chronic; **dur** = duration; **exp** = exposure.

Table 10b. Parameters for Oral Sediment Exposure Scenarios, Children

Parameters for Oral Exposures to TCDD TEQ in Sediments while Fishing at the SJRWP Site Children	Child of Subsistence Fisherman	Child of Weekend Fisherman	Child of Sporadic Fisherman
Avg SIR over entire exp period (Ca) (mg_{sed}/day)	120.21	120.21	129.69
SIR for Acu, Int, & Chr dur exp (Non-Ca) (mg_{sed}/day)	200.00	200.00	200.00
Conversion Factor 1 (10^{-9} mg_{TEQ}/pg_{TEQ})	1.00E-09	1.00E-09	1.00E-09
Conversion Factor 2 (10^{-3} g_{sed}/mg_{sed})	1.00E-03	1.00E-03	1.00E-03
Oral Absorption Factor for TCDD in sediments (unitless)	0.50	0.50	0.50
Oral Ca Slope Factor for TCDD $(mg/kg/day)^{-1}$	150,000	150,000	150,000
Acute Oral MRL for TCDD (mg/kg/day)	1.67E-07	1.67E-07	1.67E-07
Intermediate Oral MRL for TCDD (mg/kg/day)	2.33E-08	2.33E-08	2.33E-08
Chronic Oral MRL for TCDD (mg/kg/day)	1.20E-09	1.20E-09	1.20E-09
Avg BW over entire exposure period (Ca) (kg)	60.10	60.10	54.47
Avg BW for Acu dur exp (7 day, Non-Ca) (kg)	14.77	14.77	14.77
Avg BW for Int dur exp (182 day, Non-Ca) (kg)	15.30	15.30	15.30
Avg BW for Chr dur exp (365 day, Non-Ca) (kg)	15.86	15.86	15.86
Exposure Duration Factors for Less Than Daily (24-7-52-70) Exposures	**Child of Subsistence Fisherman**	**Child of Weekend Fisherman**	**Child of Sporadic Fisherman**
Age at beginning of exposure period	3	3	3
Age at ending of exposure period	50	50	35
Number of hours exposed per day	8	8	8
Number of days exposed per week	5	1	1
Number of weeks exposed per year	52	52	12
Number of years of lifetime exposed	47	47	32
Number of hours in a day	24	24	24
Number of days in a week	7	7	7
Number of weeks in a year	52	52	52
Number of years in a standard lifetime	70	70	70
Exposure factor for Ca scenarios (unitless)	0.159864	0.031973	0.005024
Exposure factor for Non-Ca scenarios (unitless)	0.238095	0.047619	0.010989

Abbreviations: **TCDD** = tetrachlorodibenzo-p-dioxin; **TEQ** = toxic equivalent concentration; **SJRWP** = San Jacinto River Waste Pits; **SIR** = Sediment Ingestion Rate; **Ca** = Cancer; **mg_{sed}/day** = milligrams sediment per day; **mg_{TEQ}/pg_{TEQ}** = milligrams toxicity equivalents per picogram toxicity equivalents; **g_{sed}/mg_{sed}** = grams sediment per milligram sediment; **mg/kg/day** = milligrams per kilogram per day; **kg** = kilogram; **MRL** = Minimal Risk Level; **Avg** = average; **BW** = body weight; **Acu** = acute; **Int** = intermediate; **Chr** = chronic; **dur** = duration; **exp** = exposure..

Table 11. Theoretical Adult Cancer Risks (Oral Exp), On & Off-Site Locations

Sediments, Oral Ingestion Pathway			Subsistence Fisherman		Weekend Fisherman		Sporadic Fisherman	
Sediment Sample Collection Location	Sample	TCDD TEQ (pg/g)	Theo Ca Risk (Oral Exp)	Ca Odds	Theo Ca Risk (Oral Exp)	Ca Odds	Theo Ca Risk (Oral Exp)	Ca Odds
SJRWP, On-Site Samples	Avg	15,594	1.69E-04	5,914	3.38E-05	29,570	3.99E-06	250,730
	Max	34,028	3.69E-04	2,710	7.38E-05	13,551	8.70E-06	114,901
Down-Stream from SJRWP SJR, HSC, & UGB	Avg	13.75	1.49E-07	6,705,058	2.98E-08	33,525,288	3.52E-09	284,268,588
	Max	86.16	9.34E-07	1,070,303	1.87E-07	5,351,515	2.20E-08	45,376,723
SJRWP Site-Vicinity, SJR Near SJRWP	Avg	82.24	8.92E-07	1,121,374	1.78E-07	5,606,870	2.10E-08	47,541,933
	Max	572.5	6.21E-06	161,089	1.24E-06	805,447	1.46E-07	6,829,569
Houston Ship Channel, Above/West of SJR	Avg	65.69	7.12E-07	1,403,800	1.42E-07	7,019,001	1.68E-08	59,515,719
	Max	856.8	9.29E-06	107,639	1.86E-06	538,195	2.19E-07	4,563,476
Up-Stream & Tributaries to SJR-HSC-UGB	Avg	15.97	1.73E-07	5,775,873	3.46E-08	28,879,364	4.08E-09	244,874,736
	Max	102.9	1.12E-06	896,269	2.23E-07	4,481,345	2.63E-08	37,998,347
All Off-Site Samples	Avg	40.04	4.34E-07	2,303,297	8.68E-08	11,516,487	1.02E-08	97,650,928
	Max	856.8	9.29E-06	107,639	1.86E-06	538,195	2.19E-07	4,563,476

Abbreviations: Avg = average; Max = maximum; Exp = exposure; Theo = theoretical; Ca = cancer; SJRWP = San Jacinto River Waste Pitts; SJR = San Jacinto River; HSC = Houston Ship Channel; UGB = Upper Galveston Bay; pg/g = picograms per gram; TCDD TEQ = tetrachlorodibenzo-p-dioxin toxic equivalent concentration

E-02	Very High Increased Lifetime Risk
E-03	High Increased Lifetime Risk
E-04	Moderate Increased Lifetime Risk

E-05	Low Increased Lifetime Risk
E-06	No Apparent Increased Lifetime Risk
E-07	No Increased Lifetime Risk

Table 12. Theoretical Child Cancer Risks (Oral Exp), On & Off-Site Locations

Sediments, Oral Ingestion Pathway			Child of Subsistence Fisherman		Child of Weekend Fisherman		Child of Sporadic Fisherman	
Sediment Sample Collection Location	**Sample**	**TCDD TEQ (pg/g)**	**Theo Ca Risk (Oral Exp)**	**Ca Odds**	**Theo Ca Risk (Oral Exp)**	**Ca Odds**	**Theo Ca Risk (Oral Exp)**	**Ca Odds**
SJRWP, On-Site Samples	Avg	15,594	3.74E-04	2,674	7.48E-05	13,369	1.40E-05	71,485
	Max	34,028	8.16E-04	1,225	1.63E-04	6,127	3.05E-05	32,759
Down-Stream from SJRWP, SJR, HSC, & UGB	Avg	13.75	3.30E-07	3,031,484	6.60E-08	15,157,420	1.23E-08	81,047,261
	Max	86.16	2.07E-06	483,904	4.13E-07	2,419,522	7.73E-08	12,937,269
SJRWP Site-Vicinity, SJR Near SJRWP	Avg	82.24	1.97E-06	506,994	3.94E-07	2,534,972	7.38E-08	13,554,587
	Max	572.5	1.37E-05	72,832	2.75E-06	364,158	5.14E-07	1,947,165
Houston Ship Channel, Above/West of SJR	Avg	65.69	1.58E-06	634,685	3.15E-07	3,173,424	5.89E-08	16,968,410
	Max	856.8	2.05E-05	48,666	4.11E-06	243,328	7.69E-07	1,301,084
Up-Stream & Tributaries to SJR-HSC-UGB	Avg	15.97	3.83E-07	2,611,382	7.66E-08	13,056,909	1.43E-08	69,815,757
	Max	102.9	2.47E-06	405,220	4.94E-07	2,026,101	9.23E-08	10,833,634
All Off-Site Samples	Avg	40.04	9.60E-07	1,041,365	1.92E-07	5,206,823	3.59E-08	27,841,065
	Max	856.8	2.05E-05	48,666	4.11E-06	243,328	7.69E-07	1,301,084

Abbreviations: Avg = average; Max = maximum; Exp = exposure; Theo = theoretical; Ca = cancer; SJRWP = San Jacinto River Waste Pitts; SJR = San Jacinto River; HSC = Houston Ship Channel; UGB = Upper Galveston Bay; pg/g = picograms per gram; TCDD TEQ = tetrachlorodibenzo-p-dioxin toxic equivalent concentration

E-02	Very High Increased Lifetime Risk
E-03	High Increased Lifetime Risk
E-04	Moderate Increased Lifetime Risk

E-05	Low Increased Lifetime Risk
E-06	No Apparent Increased Lifetime Risk
E-07	No Increased Lifetime Risk

Table 13a. Parameters for Dermal Sediment Exposure Scenarios, Adults

Parameters for Dermal TCDD TEQ Sediment Exposures from Fishing at the SJRWP Site, Adults	**Subsistence Fisherman**	**Weekend Fisherman**	**Sporadic Fisherman**
BSA exp daily over entire period (Ca) (HA & FA) (cm^2/day)	2,056.41	2,056.41	2,040.01
BSA Acu dur exp (7-day, Non Ca) (HA & FA) (cm^2/day)	1,984.19	1,984.19	1,984.19
BSA Int dur exp (182-day, Non-Ca) (HA & FA) (cm^2/day)	1,987.33	1,987.33	1,987.33
BSA Chr dur exp (365-day, Non-Ca) (HA & FA) (cm^2/day)	1,990.61	1,990.61	1,990.61
Units Conversion Factor 1 (10^{-9} mg_{TEQ}/pg_{TEQ})	1.00E-09	1.00E-09	1.00E-09
Units Conversion Factor 2 (10^{-3} g_{sed}/mg_{sed})	1.00E-03	1.00E-03	1.00E-03
Quantity of sediment adhering per surf area (mg_{sed}/cm^2)	1.00	1.00	1.00
Dermal Absorption Factor (unitless)	0.03	0.03	0.03
Dermal Ca Slope Factor for TCDD $(mg/kg/day)^{-1}$	300,000	300,000	300,000
Acute Oral MRL for TCDD (mg/kg/day)	1.67E-07	1.67E-07	1.67E-07
Intermediate Oral MRL for TCDD (mg/kg/day)	2.33E-08	2.33E-08	2.33E-08
Chronic Oral MRL for TCDD (mg/kg/day)	1.20E-09	1.20E-09	1.20E-09
Avg BW over entire exposure period (Ca) (kg)	70.58	70.58	69.05
Avg BW for Acu dur exp (7 day, Non-Ca) (kg)	65.61	65.61	65.61
Avg BW for Int dur exp (182 day, Non-Ca) (kg)	65.77	65.77	65.77
Avg BW for Chr dur exp (365 day, Non-Ca) (kg)	65.95	65.95	65.95
Exposure Duration Factors for Less Than Daily (24-7-52-70) Exposures	**Subsistence Fisherman**	**Weekend Fisherman**	**Sporadic Fisherman**
Age at beginning of exposure period	20	20	20
Age at ending of exposure period	50	50	35
Number of hours exposed per day	8	8	8
Number of days exposed per week	5	1	1
Number of weeks exposed per year	52	52	12
Number of years of lifetime exposed	30	30	15
Number of hours in a day	24	24	24
Number of days in a week	7	7	7
Number of weeks in a year	52	52	52
Number of years in a standard lifetime	70	70	70
Exposure factor for Ca scenarios (unitless)	0.102041	0.020408	0.002355
Exposure factor for Non-Ca scenarios (unitless)	0.238095	0.047619	0.010989

Abbreviations: **TCDD** = tetrachlorodibenzo-p-dioxin; **TEQ** = Toxicity Equivalents; **SJRWP** = San Jacinto River Waste Pits; **BSA** = body surface area; **HA & FA** = hands & forearms; **cm^2/day** = square centimeters contaminated per day; **mg_{TEQ}/pg_{TEQ}** = milligrams toxicity equivalents per picogram toxicity equivalents; **g_{sed}/mg_{sed}** = grams sediment per milligram sediment; **mg_{sed}/cm^2** = milligrams sediment per square centimeter; **MRL** = Minimal Risk Level; **mg/kg/day** = milligrams per kilogram per day; **Avg** = average; **BW** = body weight; **Ca** = Cancer; **Chr** = chronic; **Int** = intermediate; **Acu** = acute; **dur** = duration; **exp** = exposure; **kg** = kilogram.

Table 13b. Parameters for Dermal Sediment Exposure Scenarios, Children

Parameters for Dermal TCDD TEQ Sediment Exposures from Fishing at the SJRWP Site, Children	**Child of Subsistence Fisherman**	**Child of Weekend Fisherman**	**Child of Sporadic Fisherman**
BSA exp daily over entire period (Ca) (HA & FA) (cm^2/day)	1,815.97	1,815.97	1,695.56
BSA Acu dur exp (7-day, Non Ca) (HA & FA) (cm^2/day)	698.51	698.51	698.51
BSA Int dur exp (182-day, Non-Ca) (HA & FA) (cm^2/day)	717.65	717.65	717.65
BSA Chr dur exp (365-day, Non-Ca) (HA & FA) (cm^2/day)	742.56	742.56	742.56
Units Conversion Factor 1 (10^{-9} mg_{TEQ}/pg_{TEQ})	1.00E-09	1.00E-09	1.00E-09
Units Conversion Factor 2 (10^{-3} g_{sed}/mg_{sed})	1.00E-03	1.00E-03	1.00E-03
Quantity of sediment adhering per surf area (mg_{sed}/cm^2)	1.00	1.00	1.00
Dermal Absorption Factor (unitless)	0.03	0.03	0.03
Dermal Ca Slope Factor for TCDD $(mg/kg/day)^{-1}$	300,000	300,000	300,000
Acute Oral MRL for TCDD (mg/kg/day)	1.67E-07	1.67E-07	1.67E-07
Intermediate Oral MRL for TCDD (mg/kg/day)	2.33E-08	2.33E-08	2.33E-08
Chronic Oral MRL for TCDD (mg/kg/day)	1.20E-09	1.20E-09	1.20E-09
Avg BW over entire exposure period (Ca) (kg)	60.10	60.10	54.47
Avg BW for Acu dur exp (7 day, Non-Ca) (kg)	14.77	14.77	14.77
Avg BW for Int dur exp (182 day, Non-Ca) (kg)	15.30	15.30	15.30
Avg BW for Chr dur exp (365 day, Non-Ca) (kg)	15.86	15.86	15.86
Exposure Duration Factors for Less Than Daily (24-7-52-70) Exposures	**Child of Subsistence Fisherman**	**Child of Weekend Fisherman**	**Child of Sporadic Fisherman**
Age at beginning of exposure period	3	3	3
Age at ending of exposure period	50	50	35
Number of hours exposed per day	8	8	8
Number of days exposed per week	5	1	1
Number of weeks exposed per year	52	52	12
Number of years of lifetime exposed	47	47	32
Number of hours in a day	24	24	24
Number of days in a week	7	7	7
Number of weeks in a year	52	52	52
Number of years in a standard lifetime	70	70	70
Exposure factor for Ca scenarios (unitless)	0.159864	0.031973	0.005024
Exposure factor for Non-Ca scenarios (unitless)	0.238095	0.047619	0.010989

Abbreviations: **TCDD** = tetrachlorodibenzo-p-dioxin; **TEQ** = Toxicity Equivalents; **SJRWP** = San Jacinto River Waste Pits; **BSA** = body surface area; **HA & FA** = hands & forearms; **cm^2/day** = square centimeters contaminated per day; **mg_{TEQ}/pg_{TEQ}** = milligrams toxicity equivalents per picogram toxicity equivalents; **g_{sed}/mg_{sed}** = grams sediment per milligram sediment; **mg_{sed}/cm^2** = milligrams sediment per square centimeter; **MRL** = Minimal Risk Level; **mg/kg/day** = milligrams per kilogram per day; **Avg** = average; **BW** = body weight; **Ca** = Cancer; **Chr** = chronic; **Int** = intermediate; **Acu** = acute; **dur** = duration; **exp** = exposure; **kg** = kilogram.

Table 14. Theoretical Adult Cancer Risks from TCDD TEQ (Dermal Exp), On & Off-Site

Sediments, Dermal Absorption Pathway			Subsistence Fisherman		Weekend Fisherman		Sporadic Fisherman	
Sediment Sample Collection Location	Sample	TCDD TEQ (pg/g)	Theo Ca Risk (Dermal Exp)	Ca Odds	Theo Ca Risk (Dermal Exp)	Ca Odds	Theo Ca Risk (Dermal Exp)	Ca Odds
SJRWP, On-Site Samples	Avg	15,594	4.17E-04	2,397	8.35E-05	11,983	9.76E-06	102,422
	Max	34,028	9.11E-04	1,098	1.82E-04	5,491	2.13E-05	46,937
Down-Stream from JRWP, SJR, HSC, & UGB	Avg	13.75	3.68E-07	2,717,131	7.36E-08	13,585,653	8.61E-09	116,122,225
	Max	86.16	2.31E-06	433,725	4.61E-07	2,168,627	5.39E-08	18,536,153
SJRWP Site-Vicinity, SJR Near SJRWP	Avg	82.24	2.20E-06	454,421	4.40E-07	2,272,105	5.15E-08	19,420,630
	Max	572.5	1.53E-05	65,279	3.06E-06	326,396	3.58E-07	2,789,843
Houston Ship Channel, Above/West of SJR	Avg	65.69	1.76E-06	568,870	3.52E-07	2,844,352	4.11E-08	24,311,859
	Max	856.8	2.29E-05	43,619	4.59E-06	218,096	5.36E-07	1,864,156
Up-Stream & Tributaries to SJR-HSC-UGB	Avg	15.97	4.27E-07	2,340,592	8.54E-08	11,702,958	1.00E-08	100,030,043
	Max	102.9	2.75E-06	363,200	5.51E-07	1,816,002	6.44E-08	15,522,125
All Off-Site Samples	Avg	40.04	1.07E-06	933,379	2.14E-07	4,666,895	2.51E-08	39,889,891
	Max	856.8	2.29E-05	43,619	4.59E-06	218,096	5.36E-07	1,864,156

Abbreviations: Avg = average; Max = maximum; Exp = exposure; Theo = theoretical; Ca = cancer; SJRWP = San Jacinto River Waste Pitts; SJR = San Jacinto River; HSC = Houston Ship Channel; UGB = Upper Galveston Bay; pg/g = picograms per gram; TCDD TEQ = tetrachlorodibenzo-p-dioxin toxic equivalent concentration

E-02	Very High Increased Lifetime Risk
E-03	High Increased Lifetime Risk
E-04	Moderate Increased Lifetime Risk

E-05	Low Increased Lifetime Risk
E-06	No Apparent Increased Lifetime Risk
E-07	No Increased Lifetime Risk

Table 15. Theoretical Child Cancer Risks from TCDD TEQ (Dermal Exp), On & Off-Site

Sediments, Dermal Absorption Pathway			Child of Subsistence Fisherman		Child of Weekend Fisherman		Child of Sporadic Fisherman	
Sediment Sample Collection Location	**Sample**	**TCDD TEQ (pg/g)**	**Theo Ca Risk (Dermal Exp)**	**Ca Odds**	**Theo Ca Risk (Dermal Exp)**	**Ca Odds**	**Theo Ca Risk (Dermal Exp)**	**Ca Odds**
SJRWP, On-Site Samples	Avg	15,594	6.78E-04	1,475	1.36E-04	7,375	2.19E-05	45,564
	Max	34,028	1.48E-03	675.9	2.96E-04	3,380	4.79E-05	20,880
Down-Stream from JRWP, SJR, HSC, & UGB	Avg	13.75	5.98E-07	1,672,311	1.20E-07	8,361,555	1.94E-08	51,658,381
	Max	86.16	3.75E-06	266,945	7.49E-07	1,334,723	1.21E-07	8,246,033
SJRWP Site-Vicinity, SJR Near SJRWP	Avg	82.24	3.58E-06	279,682	7.15E-07	1,398,412	1.16E-07	8,639,503
	Max	572.5	2.49E-05	40,177	4.98E-06	200,887	8.06E-07	1,241,095
Houston Ship Channel, Above/West of SJR	Avg	65.69	2.86E-06	350,122	5.71E-07	1,750,612	9.25E-08	10,815,425
	Max	856.8	3.72E-05	26,846	7.45E-06	134,231	1.21E-06	829,292
Up-Stream & Tributaries to SJR-HSC-UGB	Avg	15.97	6.94E-07	1,440,563	1.39E-07	7,202,813	2.25E-08	44,499,579
	Max	102.9	4.47E-06	223,539	8.95E-07	1,117,694	1.45E-07	6,905,206
All Off-Site Samples	Avg	40.04	1.74E-06	574,466	3.48E-07	2,872,331	5.64E-08	17,745,502
	Max	856.8	3.72E-05	26,846	7.45E-06	134,231	1.21E-06	829,292

Abbreviations: Avg = average; Max = maximum; Exp = exposure; Theo = theoretical; Ca = cancer; SJRWP = San Jacinto River Waste Pitts; SJR = San Jacinto River; HSC = Houston Ship Channel; UGB = Upper Galveston Bay; pg/g = picograms per gram; TCDD TEQ = tetrachlorodibenzo-p-dioxin toxic equivalent concentration

E-02	Very High Increased Lifetime Risk
E-03	High Increased Lifetime Risk
E-04	Moderate Increased Lifetime Risk

E-05	Low Increased Lifetime Risk
E-06	No Apparent Increased Lifetime Risk
E-07	No Increased Lifetime Risk

Table 16a. Parameters for TCDD Exposures from Fish or Crab Consumption, Adults

Fish and Crab Consumption Parameters for Oral TCDD TEQ Exposures for People Eating Fish or Crab Caught Near the SJRWP Site	Subsistence Fisherman	Weekend Fisherman	Sporadic Fisherman
Avg FCR on fishing days (Ca calcs) (gFish/day)	227.94	227.94	224.23
Avg FCR on fishing days (Acu, Non-Ca) (gFish/day)	215.83	215.83	215.83
Avg FCR on fishing days (Int, Non-Ca) (gFish/day)	216.24	216.24	216.24
Avg FCR on fishing days (Chr, Non-Ca) (gFish/day)	216.67	216.67	216.67
Units conversion factor (10^{-9} mg_{TEQ}/pg_{TEQ})	1.00E-09	1.00E-09	1.00E-09
Oral absorption factor for TCDD from fish (unitless)	0.95	0.95	0.95
Oral Cancer Slope Factor for TCDD $(mg/kg/day)^{-1}$	150,000	150,000	150,000
Acute Oral MRL for TCDD (mg/kg/day)	1.67E-07	1.67E-07	1.67E-07
Intermediate Oral MRL for TCDD (mg/kg/day)	2.33E-08	2.33E-08	2.33E-08
Chronic Oral MRL for TCDD (mg/kg/day)	1.20E-09	1.20E-09	1.20E-09
Avg body wt over entire exposure interval (Ca) (kg)	70.58	70.58	69.05
Avg body wt for Acu dur exp (7 day, Non-Ca) (kg)	65.61	65.61	65.61
Avg body wt for Int dur exp (182 day, Non-Ca) (kg)	65.77	65.77	65.77
Avg body wt for Chr dur exp (365 day, Non-Ca) (kg)	65.95	65.95	65.95
Exposure Duration Factors for Less Than Daily (24-7-52-70) Exposures	**Subsistence Fisherman**	**Weekend Fisherman**	**Sporadic Fisherman**
Age at beginning of exposure period	20	20	20
Age at ending of exposure period	50	50	35
Number of hours exposed per day	24	24	24
Number of days exposed per week	5	1	1
Number of weeks exposed per year	52	52	12
Number of years of lifetime exposed	30	30	15
Number of hours in a day	24	24	24
Number of days in a week	7	7	7
Number of weeks in a year	52	52	52
Number of years in a standard lifetime	70	70	70
Exposure factor for Ca scenarios (unitless)	0.306122	0.061224	0.007064
Exposure factor for Non-Ca scenarios (unitless)	0.714286	0.142857	0.032967

Abbreviations: **TCDD** = 2,3,7,8-tetrachlorodibenzo-p-dioxin; **TEQ** = toxic equivalent concentration; **SJRWP** = San Jacinto River Waste Pits; **FCR** = fish and/or crab consumption rate; **g_{fish}/day** = grams of fish eaten per day; **mg_{TEQ}/pg_{TEQ}** = milligram TEQ per picogram TEQ; **g_{sed}/mg_{sed}** = grams sediment per milligram sediment; **mg/kg/day** = milligrams per kilogram per day; **Ca** = Cancer; **Non-Ca** = Non-cancer; **MRL** = Minimal Risk Level.; **Avg** = average; **Acu** = acute; **Chr** = chronic; **Int** = intermediate; **dur** = duration; **exp** = exposure; **BW** = body weight; **kg** = kilogram.

Table 16b. Parameters for TCDD Exposures from Fish or Crab Consumption, Children

Parameters for Oral TCDD TEQ Exposures for People Eating Fish or Crab Caught Near the SJRWP Site	**Child of Subsistence Fisherman**	**Child of Weekend Fisherman**	**Child of Sporadic Fisherman**
Avg FCR on fishing days (Ca calcs) (gFish/day)	200.04	200.04	185.22
Avg FCR on fishing days (Acu, Non-Ca) (gFish/day)	70.61	70.61	70.61
Avg FCR on fishing days (Int, Non-Ca) (gFish/day)	72.48	72.48	72.48
Avg FCR on fishing days (Chr, Non-Ca) (gFish/day)	74.45	74.45	74.45
Units conversion factor (10^{-9} mg_{TEQ}/pg_{TEQ})	1.00E-09	1.00E-09	1.00E-09
Oral absorption factor for TCDD from fish (unitless)	0.95	0.95	0.95
Oral Cancer Slope Factor for TCDD $(mg/kg/day)^{-1}$	150,000	150,000	150,000
Acute Oral MRL for TCDD (mg/kg/day)	1.67E-07	1.67E-07	1.67E-07
Intermediate Oral MRL for TCDD (mg/kg/day)	2.33E-08	2.33E-08	2.33E-08
Chronic Oral MRL for TCDD (mg/kg/day)	1.20E-09	1.20E-09	1.20E-09
Avg body wt over entire exposure interval (Ca) (kg)	60.10	60.10	54.47
Avg body wt for Acu dur exp (7 day, Non-Ca) (kg)	14.77	14.77	14.77
Avg body wt for Int dur exp (182 day, Non-Ca) (kg)	15.30	15.30	15.30
Avg body wt for Chr dur exp (365 day, Non-Ca) (kg)	15.86	15.86	15.86
Exposure Duration Factors for Less Than Daily (24-7-52-70) Exposures	**Child of Subsistence Fisherman**	**Child of Weekend Fisherman**	**Child of Sporadic Fisherman**
Age at beginning of exposure period	3	3	3
Age at ending of exposure period	50	50	35
Number of hours exposed per day	24	24	24
Number of days exposed per week	5	1	1
Number of weeks exposed per year	52	52	12
Number of years of lifetime exposed	47	47	32
Number of hours in a day	24	24	24
Number of days in a week	7	7	7
Number of weeks in a year	52	52	52
Number of years in a standard lifetime	70	70	70
Exposure factor for Ca scenarios (unitless)	0.479592	0.095918	0.015071
Exposure factor for Non-Ca scenarios (unitless)	0.714286	0.142857	0.032967

Abbreviations: **TCDD** = 2,3,7,8-tetrachlorodibenzo-p-dioxin; **TEQ** = toxic equivalent concentration; **SJRWP** = San Jacinto River Waste Pits; **FCR** = fish and/or crab consumption rate; **g_{fish}/day** = grams of fish eaten per day; **mg_{TEQ}/pg_{TEQ}** = milligram TEQ per picogram TEQ; **g_{sed}/mg_{sed}** = grams sediment per milligram sediment; **mg/kg/day** = milligrams per kilogram per day; **Ca** = Cancer; **Non-Ca** = Non-cancer; **MRL** = Minimal Risk Level.; **Avg** = average; **Acu** = acute; **Chr** = chronic; **Int** = intermediate; **dur** = duration; **exp** = exposure; **BW** = body weight; **kg** = kilogram.

Table 17. Theoretical Cancer Risks (Fish/Crab Consumption), On & Off-Site

Fish or Crab Consumption Pathway			Subsistence Fisherman		Weekend Fisherman		Sporadic Fisherman	
Fish or Shellfish Species	Count	Avg WHO_{1998} TEQ (pg/g)	Theo Ca Risk (Fish Exp)	Ca Odds	Theo Ca Risk (Fish Exp)	Ca Odds	Theo Ca Risk (Fish Exp)	Ca Odds
Blue Crab	2	3.107	4.38E-04	2,285	8.75E-05	11,423	1.02E-05	98,457
Blue Catfish	2	6.040	8.51E-04	1,175	1.70E-04	5,876	1.97E-05	50,647
Spotted Seatrout	2	0.233	3.28E-05	30,463	6.57E-06	152,316	7.62E-07	1,312,897
Hybrid Striped Bass	1	1.541	2.17E-04	4,606	4.34E-05	23,030	5.04E-06	198,511
Red Drum	2	0.097	1.37E-05	73,175	2.73E-06	365,873	3.17E-07	3,153,659
All Fish Species	7	2.040	2.87E-04	3,479	5.75E-05	17,397	6.67E-06	149,953
All Species	9	2.277	3.21E-04	3,117	6.42E-05	15,586	7.44E-06	134,346
Fish or Crab Consumption Pathway			**Child of Subsistence Fisherman**		**Child of Weekend Fisherman**		**Child of Sporadic Fisherman**	
Fish or Shellfish Species	**Count**	**Avg WHO_{1998} TEQ (pg/g)**	**Theo Ca Risk (Fish Exp)**	**Ca Odds**	**Theo Ca Risk (Fish Exp)**	**Ca Odds**	**Theo Ca Risk (Fish Exp)**	**Ca Odds**
Blue Crab	2	3.107	7.07E-04	1,415	1.41E-04	7,074	2.27E-05	44,071
Blue Catfish	2	6.040	1.37E-03	727.8	2.75E-04	3,639	4.41E-05	22,670
Spotted Seatrout	2	0.233	5.30E-05	18,866	1.06E-05	94,331	1.70E-06	587,680
Hybrid Striped Bass	1	1.541	3.51E-04	2,853	7.01E-05	14,263	1.13E-05	88,858
Red Drum	2	0.097	2.21E-05	45,318	4.41E-06	226,590	7.08E-07	1,411,644
All Fish Species	7	2.040	4.64E-04	2,155	9.28E-05	10,774	1.49E-05	67,122
All Species	9	2.277	5.18E-04	1,931	1.04E-04	9,653	1.66E-05	60,136

Abbreviations: Avg = average; Exp = exposure; Theo = theoretical; Ca = cancer; pg/g = picograms per gram; TEQ = tetrachlorodibenzo-p-dioxin toxic equivalent concentration; WHO = World Health Organization.

E-02	Very High Increased Lifetime Risk
E-03	High Increased Lifetime Risk
E-04	Moderate Increased Lifetime Risk

E-05	Low Increased Lifetime Risk
E-06	No Apparent Increased Lifetime Risk
E-07	No Increased Lifetime Risk

Table 18. Theoretical Cancer Risks, Adult (Oral + Dermal + Fish), On & Off-Site

Sediments, Dermal Absorption Pathway			Subsistence Fisherman		Weekend Fisherman		Sporadic Fisherman	
Sediment Sample Collection Location	Sample	TCDD TEQ (pg/g)	Theo Ca Risk (Dermal Exp)	Ca Odds	Theo Ca Risk (Dermal Exp)	Ca Odds	Theo Ca Risk (Dermal Exp)	Ca Odds
SJRWP, On-Site Samples	Avg	15,594	9.07E-04	1,102	1.81E-04	5,512	2.12E-05	47,180
	Max	34,028	1.60E-03	624.9	3.20E-04	3,124	3.75E-05	26,701
Down-Stream from SJRWP, SJR, HSC, & UGB	Avg	13.75	3.21E-04	3,112	6.43E-05	15,561	7.46E-06	134,127
	Max	86.16	3.24E-04	3,086	6.48E-05	15,430	7.52E-06	132,988
SJRWP Site-Vicinity, SJR Near SJRWP	Avg	82.24	3.24E-04	3,087	6.48E-05	15,437	7.52E-06	133,049
	Max	572.5	3.42E-04	2,921	6.85E-05	14,606	7.95E-06	125,812
Houston Ship Channel, Above/West of SJR	Avg	65.69	3.23E-04	3,093	6.47E-05	15,467	7.50E-06	133,308
	Max	856.8	3.53E-04	2,833	7.06E-05	14,164	8.20E-06	121,965
Up-Stream & Tributaries to SJR-HSC-UGB	Avg	15.97	3.21E-04	3,111	6.43E-05	15,557	7.46E-06	134,092
	Max	102.9	3.25E-04	3,080	6.49E-05	15,400	7.53E-06	132,728
All Off-Site Samples	Avg	40.04	3.22E-04	3,103	6.45E-05	15,513	7.48E-06	133,711
	Max	856.8	3.53E-04	2,833	7.06E-05	14,164	8.20E-06	121,965

Abbreviations: Avg = average; Max = maximum; Exp = exposure; Theo = theoretical; Ca = cancer; SJRWP = San Jacinto River Waste Pitts; SJR = San Jacinto River; HSC = Houston Ship Channel; UGB = Upper Galveston Bay; pg/g = picograms per gram; TCDD TEQ = tetrachlorodibenzo-p-dioxin toxic equivalent concentration.

E-02	Very High Increased Lifetime Risk
E-03	High Increased Lifetime Risk
E-04	Moderate Increased Lifetime Risk

E-05	Low Increased Lifetime Risk
E-06	No Apparent Increased Lifetime Risk
E-07	No Increased Lifetime Risk

Table 19. Theoretical Cancer Risks, Child (Oral + Dermal + Fish), On & Off-Site

Soil/Sediments, Oral + Dermal + Fish Consumption Pathways			Child of Subsistence Fisherman		Child of Weekend Fisherman		Child of Sporadic Fisherman	
Sediment Sample Collection Location	Sample	TCDD TEQ (pg/g)	Theo Ca Risk (Dermal Exp)	Ca Odds	Theo Ca Risk (Dermal Exp)	Ca Odds	Theo Ca Risk (Dermal Exp)	Ca Odds
SJRWP, On-Site Samples	Avg	15,594	1.57E-03	637.0	3.14E-04	3,185	5.26E-05	19,024
	Max	34,028	2.81E-03	355.4	5.63E-04	1,777	9.50E-05	10,521
Down-Stream from SJRWP, SJR, HSC, & UGB	Avg	13.75	5.19E-04	1,927	1.04E-04	9,635	1.67E-05	60,022
	Max	86.16	5.24E-04	1,909	1.05E-04	9,546	1.68E-05	59,426
SJRWP Site-Vicinity, SJR Near SJRWP	Avg	82.24	5.24E-04	1,910	1.05E-04	9,550	1.68E-05	59,458
	Max	572.5	5.57E-04	1,797	1.11E-04	8,983	1.79E-05	55,716
Houston Ship Channel, Above/West of SJR	Avg	65.69	5.22E-04	1,914	1.04E-04	9,571	1.68E-05	59,593
	Max	856.8	5.76E-04	1,737	1.15E-04	8,684	1.86E-05	53,754
Up-Stream & Tributaries to SJR-HSC-UGB	Avg	15.97	5.19E-04	1,927	1.04E-04	9,633	1.67E-05	60,003
	Max	102.9	5.25E-04	1,905	1.05E-04	9,525	1.69E-05	59,290
All Off-Site Samples	Avg	40.04	5.21E-04	1,921	1.04E-04	9,603	1.67E-05	59,804
	Max	856.8	5.76E-04	1,737	1.15E-04	8,684	1.86E-05	53,754

Abbreviations: Avg = average; Max = maximum; Exp = exposure; Theo = theoretical; Ca = cancer; SJRWP = San Jacinto River Waste Pitts; SJR = San Jacinto River; HSC = Houston Ship Channel; UGB = Upper Galveston Bay; pg/g = picograms per gram; TCDD TEQ = tetrachlorodibenzo-p-dioxin toxic equivalent concentration.

E-02	Very High Increased Lifetime Risk
E-03	High Increased Lifetime Risk
E-04	Moderate Increased Lifetime Risk

E-05	Low Increased Lifetime Risk
E-06	No Apparent Increased Lifetime Risk
E-07	No Increased Lifetime Risk

Table 20. Max Hazard Quotients, Acute Oral Sediment Exp, Adult, On & Off-Site

Soil/Sediments, Acute Duration Exposures, Oral Ingestion Pathway			Subsistence Fisherman		Weekend Fisherman		Sporadic Fisherman	
Sediment Sample Collection Location	Sample	TCDD TEQ (pg/g)	Max Haz Quotient at Age 20	Margin of Safety	Max Haz Quotient at Age 20	Margin of Safety	Max Haz Quotient at Age 20	Margin of Safety
SJRWP, On-Site Samples	Avg	15,594	1.70E-02	58.90	3.40E-03	294.5	7.84E-04	1,276
	Max	34,028	3.70E-02	26.99	7.41E-03	135.0	1.71E-03	584.8
Down-Stream from SJRWP, SJR, HSC, & UGB	Avg	13.75	1.50E-05	66,780	2.99E-06	333,900	6.91E-07	1,446,899
	Max	86.16	9.38E-05	10,660	1.88E-05	53,299	4.33E-06	230,963
SJRWP Site-Vicinity, SJR Near SJRWP	Avg	82.24	8.95E-05	11,168	1.79E-05	55,842	4.13E-06	241,984
	Max	572.5	6.23E-04	1,604	1.25E-04	8,022	2.88E-05	34,762
Houston Ship Channel, Above/West of SJR	Avg	65.69	7.15E-05	13,981	1.43E-05	69,907	3.30E-06	302,929
	Max	856.8	9.33E-04	1,072	1.87E-04	5,360	4.31E-05	23,228
Up-Stream & Tributaries to SJR-HSC-UGB	Avg	15.97	1.74E-05	57,526	3.48E-06	287,628	8.02E-07	1,246,388
	Max	102.9	1.12E-04	8,927	2.24E-05	44,633	5.17E-06	193,408
All Off-Site Samples	Avg	40.04	4.36E-05	22,940	8.72E-06	114,700	2.01E-06	497,034
	Max	856.8	9.33E-04	1,072	1.87E-04	5,360	4.31E-05	23,228

Abbreviations: Avg = average; Max = maximum; Exp = exposure; SJRWP = San Jacinto River Waste Pitts; SJR = San Jacinto River; HSC = Houston Ship Channel; UGB = Upper Galveston Bay; pg/g = picograms per gram; TCDD TEQ = tetrachlorodibenzo-p-dioxin toxic equivalent concentration.

E+03	Very High Increased Risk
E+02	High Increased Risk
E+01	Moderately Increased Risk

E+00	Low Increased Risk
E-01	No Apparent Increased Risk
E-02	No Increased Risk

Table 21. Max Hazard Quotients, Acute Oral Sediment Exp, Child, On & Off-Site

Soil/Sediments, Acute Duration Exposures, Oral Ingestion Pathway			Child of Subsistence Fisherman		Child of Weekend Fisherman		Child of Sporadic Fisherman	
Sediment Sample Collection Location	**Sample**	**TCDD TEQ (pg/g)**	**Max Haz Quotient at Age 3**	**Margin of Safety**	**Max Haz Quotient at Age 3**	**Margin of Safety**	**Max Haz Quotient at Age 3**	**Margin of Safety**
SJRWP, On-Site Samples	Avg	15,594	1.51E-01	6.631	3.02E-02	33.15	6.96E-03	143.7
	Max	34,028	3.29E-01	3.039	6.58E-02	15.19	1.52E-02	65.84
Down-Stream from SJRWP, SJR, HSC, & UGB	Avg	13.75	1.33E-04	7,518	2.66E-05	37,588	6.14E-06	162,882
	Max	86.16	8.33E-04	1,200	1.67E-04	6,000	3.85E-05	26,000
SJRWP Site-Vicinity, SJR Near SJRWP	Avg	82.24	7.95E-04	1,257	1.59E-04	6,286	3.67E-05	27,241
	Max	572.5	5.54E-03	180.6	1.11E-03	903.1	2.56E-04	3,913
Houston Ship Channel, Above/West of SJR	Avg	65.69	6.35E-04	1,574	1.27E-04	7,870	2.93E-05	34,102
	Max	856.8	8.29E-03	120.7	1.66E-03	603.4	3.82E-04	2,615
Up-Stream & Tributaries to SJR-HSC-UGB	Avg	15.97	1.54E-04	6,476	3.09E-05	32,379	7.13E-06	140,310
	Max	102.9	9.95E-04	1,005	1.99E-04	5,024	4.59E-05	21,773
All Off-Site Samples	Avg	40.04	3.87E-04	2,582	7.74E-05	12,912	1.79E-05	55,953
	Max	856.8	8.29E-03	120.7	1.66E-03	603.4	3.82E-04	2,615

Abbreviations: Avg = average; Haz = hazard; Max = maximum; Exp = exposure; SJRWP = San Jacinto River Waste Pitts; SJR = San Jacinto River; HSC = Houston Ship Channel; UGB = Upper Galveston Bay; pg/g = picograms per gram; TCDD TEQ = tetrachlorodibenzo-p-dioxin toxic equivalent concentration.

E+03	Very High Increased Risk
E+02	High Increased Risk
E+01	Moderately Increased Risk

E+00	Low Increased Risk
E-01	No Apparent Increased Risk
E-02	No Increased Risk

Table 22. Max Hazard Quotients, Acute Dermal Sediment Exp, Adult, On & Off-Site

Soil/Sediments, Acute Duration Exposures, Dermal Absorption Pathway			Subsistence Fisherman		Weekend Fisherman		Sporadic Fisherman	
Sediment Sample Collection Location	Sample	TCDD TEQ (pg/g)	Max Haz Quotient at Age 20	Margin of Safety	Max Haz Quotient at Age 20	Margin of Safety	Max Haz Quotient at Age 20	Margin of Safety
SJRWP, On-Site Samples	Avg	15,594	2.02E-02	49.48	4.04E-03	247.4	9.33E-04	1,072
	Max	34,028	4.41E-02	22.67	8.82E-03	113.4	2.04E-03	491.2
Down-Stream from SJRWP, SJR, HSC, & UGB	Avg	13.75	1.78E-05	56,093	3.57E-06	280,467	8.23E-07	1,215,356
	Max	86.16	1.12E-04	8,954	2.23E-05	44,770	5.15E-06	194,003
SJRWP Site-Vicinity, SJR Near SJRWP	Avg	82.24	1.07E-04	9,381	2.13E-05	46,906	4.92E-06	203,260
	Max	572.5	7.42E-04	1,348	1.48E-04	6,738	3.42E-05	29,199
Houston Ship Channel, Above/West of SJR	Avg	65.69	8.52E-05	11,744	1.70E-05	58,720	3.93E-06	254,452
	Max	856.8	1.11E-03	900.5	2.22E-04	4,502	5.13E-05	19,511
Up-Stream & Tributaries to SJR-HSC-UGB	Avg	15.97	2.07E-05	48,320	4.14E-06	241,600	9.55E-07	1,046,932
	Max	102.9	1.33E-04	7,498	2.67E-05	37,490	6.16E-06	162,457
All Off-Site Samples	Avg	40.04	5.19E-05	19,269	1.04E-05	96,345	2.40E-06	417,495
	Max	856.8	1.11E-03	900.5	2.22E-04	4,502	5.13E-05	19,511

Abbreviations: Avg = average; Haz = hazard; Max = maximum; Exp = exposure; SJRWP = San Jacinto River Waste Pitts; SJR = San Jacinto River; HSC = Houston Ship Channel; UGB = Upper Galveston Bay; pg/g = picograms per gram; TCDD TEQ = tetrachlorodibenzo-p-dioxin toxic equivalent concentration.

E+03	Very High Increased Risk
E+02	High Increased Risk
E+01	Moderately Increased Risk

E+00	Low Increased Risk
E-01	No Apparent Increased Risk
E-02	No Increased Risk

Table 23. Max Hazard Quotients, Acute Dermal Sediment Exp, Child, On & Off-Site

Soil/Sediments, Acute Duration Exposures, Dermal Absorption Pathway			Child of Subsistence Fisherman		Child of Weekend Fisherman		Child of Sporadic Fisherman	
Sediment Sample Collection Location	Sample	TCDD TEQ (pg/g)	Max Haz Quotient at Age 3	Margin of Safety	Max Haz Quotient at Age 3	Margin of Safety	Max Haz Quotient at Age 3	Margin of Safety
SJRWP, On-Site Samples	Avg	15,594	3.16E-02	31.64	6.32E-03	158.2	1.46E-03	685.6
	Max	34,028	6.90E-02	14.50	1.38E-02	72.50	3.18E-03	314.2
Down-Stream from SJRWP, SJR, HSC, & UGB	Avg	13.75	2.79E-05	35,875	5.57E-06	179,374	1.29E-06	777,286
	Max	86.16	1.75E-04	5,727	3.49E-05	28,633	8.06E-06	124,075
SJRWP Site-Vicinity, SJR Near SJRWP	Avg	82.24	1.67E-04	6,000	3.33E-05	29,999	7.69E-06	129,996
	Max	572.5	1.16E-03	861.9	2.32E-04	4,309	5.35E-05	18,674
Houston Ship Channel, Above/West of SJR	Avg	65.69	1.33E-04	7,511	2.66E-05	37,554	6.14E-06	162,736
	Max	856.8	1.74E-03	575.9	3.47E-04	2,880	8.01E-05	12,478
Up-Stream & Tributaries to SJR-HSC-UGB	Avg	15.97	3.24E-05	30,903	6.47E-06	154,516	1.49E-06	669,570
	Max	102.9	2.09E-04	4,795	4.17E-05	23,977	9.62E-06	103,900
All Off-Site Samples	Avg	40.04	8.11E-05	12,324	1.62E-05	61,618	3.75E-06	267,011
	Max	856.8	1.74E-03	575.9	3.47E-04	2,880	8.01E-05	12,478

Abbreviations: Avg = average; Haz = hazard; Max = maximum; Exp = exposure; SJRWP = San Jacinto River Waste Pitts; SJR = San Jacinto River; HSC = Houston Ship Channel; UGB = Upper Galveston Bay; pg/g = picograms per gram; TCDD TEQ = tetrachlorodibenzo-p-dioxin toxic equivalent concentration.

E+03	Very High Increased Risk
E+02	High Increased Risk
E+01	Moderately Increased Risk

E+00	Low Increased Risk
E-01	No Apparent Increased Risk
E-02	No Increased Risk

Table 24. Max Hazard Quotients, Acute Fish/Crab Consumption, On & Off-Site

Acute Duration Exposures, Fish or Crab Consumption Pathway			Subsistence Fisherman		Weekend Fisherman		Sporadic Fisherman	
Fish or Shellfish Species	Count	Avg TCDD TEQ (pg/g)	Max Haz Quotient at Age 20	Margin of Safety	Max Haz Quotient at Age 20	Margin of Safety	Max Haz Quotient at Age 20	Margin of Safety
Blue Crab	2	3.107	4.16E-02	24.03	8.32E-03	120.1	1.92E-03	520.6
Blue Catfish	2	6.040	8.09E-02	12.36	1.62E-02	61.80	3.73E-03	267.8
Spotted Seatrout	2	0.233	3.12E-03	320.4	6.24E-04	1,602	1.44E-04	6,943
Hybrid Striped Bass	1	1.541	2.06E-02	48.45	4.13E-03	242.2	9.53E-04	1,050
Red Drum	2	0.097	1.30E-03	769.7	2.60E-04	3,848	6.00E-05	16,676
All Fish Species	7	2.040	2.73E-02	36.60	5.46E-03	183.0	1.26E-03	793.0
All Species	9	2.277	3.05E-02	32.79	6.10E-03	163.9	1.41E-03	710.4
Acute Duration Exposures, Fish or Crab Consumption Pathway			**Child of Subsistence Fisherman**		**Child of Weekend Fisherman**		**Child of Sporadic Fisherman**	
Fish or Shellfish Species	**Count**	**Avg TCDD TEQ (pg/g)**	**Max Haz Quotient at Age 3**	**Margin of Safety**	**Max Haz Quotient at Age 3**	**Margin of Safety**	**Max Haz Quotient at Age 3**	**Margin of Safety**
Blue Crab	2	3.107	6.05E-02	16.54	1.21E-02	82.69	2.79E-03	358.3
Blue Catfish	2	6.040	1.18E-01	8.507	2.35E-02	42.53	5.43E-03	184.3
Spotted Seatrout	2	0.233	4.53E-03	220.5	9.07E-04	1,103	2.09E-04	4,778
Hybrid Striped Bass	1	1.541	3.00E-02	33.34	6.00E-03	166.7	1.38E-03	722.4
Red Drum	2	0.097	1.89E-03	529.7	3.78E-04	2,649	8.71E-05	11,477
All Fish Species	7	2.040	3.97E-02	25.19	7.94E-03	125.9	1.83E-03	545.7
All Species	9	2.277	4.43E-02	22.57	8.86E-03	112.8	2.05E-03	488.9

Abbreviations: Avg = average; Haz = hazard; Max = maximum; Exp = exposure; SJRWP = San Jacinto River Waste Pitts; SJR = San Jacinto River; HSC = Houston Ship Channel; UGB = Upper Galveston Bay; pg/g = picograms per gram; TCDD TEQ = tetrachlorodibenzo-p-dioxin toxic equivalent concentration.

E+03	Very High Increased Risk
E+02	High Increased Risk
E+01	Moderately Increased Risk

E+00	Low Increased Risk
E-01	No Apparent Increased Risk
E-02	No Increased Risk

Table 25. Max Hazard Indices, Acute Oral + Dermal + Fish Exp, Adult, On & Off-Site

Soil/Sediments, Acute Duration Exposures, Oral + Dermal + Fish Consumption Pathways			Subsistence Fisherman		Weekend Fisherman		Sporadic Fisherman	
Sediment Sample Collection Location	Sample	TCDD TEQ (pg/g)	Max Haz Index at Age 20	Margin of Safety	Max Haz Index at Age 20	Margin of Safety	Max Haz Index at Age 20	Margin of Safety
SJRWP, On-Site Samples	Avg	15,594	6.77E-02	14.77	1.35E-02	73.87	3.12E-03	320.1
	Max	34,028	1.12E-01	8.956	2.23E-02	44.78	5.15E-03	194.1
Down-Stream from SJRWP, SJR, HSC, & UGB	Avg	13.75	3.05E-02	32.75	6.11E-03	163.8	1.41E-03	709.7
	Max	86.16	3.07E-02	32.57	6.14E-03	162.8	1.42E-03	705.7
SJRWP Site-Vicinity, SJR Near SJRWP	Avg	82.24	3.07E-02	32.58	6.14E-03	162.9	1.42E-03	705.9
	Max	572.5	3.19E-02	31.38	6.37E-03	156.9	1.47E-03	680.0
Houston Ship Channel, Above/West of SJR	Avg	65.69	3.07E-02	32.62	6.13E-03	163.1	1.41E-03	706.8
	Max	856.8	3.25E-02	30.73	6.51E-03	153.6	1.50E-03	665.8
Up-Stream & Tributaries to SJR-HSC-UGB	Avg	15.97	3.05E-02	32.75	6.11E-03	163.7	1.41E-03	709.5
	Max	102.9	3.07E-02	32.53	6.15E-03	162.6	1.42E-03	704.7
All Off-Site Samples	Avg	40.04	3.06E-02	32.69	6.12E-03	163.4	1.41E-03	708.2
	Max	856.8	3.25E-02	30.73	6.51E-03	153.6	1.50E-03	665.8

Abbreviations: Avg = average; Haz = hazard; Max = maximum; Exp = exposure; SJRWP = San Jacinto River Waste Pits; SJR = San Jacinto River; HSC = Houston Ship Channel; UGB = Upper Galveston Bay; pg/g = picograms per gram; TCDD TEQ = tetrachlorodibenzo-p-dioxin toxic equivalent concentration.

E+03	Very High Increased Risk		E+00	Low Increased Risk
E+02	High Increased Risk		E-01	No Apparent Increased Risk
E+01	Moderately Increased Risk		E-02	No Increased Risk

Table 26. Max Hazard Indices, Acute Oral + Dermal + Fish Exp, Child, On & Off-Site

Soil/Sediments, Acute Duration Exposures, Oral + Dermal + Fish Consumption Pathways			Child of Subsistence Fisherman		Child of Weekend Fisherman		Child of Sporadic Fisherman	
Sediment Sample Collection Location	**Sample**	**TCDD TEQ (pg/g)**	**Max Haz Index at Age 3**	**Margin of Safety**	**Max Haz Index at Age 3**	**Margin of Safety**	**Max Haz Index at Age 3**	**Margin of Safety**
SJRWP, On-Site Samples	Avg	15,594	2.27E-01	4.410	4.53E-02	22.05	1.05E-02	95.56
	Max	34,028	4.42E-01	2.261	8.85E-02	11.30	2.04E-02	48.98
Down-Stream from SJRWP, SJR, HSC, & UGB	Avg	13.75	4.45E-02	22.48	8.90E-03	112.4	2.05E-03	487.2
	Max	86.16	4.53E-02	22.06	9.06E-03	110.3	2.09E-03	478.0
SJRWP Site-Vicinity, SJR Near SJRWP	Avg	82.24	4.53E-02	22.09	9.06E-03	110.4	2.09E-03	478.5
	Max	572.5	5.10E-02	19.60	1.02E-02	98.02	2.35E-03	424.7
Houston Ship Channel, Above/West of SJR	Avg	65.69	4.51E-02	22.18	9.02E-03	110.9	2.08E-03	480.6
	Max	856.8	5.43E-02	18.40	1.09E-02	92.02	2.51E-03	398.7
Up-Stream & Tributaries to SJR-HSC-UGB	Avg	15.97	4.45E-02	22.47	8.90E-03	112.4	2.05E-03	486.9
	Max	102.9	4.55E-02	21.97	9.10E-03	109.8	2.10E-03	476.0
All Off-Site Samples	Avg	40.04	4.48E-02	22.33	8.96E-03	111.6	2.07E-03	483.8
	Max	856.8	5.43E-02	18.40	1.09E-02	92.02	2.51E-03	398.7

Abbreviations: Avg = average; Haz = hazard; Max = maximum; Exp = exposure; SJRWP = San Jacinto River Waste Pitts; SJR = San Jacinto River; HSC = Houston Ship Channel; UGB = Upper Galveston Bay; pg/g = picograms per gram; TCDD TEQ = tetrachlorodibenzo-p-dioxin toxic equivalent concentration.

E+03	Very High Increased Risk
E+02	High Increased Risk
E+01	Moderately Increased Risk

E+00	Low Increased Risk
E-01	No Apparent Increased Risk
E-02	No Increased Risk

Table 27. Max Hazard Quotients, Intermediate Oral Sediment Exp, Adult, On & Off-Site

Soil/Sediments, Intermediate Duration Exposures, Oral Ingestion Pathway			Subsistence Fisherman		Weekend Fisherman		Sporadic Fisherman	
Sediment Sample Collection Location	Sample	TCDD TEQ (pg/g)	Max Haz Quotient at Age 20	Margin of Safety	Max Haz Quotient at Age 20	Margin of Safety	Max Haz Quotient at Age 20	Margin of Safety
SJRWP, On-Site Samples	Avg	15,594	1.21E-01	8.267	2.42E-02	41.34	5.58E-03	179.1
	Max	34,028	2.64E-01	3.789	5.28E-02	18.94	1.22E-02	82.09
Down-Stream from SJRWP, SJR, HSC, & UGB	Avg	13.75	1.07E-04	9,373	2.13E-05	46,866	4.92E-06	203,084
	Max	86.16	6.68E-04	1,496	1.34E-04	7,481	3.08E-05	32,418
SJRWP Site-Vicinity, SJR Near SJRWP	Avg	82.24	6.38E-04	1,568	1.28E-04	7,838	2.94E-05	33,964
	Max	572.5	4.44E-03	225.2	8.88E-04	1,126	2.05E-04	4,879
Houston Ship Channel, Above/West of SJR	Avg	65.69	5.10E-04	1,962	1.02E-04	9,812	2.35E-05	42,519
	Max	856.8	6.65E-03	150.5	1.33E-03	752.4	3.07E-04	3,260
Up-Stream & Tributaries to SJR-HSC-UGB	Avg	15.97	1.24E-04	8,074	2.48E-05	40,371	5.72E-06	174,941
	Max	102.9	7.98E-04	1,253	1.60E-04	6,265	3.68E-05	27,146
All Off-Site Samples	Avg	40.04	3.11E-04	3,220	6.21E-05	16,099	1.43E-05	69,763
	Max	856.8	6.65E-03	150.5	1.33E-03	752.4	3.07E-04	3,260

Abbreviations: Avg = average; Haz = hazard; Max = maximum; Exp = exposure; SJRWP = San Jacinto River Waste Pitts; SJR = San Jacinto River; HSC = Houston Ship Channel; UGB = Upper Galveston Bay; pg/g = picograms per gram; TCDD TEQ = tetrachlorodibenzo-p-dioxin toxic equivalent concentration.

E+03	Very High Increased Risk
E+02	High Increased Risk
E+01	Moderately Increased Risk

E+00	Low Increased Risk
E-01	No Apparent Increased Risk
E-02	No Increased Risk

Table 28. Max Hazard Quotients, Intermediate Oral Sediment Exp, Child, On & Off-Site

Soil/Sediments, Intermediate Duration Exposures, Oral Ingestion Pathway			Child of Subsistence Fisherman		Child of Weekend Fisherman		Child of Sporadic Fisherman	
Sediment Sample Collection Location	Sample	TCDD TEQ (pg/g)	Max Haz Quotient at Age 3	Margin of Safety	Max Haz Quotient at Age 3	Margin of Safety	Max Haz Quotient at Age 3	Margin of Safety
SJRWP, On-Site Samples	Avg	15,594	1.04E+00	0.9614	2.08E-01	4.807	4.80E-02	20.83
	Max	34,028	2.27E+00	0.4406	4.54E-01	2.203	1.05E-01	9.546
Down-Stream from SJRWP, SJR, HSC, & UGB	Avg	13.75	9.17E-04	1,090	1.83E-04	5,450	4.23E-05	23,618
	Max	86.16	5.75E-03	174.0	1.15E-03	870.0	2.65E-04	3,770
SJRWP Site-Vicinity, SJR Near SJRWP	Avg	82.24	5.49E-03	182.3	1.10E-03	911.5	2.53E-04	3,950
	Max	572.5	3.82E-02	26.19	7.64E-03	130.9	1.76E-03	567.4
Houston Ship Channel, Above/West of SJR	Avg	65.69	4.38E-03	228.2	8.76E-04	1,141	2.02E-04	4,945
	Max	856.8	5.71E-02	17.50	1.14E-02	87.49	2.64E-03	379.1
Up-Stream & Tributaries to SJR-HSC-UGB	Avg	15.97	1.06E-03	939.0	2.13E-04	4,695	4.92E-05	20,345
	Max	102.9	6.86E-03	145.7	1.37E-03	728.5	3.17E-04	3,157
All Off-Site Samples	Avg	40.04	2.67E-03	374.4	5.34E-04	1,872	1.23E-04	8,113
	Max	856.8	5.71E-02	17.50	1.14E-02	87.49	2.64E-03	379.1

Abbreviations: Avg = average; Haz = hazard; Max = maximum; Exp = exposure; SJRWP = San Jacinto River Waste Pitts; SJR = San Jacinto River; HSC = Houston Ship Channel; UGB = Upper Galveston Bay; pg/g = picograms per gram; TCDD TEQ = tetrachlorodibenzo-p-dioxin toxic equivalent concentration.

E+03	Very High Increased Risk		E+00	Low Increased Risk
E+02	High Increased Risk		E-01	No Apparent Increased Risk
E+01	Moderately Increased Risk		E-02	No Increased Risk

Table 29. Max Hazard Quotients, Intermediate Dermal Sediment Exp, Adult, On & Off-Site

Soil/Sediments, Intermediate Duration Exposures, Dermal Absorption Pathway			Subsistence Fisherman		Weekend Fisherman		Sporadic Fisherman	
Sediment Sample Collection Location	Sample	TCDD TEQ (pg/g)	Max Haz Quotient at Age 20	Margin of Safety	Max Haz Quotient at Age 20	Margin of Safety	Max Haz Quotient at Age 20	Margin of Safety
SJRWP, On-Site Samples	Avg	15,594	1.442E-01	6.933	2.885E-02	34.67	6.657E-03	150.2
	Max	34,028	3.147E-01	3.177	6.295E-02	15.89	1.453E-02	68.84
Down-Stream from SJRWP, SJR, HSC, & UGB	Avg	13.75	1.27E-04	7,861	2.54E-05	39,304	5.87E-06	170,316
	Max	86.16	7.97E-04	1,255	1.59E-04	6,274	3.68E-05	27,187
SJRWP Site-Vicinity, SJR Near SJRWP	Avg	82.24	7.61E-04	1,315	1.52E-04	6,573	3.51E-05	28,484
	Max	572.5	5.30E-03	188.9	1.06E-03	944.3	2.44E-04	4,092
Houston Ship Channel, Above/West of SJR	Avg	65.69	6.08E-04	1,646	1.22E-04	8,229	2.80E-05	35,658
	Max	856.8	7.92E-03	126.2	1.58E-03	631.0	3.66E-04	2,734
Up-Stream & Tributaries to SJR-HSC-UGB	Avg	15.97	1.48E-04	6,771	2.95E-05	33,857	6.82E-06	146,714
	Max	102.9	9.52E-04	1,051	1.90E-04	5,254	4.39E-05	22,766
All Off-Site Samples	Avg	40.04	3.70E-04	2,700	7.41E-05	13,501	1.71E-05	58,506
	Max	856.8	7.92E-03	126.2	1.58E-03	631.0	3.66E-04	2,734

Abbreviations: Avg = average; Haz = hazard; Max = maximum; Exp = exposure; SJRWP = San Jacinto River Waste Pitts; SJR = San Jacinto River; HSC = Houston Ship Channel; UGB = Upper Galveston Bay; pg/g = picograms per gram; TCDD TEQ = tetrachlorodibenzo-p-dioxin toxic equivalent concentration.

E+03	Very High Increased Risk
E+02	High Increased Risk
E+01	Moderately Increased Risk

E+00	Low Increased Risk
E-01	No Apparent Increased Risk
E-02	No Increased Risk

Table 30. Max Hazard Quotients, Intermediate Dermal Sediment Exp, Child, On & Off-Site

Soil/Sediments, Intermediate Duration Exposures, Dermal Absorption Pathway			Child of Subsistence Fisherman		Child of Weekend Fisherman		Child of Sporadic Fisherman	
Sediment Sample Collection Location	Sample	TCDD TEQ (pg/g)	Max Haz Quotient at Age 3	Margin of Safety	Max Haz Quotient at Age 3	Margin of Safety	Max Haz Quotient at Age 3	Margin of Safety
SJRWP, On-Site Samples	Avg	15,594	2.24E-01	4.466	4.48E-02	22.33	1.03E-02	96.76
	Max	34,028	4.89E-01	2.046	9.77E-02	10.23	2.26E-02	44.34
Down-Stream from SJRWP, SJR, HSC, & UGB	Avg	13.75	1.98E-04	5,063	3.95E-05	25,315	9.12E-06	109,699
	Max	86.16	1.24E-03	808.2	2.47E-04	4,041	5.71E-05	17,511
SJRWP Site-Vicinity, SJR Near SJRWP	Avg	82.24	1.18E-03	846.8	2.36E-04	4,234	5.45E-05	18,346
	Max	572.5	8.22E-03	121.6	1.64E-03	608.2	3.79E-04	2,636
Houston Ship Channel, Above/West of SJR	Avg	65.69	9.43E-04	1,060	1.89E-04	5,300	4.35E-05	22,967
	Max	856.8	1.23E-02	81.28	2.46E-03	406.4	5.68E-04	1,761
Up-Stream & Tributaries to SJR-HSC-UGB	Avg	15.97	2.29E-04	4,361	4.59E-05	21,807	1.06E-05	94,497
	Max	102.9	1.48E-03	676.8	2.96E-04	3,384	6.82E-05	14,664
All Off-Site Samples	Avg	40.04	5.75E-04	1,739	1.15E-04	8,696	2.65E-05	37,683
	Max	856.8	1.23E-02	81.28	2.46E-03	406.4	5.68E-04	1,761

Abbreviations: Avg = average; Haz = hazard; Max = maximum; Exp = exposure; SJRWP = San Jacinto River Waste Pitts; SJR = San Jacinto River; HSC = Houston Ship Channel; UGB = Upper Galveston Bay; pg/g = picograms per gram; TCDD TEQ = tetrachlorodibenzo-p-dioxin toxic equivalent concentration.

E+03	Very High Increased Risk
E+02	High Increased Risk
E+01	Moderately Increased Risk

E+00	Low Increased Risk
E-01	No Apparent Increased Risk
E-02	No Increased Risk

Table 31. Max Hazard Quotients, Intermediate Fish/Crab Consumption, On & Off-Site

Intermediate Duration Exposures, Fish or Crab Consumption Pathway			Subsistence Fisherman		Weekend Fisherman		Sporadic Fisherman	
Fish or Shellfish Species	Count	Avg TCDD TEQ (pg/g)	Max Haz Quotient at Age 20	Margin of Safety	Max Haz Quotient at Age 20	Margin of Safety	Max Haz Quotient at Age 20	Margin of Safety
Blue Crab	2	3.107	2.97E-01	3.366	5.94E-02	16.83	1.37E-02	72.94
Blue Catfish	2	6.040	5.77E-01	1.732	1.15E-01	8.658	2.67E-02	37.52
Spotted Seatrout	2	0.233	2.23E-02	44.89	4.46E-03	224.4	1.03E-03	972.6
Hybrid Striped Bass	1	1.541	1.47E-01	6.787	2.95E-02	33.94	6.80E-03	147.1
Red Drum	2	0.097	9.27E-03	107.8	1.85E-03	539.1	4.28E-04	2,336
All Fish Species	7	2.040	1.95E-01	5.127	3.90E-02	25.64	9.00E-03	111.1
All Species	9	2.277	2.18E-01	4.593	4.35E-02	22.97	1.00E-02	99.52
Intermediate Duration Exposures, Fish or Crab Consumption Pathway			Child of Subsistence Fisherman		Child of Weekend Fisherman		Child of Sporadic Fisherman	
Fish or Shellfish Species	Count	Avg TCDD TEQ (pg/g)	Max Haz Quotient at Age 3	Margin of Safety	Max Haz Quotient at Age 3	Margin of Safety	Max Haz Quotient at Age 3	Margin of Safety
Blue Crab	2	3.107	4.28E-01	2.336	8.56E-02	11.68	1.98E-02	50.61
Blue Catfish	2	6.040	8.32E-01	1.202	1.66E-01	6.008	3.84E-02	26.03
Spotted Seatrout	2	0.233	3.21E-02	31.15	6.42E-03	155.7	1.48E-03	674.9
Hybrid Striped Bass	1	1.541	2.12E-01	4.710	4.25E-02	23.55	9.80E-03	102.0
Red Drum	2	0.097	1.34E-02	74.82	2.67E-03	374.1	6.17E-04	1,621
All Fish Species	7	2.040	2.81E-01	3.558	5.62E-02	17.79	1.30E-02	77.08
All Species	9	2.277	3.14E-01	3.187	6.27E-02	15.94	1.45E-02	69.06

Abbreviations: Avg = average; Haz = hazard; Max = maximum; Exp = exposure; SJRWP = San Jacinto River Waste Pitts; SJR = San Jacinto River; HSC = Houston Ship Channel; UGB = Upper Galveston Bay; pg/g = picograms per gram; TCDD TEQ = tetrachlorodibenzo-p-dioxin toxic equivalent concentration.

E+03	Very High Increased Risk
E+02	High Increased Risk
E+01	Moderately Increased Risk

E+00	Low Increased Risk
E-01	No Apparent Increased Risk
E-02	No Increased Risk

Table 32. Max Hazard Indices, Intermediate Oral + Derm + Fish Exp, Adult, On & Off-Site

Soil/Sediments, Intermediate Duration Exposures, Oral + Dermal + Fish Consumption Pathways			Subsistence Fisherman		Weekend Fisherman		Sporadic Fisherman	
Sediment Sample Collection Location	Sample	TCDD TEQ (pg/g)	Max Haz Index at Age 20	Margin of Safety	Max Haz Index at Age 20	Margin of Safety	Max Haz Index at Age 20	Margin of Safety
SJRWP, On-Site Samples	Avg	15,594	4.83E-01	2.071	9.66E-02	10.35	2.23E-02	44.87
	Max	34,028	7.96E-01	1.256	1.59E-01	6.278	3.68E-02	27.21
Down-Stream from SJRWP, SJR, HSC, & UGB	Avg	13.75	2.18E-01	4.588	4.36E-02	22.94	1.01E-02	99.42
	Max	86.16	2.19E-01	4.563	4.38E-02	22.81	1.01E-02	98.86
SJRWP Site-Vicinity, SJR Near SJRWP	Avg	82.24	2.19E-01	4.564	4.38E-02	22.82	1.01E-02	98.89
	Max	572.5	2.27E-01	4.397	4.55E-02	21.98	1.05E-02	95.26
Houston Ship Channel, Above/West of SJR	Avg	65.69	2.19E-01	4.570	4.38E-02	22.85	1.01E-02	99.01
	Max	856.8	2.32E-01	4.305	4.65E-02	21.53	1.07E-02	93.28
Up-Stream & Tributaries to SJR-HSC-UGB	Avg	15.97	2.18E-01	4.588	4.36E-02	22.94	1.01E-02	99.40
	Max	102.9	2.19E-01	4.557	4.39E-02	22.78	1.01E-02	98.73
All Off-Site Samples	Avg	40.04	2.18E-01	4.579	4.37E-02	22.90	1.01E-02	99.21
	Max	856.8	2.32E-01	4.305	4.65E-02	21.53	1.07E-02	93.28

Abbreviations: Avg = average; Haz = hazard; Max = maximum; Exp = exposure; SJRWP = San Jacinto River Waste Pitts; SJR = San Jacinto River; HSC = Houston Ship Channel; UGB = Upper Galveston Bay; pg/g = picograms per gram; TCDD TEQ = tetrachlorodibenzo-p-dioxin toxic equivalent concentration.

E+03	Very High Increased Risk
E+02	High Increased Risk
E+01	Moderately Increased Risk

E+00	Low Increased Risk
E-01	No Apparent Increased Risk
E-02	No Increased Risk

Table 33. Max Hazard Indices, Intermediate Oral + Derm + Fish Exp, Child, On & Off-Site

Soil/Sediments, Intermediate Duration Exposures, Oral + Dermal + Fish Consumption Pathways			Child of Subsistence Fisherman		Child of Weekend Fisherman		Child of Sporadic Fisherman	
Sediment Sample Collection Location	Sample	TCDD TEQ (pg/g)	Max Haz Index at Age 3	Margin of Safety	Max Haz Index at Age 3	Margin of Safety	Max Haz Index at Age 3	Margin of Safety
SJRWP, On-Site Samples	Avg	15,594	1.58E+00	0.6338	3.16E-01	3.169	7.28E-02	13.73
	Max	34,028	3.07E+00	0.3255	6.14E-01	1.628	1.42E-01	7.053
Down-Stream from SJRWP, SJR, HSC, & UGB	Avg	13.75	3.15E-01	3.176	6.30E-02	15.88	1.45E-02	68.81
	Max	86.16	3.21E-01	3.118	6.41E-02	15.59	1.48E-02	67.56
SJRWP Site-Vicinity, SJR Near SJRWP	Avg	82.24	3.20E-01	3.121	6.41E-02	15.61	1.48E-02	67.62
	Max	572.5	3.60E-01	2.777	7.20E-02	13.88	1.66E-02	60.16
Houston Ship Channel, Above/West of SJR	Avg	65.69	3.19E-01	3.134	6.38E-02	15.67	1.47E-02	67.91
	Max	856.8	3.83E-01	2.610	7.66E-02	13.05	1.77E-02	56.54
Up-Stream & Tributaries to SJR-HSC-UGB	Avg	15.97	3.15E-01	3.174	6.30E-02	15.87	1.45E-02	68.78
	Max	102.9	3.22E-01	3.105	6.44E-02	15.52	1.49E-02	67.27
All Off-Site Samples	Avg	40.04	3.17E-01	3.155	6.34E-02	15.77	1.46E-02	68.35
	Max	856.8	3.83E-01	2.610	7.66E-02	13.05	1.77E-02	56.54

Abbreviations: Avg = average; Haz = hazard; Max = maximum; Exp = exposure; SJRWP = San Jacinto River Waste Pitts; SJR = San Jacinto River; HSC = Houston Ship Channel; UGB = Upper Galveston Bay; pg/g = picograms per gram; TCDD TEQ = tetrachlorodibenzo-p-dioxin toxic equivalent concentration.

E+03	Very High Increased Risk
E+02	High Increased Risk
E+01	Moderately Increased Risk

E+00	Low Increased Risk
E-01	No Apparent Increased Risk
E-02	No Increased Risk

Table 34. Max Hazard Quotients, Chronic Oral Sediment Exp, Adult, On & Off-Site

Soil/Sediments, Chronic Duration Exposures, Oral Ingestion Pathway			Subsistence Fisherman		Weekend Fisherman		Sporadic Fisherman	
Sediment Sample Collection Location	**Sample**	**TCDD TEQ (pg/g)**	**Max Haz Quotient at Age 20**	**Margin of Safety**	**Max Haz Quotient at Age 20**	**Margin of Safety**	**Max Haz Quotient at Age 20**	**Margin of Safety**
SJRWP, On-Site Samples	Avg	15,594	2.35E+00	0.4263	4.69E-01	2.132	1.08E-01	9.237
	Max	34,028	5.12E+00	0.1954	1.02E+00	0.9768	2.36E-01	4.233
Down-Stream from SJRWP, SJR, HSC, & UGB	Avg	13.75	2.07E-03	483.3	4.14E-04	2,417	9.55E-05	10,472
	Max	86.16	1.30E-02	77.15	2.59E-03	385.8	5.98E-04	1,672
SJRWP Site-Vicinity, SJR Near SJRWP	Avg	82.24	1.24E-02	80.83	2.47E-03	404.2	5.71E-04	1,751
	Max	572.5	8.61E-02	11.61	1.72E-02	58.06	3.97E-03	251.6
Houston Ship Channel, Above/West of SJR	Avg	65.69	9.88E-03	101.2	1.98E-03	506.0	4.56E-04	2,193
	Max	856.8	1.29E-01	7.759	2.58E-02	38.80	5.95E-03	168.1
Up-Stream & Tributaries to SJR-HSC-UGB	Avg	15.97	2.40E-03	416.4	4.80E-04	2,082	1.11E-04	9,021
	Max	102.9	1.55E-02	64.61	3.10E-03	323.0	7.14E-04	1,400
All Off-Site Samples	Avg	40.04	6.02E-03	166.0	1.20E-03	830.2	2.78E-04	3,597
	Max	856.8	1.29E-01	7.759	2.58E-02	38.80	5.95E-03	168.1

Abbreviations: Avg = average; Haz = hazard; Max = maximum; Exp = exposure; SJRWP = San Jacinto River Waste Pitts; SJR = San Jacinto River; HSC = Houston Ship Channel; UGB = Upper Galveston Bay; pg/g = picograms per gram; TCDD TEQ = tetrachlorodibenzo-p-dioxin toxic equivalent concentration.

E+03	Very High Increased Risk
E+02	High Increased Risk
E+01	Moderately Increased Risk

E+00	Low Increased Risk
E-01	No Apparent Increased Risk
E-02	No Increased Risk

Table 35. Max Hazard Quotients, Chronic Oral Sediment Exp, Child, On & Off-Site

Soil/Sediments, Chronic Duration Exposures, Oral Ingestion Pathway			Child of Subsistence Fisherman		Child of Weekend Fisherman		Child of Sporadic Fisherman	
Sediment Sample Collection Location	Sample	TCDD TEQ (pg/g)	Max Haz Quotient at Age 3	Margin of Safety	Max Haz Quotient at Age 3	Margin of Safety	Max Haz Quotient at Age 3	Margin of Safety
SJRWP, On-Site Samples	Avg	15,594	1.95E+01	0.05125	3.90E+00	0.2562	9.01E-01	1.110
	Max	34,028	4.26E+01	0.02349	8.52E+00	0.1174	1.97E+00	0.5088
Down-Stream from SJRWP, SJR, HSC, & UGB	Avg	13.75	1.72E-02	58.10	3.44E-03	290.5	7.94E-04	1,259
	Max	86.16	1.08E-01	9.275	2.16E-02	46.37	4.98E-03	201.0
SJRWP Site-Vicinity, SJR Near SJRWP	Avg	82.24	1.03E-01	9.717	2.06E-02	48.59	4.75E-03	210.5
	Max	572.5	7.16E-01	1.396	1.43E-01	6.980	3.31E-02	30.25
Houston Ship Channel, Above/West of SJR	Avg	65.69	8.22E-02	12.16	1.64E-02	60.82	3.79E-03	263.6
	Max	856.8	1.07E+00	0.9328	2.14E-01	4.664	4.95E-02	20.21
Up-Stream & Tributaries to SJR-HSC-UGB	Avg	15.97	2.00E-02	50.05	4.00E-03	250.3	9.22E-04	1,084
	Max	102.9	1.29E-01	7.767	2.58E-02	38.83	5.94E-03	168.3
All Off-Site Samples	Avg	40.04	5.01E-02	19.96	1.00E-02	99.80	2.31E-03	432.5
	Max	856.8	1.07E+00	0.9328	2.14E-01	4.664	4.95E-02	20.21

Abbreviations: Avg = average; Haz = hazard; Max = maximum; Exp = exposure; SJRWP = San Jacinto River Waste Pitts; SJR = San Jacinto River; HSC = Houston Ship Channel; UGB = Upper Galveston Bay; pg/g = picograms per gram; TCDD TEQ = tetrachlorodibenzo-p-dioxin toxic equivalent concentration.

E+03	Very High Increased Risk
E+02	High Increased Risk
E+01	Moderately Increased Risk

E+00	Low Increased Risk
E-01	No Apparent Increased Risk
E-02	No Increased Risk

Table 36. Max Hazard Quotients, Chronic Dermal Sediment Exp, Adult, On & Off-Site

Soil/Sediments, Chronic Duration Exposures, Dermal Absorption Pathway			Subsistence Fisherman		Weekend Fisherman		Sporadic Fisherman	
Sediment Sample Collection Location	**Sample**	**TCDD TEQ (pg/g)**	**Max Haz Quotient at Age 20**	**Margin of Safety**	**Max Haz Quotient at Age 20**	**Margin of Safety**	**Max Haz Quotient at Age 20**	**Margin of Safety**
SJRWP, On-Site Samples	Avg	15,594	2.80E+00	0.3569	5.60E-01	1.785	1.29E-01	7.734
	Max	34,028	6.11E+00	0.1636	1.22E+00	0.8179	2.82E-01	3.544
Down-Stream from SJRWP, SJR, HSC, & UGB	Avg	13.75	2.47E-03	404.7	4.94E-04	2,023	1.14E-04	8,768
	Max	86.16	1.55E-02	64.60	3.10E-03	323.0	7.14E-04	1,400
SJRWP Site-Vicinity, SJR Near SJRWP	Avg	82.24	1.48E-02	67.68	2.96E-03	338.4	6.82E-04	1,466
	Max	572.5	1.03E-01	9.722	2.06E-02	48.61	4.75E-03	210.7
Houston Ship Channel, Above/West of SJR	Avg	65.69	1.18E-02	84.72	2.36E-03	423.6	5.45E-04	1,836
	Max	856.8	1.54E-01	6.496	3.08E-02	32.48	7.10E-03	140.8
Up-Stream & Tributaries to SJR-HSC-UGB	Avg	15.97	2.87E-03	348.6	5.74E-04	1,743	1.32E-04	7,553
	Max	102.9	1.85E-02	54.09	3.70E-03	270.5	8.53E-04	1,172
All Off-Site Samples	Avg	40.04	7.19E-03	139.0	1.44E-03	695.1	3.32E-04	3,012
	Max	856.8	1.54E-01	6.496	3.08E-02	32.48	7.10E-03	140.8

Abbreviations: Avg = average; Haz = hazard; Max = maximum; Exp = exposure; SJRWP = San Jacinto River Waste Pitts; SJR = San Jacinto River; HSC = Houston Ship Channel; UGB = Upper Galveston Bay; pg/g = picograms per gram; TCDD TEQ = tetrachlorodibenzo-p-dioxin toxic equivalent concentration.

E+03	Very High Increased Risk
E+02	High Increased Risk
E+01	Moderately Increased Risk

E+00	Low Increased Risk
E-01	No Apparent Increased Risk
E-02	No Increased Risk

Table 37. Max Hazard Quotients, Chronic Dermal Sediment Exp, Child, On & Off-Site

Soil/Sediments, Chronic Duration Exposures, Dermal Absorption Pathway			Child of Subsistence Fisherman		Child of Weekend Fisherman		Child of Sporadic Fisherman	
Sediment Sample Collection Location	**Sample**	**TCDD TEQ (pg/g)**	**Max Haz Quotient at Age 3**	**Margin of Safety**	**Max Haz Quotient at Age 3**	**Margin of Safety**	**Max Haz Quotient at Age 3**	**Margin of Safety**
SJRWP, On-Site Samples	Avg	15,594	4.35E+00	0.2301	8.69E-01	1.150	2.01E-01	4.984
	Max	34,028	9.49E+00	0.1054	1.90E+00	0.5271	4.38E-01	2.284
Down-Stream from SJRWP, SJR, HSC, & UGB	Avg	13.75	3.83E-03	260.8	7.67E-04	1,304	1.77E-04	5,651
	Max	86.16	2.40E-02	41.63	4.80E-03	208.2	1.11E-03	902.1
SJRWP Site-Vicinity, SJR Near SJRWP	Avg	82.24	2.29E-02	43.62	4.58E-03	218.1	1.06E-03	945.1
	Max	572.5	1.60E-01	6.266	3.19E-02	31.33	7.37E-03	135.8
Houston Ship Channel, Above/West of SJR	Avg	65.69	1.83E-02	54.61	3.66E-03	273.0	8.45E-04	1,183
	Max	856.8	2.39E-01	4.187	4.78E-02	20.94	1.10E-02	90.72
Up-Stream & Tributaries to SJR-HSC-UGB	Avg	15.97	4.45E-03	224.7	8.90E-04	1,123	2.05E-04	4,868
	Max	102.9	2.87E-02	34.86	5.74E-03	174.3	1.32E-03	755.4
All Off-Site Samples	Avg	40.04	1.12E-02	89.60	2.23E-03	448.0	5.15E-04	1,941
	Max	856.8	2.39E-01	4.187	4.78E-02	20.94	1.10E-02	90.72

Abbreviations: Avg = average; Haz = hazard; Max = maximum; Exp = exposure; SJRWP = San Jacinto River Waste Pitts; SJR = San Jacinto River; HSC = Houston Ship Channel; UGB = Upper Galveston Bay; pg/g = picograms per gram; TCDD TEQ = tetrachlorodibenzo-p-dioxin toxic equivalent concentration.

E+03	Very High Increased Risk
E+02	High Increased Risk
E+01	Moderately Increased Risk

E+00	Low Increased Risk
E-01	No Apparent Increased Risk
E-02	No Increased Risk

Table 38. Max Hazard Quotients, Chronic Fish/Crab Consumption, On & Off-Site

Chronic Duration Exposures, Fish or Crab Consumption Pathway			Subsistence Fisherman		Weekend Fisherman		Sporadic Fisherman	
Fish or Shellfish Species	Count	Avg TCDD TEQ (pg/g)	Max Haz Quotient at Age 20	Margin of Safety	Max Haz Quotient at Age 20	Margin of Safety	Max Haz Quotient at Age 20	Margin of Safety
Blue Crab	2	3.107	5.77E+00	0.1732	1.15E+00	0.8662	2.66E-01	3.754
Blue Catfish	2	6.040	1.12E+01	0.08912	2.24E+00	0.4456	5.18E-01	1.931
Spotted Seatrout	2	0.233	4.33E-01	2.310	8.66E-02	11.55	2.00E-02	50.05
Hybrid Striped Bass	1	1.541	2.86E+00	0.3493	5.73E-01	1.746	1.32E-01	7.568
Red Drum	2	0.097	1.80E-01	5.549	3.60E-02	27.75	8.32E-03	120.2
All Fish Species	7	2.040	3.79E+00	0.2639	7.58E-01	1.319	1.75E-01	5.717
All Species	9	2.277	4.23E+00	0.2364	8.46E-01	1.182	1.95E-01	5.122
Chronic Duration Exposures, Fish or Crab Consumption Pathway			Child of Subsistence Fisherman		Child of Weekend Fisherman		Child of Sporadic Fisherman	
Fish or Shellfish Species	Count	Avg TCDD TEQ (pg/g)	Max Haz Quotient at Age 3	Margin of Safety	Max Haz Quotient at Age 3	Margin of Safety	Max Haz Quotient at Age 3	Margin of Safety
Blue Crab	2	3.107	8.25E+00	0.1212	1.65E+00	0.6061	3.81E-01	2.627
Blue Catfish	2	6.040	1.60E+01	0.06236	3.21E+00	0.3118	7.40E-01	1.351
Spotted Seatrout	2	0.233	6.19E-01	1.616	1.24E-01	8.082	2.86E-02	35.02
Hybrid Striped Bass	1	1.541	4.09E+00	0.2444	8.18E-01	1.222	1.89E-01	5.296
Red Drum	2	0.097	2.58E-01	3.883	5.15E-02	19.41	1.19E-02	84.13
All Fish Species	7	2.040	5.42E+00	0.1846	1.08E+00	0.9231	2.50E-01	4.000
All Species	9	2.277	6.05E+00	0.1654	1.21E+00	0.8271	2.79E-01	3.584

Abbreviations: Avg = average; Haz = hazard; Max = maximum; Exp = exposure; SJRWP = San Jacinto River Waste Pitts; SJR = San Jacinto River; HSC = Houston Ship Channel; UGB = Upper Galveston Bay; pg/g = picograms per gram; TCDD TEQ = tetrachlorodibenzo-p-dioxin toxic equivalent concentration.

E+03	Very High Increased Risk
E+02	High Increased Risk
E+01	Moderately Increased Risk

E+00	Low Increased Risk
E-01	No Apparent Increased Risk
E-02	No Increased Risk

Table 39. Max Hazard Indices, Chronic Oral + Dermal + Fish Exp, Adult, On & Off-Site

Soil/Sediments, Chronic Duration Exposures, Oral + Dermal + Fish Consumption Pathways			Subsistence Fisherman		Weekend Fisherman		Sporadic Fisherman	
Sediment Sample Collection Location	Sample	TCDD TEQ (pg/g)	Max Haz Index at Age 20	Margin of Safety	Max Haz Index at Age 20	Margin of Safety	Max Haz Index at Age 20	Margin of Safety
SJRWP, On-Site Samples	Avg	15,594	9.38E+00	0.1066	1.88E+00	0.5332	4.33E-01	2.310
	Max	34,028	1.55E+01	0.0647	3.09E+00	0.3234	7.14E-01	1.401
Down-Stream from SJRWP, SJR, HSC, & UGB	Avg	13.75	4.23E+00	0.2361	8.47E-01	1.181	1.95E-01	5.116
	Max	86.16	4.26E+00	0.2348	8.52E-01	1.174	1.97E-01	5.088
SJRWP Site-Vicinity, SJR Near SJRWP	Avg	82.24	4.26E+00	0.2349	8.51E-01	1.174	1.96E-01	5.089
	Max	572.5	4.42E+00	0.2263	8.84E-01	1.131	2.04E-01	4.903
Houston Ship Channel, Above/West of SJR	Avg	65.69	4.25E+00	0.2352	8.50E-01	1.176	1.96E-01	5.096
	Max	856.8	4.51E+00	0.2216	9.03E-01	1.108	2.08E-01	4.801
Up-Stream & Tributaries to SJR-HSC-UGB	Avg	15.97	4.24E+00	0.2361	8.47E-01	1.180	1.95E-01	5.115
	Max	102.9	4.26E+00	0.2345	8.53E-01	1.173	1.97E-01	5.081
All Off-Site Samples	Avg	40.04	4.24E+00	0.2357	8.49E-01	1.178	1.96E-01	5.106
	Max	856.8	4.51E+00	0.2216	9.03E-01	1.108	2.08E-01	4.801

Abbreviations: Avg = average; Haz = hazard; Max = maximum; Exp = exposure; SJRWP = San Jacinto River Waste Pits; SJR = San Jacinto River; HSC = Houston Ship Channel; UGB = Upper Galveston Bay; pg/g = picograms per gram; TCDD TEQ = tetrachlorodibenzo-p-dioxin toxic equivalent concentration.

E+03	Very High Increased Risk
E+02	High Increased Risk
E+01	Moderately Increased Risk

E+00	Low Increased Risk
E-01	No Apparent Increased Risk
E-02	No Increased Risk

Table 40. Max Hazard Indices, Chronic Oral + Dermal + Fish Exp, Child, On & Off-Site

Soil/Sediments, Chronic Duration Exposures, Oral + Dermal + Fish Consumption Pathways			Child of Subsistence Fisherman		Child of Weekend Fisherman		Child of Sporadic Fisherman	
Sediment Sample Collection Location	**Sample**	**TCDD TEQ (pg/g)**	**Max Haz Index at Age 3**	**Margin of Safety**	**Max Haz Index at Age 3**	**Margin of Safety**	**Max Haz Index at Age 3**	**Margin of Safety**
SJRWP, On-Site Samples	Avg	15,594	2.99E+01	0.03344	5.98E+00	0.1672	1.38E+00	0.7245
	Max	34,028	5.81E+01	0.01721	1.16E+01	0.08604	2.68E+00	0.3729
Down-Stream from SJRWP, SJR, HSC, & UGB	Avg	13.75	6.07E+00	0.1648	1.21E+00	0.8242	2.80E-01	3.571
	Max	86.16	6.18E+00	0.1619	1.24E+00	0.8094	2.85E-01	3.507
SJRWP Site-Vicinity, SJR Near SJRWP	Avg	82.24	6.17E+00	0.1620	1.23E+00	0.8102	2.85E-01	3.511
	Max	572.5	6.92E+00	0.1445	1.38E+00	0.7224	3.19E-01	3.130
Houston Ship Channel, Above/West of SJR	Avg	65.69	6.15E+00	0.1627	1.23E+00	0.8135	2.84E-01	3.525
	Max	856.8	7.36E+00	0.1359	1.47E+00	0.6797	3.40E-01	2.945
Up-Stream & Tributaries to SJR-HSC-UGB	Avg	15.97	6.07E+00	0.1647	1.21E+00	0.8237	2.80E-01	3.570
	Max	102.9	6.20E+00	0.1612	1.24E+00	0.8061	2.86E-01	3.493
All Off-Site Samples	Avg	40.04	6.11E+00	0.1638	1.22E+00	0.8188	2.82E-01	3.548
	Max	856.8	7.36E+00	0.1359	1.47E+00	0.6797	3.40E-01	2.945

Abbreviations: Avg = average; Haz = hazard; Max = maximum; Exp = exposure; SJRWP = San Jacinto River Waste Pitts; SJR = San Jacinto River; HSC = Houston Ship Channel; UGB = Upper Galveston Bay; pg/g = picograms per gram; TCDD TEQ = tetrachlorodibenzo-p-dioxin toxic equivalent concentration.

E+03	Very High Increased Risk
E+02	High Increased Risk
E+01	Moderately Increased Risk

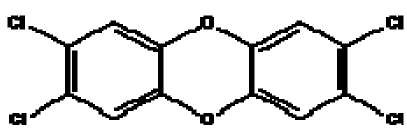
E+00	Low Increased Risk
E-01	No Apparent Increased Risk
E-02	No Increased Risk

Appendix D – Risk Assessment Calculations

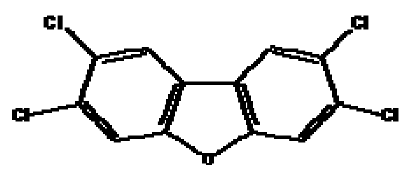
Calculation of the Toxic Equivalency (TEQ) for Mixed Dioxins

Polychlorinated dibenzo-p-dioxins (PCDDs) and polychlorinated dibenzofurans (PCDFs) are chlorinated tricyclic compounds that are extremely persistent in the environment and can adversely affect human or animal health at very low concentrations. These families of compounds can contain from 1-8 chlorine atoms replacing the hydrogen atoms at any one or more of the eight bonding locations around the molecules. The PCDD family includes 75 possible unique congeners, and PCDF family includes 135 possible unique congeners. However, only 7 out of the 75 PCDD congeners and 10 out of the 135 PCDF congeners are thought to have dioxin-like toxicity [11].

Toxicity generally increases with the number of chlorine atoms present on the molecule (up to four chlorines) but decreases thereafter as the number of chlorines increases to eight. Those congeners of PCDDs and PCDFs having chlorine atoms in the 2, 3, 7, and 8 positions appear to be more toxic than other PCDD/PCDF congeners. The most toxic of all PCDDs is 2,3,7,8-tetrachlorodibenzo-p-dioxin [19] (see 2,3,7,8-TCDD below). Consequently, 2,3,7,8-TCDD has been designated the standard against which the toxicity of other congeners is measured.



2,3,7,8-TCDD



2,3,7,8-TCDF

The 17 PCDD/PCDF congeners with dioxin-like toxicity are often found in complex mixtures. For risk assessment purposes, scientists from the World Health Organization (WHO) have developed a toxicity equivalency procedure to describe the combined toxicity of these mixtures [19]. This procedure involves assigning individual toxicity equivalency factors (TEFs) to the various congeners with dioxin-like toxicity. Under this scheme, the most toxic congener (2,3,7,8-TCDD) is assigned a TEF of 1.0, and the other 16 congeners have been assigned TEFs from 0.5 down to 0.0001 (with the exception of 1,2,3,7,8-PeCDD which also was assigned a TEF of 1.0) (See Table 1, Appendix B).

To calculate the toxic equivalency (TEQ) of a mixture, the concentrations of individual congeners are multiplied by their respective TEFs, and the sum of the individual TEQs is defined as the TCDD TEQ concentration for the mixture. This process, in effect, converts the concentrations of the various congeners into concentrations of 2,3,7,8-TCDD that would have an equivalent toxicity (and that can therefore be summed to arrive at the overall toxicity of the mixture). This is described mathematically as follows:

$$\text{Total TCDD TEQ} = \sum_{i=1}^{n} (C_i \times TEF_i)$$

Where

C_i = Concentration of the i'th congener,
TEF_i = Toxicity equivalency factor for the i'th congener,
n = Number of congeners with dioxin-like toxicity, and
i = Term-counting integer that goes from 1 through n.

In the Dioxin TMDL Project, the University of Houston used the "Texas" TEFs (often employed by the TCEQ) for calculating the total TCDD TEQs for the various sediment samples [11]. However, for this PHA, we used the updated World Health Organization (2005) TEFs to calculate the total TCDD TEQs [19]. Consequently, our TEQ numbers vary slightly from those reported in Tables 3.3 and 3.4 of the Dioxin TMDL Project, 3rd Quarterly Report [11].

Calculation of Oral Exposure Doses from Sediments

For all six scenarios, the individual's average body weight was determined through use of an Excel® 2003 spreadsheet developed by DSHS that – given a gender (males, females, or males and females combined), a starting age, and an ending age of exposure – integrates the age-specific 50 percentile body weights over time (by the method of Riemann sums [20] with up to n = 46 subintervals of age and with body weights determined for the midpoint of each age subinterval). Selecting for males and females combined, resultant average body weights for exposure scenarios 1 through 6 were calculated to be 70.58, 70.58, 69.05, 60.10, 60.10, and 54.47 kg, respectively. It was further assumed that the fisherman/fisherman's child ingests a similarly-calculated quantity of dioxin-contaminated sediment on each visit to the site through hand-to-mouth activities with dirty hands (e.g., eating, drinking, smoking, biting nails, etc.). Sediment ingestion rates were set at 200 mg/day for ages 3 through 5 years; after age 5, rates decreased linearly to 100 mg/day by age 20; rates remained at 100 mg/day from ages 20 through 70 years. Average daily sediment ingestion rates for scenarios 1 through 6 were calculated to be 100, 100, 100, 120.21, 120.21, and 129.69 mg/day, respectively. The TCDD oral absorption factor for sediments was assumed to be 50% [34]. Oral exposure doses on exposure days are calculated as follows:

$$AD_o = \text{Total } TEQ_n \times IR_{sed} \times CF_1 \times CF_2 \times AF_{o,sed} \div BW_{avg}$$

Where,

AD_o = Oral absorbed dose on exposure days (mg_{TEQ}/kg_{BW}/day),
Total TEQ_n = TCDD TEQ concentration at the n'th sampling location (pg_{TEQ}/g_{sed}),
IR_{sed} = Oral sediment intake rate (mg_{sed}/day),
CF_1 = Conversion factor 1 (10^{-9} mg_{TEQ}/pg_{TEQ}), and
CF_2 = Conversion factor 2 (10^{-3} g_{sed}/mg_{sed}),
$AF_{o,sed}$ = TCDD oral absorption factor for sediments (unitless),
BW_{avg} = Average body weight over exposure period (kg_{BW})

Since, in most conservative exposure models, toxicity/carcinogenicity (in low dose exposures) is assumed to be linear with respect to exposure dose, cutting any of the above exposure parameters in half would cut the resulting risk in half as well (except for body weight which would double the resulting risk). Similarly, doubling any of the exposure parameters (except for body weight) would double the resulting risk. In the event that some fishermen may not contact the same site sediments every day but may contact some site sediments every day they fish at the site, we have also calculated the average concentration for each congener and assumed that the Total TCDD TEQ to which the individual is exposed is the average TCDD TEQ of all the sampling locations on the site.

Calculation of Dermal Exposure Doses from Sediments

Dermal exposure levels for individuals fishing at the San Jacinto River Waste Pits site are unknown; thus, we made a number of conservative assumptions about possible dermal exposures and set up six scenarios describing a range of possibilities (see exposure scenarios above). For all six scenarios, the individual's body weights are assumed to be the same as those calculated in the oral sediment exposure scenarios described above. On each visit, it is assumed that the fisherman/fisherman's child gets dioxin-contaminated sediment on both hands and forearms. Surface areas for exposed body parts are based on tables appearing in the EPA's Exposure Factors Handbook [Tables 6-2 through 6-9 in reference 21]. Age-specific 50 percentile total body surface areas and surface areas of various body parts are calculated and integrated over time by the same method described for body weights to give the average body surface area exposed. Resultant average body surface areas for exposure scenarios 1 through 6 were calculated to be 2056, 2056, 2040, 1816, 1816, and 1696 square centimeters per exposure day (cm^2/day), respectively. The rate of sediment loading per surface area is assumed to be 1.0 mg_{sed}/cm^2 [Table 6-17 in reference 21]. The dermal absorption factor for TCDD is assumed to be 0.03 [22,23]. The absorbed dermal exposure dose on exposure days is calculated as follows:

$$AD_d = \text{Total TEQ}_n \times SL_s \times SA_{con} \times CF_1 \times CF_2 \times AF_d \div BW_{avg}$$

Where,

AD_d = Dermal absorbed dose on exposure days (mg_{TEQ}/kg_{BW}/day)
Total TEQ_n = TCDD TEQ concentration at the n'th sampling location (pg_{TEQ}/g_{sed}),
SL_s = Sediment loading per surface area (mg_{sed}/cm^2),
SA_{con} = Skin surface area contaminated with sediment (cm^2/day),
CF_1 = Conversion factor 1 (10^{-9} mg_{TEQ}/pg_{TEQ}),
CF_2 = Conversion factor 2 (10^{-3} g_{sed}/mg_{sed}),
AF_d = Dermal absorption factor (unitless),
BW_{avg} = Average body weight over exposure period (kg_{BW})

Calculation of Oral Exposure Doses from Fish or Crab Consumption

For this exposure pathway, we have assumed that an individual's fish or crab consumption rate is proportional to the frequency of visits to the site for all six exposure scenarios. It was further assumed that a standard 70 kg adult individual would potentially eat 8 ounces (226.8 g) of fish from each visit to the site. The individual's average body weight was determined by the same method described above, and the child's starting weight was assumed to be 15 kg (corresponding to a child of approximately 3 years of age). The child's body weight was allowed to progress normally with age, and the child's fish consumption rate was allowed to increase proportionally to the ¾ th power of the body weight over the exposure interval relative to a 70 kg adult's fish consumption rate (taken to be 8 oz./day = 226.8 g/day) according to the following formula:

$$FC(BW_x) = FC_{70} \times (BW_x)^{3/4} \div (70\ kg)^{3/4}$$

Where,

$FC(BW_x)$ = Fish consumption rate as a function of body weight (g_{fish}/day),
FC_{70} = Fish consumption rate (g_{fish}/day) for an adult weighing 70 kg, and
BW_x = Body weight of child (kg).

The incremental fish consumption rates were integrated over the exposure interval (by the method of Riemann sums [20] as described above) to give the time-weighted fish consumption rate in (g_{fish}/day)-years. This value was divided by the total years of exposure to give the average fish consumption rate over the exposure interval in g_{fish}/day. This process resulted in fish consumption rates for the six exposure scenarios of 227.94, 227.94, 224.23, 200.04, 200.04, and 185.22 g_{fish}/day. For the purpose of this PHA, average fish tissue levels of TCDD TEQ were assumed to be equal to those found in the various fish and shellfish species reported in the DSHS risk characterization done in 2005 [7]. The TCDD oral absorption factor for food items was assumed to be 95% [34]. The TCDD TEQ exposure dose from fish consumption was then calculated using the following formula:

$$AD_{fc} = FC_{avg} \times TEQ_{avg} \times CF_1 \times AF_{o,food} \div BW_{avg}$$

Where,

AD_{fc} = Fish consumption absorbed dose on exposure days (mg_{TEQ}/kg_{BW}/day),
FC_{avg} = Average fish consumption rate over exposure period (g_{fish}/day),
TEQ_{avg} = Average concentration of TCDD TEQ in blue catfish (pg_{TEQ}/g_{fish}) [7],
CF_1 = Conversion factor 1 (10^{-9} mg_{TEQ}/pg_{TEQ}), and
$AF_{o,food}$ = Oral absorption factor for food items (unitless),
BW_{avg} = Average body weight over exposure interval (kg_{BW}).

Exposure Factors for Cancer Risk Estimate Calculation

Exposure factors for the cancer risk estimates represent adjustments for less-than-daily, less-than-weekly, and less-than-lifetime exposure durations and are calculated as follows:

$$EF_{Ca,n} = (Hr_{ex} \div 24) \times (Da_{ex} \div 7) \times (Wk_{ex} \div 52) \times (Yr_{ex} \div 70)$$

Where,

$EF_{Ca,n}$ = Exposure factor for n'th scenario (unitless),
Hr_{ex} = Hours per day individual is exposed,

Da_{ex} = Days per week individual is exposed,
Wk_{ex} = Weeks per year individual is exposed, and
Yr_{ex} = Number of years individual is exposed

Exposure Factors for Non-Cancer (Hazard Quotient) Calculations

For non-cancer effects, exposures need not be life-long in order for acute, intermediate, or chronic exposure guidelines to have been exceeded. Exposures that exceed 365 days are sufficient to qualify as *chronic*, and are compared with ATSDR's chronic MRLs or EPA's RfDs. Consequently, the exposure factor for less-than-lifetime exposures (i.e., $Yr_{ex} \div 70$) is not used and the net exposure factors for the three scenarios for hazard quotient calculations represent adjustments for less-than-daily and less-than-weekly exposure durations and are calculated as follows:

$$EF_{NCa,n} = (Hr_{ex} \div 24) \times (Da_{ex} \div 7) \times (Wk_{ex} \div 52)$$

Where,

$EF_{NCa,n}$ = Exposure factor for n'th scenario (unitless),
Hr_{ex} = Hours per day individual is exposed,
Da_{ex} = Days per week individual is exposed, and
Wk_{ex} = Weeks per year individual is exposed,

Calculating Theoretical Cancer Risks for Oral Sediment Exposures

Cancer risk estimates, such as those presented in this analysis, represent the theoretical probability that any exposed individual may develop cancer as a result of a given carcinogen exposure scenario. The reciprocal of the cancer risk estimate (i.e., 1 divided by the cancer risk estimate) gives the size of the exposed population necessary to see 1 additional cancer case above the background rate if that population is followed for a 70-year "lifetime." For example, a calculated cancer risk estimate of 1×10^{-6} implies that there is a theoretical probability of one additional cancer case over background rates in a population of 1 million people exposed continuously for a 70-year lifetime at the specified level of exposure. To put this in perspective, current US cancer statistics would indicate that approximately 4 out of 10 people will be diagnosed with cancer at some point in their lifetime [24]. This translates to an expected "background" of 400,000 cancer cases occurring in a population of 1 million people followed throughout their lifetimes. Increasing the population's risk for cancer by 1×10^{-6} brings the expected number of cases to 400,001 instead of 400,000 per million population. It should be noted that, because of the conservative models used to derive oral and dermal slope factors, the above approach provides a theoretical upper bound estimate of the excess risk; the true or actual excess risk is unknown and could be as low as zero [1].

Theoretical excess lifetime cancer risks associated with oral exposures to the Total TCDD TEQ for each sampling location on the site were calculated as follows:

$$TR_{o:m,n} = AD_{o:m} \times SF_o \times EF_{Ca,n}$$

Where,

$TR_{o:m,n}$ = Theoretical risk from oral exposure at the m'th sample location for the n'th exposure scenario,
$AD_{o:m}$ = Oral absorbed dose at the m'th sample location ($mg_{TEQ}/kg_{BW}/day$),
SF_o = EPA's oral slope factor for TCDD [150,000 $(mg_{TEQ}/kg_{BW}/day)^{-1}$], and
$EF_{Ca,n}$ = Exposure factor for the n'th exposure scenario (unitless).

Calculating Theoretical Cancer Risks for Dermal Exposures

Theoretical excess lifetime cancer risks associated with dermal exposures to the Total TCDD TEQ for each sampling location (Station ID) were calculated as follows:

$$TR_{d:m,n} = AD_{d:m} \times SF_d \times EF_{Ca,n}$$

Where,

$TR_{d:m,n}$ = Theoretical risk from dermal exposure at the m'th sample location for the n'th exposure scenario,
$AD_{d:m}$ = Dermal exposure dose at the m'th sample location ($mg_{TEQ}/kg_{BW}/day$),
SF_d = Risk Assessment Information System (RAIS) dermal slope factor for TCDD [300,000 $(mg_{TEQ}/kg_{BW}/day)^{-1}$] [22], and
$EF_{Ca,n}$ = Exposure factor for the n'th exposure scenario (unitless).

Calculating Theoretical Cancer Risks for Fish Consumption Exposures

Theoretical excess lifetime cancer risks associated with oral exposures to the Total TCDD TEQ for each sampling location on the site were calculated as follows:

$$TR_{FC:m,n} = AD_{FC:m} \times SF_o \times EF_{Ca,n}$$

Where,

$TR_{FC:m,n}$ = Theoretical risk from fish consumption exposures at the m'th sample location for the n'th exposure scenario,
$AD_{FC:m}$ = Fish consumption absorbed dose at the m'th sample location ($mg_{TEQ}/kg_{BW}/day$),
SF_o = EPA's oral slope factor for TCDD [150,000 $(mg_{TEQ}/kg_{BW}/day)^{-1}$], and
$EF_{Ca,n}$ = Exposure factor for the n'th exposure scenario (unitless).

Calculating Theoretical Cancer Risks for All Exposures

The theoretical cancer risks for all site-related exposure routes combined were calculated as the sum of the risks for oral exposure, dermal exposure, and fish consumption, for each of the sampling locations (and for the average of all sampling locations combined). For the purpose of this PHA, we have assumed that the inhalation pathway contributes negligibly to site-related exposures and that ingestion of water from this area of the San Jacinto River does not occur.

Theoretical excess lifetime cancer risks associated with all TCDD TEQ exposures combined for each exposure scenario and for each sampling location were calculated as follows:

$$TR_{tot:m,n} = TR_{o:m,n} + TR_{d:m,n} + TR_{FC:m,n}$$

Where,

$TR_{tot:m,n}$ = Theoretical risk from all exposures combined at the m'th sample location for the n'th exposure scenario,

$TR_{o:m,n}$ = Theoretical risk from oral exposure at the m'th sample location for the n'th exposure scenario,

$TR_{d:m,n}$ = Theoretical risk from dermal exposure at the m'th sample location for the n'th exposure scenario,

$TR_{fc:m,n}$ = Theoretical risk from fish consumption exposure at the m'th sample location for the n'th exposure scenario,

Calculating Hazard Quotients, Hazard Indices, and Margins of Safety

Hazard quotients (HQs) are frequently used in the evaluation of non-cancer adverse health effects. An exposure dose (in mg/kg/day) is calculated for each exposure scenario as described above and this value is divided by the acute, intermediate, or chronic MRL to give the HQ for the exposure. Depending on the magnitude of the HQ and of the uncertainty factors used in deriving the MRL, HQs <1.0 generally imply that adverse health effects are unlikely to occur as a result of the exposure, even for sensitive sub-populations. HQs greater than 1.0 may imply some increased risk for adverse health effects in exposed individuals. Thus when HQs>1.0 are encountered, risk assessors will often refer to the original study upon which the MRL is based to determine the likelihood of adverse effects. They may then evaluate the exposure dose in the context of the study NOAEL/LOAEL and the uncertainty factors used in deriving the MRL.

When multiple routes of exposure are considered, it is customary to combine the exposure doses from each route into a total exposure dose, which is then divided by the various MRLs to give the combined Hazard Index (HI) for the exposure. The "margin of safety" as used in this PHA is defined as the reciprocal of the HQ or the HI and, as such, is a measure of how close the given exposure dose is to a reference "safe" exposure dose as defined by the acute, intermediate, or chronic MRL.

Hazard quotients for the six scenarios and three exposure durations for oral, dermal, and fish consumption exposure pathways are calculated as follows:

HQ for Acute Duration, Oral Sediment Exposure:

$$HQ_{ao} = AD_o \times EF_{NCa,n} \div MRL_{ao}$$

Where,

HQ_{ao} = Hazard quotient for acute oral sediment exposures ($mg_{TEQ}/kg_{BW}/day$),
AD_o = Oral absorbed dose on exposure days ($mg_{TEQ}/kg_{BW}/day$),
$EF_{NCa,n}$ = Exposure factor for n'th scenario (unitless), and
MRL_{ao} = ATSDR's acute oral Minimal Risk Level for TCDD ($mg_{TEQ}/kg_{BW}/day$).

HQ for Acute Duration, Dermal Sediment Exposure:

$$HQ_{ad} = AD_d \times EF_{NCa,n} \div MRL_{ad}$$

Where,

HQ_{ad} = Hazard quotient for acute dermal sediment exposures ($mg_{TEQ}/kg_{BW}/day$),
AD_d = Dermal absorbed dose on exposure days ($mg_{TEQ}/kg_{BW}/day$)
$EF_{NCa,n}$ = Exposure factor for n'th scenario (unitless), and
MRL_{ad} = Estimated acute dermal Minimal Risk Level for TCDD ($mg_{TEQ}/kg_{BW}/day$).

HQ for Acute Duration, Fish Consumption Exposure:

$$HQ_{afc} = AD_{fc} \times EF_{NCa,n} \div MRL_{ao}$$

Where,

HQ_{afc} = Hazard quotient for acute fish consumption exposures ($mg_{TEQ}/kg_{BW}/day$),
AD_{fc} = Fish consumption absorbed dose on exposure days ($mg_{TEQ}/kg_{BW}/day$),
$EF_{NCa,n}$ = Exposure factor for n'th scenario (unitless), and
MRL_{ao} = ATSDR's acute oral Minimal Risk Level for TCDD ($mg_{TEQ}/kg_{BW}/day$).

HI for Acute Duration, All Exposure Routes Combined:

$$HI_{atot} = HQ_{ao} + HQ_{ad} + HQ_{afc}$$

Where,

HI_{atot} = Hazard index for acute all exposures combined ($mg_{TEQ}/kg_{BW}/day$),
HQ_{ao} = Hazard quotient for acute oral sediment exposures ($mg_{TEQ}/kg_{BW}/day$),
HQ_{ad} = Hazard quotient for acute dermal sediment exposures ($mg_{TEQ}/kg_{BW}/day$), and
HQ_{afc} = Hazard quotient for acute fish consumption exposures ($mg_{TEQ}/kg_{BW}/day$).

HQ for Intermediate Duration, Oral Sediment Exposure:

$$HQ_{io} = AD_o \times EF_{NCa,n} \div MRL_{io}$$

Where,

HQ_{io} = Hazard quotient for intermediate oral sediment exposures ($mg_{TEQ}/kg_{BW}/day$),
AD_o = Oral absorbed dose on exposure days ($mg_{TEQ}/kg_{BW}/day$),
$EF_{NCa,n}$ = Exposure factor for n'th scenario (unitless), and

MRL_{io} = ATSDR's intermed oral Minimal Risk Level for TCDD (mg_{TEQ}/kg_{BW}/day).

HQ for Intermediate Duration, Dermal Sediment Exposure:

$$HQ_{id} = AD_d \times EF_{NCa,n} \div MRL_{id}$$

Where,

HQ_{id} = Hazard quotient for intermed dermal sediment exp (mg_{TEQ}/kg_{BW}/day),
AD_d = Dermal absorbed dose on exposure days (mg_{TEQ}/kg_{BW}/day)
$EF_{NCa,n}$ = Exposure factor for n'th scenario (unitless), and
MRL_{id} = Est intermed dermal Minimal Risk Level for TCDD (mg_{TEQ}/kg_{BW}/day).

HQ for Intermediate Duration, Fish Consumption Exposure:

$$HQ_{ifc} = AD_{fc} \times EF_{NCa,n} \div MRL_{io}$$

Where,

HQ_{ifc} = Hazard quotient for intermed fish consumption exp (mg_{TEQ}/kg_{BW}/day),
AD_{fc} = Fish consumption absorbed dose on exposure days (mg_{TEQ}/kg_{BW}/day),
$EF_{NCa,n}$ = Exposure factor for n'th scenario (unitless), and
MRL_{io} = ATSDR's intermed oral Minimal Risk Level for TCDD (mg_{TEQ}/kg_{BW}/day).

HI for Intermediate Duration, All Exposure Routes Combined:

$$HI_{itot} = HQ_{io} + HQ_{id} + HQ_{ifc}$$

Where,

HI_{itot} = Hazard index for intermed all exp combined (mg_{TEQ}/kg_{BW}/day),
HQ_{io} = Hazard quotient for intermed oral sediment exp (mg_{TEQ}/kg_{BW}/day),
HQ_{id} = Hazard quotient for intermed dermal sediment exp (mg_{TEQ}/kg_{BW}/day), and
HQ_{ifc} = Hazard quotient for intermed fish consumption exp (mg_{TEQ}/kg_{BW}/day),

HQ for Chronic Duration, Oral Sediment Exposure:

$$HQ_{co} = AD_o \times EF_{NCa,n} \div MRL_{co}$$

Where,

HQ_{co} = Hazard quotient for chronic oral sediment exposures (mg_{TEQ}/kg_{BW}/day),
AD_o = Oral absorbed dose on exposure days (mg_{TEQ}/kg_{BW}/day),
$EF_{NCa,n}$ = Exposure factor for n'th scenario (unitless), and
MRL_{co} = ATSDR's chronic oral Minimal Risk Level for TCDD (mg_{TEQ}/kg_{BW}/day).

HQ for Chronic Duration, Dermal Sediment Exposure:

$$HQ_{cd} = AD_d \times EF_{NCa,n} \div MRL_{cd}$$

Where,

HQ_{cd} = Hazard quotient for chronic dermal sediment exposures (mg_{TEQ}/kg_{BW}/day),
AD_d = Dermal absorbed dose on exposure days (mg_{TEQ}/kg_{BW}/day)
$EF_{NCa,n}$ = Exposure factor for n'th scenario (unitless), and
MRL_{cd} = Estimated chronic dermal Minimal Risk Level for TCDD (mg_{TEQ}/kg_{BW}/day).

HQ for Chronic Duration, Fish Consumption Exposure:

$$HQ_{cfc} = AD_{fc} \times EF_{NCa,n} \div MRL_{ao}$$

Where,

HQ_{cfc} = Hazard quotient for chronic fish consumption exposures (mg_{TEQ}/kg_{BW}/day),
AD_{fc} = Fish consumption absorbed dose on exposure days (mg_{TEQ}/kg_{BW}/day),
$EF_{NCa,n}$ = Exposure factor for n'th scenario (unitless), and
MRL_{co} = ATSDR's chronic oral Minimal Risk Level for TCDD (mg_{TEQ}/kg_{BW}/day).

HI for Chronic Duration, All Exposure Routes Combined:

$$HI_{ctot} = HQ_{co} + HQ_{cd} + HQ_{cfc}$$

Where,

HI_{ctot} = Hazard index for chronic all exposures combined (mg_{TEQ}/kg_{BW}/day),
HQ_{co} = Hazard quotient for chronic oral sediment exp (mg_{TEQ}/kg_{BW}/day),
HQ_{cd} = Hazard quotient for chronic dermal sediment exp (mg_{TEQ}/kg_{BW}/day), and
HQ_{cfc} = Hazard quotient for chronic fish consumption exp (mg_{TEQ}/kg_{BW}/day),