Public Health Assessment

Final Release

SAN JACINTO RIVER WASTE PITS

CHANNELVIEW, HARRIS COUNTY, TEXAS

EPA FACILITY ID: TXN000606611

Prepared by the
Texas Department of State Health Services

OCTOBER 30, 2012

Prepared under a Cooperative Agreement with the
U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES
Agency for Toxic Substances and Disease Registry
Division of Community Health Investigations
Atlanta, Georgia 30333

THE ATSDR PUBLIC HEALTH ASSESSMENT: A NOTE OF EXPLANATION

This Public Health Assessment was prepared by ATSDR's Cooperative Agreement Partner pursuant to the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA or Superfund) section 104 (i)(6) (42 U.S.C. 9604 (i)(6)), and in accordance with our implementing regulations (42 C.F.R. Part 90). In preparing this document, ATSDR's Cooperative Agreement Partner has collected relevant health data, environmental data, and community health concerns from the Environmental Protection Agency (EPA), state and local health and environmental agencies, the community, and potentially responsible parties, where appropriate.

In addition, this document has previously been provided to EPA and the affected states in an initial release, as required by CERCLA section 104 (i)(6)(H) for their information and review. The revised document was released for a 60-day public comment period. Subsequent to the public comment period, ATSDR's Cooperative Agreement Partner addressed all public comments and revised or appended the document as appropriate. The public health assessment has now been reissued. This concludes the public health assessment process for this site, unless additional information is obtained by ATSDR's Cooperative Agreement Partner which, in the agency's opinion, indicates a need to revise or append the conclusions previously issued.

PUBLIC HEALTH ASSESSMENT

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CHANNELVIEW, HARRIS COUNTY, TEXAS

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Prepared by:

Texas Department of State Health Services
Environmental & Injury and Toxicology Branch
Under a Cooperative Agreement with the
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 these evaluations 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:

Health Assessment & Toxicology Program
Environmental & Injury Epidemiology & Toxicology Unit
Texas Department of State Health Services
PO Box 149347, MC1964
Austin, Texas 78714-9347

Summary

INTRODUCTION	The San Jacinto River Waste Pits (SJRWP) site, in the city of Channelview, Texas, consists of a series of three surface impoundments (pits) that were constructed on the west bank of the San Jacinto River near the Interstate -10 (I-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 sometime in the 1960s and 1970s. Since the pits were constructed, the pit area has subsided, and river currents have eroded the outer berm, allowing the two eastern pits to become partially submerged under a few inches to a few feet of river 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 and Upper and Lower Galveston Bay. Elevated dioxin levels have been found in fish and crabs caught near the site. The maximum sediment dioxin level found on site was over 680 times higher than the ATSDR's screening level for dioxins in residential soil. 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 San Jacinto River. 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 Public Health Assessment presents conclusions about whether a health threat is present or possible 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 population living near the site. 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 San Jacinto River, the Houston Ship Channel and Upper Galveston Bay:
Conclusion 1	Exposures to contaminated sediments from the SJRWP site by mouth and/or through skin for periods of 1 year or longer could harm people's health by increasing possible risks for cancer and non-cancer adverse health effects.
Basis for Conclusion	Dioxins have been detected in sediments at the SJRWP site at levels that would possibly cause unacceptably high risks for cancer (greater than one out of 10,000 people exposed) and unacceptably high risks for non-cancer effects for children and adults under the subsistence fisherman exposure scenario (Subsistence fishermen are people who fish frequently and rely on fish for a large part of their diet, in this case, we use 260 times per year for 47 and 30 years, respectively) and under the child-of-a-weekend-fisherman exposure scenario (children who accompanying their parent on fishing trips each weekend throughout the year, 52 times per year for 47 years) for either oral and/or dermal exposures. (See SJRWP Exposure Scenarios on pages 35 and 36 for more complete definitions of exposure scenarios.)
Current Progress	The following actions have been taken regarding the SJRWP site: • 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. • DSHS made initial site visit in Dec 2007 to document baseline conditions at the proposed SJRWP site. • DSHS made a 2nd, follow-up site visit, in Oct 2009 and distributed pamphlets in and around Channelview and Highlands warning residents to avoid visiting or fishing at the SJRWP site and to avoid eating fish caught from the San Jacinto River near the site or from the Houston Ship Channel or Upper Galveston Bay. • The EPA began implementing a Remedial Investigation/Feasibility Study (RI/FS) in Jan 2010, and the following documents were submitted and approved: o Sediment Sampling and Analysis Plan (SAP) (Integral and Anchor QEA 2010). Describes the design, rationale, data quality objectives, and data analysis plans for the sediment study at the Site. This document was approved by EPA on April 26, 2010. o RI/FS Work Plan (Anchor QEA and Integral 2010). Describes the Site setting, available data sets describing conditions at the Site, and a general site conceptual model. Describes the approach to

		conducting risk assessments, fate and transport modeling, remedial alternatives analysis and development of the feasibility study (FS). Provides a schedule for completion of all deliverables. This document was approved by EPA on November 2, 2010. o Technical Memorandum on Bioaccumulation Modeling (Integral 2010a). Describes the selected approach for evaluating relationships between concentrations of chemicals in tissue and in abiotic media and the rationale for method selection, including an extensive analysis of available sediment, water and tissue data, and of the literature. This document was approved by EPA on September 24, 2010. o Tissue SAP (Integral 2010b). Describes the design, rationale, data quality objectives, and data analysis plans for the biological tissue study at the Site. This document was approved by EPA on September 24, 2010. o Soil SAP (Integral 2011a) and Soil SAP Addendum 1 (Integral 2011b). Describes the design, rationale, data quality objectives, and data analysis plans for the soil study at the Site. This document was approved by EPA on January 10, 2011. o Groundwater SAP (Anchor QEA and Integral 2011a). Describes the design, rationale, data quality objectives, and data analysis plans for the groundwater study at the Site. This document was approved by EPA on December 23, 2010. o Fate and Transport Modeling Memorandum (Anchor QEA and Integral 2011b). Describes the purpose and approach to fate and transport modeling for the RI. This document was approved by EPA on January 10, 2011. o Bathymetric Survey Field Sampling Plan (FSP) (Anchor QEA 2011a). Describes the methods for performing a bathymetry survey for use in the fate and transport modeling. This document was approved by EPA on March 21, 2011. o Bed Property Study FSP (Anchor QEA 2011b). Describes the methods for performing a study of river bed properties for use in the fate and transport modeling. This document was approved by EPA on March 21, 2011. o Current Velocity Study FSP (Anchor QEA 2011c). Describes the methods for characterizing current velocities at the Site for use in the fate and transport modeling. This document was approved by EPA on May 3, 2011. o Chemicals of Potential Concern Technical Memorandum (Integral 2011c). Provides an interpretation of sediment chemistry data to identify the final list of chemicals of potential concern. This

	document was approved by EPA on May 5, 2011. o Radioisotope Coring Study FSP (Anchor QEA 2011d). Describes the methods for performing a sediment core and radio dating analysis for use in the fate and transport modeling. This document was approved by EPA on May 5, 2011. o Sedflume Study FSP (Anchor QEA 2011e). Describes the methods for collecting and analyzing sediment cores for erodability, results of which will be used in the fate and transport modeling. This document was approved by EPA on May 20, 2011 o Upstream Sediment Load Study FSP (Anchor QEA 2011f). Describes the methods for collecting data to be used to estimate rates of sediment loading from upstream to the Site, results of which will be used in the fate and transport modeling. This document was approved by EPA on May 18, 2011. • The U.S. Environmental Protection Agency (EPA) implemented a time critical removal action (TCRA) (beginning in Feb 2011 and completed in Jul 2011) which included the following activities: o Placement of fencing, warning signs, and a remote camera surveillance system in the Texas Department of Transportation right-of-way adjacent to the waste impoundments north of I-10 to prevent access to the impoundments and to prevent shoreline access for fishing in adjacent areas on both the east and west sides of the San Jacinto River near the impoundments. o Placement of buoys, ropes, and signs in the water around the perimeter of the site to prevent boat access to the impoundments. o Clearing of vegetation from the site in the vicinity of the waste impoundments north of I-10 and clearing of trash and debris from the area beneath I-10. o Construction of a truck turnaround area, a road, equipment laydown, and material storage area and other features for construction staging and equipment access to the waste impoundments. o Placement of geotextile and armor caps on the eastern cell and placement of geomembrane, geotextile, and armored caps on the western cell of the impoundments north of I-10. • DSHS made a 3rd follow-up site visit in May 2011 to evaluate site activities related to EPA's TCRA and make PowerPoint presentation of the SJRWP Public Health Assessment document at a public meeting in Highlands, TX. • DSHS & ATSDR released the public comment draft of the SJRWP Public Health Assessment document, and the public comment period

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began in Apr 2011 and ended in Jun 2011.

- During the public comment period, DSHS received comments from the following groups:

Harris County Pollution Control Services Department
101 South Richey, Suite H
Pasadena, Texas 77506
And
Integral Consulting, Inc.
411 1st Street South
Seattle, WA 98104

- The Galveston Bay Foundation with funding from the Texas Coastal Management Program posted seafood consumption advisory signs in the area of the SJRWP pits and in numerous other locations where public access to the affected waterways was possible in Aug-Oct 2011.
- DSHS made a 4th follow-up site visit in Jan 2012 to attend a meeting of the Community Awareness Committee, and evaluate site conditions following completion of EPA's TCRA.
- DSHS made a 5th follow-up site visit to attend a public meeting in Highlands in June 2012 and hand out information brochures about the site.
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<tr><td>Next Steps</td><td>
The following EPA reports are scheduled for release:

- EPA's Baseline Ecological Risk Assessment report to be completed in June 2012.
- EPA's Baseline Human Health Risk Assessment report to be completed in Oct 2012.
- EPA's Remedial Investigation initial draft report to be completed in Oct 2012; approval of final report due in Feb 2013.
- EPA's Feasibility Study initial draft to be completed in Apr 2013; approval of final report due in Sep 2013.
- Public comment period begins for proposed plan for remediation begins in Oct 2013.
- In 2014, following a public comment period & public meeting, the EPA's Record of Decision (ROD) will be issued which will select the final remedy for the waste pits & the entire SJRWP site.

Once the RI/FS has been completed, dioxins and other hazardous materials should be removed from the SJRWP site according to standard EPA protocol.
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<tr><td>Conclusion 2</td><td>Consuming fish or crabs caught near the SJRWP site for periods of one year or</td></tr>
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	longer could harm people's health by increasing possible risks for cancer.
Basis for Conclusion	Dioxins have been detected in fish and crabs caught near the SJRWP site at levels that would cause unacceptably high possible risks for cancer (greater than one out of 10,000 people exposed) under all but the sporadic-fishermen-and-their-children exposure scenarios.
Current Progress	The following actions have been taken: • 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 dioxin concentrations in fish, crabs, and shellfish caught near the site. • In November 2010 and January 2011, DSHS SALG collected 45 additional fish and crab samples from the San Jacinto River (10 from upstream of the site, 25 from near the site, and 10 from downstream of the site) and tested them for arsenic, mercury, pesticides, polychlorinated biphenyls (PCBs), and dioxins. Eighteen out of twenty-five samples collected near the site contain detectable levels of dioxins (average all 25 fish = 4.96 pg/g). Upstream samples averaged 0.482 pg/g and downstream samples averaged 1.49 pg/g.
Next Steps	The following actions should be pursued: • DSHS should continue to periodically collect fish and crab samples from the San Jacinto River near the I-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	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	Residents of Channelview receive their drinking water from the Harris County Water District. 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.
Next Steps	None needed
Conclusion 4	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	Exposures to ambient air near 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 from sand mining activities near the SJRWP site could harm people's health.
Basis for Conclusion	Dioxins 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, and attempts need to be made to determine where the mined sand has been distributed. • Samples of mined sand should be tested for dioxins and other hazardous contaminants. • If mined sand is found in areas where human exposure might occur and if dioxins 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	Although two of the surface impoundments are inundated with water from the

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.

Conclusion	San Jacinto River and site contaminants are likely being washed downstream to some extent during high water flow periods, the scattered sediment samples collected downstream (under the Dioxin Total Maximum Daily Load Project) have not shown any clear evidence of significant off-site migration of dioxins from the SJRWP site. However, the extent of transport of dioxin-contaminated sediments off-site has not yet been 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 San Jacinto River as it passes under the I-10 Bridge should be studied 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 for dioxins and other site-related contaminants. • If distributed sediments are found to contain excessive amounts of dioxins 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: • Follow-up with individuals living in the surrounding neighborhoods was not deemed necessary 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 routinely visited the site because such individuals are unknown and they may live anywhere in the greater Houston area. • DSHS staff will continue to participate in EPA or Texas Commission on Environmental Quality (TCEQ) availability sessions or other community meetings to collect and address any community health concerns related to the SJRWP site. • During the public comment period, the SJRWP PHA document was reviewed by the Harris County Pollution Control Services Department and by Integral Consulting, Inc. This Final version of the PHA document addresses the comments received from these reviewers.

FOR MORE INFORMATION	If you have any questions regarding the most current status and conditions at the San Jacinto River Waste Pits Superfund Site, much of the information is available on the following EPA websites: http://www.epa.gov/region6/6sf/texas/san_jacinto/ http://epaosc.org/site/site_profile.aspx?site_id=6534 http://www.epa.gov/earth1r6/6sf/pdffiles/0606611.pdf Also, a complete set of documents is available for viewing at the site repository: Stratford Branch Library 509 Stratford Street Highlands, Texas 77562-2547 (281) 426-3521 If you have any questions or concerns about this Public Health Assessment or about potential dioxin risks from exposures to sediments from the San Jacinto River, Houston Ship Channel, or Upper Galveston Bay, you may contact: Richard A. Beauchamp, M.D., Texas Department of State Health Services Austin, TX 78714-9347 (512) 458-7269. A copy of this Public Health Assessment document will be made available on the DSHS and ATSDR websites at: http://www.dshs.state.tx.us/epitox/assess.shtm http://www.atsdr.cdc.gov/hac/pha/index.asp For additional information on dioxins, you may call the ATSDR at: (800) CDC-INFO. 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 public health assessment (PHA) was prepared for the San Jacinto River Waste Pits (SJRWP) Superfund site in accordance with the Interagency Cooperative Agreement between the Agency for Toxic Substances and Disease Registry (ATSDR) and the Texas Department of State Health Services (DSHS). The aim of this evaluation is to determine if people are being (or may have been) exposed to hazardous substances from the site and, if so, whether that exposure, if allowed to continue, would be potentially harmful to human health and should be significantly reduced or eliminated. In preparing this PHA, no independent sediment, fish tissue, or other samples were collected and/or analyzed. Instead, DSHS and ATSDR evaluated environmental data and conditions at the site at the time it was added to the Environmental Protection Agency's National Priorities List. These data included the results for on-site sediment samples collected 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, Houston Ship Channel, and Upper Galveston Bay by the University of Houston.

Exposure Routes and Scenarios

This PHA evaluates three primary and secondary routes of exposure to contaminants from the site: 1) inadvertent 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 Exposure 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 to be a significant pathway of exposure because the site is on the bank of the San Jacinto River in a tidal area, shallow ground water in this area is brackish and non-potable, there are no wells in the immediate vicinity of the site, and groundwater samples were not collected. Likewise, surface water was not considered to be a significant pathway of exposure because the site is in a tidal area of the river where the waters are brackish and non-potable. Thus, the probability of regular ingestion of surface water from the San Jacinto River, Houston Ship Channel, or Upper Galveston Bay is extremely low.

Consequently, surface water samples were not collected, analyzed, or reported in the hazard ranking system (HRS) documentation.

Health Outcome Data

Residential health surveys for residents of Channelview, TX (one half mile west of the site) or from Highlands, TX (across the river and one half mile east of the site) were not conducted for this PHA because the airborne, groundwater, and surface water pathways had been eliminated for the site. Consequently, the exposed population would only include those individuals who regularly visited the site and came in contact with contaminated sediment and/or those who regularly ate fish or crabs caught from the San Jacinto River, Houston Ship Channel, and/or Upper Galveston Bay. Individuals who fall into one of these categories could easily live anywhere in the Houston vicinity and therefore, could not be differentiated from non-exposed individuals. Consequently, analysis of health outcome data from the Texas Cancer Registry and/or the Texas Birth Defect Registry databases could not have provided any insight regarding site-related health effects.

Background

Site Description

The SJRWP site is located in eastern Harris County, Texas, between the cities of Channelview and Highlands (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 San Jacinto River immediately north of the I-10 Bridge. The pits consist of a series of three surface impoundments that were constructed sometime between October 8, 1964, and February 15, 1973. Pits A, B, and C cover 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 land 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 San Jacinto River. 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 were used from the mid-1960s to the mid-1970s for the disposal of paper mill wastes. A witness, previously employed as a marine surveyor who inspected barges, reported seeing tugboats pushing barges filled with waste sludge from the Champion Paper Co. in Pasadena, Texas, to the pit location. 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 have contained high levels of dioxins and other chemicals as a result of the chlorine bleaching process then in use, the waste pits are thought to have contributed to the elevated levels of dioxins found in the San Jacinto River and Upper Galveston Bay [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 San Jacinto River, Houston Ship Channel, and Upper Galveston Bay. As a result of excessive dioxin concentrations found in these samples, TDH issued a seafood consumption advisory for catfish and blue crabs caught from these waters in September of 1990. 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 Houston Ship Channel or the Upper Galveston Bay [4]. Since 1990, TDH/DSHS has conducted five additional health consultations/risk characterizations for the consumption of seafood from the Houston Ship Channel and Upper Galveston Bay, all of which have recommended the continuance of the previously issued advisory on the consumption of catfish and/or blue crabs [5-9]. The two most recent health consultations/risk characterizations [8,9] lifted the advisory on blue crabs but added an advisory on spotted seatrout from the Upper Galveston Bay and Lower Galveston Bay.

In July 1995, the Houston Ship Channel Toxicity Study reported unexplained, high concentrations of dioxins in sediment samples in the vicinity of the San Jacinto River where it flows under the I-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 Texas Commission on Environmental Quality (TCEQ) is responsible for ensuring that TMDLs are developed for impaired surface waters in Texas. The ultimate goal is to restore the quality of the impaired water bodies [11].

Because of the elevated levels of dioxins found in fish and crabs, the Houston Ship Channel system was placed on the §303(d) impaired surface waters list, and the TCEQ initiated a TMDL project [11]. In carrying out the dioxin TMDL project, the University of Houston collected hundreds of sediment, water, fish, and other aquatic life samples from 2002 through 2005 and analyzed them for various congeners of PCDDs and PCDFs [11]. The University of Houston also 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 what appeared to be a number of waste pits located in a sandbar in the San Jacinto River, immediately north of the I-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 in early 2007. Figure 3, Appendix B, shows the approximate locations where the site sediment samples were collected, 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 identified very high levels of dioxins in the sediments from the waste pits on-site.

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].

Numerous individual sediment samples collected under the Dioxin TMDL Project identified somewhat elevated levels of dioxins scattered over a much larger area throughout the San Jacinto River, Houston Ship Channel, and Upper Galveston Bay [3,11]. Because of their considerable distances from the site and their up-stream or up-tributary locations, most of these scattered samples appear to be unrelated to the SJRWP site.

In January 2010, the EPA posted warning signs and erected a fence to restrict site access, and released the Remedial Investigation/Feasibility Study (RI/FS) work plan. Shortly thereafter, they began the extensive field sediment sampling study, the shallow and deep groundwater assessment study, the fate and transport modeling assessment, and the bioaccumulation assessment.

Part of the EPA's RI/FS activities included the review of historical documents and aerial photographs of the area surrounding the site. These documents indicated that an additional "southern" impoundment had been constructed on the peninsula of land immediately across the highway from the primary site and that this area had also received paper mill waste for disposal in the mid-1960s.

In 2010, under a project to develop Biota-Sediment Accumulation Factors (BSAFs) funded by the Texas Environmental Health Institute (TEHI), Baylor University began collecting benthic samples in the vicinity of the site to more completely characterize dioxin concentrations in fish, crabs, and shellfish.

In November 2010 and January 2011, DSHS SALG collected 45 additional fish and crab samples from the San Jacinto River (10 from upstream, 25 from near the SJRWP site, and 10 from downstream) and tested them for arsenic, mercury, pesticides, polychlorinated biphenyls (PCBs), and dioxins. Eight out of ten samples collected upstream of the SJRWP site (near the US Highway 90 bridge) contained detectable levels of dioxins (average all 10 fish = 0.482 pg/g). Eighteen out of twenty-five samples collected near the site contained detectable levels of dioxins (average all 25 fish = 4.96 pg/g). Three out of ten samples collected downstream of the site (near the Lynchburg Ferry Crossing) contained detectable levels of dioxins (average all 10 fish = 1.49 pg/g).

DSHS and ATSDR released the public comment draft of the SJRWP Public Health Assessment document, and the public comment period began in Apr 2011 and ended in Jun 2011.

The EPA implemented a time critical removal action (TCRA) at the site, beginning in Feb 2011 and finishing in Jul 2011. Activities included placement of more extensive fencing, warning signs, and a remote camera surveillance system in the Texas Department of Transportation right-of-way adjacent to the waste impoundments north of I-10. Buoys, ropes, and signs were placed in the water around the perimeter of the site to prevent boat access to the impoundments. Vegetation was cleared from the site north of I-10, and trash and debris were cleared from the area beneath I-10. A truck turnaround area, access road, equipment laydown area, material storage area, and other features were constructed to allow for equipment staging and access to the waste impoundments. To stabilize the contaminated sediments in place, overlapping strips of geotextile fabric were laid down over the submerged pits of the eastern cell and were anchored in place by an armor cap (a 12-24 inch layer of mixed 2-12 inch diameter rocks). For the western cell of the impoundments, an additional geomembrane layer was laid down under the geotextile layer, and both were anchored in place by an armored cap similar to the eastern cell.

The Galveston Bay Foundation with funding from the Texas Coastal Management Program posted seafood consumption advisory signs in the area of the SJRWP and in numerous other locations where public access to the affected waterways was possible in Aug-Oct 2011.

Land and Natural Resource Use

The SJRWP site is located on the west bank of the San Jacinto River, just north of the I-10 Bridge. This area is approximately 2.5 miles north-northeast of the confluence of the San Jacinto River with the Houston Ship Channel, toward the eastern end of the Port of Houston. The Port of Houston is 25 miles long and includes both public and private facilities. In the year 2006, approximately 211.7 million tons of cargo moved through the port and 7,550 vessel calls were recorded in which vessel captains call the Port Authority for assistance in navigating the Houston Ship Channel [15]. Port Authority facilities offer shippers water access to world markets and a link to 14,000 miles of United States intracoastal waterways. These waterways are 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 San Jacinto River and Galveston Bay offer recreational anglers and commercial shrimpers opportunities for boating and fishing access. The San Jacinto River State Park is open to public fishing and does not require a fishing license (see TPWD's website http://www.tpwd.state.tx.us/fishboat/fish/programs/familyfish).

Demographics

The nearest residential population is Channelview, Texas, located approximately ½ mile west of the SJRWP site. The city 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]. South of I-10 and east of the river, 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. 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). Channelview and Highlands are upstream from the site, and the only location in Lynchburg with access to the river (prior to the EPA's fencing activities) was immediately south of the I-10 Bridge. Baytown is approximately a mile southeast of the site and is separated from the main channel of the river by Black Duck Bay, Tabbs Bay, and Hog Island. Approximately 1,155 people live within 1 mile of the site and most of these are on the east side of the San

Jacinto River [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

Representatives from DSHS, TCEQ, and EPA visited the SJRWP site on December 18, 2007. At that time, the site was unfenced and easily accessible from the San Jacinto River by small boat. Approaching by vehicle from the west, the paved service road on the north side of I-10 ended at an unlocked, swinging-arm, metal "gate" approximately 400-500 yards west of the site. Beyond the gate, an unimproved dirt road paralleling I-10 allows somewhat closer vehicular access to within 100-200 yards of the site, depending on the vehicle. From there, a well-traveled foot trail led to the site and turned north among a grove of small trees. The wooded trail followed the crest of a low ridge (roughly 5-6 feet above river level and formed by the berm between the east and west pits) and then out to an open "point," surrounded on three sides by waters from the San Jacinto River. The river water overlying the two pits on the east side of the site appeared to be relatively shallow (1-4 feet deep) for 30-50 yards out from the berm. The west pit, being 3-4 feet above river level, was visible as a boggy area containing stagnant water, surrounded by small trees and thick undergrowth. The "point" and the trail leading to it were well-used and littered with trash, including 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 the nature of the litter, the north point appeared to be a popular fishing and limited picnicking location, and the shallow waters over the pits on the east side appeared to be conducive to wading. Figures 6-13, Appendix B, show various features of the site and the surrounding areas.

On October 14, 2009, a team from DSHS made a 2nd, follow-up visit to Channelview, Texas, to distribute educational materials about the fish consumption advisory and other contaminant exposure hazards related to the SJRWP. The team also met with staff from TCEQ and Baylor University for a tour of the SJRWP site. During the site visit, DSHS team members talked with a number of families who were fishing and wading in the San Jacinto River beneath the I-10 Bridge immediately downstream of the site and others who were fishing while squatting in 2-3 feet of water directly over the pits on the east side of the site. In addition to the verbal communications, the team distributed brochures explaining the hazards of eating fish caught from the Houston Ship Channel and San Jacinto River, especially for small children and women of child bearing age. The DSHS team also distributed brochures across the river at nearby R.V. parks, bait houses, and restaurants along South Main Street in Highlands, Texas. The following day, DSHS met with the Assistant Harris County Commissioner, Precinct 2, informed her of our plans to distribute informational brochures in the Channelview area, and left a box of brochures for her to distribute through her office. The team also visited the Baytown Health Department, Environmental Health Division, and left a stack of 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 and left a supply of brochures with the park rangers who agreed to distribute them to visitors planning to fish in the park. In total, the DSHS team distributed approximately 3,000 brochures and received a great deal of positive feedback from citizens, business owners, and county officials regarding our efforts to inform the public of the potential hazards from dioxin exposures.

The Galveston Bay Foundation with funding from the Texas Coastal Management Program posted seafood consumption advisory signs in the area of the SJRWP pits and in numerous other locations where public access to the affected waterways was possible in Aug-Oct 2011.

DSHS made a 3rd follow-up site visit in May 2011 to evaluate site activities related to EPA's TCRA and make PowerPoint presentation of the SJRWP Public Health Assessment document at a public meeting in Highlands, TX.

DSHS made a 4th follow-up site visit in Jan 2012 to attend a meeting of the Community Awareness Committee, and evaluate site conditions following completion of EPA's TCRA.

DSHS made a 5th follow-up site visit to attend a public meeting in Highlands in June 2012 and hand out information brochures about the site.

Community Health Concerns

Community health concerns, comments, and questions have been voiced by nearby residents at public meetings and through the Harris County Pollution Control Department. These comments or questions include the following:

Q1: *"My question is why water wells were not considered in the health risk factor. What was considered the 'immediate vicinity of the site?' I have learned the Highland neighborhood relies on household wells for their drinking water."*

A1: There a number of reasons why groundwater wells in Highlands should not be expected to be affected by contaminants from the San Jacinto River Waste Pits (SJRWP) superfund site. The dioxin wastes from the pits bind tightly to sediments, clays, and sands, so they are not free to move significantly with groundwater flow. Contaminants would have to pass down through over 300 feet of overlying clays and alluvial deposits and then migrate a mile north to get down to the level where water wells in the Highlands area are screened (generally around 330-350 ft.). Compacted clays under areas with significant subsidence (as in the vicinity of the SJRWP site) form nearly an impermeable barrier to the downward passage of water. Groundwater flow through the Chicot and Evangeline aquifers is relatively slow – in the range of a few feet per year. Ground water in these aquifers generally flows toward the gulf and consequently away from Highlands which is north of and on the other side of the river from the waste pits. In the vicinity of rivers (such as the San Jacinto), the shallow groundwater from both sides of the river tends to flow toward the river and would not be expected to cross under the river, carrying contaminants to the other side (even if the contaminants were dissolved and could move freely with the groundwater).

The nearest residential neighborhood would be in Channelview, TX, approximately ½ mile west of the site. DSHS does not consider this neighborhood to be in the "immediate vicinity of the site." Highlands, TX, approximately ½ to 1 mile east or northeast of (and across the river from) the site would also not be considered to be in the "immediate vicinity of the site." For this PHA, water wells in either of these communities were not considered to have any significant possibility of dioxin contamination from the SJRWP site. Subsequent EPA sampling of shallow groundwater at a depth of 60 feet directly beneath the surface impoundments did not detect any measurable amounts of dioxins, thus confirming the validity of our initial assessments about groundwater.

Q2: *"I noticed that in the health assessment the issue of the San Jacinto River flooding its banks was not mentioned. I believe that Highlands is in a 10 year flood plain. Since flood waters can contaminate wells, would this not be a problem for homeowners?"*

A2: It is true that parts of Highlands are in the 10-year flood plain. However, during most flooding events, massive amounts of water are flowing in from the entire catchment area of the San Jacinto River. These waters are trying their best to get into the river and from there into the gulf, the area of lowest elevation. When too much water has fallen in Highlands and farther up-stream, the river channel is not big enough to carry the volume, and water "backs up" causing the area to flood. The water is still gradually working its way down-stream (and not really "backing up" or flowing in reverse), it just can't drain out of the area fast enough to keep the water from building up in the flood plain areas. The only times that water may move somewhat in a retrograde direction is during unusually high tide events and, to a far greater extent, during storm surges from hurricanes, such as Hurricane Ike in 2008. During these events, massive amounts of salt water from the gulf are "piled up" on the east side of the hurricane as a result of the counter-clockwise rotation of the hurricane-force winds. When the gulf waters are piled up in front of a river channel, huge volumes of gulf water flow retrograde up the river causing severe flooding up-stream.

Clearly some of the contaminated sediments from the site may have become suspended in the storm-surge waters. However, it is also clear that there would be massive dilution of these suspended and contaminated sediments into millions (or possibly billions) of gallons of salt water, the vast majority of which made its way back into the gulf as the storm-surge subsided. The minor amounts of residual, highly-diluted, contaminated sediments still would have to percolate down through 350 feet of sand and clay which would act as a filter, effectively removing any significant trace of sediment from the water that eventually winds up in the aquifer where it could be accessed by someone's well. (Remember, dioxins bind tightly to sediments and therefore do not move well horizontally or vertically through a sand and clay aquifer). Consequently, it is just not plausible to imagine significant amounts of sediments being washed out of the surface impoundments at the site and being transported a mile north and across the river to Highlands where they could get down into someone's well at concentrations high enough to be a health hazard. Thus DSHS does feel there is any significant likelihood that well water contamination (with dioxins) would be a problem for homeowners in Highlands. Fecal coliform (and other fecal micro-organism) contamination of wells from nearby flooded sewers, septic systems, and animal wastes are a far more likely health risk during such floods.

Q3: *"In previous community meetings, residents have vocalized concerns of negative health impacts including increased cancer risk from living near the SJRWP."*

A3: These concerns are quite understandable, and this is precisely why DSHS has gone to such great lengths to identify all the potential exposure pathways whereby individuals may be, in fact, exposed to site contaminants. It is important for everyone to understand that proximity to the SJRWP site does not in itself imply exposure to 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 for this site. Groundwater was not a significant pathway because shallow groundwater is brackish and non-potable, contaminants are tightly bound to sediment and do not migrate to deeper aquifers or horizontally to strata under neighborhoods in Channelview or Highlands where they might get into someone's well water. Consequently, living near the SJRWP site has no bearing on cancer risks or other negative health impacts, unless the individual (in addition to living near the site) also consistently engages in one of the identified risky behaviors such as regular oral ingestion of site sediments, regular skin contact with site sediments, or regular ingestion of fish or crabs from the river or ship channel.

Q4: *"The residents have also expressed concerns regarding contact with contaminated water via flooding, recreational use of the river as well as eating contaminated fish and crabs."*

A4: As part of the Dioxin TMDL Project, the University of Houston collected over 150 water samples from the San Jacinto River, Houston Ship Channel, and Upper Galveston Bay in 2002-2004. The highest dioxin concentration among these data was 3.09 pg TCDD TEQ/L (1 picogram or pg is one millionth of one millionth of a gram). Even if a person was drinking 2 liters of that water per day for a 70 year lifetime, the possible increased risk for cancer would be only 6.6×10^{-6} (far below any level of concern). Periodic swimming or other recreational use of the river would produce far lower levels of exposure than drinking 2 liters of the water per day. Of course fish and crabs tend to accumulate dioxins in their tissues, thus delivering a much higher dose to people who consume them. Fishing advisories have been in effect for these waters for years, recommending that men should eat no more than one 8-ounce meal of catfish or blue crabs from this area per month and that women of child-bearing age and children should not consume any catfish or blue crabs from the San Jacinto River near I-10, the Houston Ship Channel, or the Upper Galveston Bay.

Q5: *"Residents along the San Jacinto River at the community meeting have also expressed concern that dust from the sediment (possibly at low tide or time of drought) where soil that has been contaminated may blow from the site and possible expose residents and/or fishermen and that needs to be more fully explained."*

A5: Prior to the EPA's recent TCRA, the site was covered with thick vegetation, small trees, and heavy undergrowth. Even at the lowest tide (typical diurnal tidal range 1-2 feet) and under drought conditions, the eastern impoundments were covered with muddy sediments (during higher tides they were covered with water) and the western impoundment was boggy and covered with heavy vegetation. The trail along the ridge between the eastern and western impoundments was hard-packed mud with very low likelihood of dust generation even in windy conditions. Consequently, inhalation of blowing dust from the site was not considered to be a significant pathway of exposure either for distant residents or for fishermen at the site. For additional discussion of this issue, see Appendix E, Response 1-6C.

Q6: *"We know that children eat more food, drink more fluids, and breathe more air in proportion to their body weights than do adults, we believe that the Health Assessment should consider the childhood obesity issue and possibly reevaluate the consumption rate for children."*

A6: While it is true that children eat mote food, drink more fluids, and breathe more air in proportion to body weight than do adults, this factor has already been taken into account by the method used by DSHS to calculate the child's fish consumption rate. This rate was calculated as the adult fish consumption rate multiplied by the child's body weight to the 3/4th power divided by the adult's body weight to the 3/4th power. For example, given an adult weighing 70 kg, eating 8 ounces of fish per day, and a child weighing 35 kg (50% of the adult's weight), the child's fish consumption rate is calculated as 4.76 ounces per day (59% of the adult's fish consumption). Remember too that if a child is 20% overweight and that child eats 20% more fish than the normal-weight child, the exposure dose, in mg/kg body weight, is the same as for the normal-weight child. This occurs because you have multiplied both the numerator and the denominator of the exposure dose calculation by a factor of 1.2. The SJRWP PHA is already replete with conservative assumptions, and the fish consumption rate for children and adults in the Subsistence Fisherman Scenario is a prime example. While the consumption rates used for this scenario in the PHA are plausible (because they lie somewhere between the 95th and 99th percentile for fish consumption), they are higher than any average fish consumption rate quoted in the EPA's Exposure Factors Handbook. Consequently, we feel that there is no need or justification for an additional, arbitrary, fish-consumption factor for obese children. (How many children like or eat that much fish anyway?) Recalculating the risk numbers, based on an even higher fish consumption rates for children, would not change the conclusions or recommendations of the SJRWP PHA.

Q7: *"PCDDs and PCDFs have very low volatility and are tightly bound to sediment. However, drought and low tide conditions create inviting fishing locations in the riverbed which may expose fishermen to sediment-bound contamination."*

A7: Since the site is in a tidal area of the river, the riverbed is not really ever exposed (and this is not where the highest dioxin levels were found). Before the EPA's Time Critical Removal Action, water standing over the eastern impoundments, along the western bank of the river, would indeed have receded and exposed more of the muddy sediments covering the pit area during low tides (typical diurnal tidal variation 1-2 feet). However, our basic assumption is that people who visit the site are being exposed to those sediments anyway, so this wouldn't change any of the numbers, conclusions, or recommendations for this PHA.

Q8: *"Wind gusts may also carry sediment bound contaminants to nearby residential properties. We recommend that the Health Assessment consider these issues more fully."*

A8: This concern is very similar to **Q5**, and the response is given in **A5** above.

Q9: *"In cases such as this, cancer cluster analysis or a questionnaire regarding health disparities can be very helpful. A request for a cancer cluster analysis was made by residents at the last community meeting. Information gained as a result of such an analysis can provide relevant information to the residents and possibly abate concerns."*

A9: This issue is addressed in the section titled "Health Outcome Data" above. It is also addressed in much greater detail in Appendix E, Response 1-8B.

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]. Once the site has been more thoroughly characterized in the RI/FS phase of the superfund process, it is likely that other hazardous chemicals will be identified in the pits along with the PCDDs and PCDFs.

Methods Used in this Public Health Assessment

Quality Assurance/Quality Control (QA/QC)

In preparing this report, DSHS and ATSDR relied on data provided by the TCEQ in the HRS Documentation Record for the site (sediment samples) and DSHS SALG fish and crab sample results [2, 4-9]. The SALG followed appropriate QA/QC methods as outlined 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]. The University of Houston also followed appropriate QA/QC methods in their TMDL Project for the evaluation of dioxins in the San Jacinto River, Houston Ship Channel, and Upper Galveston Bay waterway system [11]. Thus, adequate QA/QC procedures were followed with regard to data collection, chain of custody, laboratory procedures, and data reporting.

Toxic Equivalency (TEQ) for Mixed Dioxins

The PCDD/PCDF congeners with dioxin-like toxicity are often found in complex mixtures in the environment. For the purpose of this PHA, we have calculated the total TCDD TEQ for each sediment or fish tissue sample, based on the unique mixture of PCDDs and PCDFs present in the sample. This procedure involves multiplying the concentration of each congener by its individual toxicity equivalency factor (TEF) and summing these products for each congener present in the sediment or biota sample (see Table 3, Appendix C, for a list of PCDD/PCDF congeners with TCDD-like toxicity 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).

Exposure Pathway Analysis

High concentrations of PCDDs and PCDFs from paper mill waste were found in soil and sediments contained in three large surface impoundments at the SJRWP site. The land on which the pits are located subsided over the years, and two of the pits are partially submerged under a few inches to a few feet of water from the San Jacinto River. Prior to the EPA's remedial investigation & feasibility study activities, the site was not fenced and there was clear evidence that people had been frequenting the site for years for fishing and wading. Consequently, on-site oral and dermal exposures to contaminated sediments are considered to be significant past exposure pathways. During high water flow events, some of the site contaminants are likely to have washed downstream. Thus, off-site oral and dermal contacts with contaminated sediments from the site are also considered to be potential past, present, and future exposure pathways.

Elevated concentrations of dioxins were measured in fish caught near the SJRWP site and fishing advisories have been issued by DSHS over the years. Consequently, fish and crab consumption are considered potential past, present, and future pathways for exposure to dioxins, whether they came from the SJRWP site or not.

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 to be a significant pathway of exposure for this site. Additionally, groundwater was not considered to be a significant pathway of exposure because dioxins bind tightly to sediments and do not migrate down through saturated sands and clays to get into deeper potable groundwater, shallow groundwater is brackish and non-potable, and there are no groundwater wells in the immediate vicinity of the site. Finally, the probability of regular ingestion of surface water from nearby waterways is low because these waters are brackish and non-potable. Consequently, 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.

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 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 CVs to assure protection of the immature system [29]. This comes in the form of an additional uncertainty factor (typically 10). Although comparison values used for assessing the probability of cancer do not contain uncertainty factors as such, conclusions drawn from those probability determinations do represent 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), 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 making recommendations regarding the maximum quantity of a potentially contaminated fish species a person should consume, the DSHS Seafood and Aquatic Life Group (SALG) calculates an EMEG representing a fish-tissue concentration for each contaminant of concern (usually expressed as milligrams contaminant per kilogram fish). This CV amounts to an EMEG for the contaminant in fish tissues. For carcinogenic contaminants, a fish tissue concentration is calculated which would produce a possible cancer risk of 10^{-4} (one excess cancer case out of 10,000 people exposed), 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 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.

As a result of excessive dioxin concentrations found in the fish and crab samples collected near the SJRWP site, TDH issued a seafood consumption advisory for catfish and blue crabs caught from these waters in September of 1990. 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 Houston Ship Channel or the Upper Galveston Bay [4].

Comparison Values

ATSDR, EPA, and a few state health or environmental agencies have identified lists of hazardous chemicals that are commonly identified at superfund or hazardous waste sites, or are being emitted from active industrial facilities. To help evaluate the significance of exposures to these substances, scientists at the various agencies review the toxicologic and epidemiologic literature and derive comparison values (CVs) for the various substances of toxicologic concern. CVs can be categorized as either *health guidelines* (expressed as absorbed doses in humans) or *environmental guidelines* (expressed as substance concentrations in various environmental media such as air, soil, or drinking water). These substance-specific CVs, which are intended to serve as screening levels, are used by ATSDR health assessors and other responders to identify contaminants and potential health effects that may be of concern at hazardous waste sites.

Health Guidelines

Health guidelines for many of the substances commonly encountered at hazardous waste sites or other locations in the environment are derived for specific routes of exposure (e.g., inhalation, oral ingestion, or dermal absorption). The ATSDR derives both oral Minimal Risk Levels (oral MRLs) and inhalation Minimal Risk Levels (inhalation MRLs), but does not, as yet, derive MRLs for the dermal absorption exposure route. Oral MRLs are expressed in terms of dose, with units of milligrams per kilogram body weight per day (mg/kg/day), and inhalation MRLs are expressed as concentrations of a contaminant in air, generally with units of micrograms per cubic meter ($\mu g/m^3$) but sometimes expressed in parts per billion (ppb). MRLs may be derived for up to three different exposure durations, acute (1–14 days), intermediate (>14–364 days), and chronic (365 days or longer). The MRL is an estimate of the daily human exposure to a hazardous substance that is likely to be without appreciable risk of adverse non-cancer health effects over the specified duration of exposure.

Using similar methodology, the EPA derives a CV for oral exposures called the *reference dose* (RfD) for many of the substances listed in their Integrated Risk Information System (IRIS) database. They also derive a CV called the *reference concentration* (RfC) for evaluating inhalation exposures to airborne contaminants. The EPA's RfD is roughly equivalent to ATSDR's chronic oral MRL, and the RfC is roughly comparable to the chronic inhalation MRL. The RfD is an estimate (with uncertainty spanning perhaps an order of magnitude) of a daily oral exposure to the human population (including sensitive subgroups) that is likely to be without an appreciable risk of deleterious (non-cancer) effects during a lifetime. Likewise, the EPA's RfC is an estimate (with uncertainty spanning perhaps an order of magnitude) of a continuous inhalation exposure to the human population (including sensitive subgroups) that is likely to be without an appreciable risk of deleterious effects during a lifetime.

RfDs and MRLs are based on the most sensitive substance-induced end point (or critical effect) considered to be of relevance to humans. These end points include 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. ATSDR does not use serious health effects (such as irreparable damage to the liver or kidneys, or birth defects) as a basis for establishing

MRLs. Exposure to a level above the MRL does not necessarily mean that adverse health effects will occur.

RfDs and MRLs can be derived from a no observed adverse effect level (NOAEL), a lowest observed adverse effect level (LOAEL), or a benchmark dose (BMD), with uncertainty factors applied to reflect limitations of the data used. Uncertainty factors (generally with values of 3 or 10) may be used:

- for extrapolation of the dose from an animal study to a human equivalent dose,
- to account for the possibility of sensitive human sub-populations,
- for the use of a minimal LOAEL instead of a NOAEL, and
- for database deficiencies.

Total uncertainty factors for MRLs or RfDs (all uncertainties combined) generally range from 3 up to 1,000, depending on the substance and the apparent reliability of the study and quality of the data upon which the MRL or RfD was based.

Environmental Guidelines

To facilitate the evaluation of environmental sampling results in various contexts, ATSDR has developed a family of CVs called environmental guidelines for the more frequently encountered hazardous substances. Environmental guidelines are calculated for specific media (soil, drinking water, and air) using the various health guidelines discussed above. Depending on the availability of health guideline values, environmental guidelines for adults and children may be calculated for chronic, intermediate, or acute duration exposures. The calculation requires making certain assumptions about the average daily intake of soil, drinking water, or air and 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).

Environmental guidelines are frequently referred to as "screening 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. If these screening 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). EMEGs and RMEGs are calculated so that, using the default assumptions about the food, water, or soil/sediment consumption rates, air inhalation rates, and body weight, the daily exposure dose (in mg/kg/day) is just equal to the MRLs or RfDs upon which they are based.

If the environmental guidelines are based on the EPA's chemical-specific cancer slope factors, they are called *cancer risk evaluation guides* (CREGs). In this case, the CREGs are calculated (again using default assumptions about media-specific consumption or exposure rates, body weights, and exposure durations) so that the calculated daily exposure dose (in mg/kg/day), multiplied by the cancer slope factor, would produce a possible lifetime cancer risk of 1×10^{-6} (i.e., one additional cancer case out of one million people exposed over a 70-year lifetime) [1].

Use of Comparison 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 contaminants and the plausible, site-specific pathways and routes of exposure based on the media that are contaminated (e.g., dust, soil, sediment, sludge, ambient air, groundwater, drinking water, food product, etc.). Once the contaminants, affected media, and exposure pathways are identified, the most appropriate initial screening values can be selected from the list of available CVs. While it may seem reasonable to initially screen single point-in-time measurements against acute duration screening CVs, this screen may inappropriately eliminate contaminants whose peak values pose no acute exposure risks but whose average values may still exceed chronic exposure guidelines.

Consequently, for a first quick screen, the maximum detected concentrations of the various contaminants in the environmental media of interest are generally compared with the most conservative (i.e., lowest) published environmental screening value for each contaminant. If the maximum concentration exceeds the contaminant's lowest screening CV, then the substance requires a more in-depth evaluation using site-specific exposure scenarios and health guideline screening. If the maximum contaminant concentration in a particular medium is below the contaminant's screening CV, then exposure to the contaminant is not expected to result in adverse health effects for that route of exposure. However, it may be premature to eliminate it from further consideration if any of the following may apply:

- Additional exposures may be occurring through other affected media, in which case cumulative exposures through multiple pathways should be considered and evaluated,
- Community concerns have focused on the specific contaminant, in which case the substance should be included for further evaluation and discussion,
- Special populations may be disproportionately affected through increased susceptibility or higher-than-normal exposures (e.g., children, pregnant women, a subsistence fishing population, or a population with greater dependence on home-grown fruits and vegetables) or
- Multiple chemicals with similar modes of action, and/or the same target organ are present at the site, in which case aggregate exposures to multiple chemicals should be considered and evaluated.

Since the lowest screening CV is usually 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 minimum screening CV 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 CVs, intermediate-term average concentrations are exceeding intermediate-exposure-duration CVs, or long-term average concentrations are exceeding chronic-exposure-duration CVs.

Once the substances requiring further consideration have been identified, the concentrations to be used in exposure dose calculations must be chosen. Some health assessors prefer using the very conservative, maximum contaminant level; others prefer using the mean value, the upper

95% confidence limit on the sample mean, or the geometric mean value. While the maximum substance concentration was appropriate to use in the initial screening, using this value alone in the secondary screening analysis will in most cases significantly over-estimate the true risks associated with exposures at the site. Some health assessors have advocated using the geometric mean because many environmental data sets appear to have a lognormal distribution. However, people exposed over an extended period of time are going to be exposed to high values and low values as well, and thus they are exposed to the over-all average concentration, not the geometric mean concentration. A more balanced approach (and the one used in this PHA) would be to be to use the mean concentrations to represent the central tendency exposures, but to pair it with the maximum concentrations, thereby representing the reasonable maximum exposure as well.

Next, exposure scenarios (taking into consideration all the site-specific factors, special populations, multiple media, etc.) can be developed and used to calculate the anticipated exposure doses for comparison with the health guideline doses (RfDs or MRLs). This comparison is typically done through calculation of a value called the Hazard Quotient (HQ) which is the ratio of the calculated exposure dose for a particular substance and scenario to the health guideline dose for that substance (see Appendix D). If the HQ is less than 1.0, then the exposure dose does not exceed the health guideline dose, and adverse health effects from the exposure would not be expected to occur. If the HQ is greater than 1.0, then the calculated exposure dose exceeds the health guideline dose, and there is a possibility of adverse health effects associated with the exposure. However, RfDs and MRLs should not be thought of as sharp dividing lines between "safe" and "unsafe" exposure doses. We can be reasonably confident that exposures at the RfD or MRL dose are not likely to produce any adverse effects over the specified duration of exposure. However, when the exposure dose begins exceeding the RfD or MRL (HQ > 1.0), our confidence in the likely freedom from adverse effects diminishes. When the HQ is greater than or equal to the uncertainty factor used in deriving the health guideline dose, exposures may well be close the levels 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 from the original study was based on the study LOAEL).

If multiple media are affected at the site and/or multiple routes of exposure are possible, scenarios for each exposure pathway or route should be developed and HQs for each pathway or route should be calculated. To evaluate simultaneous exposures through multiple pathways or routes, the HQs for each are summed to give a value called the Hazard Index (HI) (see Appendix D). If the HI exceeds 1.0, then there is a possibility that the combined exposure may produce adverse health effects for some sensitive individuals. If the HI is less than 1.0, then it is unlikely that the combined exposure would be sufficient to produce adverse health effects in an exposed population.

If the substance is a carcinogen, the calculated exposure doses are multiplied by the substance-specific oral cancer slope factor and any additional exposure factors (to account for less than 24 hours per day, less than daily, and/or less than lifetime exposures). The resulting possible cancer risk estimates for the exposures are compared with the acceptable range of risks (typically 10^{-4}–10^{-6}).

Comparison Values for the SJRWP Site

The oral MRL values were calculated from original study data and uncertainty factors presented in the MRL Worksheets of the Toxicological Profile [18]; the resulting values were rounded to three significant digits and are listed below. For the estimated dermal MRL values, DSHS assumed that a dermally absorbed dose would have the same potential for producing adverse effects as an orally absorbed dose of the same magnitude. With these caveats, the following health guideline CVs were used for calculating oral and/or dermal exposure doses for evaluating possible cancer risk estimates and non-cancer HQs and HIs for the various SJRWP exposure scenarios:

- Chronic Oral MRL 1.2×10^{-9} $mg_{TEQ}/kg_{BW}/day$
- Intermediate Oral MRL 2.33×10^{-8} $mg_{TEQ}/kg_{BW}/day$
- 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} $mg_{TEQ}/kg_{BW}/day$
- TCDD Oral Slope Factor 150,000 $(mg_{TEQ}/kg_{BW}/day)^{-1}$
- TCDD Dermal Slope Factor 300,000 $(mg_{TEQ}/kg_{BW}/day)^{-1}$

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 soils or sediments; 2.) dermal absorption of contaminants through skin contact with soils or sediments; and 3.) ingestion of fish or crabs containing elevated levels of contaminants from the site. For comparison purposes, the PHA also evaluates 208 sediment samples collected from other locations in the San Jacinto River, Houston Ship Channel, and Upper Galveston Bay waterway system by the University of Houston under the TMDL Project. TCDD TEQ values are calculated from the various PCDD/PCDF concentrations measured in each sample, and these values are used to estimate the risks from oral and dermal sediment exposures and fish or crab consumption at these comparison locations.

Oral and dermal exposure levels for individuals fishing at the SJRWP site and other locations in the San Jacinto River, Houston Ship Channel, and Upper Galveston Bay waterway system are unknown. Consequently, on the basis of professional judgment, knowledge of the site, and pathway analysis, DSHS 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 represents people who fish frequently and rely on fish for a large part of their diet. For this scenario, we have assumed the person fishes at the site 5 days per week, 52 weeks per year, for 30 years (from ages 20 through 50). We have also assumed the fisherman gets contaminated soils or sediments on his or her hands and forearms, leading to both dermal and oral exposures.

The second scenario is that of the **weekend fisherman** who fishes at the site 1 day per week, 52 weeks per year, for 30 years (from ages 20 through 50). We have also assumed the fisherman gets contaminated soils or sediments on his or her hands and forearms, leading to both dermal and oral exposures.

The third scenario is that of the **sporadic fisherman** who fishes at the site 12 times per year, for 15 years (from ages 20 through 35). This fisherman is also assumed to get contaminated soils or sediments on his or her hands and forearms, leading to both dermal and oral exposures.

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 get contaminated soils or 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).

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 get contaminated soils or 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).

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 get contaminated soils or 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).

Sediment ingestion rates for each site visit were assumed to be 200 mg/day for children ages 3 through 5 years. After age 5, the sediment ingestion rates were assumed to decrease linearly to 100 mg/day by age 20. For adults, sediment ingestion rates were assumed to remain constant at 100 mg/day from ages 20 through 50 years.

Under all six scenarios, it is assumed that dioxin-contaminated fish and/or crabs are caught during each visit and are later eaten, leading to additional oral dioxin exposures. The assumptions employed in calculating the various risk estimates for this health assessment should be considered “conservative” to “extremely conservative.” The highest exposure group is intended to represent the reasonable maximum exposure (RME) for the site and should not be construed to represent any existing population or group of people (known or suspected) who have frequented the site.

Cancer Risk Estimates and Exposed Population Calculations

In this PHA document, possible cancer risk estimates are presented in scientific notation, with values rounded to three significant digits (e.g., calculated value = $1.25384534528542 \times 10^{-5}$; displayed value = 1.25×10^{-5}). The tables in Appendix C, showing possible cancer risk estimates, have additional columns labeled “Ca Odds (Ca Risk)$^{-1}$” which are defined in this PHA as the simple reciprocals of the un-rounded cancer risk estimates. Ca Odds values are rounded to the nearest whole number in the tables and represent the size of an exposed population necessary to be likely to see one additional cancer case above background rates over the specified duration of exposure. Any apparent discrepancy between the risk estimate and its corresponding Ca Odds number is due to the different degree of rounding employed in the two numbers.

Results and Discussion

Toxicological Evaluation of PCDDs/PCDFs

Sources and Production

Dioxins and dioxin-like compounds 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 inadvertently released into the environment generally originate as 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 and brush fires, structure fires, and medical or municipal waste incineration. 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 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) TCDD TEQ/day] [18]. Foods that contribute most to the total daily dietary intake of dioxins include pork, beef, chicken, and eggs (66.1 pg TCDD TEQ/day); dairy products (42 pg TCDD TEQ/day); and fish (7.8 pg TCDD 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 TCDD TEQ/day. Additional but minor sources of exposure for the general population include breathing ambient air containing low levels of dioxins (2.2 pg TCDD TEQ/day), ingesting small amounts of soil containing low levels of dioxins (0.8 pg TCDD TEQ/day), and drinking water containing low levels of dioxins (0.008 pg TCDD TEQ/day). For some individuals, additional exposures to dioxins may occur through skin contact with herbicides and pesticides [e.g., 2,4,5-T or pentachlorophenol (PCP)]; oral or dermal contact with contaminants at hazardous waste site containing dioxins; and occupational exposures at paper and pulp mills, wood treatment facilities using PCP, or municipal, medical, or hazardous waste incinerators [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/g. In the US general population with no known occupational exposures to dioxins, the mean whole blood level (lipid basis) ranged from 15.1–58.0 pg TCDD TEQ/g [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].

Non-Cancer Effects of Dioxin Exposure

Numerous instances of occupational and environmental exposures to dioxins have been studied and reported in the toxicological literature. In these studies, the most frequently noted and readily diagnosable health effect in people exposed to excessive amounts of dioxins is chloracne – a 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 levels of dioxins include excessive body hair, skin discoloration, and other skin rashes. Based on the lipid-adjusted serum dioxin levels in exposed individuals with clinical cases of chloracne, this effect generally occurs only when lipid-adjusted serum levels exceed 1,000 parts per trillion (ppt). Because of individual differences in sensitivity, some individuals do not exhibit any signs of chloracne until lipid-adjusted serum levels exceed 10,000 ppt or more. The average lipid-adjusted serum dioxin level in general US population is approximately 6.2 ppt, and the average daily intake of dioxin is approximately 47 picograms per day (pg/day) [18]. Consequently, we would expect to see chloracne in a population only if their exposure rates were in the range of 160–1,600 times background exposure rates.

Neurologic effects of dioxin exposures include lassitude, weakness of the lower limbs, muscular pains, sleepiness or sleeplessness, increased perspiration, loss of appetite, headaches, peripheral neuropathy (a form of peripheral nerve damage), abnormal reflexes, altered nerve conduction velocity, loss of libido, and sexual dysfunction. Also, men who are exposed to high levels of dioxins appear to be less likely to father boys. Neurodevelopmental delays and neurobehavioral effects of dioxin exposure include neonatal hypotonia and poorer performance on neurobehavioral tests [18].

Exposures to high levels of dioxins in the environment may trigger a clinical porphyria cutanea tarda in persons with an underlying genetic abnormality of uroporphyrinogen decarboxylase.

Also, exposure to high concentrations of dioxins may cause long-term alterations in glucose metabolism, increased incidence of Type 2 diabetes, subtle changes in thyroid function, increased susceptibility to infections, and/or mild transient hepatotoxicity (liver damage) [18].

In certain animal species, such as the Hartley guinea pig, 2,3,7,8-TCDD is especially harmful and can cause death after a single, relatively low-dose exposure [i.e., LD_{50} doses[3] 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 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].

It should be noted that none of the preceding adverse human or animal health effects have been reported – or are suspected to have actually occurred – in individuals as a result of contact with contaminants from the SJRWP Superfund site. Even in out worst-case scenario, exposures at this site are below the levels that are likely to produce any significant risk of clinically apparent adverse effects such as chloracne. We have included this discussion of adverse effects reported at doses much higher than those expected at the SJRWP site only in the interest of illustrating some of the toxicologic properties of dioxins for highly exposed individuals. For the range of exposures covered by our defined scenarios, we would not expect any observable effects in isolated individuals. Any effects in this exposure range are extremely subtle and could be indirectly inferred only through careful study of a very large exposed population.

Cancer Effects of Dioxin Exposure

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. Cancer health effects that are suspected, but not yet confirmed to be associated with dioxin exposures in humans include soft-tissue sarcoma, non-Hodgkin's lymphoma, respiratory cancer, prostate cancer, and multiple myeloma (malignant tumor of the bone marrow).

Numerous animal studies have also suggested that exposure to 2,3,7,8-TCDD increases the risk of cancer in animals. Cancers seen in animal studies include thyroid follicular cell adenoma, hepatic neoplastic nodules, hepatocellular carcinoma, ear duct carcinoma, lymphocytic leukemia,

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

kidney adenocarcinoma, peritoneal malignant histiocytoma, skin angiosarcoma, and Leydig cell adenoma.

The National Institute of Environmental Health Sciences' National Toxicology Program (NTP) has determined that 2,3,7,8-TCDD may reasonably be anticipated to cause cancer in humans and thus has 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 and 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 with 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 San Jacinto River, Houston Ship Chanel, and Upper Galveston Bay, the University of Houston collected 210 sediment samples from 84 different locations throughout the San Jacinto River, Houston Ship Channel, and Upper Galveston Bay 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 San Jacinto River, Houston Ship Channel, and Upper Galveston Bay waterway system. The 210 TMDL samples were measured for all 17 of the PCDD/PCDF congeners having TCDD-like toxicity.

DSHS SALG Fish and Crab Samples

As part of its routine fish consumption advisory follow-up activities for the Houston Ship Channel, San Jacinto River, and Upper Galveston Bay, DSHS traveled to the Houston area on four different occasions in February-April of 2004 to obtain additional fish samples. One of the sites visited was the tidal portion of the San Jacinto River immediately upstream of the I-10 Bridge. Seven fish (2 blue catfish, 2 spotted seatrout, 1 hybrid striped bass, and 2 red drum) and two blue crab specimens were collected from this location. The skin-off fish fillets were labeled, packaged, frozen, and hand-delivered to the DSHS laboratory for analysis. The blue crab samples were prepared by removing the top shell and apron of each crab, followed by removal of gills, viscera, and eggs from the body cavity. Crabs were split along the ventral line, half of each crab was used to form a composite for the site, and composites were packaged, labeled, frozen, and hand-delivered to the DSHS laboratory for analysis.

Grouping of Samples for Analysis

For the purpose of this analysis, the sediment samples were grouped into five geographical categories: 1) those collected on the SJRWP site (the two TMDL samples were grouped with the seven TCEQ HRS samples); 2) those collected down-stream from the SJRWP site in the San Jacinto River, Houston Ship Channel, or Upper Galveston Bay (59 samples); 3) those collected from the San Jacinto River in the immediate vicinity of the SJRWP site (31 samples); 4) those collected from the Houston Ship Channel above (west) of its confluence with the San Jacinto River (62 samples); and 5) those collected up-stream from the SJRWP site or up various tributaries to the San Jacinto River, Houston Ship Channel, or Upper Galveston Bay (56 samples).

TCDD TEQ Concentrations at the SJRWP Site & Background Locations

Of the nine sediment samples collected on the SJRWP site, only one (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 site samples 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 Area Waterways

For comparison purposes, DSHS reviewed TCDD TEQ concentrations measured at other locations in the San Jacinto River/Houston Ship Channel/Upper Galveston Bay 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), Houston Ship Channel 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 and Figures 4b and 6, Appendix B, for some of the elevated off-site sample locations).

Public Health Implications

Details of the possible cancer and non-cancer risk assessment calculations employed in this section can be found in Appendix D. The assumptions used in calculating the various risk estimates for this health assessment should be considered to range from "conservative" to "extremely conservative" and should not be construed to represent actual or likely risks for casual visitors to the site. Since possible cancer 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 possible cancer risk in half as well.

Evaluation of Cancer Risks

a. Oral Sediment Exposures

Using the parameters shown in Tables 10a and 10b, Appendix C, DSHS calculated the possible 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 possible cancer risks (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 possible 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, DSHS 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 that the preceding estimate is based on an extremely 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 possible lifetime cancer risk estimates of less than 10^{-4} for children of subsistence fishermen (average risk, all samples, 9.60×10^{-7}, range 1.77×10^{-8} – 2.05×10^{-5}). Qualitatively, DSHS would describe risks in this range as posing a **no increased lifetime risk** to a **low increased lifetime risk** for cancer.

Sediment sample number 11280 collected from the Houston Ship Channel approximately 7 miles upstream from its confluence with the San Jacinto River (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 a child of a subsistence fisherman (see Figure 4b, Appendix B, for the approximate sample collection location). Theoretically, this means that if 48,666 people were exposed to the levels of TCDD TEQ found at this location 260 days per year, for 47 years (starting at age 3), we would predict that one additional person might get cancer as a result of that exposure. Qualitatively, DSHS 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 theoretical 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, DSHS 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 the 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. DSHS categorizes these values as posing a **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

Using the parameters for dermal exposures shown in Tables 13a and 13b in Appendix C, we calculated the possible 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}) possible 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 to the average TCDD TEQ concentration of 15,594 pg/g would produce a possible lifetime risk of 6.78×10^{-4}. This means that if 1,475 people were exposed to the average concentration of TCDD TEQ found in on-site sediments for 260 days every 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, DSHS would describe a risk of this magnitude as posing a **moderate increased lifetime risk** for cancer (see Tables 14 and 15, Appendix C). Again, this estimate is based on an extremely conservative, worst-case scenario, and 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.

Only five out of 208 sediment samples from off-site locations were high enough to produce possible 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 $3.21 \times 10^{-8} – 3.72 \times 10^{-5}$). Dermal exposure at the maximum off-site concentration of 857 pg/g would produce a possible lifetime cancer risk of 3.72×10^{-5}. This means that if 26,846 people were exposed to the concentration of TCDD TEQ found at this location 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, DSHS 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 cancer 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 possible 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, DSHS 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. DSHS would categorize these values as posing a **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, DSHS calculated the possible 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). Regular fish and crab consumption of the species caught near the SJRWP site was found to pose unacceptably high possible 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 predominantly blue catfish (with a TCDD TEQ concentration of 6.04 pg/g) caught near the site. This means that if 728 people were routinely consuming blue catfish containing TCDD TEQ at the 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, DSHS would describe a risk of this magnitude as posing a **high increased lifetime risk** for cancer (See Table 17, Appendix C). As before, the preceding estimate is based on an extremely 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.

Consumption of a variety of fish and crab species, having the all-species-average concentration of 2.28 pg/g, would result in a possible increased risk of 5.18×10^{-4}. This means that if 1,931 people were routinely consuming fish containing TCDD TEQ at the levels found in fish 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, DSHS would describe a risk of this magnitude as posing a **moderate increased lifetime risk** for cancer.

See Table 17, Appendix C, for risk estimates and odds for consumption of other fish and crab species.

More realistic risks for fish and crab consumption exposures, 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. DSHS would categorize these risk estimates as posing **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 possible 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 possible 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, DSHS 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 an extremely 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. DSHS would categorize these risks as posing a **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 sporadic-fisherman and child-of-a-sporadic-fisherman scenarios, 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. DSHS would categorize these values as posing a **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).

Evaluation of Non-Cancer Risks

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 and HIs 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, DSHS 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, DSHS 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, DSHS 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, DSHS 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, DSHS 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, DSHS 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, DSHS 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, DSHS 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, DSHS 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, DSHS 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.

Uncertainties Associated with the Risk Assessment Process

Cancer and non-cancer risk assessments are inevitably affected by a broad range of uncertainties including:

- The contaminant point concentrations in sediment or fish used in the exposure dose calculations (e.g., maximum concentration vs. average concentration vs. upper 95% confidence limit on the average concentration)

- The quantity of sediment assumed to be ingested by a child or an adult during each visit to the site
- The percent of ingested sediment that is assumed to be absorbed into the body
- The quantity of sediment assumed to be adhering to each square centimeter (cm^2) of skin exposed to site sediments
- The number of cm^2 of skin assumed to be exposed to sediments from the site on each visit (what parts of the body are most plausibly exposed)
- The percent of the contaminant in contact with skin that is assumed to be absorbed into the body
- The quantity of fish or crabs assumed to be ingested by a child or an adult following each visit to the site
- The assumed body weight of each exposed individual
- The assumed frequency of visits to the site (days per week, days per month, days per year, etc.)
- The assumed number of years that the exposures continue.

DSHS has elected to calculate risk estimates for both maximum values and average values for sediments for the sake of completeness, but the public health implications are based on risk estimates derived from average values. For comparison purposes risk estimates were calculated for each fish or crab species based on their respective average concentrations. Public health implications were based on the assumption that people eat a variety of fish (whatever they happen to catch) over an extended period of time, which in turn implies that they would be exposed to the average concentration for all fish and crab species.

The quantity of sediment ingested per visit for children up to 6 years of age was assumed to be 200 mg. This value was assumed to decrease linearly to 100 mg per visit by age 18 and continue at that rate (100 mg per visit) for any adult exposures. These values are standard assumptions commonly used in ATSDR health assessments [1]. The oral absorption factor was assumed to be 50% for the absorption of TCDD TEQ out of sediments and 95% for the absorption of TCDD TEQ out of fish or crabs.

For dermal exposures we assumed a soil adherence factor of 1 mg/cm^2 and a dermal absorption factor of 3%. We assumed each child and adult would receive exposure to sediments on both hands and forearms on each visit to the site (alternatively, exposure of both hands and both feet would produce a similar exposed body surface area). We assumed that each child and each adult would eat a fish meal consisting of fish and/or crabs caught at the sight for each visit to the site. We assumed the size of each fish meal for a 70 kg adult would be 8 ounces of skin-off filets. For children we scaled the size of the fish meal down in proportion to the ¾th power of the body weight of the child with respect to the ¾th power of the body weight of the adult. Body weights for children and adults visiting the site were calculated for one-year or less age groups for children and five year or less age groups for adults derived from average body weights by age reported in the EPA Exposure Factors Handbook [21]. To account for variability in the frequency of visits to the site and years of exposure, we set up six different scenarios to cover a wide range of different plausible exposures.

Since the risk estimates are essentially linear at the exposure levels anticipated in this PHA, changing any one of the above parameters (except for body weight) changes the risk estimate by the same factor. For example, increasing the sediment ingestion rate by 20% (100 mg/day to 120 mg/day) would increase the risks from oral sediment ingestion by 20%. Likewise, decreasing any parameter by 20% (80% of the default parameter) decreases the resulting risk by 20%. Since risks are inversely proportional to the body weight, increasing the body weight by 20% decreases the resulting risk to 83.3% of its original value (1.0 ÷ 1.2 = 0.833). Likewise, decreasing the body weight by 20% increases the resulting risk by 25% (1.0 ÷ 0.8 = 1.25).

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 San Jacinto River, the Houston Ship Channel, and Upper Galveston Bay:

1. PCDDs and PCDFs were detected in sediments at the SJRWP site at concentrations that would cause unacceptably high possible 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, DSHS and ATSDR conclude 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 possible risks for cancer (greater than 10^{-4}) for all but the sporadic-fishermen-and-their-children exposure scenarios. Therefore, DSHS and ATSDR conclude 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, DSHS and ATSDR conclude 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. 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, DSHS and ATSDR conclude 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, DSHS and ATSDR conclude 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, 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.
7. Although two of the surface impoundments are inundated with water from the San Jacinto River and site contaminants were 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 dioxins from the SJRWP site. However, the extent of transport of dioxin-contaminated sediments off-site has not yet been adequately evaluated. Therefore, DSHS and ATSDR cannot conclude whether or not past or present off-site migration of dioxin-contaminated sediments could harm people's health.

Recommendations

DSHS and ATSDR make 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. The 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 replaced if they disappear or become defaced.
3. The current fishing advisory issued by the SALG at DSHS should continue in order to minimize exposures to potentially hazardous levels of dioxins 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 dioxins 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 dioxin measurements.
7. All sediments at the SJRWP site with significant levels of dioxins 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 San Jacinto River, 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 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 completed 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 dioxin concentrations in fish, crabs, and shellfish caught near the site.

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

10. In November 2010 and January 2011, DSHS SALG collected 45 additional fish and crab samples from the San Jacinto River (10 from upstream of the site, 25 from near the site, and 10 from downstream of the site) and tested them for arsenic, mercury, pesticides, polychlorinated biphenyls (PCBs), and dioxins. Eighteen out of twenty-five samples collected near the site contain detectable levels of dioxins (average all 25 fish = 4.96 pg/g). Upstream samples averaged 0.482 pg/g and downstream samples averaged 1.49 pg/g.

11. EPA began implementing the TCRA in Feb 2011 and had completed it by Jul 2011. The TCRA included the following activities:

- Placement of fencing, warning signs, and a remote camera surveillance system in the Texas Department of Transportation right-of-way adjacent to the waste impoundments north of I-10 to prevent access to the impoundments and to prevent shoreline access for fishing in adjacent areas on both the east and west sides of the San Jacinto River near the impoundments.
- Placement of buoys, ropes, and signs in the water around the perimeter of the site to prevent boat access to the impoundments.
- Clearing of vegetation from the site in the vicinity of the waste impoundments north of I-10 and clearing of trash and debris from the area beneath I-10.
- Construction of a truck turnaround area, a road, equipment laydown, and material storage area and other features for construction staging and equipment access to the waste impoundments.
- Placement of geotextile and armor caps on the eastern cell and placement of geomembrane, geotextile, and armored caps on the western cell of the impoundments north of I-10.

12. DSHS made a 3rd follow-up site visit in May 2011 to evaluate site activities related to EPA's TCRA and make PowerPoint presentation of the SJRWP Public Health Assessment document at a public meeting in Highlands, TX.
13. DSHS and ATSDR released the public comment draft of the SJRWP Public Health Assessment document, and the public comment period began in Apr 2011 and ended in Jun 2011.
14. During the public comment period, DSHS received comments from the following groups:

    Harris County Pollution Control Services Department
    101 South Richey, Suite H
    Pasadena, Texas 77506

    And

    Integral Consulting, Inc.
    411 1st Street South
    Seattle, WA 98104

15. The Galveston Bay Foundation with funding from the Texas Coastal Management Program posted seafood consumption advisory signs in the area of the SJRWP pits and in numerous other locations where public access to the affected waterways was possible in Aug-Oct 2011.
16. DSHS made a 4th follow-up site visit in Jan 2012 to attend a meeting of the Community Awareness Committee, and evaluate site conditions following completion of EPA's TCRA.
17. DSHS made a 5th follow-up site visit to attend a public meeting in Highlands in June 2012 and hand out information brochures about the site.

Actions Planned

1. DSHS staff will participate in EPA or TCEQ availability sessions or other community meetings to collect and address any new 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.

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

3. 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.

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

5. Follow up with DSHS SALG and/or Galveston Bay Foundation to insure that signs remain posted near the site warning the public not to eat fish or blue crab caught near the site.

6. The following EPA reports are scheduled for release:

    - EPA’s Baseline Ecological Risk Assessment report to be completed in June 2012.

    - EPA’s Baseline Human Health Risk Assessment report to be completed in Oct 2012.

    - EPA’s Remedial Investigation initial draft report to be completed in Oct 2012; approval of final report due in Feb 2013.

    - EPA’s Feasibility Study initial draft to be completed in Apr 2013; approval of final report due in Sep 2013.

    - Public comment period begins for proposed plan for remediation begins in Oct 2013.

    - In 2014, following a public comment period & public meeting, the EPA’s Record of Decision (ROD) will be issued which will select the final remedy for the waste pits & the entire SJRWP site.

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Appendices

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
I-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.

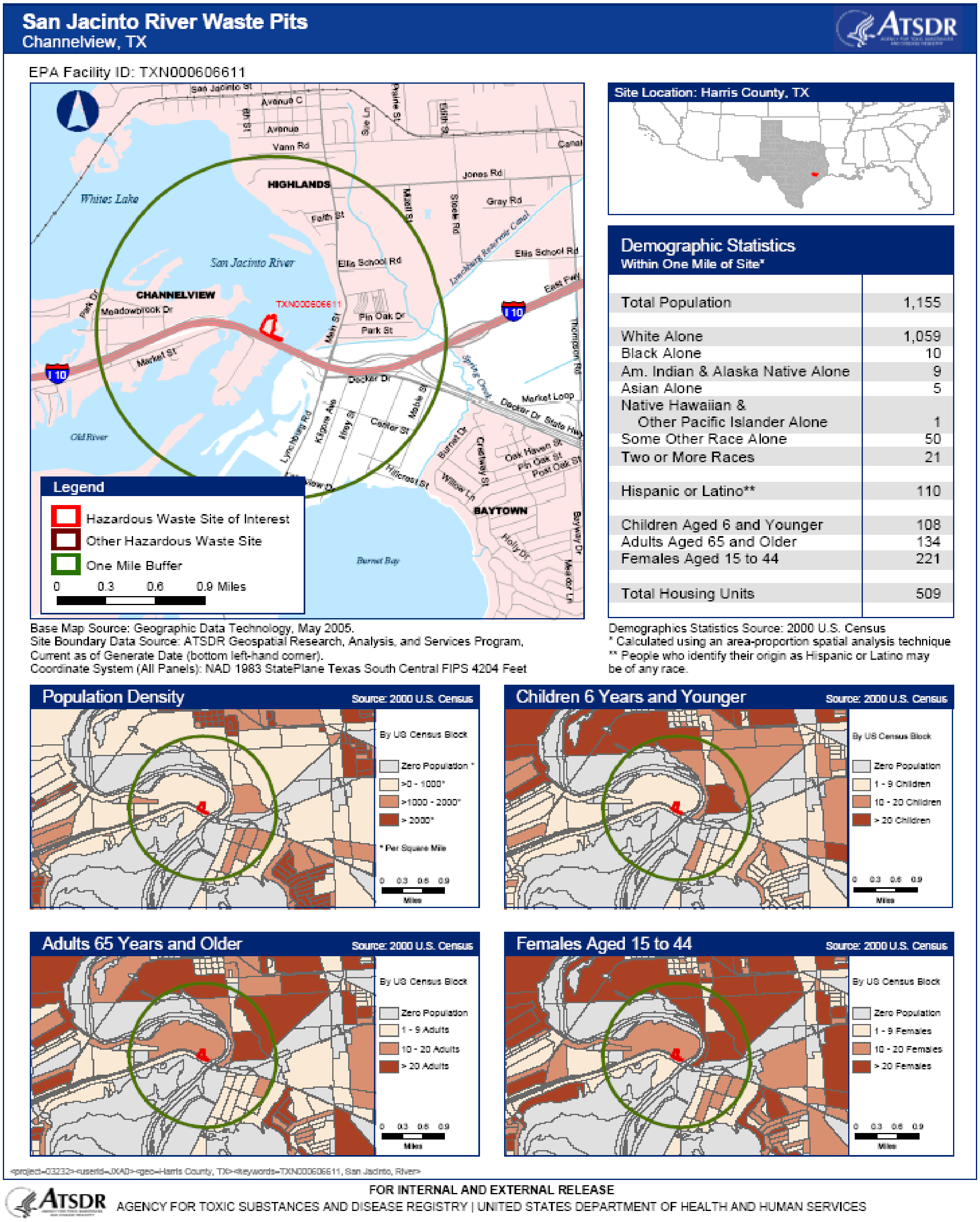


Figure 2. Aerial Photo of San Jacinto River Waste Pits Showing General Location

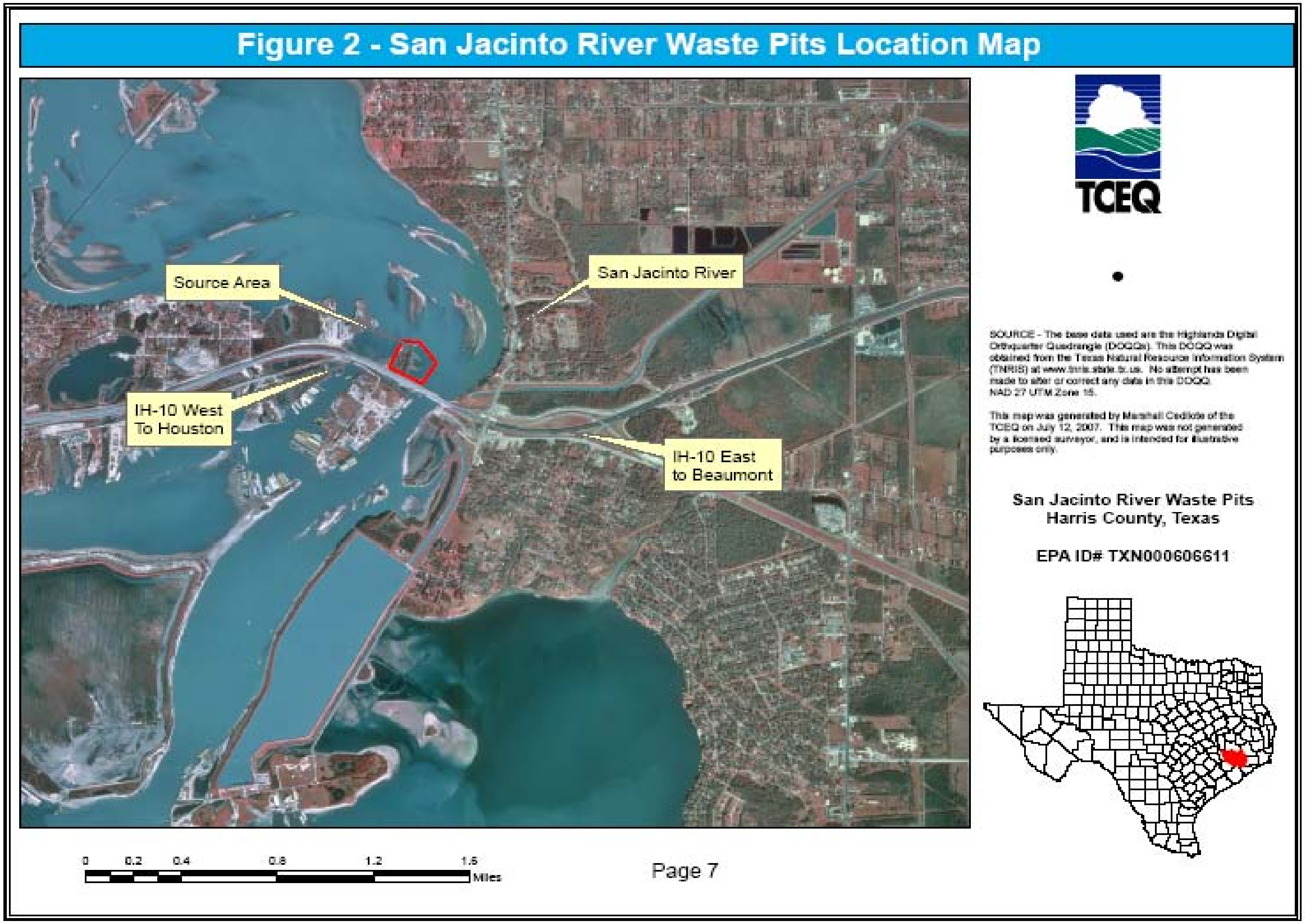


Figure 3. Aerial Photo of San Jacinto River Waste Pits, Sediment Sample Locations

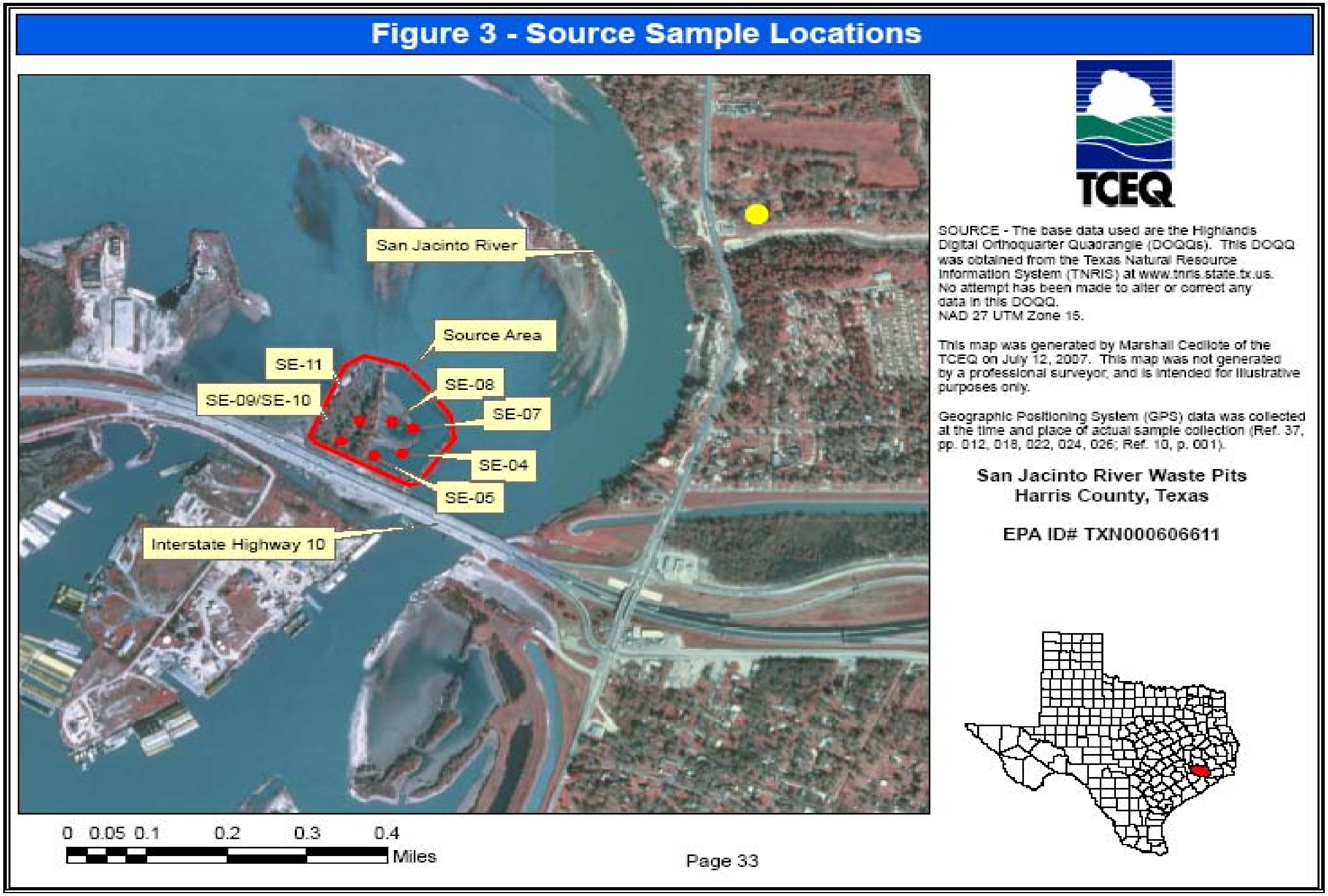


Figure 4a. Aerial Photo, San Jacinto River Waste Pits, Background Sample Locations.

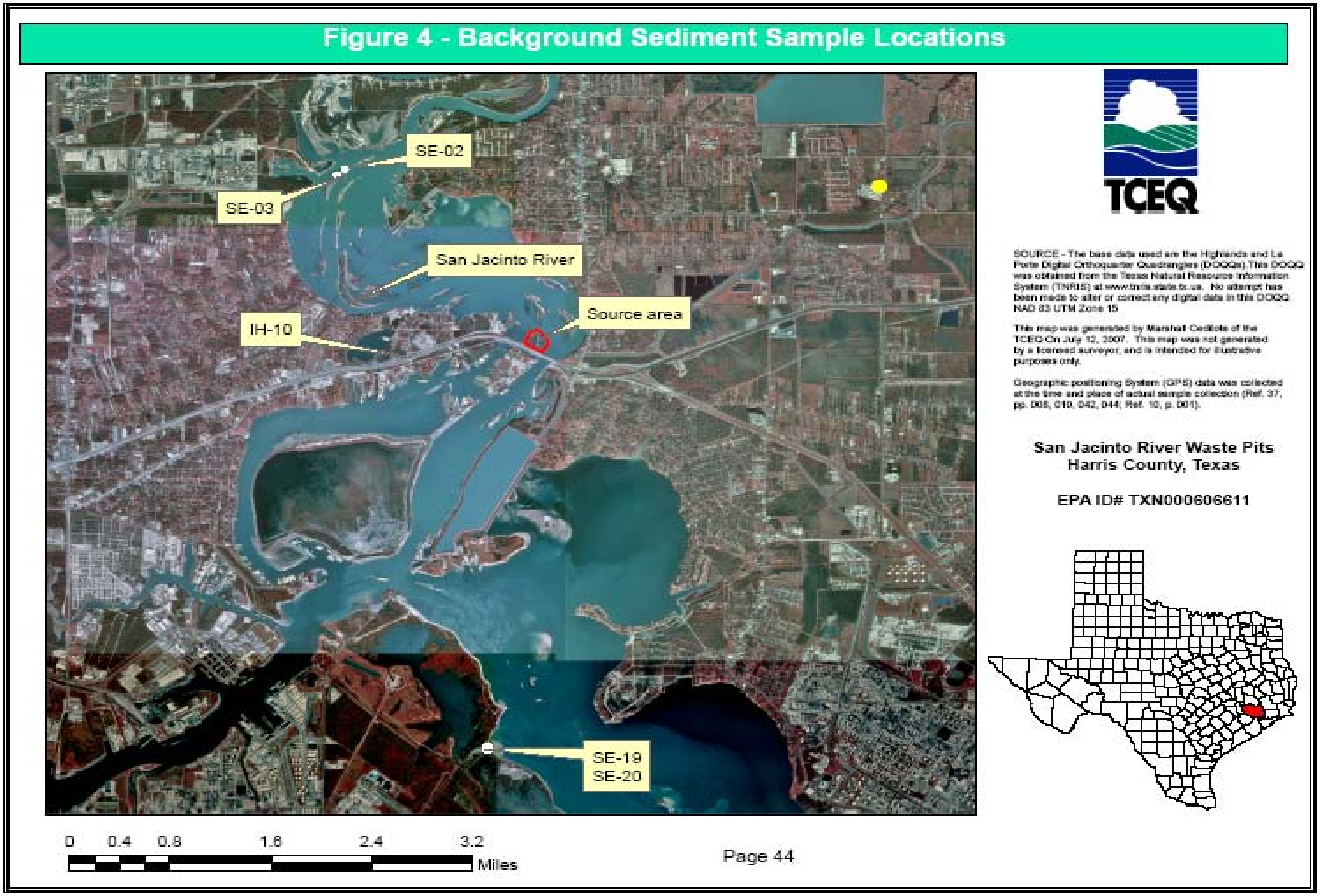


Figure 4b. Aerial Photo, Houston Ship Channel TMDL Sample Locations.

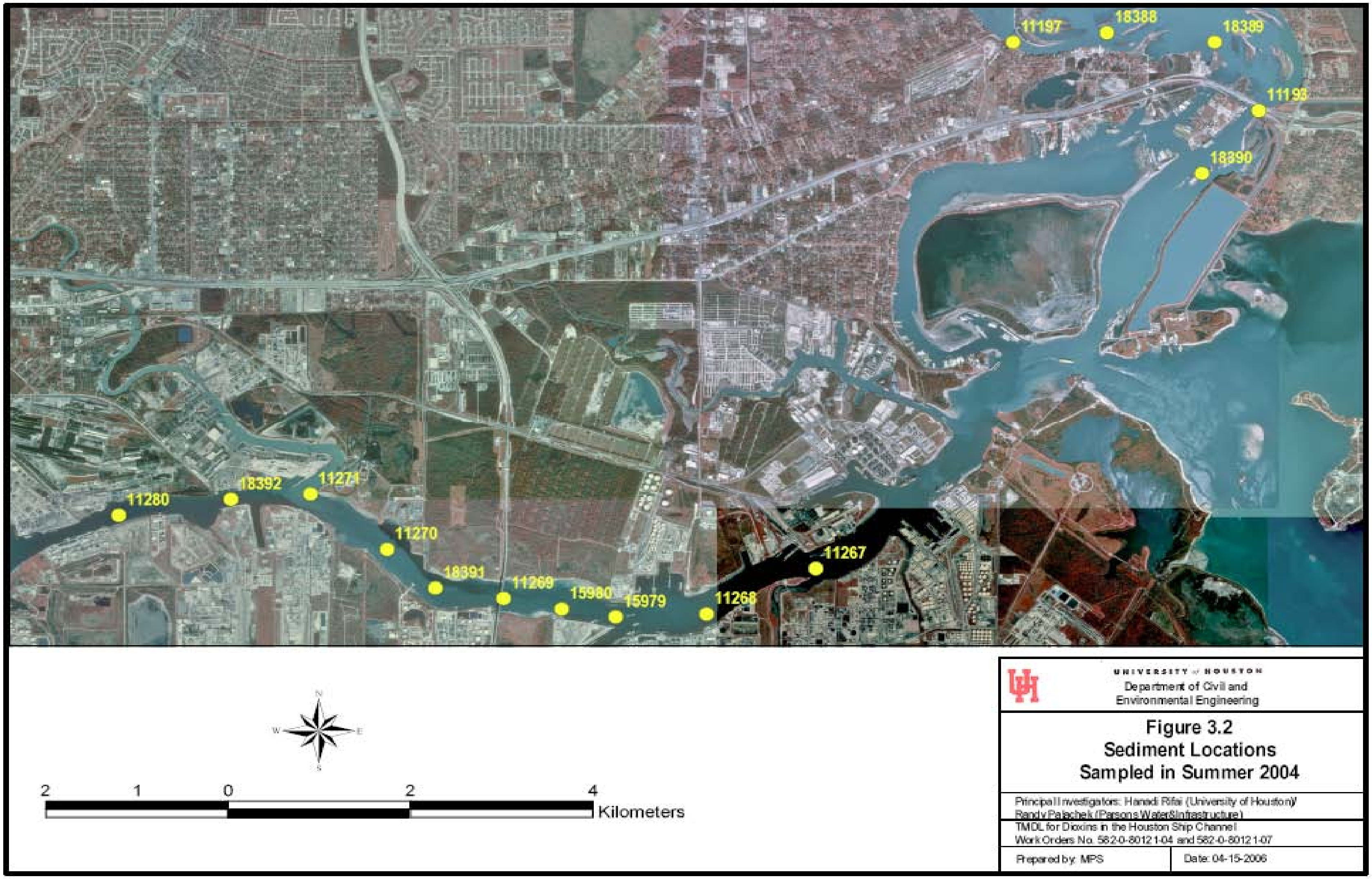


Figure 5. San Jacinto River Waste Pits, Pit Surface Areas (in square feet)

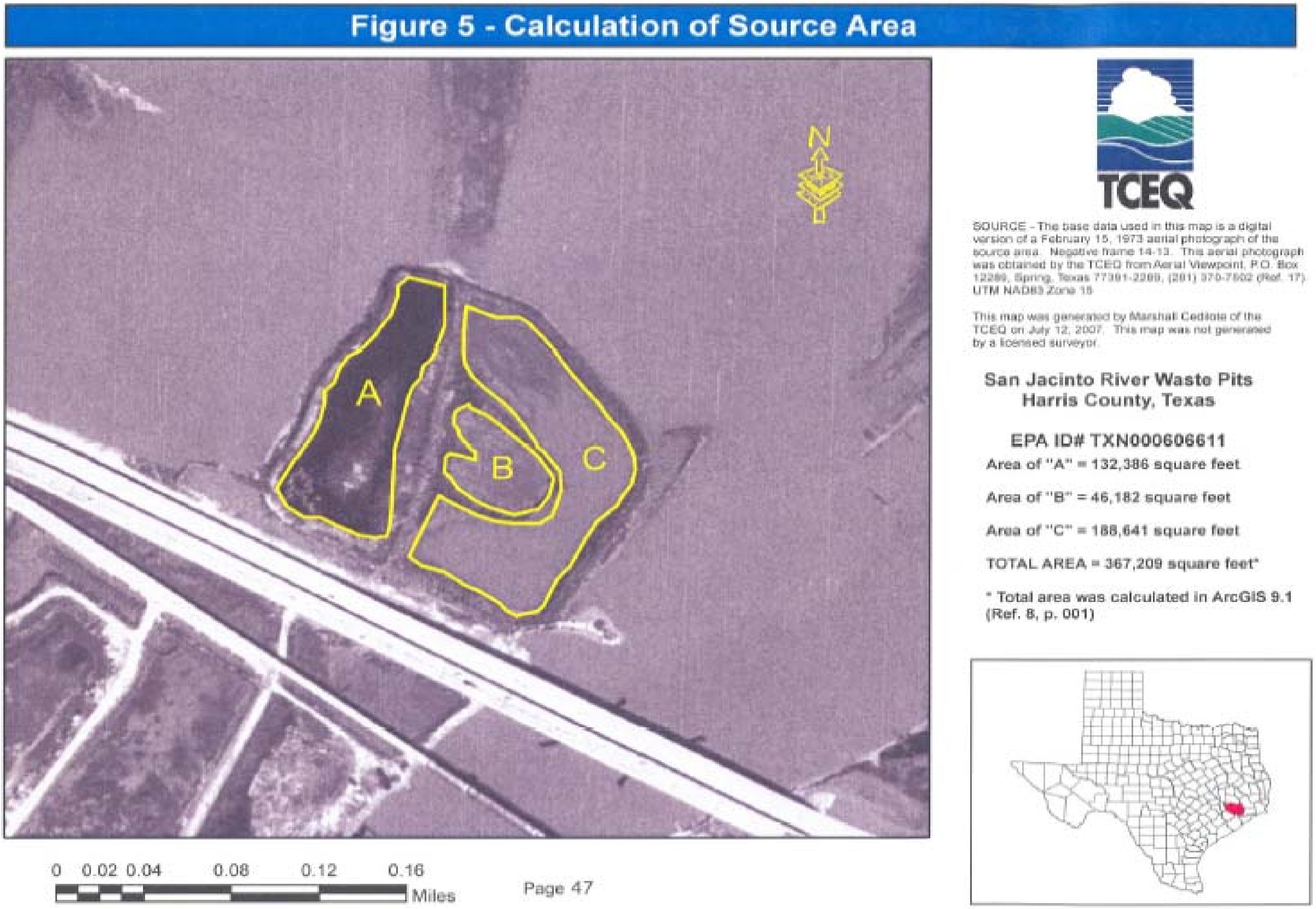


Figure 6. TMDL Project Sample Locations, Collected by the University of Houston

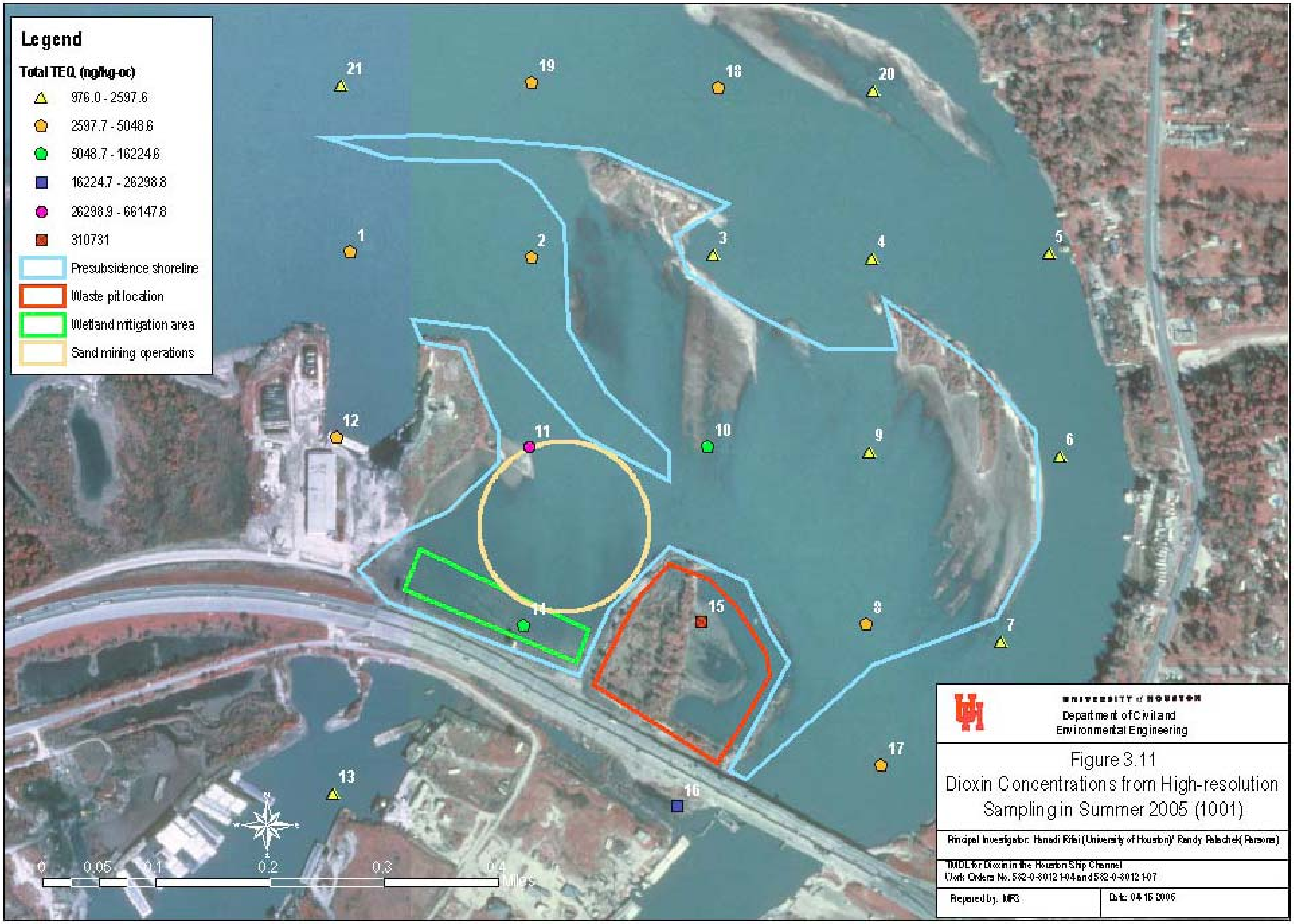


Figure 7. Pit A from Berm Trail, Camera Looking Southwest

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 I-10, Camera Looking East

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

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

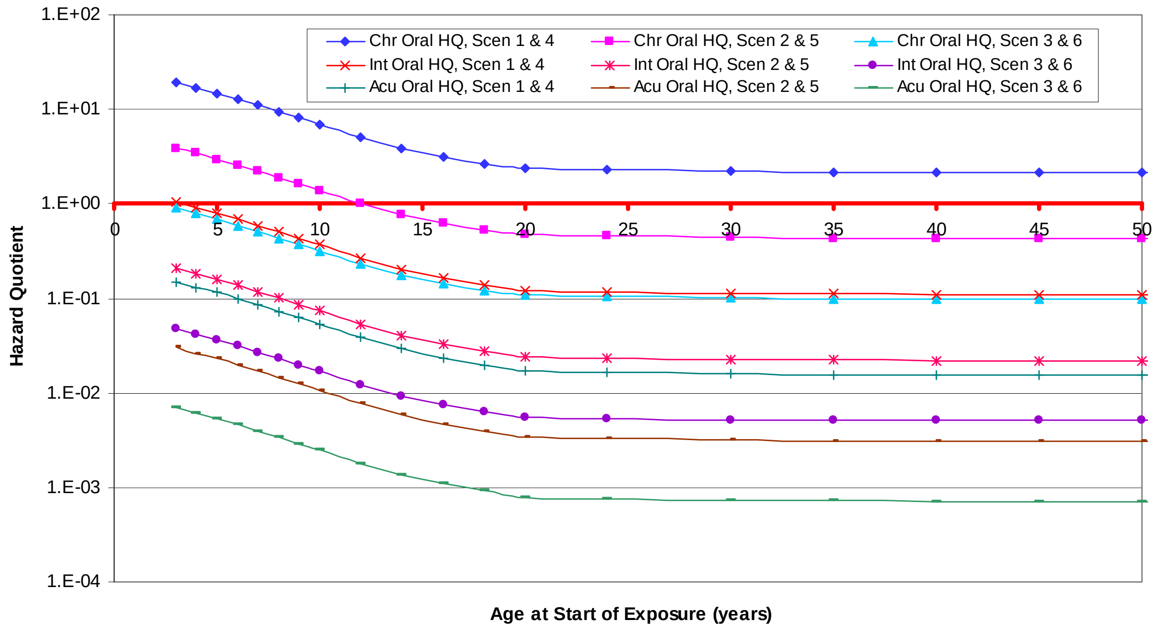
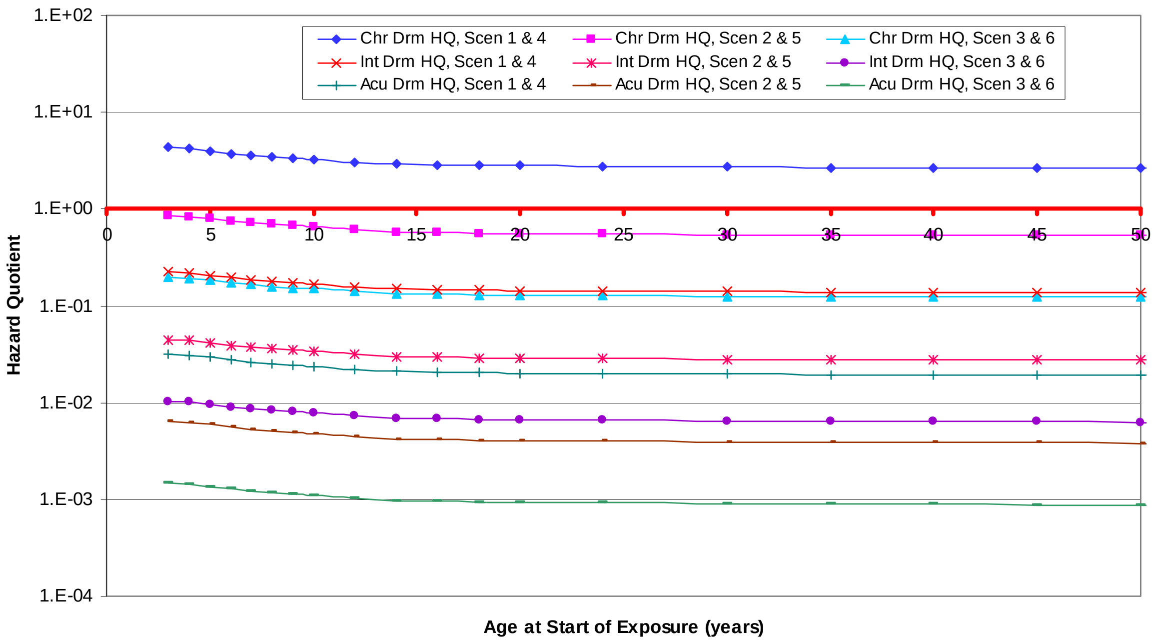


Figure 16. Hazard Quotients for TCDD TEQ, Dermal Absorption Route



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; Scen 1 = Subsistence fisherman; Scen 2 = Weekend Fisherman; Scen 3 = Sporadic Fisherman; Scen 4 = Child of Subsistence Fisherman; Scen 5 = Child of Weekend Fisherman; Scen 6 = Child of Sporadic Fisherman.

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

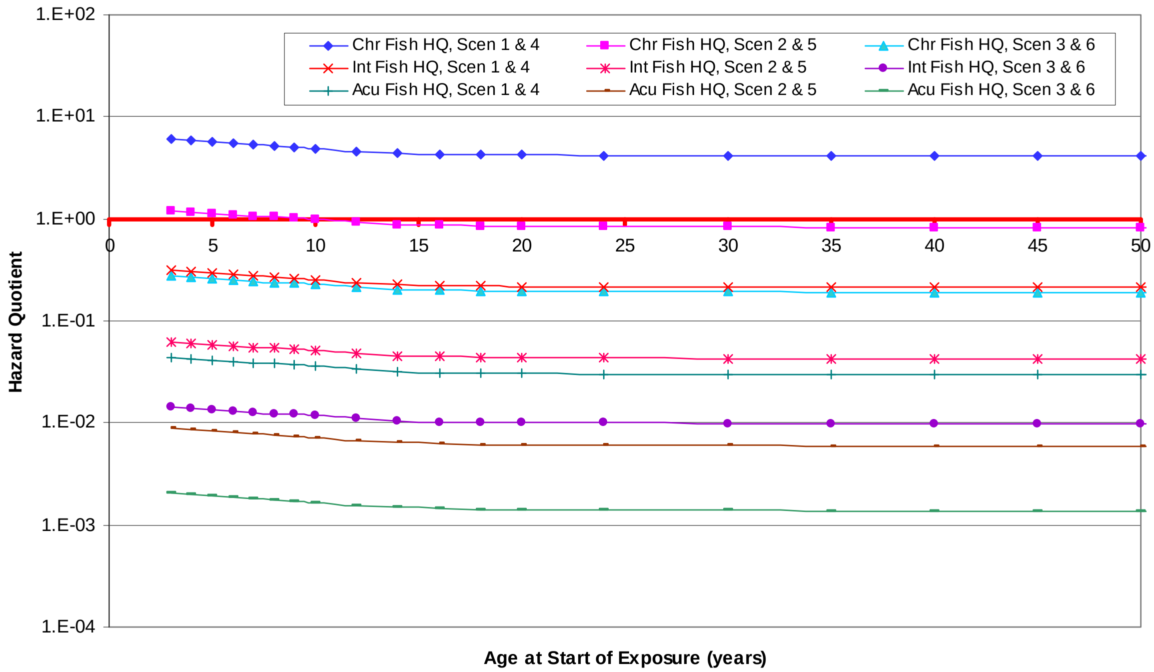
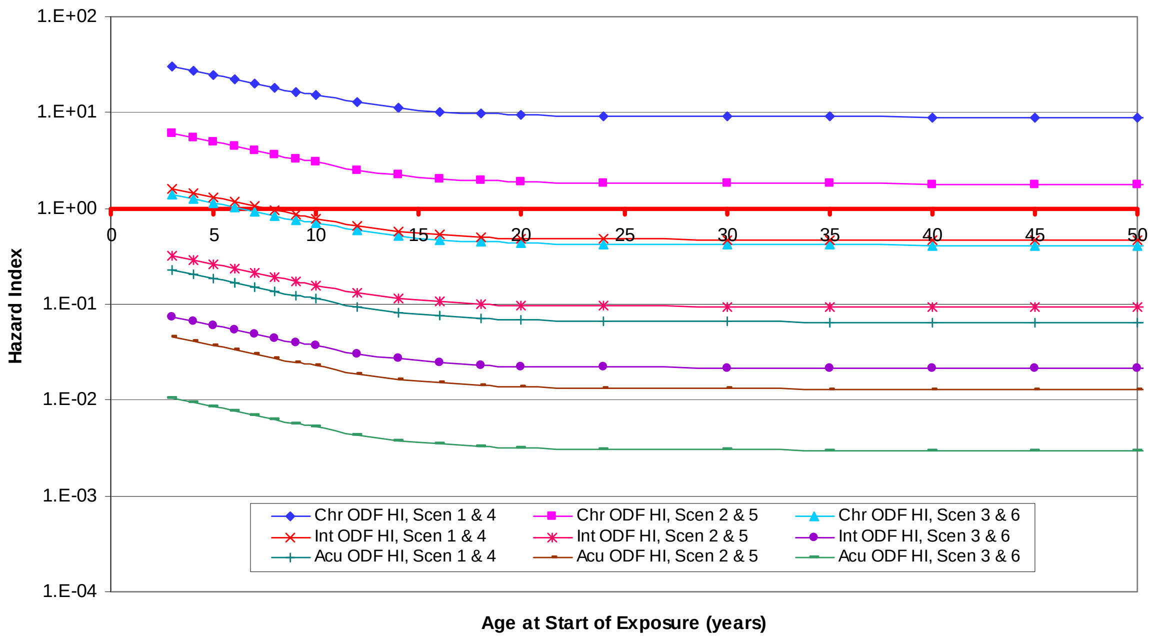


Figure 18. Hazard Indices for TCDD TEQ, Oral, Dermal, & Fish Routes



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; Scen 1 = Subsistence fisherman; Scen 2 = Weekend Fisherman; Scen 3 = Sporadic Fisherman; Scen 4 = Child of Subsistence Fisherman; Scen 5 = Child of Weekend Fisherman; Scen 6 = Child of Sporadic Fisherman.

Appendix C – Tables

Table 1. SJRWP Exposure Pathway Analysis, Sediment Pathway

Pathway Name	Contaminant of Concern	Exposure Pathway Elements										Time	Comments and Pathway Status
		Contaminant Source		Transport Medium		Point of Exposure		Route of Exposure		Exposed Population			
		Source	Status	Medium	Status	Point	Status	Route	Status	Population	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										Time	Comments and Pathway Status
		Source		Transport Medium		Point of Exposure		Route of Exposure		Exposed Population			
		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. Possible 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)	Poss Ca Risk (Oral Exp)	Ca Odds $(Ca\ Risk)^{-1}$	Poss Ca Risk (Oral Exp)	Ca Odds $(Ca\ Risk)^{-1}$	Poss Ca Risk (Oral Exp)	Ca Odds $(Ca\ Risk)^{-1}$
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	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 Combined	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; Poss = possible; 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; Ca Odds = the number of people that would have to be exposed in order to expect to see one additional case of cancer above background cancer mortality rates

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. Possible 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)	Poss Ca Risk (Oral Exp)	Ca Odds $(Ca\ Risk)^{-1}$	Poss Ca Risk (Oral Exp)	Ca Odds $(Ca\ Risk)^{-1}$	Poss Ca Risk (Oral Exp)	Ca Odds $(Ca\ Risk)^{-1}$
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	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; Poss = possible; 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; Ca Odds = the number of people that would have to be exposed in order to expect to see one additional case of cancer above background cancer mortality rates

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. Possible 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)**	**Poss Ca Risk (Dermal Exp)**	**Ca Odds (Ca Risk)$^{-1}$**	**Poss Ca Risk (Dermal Exp)**	**Ca Odds (Ca Risk)$^{-1}$**	**Poss Ca Risk (Dermal Exp)**	**Ca Odds (Ca Risk)$^{-1}$**
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 SJRWP	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; Poss = possible; 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; Ca Odds = the number of people that would have to be exposed in order to expect to see one additional case of cancer above background cancer mortality rates

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. Possible 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)**	**Poss Ca Risk (Dermal Exp)**	**Ca Odds (Ca Risk)$^{-1}$**	**Poss Ca Risk (Dermal Exp)**	**Ca Odds Ca Risk)$^{-1}$**	**Poss Ca Risk (Dermal Exp)**	**Ca Odds (Ca Risk)$^{-1}$**
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 SJRWP	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; Poss = possible; 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; Ca Odds = the number of people that would have to be exposed in order to expect to see one additional case of cancer above background cancer mortality rates

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. Possible 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)	Poss Ca Risk (Fish Exp)	Ca Odds $(Ca\ Risk)^{-1}$	Poss Ca Risk (Fish Exp)	Ca Odds $(Ca\ Risk)^{-1}$	Poss Ca Risk (Fish Exp)	Ca Odds $(Ca\ Risk)^{-1}$
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)**	**Poss Ca Risk (Fish Exp)**	**Ca Odds $(Ca\ Risk)^{-1}$**	**Poss Ca Risk (Fish Exp)**	**Ca Odds $(Ca\ Risk)^{-1}$**	**Poss Ca Risk (Fish Exp)**	**Ca Odds $(Ca\ Risk)^{-1}$**
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; Poss = possible; Ca = cancer; pg/g = picograms per gram; TEQ = tetrachlorodibenzo-p-dioxin toxic equivalent concentration; WHO = World Health Organization; Ca Odds = the number of people that would have to be exposed in order to expect to see one additional case of cancer above background cancer mortality rates

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. Possible 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)**	**Poss Ca Risk (Dermal Exp)**	**Ca Odds (Ca Risk)$^{-1}$**	**Poss Ca Risk (Dermal Exp)**	**Ca Odds (Ca Risk)$^{-1}$**	**Poss Ca Risk (Dermal Exp)**	**Ca Odds (Ca Risk)$^{-1}$**
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	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; Poss = possible; 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; Ca Odds = the number of people that would have to be exposed in order to expect to see one additional case of cancer above background cancer mortality rates

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. Possible 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)	Poss Ca Risk (Dermal Exp)	Ca Odds $(Ca\ Risk)^{-1}$	Poss Ca Risk (Dermal Exp)	Ca Odds $(Ca\ Risk)^{-1}$	Poss Ca Risk (Dermal Exp)	Ca Odds $(Ca\ Risk)^{-1}$
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	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; Poss = possible; 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; Ca Odds = the number of people that would have to be exposed in order to expect to see one additional case of cancer above background cancer mortality rates

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	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	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+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 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	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	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	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 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 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	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	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	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+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 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	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	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	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 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 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	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	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	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	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	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	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	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

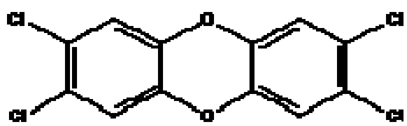
E+00	Low Increased Risk
E-01	No Apparent Increased Risk
E-02	No Increased Risk

Appendix D – Risk Assessment Calculations

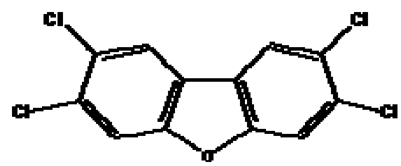
Calculation of the Toxic Equivalency (TEQ) for Mixed Dioxins

Polychlorinated dibenzo-p-dioxins (PCDDs) and polychlorinated dibenzofurans (PCDFs) are chlorinated 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

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

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 Possible 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].

Possible 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,

$TR_{o:m,n}$ = Possible 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 Possible Cancer Risks for Dermal Exposures

Possible 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,

$TR_{d:m,n}$ = Possible 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 Possible Cancer Risks for Fish Consumption Exposures

Possible 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,

$TR_{FC:m,n}$ = Possible 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 Possible Cancer Risks for All Exposures

The possible 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.

Possible 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,

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

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

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

$TR_{fc:m,n}$ = Possible 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),

Appendix E – Public Comments and Responses

Commenter #1: Harris County Pollution Control Department

Comment 1-1 PHA Does Not Include Most Recent Data, Page 13:

The Health Assessment states that TDSHS and ASTDR (sic) did not collect or analyze independent sediment, fish, or other samples and that it relied on the following:

> *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. HA at Page 13.*

The most recent sample materials referenced in the cited materials appear to be 2008 or prior. There have been additional sampling data available since the above-referenced data were collected and we encourage the TDSHS to consider all sampling data that has been collected to-date by various agencies and entities and update the Health Assessment as appropriate. It is particularly important to consider post-2008 sampling data due to the potential for the redistribution of sediments by Hurricane Ike and dredging operations in the waterway.

Response 1-1:

In general, Public Health Assessment (PHA) documents done under the Cooperative Agreement Program for the Agency for Toxic Substances and Disease Registry (ATSDR) serve more as a static snapshot-in-time of the conditions at a particular Superfund Site, documenting the need for the site to be cleaned up, and less as a dynamic video and/or daily chronicle of all events that take place at the site or affect the site after it has become an official NPL site. If new data becomes available and it is felt that evaluation of these data would be of benefit to the public, these issues are usually addressed through supplements to the Health Assessment or through separate Health Consultations designed to address a specific issue.

The San Jacinto River Waste Pits Public Health Assessment (SJRWP PHA) was generated, based primarily on the types and concentrations of waste that were present on the site at the time it was proposed and added to the National Priorities List (NPL). The intent was to characterize the risks to the public that could potentially occur if nothing were done to clean up the site. To add additional context, the Texas Department of State Health Services (DSHS) evaluated additional data obtained by the University of Houston under the Dioxin Total Maximum Daily Load (TMDL) project. These data included 208 sediment samples from throughout the San Jacinto River (SJR), Houston Ship Channel (HSC), and Upper Galveston Bay (UGB) waterways. As such, they were outside the confines of the "Site" as defined in the Texas Commission on Environmental Quality's (TCEQ) Hazard Ranking System (HRS) document and the final rule published in 40 CFR Part 300, as published in the Federal Register on March 19, 2008.

Comment 1-2A Description of Site Location Unclear, Page 16:

This section seeks to provide the reader with a general description of the area of interest in this Health Assessment. The description indicates that the area of interest is "near what is referred to as the Port of Houston" without directional guidance (i.e. east of the Port) or distance from the area of Port activity. A clearer description needs to be provided.

Response 1-2A:

The SJRWP PHA document was updated to reflect a clearer description of the location of the site with respect to the HSC and the Port of Houston as follows:

"This area is approximately 2.5 miles north-northeast of the confluence of the SJR with the HSC, toward the eastern end of the Port of Houston."

Comment 1-2B Southern Impoundments Not Mentioned, Page 16:

The U.S. EPA has also additional sampling data on pits south of I-10 called the Southern Impoundments and those should be referenced in this Health Assessment.

Response 1-2B:

Since the pits south of I-10 (the Southern Impoundments) were discovered relatively recently, the additional sampling data from these pits are outside the scope of the initial PHA. To "reference" them in the initial PHA would potentially raise a lot of questions in the mind of the reader that could not be answered without thoroughly assessing the new data and evaluating the risks. Since these pits are already in the EPA work-plan, there is no need to justify to the EPA why they should be evaluated, stabilized, and/or cleaned up. If there is sufficient interest and need to evaluate these new data, DSHS is willing to address this issue as a separate Health Consultation, but finalization of the initial PHA should not be further delayed.

Comment 1-3A No New Data Collected for PHA, Pages 17-18.

The Health Assessment relied only on certain data collected previously and no independent sediment, fish, or other samples were taken.

Response 1-3A:

That is correct, Public Health Assessments at Superfund Sites, done under a Cooperative Agreement with the ATSDR, do not generally involve collecting new soil, sediment, fish, or other samples. Instead, they involve the evaluation (in a public health context) of data that has already been collected by other state or federal environmental agencies.

Comment 1-3B A Residential Health Survey Was Not Done, Pages 17-18.

Also, the Health Assessment did not conduct a residential health "survey" as a means to gather health information from area residents.

Response 1-3B:

Residential health surveys in the surrounding neighborhoods or other health outcome data evaluations were not done at this site because the airborne and water-borne routes were not considered significant pathways that may have exposed a larger, geographically circumscribed population. At this particular site, only those individuals who visit the site and have skin contact with site contaminants or who eat fish caught from the San Jacinto River, Houston Ship Channel, or Upper Galveston Bay are at potential risk from dioxin exposures. A residential health survey of hundreds of people living in the surrounding neighborhoods (most of whom do not have any quantifiable exposures to site contaminants) would produce results that were scientifically uninterpretable and potentially mislead the public. The only possibility of obtaining a meaningful result depends on being able to differentiate between truly exposed and non-exposed individuals and having sufficient numbers in the exposed category to produce statistically quantifiable results. Since truly exposed individuals, routinely visiting the site and/or eating fish or crabs from the various Houston waterways, may live anywhere in the Houston area, the exposed population is undefinable. Similarly, detailed assessments of the birth defects database or cancer registry database would yield ambiguous results because exposed individuals could not be differentiated from unexposed individuals in these registries. Also, the proximity of the Houston Ship Channel (and all the VOC air contaminants associated with activities in the Port of Houston) would be a significant confounding factor for any studies of the site and its surrounding neighborhoods.

Comment 1-3C Residents Concerned About Cancer Risks, Pages 17-18.

In previous community meetings, residents have vocalized concerns of negative health impacts including increased cancer risk from living near the SJRWP.

Response 1-3C:

These concerns are quite understandable, and this is precisely why DSHS has gone to such great lengths to identify all the potential exposure pathways whereby individuals may be, in fact, exposed to site contaminants. It is important for everyone to understand that proximity to the SJRWP site does not imply exposure to site contaminants. Consequently, living near the SJRWP site has no bearing on cancer risks or other negative health impacts, unless the individual (in addition to living near the site) also consistently engages in one of the identified risky behaviors.

A number of factors combine to virtually eliminate the significant possibility of exposures to site contaminants by neighborhood residents who do not frequent the site:

1. First of all, dioxins are relatively non-volatile, solids, which means they do not readily sublimate (become vaporized) into the air where they could be easily transported to nearby residents.
2. While dioxins having only one, two, or three chlorine atoms attached to the rings do have a slight volatility, these mono, di, and trichlorodibenzodioxins are not considered to have any cancer-causing or other toxic potential.
3. The dioxins with four, five, six, seven, or eight chlorine atoms are the only dioxins with cancer-causing potential, and they are all virtually non-volatile.
4. Consequently, dioxin vapors with cancer-causing potential are not a significant possibility at the SJRWP site or, for that matter, for any other dioxin site.
5. Even in the driest periods of the hot summers, pit A, on the west side of the site, was swampy, and there was heavy vegetation covering and surrounding this pit. Pits B and C on the east side of the site have been under water for at least 10 years due to subsidence of the entire area.
6. The highest concentrations of dioxins were found primarily in the pits, as opposed to the soil berms surrounding the pits.
7. Consequently, there has been no possibility of blowing dust from the more heavily contaminated pit areas.
8. The only part of the site not covered by either water or heavy vegetation was the foot path trail along the soil berm between pit A and pits B and C. In most places, the trail consisted of compacted, but still moist, clay which would not have been conducive to the generation of dioxin-contaminated dust that could possibly be blown off-site during high winds.
9. Consequently, significant exposures of nearby residents to wind-blown, dioxin-contaminated dust are not a possibility at the SJRWP site, and the inhalation pathway is totally ruled out at this site.
10. Dioxins have a high affinity for soil particles, and consequently, they do not migrate significantly in groundwater. The sandy sediments of the shallow aquifers in the area act as a filter trapping individual soil particles (and any attached dioxin molecules) effectively preventing their migration either laterally or down to deeper aquifers that might be used as a drinking water source by people in the general vicinity.

11. Consequently, the possibility of significant exposure to dioxins from the site through consumption of water from private wells or other groundwater sources in the area is extremely remote.
12. The surface water in this part of the San Jacinto River is brackish, and no one is likely to drink significant amounts of river or Houston Ship Channel water.
13. The Dioxin TMDL Study measured surface water dioxin levels at hundreds of locations throughout the San Jacinto River/Houston Ship Channel/Upper Galveston Bay waterway. Not surprisingly, the highest concentration found was from the SJR under the I-10 Bridge (immediately down-stream of the site). Even if people drank 2 liters of this water per day for a lifetime, the possible cancer risks would be only 6.6×10^{-6} which would put it in the "No Apparent Public Hazard" category.
14. Consequently, there is no significant possibility of excess dioxin exposure through consumption of surface water in the area.
15. Since exposure to dioxins through skin contact with dioxin-contaminated river waters (as in the occasional swimmers or waders in the San Jacinto River) would be insignificant compared with some hypothetical person who drank 2 liters of river water per day, the possible cancer risk would be far less than 6.6×10^{-6}.
16. Consequently, there is no significant possibility of excess dioxin exposure through skin contact with surface water by recreational swimmers or waders in the area.

After examining all of the scientific evidence outlined above, DSHS can conclude with great confidence that merely living in the vicinity of the SJRWP does not convey any quantifiable risks. As noted in the PHA, the only significant risky behaviors would be daily (or several times weekly) visits to the site, involving direct skin contact with (or ingestion of) contaminated sediments from the pits or catching and eating fish from the San Jacinto River near the I-10 bridge or other nearby waterways.

Comment 1-3D Residents Concerned Re Flooding, Fish, & Crabs, Pages 17-18.

The residents have also expressed concerns regarding contact with contaminated water via flooding, recreational use of the river as well as eating contaminated fish and crabs.

Response 1-3D:

The relatively minute quantities of contaminated sediments, diluted in millions (maybe billions?) of gallons of flood water, might result in a brief, minor, one-time exposure for people in contact with flood water. However, since risks from chemical exposures are related to the product of (magnitude of exposure) × (duration of exposure) and both the magnitude and the duration are vanishingly small, the possible increased risk for flood victims would be virtually nil.

Likewise, as explained in Response 1-3C above, recreational contact with water from the SJR also does not constitute any measurable increased risk from dioxin skin-contact exposure. The highest dioxin water concentration (3.09 pg/L) reported in the Dioxin TMDL Project data was collected from the SJR below the I-10 bridge. Even if water with that concentration of dioxin was used as a drinking water source and people consumed 2 liters per day for their entire lifetime, the increased cancer risk would be approximately 6.6 x 10^{-6}. Skin contact with dioxin-contaminated surface water would be a far less efficient pathway of exposure than drinking 2 liters of dioxin-contaminated water per day. Consequently, dioxin in surface water near the site does not appear to be a significant health issue.

The consumption of fish and crab caught near the SJRWP site was thoroughly addressed in this PHA, and a fish-consumption advisory has been in effect for years for the waterways in the vicinity of the SJRWP site. The fish consumption advisory states that adults should eat no more than one meal (8-ounces of fish) per month and women of child-bearing age and children should eat no fish from the affected waters. However, as there are multiple foci of lower level dioxin-contaminated sediments at many locations in the San Jacinto River/Houston Ship Channel/Upper Galveston Bay waterways, unrelated to the SJRWP site, it is not anticipated that the dioxins-in-fish problem or the fish-consumption advisories will entirely go away after the SJRWP has been cleaned up.

Comment 1-3E Residents Concerned Re Dredging, Pages 17-18.

These other concerns and methods should have been considered especially since the data relied upon is not current and, as previously stated, river sediments may have been redistributed by natural occurrences and dredging operations.

Response 1-3E:

Currency of the data evaluated in the SJRWP PHA is not an issue. In evaluating site contaminants, exposure pathways, and potential theoretical risks, DSHS used existing data and conditions at the site at the time it was added to the National Priorities List. The intent was to provide scientific evidence why the site should be cleaned up and what the possible risks might be if the site was not cleaned up. Data collected by the EPA as part of the time-critical removal action or the remedial investigation and feasibility study (RI/FS) are outside the scope and purpose of the PHA. The data evaluated is sufficient to say that the site is contaminated with unacceptable levels of dioxins, it needs to be cleaned up, and the EPA is appropriately addressing the issue.

Activities at the site over the last 8 or 10 months have focused first on preventing any further land access to the site by the public by fencing the entire area. Second, they have worked intensively on placing a physical barrier on top of all the contaminated sediments in the surface impoundments so that there will be no redistribution of the highly contaminated sediments by natural occurrences or by dredging operations. These activities have eliminated two of the three potential exposure pathways, thereby greatly reducing the possibilities for exposure. Consequently, use of more “current” data and conditions at the site would produce significantly lower risk estimates, which might give the mistaken impression that nothing further needs to be done.

Comment 1-4A Imputed or Derived HAC Values, Pages 23-24.

Great detail is taken to explain how the imputed values are calculated to extrapolate inhalation values to equate to an ingested value. Additionally, calculated values of oral and dermal exposures to 2, 3, 7, 8-TCDD are listed;

Response 1-4A:

In general health assessment comparison values (HAC values) serve as yardsticks, to which measured site contaminant levels are compared. The soil/sediment CREG for dioxin represents the concentration of dioxin TEQ in soil that would produce a possible risk of one in a million for a 70 kg person consuming 100 mg of the soil daily for a 70 year lifetime, assuming 100% absorption. The acute, intermediate, and chronic HAC values for adults are non-cancer HAC values and represent the maximum soil/sediment dioxin levels that are expected to be without significant risk of adverse effects when consumed by a 70 kg adult at 100 mg contaminated soil per day over the duration of the exposure, assuming 100% absorption. An exposure lasting 1-14 days is considered acute, 15-365 days is considered intermediate, and greater than 365 days is considered chronic. Similarly, the acute, intermediate, and chronic HAC values for children are also non-cancer HAC values and represent the maximum soil/sediment dioxin levels that are expected to be without significant risk of adverse effects when consumed by a 10 kg child at 200 mg contaminated soil per day over the duration of the exposure, assuming 100% absorption. Since oral and dermal exposures were considered to be significant possibilities at the site, oral and dermal HAC values were presented in the PHA.

Comment 1-4B No HAC Values for Inhalation Exposures, Pages 23-24.

…however, there are no values listed for comparison of possible inhalation exposure and we recommend that those need to be included. Residents along the SJR at the community meeting have also expressed concern that dust from the sediment (possibly at low tide or time of drought) where soil that has been contaminated may blow from the site and possible expose residents and/or fishermen and that needs to be more fully explained. Further comment regarding inhalation exposure from exposed sediments is made on page 3.

Response 1-4B:

As thoroughly explored in Response 1-3C above, the airborne route of exposure was totally eliminated as a significant possibility for this site. Since air exposures are not a credible possibility for the site and no air dioxin data were available for analysis, listing dioxin air comparison values in the SJRWP PHA would have served no purpose and may have given the false impression that the airborne route was one of the completed pathways of exposure, about which people should be concerned.

For those who are interested, a dioxin air concentration of 0.0233 pg/m^3 if inhaled daily at 20 m^3/day by a 70 kg adult over a 70 year lifetime would produce a possible cancer risk of one in a million. This concentration would be the inhalation CREG for dioxin. Other acute, intermediate, and chronic non-cancer inhalation HAC Values could be calculated for adults and children, but there is no data from the SJRWP that need any of these yardsticks for comparison.

As an additional exercise, we calculated the possible cancer risks from a totally hypothetical scenario involving the inhalation of dioxin-contaminated dust from the site under worst-case assumptions (see Response 1-6C below). Even under worst-case (and entire hypothetical) conditions, airborne dioxin-laden dust would not (and in fact could not) be a problem at the SJRWP site.

Comment 1-5 Overweight Children Not Taken Into Consideration, Pages 25-26.

The Health Assessment states:

In this HA, DSHS has scaled the fish consumption rates for children in proportion to the ¾ power of the body weight of the child with respect to the ¾ power of the body weight of the adult (child consumption rate = adult consumption rate X [child body weight]$^{3/4}$ ÷ [adult body weight]$^{3/4}$). HA, Page 26.

However, because we know that children eat more food, drink more fluids and breathe more air in proportion to their body weights than do adults, we believe that the Health Assessment should consider the childhood obesity issue and possibly reevaluate the consumption rate for children.

Response 1-5:

That is precisely why DSHS used the above-referenced method for adjusting fish consumption rates for age & body weight differences. Scaling dietary intakes proportionally to the ¾th power of the body weights is a relatively standard means of accounting for differences in body weight in setting various Estimated Average Requirements (EARs) or Adequate Intakes (AIs). It is one of the commonly used means of extrapolating data from adults to children, used by the Food and Nutrition Board of the National Academy of Sciences. Using this method for calculating protein requirements for people of different ages and body weights gives a very good correlation with published protein requirements for people of various ages.

Remember too that if a child is 20% overweight and that child eats 20% more fish than the normal-weight child, the exposure, in mg/kg body weight, is the same as for the normal-weight child. This occurs because you have multiplied both the numerator and the denominator of the exposure calculation by a factor of 1.2. The SJRWP PHA is already replete with conservative assumptions, and the fish consumption rate for children and adults in the Subsistence Fisherman Scenario is a prime example. While the consumption rates used for this scenario in the PHA are plausible, they are higher than any rates quoted in the EPA's Exposure Factors Handbook. Consequently, we feel that there is no need or justification for an additional, arbitrary, fish-consumption factor for obese children. Besides, there is already a fish-consumption advisory in place for the SJR, HSC, & UGB which states that adults should eat no more than one meal (8-ounces of fish) per month and that women of child-bearing age and children should eat no fish from the affected waters. Recalculating the risk numbers, based on higher fish consumption rates for children, would not change the conclusions or recommendations of the SJRWP PHA.

Comment 1-6A Data from Surface Impoundment Not Captured, Page 27.

The Health Assessment states:

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. HA, Page 27.

Table 2, page 67, however, indicates that there has not been any data captured in the Surface Impoundment.

Response 1-6A:

The TCEQ's soil/sediment data was, indeed, captured from the surface impoundments (see Table 1, page 66), and this issue was covered fully in the SJRWP PHA. Table 2, page 67 addresses other potential pathways of exposure such as air, groundwater, and surface water (soil and sediment were addressed in Table 1, page 66). Table 2 shows we had data for biota (fish and crabs) but did not have any data for ground water or ambient air. There was data for surface water from the Dioxin TMDL Study, but initial evaluations of the maximum concentration plus the fact that surface water in these waterways is not potable and is not a drinking water source indicated that this was not a significant risk.

Comment 1-6B Drought & Low Tide May Affect Exposures, Page 27.

The Comments and Pathway Status column continues by stating that the PCDDs and PCDFs have very low volatility and are tightly bound to sediment. However, drought and low tide conditions create inviting fishing locations in the riverbed which may expose fishermen to sediment-bound contamination.

Response 1-6B:

Since the SJRWP site and surrounding area has subsided over the years, its elevation with respect to sea level is gradually decreasing. Because of the overall subsidence of the area, less and less of the riverbed are actually being exposed. Since tides generally come in and go out twice a day, there is insufficient time between low tide and high tide for there to be any significant drying of tidally exposed sediments. However, it is indeed true that fishermen visiting and fishing at the site may be exposed dioxin-contaminated sediments. That is one of the major points made and thoroughly evaluated in the SJRWP PHA document, as justification for why the site should be cleaned up.

Comment 1-6C Airborne Exposures Not Adequately Discussed, Page 27.

Wind gusts may also carry sediment bound contaminants to nearby residential properties. We recommend that the Health Assessment consider these issues more fully.

Response 1-6C:

As previously explained in Response 1-3C above, the site is heavily covered with vegetation, and even under the recent drought conditions, the surface impoundments were either marshy and damp (pit A) or submerged under water (pits B & C), and the likelihood of contaminated wind-blown dust coming from the surface impoundments is virtually nil. With no data on ambient air levels of dioxins and no expectation that airborne exposures would be occurring, we feel that we have already adequately addressed the possibility of airborne exposures and found it not to be a viable concern.

With that said, if we were to make an assumption that sediment from the impoundments, with an average of 15,594 pg TCDD TEQ/g sediment were somehow being dried out and becoming airborne at 65 µg sediment-dust per cubic meter of air (the EPA's current 24-hour NAAQS primary standard for PM 2.5 particulates in air), and this dioxin-contaminated dust-laden air was in constant suspension in the neighborhoods near the site, the air would contain 65 x 15,594 ÷ 1,000,000 = 1.01 pg TCDD TEQ/m^3. The possible lifetime risk from such an exposure for a 70 kg person inhaling 20 m^3 of this air per day for a 70-year lifetime (assuming 100% absorption) would be 4.33 x 10^{-5}. If the exposure duration is changed to a more realistic 30 years and the absorption is set to a more realistic 50%, the possible risk would be 9.28 x 10^{-6}. Both of these risk estimates would be interpreted as "No Apparent Public Health Hazard" and would amount to less than 6% of the possible risks from either oral or dermal exposures for the Subsistence Fisherman. Consequently, even under the worst imaginable (and entire hypothetical) conditions, airborne dioxin-laden dust would not be a significant problem at the SJRWP site.

Comment 1-7 Reference For No Adverse Health Effects Reported, Pages 28-29.

The Health Assessment states:

> *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. HA, Page 29.*

Please provide a reference and basis for the above-referenced sentence.

Response 1-7:

The sentence does not have a reference; we were merely stating that we have not received any reports of people experiencing any of the adverse health effects mentioned in the preceding paragraphs. Furthermore, the effects to which the statement referred have only been observed in occupational settings or in controlled animal studies at doses that are approached only in our highest and most unlikely scenario. The unlikelihood of the scenario is sufficient to justify our qualitative assessment that we would not suspect such adverse health effects to have occurred at the SJRWP site.

Comment 1-8A Exposure Sources from Living Near Site, Page 29.

The Health Assessment indicated that some exposures occur as a result of living "near" a hazardous waste site containing dioxin.

Response 1-8A:

Toward the bottom of page 27, in the discussion of possible exposures and pathways, we do mention that "living near a hazardous waste site containing dioxins" may be a possible pathway for a person to get additional exposures to dioxins. However, each waste site must be evaluated, based on the unique conditions at that site, and this route may or may not provide a significant contribution to total exposures at any particular site. For example, if this site were in Odessa and the pits were dusty and dry and fine powdery sediments were easily picked up by every little breeze that came by, then airborne dust would have been one of the pathways that would have been fully evaluated and addressed in the PHA. In Response 1-6C above, we quantitatively explore the inhalation pathway under worst-case conditions similar to the hypothetical Odessa scenario above. Even under the worst imaginable (and entire hypothetical) conditions, airborne dioxin-laden dust would not be a significant problem at the SJRWP site.

One of the subtle points is that living in proximity to a waste site does not necessarily imply exposure to site contaminants. This is precisely why DSHS has gone to such great lengths to identify all the potential exposure pathways whereby individuals may, in fact, become exposed to site contaminants. As noted in the PHA, the only significant risky behaviors for this site would be daily (or at least several times weekly) visits to the site, involving direct skin contact with (or ingestion of) contaminated sediments from the pits or catching and eating fish from the San Jacinto River near the I-10 Bridge or other nearby waterways. Because of this, living near the SJRWP site has no direct bearing on cancer risks or other negative health impacts, unless the individual (in addition to living near the site) also consistently engages in one or more of the identified risky behaviors. On the other hand, living several miles away from the site does not necessarily imply that the person is not exposed to and at risk from site contaminants. In both cases, risks depend entirely on the presence or absence of risky behaviors (i.e., oral and dermal contact with site sediments and SJR fish consumption).

Comment 1-8B A Cancer Cluster Analysis May Be Helpful, Page 29.

The Health Assessment states:

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. HA, Page 29.

This is where cancer cluster analysis or a questionnaire regarding health disparities can be very helpful. A request for a cancer cluster analysis was made by residents at the last community meeting. Information gained as a result of such an analysis can provide relevant information to the residents and possibly abate concerns.

Response 1-8B:

Unfortunately, cancer cluster analyses are not quite the panacea that many people perceive them to be. A "cancer cluster analysis" may be somewhat of a misnomer in cases where a cluster has not been identified. Nevertheless, such analyses can only tell us whether the cancer incidence rates or cancer mortality rates in one area are significantly higher than, comparable to, or significantly lower than the rates in some other area. It cannot tell us what, if anything (outside of pure random chance), may have caused difference in the rates for the two areas.

Another limitation of "cancer cluster analysis" for small population areas in proximity to a particular site (where the airborne route is the major exposure pathway) is that the number of new cancer cases or cancer deaths in such areas is small, and the numbers can and do vary drastically from one year to the next by sheer chance. This leads to considerable uncertainty in the true underlying cancer incidence or mortality rates for the area. Expanding the area to include a much larger and more stable population size invariably dilutes any truly exposed population with thousands of people who are not exposed, making it harder to identify slightly increased rates in the exposed.

When cancer rates are significantly elevated in the study area, it is tempting to conclude that they are elevated because of, for example, the waste site situated in the study area. However, when the converse is found, few people are willing to argue that the waste site in the study area is providing a protective effect for the study population. Elevated cancer rates in a study area are not sufficient evidence to prove (or even strongly suggest) that a waste site in the area is the cause of the problem. For a good scientific argument, one must demonstrate an unbroken chain of evidence that shows that:

1. the cancer rates in the study area are significantly elevated when compared to an appropriate comparison population of similar racial, ethnic, cultural, and socioeconomic characteristics,
2. (Here, a "significantly elevated rate" implies a standardized incidence or mortality ratio of 5.0 or higher and 95% confidence interval that does not include 1.0),
3. the two populations are similar with respect to access to medical care, dietary patterns, smoking habits, alcohol consumption, and other leading risk factors for cancer,
4. the contaminants at the site are carcinogenic,
5. the cancer(s) being observed are to be expected based on the specific carcinogens and completed pathways of exposure identified for the site,
6. the exposure to site carcinogens has been occurring over a long period of time (at least as long as the typical latency period for the specific cancer, which may be 20-30 years),
7. the combined exposures at the site have delivered sufficient doses to individual cancer victims for this to be a plausible explanation for the cancers.

If any link in this chain of evidence is missing or unknown, then the conclusions become more speculative in nature; if a link is broken or disproven, it may be necessary to conclude that the increased cancer rates in the study area are the result of a chance occurrence and not of a common exposure.

Health disparity data or residential health surveys for the surrounding neighborhoods were not collected or evaluated for the SJRWP site because the airborne and water-borne routes were not considered significant pathways that may have exposed a larger, geographically circumscribed population. At this particular site, only those individuals who visit the site and have skin contact with site contaminants or who eat fish caught from the San Jacinto River, Houston Ship Channel, or Upper Galveston Bay are at potential risk from dioxin exposures. A residential health survey of hundreds of people living in the surrounding neighborhoods (most of whom do not have any quantifiable exposures to site contaminants) would produce uninterpretable results that, unfortunately, would be highly prone to misinterpretation.

The only possibility of obtaining a meaningful result depends on being able to differentiate between truly exposed and non-exposed individuals and having sufficient numbers in the exposed category to produce statistically quantifiable results. Since truly exposed individuals, routinely visiting the site and/or eating fish or crabs from the various Houston waterways, may live anywhere in the Houston area, the exposed population is nearly impossible to identify. Similarly, detailed assessments of the birth defects database or cancer registry database could be done and might be of some interest to area residents but they could easily be misinterpreted. These analyses would yield ambiguous results because exposed individuals could not be differentiated from unexposed individuals in these registries. Also, the proximity of the Houston Ship Channel (and all the VOC air contaminants associated with activities in the Port of Houston) would be a significant confounding factor for any studies of the site and its surrounding neighborhoods.

Comment 1-8C NTP and EPA Cancer Classifications Incongruent, Page 29.

In addition, the HA provides the following two statements that seem incongruent:

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). HA at 29.

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. HA at 30.

The two statements above provide somewhat of a conflict that can leave the reader with a degree of uncertainty. The final Health Assessment should provide a cohesive statement regarding 2, 3, 7, 8-TCDD carcinogenicity and explains the different classifications clearly.

Response 1-8C:

Unfortunately, there is still some disagreement among the experts and the different agencies as to how the classifications of carcinogenicity should be worded, hence the apparent incongruity of the two statements. DHHS and EPA use different classification schemes with different names and different definitions for the different classifications of carcinogenicity. The differences in wording are moot. What should be noted is that both definitions do acknowledge that 2,3,7,8-TCDD is considered to be an animal and a human carcinogen. We have chosen to show (quote) each agency's classification of the compound rather than make up our own classification scheme and definitions.

Comment 1-9 Needs Definition of "Casual Visitor," Page 31.

The HA states that:

> *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. HA at Page 31.*

A definition of "casual visitor" and further risk assessment for this category is recommended so that individuals that may fish in this area have a point of reference on how to gauge concern of possible health impacts from the site. Based on the data from a recent survey conducted as part of the EPA Community Involvement Plan for the site, it appears that of those participants surveyed, the majority (47%) fished 2-3 times per month; another 24% visited the hot spots 1 or more days per week; and of these 88% visited on weekends. Although not clear from the survey, children as evidenced by anecdotal evidence are likely to accompanying [sic] the fishermen. As for women, the survey indicated they were accompanying the males that were engaged in fishing activities. It is this type of activity that requires definition of what is considered "casual," and needs to be considered more fully especially because of potential health risks to women and children.

Response 1-9:

For the SJRWP PHA, we felt that three adult exposure scenarios and three childhood exposure scenarios were sufficient to cover a wide range of possible exposures. From the survey results presented above, it appears that DSHS made an excellent choice in setting up our exposure scenarios. The majority of the survey participants (47%) would fall in the "Weekend Fisherman" or "Child of a Weekend Fisherman" exposure scenario. Another 24% would appear to fall between the "Subsistence Fisherman" and the "Weekend Fisherman" exposure scenarios. No mention was made of how many if any individuals actually fished consistently at the site for five days per week for 30 years and could actually be classified as "Subsistence Fishermen." Likewise no mention was made of how many individuals didn't fish at the site at all or fished at the site less than 2 times per month (this latter would be the "Sporadic Fisherman" exposure scenario). Since the "Sporadic Fisherman" exposure scenarios resulted in possible cancer risks that would be interpreted as "No Apparent Public Health Hazard," and the "casual visitor" category was obviously intended to apply to individuals who had less exposure that the "Sporadic Fisherman", the risks for these individuals would be too small or inconsequential to attempt to quantitate.

In the SJRWP PHA, we have assumed that a "Fisherman" could be either a man or a woman and that a woman accompanying a male "Fisherman" would receive the same exposures that the man would. Since children are already adequately addressed in three of the six scenarios, we feel that the "potential health risks to women and children" have both been adequately addressed in the SJRWP PHA.

Comment 1-10 Follow-up of Residents in Surrounding Neighborhoods, Page 41.

For actions planned, the HA states that:

> *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. HA at Page 41.*

Based on concerns of the community raised at the April, 2011 community meeting, our recommendations to take into consideration additional sampling data, and the Health Assessment's evaluation that there are unknowns in regards to ambient air and surface water (*see* Table 2, page 67), it is recommended that the Health Assessment consider conducting a follow-up of residents living in the surrounding neighborhoods to make the assessment process as inclusive as possible.

Response 1-10:

If the EPA has collected recent up-wind and down-wind ambient air samples, surface water samples, and/or ground water samples, and if there is sufficient interest, these data potentially could be evaluated under a separate Health Consultation. However, since the site conditions have changed drastically since the EPA's Emergency Action began, these new air data (whatever they might show) could not be assumed to be representative of historical air exposures. Unfortunately, historical data gaps cannot be filled by collecting new data.

Although surface water data from the Dioxin TMDL Project were not evaluated and reported in the SJRWP PHA, we did look at the highest dioxin level found in surface water in the San Jacinto River/Houston Ship Channel/Upper Galveston Bay system (collected from the SJR below the I-10 Bridge). If water with that concentration of dioxin was used as a drinking water source and people consumed 2 liters per day for their entire lifetime, the increased cancer risk would be approximately 6.6×10^{-6}. This would be interpreted as no apparent increased lifetime risk for cancer. However, since the SJR near the I-10 Bridge is not a consistent drinking water source for anyone we know of, these numbers are purely hypothetical as well as inconsequential.

Since the airborne and surface water routes of exposure have been eliminated as significant possibilities for the site, the absence of data in these media has no impact on and in no way weakens the overall conclusions of the PHA.

Commenter #2: Integral Consulting Inc.

Comment 2-1A Purpose and Intended Use of the Draft PHA, Pages 2 & 3:

(p 2, ¶ 1) The document Foreword explains that a public health assessment is conducted to assess the presence and nature of health hazards to communities living near Superfund sites. Such assessments are generally undertaken very early in the CERCLA process to determine whether it is advisable to add a site to the National Priorities List (NPL) (USEPA 1988). This Draft PHA, however, was drafted after the Site was added to the NPL and does not take into consideration the Superfund actions that have already been undertaken or are ongoing at the Site…

Response 2-1A:

The San Jacinto River Waste Pits Health Assessment (SJRWP HA) was begun when the site was proposed for the National Priorities List (NPL). It was based primarily on the types and concentrations of waste that were present on the site at the time it was proposed and later added to the NPL. Its intent was to characterize the risks to the public that could potentially occur if nothing were to be done to clean up the site.

To add additional context to the PHA, the Texas Department of State Health Services (DSHS) evaluated additional data obtained by the University of Houston under the Dioxin Total Maximum Daily Load (TMDL) project. These data included 208 sediment samples from throughout the San Jacinto River (SJR), Houston Ship Channel (HSC), and Upper Galveston Bay (UGB) waterways. As such, they were outside the confines of the "Site" as defined in the Texas Commission on Environmental Quality's (TCEQ) Hazard Ranking System (HRS) document and the final rule published in 40 CFR Part 300, and published in the Federal Register on March 19, 2008.

In general, Public Health Assessment (PHA) documents done under the Cooperative Agreement Program for the ATSDR serve more as a static snapshot-in-time of the conditions at a particular Superfund Site, documenting the need for the site to be cleaned up. They are not intended to serve as a dynamic video and/or daily chronicle of all events that take place at the site or affect the site after it has officially become an NPL site. If new data becomes available and it is felt that evaluation of these data would be of benefit to the public, these issues are usually addressed through supplements to the Health Assessment or through separate Health Consultations designed to address a specific issue.

Comment 2-1B Draft PHA Does Not Address Current Risks, Pages 2 & 3:

(p 2, ¶ 2) EPA guidance states that the purpose of such an assessment "is to assist in determining whether current or potential risk to human health exists at a site and whether additional information on human exposure and associated health risks is needed." The Draft PHA does not address current and potential risks associated with the Site, consistent with EPA's guidance…

Response 2-1B:

The PHA addresses "current" and potential risks associated with the site at the time it was added to the NPL and thus is consistent with EPA's guidance. Because of the unstable conditions at the site (with land subsidence and river water flowing over uncapped surface impoundments) the EPA rapidly undertook measures to stabilize the surface impoundments, prevent further off-migration of dioxin contaminants, and prevent further access to the site by the public. These measures were begun while the PHA was still in the review process and have progressed rapidly over the past six or eight months. Current conditions at the site are outside the scope of the PHA. If every new development at the site had to be evaluated and included in the initial PHA, the PHA could never be finalized until all activities at the site had been completed.

Comment 2-1C Draft PHA Omits Current Information, Pages 2 & 3:

(p 3, ¶ 1) The data used in the Draft PHA are heavily biased toward the most contaminated area of the Site (which has now been capped with rock, fully fenced from the land and isolated from water access by ropes and signs). As a result, the data used in the Draft PHA are not a complete representation of current information and the Draft PHA should be revised to take more current information into account. Clarification of both the intended role or use of the Draft PHA, and of the broader context of the ongoing RI/FS and TCRA, is necessary for readers to understand the relevance of the exposures evaluated in the Draft PHA and the uncertainties associated with its conclusions.

Response 2-1C:

The data used in the PHA, naturally, focused on contaminant levels in the surface impoundments on the 20 acre tract of land on the west bank of the SJR immediately north of the I-10 Bridge because that is how the "site" was defined in the PHA. Risk calculations were based on the average concentration for all of the samples collected from the site at the time it was added to the NPL. The EPA recommends using either the average or the upper 95% confidence limit on the average for such calculations. Risks based on the 95% UCL naturally would have been higher than those based on the average value. We also evaluated and presented results for 208 other sediment samples collected throughout the San Jacinto River/Houston Ship Channel/Upper Galveston Bay waterway system. On page 13, under "Purpose and Health Issues" we clearly stated the purpose of the Draft PHA and specified what data we used in our evaluation. Data collected by the EPA or their contractors under the Time Critical Removal Action (TCRA) are outside the scope of the Draft PHA. If there is sufficient interest and need to evaluate these new data, DSHS is willing to address this issue as a separate focused Health Consultation, but finalization of the initial PHA should not be further delayed.

Comment 2-2A Ambiguities in Use of Term "Site":

(p 4, ¶ 1) Some terminology and some of the statements presented in the Draft PHA to describe Site conditions are not consistent with documents that are currently available in the public record. One source of confusion is that the Draft PHA uses the term "site" to describe only the area of the historical waste impoundments that are located north of I-10, and not the "Site," as EPA has defined that term in the EPA administrative orders pursuant to which the RI/FS and the TCRA are being performed by the Respondents. For the Draft PHA to be consistent with the ongoing Superfund activities, the term "site" should be used to refer to the Site as defined in the EPA administrative orders, and the phrase "waste impoundments north of I-10," the apparent focus of the Draft PHA, should be specifically referenced as such. The current usage of the term "site" in the Draft PHA to refer to the waste impoundments north of I-10 creates inaccuracies in many aspects of the Draft PHA…

Response 2-2A:

The EPA currently describes the site as follows on their website:

"The Site consists of a set of impoundments approximately 14 acres in size, built in the mid-1960s for disposal of paper mill wastes, and the surrounding areas containing sediments and soils potentially contaminated with the waste materials that had been disposed of in the impoundments. The set of impoundments is located on a partially submerged 20-acre parcel of real estate on the western bank of the San Jacinto River, in Harris County, Texas, immediately north of the Interstate Highway 10 (I-10) Bridge over the San Jacinto River between two unincorporated areas known as Channelview and Highlands…"

For the purpose of this PHA, the term "Site" is clearly defined in the Background section under Site Description as the 20 acre tract of land on the west bank of the SJR north of the I-10 bridge. Our definition is sufficiently close to the EPA's definition, and the accompanying four figures in Appendix B of the PHA, should be sufficient to unequivocally identify the "site" to which this PHA refers.

Comment 2-2B Draft PHA Does Not Reflect Current Conditions:

(p 4, ¶ 2) When revising this draft, the authors will also need to update all of the sections that describe "Current Progress" in the conclusions that are summarized at the beginning of the document to reflect the current status of data collection and analysis under the RI/FS, and to provide citations to relevant documents. As written, the Draft PHA accurately reports that an RI/FS Work Plan, sediment study, fate and transport evaluation, and bioaccumulation assessment have been undertaken, but does not acknowledge the additional steps that have been completed, including the completion of four major field programs, provision of the resulting chemistry data sets to EPA, and data analysis. A comprehensive list of the data collection and analysis steps that have been completed under the TCRA and RI/FS, and relevant document citations, are provided in Attachment A; this list should be included in the final PHA.

Response 2-2B:

DSHS appreciates the detailed listing of data collection and analysis steps and references provided by the commenter. We have listed some highlights of these activities in the PHA document under the Site History section. However, the PHA addresses the potential risks associated with the Site at the time it was added to the NPL, and these latest developments are outside the scope if the initial PHA.

Rather than attempting to discuss the implications of each of these activities, DSHS added the following reference to the availability of documents containing the most current status and conditions at the SJRWP site (presumably including all of the items on the commenter's list) in the Summary section under For More Information:

> If you have any questions regarding the most current status and conditions at the San Jacinto River Waste Pits Superfund Site, much of the information is available on the EPA websites:
>
> http://www.epa.gov/region6/6sf/texas/san_jacinto/
> http://epaosc.org/site/site_profile.aspx?site_id=6534
> http://www.epa.gov/earth1r6/6sf/pdffiles/0606611.pdf
>
> Also, a complete set of documents is available for viewing by interested parties at the site repository:
>
> Stratford Branch Library
> 509 Stratford Street
> Highlands, Texas 77562-2547
> (281) 426-3521

Comment 2-2C Speculative Statements Should be Deleted:

(p 5, ¶ 4) Finally, there are statements in the Introduction and elsewhere that appear to be both speculative and have little relevance to the purpose of the Draft PHA, and therefore should be deleted. For example, statements in the second paragraph of the Introduction describe potential transport of dioxin-contaminated sediment or sand off of the "site" (i.e., waste impoundments north of I-10).

Response 2-2C:

PHAs at Superfund sites are intended to consider all plausible pathways of exposure to site contaminants. The intent is to insure that potentially significant exposures are not overlooked. The statements about dioxin-contaminated sand being transported off-site are more than speculative. Fact 1. Sand mining operations to the northwest of the site (our definition) excavated partially into surface impoundment A, which contains dioxin wastes. Fact 2. Residual sand from the excavated area northwest of the site is contaminated with dioxin wastes. Fact 3. The sand that was mined from the excavated area was no longer present at the site. Therefore, in our opinion, dioxin-contaminated sediments or sand must have been transported off-site at some point in time.

Comment 2-2D Statements Re Site & Other Dioxin Locations Speculative:

(p 5, ¶ 4) … Similarly, a statement on page 15 makes an inferential link between the wastes on the Site and "scattered elevated levels of dioxin over a much larger area in the [San Jacinto River], [Houston Ship Channel] and [Upper Galveston Bay]." Such statements are not based on established facts or on a systematic evaluation of available data, and are therefore speculative.

Response 2-2D:

Integral Consulting may have inferred a relationship between site contaminants and "scattered elevated levels of dioxin over a much larger area," but the PHA did not imply such a relationship; it merely reported that scattered elevated levels of dioxins had been found throughout the SJR, HSC, and UGB as well as at the site. These statements are based on established facts (objective sediment sampling results), and they are based on a systematic evaluation of available data (the TCEQ's HRS Package and the University of Houston's Dioxin TMDL Project dataset), and therefore they should not be dismissed as speculative. However, DSHS qualified the statement in question as follows:

"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 foci of elevated levels of dioxin over a much larger area in the SJR, HSC, and UGB [3,11], most of which appear to be unrelated to the SJRWP site."

Comment 2-2E Other Areas with Elevated Dioxins Not Related to Site:

(p 5, ¶ 4) … As discussed in Attachment A, there are numerous sources of dioxins and furans in the Houston Ship Channel and Galveston Bay that are not related to the waste impoundments associated with the Site. There has been no analysis that demonstrates any link between the dioxins and furans in the waste impoundments and those found in other areas of the Houston Ship Channel or Galveston Bay. In fact, the results of two independent analyses found different patterns of dioxin and furan congeners across the regional area and within the Site itself (Tzhone 2011; Louchouarn and Brinkmeyer 2009); findings that indicate that more than one source of dioxins and furans exists within the areas evaluated. Therefore, we request that these statements and inferences be removed from the Draft PHA.

Response 2-2E:

DSHS acknowledges that we are not aware of any analysis that demonstrates any link between the dioxins and furans in the waste impoundments and those found in other areas of the Houston Ship Channel or Galveston Bay. Indeed, we clearly state in Conclusion 7 that "…sediment samples downstream…have not shown any clear evidence of significant off-site migration of PCDD/PCDFs from the SJRWP site." We have also agreed to qualify the statement on page 15 about scattered foci of elevated levels of dioxin (see Response 2-2D above). Consequently, we feel that we have adequately qualified any of our statements mentioning off-site dioxin contaminants and therefore have elected to keep these references to off-site dioxins in the PHA document.

Comment 2-3 Some Scenarios Not Plausible, May Over-Estimate Risk:

(p 6, ¶ 4) … There are some areas, however, in which the Draft PHA uses approaches that are not consistent with standard risk assessment practices. It includes some scenarios that are not plausible and bases exposure point concentrations on older data (i.e., collected between 2002 and 2005) that are not representative of current conditions at the Site. In addition, the Draft PHA bases risk calculations on assumptions and parameters that are not well supported and, when combined, are likely to over-represent actual exposures at the Site. Finally, the substantial uncertainties associated with the scenarios evaluated, and the potential for high levels of conservatism that likely overestimate risks for individuals who may use the Site, have not been adequately discussed.

Response 2-3:

The TCEQ collected sediment sample data from the site in July and August of 2005, and the site was proposed as a Superfund site approximately 2 years later. Only the off-site sediment samples from other areas in the San Jacinto River/Houston Ship Channel/Upper Galveston Bay waterway system, collected under the Dioxin TMDL Project, went back as far as 2002. These were the most current data available for the analysis. Since dioxin in the environment changes only very slowly over time, we would not expect significant changes over a period of a few years. PHAs done at Superfund sites are not designed or intended to portray the changing risks over time as cleanup activities progress; instead, they are intended to portray the potential risks from exposures that may have occurred if nothing were to be done to clean up the site.

Oral and dermal exposure levels for all individuals visiting or fishing at the SJRWP site and other locations in the San Jacinto River/Houston Ship Channel/Upper Galveston Bay waterway system are unknown; however, on the basis of the pathway analysis, we made a number of admittedly conservative assumptions about possible oral and dermal exposures and set up six scenarios describing a broad range of possible exposures. DSHS acknowledges that the highest exposure scenario (the Subsistence Fisherman) is, in all probability, an unlikely scenario, however we feel that it is at least plausible that someone could visit and/or fish at the site 5 days per week and could eat an average of 40 ounces of fish caught near the site per week. These are doable things; they may be unlikely, but they are not entirely implausible.

Comment 2-4A PHA Needs a Section Describing Uncertainties:

(p 7, ¶ 2) A new section describing uncertainties associated with the data and assumptions applied in calculating human risks should be added to give context to the risk results.

Response 2-4A:

DSHS agrees that a section describing the uncertainties associated with the data and assumptions applied in calculating human risks is appropriate in a PHA of this nature and will add such a section. However, many of the uncertainties mentioned in the supporting document for this general technical comment are already more than adequately addressed by our display of the risk estimates for all the tested fish and crab species and by our use of six different exposure scenarios.

Therefore, DSHS added the following section to the SJRWP PHA immediately before the Conclusions Section:

Uncertainties Associated with the Risk Assessment Process

Cancer and non-cancer risk assessments are inevitably affected by a broad range of uncertainties including:

- The contaminant point concentrations in sediment or fish used in the exposure dose calculations (e.g., maximum concentration vs. average concentration vs. upper 95% confidence limit on the average concentration)
- The quantity of sediment assumed to be ingested by a child or an adult during each visit to the site
- The percent of ingested sediment that is assumed to be absorbed into the body
- The quantity of sediment assumed to be adhering to each square cm (cm^2) of skin exposed to site sediments
- The number of cm^2 of skin assumed to be exposed to sediments from the site on each visit (what parts of the body are most plausibly exposed)
- The percent of the contaminant in contact with skin that is assumed to be absorbed into the body
- The quantity of fish or crabs assumed to be ingested by a child or an adult following each visit to the site
- The assumed body weight of each exposed individual

- The assumed frequency of visits to the site (days per week, days per month, days per year, etc.)
- The assumed number of years that the exposures continue.

DSHS has elected to calculate risk estimates for both maximum values and average values for sediments for the sake of completeness, but the public health implications are based on risk estimates derived from average concentration values. For comparison purposes, risk estimates were calculated for each fish or crab species, based on their respective average concentrations. Public health implications for cumulative risks were based on the assumption that people eat a variety of fish (whatever they happen to catch) over an extended period of time, which in turn implies that they would be exposed to the average TCDD TEQ concentration for all fish and crab species combined.

The quantity of sediment ingested per visit for children up to 6 years of age was assumed to be 200 mg. After age 6, this value was assumed to decrease linearly to 100 mg per visit by age 18 and continue at that rate (100 mg per visit) for any adult exposures. These values are standard assumptions commonly used in ATSDR health assessments. The oral absorption factor was assumed to be 50% for the absorption of TCDD TEQ out of sediments and 95% for the absorption of TCDD TEQ out of fish or crabs.

For dermal exposures we assumed a soil adherence factor of 1 mg/cm^2 and a dermal absorption factor of 3%. We assumed each child and adult would receive exposure to sediments on both hands and forearms on each visit to the site. We assumed that each child and each adult would eat a fish meal consisting of fish and/or crabs caught at the sight for each visit to the site. We assumed the size of each fish meal for an adult would be 8 ounces of skin-off filets. For children, we scaled the size of the fish meal down in proportion to the ¾th power of the body weight of the child with respect to the ¾th power of the body weight of the adult. Body weights for children and adults visiting the site were calculated for one-year or less age groups for children and five year or less age groups for adults derived from average body weights by age reported in the EPA Exposure Factors Handbook [21]. To account for variability in the frequency of visits to the site and years of exposure, we set up six different scenarios to cover a wide range of different plausible exposures.

Since the risk estimates are essentially linear at the exposure levels anticipated in this PHA, changing any one of the above parameters (except for body weight) changes the risk estimate by the same factor. For example, increasing the sediment ingestion rate by 20% (100 mg/day to 120 mg/day) would increase the risks from oral sediment ingestion by 20%. Likewise, decreasing any parameter by 20% (80% of the default parameter) decreases the resulting risk by 20%. Since risks are inversely proportional to the body weight, increasing the body weight by 20% decreases the resulting risk to 83.3% of its original value ($1.0 \div 1.2 = 0.833$). Likewise, decreasing the body weight by 20% increases the resulting risk by 25% ($1.0 \div 0.8 = 1.25$).

<u>Comment 2-4B Using Multiple Upper-Bound Parameters Over-Estimates Risk:</u>

> **(At A, p 5, ¶ 2)** An evaluation of the assumptions used in the fish consumption pathway helps to demonstrate the multiplicative effects of combining multiple upper-bound

parameters. For the child of the subsistence angler scenario, the estimated cancer risks are presented by species in Table 17 of the Draft PHA. Using the average TEQDF concentration for the blue catfish, the species with the highest average concentration, along with the assumed meal frequency of 260 days/year and exposure duration of 47 years, the estimated cancer risk is reported to be 1.37E-03. Table 17 of the Draft PHA demonstrates the effect of changing the EPC and, therefore, shows the sensitivity of the risk calculation to that input. For example, if it is assumed that the individual consumes red drum instead of blue catfish, then the estimated risk is reduced to 2.20E-05. However, there is no discussion of the impact of the combination of assumptions used in estimating risks.

(At A, p 5, ¶ 3) As demonstrated below, the impact of reducing individual parameters substantially reduces the risk estimate. However, when several parameters are changed concurrently, the difference in risk estimates is even more significant.

Parameter Changed for Child of Subsistence Angler	Estimated Cancer Risk
Current assumptions	1.37E-03
Assuming red drum instead of blue catfish	2.20E-05
Reducing exposure frequency to 2 meals per week	5.48E-04
Reducing exposure duration to 30 years	8.75E-04
Combining all changes in parameters	5.62E-06

Response 2-4B (Attachment A):

Most of the detailed comments in the supporting Attachment A seem to be suggesting that DSHS should include in the PHA only those scenarios and parameters that produce the lowest calculated risk estimates, arguing that those with higher risks are high because of the "multiplicative effects of combining multiple upper-bound parameters." The argument that the higher risk numbers are not valid because, if you switch to a different fish species (with a lower dioxin level), the risks go down, or if you assume that a person has only 2 fish meals per week (instead of 5 as in the Subsistence Fisherman scenario) the risks go down, or if you combine both of these changes, the risks go down even more, seems to be stating the obvious (i.e., if you reduce the exposure, you reduce the risk). Yes, the risks go down if you eat only those fish species with less dioxin contamination or if you eat less fish. However, this is not a justification for not showing the risks associated with eating more highly contaminated fish or eating larger quantities of fish. The purpose of showing dioxin levels and risk numbers for each fish species (as well as for all species combined) and showing how each species fairs under the six exposure scenarios is to show how the risks vary over a wide range of exposures. All the data were presented, not just the low risk numbers, not just the high risk numbers.

In general, DSHS tends to use assumptions that are protective for 95% or more of the population. This means that we must frequently base our scenarios on parameters coming from the 75th or higher percentile level of the anticipated probability distributions. We understand that the chosen parameters do not all represent the best guess average exposure for all individuals who have ever or may ever visit the site. We also understand that combining a series of 75 percentile (or higher) assumptions, may well produce a risk estimate that may be 95th, 99th, or 99.9th percentile in a probabilistic risk assessment. However, since our intent is to protect public health and not to attempt to approximate the real-life average exposure occurring at the site, we make no apologies for using conservative parameters in our scenarios. If the only scenario we evaluated was the best-guess average, we would potentially only be protecting 50% of the population, because 50% would have lower than average exposures (and would be protected) and the other 50% would have higher than average exposures (and would not be protected).

<u>Comment 2-4C Use of the Subsistence Fisherman Scenario Not Plausible:</u>

(p 7, ¶ 3) The evaluation of subsistence fishermen is not plausible and should be removed. (At A, p 6, ¶ 3) While the Draft PHA has included these scenarios, it has provided no justification for the assumption that there is a population of anglers who use the waste impoundments in this way. The Draft PHA acknowledges this when it states that "it is unlikely that any individuals are actually consuming such large quantities of fish and crabs with these levels of [tetrachlorodibenzo-p-dioxin] TCDDs for such an extended period of time" (Draft PHA p. 34).

Response 2-4C:

The entire point of defining six different exposure scenarios was to show the potential risks to the public under a wide range of different possible exposures. One does not accomplish such an objective by eliminating and ignoring all potential exposures that are not in line with the best-guess average exposure. Since half the people have greater than average exposures and half the people have less than average exposures, to base all risk estimates and recommendations on average exposures is to fail to protect half of the population.

DSHS does not assume that there is a real population of anglers who use the waste impoundments at the site for subsistence fishing. This is a scenario. If you or someone you know fishes like a subsistence fisherman then your risks would be such and such. If instead, you only fish at or visit the site on an occasional basis, then your risks would be only a small fraction of such and such. DSHS acknowledged in the PHA that the risk estimate under the Subsistence Fisherman scenario 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. Nevertheless, the Subsistence Fisherman scenario, we believe, appropriately defines the upper range of plausible exposures, and as such serves an important function in the risk assessment, needing no specific justification or surveillance data proving the existence of actual subsistence fishermen at the site.

Comment 2-4D Dioxins Come From Multiple Sources:

(p 7, ¶ 4) The Draft PHA should recognize that dioxins and furans present both in the immediate vicinity of the waste impoundments and in the surrounding areas evaluated in the Draft PHA originate from multiple sources.

(At A, p 10, ¶ 4) … Both the results of location-specific studies, and general information about dioxin and furan sources in the environment, indicate that multiple sources have contributed to dioxins and furans measured at the Site and within the surrounding areas evaluated within the Draft PHA. This fact should be discussed within the PHA in order to give context to the results presented within.

(At A, p 10, ¶ 4) Given the documented existence of other sources, the lack of rigorous fate and transport analysis to support these inferences about dispersal of waste-related dioxins and furans into other areas downstream, and the lack of relevance of such information, any statements in the Draft PHA that assume a link between dioxins and furans from the impoundments to sediments in the San Jacinto River estuary and Upper Galveston Bay should be removed.

Response 2-4D:

Since the SJRWP PHA is, by definition, focused on the site, it is beyond the scope of the PHA to go into a lengthy discussion theorizing about the possible origins of dioxin wastes appearing in numerous locations throughout the San Jacinto River/Houston Ship Channel/Upper Galveston Bay waterway system. For the purposes of the PHA, the source of the contaminants or who is responsible for causing them to be in their various off-site locations is immaterial. The PHA does not attempt to ascribe blame for any off-site dioxin contamination. However, one does not need a rigorous fate and transport analysis to support the simple conclusion that river water flowing over an uncapped surface impoundment containing dioxin and furan wastes is likely to result in some sort of dispersal of these contaminants to other areas downstream.

Comment 2-4E Dioxin Risks in Other Areas Should be Discussed:

(p 7, ¶ 5) Risks for other parts of the San Jacinto estuary and Galveston Bay area should be discussed in a manner that helps provide context to the risks estimated for the waste impoundments.

(At A, p 10, ¶ 4) While the Draft PHA includes both sets of results, it provides no discussion or interpretation of the relative risks and hazards from exposures at the waste impoundments and those associated with exposures outside that area. Additional discussion of the relative risks is needed. For example, for the child of subsistence fisherman and adult fisherman scenarios, the Draft PHA determines the potential cancer risks associated with the average concentration in the waste impoundments north of I-10 as 1.57E-03 and 9.07E-04, respectively which are outside the EPA's acceptable risk range. As addressed above, these scenarios are implausible and are not representative of potential exposures associated with the Site and therefore should be removed. To the extent that they are retained, however, it should be noted that the estimated average "off-site" cancer risks are 5.21E-04 and 3.22E-04, respectively, which also exceed the EPA's acceptable risk range. It is important to discuss the "off-site" risk estimates in more detail to provide better information for risk managers about background risk levels and the specific risks associated with the waste impoundments. Adding such discussion would provide important perspectives on the overly conservative nature of the exposure parameters used for the risk estimates.

Response 2-4E:

This is exactly what the PHA does; it evaluates the potential risks from dioxin exposures that might result from contact with sediments from other areas of the SJR, HSC, and UGB as a backdrop for the risks that might result from contact with contaminated sediment present at the site. The relative risks of off-site versus on-site exposures are self-evident in the risk numbers themselves, and DSHS repeatedly compares on-site risks with off-site risks. These facts should need no particular additional discussion beyond what is already presented in the PHA. DSHS does mention that for off-site fishing locations, the cumulative risk for oral, dermal, and fish/crab exposures combined 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 (see Table 19). A quick check of Table 17 for the risks from fish/crab consumption alone shows the risk to be 5.18×10^{-4} (clearly the major contributor to the cumulative risk numbers).

<u>Comment 2-4F PHA Should be Re-Done as a Probabilistic Analysis</u>

(p 7, ¶ 6) The Draft PHA should be revised to present a probabilistic analysis to explain variability in exposure estimates.

(At A, p 12, ¶ 2) Implausible results can be avoided through the use of a probabilistic approach instead of a deterministic approach. There are data available on the behaviors of anglers that provide a wide range of consumption rates, exposure frequencies, and species preferences (e.g., multiple studies presented in USEPA 1997, 2009). These data can be used to estimate statistical distributions for individual exposure parameters that better reflect the range of possible values and their probabilities of occurrence within the exposure model. If these distributions are combined in a meaningful way, with careful thought about their interdependencies, then the Draft PHA can provide a better representation of the full range of risks and the likelihood that specific levels of risk will occur. Such an approach will more appropriately capture the substantial variability in human behaviors and will help to frame and quantify the uncertainties introduced into risk estimates by using single-point estimates to represent exposures.

Response 2-4F:

Probabilistic risk assessment is indeed a powerful tool for evaluating the range of risks that may occur when probability distributions are used for the various input parameters for the risk calculations, but for the purposes of this PHA, these techniques would be somewhat of an "over-kill" and would unnecessarily cause further delay in finalizing the SJRWP PHA. Incidentally, implausible results are not necessarily avoided through the use of a probabilistic approach. In fact, the values representing the upper extremes of the various probability distributions are selected in accordance with their various probabilities. Periodically, when the Monte Carlo analysis is run, all of the extreme values will be selected by chance for a particular calculation, producing an implausible combination of extremes.

DSHS agrees that a probabilistic approach will more appropriately capture the substantial variability in human behaviors and will help to frame and quantify the uncertainties introduced into risk estimates by using single-point estimates to represent exposures. However, we did not use only single-point estimates to represent exposures; we used six different exposure scenarios covering a wide range of possible exposures and risks. At this point in the process, redoing the entire analysis using a probabilistic approach is not an option. We feel the analysis is already complicated enough, and we would be concerned that the probabilistic approach would be even more difficult for the general public to understand than the current analysis.

Comment 2-4G PHA Should Include a Quantitative Sensitivity Analysis:

(At A, p 12, ¶ 3) If TDSHS does not elect to complete a probabilistic analysis, then it can improve the clarity of its deterministic approach by conducting a simpler, but still quantitative, sensitivity analysis. By varying the assumptions included in each scenario and reporting the resulting changes in risk estimates when assumptions are varied, it can better demonstrate the sensitivity of the risk results to the assumptions used and the levels of conservatism associated with each.

Response 2-4G: (Attachment A)

Carcinogenic risk assessment calculations involve the calculation of a dose term for a particular exposure scenario, an exposure duration term that accounts for exposures that are less than 24hr – 7d – 52wk – 70yr, and the carcinogenic potency factor (or slope factor) for the contaminant. For relatively low dose exposures, producing risks of 10^{-3} or less, the linear form of the risk calculation produces results that are a relatively good approximation of the true exponential form of the risk calculation. Quantitative sensitivity analysis for a straightforward linear equation is trivial and therefore not particularly informative. Anything that increases the dose term (e.g., contaminant concentration or consumption or inhalation rates) or the exposure duration term (e.g., exposure frequency or years of exposure) produces a linear increase in the resulting risk. Of course, the body weight is in the denominator of the dose term, so increasing body weight causes a decrease in the risk. The ways of manipulating the risk calculations are virtually limitless but adding quantitative sensitivity analyses for each parameter would serve no practical purpose in this PHA; the effect on the risk estimate of changing the various parameters is always going to be linear, and including such analyses in the PHA would almost certainly tend to confuse the average reader.

Comment 2-4H PHA Exposure Parameters Need Greater Transparency:

(p 7, ¶ 7) Greater transparency of the exposure parameters assumed is necessary.

(At A, p 13, ¶ 1) The actual assumptions used for each age category included in the three scenarios for children of the various types of anglers are not transparent because all of the parameters used are combined and age-adjusted for the entire exposure period. The result is a single parameter value that represents the entire child-through-adult exposure period. If the purpose of the Draft PHA is to look at cumulative exposures from childhood through adulthood, then it would be more transparent and more appropriate to select and use reasonable and representative exposure parameters for each age group and then sum the risks to derive a total risk. By selecting and explicitly providing specific parameters for each age group, the assumptions that have been used to make those parameter estimates will be clear, and will make it easier to discuss the uncertainties associated with the selected parameters.

Response 2-4H:

The PHA shows six full-page tables that describe and list all of the parameters used in the risk calculations for the various exposure scenarios. We feel that this is sufficiently transparent.

DSHS agrees with the comments in the supporting document (Attachment A, page 13) about getting more accurate risk numbers by calculating age specific risks and summing over the entire duration of the exposure than by using average values over the duration of the exposure for the various parameters to calculate risks. DSHS has indeed developed risk assessment software that uses age-specific risk calculations and allows for a highly flexible setup for the various exposure scenarios. The risk estimates come out somewhat higher using age-specific risk calculations that involve childhood exposure scenarios. For example oral sediment exposures from age 3 to 50 in the Child-of-a-Subsistence-Fisherman or Child-of-a-Weekend-Fisherman scenarios have approximately 37% higher results when risks are summed over the 27 different age intervals comprising this age range. But the risks for dermal exposures and fish consumption exposures are only 4.2% and 3.3% higher, respectively. Risk calculations for adult-only exposures are virtually unchanged. For the purposes of this PHA, these somewhat higher risk numbers would not change any of the basic conclusions. Also, using this alternative method would necessitate redoing the analysis, multiplying the risks by an adjustment factor of 1.033 to 1.37 (determined by the exposure period and the exposure route), and rewriting the entire document. As this would cause unnecessary delays in the completion of the SJRWP

PHA, DSHS has elected to stay with the more conventional method of risk calculation (using average parameter values over the various exposure periods) for this PHA.

Comment 2-4I PHA Should Include More Discussion of Fish Tissue Data:

(p 7, ¶ 8) There is insufficient discussion of the fish tissue data used in the analysis, including where and when the samples were collected.

(At A, p 13, ¶ 2) … In order for the Draft PHA to be transparent and its meaning to be clear, the tissue data used to derive EPCs and the locations and dates from which these samples were collected should be more thoroughly described and presented. It is recommended that the data for individual tissue samples, including individual dioxin and furan congeners in each sample, also be presented. The locations and dates of fish collections should be provided, and the sample numbers in each data set used to calculate EPCs should be included. It would also be helpful if the specific tissue types included in the assessment were presented. To do this, a description of the samples (i.e., whole-body versus fillet; skin-on versus skin-off, etc.) should be included as an Appendix to the PHA.

Response 2-4I:

DSHS agrees with this comment; a description of the location and date of collection were inadvertently omitted from the "Environmental Samples Collected" section, and such a section will be added to the PHA.

DSHS disagrees with the suggestion of adding a new set of tables showing the concentrations for each of the 17 individual dioxin/furan congeners present in each sample as this would add (for most readers) nothing but page after page of meaningless numbers and would add more confusion than illumination. Consequently, DSHS added the following section to the SJRWP PHA under the "Environmental Samples Collected" section:

DSHS SALG Fish and Crab Samples

As part of its routine follow up activities regarding earlier fish consumption advisories for the HSC, SJR, and UGB, DSHS SALG traveled to the Houston area on four different occasions in February-April of 2004 to obtain additional fish samples. One of the sites visited was the tidal portion of the SJR immediately upstream of the I-10 Bridge. Seven fish (2 blue catfish, 2 spotted seatrout, 1 hybrid striped bass, and 2 red drum) and 2 blue crab specimens were collected from this location. The skin-off fish fillets were packaged, labeled, frozen, and hand-delivered to the DSHS laboratory for analysis. The blue crab samples were prepared by removing the top shell and apron of each crab, followed by removal of gills, viscera, and eggs from the body cavity. Crabs were split along the ventral line, half of each crab was used to form a composite for the site, and composites were packaged, labeled, frozen, and hand-delivered to the DSHS laboratory for analysis.

Comment 2-4J Data Should be Revised to Reflect Current Conditions:

(p 7, ¶ 9) Data used to estimate concentration terms do not reflect current conditions.

(At A, p 13, ¶ 3) … Given these temporal changes, the calculated risks based on older data are not reflective of current conditions at the waste impoundments. It is recommended that the data collected most recently, as part of the RI/FS for the Site, be acknowledged in the Draft PHA (e.g., using data presented in the PSCR to be delivered in July 2011), to ensure that the risk estimates provided in the Draft PHA reflect current conditions.

Response 2-4J:

Again, the PHA is not intended to portray only the most current conditions at the site or to estimate risks that might occur at the site only in the context of the most current conditions. Likewise, it is not intended to show a chronology of risks over time as conditions change. Instead, it is intended to show the possible risks that existed at the time the site was added to the NPL.

Comment 2-4K Use of Cumulative Exposures Not Justified:

(p 7, ¶ 10) There is no justification for the cumulative exposures presented in the PHA.

(At A, p 14, ¶ 5) The Draft PHA reports separate risk estimates for oral ingestion of sediments, dermal absorption of sediments, and ingestion of fish, and then only provides a combined risk for all three. While all individuals who may have fished from the waste impoundments in the past may have had some contact with sediment there, the reverse is not true. There may be a number of individuals who visited the waste impoundments in the past for recreational purposes but did not consume fish caught there. In order to characterize risks for this subset of the population, oral and dermal exposures to sediments should be summed, and risks associated with the combination of these two exposure pathways alone (i.e., without fish consumption) should be presented.

Response 2-4K:

DSHS disagrees with this comment; whenever multiple exposure pathways come into play at a superfund or other type of site, it is always appropriate to consider cumulative risks from all pathways combined in the risk assessment. In the SJRWP PHA, we showed individual risk tables for sediment ingestion, sediment dermal absorption, and fish consumption and then showed tables with cumulative risks for all three routes of exposure combined. Adding another table showing partial cumulative risks from oral and dermal sediment exposures without the fish consumption would probably not add significantly to the understanding of the potential risks from dioxin exposures at the site. Anyone interested in those particular numbers can relatively easily sum the corresponding risks from the oral and the dermal tables to get the cumulative risks for those two pathways without the fish.

Comment 2-5A PHA Focuses too Much on Site-Related Exposures:

(p 7, ¶ 11) The fraction of total exposure that is assumed to be derived from the waste impoundments north of I-10 is not realistic.

(At A, p 15, ¶ 1,2,3) The Draft PHA assumes that 100 percent of the fish consumed and 100 percent of the sediment contacted during the exposure period for all six scenarios evaluated occurs exclusively at the waste impoundments north of I-10. Although individuals may eat fish or recreate on a regular basis along the shores of the San Jacinto River, it is highly unlikely and unrealistic to assume that 100 percent of their time will be spent within the impoundments north of I-10. That is particularly true if the focus is on current conditions, under which controls exist to prevent unauthorized access to the waste impoundment area that is the focus of the analyses presented in the Draft PHA.

As discussed in the Draft PHA, there are many attractive and easily accessible fishing locations along the shoreline of Galveston Bay including bridges, cleared bank areas, boats, and parks such as the Battleground State Park, where it is known that people frequently fish…

The fraction of total exposure from the waste impoundments is relevant, but is not a critical consideration when evaluating either the weekend or the sporadic fishermen scenarios because these individuals were assumed to fish the waste impoundments at a maximum rate of 1 day per week… For example, if TDSHS continues to assume that there are individuals who fish Galveston Bay 5 days per week, then it may be appropriate to assume that anglers historically fished at the waste impoundments on no more than one of those days. Therefore, the fraction of total exposure and risk that could be attributed to the waste impoundments north if I-10 in this scenario would be reflected by applying an adjustment factor of 20 percent (0.2) to the final exposure estimate.

Response 2-5A:

DSHS used the average dioxin levels for all sediment samples collected at the site to represent the possibility that an individual might come in contact with sediments from multiple locations on the site over time. We assumed that a very small amount of contaminated sediment might be ingested by inadvertent hand-to-mouth activities, and we assumed that a small amount of contaminated sediment could be distributed on the hands and forearms of people visiting or fishing at the site. Since the SJRWP site is the focus for this PHA, the scenarios involving oral and dermal sediment exposures naturally use the average dioxin levels seen at the site. In the PHA, we present scenarios involving exposures to down-stream sediments, off-site sediments collected in the vicinity of the site, sediments from the HSC, sediments from tributaries & up-stream of the site, and all off-site sediments combined. So, there are plenty of scenarios evaluating risks from off-site exposures. However, one does not evaluate the potential risks from exposure to SJRWP sediments by assuming that 80% of a person's fishing time occurs somewhere else. Consequently, it is entirely inappropriate to arbitrarily alter all the risk calculations in this PHA by the suggested factor of 20% of the present values.

Comment 2-5B Scenario Exposure Durations Not Appropriate

(p 7, ¶ 12) The exposure duration assumed is not realistic or in line with standard risk assessment practice.

(At A, p 16, ¶ 2,3) The Draft PHA assumes that adult subsistence and weekend anglers fish at the waste impoundments for a total of either 30 years (adults only) or 47 years (children and adults). While the assumption of 30 years as an upper-bound estimate of the exposure duration is consistent with standard risk assessment approaches (USEPA 1997), the exposure duration of 47 years for the child and adult is not. The upper-end exposure duration of 30 years used by EPA is based on the 90th percentile of the number of years spent by individuals in one residence…

Response 2-5B:

The duration of an exposure is of course one of key factors in any exposure scenario. DSHS used a 30 year exposure duration for the adult exposure scenarios, which corresponds to the 95th percentile of residence duration recommended by the EPA in their Exposure Factors Handbook. While 30 years may be the 95th percentile of the number of years spent by individuals in one residence, it doesn't automatically mean that they move to a different city; they may well move to a different neighborhood in the same city where exposures at their favorite fishing locations could continue. Some purists would actually assume a 70-year-lifetime exposure duration for all of the exposure and risk calculations. However DSHS feels that our 30-year adult and 47-year childhood-to-adult exposure duration assumptions are sufficiently in line with standard risk assessment practices to not require any changes to our scenarios or methodology. Again, these are scenarios, and proof that there are substantial numbers of real people who fit into every scenario is not required prior to calculating the possible risks for each scenarios.

Comment 2-5C Scenario Exposure Frequencies Not Appropriate

(p 7, ¶ 13) The exposure frequency for the child subsistence fisher is not plausible and should be reduced.

(At A, p 16, ¶ 4) The exposure frequency assumed for the child of subsistence fishermen is 5 days a week, for 8 hours a day, throughout the year for every year of exposure. It assumes that the child never goes to school, never participates in after-school activities, and never has a job as a teenager or adult. It also does not realistically account for extended periods of high water or poor weather conditions. Such assumptions are unreasonable, even if an individual is the child of a subsistence angler. If the Draft PHA continues to evaluate a subpopulation that fishes at the waste impoundments 5 days per week throughout the year, the assumptions for children need to be adjusted to reflect more realistic conditions (e.g., a schedule that includes attendance at school). It should also be qualified as a retrospective analysis, because access to the area that is the subject of the PHA no longer exists.

Response 2-5C:

The Subsistence-Fisherman and Child-of-a-Subsistence-Fisherman scenarios represent the upper extremes of the plausible exposures for the site and are presented as such. There are already four other exposure scenarios to account for people who have lesser exposures. There is no justification for reducing the upper extremes of the plausible exposures until they merely represent the most likely exposure level for the average person.

Comment 2-5D PHA Should Not Mention Maximum Exposures:

(p 8, ¶ 1) The use of maximum concentrations as the exposure point concentration for sediment is not appropriate for calculating risks associated with chronic exposures.

(At A, p 17, ¶ 2,3) In the Draft PHA, some of the risk calculations that are presented are based on the maximum measured media concentration as the exposure point concentration. The resulting risk estimates do not reasonably reflect chronic exposures, even for a retrospective risk assessment, because it is unreasonable to anticipate that an individual would be continuously exposed to the maximum concentration during all exposure events over the entire 30- or 47-year exposure duration. For example, this approach effectively assumes that a subsistence child fisher was exposed to the maximum TEQDF concentration measured in sediments from within the impoundments, 5 days per week, 52 weeks per year for 47 years and/or that he or she only consumed fish containing the highest measured concentration.

To make risks more representative of actual exposures, an upper bound estimate on the mean (e.g., 95UCL) should be used in place of the maximum for the upper-end estimate of exposure. The use of this statistic is still conservative in nature but conforms with standard risk assessment practice. If the available data do not allow for an upper bound estimate to be calculated (i.e., if the relatively small sample set is largely variable) then, at the very least, a discussion of the uncertainty associated with the use of a maximum concentration should be included.

Response 2-5D:

Risks from exposures to the maximum contaminant level seen at the site were presented to provide context for discussing the risks from exposures to the average contaminant level at the site, which were always the major focus for the discussions. DSHS agrees that use of the upper 95% confidence limit for the mean contaminant concentration would be another (possibly preferred) method for estimating the risks. If we used the 95% UCL on the mean, however, we would probably use only that value and not the mean for calculating risks in the SJRWP PHA. This would require a re-write of the entire document, would result in needless delays, would not add anything substantive to the content, and is not in the best interest of the public.

Comment 2-5E PHA Should Use Central Tendency Exposures Only

(p 8, ¶ 2) The central tendency exposure estimates should incorporate central tendencies for the range of exposure parameters used so that the result reflects average exposures that might be anticipated to occur at the waste impoundments north of I-10.

(At A, p 17, ¶ 4) The Draft PHA should present a central tendency exposure (CTE) estimate for each of the defined receptor groups, which would represent a more plausible estimate of average exposure. Although the assessment does present an estimate of exposure using the average TEQ_{DF} concentrations in sediment and tissue, the remaining exposure parameters assumed (e.g., sediment and fish ingestion rates, exposure duration, and exposure frequency) are all the same as those used to estimate high-end exposure. As defined by EPA, the CTE analysis is developed using a combination of mid-range or average values (USEPA 1989; USEPA 1992); therefore, CTE estimates that incorporate CTE values for these other exposure parameters should be calculated.

Response 2-5E:

Rather than using single central tendency estimates of the exposure parameters, DSHS utilized six different exposure scenarios to represent a range of potential risks that might be anticipated to occur at the waste impoundments north of I-10. We feel that this gives a better perspective of the possible range risks than would a single central tendency estimate. Also, using only central tendency estimates, while arguably giving a better estimate of risk for the average person, tends to overlook the risks to people who are closer to the upper end of the distribution for the various exposure parameters. In general, DSHS tends to use assumptions that are protective for 95% or more of the population rather than only 50% as would be the case if we used central tendency estimates for all of our assumptions.

Comment 2-5F PHA Should Consider Effects of Cooking on Dioxins:

(p 8, ¶ 3) Reduction of dioxin and furan concentrations in fish tissue from cooking should be incorporated into the risk calculations.

(At A, p 18, ¶ 1,2,3,4) It is well recognized that tissue preparation and cooking methods used influence the concentrations of dioxins and furans in fish tissue (USEPA 1999, 2000b). Concentrations of lipophilic chemicals, such as dioxins and furans, which are present in fatty tissues, may be reduced by removing the skin, trimming the fat and implementing various cooking methods.

Very limited information is provided in the Draft PHA for the fish samples that were used to calculate EPCs. It appears that the TDSHS fish sampling included analysis of skin-off fillets, so that the samples have likely been trimmed. However, actual exposure to dioxins and furans in trimmed, skinless fish fillets will depend on the cooking methods used by the individuals who consume them. A lack of consideration of these changes in concentration from cooking overestimates potential exposures and risk…

Response 2-5F:

DSHD SALG (who collected the fish samples referenced in this PHA) uses skin-off fillets for measuring dioxins in fish. Since dioxins and furans are relatively stable at ordinary cooking temperatures, DSHS always assumes the concentrations of these specific compounds are essentially unchanged by cooking. Technically, cooking, by reducing water content, could be argued to actually increase dioxin concentrations in the cooked fish. Also, cooking with skin-on as many people do could actually drive subcutaneous fats (where much of the dioxins are concentrated) into the tissues and juices that are more likely to be eaten. While a "skin-on cooking gain factor" would potentially be justifiable if we had sufficient data to quantitate the likely increase, we feel an arbitrary "cooking-loss factor" is inappropriate and reject the suggestion to add such a factor to the risk calculations.

Comment 2-5G PHA Should Not Consider Individual Fish Species:

(p 8, ¶ 4) The uncertainties associated with the estimated risks for different species of fish and species combinations should be fully discussed to provide perspective on species specific risk results.

(At A, P 19, ¶ 1,2,3) …Calculating risks from consumption of different fish species allows for a range of hypothetical risks to be estimated. It is unlikely, however, that fishermen at the waste impoundments would have confined their consumption to a single species of fish, particularly at the frequency and over the chronic duration assumed in the assessment. It is more likely that fishers would have consumed a variety of tissue types. This is particularly true for a subsistence scenario, if this is to be retained in the Draft PHA, because a true subsistence person would have been opportunistic and would likely have eaten any fish species caught.

The average TEQ_{DF} concentrations presented in the document vary more than 50-fold among tissue types. Given the large variability in these data, together with the likelihood that the true diet of a chronically exposed individual is made up of a variety of fish and crab types, the assumption that he or she exclusively ate catfish (i.e., the tissue type with the highest average concentration), artificially inflates the true exposure that would have been experienced by an individual. In fact, the Texas Parks and Wildlife Department reported in its 2005 Coastal Fishing Forecast2 that the species most preferred by anglers who fish Galveston Bay are red drum, spotted seatrout, and flounder.

The average TEQ_{DF} of all fish types that might be consumed is likely to provide a more accurate representation of true exposure. If TDSHS continues to use the current approach, then the uncertainties and levels of conservatism associated with the species-specific results should be presented and discussed. Additionally, the range of risks for different exposure scenarios, species, and locations should be presented in both the conclusions and the summary of the Draft PHA, rather than just reporting the highest risk results for the waste impoundments alone and the implausible subsistence fishing scenarios.

Response 2-5G:

In the tables showing risks from fish consumption, DSHS shows risks for each species individually as well as risks for the average for all species combined. Contrary to what the commenter assumes on page 19 of Attachment A, for our cumulative risk estimates (oral sediment, dermal sediment, and fish consumption exposures combined), DSHS used the average concentration for all fish and crab species combined, assuming that over the years a person would eat a variety of fish and crabs rather than only a single species (See section d. All exposure Routes Combined, SJRWP PHA, p34). Since a relatively small number of fish had been analyzed for dioxins and furans, we presented detailed risk estimates based on average concentrations by fish species in the various tables presenting the risks from fish consumption. We do not feel that a much more in-depth analysis or discussion would add significantly to the PHA. As should easily be noted by carefully examining all of the tables presented in this PHA, DSHS does not make a practice of presenting only the highest risk results (or only the lowest risk results). Instead, we tend to ere on the side of publishing all of the risk results, be they high or low.

Comment 2-5H Body Weight Scaling for Fish Consumption Not Justified:

(p 8, ¶ 5) The body weight scaling applied for calculating fish consumption rates is not technically justified.

(At A, p 19, ¶ 4,5) While it is stated that the fish ingestion rates for children have been developed using a body weight to the three-quarters power, there is no justification provided for using this approach to adjust fish consumption rates. This approach is commonly used for scaling of toxicity factors for inter-species differences, to reflect the different bioenergetics associated with smaller body weights and the effect that differing metabolic rates may have on toxicity of a compound. It is not common risk assessment practice, however, to estimate the fish consumption rates on the basis of rates of metabolism. Moreover, there are empirical data available for the fish consumption rates of different age groups, making this uncertain adjustment unnecessary.

In its 2009 draft revision of the Exposure Factors Handbook, USEPA (2009) recommends age-specific mean and 95th percentile values for fish consumption for various populations. It is recommended that these values be used to estimate potential exposures for each age group evaluated.

Response 2-5H:

Scaling dietary intakes proportionally to the ¾th power of the body weights is a relatively standard means of accounting for differences in body weight between adults and children in setting various Estimated Average Requirements (EARs) or Adequate Intakes (AIs). It is one of the commonly used means of extrapolating data from adults to children, used by the Food and Nutrition Board of the National Academy of Sciences. Using this method for calculating protein requirements for people of different ages and body weights gives a very good correlation with published protein requirements for people of various ages. Thus this method provides a simple, straightforward, and consistent means of obtaining a relatively good estimate of likely dietary intakes for people of various body weights in cases where actual intakes are unknown. It is based on the ¾th power law for metabolic rates which are characteristic of nearly all organisms. Consequently, we feel that the body weight scaling method used is sufficiently justified for the purposes of this PHA.

<u>Comment 2-5I Uncertainties Due to "Non-Detect" Results Should be Discussed:</u>

(p 8, ¶ 6) Uncertainties introduced by treatment of non-detected results should be quantified and discussed.

(At A, p 20, ¶ 3,4) When calculating TEQ_{DF}, the Draft PHA substituted one-half the estimated detection limit (EDL) for dioxin/furan congeners when those congeners are not-detected in individual samples. This assumption introduces substantial uncertainty into the summed TEQ_{DF} concentration.

It is recommended that TDSHS complete a quantitative uncertainty analysis to better clarify the impacts of the treatment of censored data. This analysis would entail assigning different values (e.g., full EDL or zero) to non-detected values, and investigating the difference that such assumption make on the estimated exposure point concentrations and risk estimates.

Response 2-5I:

The only non-detect results in the data sets used in the SJRWP PHA are in the individual dioxin or furan congener concentrations. In our calculations of the TCDD TEQ for each specimen, these non-detect results were appropriately assigned a value of ½ the detection limit. DSHS has found through previous Monte Carlo analysis that this practice gives a better representation of a left-censored log-normally distributed data set than assigning a value of 0 (or the full EDL) to non-detects. If we had assumed that a non-detect represented a true 0 value or the full EDL, the resulting TCDD TEQ for some of the samples would have been slightly lower or slightly higher, respectively. Samples with dioxin levels of 8,000 pg TCDD TEQ/g or higher had real values for all congeners (i.e., no non-detects) and consequently there would have been no uncertainty introduced with these samples. Samples in the intermediate concentration range (i.e., from 500 to 1,400 pg TCDD TEQ/g) would have seen a slight changes at the third or fourth significant digit. Assuming that such a small change constitutes a "substantial uncertainty" is quite a stretch of the imagination. It makes no practical difference whatsoever whether the calculated value comes out as 1,391.962 or 1,391.840 pg/g. In the very low dioxin concentration samples, some greater degree of uncertainty may have been introduced if we had mistakenly counted non-detects as true 0 values. For example, for samples less than 5 pg/g, the TCDD TEQs could have been underestimated by 45% to 65%. Of course low concentrations produce low risk exposures, and a 65% under-estimation of the TCDD TEQ in a low-risk exposure would have been of no practical consequence to anyone. However, since we didn't use the short-cut method of calculating the TCDD TEQ, this is not an issue, and attempting to further quantify the slight differences in calculated TCDD TEQs or discussing the merits of different methods of handling non-detects (beyond this brief discussion) would be an unnecessary academic exercise that would not add significantly to the PHA. Uncertainties at the third or fourth significant digit (which might be important in sending a space ship to the moon) are inconsequential for the purposes of this PHA.