CONTAMINATED SEDIMENT MANAGEMENT PLAN: DOMINGUEZ CHANNEL ESTUARY

In Support of

Final Dominguez Channel and Greater Los Angeles and Long Beach Harbor Waters Toxic Pollutants Total Maximum Daily Loads

Submitted to

California Regional Water Quality Control Board, Los Angeles Region

Submitted by

California Department of Transportation
City of Long Beach
City of Los Angeles
City of Torrance
Los Angeles County
Los Angeles County Flood Control District

March 2014

TABLE OF CONTENTS

1 INTRODUCTION 1
1.1 Setting: Dominguez Channel and Dominguez Channel Estuary 2
1.2 Dominguez Channel Toxics TMDL 4
1.2.1 TMDL Compliance 5
1.2.2 TMDL Schedule 7
1.2.3 Contaminated Sediment Management Plan 8
1.3 Regional Sediment Management Regulatory Process 10
1.4 Federal Sediment Management Guidance 12

2 CONTAMINATED SEDIMENT MANAGEMENT APPROACH OVERVIEW 14
2.1 Milestone 1: Monitoring and Data Collection Program 14
2.2 Milestone 2: Identification of Potential Management Areas 16
2.3 Milestone 3: Identification of Management Alternatives 17
2.4 Milestone 4: Selection of Management Alternatives 19
2.5 Milestone 5: Commence Management Action 20

3 DEFINED PRIORITY SITES: DOMINGUEZ CHANNEL ESTUARY 21
3.1 Milestone 1: Monitoring and Data Collection Program 22
3.1.1 Sediment Data Review and Summary 23
3.1.1.1 Sediment Quality Data Gaps 25
3.1.2 Sediment Quantity Data Review and Data Gaps 26
3.1.3 Fish Tissue Data Review and Data Gaps 26
3.2 Milestone 2: Identification of Potential Management Areas 27
3.3 Milestone 3: Identification of Management Alternatives 27
3.4 Milestone 4: Selection of Management Alternatives 28
3.5 Milestone 5: Commence Management Actions 28
3.6 CSMP Schedule 28

4 SUMMARY 31

5 REFERENCES 32

List of Tables

Table 1 Final, Mass-Based TMDLs and Allocations for Metals, PAHs, DDT, and PCBs 5
Table 2 CSMP Schedule 29

List of Figures

Figure 1 Dominguez Watershed Management Area 3
Figure 2 CSMP Milestones 15
Figure 3 TDDT Concentrations in Dominguez Channel Estuary 24

List of Appendices

Appendix A Reconnaissance Study: Dominguez Channel Estuary
Appendix B Principles for Evaluating Remedial Options for Contaminated Sediment Sites

LIST OF ACRONYMS AND ABBREVIATIONS

Basin Plan Amendment	Attachment A to Resolution No. R11-008, *Amendment to the Water Quality Control Plan – Los Angeles Region*
BMP	Best Management Practice
CCC	California Coastal Commission
CCMRP	Coordinated Compliance Monitoring and Reporting Program
CDFW	California Department of Fish and Wildlife
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CIMP	Coordinated Integrated Monitoring Programs
CSM	Conceptual Site Model
CSMP	Contaminated Sediment Management Plan
CSTF	Contaminated Sediment Task Force
DCE	Dominguez Channel Estuary
DDT	Dichlorodiphenyltrichloroethane
DMMT	Dredged Material Management Team
Dominguez Channel Toxics TMDL	*Final Dominguez Channel and Greater Los Angeles and Long Beach Harbor Waters Toxic Pollutants Total Maximum Daily Loads*
EWMP	Enhanced Watershed Management Program
MLOE	Multiple Lines of Evidence
MNR	Monitored Natural Recovery
MOA	Memoranda of Agreement
MOU	Memoranda of Understanding
MS4	Municipal Separate Storm Sewer System
NMFS	National Marine Fisheries Services
NPDES	National Pollutant Discharge Elimination System
PAH	Polycyclic Aromatic Hydrocarbon
PCB	Polychlorinated Biphenyl

POLA	Port of Los Angeles
POLB	Port of Long Beach
PRP	Potential Responsible Party
RWQCB	Los Angeles Regional Water Quality Control Board
Shell	Shell Oil Company
SQO	Sediment Quality Objectives
TDDT	Total Dichlorodiphenyltrichloroethane
TMDL	Total Maximum Daily Load
USACE	U.S. Army Corps of Engineers
USEPA	U.S. Environmental Protection Agency
WLA	Waste Load Allocation
WMA	Watershed Management Area
WMP	Watershed management program

1 INTRODUCTION

The Dominguez Channel Estuary Contaminated Sediment Management Plan (CSMP) was developed to support the long-term recovery of sediment and water quality in the Dominguez Watershed. The California Department of Transportation, City of Long Beach, City of Los Angeles, City of Torrance, Los Angeles County, and Los Angeles County Flood Control District have collaborated on the development of this CSMP. Additional CSMPs are being developed by other stakeholders for Los Angeles Harbor, Long Beach Harbor, Eastern San Pedro Bay, and Los Angeles River Estuary.

Section 1 of the CSMP provides the regulatory background requiring the creation of a CSMP and a summary of the relevant information needed to support the sediment management decision process. A description of the physical setting and known contaminant-related issues, including the 303(d) listing and subsequent development of the *Final Dominguez Channel and Greater Los Angeles and Long Beach Harbor Waters Toxic Pollutants Total Maximum Daily Loads* (Dominguez Channel Toxics TMDL), is also included. The Dominguez Channel Toxics TMDL compliance requirements, Total Maximum Daily Load (TMDL) schedule, CSMP requirements, and integration with the stormwater programs are provided, as is a summary of regional regulatory programs and the national guidance for contaminated sediment management.

Section 2 of the CSMP describes an approach designed to form the basis for all CSMPs developed to support sediment contaminant reductions in affected waterbodies as noted in the Dominguez Channel Toxics TMDL. The approach describes a process for defining actions and decisions to be implemented for each of five identified milestones to support contaminated sediment management.

Section 3 of the CSMP summarizes specific actions and decisions relevant to the Dominguez Channel Estuary (DCE). A description of current site conditions is followed by a data gaps analysis to support additional data needs. The recommended approach to integrate the CSMP with other water quality related programs is discussed. A schedule linking CSMP milestones to the TMDL schedule is also presented.

1.1 Setting: Dominguez Channel and Dominguez Channel Estuary

Dominguez Channel is a channelized stormwater conveyance system beginning at 116th Street in the city of Hawthorne and runs in a generally southerly direction, passing through the cities of Gardena, Torrance, Carson, and Los Angeles and the unincorporated County of Los Angeles before discharging into Consolidated Slip within the Port of Los Angeles (POLA). Historically, the southern end of the Dominguez Channel consisted of marshes and wetlands. This area was dredged in the early twentieth century to create the Los Angeles/Long Beach Harbor. The channelization of this drainage system in the 1960s ended ongoing flooding concerns and provided land for the construction of homes and businesses (City of Los Angeles 2014). The Dominguez Watershed Management Area (WMA) is shown in Figure 1. The Dominguez WMA includes the drainage area of the Dominguez Channel, Machado Lake, and the Los Angeles/Long Beach Harbor watersheds. Approximately 93 percent of the land within the Dominguez WMA is developed with 41 percent industrial, commercial, and transportation land uses and 40 percent residential development. The eastern portion of the watershed near the Dominguez Channel has a high concentration of industrial uses with very little vacant and open spaces present. Of the six Watershed Management Areas within Los Angeles County, the Dominguez WMA has the highest ratio of impervious land cover (Weston 2005).

The Dominguez Channel Watershed is divided into two sub-watersheds. The upper watershed is the portion that drains to the concrete-lined, rectangular reach of the Dominguez Channel (above Vermont Avenue). The lower watershed consists of the drainage area tributary to the DCE. The lower watershed also includes the Torrance Lateral, which is a significant tributary channel to the DCE. The combined drainage area is approximately 72 square miles (or approximately 62 percent of the Dominguez WMA). The remaining areas of the Dominguez WMA drain into Machado Lake, or directly into the Los Angeles/Long Beach Harbor (MEC 2004). A brief description of the channel and adjacent land use is provided in *Dominguez Watershed Management Master Plan* (MEC 2004).

Figure 1

Dominguez Watershed Management Area

The Dominguez Channel Watershed contains two Superfund sites: the Montrose Chemical Corporation (Montrose) site and the Del Amo site. Montrose manufactured Dichlorodiphenyltrichloroethane (DDT) on a 13-acre site in a light industrial/residential area in the city of Torrance from 1947 to 1982. Contaminants of concern at the Montrose site are DDT, chlorobenzene, and benzene hexachloride. DDT has been found in soils at the former plant property and surrounding areas, in sediments and soils in the historical stormwater pathway from the site (Kenwood Drain), and in the groundwater close to the former plant property.

Shell Oil Company (Shell), Dow Chemical Company, and several other companies operated the Del Amo Synthetic Rubber Manufacturing plant from 1955 to 1972 to produce synthetic rubber for the United States military operations. In 1972 the plant was dismantled, and the buildings were demolished (USEPA 1999). Contaminants of concern at the Del Amo site are volatile organic compounds, including benzene and toluene, Polycyclic Aromatic Hydrocarbons (PAHs), and semi-volatile organic compounds (Lyons and Birosik 2007).

1.2 Dominguez Channel Toxics TMDL

California's 303(d) List of Water Quality Limited Segments (SWRCB 2006) includes three areas of Dominguez Channel: lined portion above Vermont Avenue, unlined portion below Vermont Avenue (also referred to as DCE), and Torrance Lateral (also referred to as Torrance Carson Channel). The upper, freshwater portion consists of 6.7 miles of the channel located above Vermont Avenue and is constructed of reinforced concrete with vertical sides. Below Vermont Avenue, the channel changes to a trapezoidal compacted earth bottom channel with riprap banks. The 8.3 miles from Vermont Avenue to Consolidated Slip is subjected to tidal flows (WBMWD 2009) and is identified as the DCE on the 303(d) List.

On March 23, 2012, the Dominguez Channel Toxics TMDL became effective and was promulgated to protect and restore fish tissue, water, and sediment quality in the Dominguez Channel and Greater Los Angeles and Long Beach Harbor Waters by remediating contaminated sediments and controlling the sediment loading and accumulation of contaminated sediments in the Dominguez Channel Watershed.

Total maximum daily loads (TMDLs) are established to attain and maintain applicable water quality standards for impaired waterbodies. TMDLs provide pollutant limits that are implemented through permits (Municipal Separate Storm Sewer System [MS4], other National Pollutant Discharge Elimination System [NPDES] permits, etc.). This CSMP has been developed in response to the Dominguez Channel Toxics TMDL, which addresses localized sediment quality and regional fish tissue quality and is expected to achieve attainment of fish tissue, water, and sediment quality through source reduction, source control, management actions, and Monitored Natural Recovery (MNR).

1.2.1 TMDL Compliance

The Dominguez Channel Toxics TMDL set Waste Load Allocations (WLAs) in waterbodies within the Dominguez Channel Watershed to limit sediment-bound pollutant loadings from upstream and on-land sources. In addition, the Dominguez Channel Toxics TMDL set LAs in waterbodies to limit concentrations in bedded sediments believed to impact marine benthos (direct effects) and fish tissue (indirect effects). Mass-based limits for chemical constituents are provided in Table 1 and Attachment A to Resolution No. R11-008, Amendment to the Water Quality Control Plan – Los Angeles Region (Basin Plan Amendment; RWQCB and USEPA 2011).

Table 1
Final, Mass-Based TMDLs and Allocations for Metals, PAHs, DDT, and PCBs

Waterbody	Total Copper (kg/year)	Total Lead (kg/year)	Total Zinc (kg/year)	Total PAHs (kg/year)	TDDT (g/year)	Total PCBs (g/year)
Dominguez Channel Estuary	84	115.4	370.5	9.94	3.9	7.9

Notes:
g = gram
kg = kilogram
TDDT = total DDT

Compliance with sediment allocations may be demonstrated via any one of three different means:

1. Final sediment allocations, as presented in the Basin Plan Amendment (RWQCB and USEPA 2011), are met.
2. The qualitative sediment condition ranking of "unimpacted" or "likely unimpacted" by interpreting and integrating Multiple Lines of Evidence (MLOE) as defined in the Sediment Quality Objective (SQO) Part 1 is met, except for chromium which is not included in the SQO Part 1.
3. Sediment numeric targets are met in bedded sediments over a 3-year averaging period.

The SQO program provides guidance for applying the *Water Quality Control Plan for Enclosed Bays and Estuaries: Sediment Quality Plan* (SWRCB 2009). SQOs have been developed for contaminants of concern in bays and estuaries in California based on an approach that incorporates MLOE (Bay et al. 2009). These MLOE include sediment chemistry, sediment toxicity, and benthic community condition.

Compliance with fish tissue targets may be demonstrated via any one of four different means:

1. Fish tissue targets are met in species resident to the Dominguez Channel Toxics TMDL waterbodies.
2. Final sediment allocations, as presented in the Basin Plan Amendment (RWQCB and USEPA 2011), are met.
3. Sediment numeric targets to protect fish tissue are met in bed sediment over a 3-year averaging period.
4. Demonstrate that the sediment quality condition protective of fish tissue is achieved per the *Water Quality Control Plan for Enclosed Bays and Estuaries: Sediment Quality Plan* (SWRCB 2009), as amended to address contaminants in resident finfish and wildlife.

Numeric targets, implementation schedules, and listed contaminants of concern may be revised during the TMDL reopener, tentatively scheduled for spring 2018.

1.2.2 TMDL Schedule

The Dominguez Channel Toxics TMDL schedule is divided into three phases:

- Phase I, completed 5 years after effective date of the Dominguez Channel Toxics TMDL
- Phase II, completed 10 years after effective date of the Dominguez Channel Toxics TMDL
- Phase III, completed 20 years after effective date of the Dominguez Channel Toxics TMDL

The purpose of Phase I actions is to reduce the amount of sediment transport from point sources that directly or indirectly discharge to the Dominguez Channel and Greater Los Angeles and Long Beach Harbor Waters. For Dominguez Channel, Torrance Lateral, and DCE, Phase I actions should include instituting watershed-wide actions, and developing CSMPs. The Dominguez Channel Toxics TMDL states that sediment conditions in Dominguez Channel, Torrance Lateral, and DCE are to be evaluated through the SQO process detailed in the SQO Part 1. If chemicals within sediments are contributing to an impaired benthic community or toxicity, then causative agent(s) are to be determined using SQO recommended procedures and impacted sediments are to be included in the list of sites to be managed.

In addition, the Dominguez Channel Toxics TMDL states that the Los Angeles County Flood Control District and other responsible parties that discharge to Dominguez Channel should each be responsible for conducting actions to address contaminated sediments in the Dominguez Channel and DCE. Parties that are tributary to the DCE are required to develop a CSMP. The CSMP is to be submitted to the Executive Officer of the Regional Water Quality Control Board (RWQCB) no later than 2 years after the effective date of the Dominguez Channel Toxics TMDL.

Actions to achieve WLAs and LAs may be implemented in phases with information from each phase being used to inform the follow on actions in the next phase. Phase II of the TMDL schedule should include implementing additional Best Management Practices (BMPs) and site remediation actions, such as determined to be effective based on the success of upstream source control; evaluating TMDL monitoring data collected during Phase I; and performing targeted source reduction activities as identified in Phase I. Phase II should include site-specific cleanup actions for areas identified as high priority in the DCE and in accordance with the CSMP. The Basin Plan Amendment states that if the City of Los Angeles and/or Los Angeles County, should they decide to take action that impacts one of the Superfund Site Operable Units within the Dominguez Channel, shall consult with the U.S. Environmental Protection's (USEPA's) Superfund Division in advance of such action.

Phase III of the TMDL schedule should include secondary and additional remedial actions as necessary to be in compliance with the final allocations by the compliance date. TMDLs to allocate additional contaminant loads between dischargers in the Dominguez Channel, Torrance Lateral and DCE sub-watersheds may also be developed, if necessary (RWQCB and USEPA 2011).

1.2.3 Contaminated Sediment Management Plan

Meeting goals and targets in complicated TMDLs requires a holistic approach that includes source identification and control from multiple sources within the watershed, water column, and in-place (bedded) sediments. Developing a CSMP is only one component in a larger effort to meet the goals of a TMDL focused on legacy pollutants in existing sediments. Components of a holistic approach include:

- Monitoring plans
- Watershed Management Program (WMPs)/Enhanced Watershed Management Program (EWMPs)
- Sediment management plans
- Special studies, such as stressor identification, source identification, BMP effectiveness, and chemical fate and transport mechanisms and processes investigations

The Dominguez Channel Toxics TMDL requires development of a CSMP to describe an approach for contaminated sediment management. Implementation of management actions will require coordination among stakeholders and regulators across multiple regulatory programs. Because management actions are often very costly and contaminant sources to sediment are believed to be ongoing, it is critical that source reductions are coupled with the implementation of management actions in a strategic approach to ensure those actions are effective and result in meaningful improvements to water quality. In the event that multiple investigations are implemented, individual monitoring programs are encouraged to engage in a data sharing approach to ensure that the intent of these CSMPs—which is to characterize the current state of impairment of the DCE and to identify potentially critical sources of contamination—is achieved across these multiple programs and the most effective watershed-wide remediation action may be determined.

This CSMP is designed to meet the requirements of the Dominguez Channel Toxics TMDL and identify, prioritize, and manage contaminated sediments for protecting and improving benthic community condition and human health from fish consumption. This risk-based approach will assess impacts and provide information on source identification and the nature and extent of impacted areas. This CSMP provides an approach for identifying potential management areas and associated alternatives based on relevant sediment and tissue data and special studies. Management alternatives will be selected based on a stakeholder and Potential Responsible Parties (PRPs) process, while considering environmental and human health risks of each alternative.

The Dominguez Channel Toxics TMDL encourages collaboration and coordination of monitoring, reporting, and implementation efforts. The approach defined in this CSMP will require the cooperation of all responsible parties to fully execute the steps of this strategy to effectively restore sediment, water, and fish tissue quality within the entirety of the DCE. The DCE has been identified as a priority area for management in the Dominguez Channel Toxics TMDL. Named responsible parties with a LA to the DCE include:

- Los Angeles County
- Los Angeles County Flood Control District
- California Department of Transportation
- City of Long Beach
- City of Los Angeles
- City of Compton
- City of Gardena
- City of Carson

- City of Torrance

Los Angeles County, Los Angeles County Flood Control District, California Department of Transportation, City of Torrance, City of Long Beach, and City of Los Angeles have collaborated on this CSMP process for the DCE.

1.3 Regional Sediment Management Regulatory Process

Management actions identified in the Dominguez Channel Toxics TMDL include targeted sediment remediation within areas of known concern, which includes the Dominguez Channel, DCE, Consolidated Slip, and portions of the Inner Harbor. Management actions for Dominguez Channel remediation are to include and consider efforts associated with the cleanup of the two Superfund sites located within the Dominguez Watershed: the Montrose site and the Del Amo site. The USEPA has not yet reached a final remedial decision for these sites.

Sediment management actions implemented for TMDL compliance must comply with state and federal regulatory authorities. Like any other area of the United States, any voluntary in-water construction activities in navigable waters are regulated activities, subject to a variety of state and federal statutes, such as the California Environmental Quality Act, Porter-Cologne Water Quality Control Act, National Environmental Policy Act, Rivers and Harbors Act of 1899, and Clean Water Act. In addition, existing state and federal programs provide guidance on sediment management and should be the basis for CSMPs developed in response to TMDL requirements.

Guidelines for capping, dredging, disposal, and long-term management of contaminated sediments in the Los Angeles Region were developed by the Los Angeles Contaminated Sediments Task Force (CSTF). The CSTF includes representatives from the U.S. Army Corps of Engineers (USACE), USEPA, National Marine Fisheries Services (NMFS), California Coastal Commission (CCC), RWQCB, California Department of Fish and Wildlife (CDFW), Port of Long Beach (POLB), POLA, City of Long Beach, Los Angeles County Beaches and Harbors, Heal the Bay, and other interested parties. After developing the *Los Angeles Regional Contaminated Sediments Task Force: Long-Term Management Strategy* (CSTF

2005), the CSTF's role in the region shifted to that of an advisory group that convenes routinely to review and comment on procedural issues related to sediment management.

The Los Angeles Dredged Material Management Team (DMMT), led by the USACE and USEPA Region 9, is the regional regulatory group responsible for managing and authorizing sediment management programs. Participants include all state and federal permitting agencies, such as the CCC, CDFW, NMFS, and RWQCB. Using the CSTF document as its guidance, this group meets monthly to review and discuss permit applications, approve sampling plans, and provide guidance on appropriate management alternatives for contaminated and clean sediments. Strategies for managing contaminated sediment disposal are prioritized to meet regional objectives. The preferred management strategy for contaminated sediments is beneficial reuse in construction fill (e.g., nearshore confined disposal facility), temporary storage in an approved upland area (until a fill project becomes available), treatment and reuse as a marketable product (e.g., cement), other beneficial upland placement, or placement in a confined aquatic disposal site.

Implementing voluntary in-water construction activities within the jurisdiction of a port, a city, or a county would be designed, managed, and implemented by the respective staff within that port, that city, or that county or their representatives based on regional, state, and federal guidelines and strategies.

Involuntary sediment management actions, such as a response to a RWQCB Cleanup and Abatement Order for violating the Clean Water Act, or a remedial action detailed in a Record of Decision under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) or NPDES would be managed as directed by the lead regulatory agency for each respective program. For example, the USEPA has developed a formal process under CERCLA for assessing site risks, evaluating suitable numeric and narrative cleanup objectives, selecting a remedy that best meets the goals for the target action, and monitoring the effectiveness of the remedy. Regulatory oversight for sediment remediation activities within CERCLA or NPDES cleanup programs may only involve the DMMT and CSTF if material disposal was planned for an in-water confined disposal facility within the region or in an advisory role.

1.4 Federal Sediment Management Guidance

Federal regulations (CERCLA, Superfund Amendments and Reauthorization Act, and Resource and Recovery Conservation Act) provide mechanisms for the USEPA to address contaminated sediments believed to be impairing beneficial uses of rivers and harbors. In 2005, the USEPA provided technical and policy guidance for project managers and management teams making remedy decisions for contaminated sediment sites. This guidance, *Contaminated Sediment Remediation Guidance for Hazardous Waste Sites* (USEPA Guidance Document; USEPA 2005), incorporates experiences and lessons learned from more than 20 years at contaminated sediment sites and identifies 11 risk management principles that should be applied when managing contaminated sediment sites. This guidance, which remains as the primary guide for USEPA staff and project managers, provides a formal process and is based on the following 11 principles:

- Control sources early.
- Involve the community early and often.
- Coordinate with states, local governments, Indian tribes, and natural resource trustees.
- Develop and refine a Conceptual Site Model (CSM) that considers sediment stability.
- Use an iterative approach in a risk-based framework.
- Carefully evaluate the assumptions and uncertainties associated with site characterization data and site models.
- Select site-, project-, and sediment-specific risk management approaches that will achieve risk-based goals.
- Ensure that sediment cleanup levels are clearly tied to risk management goals.
- Maximize the effectiveness of institutional controls and recognize their limitations.
- Design remedies to minimize short-term risks while achieving long-term protection.
- Monitor during and after sediment remediation to assess and document remedy effectiveness.

The first principle of controlling sources early prior to conducting remediation is critical to the effectiveness of any sediment cleanup, because the site may become re-contaminated without source control (Nadeau et al. 2009). The other principles are designed to guide the project manager through understanding site conditions (e.g., CSM development) and identifying the site's risk drivers, which can then be used to evaluate potential remedial alternatives. Based on the CSM and risk assessments, remedial action objectives are derived and should reflect objectives that are achievable from remediation of the site. Some goals, such as lifting a fish consumption advisory, may require watershed level actions that are outside the scope of the site cleanup and may not be achievable on a short-term or even a long-term basis regardless of the subject site's remediation success (Nadeau et al. 2009).

Specific sediment remedy alternatives are identified in USEPA Guidance Document (2005). These include MNR, capping, dredging, in situ treatments, and combining alternatives. Nadeau et al. (2009) and Bridges et al. (2008) review implementation and residual risks for various remedies. Nadeau et al. (2009) provides an overview of MNR, capping, and dredging, while Bridges et al. (2008) focuses on resuspension, release, residual, and risk of environmental dredging. In 2013, the Office of Superfund Remediation and Technology Innovation published *Use of Amendments for In Situ Remediation at Superfund Sediment Sites* (USEPA 2013), providing an overview of technologies to treat contaminated sediments in situ. This document introduces promising amendments for in situ remediation and summarizes some of the information on contaminated sediment sites that have employed amendments. While this document is not intended to be a guidance or design document, the authors note that the USACE Engineer Research Development Center is developing technical guidelines for in situ sediment remediation.

2 CONTAMINATED SEDIMENT MANAGEMENT APPROACH OVERVIEW

To ensure management actions are ecologically beneficial and logistically and economically feasible, this CSMP was developed to identify, prioritize, and manage chemically impacted sediments, where necessary, to protect and improve benthic community condition and human health from fish consumption. This CSMP uses a risk-based approach to assess impacts due to chemically mediated effects as a means for determining the magnitude and extent of possible management actions. Overall, this approach follows guidance and lessons learned from the USEPA Guidance Document (USEPA 2005). A five step or milestone approach has been developed to logically assess and evaluate potential management actions (Figure 2). The initial step in a CSMP is to analyze available data, identify data gaps, collaborate with regional monitoring programs, conduct special studies, as needed, and identify sources and nature and extent of impacted sediments. Sediment and water quality will be evaluated as part of the required Dominguez Channel Toxics TMDL monitoring program, MS4 and NPDES permits' required monitoring programs, regional monitoring programs, and related special studies. The second milestone focuses on identification of potential management areas and includes identification of potentially responsible parties. Following this step, the next milestone will be reached when management alternatives will be identified for each area and will consider passive and remedial actions. The fourth milestone focuses on the selection of management action and approval from the RWQCB. The final milestone commences when management actions are initiated.

2.1 Milestone 1: Monitoring and Data Collection Program

Sediment, water, and fish tissue monitoring will be conducted through approved Coordinated Integrated Monitoring Programs (CIMP), Coordinated Compliance Monitoring and Reporting Programs (CCMRPs), regional monitoring programs (e.g., Southern California Bight), MS4 and NPDES permits' required monitoring, and special studies. If multiple programs are employed within the watershed, every effort should be made to engage in a data sharing program among jurisdictional groups to ensure, where possible, data gaps are filled and that all relevant and available data are compiled and analyzed prior to making a conditional assessment on the watershed.

Figure 2

CSMP Milestones

Special study data collection programs may be implemented to fill additional data gaps, examine the spatial and temporal patterns of contaminants, establish linkage between sediment contaminant concentrations and impairment, and identify and quantify sources.

Part 1 of the *Water Quality Control Plan for Enclosed Bays and Estuaries: Sediment Quality Plan* (SWRCB 2009) provides recommendations for additional investigations to be conducted to confirm impairment and identify causative agents. Potential studies/tools may include statistical procedures (principle components analysis and multiple regression analysis), toxicity identification evaluations, bioavailability studies, and dose/response spiking studies. These studies/tools will be used to:

- Analyze available data to confirm sediments are causing impairment.
- Conduct special studies to establish linkage between sediments and impairment.
- Support use of the SQO tool for direct effects to assess causative agent(s).
- Conduct source investigation.
- Define nature and extent of impacted areas.

The time and effort needed to collect data to address site-specific needs is dependent on the site and the processes that influence the fate and transport of contaminants in that system. It is also dependent on the stakeholder collaboration process and the integration and concurrence of available data.

2.2 Milestone 2: Identification of Potential Management Areas

The entire waterbody or a sub-area of the waterbody may be defined as an area to be managed. The Dominguez Channel Toxics TMDL identifies certain areas as priority areas; however, through the CSMP process, sub-areas within a priority waterbody may be identified and prioritized using a similar process as the USEPA's risk-based process for evaluating contaminated sediment sites. The PRPs will be identified. PRPs include city/agencies/dischargers with a LA and current and historical dischargers of the causative agent.

The preliminary list of sites to be managed will be provided to the RWQCB during the reopener. As new information is gained, potential management areas will be identified.

2.3 Milestone 3: Identification of Management Alternatives

For potential management areas, a range of sediment management alternatives will be summarized and their effectiveness at meeting water quality requirements within the TMDL schedule will be considered. Developing and evaluating remedial alternatives should follow the USEPA Guidance Document (USEPA 2005), which bases alternatives development on a CSM and risk assessments. Alternatives considered will range from passive actions (MNR and source control) to active remedial actions (treatment, capping, and/or dredging).

At a minimum, the following typical contaminated sediment management alternatives will be considered for each area:

- *Source Control.* Source control includes the process of identifying contaminant sources and implementing corrective actions to reduce or eliminate existing contaminants from entering the management area. Contaminants may enter the management area via one or more pathways: direct discharge from stormwater or industrial outfalls, surface runoff, sediment transport, and/or deposition. Source control actions may address the contaminant or pathway and range from passive approaches such as public education to increasingly more active approaches such as regulating or terminating discharges to the system and upgrading infrastructure to reduce contaminant loadings. Source control measures are a pre-requisite to any management alternative listed below and are most often closely associated with MNR and enhanced natural recovery alternatives where recovery is expected through a more passive remediation approaches.
- *Monitored Natural Recovery.* Natural recovery is defined as the process through which deposition of non-contaminated sediments and other natural processes (e.g., degradation, diffusion, and burial) decrease sediment contaminant concentrations over time. It is necessary to determine the rate of natural recovery in a particular area to determine its effectiveness as a remedial alternative. As recommended in the USEPA Guidance Document (USEPA 2005), MLOE are needed to establish the rate of natural recovery in a system. Typically, these lines of evidence include demonstrating decreasing fish or invertebrate tissue chemistry concentrations, decreasing water column chemical concentrations, and decreasing surface sediment chemistry trends.

- *Enhanced Natural Recovery.* Enhanced natural recovery typically refers to the activity of placing a thin-layer clean cap of sediments over the contaminated surface to enhance the natural recovery process through mixing via bioturbation or currants. This clean layer is not intended to provide complete containment of the underlying contaminated sediments but generally provides for a cleaner substrate and sufficient initial isolation that, along with future deposition of new material, will reduce contaminant migration. The degree of improvement depends on surface sediment conditions prior to placing the clean material and rate of mixing. In general, the clean material reduces average surface sediment concentrations and levels of exposure to organisms.
- *Capping.* Engineered capping involves placing clean material on top of contaminated sediments to effectively isolate the sediments in perpetuity. Engineered caps typically are 3 to 5 feet thick to account for potential erosion, contaminant mobility, and bioturbation. At sites where propeller wash or high current velocities or waves may impact the stability of the cap, an armor layer may be required to prevent cap erosion. Similarly, in areas where potential groundwater upwelling may occur, a reactive treatment layer using products such as activated carbon can be applied to filter the porewater as it fluxes up through the thin-layer clean cap.
- *In Situ Treatment.* In situ treatment of sediments refers to technologies that immobilize, transform, or destroy contaminants of concern while leaving sediments in place (i.e., without first removing sediments). In situ treatment technologies are effective for broad categories of contaminants. Carbon amendment (alone or in conjunction with other technologies) is an innovative technology that has been explored for application with organic compounds, including Polychlorinated Biphenyls (PCBs). Bench- and pilot-scale studies are likely required to demonstrate that the technology will be effective for specific compounds in specific areas.
- *Dredging.* Physically removing contaminated sediments is the most common method of sediment remediation. Removal typically involves dredging, using either mechanical or hydraulic dredging equipment. Land-based excavation equipment can sometimes be used if contaminated sediments are located within reach of the shore. Removal is always combined with some form of disposal option (e.g., upland landfill, construction fill, aquatic containment, or ocean disposal). Depending on the nature of the material being removed (grain size, chemistry, etc.), dredge residuals may be a

concern that will require additional management through measures, such as thin-layer capping of the dredge footprint.

Further information on evaluating remedial options for contaminated sediments is provided in Appendix B. Nadeau et al. (2009) highlights key risk-based decision-making factors necessary to realistically evaluate risk reduction associated with each remedial option. This paper is based upon the decision-making process recommended by the USEPA Guidance Document (USEPA 2005).

For each potential management alternative, the following should be considered:

- Technical, logistical, and economic feasibility
- Social and environmental impacts
- Estimated cost
- Estimated time to complete
- Predicted load reduction to sediment and fish

2.4 Milestone 4: Selection of Management Alternatives

Once an area is designated for management and available management alternatives are summarized, the relevant stakeholder group can select the appropriate action. The makeup of the stakeholder group, and the memoranda of agreement (MOAs) or memoranda of understanding (MOUs) between the stakeholders, will define the process for selecting management alternatives. The MOAs or MOUs will likely detail the communication process, cost-share agreements, and roles and responsibilities of each agency or stakeholder.

Environmental and human health risk levels may be considered to assist in selecting the most appropriate remediation target. The nature and extent of contaminants—including their potential to bioaccumulate, the potential for the area to scour and contribute to contaminant mobility, the presence of sensitive habitats and/or species, and the potential for the area to be re-contaminated—can be considered during selection of an appropriate management action. When possible, management activities may be coupled with other infrastructure and maintenance programs to increase economic and logistic efficiencies. These opportunities may reprioritize management actions.

The timing of the selection of management alternatives is dependent on stakeholder involvement and site-specific actions.

2.5 Milestone 5: Commence Management Action

Once all parties agree to the selected management approach and funding mechanisms are secured, the management action can be scheduled and implemented. When a sediment management action is required to meet a specific objective, post-construction verification that the action was successful in meeting cleanup objectives is required by the regulatory agencies. Methods for determining the effectiveness of the chosen action will be agreed upon prior to the management action being implemented to confirm the success of the action.

3 DEFINED PRIORITY SITES: DOMINGUEZ CHANNEL ESTUARY

Historic activities in the Dominguez Channel Watershed have contributed to the current elevated sediment concentrations observed in DCE. Watershed discharge limitations required under state and federal laws have resulted in reducing inputs to DCE. These programs are expected to continue improving sediment quality in the coming years.

Attaining sediment, water, and fish tissue quality will likely be achieved through a combination of source reduction, source control, sediment removal, and MNR. The Dominguez Channel Toxics TMDL and the recent MS4 Permit (Order No. R4-2012-0175) prescribe specific components that are to inform and enhance water and sediment management. These components include establishing regional monitoring coalitions, CIMPs, WMPs/EWMPs, CSMPs, and special studies. This CSMP is being developed to provide a mechanism for determining and prioritizing one or more sediment management alternative predicated on the information and data obtained from the monitoring efforts of the responsible stakeholder group(s).

CSMP milestones are summarized in Figure 2. The DCE program is at Milestone 1; existing data are being assembled and summarized, data gaps are being developed, and key data needs are being developed to define and develop special studies to fulfill data gaps. Sediment quality will be evaluated as part of the required monitoring programs and special studies. Impacts of sediment-bound contaminants will be evaluated through the SQO process developed by the State Water Resource Control Board (SWRCB 2009). If chemicals within sediments are contributing to impairment, then causative agent(s) will be determined using SQO recommended procedures. Impacted sediments will then be included in the list of sites to be managed. This process will prioritize management efforts at sites that have the greatest impact to the overall condition of the benthic community and risk to humans from fish consumption. The prioritization process will allow sites with lower risks to be addressed in later phases of the TMDL schedule. The site will then be managed and improvements confirmed through a sediment monitoring program. Activities and key questions to be addressed for each milestone shown in Figure 2 are summarized below.

3.1 Milestone 1: Monitoring and Data Collection Program

The initial step in a CSMP is to analyze available data, identify data gaps, collaborate with regional monitoring programs, conduct special studies, as needed, and identify sources and nature and extent of impacted sediments. Sediment and water quality will be evaluated as part of the required Dominguez Channel Toxics TMDL monitoring program, MS4 and NPDES permits' required monitoring programs, regional monitoring programs, and related special studies.

Minimal data will also be generated from the CIMP. The CIMP is currently being developed and will be submitted to the Executive Officer of the RWQCB in June 2014. Briefly, the CIMP will include sediment, water, and fish tissue data for areas conducive to the stakeholders' Watershed Management Areas in DCE. The CIMPs are being developed to address requirements defined in the Dominguez Channel Toxics TMDL and MS4 Permit (Order No. R4-2012-0175). For the purposes of cohesion watershed-wide, methodologies employed in the CIMP sediment monitoring program will be the same as those outlined in the Greater Los Angeles and Long Beach Harbor Waters CCMRP (Anchor QEA 2014a) with site-specific locations defined within the CIMP.

Sediment monitoring pursuant to jurisdictional boundaries of the participating responsible parties in agreement of this CSMP will be conducted through the collaborative monitoring program that will be developed through stakeholder processes. A preliminary description of recommended studies is described below and will be implemented prior to the TMDL reopener. During the next year, study objectives will be confirmed and studies will be designed to address key data gaps. Sampling and Analyses Plans will be developed with data summary reports.

To confirm the impairment and to identify areas within the DCE, a review of available sediment and fish chemistry data was conducted (Anchor QEA 2014b; see Appendix A). Evaluations of DCE sediment chemistry data included comparing them to TMDL targets; reviewing SQO assessments previously conducted on DCE sediment quality data; examining spatial coverage, trends, and variability; and identifying data gaps. The data evaluation examined existing data for completeness and usability. Data gaps were identified and data collection efforts were recommended.

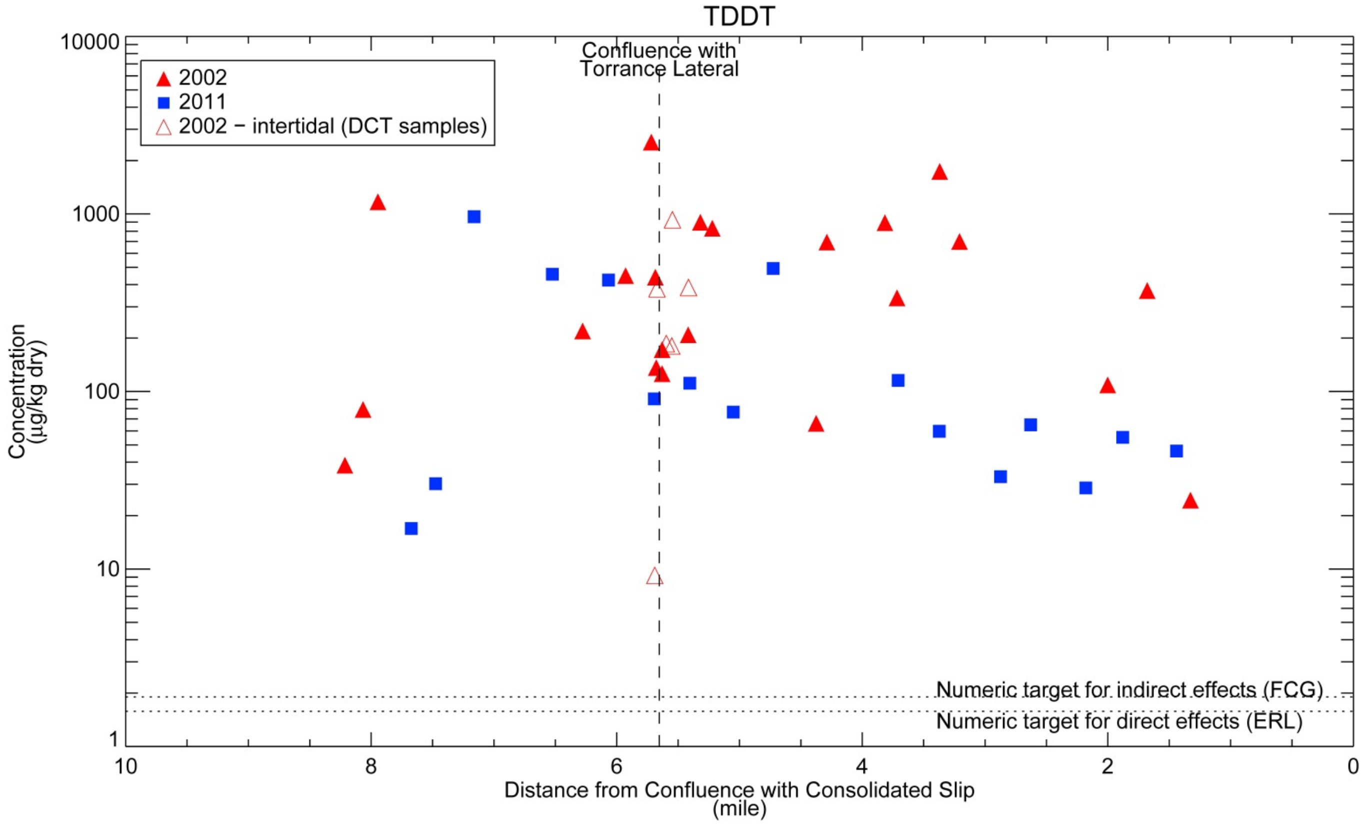
3.1.1 Sediment Data Review and Summary

A thorough data review was conducted. The primary data source was the POLB and POLA sediment chemistry database, an extensive compilation of data collected by a variety of agencies as part of characterization and monitoring studies between 1980 and 2011 (see Table 1 in Appendix A for summary of studies). Data from the Los Angeles/Long Beach Harbor, Eastern San Pedro Bay, DCE, and nearshore areas along the Southern California Bight were included in the compilation.

The 2008/2010 303(d) List for DCE includes the following pollutant impairments: DDT, PCBs, zinc, benthic community effects, benzo[a]anthracene, benzo[a]pyrene, chrysene, phenathrene, pyrene, and toxicity. The Dominguez Channel Toxics TMDL notes that the Dominguez Channel drains a highly industrialized area and also contains remnants of persistent legacy pesticides as well as PCBs that result in poor sediment quality both within the channel and in adjacent Inner Harbor areas. The loadings of organochlorine pesticides, PCBs, PAHs, and metals to Dominguez Channel reflect inputs from urban runoff and multiple NPDES permitted and stormwater permitted discharges within the watershed.

Data collected from two sediment investigations conducted in 2002 and 2011 provide reasonable spatial coverage of TMDL-listed contaminants along DCE. Most of the TMDL-listed contaminants were elevated at levels greater than their respective TMDL targets at the majority of stations. While results demonstrated a high degree of variability in concentrations of all TMDL-listed contaminants, some contaminants (i.e., DDT and cadmium) showed spatial trends with decreasing concentrations from the confluence near Torrance Lateral towards Consolidated Slip. The most notable temporal trend observed was a statistically significant decrease in average Total DDT (TDDT) concentrations from 2002 to 2011, by an order of magnitude (Figure 3).

Data from both studies also provide some indication of contamination at depth, where deeper core samples were collected. However, most sediment data collected within DCE are more than a decade old. Consequently, some uncertainty exists in older sediment chemical concentrations due to the likely movement of sediments into, within, and out of the channel throughout the past decade as a result of storms, tidal effects, and other events.



Notes:
Concentrations are from surface sediment (0 to 0.5 feet).
Torrance Lateral (TL), Kenwood Drain (KD), and Dominguez Channel Upstream of Estuary above Vermont Ave (DCU) data from 2002 are not shown.
Non−detects set to half reporting limit (not shown as different symbols; MDL not available). Duplicates averaged.
Databases = Sed_DBcomb_NDhalfMDL_tot_20140229_alignTOC_20140301.bin, Sed_DBcomb_NDhalfMDL_indv_20140229.bin

Figure 3

TDDT Concentrations in Dominguez Channel Estuary

The use of data collected more than 10 years ago may not be appropriate, because these data may no longer represent current sediment quality conditions in DCE. Disregarding data from 2002 and earlier, however, decreases the spatial coverage of TMDL-listed contaminants in the DCE and increases the spatial data gaps. For these reasons additional data are needed to define current conditions and determine the processes that influence the distribution of contaminants. Additional data will help address the feasibility and effectiveness of available management alternatives. For further discussion, refer to Reconnaissance Study: Dominguez Channel Estuary included in Appendix A.

3.1.1.1 Sediment Quality Data Gaps

Sediment chemistry data gaps for DCE include:

- Uncertainty in elevated concentrations observed for some TMDL-listed contaminants at the confluence with Torrance Lateral.
- Limited measurements of chlordane, dieldrin, and toxaphene (relative to other parameters).
- Limited SQO assessment data (i.e., based on MLOE associated with sediment chemistry, toxicity, and benthic community data) and spatial coverage; currently only seven data points are available and are from 1999 and 2003 from one portion of DCE. Data may not represent current conditions in DCE.

These data gaps may be filled by collecting new data along the entire length of DCE. Specific recommendations for filling data gaps include the following:

- Limited re-sampling along DCE for TMDL-listed contaminants to supplement and confirm results of the 2011 sampling effort and examine the potential for longer temporal trends in sediment condition.
- Collecting additional data for TDDT analysis to confirm the apparent decrease in concentrations between 2002 and 2011 and provide increased confidence in measured TDDT concentrations along DCE.
- Focused re-sampling in the area near the confluence with Torrance Lateral to determine if concentrations remain elevated for some TMDL-listed contaminants, as observed in data from the more intensive sampling conducted in that area in 2002.

- Conducting SQO analyses to confirm the assigned sediment quality value of "clearly impacted" or "likely impacted" for the DCE.
- Defining the sediment transport process by quantifying sediment loading entering DCE, sediment transport within DCE, and sediment discharge from DCE.

Given the two Superfund sites located within Dominguez Watershed, the Dominguez Channel Toxics TMDL lists specific direction for collecting additional water and sediment chemistry data related to the Superfund sites.

The detection of DDT compounds in water or sediment samples collected within Torrance Lateral shall trigger additional monitoring, by parties to be determined by the Executive Officer, in coordination with the USEPA, to evaluate potential contribution from contaminated soils related to upstream Montrose operable units discharging via the Kenwood storm drain.

3.1.2 Sediment Quantity Data Review and Data Gaps

As-built drawings for Dominguez Channel, dating to 1930, are available from the Los Angeles County Flood Control District. These as-built drawings may provide a basis for estimating existing sediment quantities within the Dominguez Channel when compared to recent or new bathymetry. Reviewing the as-built drawings and confirming through a survey to align the as-built drawings and recent bathymetry is necessary to establish common datums. A bathymetry study of DCE was completed in 2006, and POLA has indicated it will be re-surveying DCE in 2014. Comparisons between the as-built drawings, 2006 survey, and 2014 survey will provide information on sediment quantity in DCE.

3.1.3 Fish Tissue Data Review and Data Gaps

Current and relevant fish data were not found for fish caught in DCE. Some historic fish tissue chemistry data are available from 1994; however, these data are too old to be considered relevant to the current inputs in DCE. Consequently, elevated concentrations of TMDL-listed contaminants in tissue of fish caught are uncertain for DCE; therefore, linkage cannot be established between fish tissue and sediment chemical concentrations for bioaccumulative chemicals listed in the Dominguez Channel Toxics TMDL. Based on sediment bioaccumulative concentrations, many sediment chemicals are expected to have the potential to bioaccumulate in fish that are exposed (e.g., via foraging) within the DCE. This data gap in fish tissue chemistry will be addressed during the monitoring program.

3.2 Milestone 2: Identification of Potential Management Areas

The areas recommended for potential management will be defined after data gaps are filled. Identification of these areas will be informed by data collection efforts as well as information from WMPs/EWMPs within the Dominguez Channel Watershed. Meeting the sediment targets in the Dominguez Channel Toxics TMDL requires a watershed-based approach that includes both land-side and sediment-based programs that focus on identifying sources and source reduction alternatives. The MS4 Permit for Los Angeles County (Order No. R4-2012-0175), adopted November 8, 2012, incorporated Dominguez Channel Toxics TMDL stormwater WLAs. This permit requires either WMPs or EWMPs be developed to prioritize water quality issues resulting from MS4 Permit discharges to receiving waters, to identify and implement control measures, and to execute an integrated monitoring program and assessment program. On June 27, 2013, a Notice of Intent was submitted to the Executive Officer of the RWQCB, indicating that the Dominguez WMA Group[1] will develop an EWMP and CIMP. Findings and planned actions through the EWMP will help support identifying potential sediment management areas.

The preliminary list of sites to be managed will be provided to the RWQCB during the reopener tentatively scheduled in 2018.

3.3 Milestone 3: Identification of Management Alternatives

For each of the potential management areas, a range of management alternatives will be summarized and their effectiveness at meeting water quality requirements within the TMDL schedule will be considered.

[1] The Dominguez WMA Group does not include all MS4 permittees in the Dominguez Watershed. The group includes the City of Los Angeles, Los Angeles County, Los Angeles County Flood Control District, and the cities of El Segundo, Hawthorne, and Inglewood.

As recommended by the USEPA Guidance Document (USEPA 2005), the first step is to control sources. Therefore, the effectiveness of source control for inputs to DCE must be demonstrated prior to other sediment management actions. As management actions to reduce pollutants in effluent and stormwater inputs to DCE are developed and implemented, those actions may be incorporated into the CSMP.

3.4 Milestone 4: Selection of Management Alternatives

Once an area is selected and available management alternatives are summarized, the relevant stakeholder group can select the appropriate action. The makeup of the stakeholder group and agreements between the stakeholders will define the process for selecting management alternatives.

The USEPA is the regulatory agency overseeing the two Superfund sites located within Dominguez Channel Watershed. The USEPA has not yet reached a final remedial decision to several operable units that remain contaminated with DDT. It is recommended that any potential management actions be consistent with the final remedial decision for these sites and consider the timing of these activities when setting schedules and commencing with DCE sediment management actions. Any voluntary actions considered in advance of the superfund remedial action within an identified Superfund Site Operable Unit must be approved by the USEPA's Superfund Division in advance of such action.

3.5 Milestone 5: Commence Management Actions

The selected management action can be scheduled for implementation only after all responsible parties agree to the management approach and funding mechanisms. Currently, the participating agencies do not have funding identified to proceed with a management action. The implementation of a selected management approach is subject to the availability of adequate funding.

3.6 CSMP Schedule

The CSMP schedule is outlined in Table 2.

Table 2
CSMP Schedule

Deliverables to RWQCB	Task	Date	Alignment with Basin Plan Amendment	Alignment with TMDL and MS4 Permit Requirements
CSMP	Submit Draft CSMP for DCE to RWQCB for consideration by Executive Director	March 23, 2014 (2 years after effective date of TMDL)	Meets required submittal timeline	EWMP: identifies opportunities to incorporate management actions (e.g., BMPs and their effectiveness into CSMP process [see Section 3.3]) CIMP: outlines monitoring program to be used to identify areas to be managed (see Section 3.1)
CSMP Stakeholder Meetings	Conduct quarterly stakeholder meetings	Quarterly meeting agendas and minutes to stakeholders	Demonstrates coordination and cooperation of stakeholders	EWMP: Annual review of EWMP management strategies, actions, and special studies that may inform change of conditions in DCE
CSMP Update	Submit CSMP Update for DCE to RWQCB	March 23, 2017 (5 years after effective date of TMDL)	Provides updated list of sites to be managed submitted to RWQCB during TMDL reopener	

Deliverables to RWQCB	Task	Date	Alignment with Basin Plan Amendment	Alignment with TMDL and MS4 Permit Requirements
CSMP Update	Submit CSMP Update for DCE to RWQCB	March 23, 2022 (10 years after effective date of TMDL)	Demonstrates progress toward sediment management actions and provides updated list of sites to be managed	
CSMP Update	Submit CSMP Update for DCE to RWQCB	March 23, 2027 (15 years after effective date of TMDL)	Demonstrates progress toward sediment management actions and provides updated list of sites to be managed	
CSMP Update	Submit CSMP Update for DCE to RWQCB	March 23, 2032 (20 years after effective date of TMDL)	Demonstrates attainment of LAs using the means identified in Basin Plan Amendment	

4 SUMMARY

This CSMP is designed to meet the requirement of the TMDL schedule for the Dominguez Channel Toxics TMDL which requires that responsible parties in Dominguez Channel Watershed develop a CSMP to address contaminated sediments in the DCE. This CSMP is based on established guidance and is consistent with other CSMPs being developed for Los Angeles Harbor, Long Beach Harbor, Eastern San Pedro Bay, and Los Angeles River Estuary.

The objective of this CSMP is to establish specific steps to identify, prioritize, and implement sediment management actions. Initial steps were designed to inform subsequent technical and decision-making tasks and include:

- Data collection and evaluation (including chemical source investigations and defining nature and extent of impacts)
- Identification of potential management areas (including identifying potentially responsible parties)
- Identification of management alternatives
- Selection of management alternatives (considering ecological and human health risks and net benefits), and
- Commencement of management actions.

This approach encourages collaboration with regional monitoring programs, WMPs/EWMPs, and existing sediment remediation programs (e.g., Montrose CERCLA site) to inform management alternatives and schedules. Source identification and reduction is included in the first step in the management plan and will be completed through data evaluation, data gap identification, and data collection and analyses prior to identifying and implementing remedies. A schedule of deliverables is included in this CSMP to reflect requirements set forth in the Dominguez Channel Toxics TMDL for submitting the CSMP and providing updates to the RWQCB. This CSMP is an adaptive plan that provides for stakeholder and RWQCB review and interaction and sets the course for protecting and improving benthic community condition and human health from fish consumption.

5 REFERENCES

Anchor QEA, 2014a. *Coordinated Compliance Monitoring and Reporting Plan: Incorporating Quality Assurance Project Plan Components*. Greater Los Angeles and Long Beach Harbor Waters. January 2014.

Anchor QEA, 2014b. Reconnaissance Study: Dominguez Channel Estuary. March 2014.

Bay, S.M., D.J. Greenstein, J.A. Ranasinghe, D.W. Diehl, and A.E. Fetscher, 2009. *Sediment Quality Assessment Draft Technical Support Manual*. Technical Report 582. Southern California Coastal Water Research Project. May 2009.

Bridges, T.S, P. Schroeder, S. Ells, D. Hayes, D. Mount, S. Nadeau, M. Palermo, C. Patmont, 2008. *The Four Rs of Environmental Dredging: Resuspension, Release, Residual, and Risk*. Prepared for U.S. Army Corps of Engineers. ERDC/EL TR-08-4. January 2008.

City of Los Angeles, 2014. Los Angeles's Watershed Protection Program. Dominguez Watershed. Accessed February 2014. Available from: http://www.lastormwater.org/about-us/about-watersheds/dominguez-channel.

CSTF (Contaminated Sediment Task Force), 2005. *Los Angeles Regional Contaminated Sediments Task Force: Long-Term Management Strategy*.

Lyons, J.M and S. Birosik, 2007. Water Quality in the Dominguez Channel and Los Angeles/Long Beach Harbor Watershed Management Area Under the Surface Water Ambient Monitoring Program Fiscal Year 2002-2003. California Regional Water Quality Control Board, Los Angeles Region.

MEC (MEC Analytical Systems, Inc.), 2004. *Dominguez Watershed Management Master Plan*. Submitted to County of Los Angeles Department of Public Works. Alhambra, California. April 2004.

Nadeau, Steven C., Megan C. MuCulloch, and T.S. Bridges, 2009. Principles for Evaluating Remedial Options for Contaminated Sediment Sites. 5th International Conference on Remediation of Contaminated Sediments, Jacksonville, Florida. 2009.

RWQCB and USEPA (Los Angeles Regional Water Quality Control Board and U.S. Environmental Protection Agency), 2011. *Final Dominguez Channel and Greater Los*

Angeles and Long Beach Harbor Waters Toxic Pollutants Total Maximum Daily Loads. May 2011.

SWAMP (Surface Water Ambient Monitoring Program), 2007. *Water Quality in the Dominguez Channel and Los Angeles/Long Beach Harbor Watershed Management Area*. Technical Report 2002-2003. September 2007.

SWRCB (State Water Resources Control Board), 2009. *Water Quality Control Plan for Enclosed Bays and Estuaries: Sediment Quality Plan*. Final Staff Report. August 2009.

USEPA (U.S. Environmental Protection Agency), 1999. Record of Decision: Dual Site Groundwater Operable Unit Montrose Chemical and Del Amo Superfund Sites. USEPA Region IX.

USEPA, 2005. *Contaminated Sediment Remediation Guidance for Hazardous Waste Sites*. USEPA-540-R-05-012. Office of Solid Waste and Emergency Response OSWER 9355.0-85. December 2005.

USEPA, 2013. Use of Amendments for In Situ Remediation at Superfund Sediment Sites. Office of Superfund Remediation and Technology Innovation. OSWER 9200.2-128FS. April 2013.

WBMWD (West Basin Municipal Water District), 2009. Opportunities and Constraints Analysis of the Dominguez Channel Island Water Supply. Draft. Technical Memorandum 1: Water Quality. March 2009.

Weston Solutions, Inc., 2005. Los Angeles County 1994-2005 Integrated Receiving Water Impacts Report. August 2005.

APPENDIX A
RECONNAISSANCE STUDY: DOMINGUEZ CHANNEL ESTUARY

RECONNAISSANCE STUDY
DOMINGUEZ CHANNEL ESTUARY

In Support of

Final Dominguez Channel and Greater Los Angeles and Long Beach Harbor Waters Toxic Pollutants Total Maximum Daily Loads

Prepared by

California Department of Transportation
City of Long Beach
City of Los Angeles
City of Torrance
Los Angeles County
Los Angeles County Flood Control District

March 2014

TABLE OF CONTENTS

1 INTRODUCTION 1

2 DATA 2

2.1 Existing Data Review 2

2.2 Sediment Chemistry Data Analyses 4

2.3 SQO Assessment Dataset 4

2.4 PCB Aroclor versus Congener Data 4

3 DOMINGUEZ CHANNEL ESTUARY DATA EVALUATION 6

3.1 Comparison to TMDL Targets 6

3.2 SQO Assessments 6

3.3 Assessment of Spatial Coverage and Trends, Temporal Trends, and Variability 7

3.3.1 Trends in Surface Data 7

3.3.2 Trends at Depth 9

3.4 Summary 9

4 RECOMMENDED SPECIAL STUDIES TO DEVELOP AND PRIORITIZE SEDIMENT MANAGEMENT ALTERNATIVES 11

4.1 Sediment Quality Trend Data Gaps and Recommendations 11

4.2 Fish Tissue Quality Linkage Analysis 12

5 REFERENCES 13

List of Tables

Table 1 Summary of Sediment Data Collected within the Dominguez Channel Estuary

Table 2 Exceedances of TMDL Direct Effects Criteria for Sediment Samples from Dominguez Channel Estuary

Table 3 Exceedance of TMDL Indirect Effects Criteria for Sediment Samples from Dominguez Channel Estuary

Table 4 Results for Regressions Performed on 2011 DCE Surface Sediment Data between Torrance Lateral and Consolidated Slip

Table 5 Comparison of Contaminant Concentrations in 2002 vs. 2011

List of Figures

Figure 1 Dominguez Channel Estuary Sediment Sampling Locations

Figure 2 Comparison of Total PCB Congener and Aroclor Data for Paired Samples from Dominguez Channel

Figure 3 Previous Sediment Quality Objective Assessments based on 1999 and 2003 Data

Figure 4a Thiessen Polygons Showing Surface Concentrations of TDDT, 2002 and 2011 Data

Figure 4b Thiessen Polygons Showing Surface Concentrations of TPCB, 2002 and 2011 Data

Figure 4c Thiessen Polygons Showing Surface Concentrations of TPAH, 2002 and 2011 Data

Figure 4d Thiessen Polygons Showing Surface Concentrations of Mercury, 2002 and 2011 Data

Figure 4e Thiessen Polygons Showing Surface Concentrations of Lead, 2002 and 2011 Data

Figure 4f Thiessen Polygons Showing Surface Concentrations of Cadmium, 2002 and 2011 Data

Figure 4g Thiessen Polygons Showing Surface Concentrations of Chromium, 2002 and 2011 Data

Figure 4h Thiessen Polygons Showing Surface Concentrations of Copper, 2002 and 2011 Data

Figure 4i Thiessen Polygons Showing Surface Concentrations of Zinc, 2002 and 2011 Data

Figure 5a Concentrations of 2–Methylnaphthalene in Surface Sediment from Dominguez Channel Estuary (0 to 0.5 ft)

Figure 5b Concentrations of Benzo (a) Anthracene in Surface Sediment from Dominguez Channel Estuary (0 to 0.5 ft)

Figure 5c Concentrations of Benzo (a) Pyrene in Surface Sediment from Dominguez Channel Estuary (0 to 0.5 ft)

Figure 5d Concentrations of Cadmium in Surface Sediment from Dominguez Channel Estuary (0 to 0.5 ft)

Figure 5e Concentrations of Chlordane in Surface Sediment from Dominguez Channel Estuary (0 to 0.5 ft)
Figure 5f Concentrations of Chromium in Surface Sediment from Dominguez Channel Estuary (0 to 0.5 ft)
Figure 5g Concentrations of Chrysene in Surface Sediment from Dominguez Channel Estuary (0 to 0.5 ft)
Figure 5h Concentrations of Copper in Surface Sediment from Dominguez Channel Estuary (0 to 0.5 ft)
Figure 5i Concentrations of Dibenzo (a,h) Anthracene in Surface Sediment from Dominguez Channel Estuary (0 to 0.5 ft)
Figure 5j Concentrations of Dieldrin in Surface Sediment from Dominguez Channel Estuary (0 to 0.5 ft)
Figure 5k Concentrations of High Molecular Weight PAHs in Surface Sediment from Dominguez Channel Estuary (0 to 0.5 ft)
Figure 5l Concentrations of Lead in Surface Sediment from Dominguez Channel Estuary (0 to 0.5 ft)
Figure 5m Concentrations of Low Molecular Weight PAHs in Surface Sediment from Dominguez Channel Estuary (0 to 0.5 ft)
Figure 5n Concentrations of Mercury in Surface Sediment from Dominguez Channel Estuary (0 to 0.5 ft)
Figure 5o Concentrations of Phenanthrene in Surface Sediment from Dominguez Channel Estuary (0 to 0.5 ft)
Figure 5p Concentrations of Pyrene in Surface Sediment from Dominguez Channel Estuary (0 to 0.5 ft)
Figure 5q Concentrations of TDDT in Surface Sediment from Dominguez Channel Estuary (0 to 0.5 ft)
Figure 5r Concentrations of TPAH in Surface Sediment from Dominguez Channel Estuary (0 to 0.5 ft)
Figure 5s Concentrations of TPCB in Surface Sediment from Dominguez Channel Estuary (0 to 0.5 ft)
Figure 5t Concentrations of Toxaphene in Surface Sediment from Dominguez Channel Estuary (0 to 0.5 ft)

Figure 5u Concentrations of Zinc in Surface Sediment from Dominguez Channel Estuary (0 to 0.5 ft)
Figure 5v Concentrations of Median Grain Size in Surface Sediment from Dominguez Channel Estuary (0 to 0.5 ft)
Figure 6a Carbon–Normalized Concentrations of TDDT in Surface Sediment from Dominguez Channel Estuary (0 to 0.5 ft)
Figure 6b Carbon–Normalized Concentrations of TPCB in Surface Sediment from Dominguez Channel Estuary (0 to 0.5 ft)
Figure 6c Carbon–Normalized Concentrations of TPAH in Surface Sediment from Dominguez Channel Estuary (0 to 0.5 ft)

List of Appendices

Appendix A Probability Plots of Concentrations in DCE Surface Sediment
Appendix B Spatial Plots of Concentrations in DCE Sediment at Any Depth

LIST OF ACRONYMS AND ABBREVIATIONS

AMEC	AMEC Earth & Environmental, Inc.
CSMP	Contaminated Sediment Management Plan
DCE	Dominguez Channel Estuary
ERL	effects range low
ERM	effects range median
FCG	fish contaminant goal
Harbor Toxics TMDL	*Final Dominguez Channel and Greater Los Angeles and Long Beach Harbor Waters Toxic Pollutants Total Maximum Daily Loads*
HPAH	high molecular weight polycyclic aromatic hydrocarbon
IDL	Interactive Data Language
LPAH	low molecular weight polycyclic aromatic hydrocarbon
NPDES	National Pollutant Discharge Elimination System
PAH	polycyclic aromatic hydrocarbon
PCB	polychlorinated biphenyl
Ports	Ports of Long Beach and Los Angeles
SCCWRP	Southern California Coastal Water Research Project
SQO	Sediment Quality Objective
TDDT	total DDT
TOC	total organic carbon
TPAH	total polycyclic aromatic hydrocarbon
TPCB	total polychlorinated biphenyl

1 INTRODUCTION

This report summarizes the review and evaluation of the quality of Dominguez Channel Estuary (DCE) sediment chemistry data to support development of a Contaminated Sediment Management Plan (CSMP). High-quality data are essential to characterize current contaminant levels in sediment and assess potential remedies for long-term compliance with the *Final Dominguez Channel and Greater Los Angeles and Long Beach Harbor Waters Toxic Pollutants Total Maximum Daily Loads* (Harbor Toxics TMDL; RWQCB and USEPA 2011). The data evaluation included reviewing existing data for completeness and usability, comparing data to TMDL targets, reviewing assessments related to Sediment Quality Objectives (SQOs), and analyzing spatial and temporal trends as well as spatial coverage and variability in data. Data gaps and recommendations for additional data collection are also provided.

2 DATA

2.1 Existing Data Review

The main data source was the Ports of Long Beach and Los Angeles' (Ports') sediment chemistry database, an extensive compilation of data collected by a variety of agencies as part of characterization and monitoring studies between 1980 and 2011 (see Table 1 of Ports 2013 for summaries by study and year). Data from the Los Angeles/Long Beach Harbor, Eastern San Pedro Bay, DCE, and nearshore areas along the Southern California Bight were included in the compilation. Data compilation focused on DDTs, polychlorinated biphenyls (PCBs), and physical parameters (i.e., grain size). Metals, polycyclic aromatic hydrocarbons (PAHs), and other organochlorine pesticides were also included in the database when minimal effort was required to process these data. Through the use of Interactive Data Language (IDL)—a programming language used for data processing and analyses—quality control focused on accurate data compilation; the quality of individual data sources was not independently evaluated. The compilation underwent standardization, including re-calculating total DDTs (TDDTs) and total PCBs (TPCBs) for consistency across sampling studies, setting non-detects to half of the method detection limit or method reporting limit if no method detection limit was available, assigning the highest individual detection limit for total concentration if all individual component concentrations were non-detect, and averaging results from field duplicates with parent results.

Focusing on data collected within DCE, data evaluation involved revisiting raw data files from studies included in the database to ensure the completeness of the dataset for DCE sediment chemistry data, reviewing datasets discussed in the Harbor Toxics TMDL, and conducting online searches for additional data.

Five studies[1] in the Ports' database contain DCE sediment chemistry data (sampling locations illustrated in Figure 1):

- Bay Protection and Toxic Cleanup Program from 1996 (SCCWRP 2013)
- Western Environmental Monitoring and Assessment Program from 1999 (SCCWRP 2013)

[1] Data from sampling conducted in 1994 (CH2M Hill 1995) were not included in the Ports' database. Comparisons of 1994 data to 2002 data can be found in CH2M Hill 2003.

- AMEC Earth & Environmental, Inc. (AMEC) from 2002 (AMEC 2003, 2005)
- Bight Regional Monitoring from 2003 (SCCWRP 2013)
- AMEC from 2011 (AMEC 2012)

Data from the non-AMEC studies were re-downloaded from the Southern California Coastal Water Research Project (SCCWRP) database (2013) to ensure that the latest available original dataset was used. Documentation steps for the original dataset query were reviewed to confirm that no queries were performed that would have excluded DCE data.

For datasets received in spreadsheet format (AMEC 2003, 2012), spreadsheet processing steps were revisited and original files were spot-checked to ensure that DCE data were included in the compiled database.

Oil refineries that discharge into DCE conducted National Pollution Discharge Elimination System (NPDES) compliance monitoring of sediments at seven locations between 1994 and 2004 (see Tables 7 through 10 of AMEC 2005 for data summaries). The AMEC 2005 NPDES summary tables did not include key information (e.g., detection limits for TDDT, TPCB, and total PAHs [TPAH]; coordinates; and sampling date) to support their inclusion in a database; raw data could not be found during an online search of the NPDES database. Moreover, the Harbor Toxics TMDL mentions this dataset, but states that for the TMDL, analytical detection limits for DDTs, PCBs, and PAHs were not sufficiently sensitive to in comparison to SQOs (RWQCB and USEPA 2011). For these reasons, these data were not included in the Ports' database.

Upon reviewing the existing database and its original data source files, sediment data sources cited in the Harbor Toxics TMDL, and online searches for additional DCE data (including revisiting the California Environmental Data Exchange Network and National Oceanic and Atmospheric Administration's Query Manager), no new sediment data were added to the Ports' database.[2] Table 1 summarizes data counts of DDTs, PCBs, PAHs, metals, and total organic carbon (TOC) per study for DCE sediment.

[2] The Ports' database has been updated several times since April 2013 to include new datasets (no new datasets included DCE data) and to refine certain data.

2.2 Sediment Chemistry Data Analyses

Analyses of sediment chemistry data included comparing data to TMDL targets, assessing spatial coverage, and evaluating spatial and temporal trends. These analyses were performed using two software programs—IDL and ArcGIS—for better efficiency. Steps were automated, where possible, to ensure consistency and reproducibility. IDL was employed to compare data to TMDL targets and produce a variety of x-y charts, including plots of concentration versus distance from Consolidated Slip and plots of distributions of concentrations to examine distribution type, data ranges, possible outliers, etc. (Appendix A). IDL was also used to perform regression analysis to evaluate differences in sediment concentrations relative distance along the DCE. The statistical software R was also use to perform Wilcoxon non-parametric sum rank tests to evaluate differences in concentration between 2002 and 2011. ArcGIS was used to map sampling locations, create and map Thiessen polygons of concentrations, and calculate distances for plotting data in IDL. Maps and figures are presented in Section 3.3.

2.3 SQO Assessment Dataset

SQO assessments previously conducted in accordance with State of California methods (SWRCB 2009) were also reviewed. SQO assessment results were available from seven stations in DCE and were performed by SCCWRP on sediment chemistry, toxicity, and benthic infauna data. Results were provided to the Ports as part of the Harbor SQO assessment dataset (SCCWRP unknown). ArcGIS was used to create a map that depicts the SQO categorical results and sampling locations. Results are summarized in Section 3.2.

2.4 PCB Aroclor versus Congener Data

Data from 1996 and 2011 were analyzed for both PCB Aroclors and congeners. A comparison of the results from two analytical methods shows a bias, with Aroclor values being higher than congener values, just over two-fold on average (Figure 2). Differences between methods used to quantify PCB Aroclors versus PCB congeners can explain these differences in concentrations. Aroclor-based methods rely on the subjective visual determination of Aroclor speciation as well as the assumption that environmentally or metabolically weathered samples accurately reflect the composition and toxicity of the Aroclor standards used to quantify them. As a consequence, PCB Aroclor methods can result in over- or under-estimating TPCB concentrations. In comparison, congener-specific PCB analysis involves quantifying individual congeners present in a sample based on congener standards rather than Aroclor standards. These methods are preferred, as they are more sensitive, less subjective, and can yield more accurate results for environmental samples that may have weathered or were biologically degraded, and whose PCB composition is not identical with that of the Aroclors. For the comparison of data to TMDL targets and data mapping, Aroclor data are disregarded where congener data are available because the congener methodology more accurately estimates total PCBs; inclusion would result in double-counting samples in the comparison to TMDL targets and obfuscation in data mapping. For completeness, both Aroclor and congener data are shown, as different symbols, in the spatial trends plots.

3 DOMINGUEZ CHANNEL ESTUARY DATA EVALUATION

Evaluations of DCE sediment chemistry data included comparing them to TMDL targets; reviewing SQO assessments previously conducted on DCE sediment quality data; examining spatial coverage, trends, and variability; and identifying data gaps.

3.1 Comparison to TMDL Targets

DCE sediment chemistry data were compared to the Harbor Toxics TMDL direct effects targets (i.e., effects range low [ERL]) criteria) and indirect effects targets (i.e., fish contaminant goal [FCG] criteria).

DCE data[3] from the five studies in the Ports' database were compared to TMDL targets (Tables 2 and 3). Metal concentrations in surface sediments exceeded numeric targets in 31 to 81 percent of the samples; however, many metals were at levels well less than listing criteria (effects range median [ERM] values). PCB and pesticide data (e.g., DDTs, PCBs, chlordane, dieldrin, and toxaphene) exceeded criteria in more than 92 percent of samples. PAH data exceeded the numeric target in 35 to 65 percent of samples, except for 2-methylnaphthalene and dibenzo[a,h]anthracene with 0 and 5 percent exceedances, respectively. These data suggest these two analytes do not require further management. Exceedance frequencies were similar for sediment data collected from subsurface samples.

3.2 SQO Assessments

The quality of DCE sediment assessed using the SQO process was shown to range from likely unimpacted to clearly impacted (Figure 3). These findings suggest that sediment from DCE does not meet the SQO for direct effects because of impacts to benthic organisms associated with DCE sediment contaminants. However, to the best of our knowledge, results shown here are the only SQO assessment data available to date and only represent a small portion of DCE (Figure 3). In addition, these data were collected in 1999 or 2003 and therefore may not represent current sediment conditions in DCE.

3 Data collected in 2002 from Torrance Lateral, Kenwood Drain, Dominguez Channel upstream of the estuary above Vermont Avenue, and the Dominguez Channel Intertidal zone (at the confluence with Torrance Lateral) were excluded from the TMDL comparison.

3.3 Assessment of Spatial Coverage and Trends, Temporal Trends, and Variability

The spatial coverage and sample type for each of the five studies reviewed is presented in Figure 1. Of the five studies in which DCE sediment chemistry data were collected (Table 1), two datasets were found to have both comprehensive spatial coverage and comparable data. Specifically, the AMEC 2002 and 2012 datasets demonstrated similar sample types (i.e., grabs and cores), depths, and sample counts for purposes of evaluating trends over time.

However, the AMEC 2002 dataset is more than 10 years old and may not reflect current sediment conditions in DCE, which may be affected by large storms and tidal effects. For example, in late 2004 and early 2005, storms affecting the area resulted in a large volume of runoff into DCE and tributaries (LACDPW 2000–2012); their impacts on sediment movement into, within, and out of DCE are unknown. Sediment in DCE may have also been influenced by the residential soil DDT cleanups that occurred in 2002. Specifically, the U.S. Environmental Protection Agency removed DDT in residential soil along Kenwood Drain (formerly Kenwood ditch), a stormwater pathway leading from the Montrose Chemical Corporation Superfund site to DCE in 2002 (USEPA 2002).

3.3.1 Trends in Surface Data

Due to limited sample numbers of the AMEC 2002 and 2011 datasets, "surface" data used in this analysis were sediment collected from the 0- to 0.5-foot interval. Data from these two datasets were collected throughout DCE, with sampling conducted at evenly spaced intervals from Vermont Avenue to Consolidated Slip (Figure 1).

Figures 4a through 4i depicts surface sediment chemistry data in DCE using the Thiessen polygon approach for representative TMDL-listed contaminants, such as TDDT, TPCB, TPAH, mercury, lead, cadmium, chromium, copper, and zinc. Maps of surface sediment chemistry data indicate highly variable concentrations along the length of DCE for each contaminant depicted. Figure 4a also demonstrates that TDDT concentrations are elevated near the confluence with Torrance Lateral. No other visual trends for these analytes are notable in maps of the representative TMDL-listed contaminants.

Figures 5a through 5u illustrate concentrations of each TMDL-listed contaminant, separately, in sediment relative to distance of the sampling location along DCE (from Consolidated Slip). Similar to the maps of sediment chemical concentrations, a high degree of variability in concentrations of all TMDL-listed contaminants is also observed in these plots (Figures 5a to 5u). Figure 5v illustrates the grain size distribution along DCE.

Some spatial and temporal trends in contaminant concentrations are observed. Many of the TMDL-listed contaminants demonstrate a downward visual trend in concentration from the confluence with Torrance Lateral towards Consolidated Slip, including benzo(a)anthracene (Figure 5b), cadmium (Figure 5d), chlordane (Figure 5e), dieldrin (Figure 5j), high molecular weight PAHs (HPAHs; Figure 5k), lead (Figure 5l), low molecular weight PAHs (LPAHs; Figure 5m), TDDT (Figure 5q), and zinc (Figure 5u). Of these contaminants, the only statistically significant decreases in concentration between Torrance Lateral and Consolidated slip are for cadmium, chlordane, dieldrin, and TDDT at $p \leq 0.05$; however, the low R^2 values associated with these regressions suggest that distance from Torrance Lateral only explains some of the variability in contaminant concentration (Table 4).

Other TMDL-listed contaminants, including TPCB (Figure 5s), several individual PAHs (e.g., Figures 5g and 5p), copper (Figure 5h), chromium (Figure 5f), and mercury (Figure 5n), demonstrate no notable visual trends in concentration along DCE. Only toxaphene (Figure 5t) and mercury (2002 data only; Figure 5n) demonstrate upward trends in concentration along DCE from the confluence with Torrance Lateral towards Consolidated Slip, and of these, only toxaphene shows a statistically significant increase in concentration between Torrance Lateral and Consolidated Slip at $p < 0.05$. The low R^2 value for the toxaphene regression suggests that distance from Torrance Lateral only explains some of the variability in toxaphene contaminant concentration (Table 4).

For TMDL-listed contaminants with data from 2002 and 2011, some temporal trends are present. TDDT concentrations are two to three times higher in 2002 than in 2011 (Figure A-9 in Appendix A) and average concentrations in 2002 (are statistically elevated above those from 2011 (Table 5; $p = 0.008$). For all other TMDL-listed contaminants, no statistically significant differences in concentrations are found between 2002 and 2011 (Table 5).

Although TMDL criteria are based on sediment dry-weight concentrations, TMDL-listed contaminants were also plotted on a carbon-normalized basis for contaminants with a high affinity for binding to organic carbon, which can influence the bioavailability of these contaminants. Plots of TDDT, TPAH, and TPCB concentrations on a carbon-normalized[4] basis indicate similar spatial patterns to those observed in concentrations on a dry-weight basis (Figures 6a through 6c).

3.3.2 Trends at Depth

Concentrations at depth were evaluated by constructing core profiles and spatial plots of maximum concentrations, regardless of depth. Core profiles of concentration versus depth did not indicate any consistent trends with depth or core location (data not shown). Spatial plots of maximum concentrations versus distance from Consolidated Slip (Appendix B) show similar patterns to the plots of surface concentrations (Figure 5), with one exception. TPCB and metal (i.e., cadmium, chromium, lead, and mercury) concentrations are higher in deeper core samples closest to Consolidated Slip. These concentrations, however, are largely within the range of concentrations observed in surface data at other locations (see Appendix B for plots for a subset of parameters with TMDL criteria).

3.4 Summary

Data collected from two sediment investigations conducted in 2002 and 2011 provide reasonable spatial coverage of TMDL-listed contaminants along DCE. Most of the TMDL-listed contaminants are elevated relative to their respective TMDL targets at the majority of stations at which they were measured. While results demonstrated a high degree of variability in concentrations of all TMDL-listed contaminants, some contaminants (i.e., DDT and cadmium) show spatial trends with decreasing concentrations from the confluence near Torrance Lateral towards Consolidated Slip. The most notable temporal trend observed is a statistically significant decrease in average TDDT concentrations from 2002 to 2011, by two- to three-fold. Data from both studies also provide some indication of contamination at depth, where deeper core samples were possible to be collected. However, most sediment data collected within DCE are more than a decade old. Consequently, some uncertainty

[4] Carbon-normalized concentrations were obtained by dividing concentrations by TOC content; TOC data were only available in the AMEC 2011 dataset.

exists in older sediment chemical concentrations due to the likely movement of sediments into, within, and out of the channel throughout the past decade as a result of storms, tidal effects, and other events. The use of data collected more than 10 years ago may not be appropriate, because these data may no longer represent current sediment quality conditions in DCE. Disregarding data from 2002 and earlier, however, decreases the spatial coverage of TMDL-listed contaminants in the DCE and increases the spatial data gaps.

4 RECOMMENDED SPECIAL STUDIES TO DEVELOP AND PRIORITIZE SEDIMENT MANAGEMENT ALTERNATIVES

Historical activities in the Dominguez Watershed have contributed to the current elevated sediment concentrations observed in DCE. Watershed discharge limitations required under state and federal laws have resulted in reducing inputs to DCE. These programs are expected to continue improving sediment quality in the coming years.

Attaining water, sediment, and tissue quality will likely be achieved through a combination of source reduction, source control, sediment removal, and monitored natural recovery. The CSMP is being developed to provide a mechanism for determining and prioritizing one or more of these sediment management alternatives. It is anticipated that further information is needed to evaluate the feasibility of these alternatives. Specifically, special studies could be conducted to determine the following:

- The technical, logistical, and economic feasibility of sediment removal
- The technical, logistical, and economic feasibility of enhanced natural recovery as a management option
- The potential for natural attenuation and source reduction through evaluating sediment and fish tissue spatial and temporal trends within DCE, which requires a clear understanding of current and future inputs (sources)
- The sediment transport process by quantifying sediment loading entering DCE, sediment transport within DCE, and sediment discharge from DCE

4.1 Sediment Quality Trend Data Gaps and Recommendations

The data evaluation has determined the following data gaps in DCE sediment chemistry data:

- Uncertainty in elevated concentrations observed for some TMDL-listed contaminants at the confluence with Torrance Lateral
- Limited measurements of chlordane, dieldrin, and toxaphene (relative to other parameters)
- Limited SQO assessment data (i.e., based on multiple lines of evidence associated with sediment chemistry, toxicity, and benthic community data) and spatial coverage

(Currently only seven data points are available and are from 1999 and 2003 from one portion of DCE. Data may not represent current conditions in DCE.)

These data gaps may be filled by collecting new data along the entire length of DCE. Specific recommendations for filling data gaps include the following:

- Limited re-sampling along DCE for TMDL-listed contaminants to supplement and confirm results of the 2011 sampling effort and examine the potential for longer temporal trends in sediment condition
- Collecting additional data for TDDT analysis to confirm a decrease in concentrations between 2002 and 2011 and provide increased confidence in measured TDDT concentrations along DCE
- Focused re-sampling in the area near the confluence with Torrance Lateral to determine if concentrations remain elevated for some TMDL-listed contaminants, as observed in data from the more intensive sampling conducted in that area in 2002
- Conducting SQO assessments to confirm sediment quality value of "clearly impacted" or "likely impacted"

4.2 Fish Tissue Quality Linkage Analysis

Current and relevant fish data were not found for fish caught in DCE. Some historical fish tissue chemistry data are available from 1992 and 1994; however, these data are too old to be considered relevant to current sediment conditions in DCE.[5] Consequently, elevated concentrations of TMDL-listed contaminants in tissue of fish caught are uncertain for DCE; therefore, the extent of the linkage between fish tissue and sediment chemical concentrations for bioaccumulative chemicals listed in the TMDL is not clear. Based on sediment bioaccumulative concentrations, many sediment chemicals have the potential to bioaccumulate in fish that are exposed (e.g., via foraging) within the DCE. Given the presence of bioaccumulative compounds in the DCE sediments, fish foraging in DCE are exposed to these substances. Additional studies are recommended to evaluate site-specific fish exposure evaluations to determine indirect effects to human health due to sediment impairments.

[5] Based on the fish caught during the 1994 study (CH2MHill 2003), topsmelt, mosquito fish, and black surfperch may be present in certain reaches of the DCE; distribution is likely dependent to tidal influence.

5 REFERENCES

AMEC (AMEC Earth & Environmental, Inc.), 2003. ToxScan Montrose Pathways Database. Excel file. Provided to Anchor QEA, LLC, by AMEC on December 12, 2013.

AMEC, 2005. *Draft Dominguez Channel Sediment Investigation Report*. Prepared for Los Angeles Regional Water Quality Control Board and Port of Los Angeles. February 2005.

AMEC, 2012. Port of Los Angeles Dominguez Channel and Consolidated Slip Erosion Study Chemistry EDDs. Excel files. Provided to Anchor QEA, LLC, on behalf of the Port of Los Angeles.

CH2MHill, 1995. Field Report. Surface Water, Sediments, and Biological Sampling in Stormwater Pathways from Montrose Chemical Company to Los Angeles Harbor, Montrose Superfund Site, Torrance, California. Prepared for USEPA Region IX. July 1995.

CH2MHill, 2003. Technical Memorandum to: Jeff Dhont, USEPA. Regarding: Results of Fall 2002 Supplemental Sediment Sampling and Comparison of 1994 and 2002 Sediment Data. May 21, 2003.

LACDPW (Los Angeles County Department of Public Works), 2000a. *Los Angeles County 1999-2000 Stormwater Monitoring Report*. July 11, 2000.

LACDPW, 2000b. *Los Angeles County 1994-2000 Integrated Receiving Water Impacts Report*. July 31, 2000.

LACDPW, 2001. *Los Angeles County 2000-2001 Stormwater Monitoring Report*. July 6, 2001.

LACDPW, 2002. *Los Angeles County 2001-2002 Stormwater Monitoring Report*. August 15, 2002.

LACDPW, 2003. *Los Angeles County 2002-2003 Stormwater Monitoring Report*. August 15, 2003.

LACDPW, 2004. *Los Angeles County 2003-2004 Stormwater Monitoring Report*. August 15, 2004.

LACDPW, 2005. *Los Angeles County 1994-2005 Integrated Receiving Water Impacts Report*. August 15, 2005.

LACDPW, 2006. *Los Angeles County 2005-2006 Stormwater Monitoring Report*. August 22, 2006.

LACDPW, 2007. *Los Angeles County 2006-2007 Stormwater Monitoring Report*. September 4, 2007.

LACDPW, 2008. *Los Angeles County 2007-2008 Stormwater Monitoring Report*. August 20, 2008.

LACDPW, 2009. *Los Angeles County 2008-2009 Stormwater Monitoring Report*. August 25, 2009.

LACDPW, 2010. *Los Angeles County 2009-2010 Stormwater Monitoring Report*. August 12, 2010.

LACDPW, 2011. *Los Angeles County 2010-2011 Stormwater Monitoring Report*. August 11, 2011.

LACDPW, 2012. *Los Angeles County 2011-2012 Stormwater Monitoring Report*. August 22, 2012.

Ports (Ports of Long Beach and Los Angeles), 2013. Compilation of Sediment, Fish Tissue, and Mussel Tissue Datasets for the TMDL Support Program. April 2013.

RWQCB and USEPA (Los Angeles Regional Water Quality Control Board and U.S. Environmental Protection Agency), 2011. *Final Dominguez Channel and Greater Los Angeles and Long Beach Harbor Waters Toxic Pollutants Total Maximum Daily Loads*. May 2011.

SCCWRP (Southern California Coastal Water Research Project), unknown. SQO MLOE Results RB4: 1998-2005. Excel file. Provided to Anchor QEA, LLC, by the Port of Los Angeles on September 15, 2010.

SCCWRP, 2013. California Sediment Quality Objectives Database. Accessed on: December 20, 2013. Available from: http://www.sccwrp.org/Data/SearchAndMapData/DataCatalog/CaliforniaSedimentQualityObjectivesDatabase.aspx.

SWRCB (State Water Resources Control Board), 2009. *Water Quality Control Plan for Enclosed Bays and Estuaries: Sediment Quality Pla*n. Final Staff Report. August 2009.

USEPA (U.S. Environmental Protection Agency), 2002. Factsheet. USEPA Montrose Superfund Site. USEPA Region 9, San Francisco, California. Available from: http://yosemite.epa.gov/r9/sfund/r9sfdocw.nsf/3dc283e6c5d6056f88257426007417a2/ba570f5122c91b17882570070063c335/$FILE/Montrose_Knwd7_02.pdf.

TABLES

Table 1
Summary of Sediment Data Collected within the Dominguez Channel Estuary

Source[1]	Sample Year	Type	Depth	Number of Samples	Number of Samples Per Analyte					
					DDT	PCB		PAH	Metals [3]	TOC
						Aroclor	Congener			
BPTCP	1996	Grab	0-2 cm	1	1	1	1	---	1	1
WEMAP	1999	Grab	0-2 cm	1	1	---	1	---	1	1
AMEC[2]	2002	Grab	0-0.5 ft	14	12	14	---	14	14	---
		Core	0-0.5 ft, 0.5-3 ft, 3-6 ft	21 (10 cores)	21	21	---	21	21	---
SCC_B03	2003	Grab	0-2 cm	6	6	---	6	---	6	6
AMEC	2011	Grab	0-0.5 ft	16	16	16	16	16	16	16
		Core	0-2 ft, 2-up to 3.6 ft	15 (9 cores)	15	15	15	15	15	15

Notes:

1 Sediment data collected as part of compliance monitoring studies by oil refineries for the NPDES were excluded due to the unavailability of raw data and high detection limits.

2 AMEC 2002 counts do not include data collected in Torrance Lateral, Kenwood Drain, and Dominguez Channel Upstream of the Estuary above Vermont Avenue. Intertidal data collected in Dominguez Channel near the confluence with Torrance Lateral are included.

3 For simplicity, counts reflect those for one metal, not for all six considered in this memorandum.

AMEC = AMEC Earth & Environmental, Inc.
cm = centimeters
BPTCP = Bay Protection and Toxic Cleanup Program
NPDES = National Pollutant Discharge Elimination System
PAH = polycyclic aromatic hydrocarbon
PCB = polychlorinated biphenyl
SCC_B03 = Bight Regional Monitoring 2003
TMDL = total maximum daily load
TOC = total organic carbon
WEMAP = Western Environmental Monitoring and Assessment Program

Table 2
Exceedances of TMDL Direct Effects Criteria for Sediment Samples from Dominguez Channel Estuary

Parameter	Units	Direct Effects Criteria (ERL) [2]	Surface[1]			All Depths		
			Total Count	Count Exceeding Criteria	% Exceed	Total Count	Count Exceeding Criteria	% Exceed
Metals								
Cadmium	mg/kg	1.2	48	22	46%	74	34	46%
Chromium	mg/kg	81	48	15	31%	74	24	32%
Copper	mg/kg	34	48	39	81%	74	56	76%
Lead	mg/kg	46.7	48	34	71%	74	54	73%
Mercury	mg/kg	0.15	48	21	44%	74	36	49%
Zinc	mg/kg	150	48	36	75%	74	54	73%
Pesticides and PCBs								
Chlordane	µg/kg	0.5	16	16	100%	31	31	100%
Dieldrin	µg/kg	0.02	16	16	100%	31	31	100%
Toxaphene	µg/kg	0.1	16	16	100%	31	31	100%
Total PCBs[3]	µg/kg	22.7	48	45	94%	74	68	92%
Total DDTs	µg/kg	1.58	46	45	98%	72	71	99%
PAHs								
Benzo[a]anthracene	µg/kg	261	40	19	48%	66	32	48%
Benzo[a]pyrene	µg/kg	430	40	14	35%	66	24	36%
Chrysene	µg/kg	384	40	18	45%	66	31	47%
Pyrene	µg/kg	665	40	23	58%	66	38	58%
2-Methylnaphthalene	µg/kg	201	40	0	0%	66	0	0%
Dibenzo[a,h]anthracene	µg/kg	260	40	2	5%	66	3	5%
Phenanthrene	µg/kg	240	40	17	43%	66	31	47%
High Molecular Weight PAHs[6]	µg/kg	1700	40	26	65%	66	43	65%
Low Molecular Weight PAHs[6]	µg/kg	552	40	19	48%	66	35	53%
Total PAHs	µg/kg	4022	40	21	53%	66	35	53%

Notes:

1 Surface data are defined as data with a starting depth of zero (i.e., 0-2 centimeters, 0-0.5 feet). Data from 0-2 feet are excluded.

2 Direct effects criteria are from Table 3-7 of Harbor Toxics TMDL (RWQCB and USEPA 2011).

3 Congener results were used for exceedance comparisons for samples analyzed for both congeners and Aroclors. The exclusion of Aroclor data for these samples is reflected under "Total Count."

4 Sediment data collected as part of compliance monitoring studies by oil refineries for the NPDES were excluded due to the unavailability of

5 Data are from Bay Protection and Toxic Cleanup Program (1996), Western Environmental Monitoring and Assessment Program (1999), AMEC (2002), Bight 03 (2003), and AMEC (2011). Data collected in 2002 from Torrance Lateral, Kenwood Drain, Dominguez Channel Upstream of Estuary above Vermont Ave., and Dominguez Channel Intertidal (DCT) were excluded.

6 Individual PAHs included in the high and low molecular weight groups were based on Table 3.1 of the *Sediment Quality Assessment Draft Technical Support Manual* (SCCWRP 2009).

AMEC = AMEC Earth & Environmental, Inc.

ERL = Effects Range Low

NPDES = National Pollutant Discharge Elimination System

PAH = polycyclic aromatic hydrocarbon

PCB = polychlorinated biphenyl

Table 3

Exceedances of TMDL Indirect Effects Criteria for Sediment Samples from Dominguez Channel Estuary

Parameter	Units	Indirect Effects Criteria (FCG) [2]	Surface[1]			All Depths		
			Total Count	Count Exceeding Criteria	% Exceed	Total Count	Count Exceeding Criteria	% Exceed
Pesticides and PCBs								
Chlordane	µg/kg	1.3	16	16	100%	31	31	100%
Toxaphene	µg/kg	0.1	16	16	100%	31	31	100%
Total PCBs[3]	µg/kg	3.2	48	47	98%	74	72	97%
Total DDTs	µg/kg	1.9	46	45	98%	72	71	99%

Notes:

1 Surface data are defined as data with a starting depth of zero (i.e., 0-2 centimeters, 0-0.5 feet). Data from 0-2 feet are excluded.

2 Indirect effects criteria are from Table 3-8 of Harbor Toxics TMDL (RWQCB and USEPA 2011).

3 Congener results were used for exceedance comparisons for samples analyzed for both congeners and Aroclors. The exclusion of Aroclor data for these samples is reflected under "Total Count".

4 Sediment data collected as part of compliance monitoring studies by oil refineries for the NPDES were excluded due to the unavailability of raw data and high detection limits.

5 Data are from Bay Protection and Toxic Cleanup Program (1996), Western Environmental Monitoring and Assessment Program (1999), AMEC (2002), Bight 03 (2003), and AMEC (2011). Data collected in 2002 from Torrance Lateral, Kenwood Drain, Dominguez Channel Upstream of Estuary above Vermont Ave., and Dominguez Channel Intertidal (DCT) were excluded.

6 Individual PAHs included in the high and low molecular weight groups were based on Table 3.1 of the *Sediment Quality Assessment Draft Technical Support Manual* (SCCWRP 2009).

AMEC = AMEC Earth & Environmental, Inc.

FCG = fish contaminant goal

NPDES = National Pollutant Discharge Elimination System

PCB = polychlorinated biphenyl

Table 4
Results for Regressions Performed on 2011 DCE Surface Sediment Data between Torrance Lateral and Consolidated Slip

Parameter	Slope	R^2	P-value
Metals			
Cadmium	-0.11	0.39	0.05
Chromium	-0.04	0.06	0.51
Copper	-0.01	0.01	0.76
Lead	-0.11	0.27	0.12
Mercury	-0.05	0.10	0.37
Zinc	-0.08	0.28	0.12
Pesticides and PCBs			
Chlordane	-0.19	0.41	0.05
Dieldrin	-0.17	0.41	0.05
Toxaphene	0.16	0.46	0.03
Total PCBs (Aroclor)	-0.09	0.14	0.30
Total PCBs (congener)	-0.15	0.12	0.32
Total DDTs	-0.17	0.43	0.04
PAHs			
Benzo[a]anthracene	-0.03	0.02	0.73
Benzo[a]pyrene	-0.05	0.03	0.61
Chrysene	-0.07	0.05	0.54
Pyrene	-0.12	0.11	0.34
2-Methylnaphthalene	-0.06	0.07	0.46
Dibenzo[a,h]anthracene	-0.07	0.06	0.48
Phenanthrene	-0.09	0.07	0.45
High molecular weight PAHs[3]	-0.09	0.08	0.44
Low molecular weight PAHs[3]	-0.09	0.10	0.38
Total PAHs	-0.09	0.09	0.40

Notes:

1 Surface data are defined as data with a starting depth of zero (i.e., 0-2 centimeters, 0-0.5 foot). Data from 0-2 feet are excluded.

2 A positive slope indicates an increasing trend between Torrance Lateral and Consolidated Slip; a negative slope indicated a decreasing trend. The strength of the regression is indicated by the coefficient of determination, R^2; a R^2 of 1 indicates a perfect fit.

3 Individual PAHs included in the high and low molecular weight groups were based on Table 3.1 of the *Sediment Quality Assessment Draft Technical Support Manual* (SCCWRP 2009).

4 Data are from Bay Protection and Toxic Cleanup Program (1996), Western Environmental Monitoring and Assessment Program (1999), AMEC (2002), Bight 03 (2003), and AMEC (2011). Data collected in 2002 from Torrance Lateral, Kenwood Drain, Dominguez Channel Upstream of Estuary above Vermont Avenue), and Dominguez Channel Intertidal were excluded.

Table 5
Comparison of Contaminant Concentrations in 2002 vs. 2011

Parameter	Mean 2002 (n = 24)	Mean 2011 (n = 16)	P Value
Metals (mg/kg)			
Cadmium	1.38	1.55	0.751
Chromium	62.2	137	0.499
Copper	78.5	104	0.185
Mercury	0.181	0.188	0.912
Lead	149	146	0.543
Zinc	272	354	0.209
PAHs (µg/kg)			
Dibenzo (a,h) Anthracene	77.7	61.9	0.097
2-Methylnaphthalene	29.3	48.6	0.115
Benzo (a) Anthracene	542	297	0.956
Benzo (a) Pyrene	522	424	0.923
Phenanthrene	1460	254	0.897
Pyrene	2032	691	0.079
Total PAHs	10147	5203	0.795
Other Organics (µg/kg)			
Total PCBs[1]	437	373	0.652
Total DDTs	556	192	0.008

Notes:

1 Aroclor PCBs were measured in 2002 samples and PCB Congeners were measured in 2011

Wilcoxon Rank Sum (Non-Parametric) Test was used to compare contaminant concentrations between years.

µg/kg = milligrams per kilogram

mg/kg = milligrams per kilogram

PAH = polycyclic aromatic hydrocarbon

PCB = polychlorinated biphenyl

FIGURES

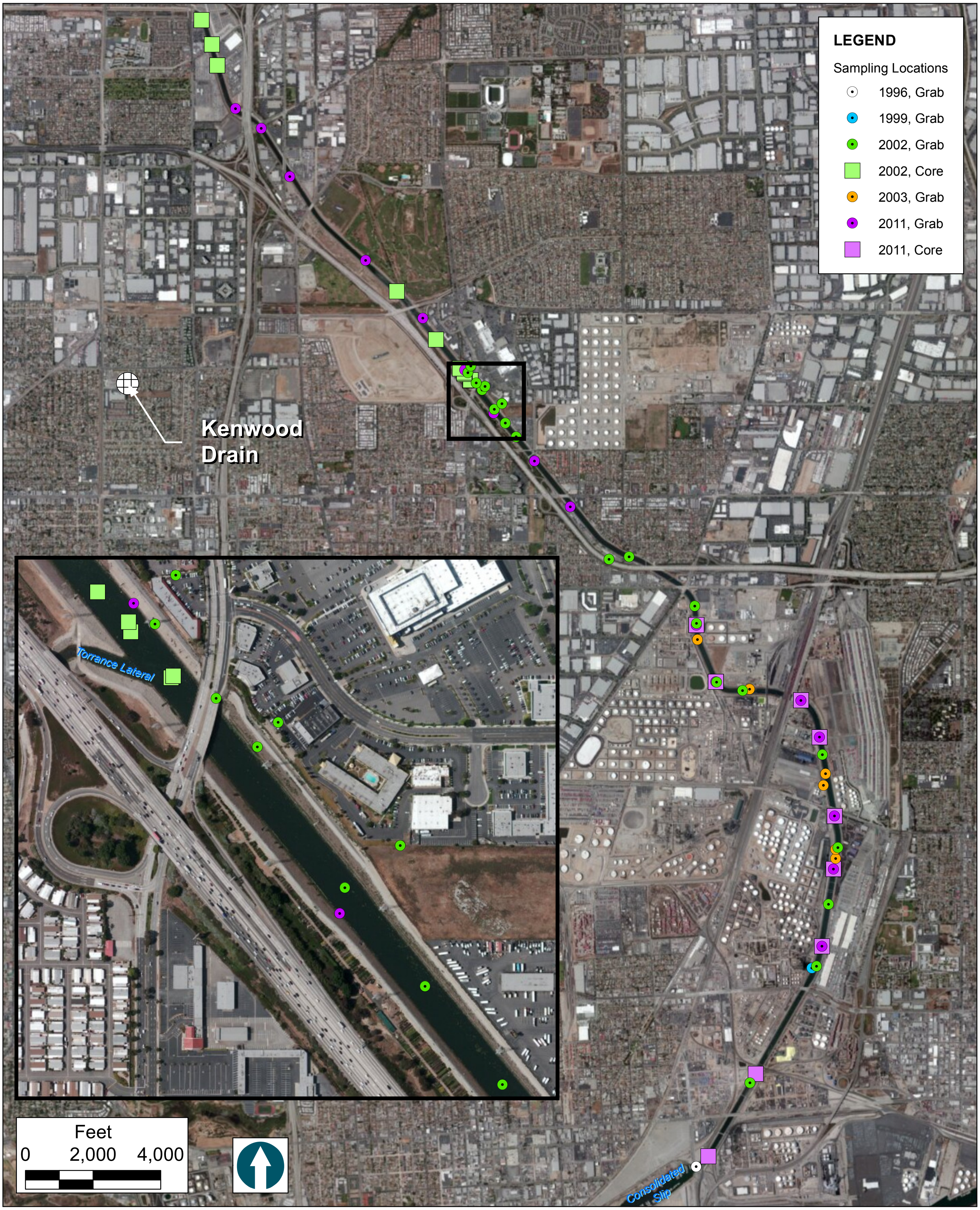


Figure 1
Dominguez Channel Estuary Sediment Sampling Locations
Dominguez Channel Estuary

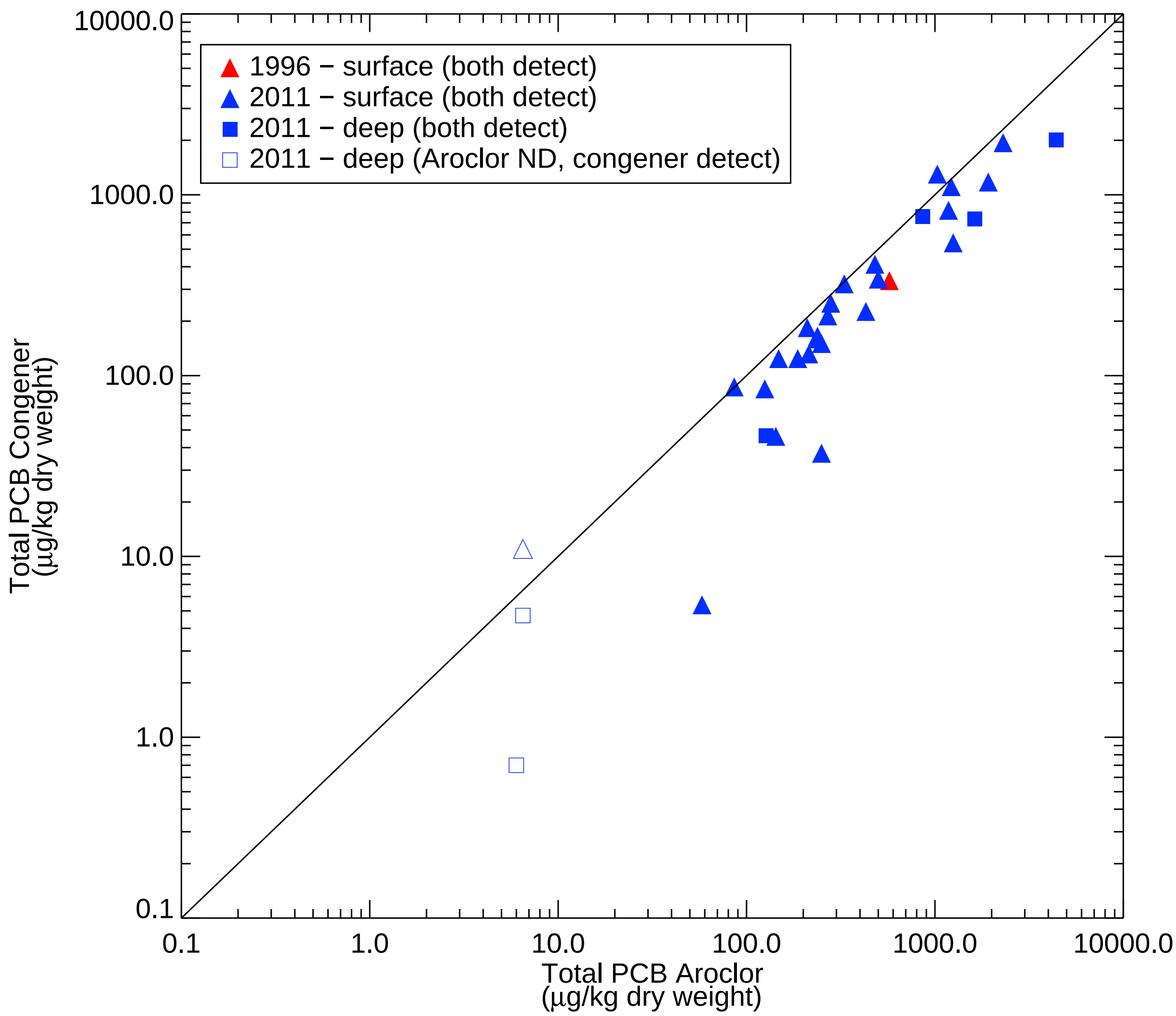
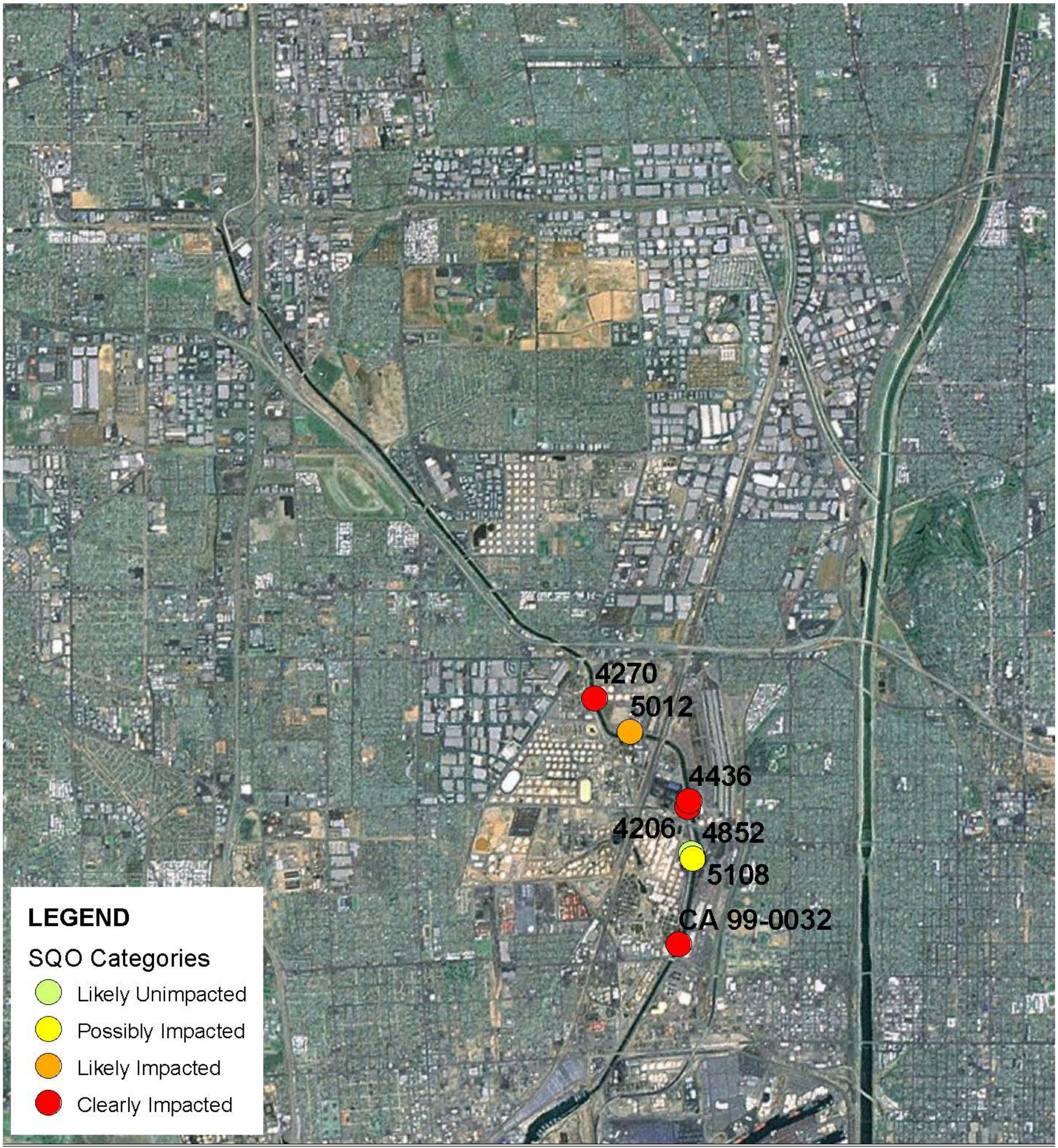


Figure 2

Comparison of Total PCB Congener and Aroclor Data for Paired Samples from Dominguez Channel Estuary

Non−detects (NDs) set to half the reporting limit when MDL not available.
Duplicates were averaged with original sample results.
Database = Sed_DBcomb_NDhalfMDL_tot_20130806.bin



NOTES:
Bight 2003 sampling stations are 4206, 4270, 4436, 4852, 5012, and 5108. WEMAP sampling station is CA99-0032.

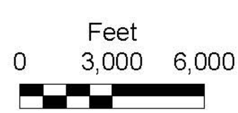
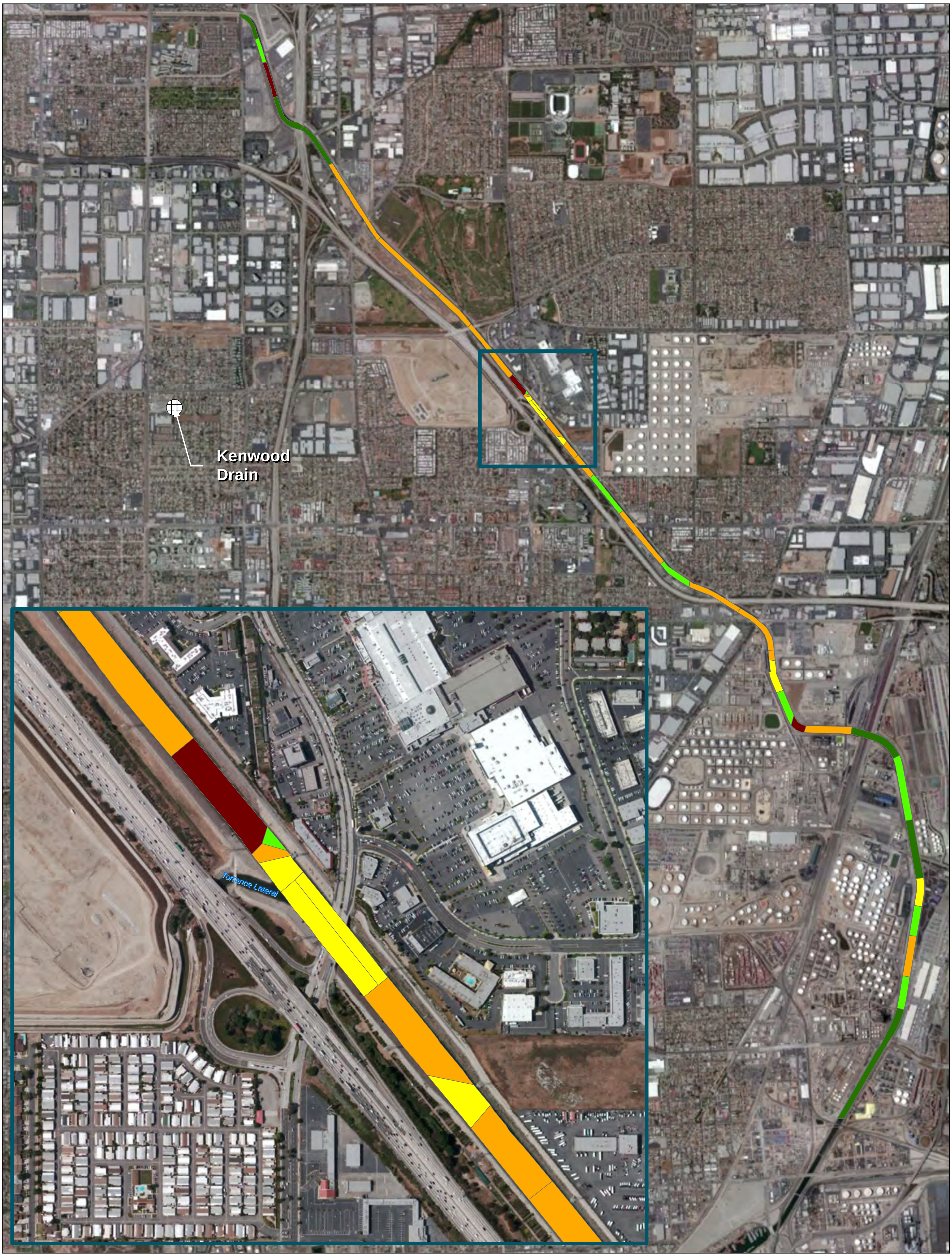


Figure 3
Previous Sediment Quality Objecive Assessment based on 1999 and 2003 Data
Dominguez Channel Estuary



LEGEND

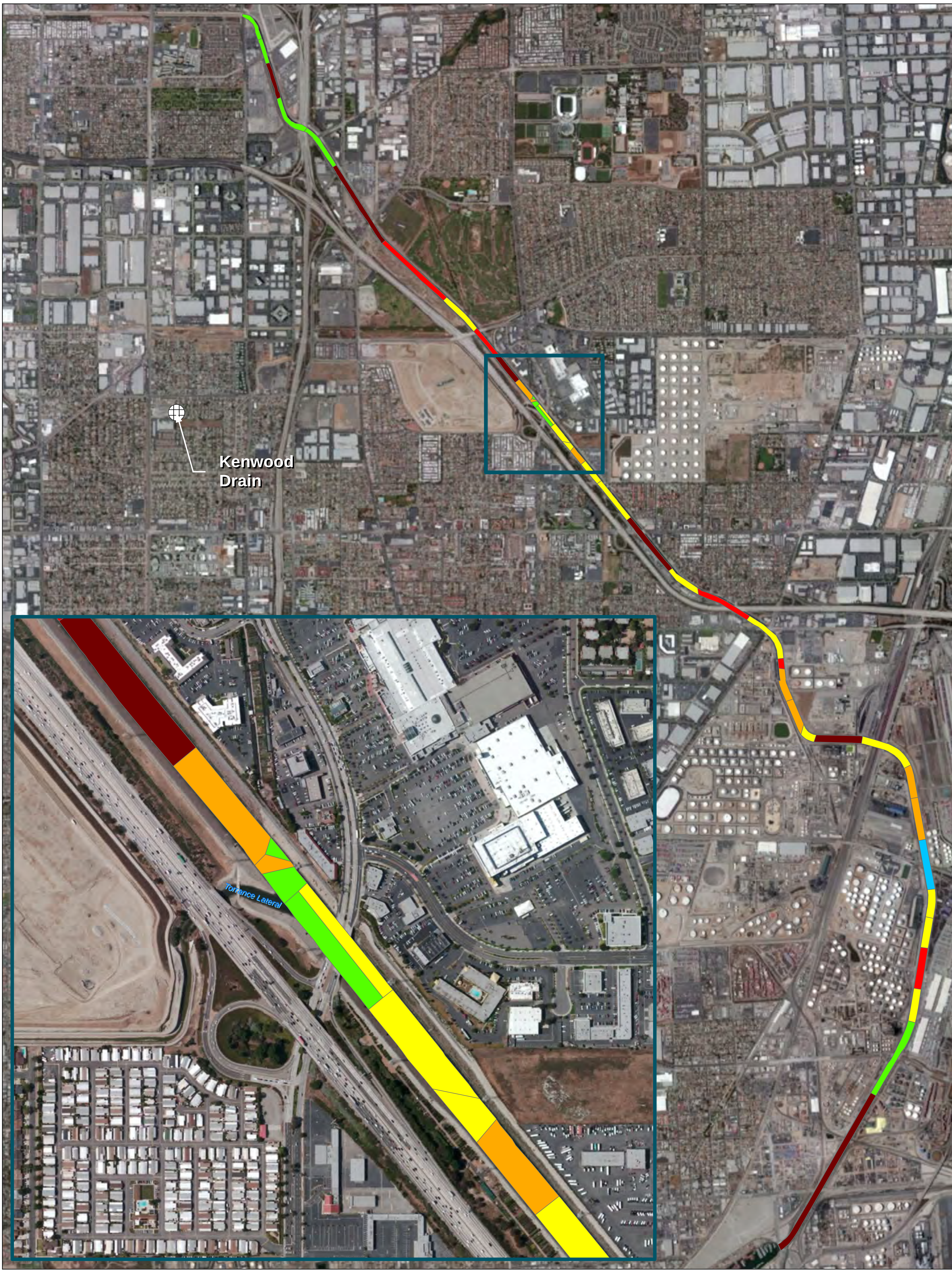
TDDT (µg/kg, 2002 and 2011 Surface Data)

- 0.95 - 1.58 (TMDL direct effects target; ERL = 1.58)
- 1.59 - 1.9 (TMDL indirect effects target = 1.9)
- 1.91 - 46.1 (ERM = 46.1)
- 46.2 - 92.2
- 92.3 - 184
- 185 - 1,000
- 1,010 - 2,540

NOTES:
1. Surface samples collected at 0 to 0.5 feet.
2. Intertidal data (DCT) from 2002 were excluded.

Feet
0 2,500 5,000

Figure 4a
Thiessen Polygons Showing Surface Concentrations of TDDT, 2002 and 2011 Data
Dominguez Channel Estuary



LEGEND

Total PCBs (µg/kg, 2002 and 2011 Surface Data)

- 5.4 - 22.7 (TMDL direct effects target; ERL = 22.7)
- 22.701 - 90
- 90.001 - 180 (ERM = 180)
- 180.001 - 376
- 376.001 - 1,000
- 1,000.001 - 2,270

NOTES:
1. Surface samples collected at 0 to 0.5 feet.
2. Intertidal data (DCT) from 2002 were excluded.
3. PCB Congener results are shown for samples also analyzed for PCB Aroclors.

Feet
0 2,500 5,000

Figure 4b
Thiessen Polygons Showing Surface Concentrations of TPCB, 2002 and 2011 Data
Dominguez Channel Estuary

LEGEND

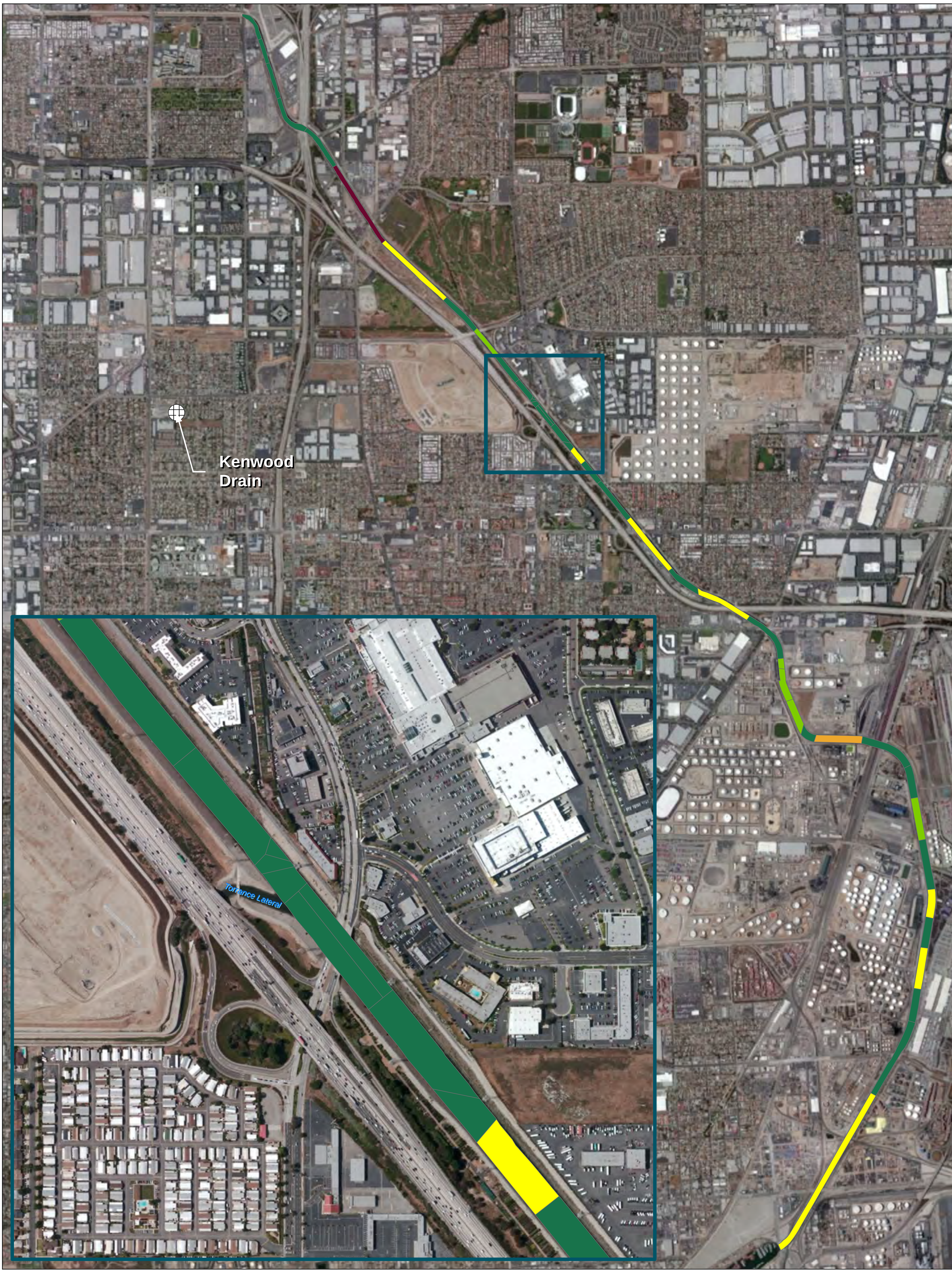
TPAH (µg/kg, 2002 and 2011 Surface Data)

- 437 - 2,500
- 2,501 - 4,022 (ERL = 4,022)
- 4,023 - 10,000
- 10,001 - 25,000
- 25,001 - 63,964

NOTES:
1. Surface samples collected at 0 to 0.5 feet.
2. Intertidal data (DCT) from 2002 were excluded.

Feet
0 2,500 5,000

Figure 4c
Thiessen Polygons Showing Surface Concentrations of TPAH, 2002 and 2011 Data
Dominguez Channel Estuary



LEGEND

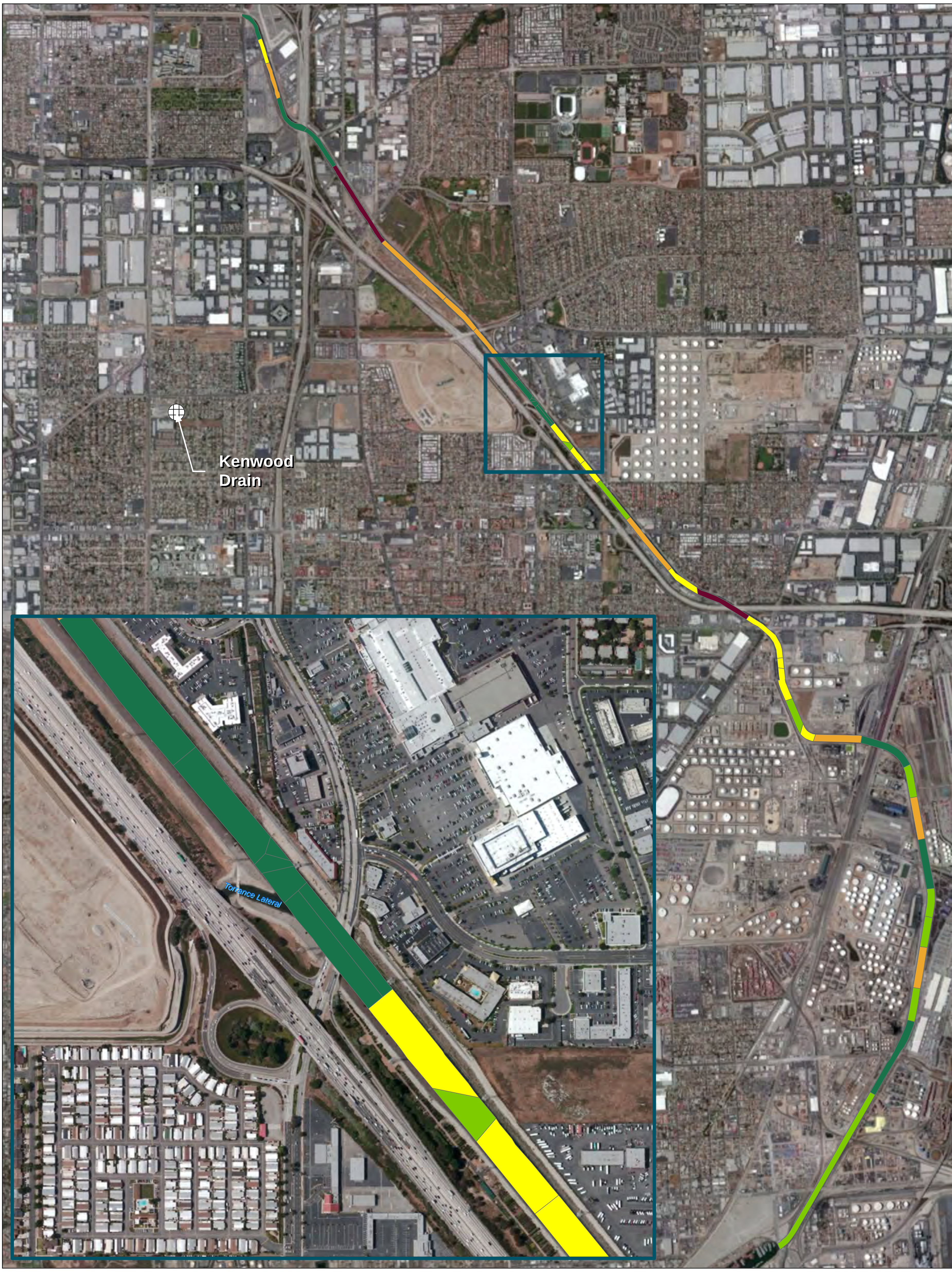
Mercury (mg/kg, 2002 and 2011 Surface Data)

- 0.038 - 0.15 (ERL = 0.15)
- 0.151 - 0.25
- 0.251 - 0.5
- 0.501 - 0.75
- 0.751 - 0.852

NOTES:
1. Surface samples collected at 0 to 0.5 feet.
2. Intertidal data (DCT) from 2002 were excluded.

Feet
0 2,500 5,000

Figure 4d
Thiessen Polygons Showing Surface Concentrations of Mercury, 2002 and 2011 Data
Dominguez Channel Estuary



LEGEND

Lead (mg/kg, 2002 and 2011 Surface Data)

- 13 - 46.7 (ERL = 46.7)
- 46.8 - 100
- 101 - 200
- 201 - 400
- 401 - 862

NOTES:
1. Surface samples collected at 0 to 0.5 feet.
2. Intertidal data (DCT) from 2002 were excluded.

Feet
0 2,500 5,000

Figure 4e
Thiessen Polygons Showing Surface Concentrations of Lead, 2002 and 2011 Data
Dominguez Channel Estuary

LEGEND

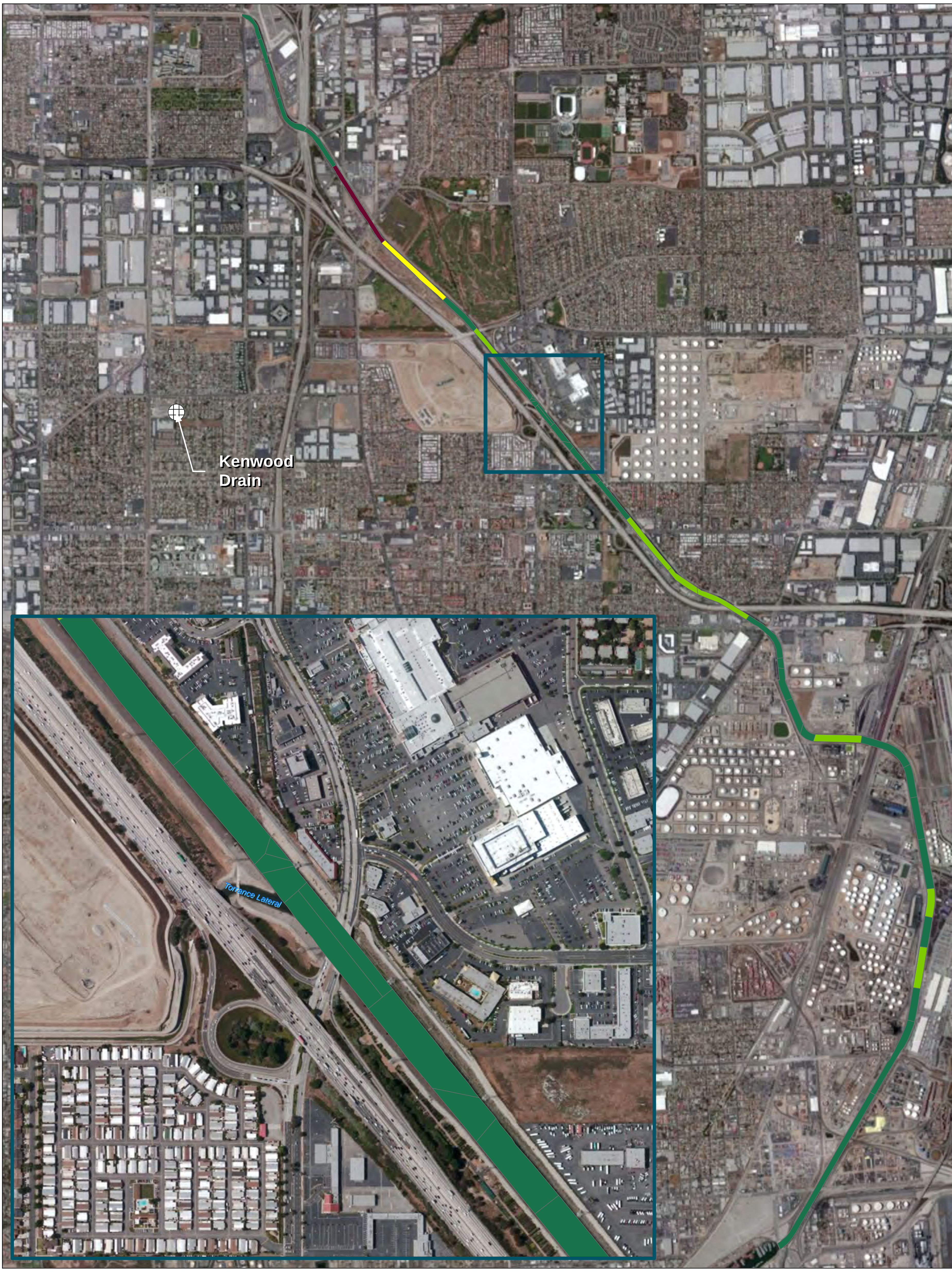
Cadmium (mg/kg, 2002 and 2011 Surface Data)

- 0.22 - 1.2 (ERL = 1.2)
- 1.3 - 2
- 2.1 - 3
- 3.1 - 4
- 4.1 - 6

NOTES:
1. Surface samples collected at 0 to 0.5 feet.
2. Intertidal data (DCT) from 2002 were excluded.

Feet
0 2,500 5,000

Figure 4f
Thiessen Polygons Showing Surface Concentrations of Cadmium, 2002 and 2011 Data
Dominguez Channel Estuary



LEGEND

Chromium (mg/kg, 2002 and 2011 Surface Data)

- 5.7 - 81 (ERL = 81)
- 81.1 - 370 (ERM = 370)
- 371 - 500
- 501 - 750
- 751 - 924

NOTES:
1. Surface samples collected at 0 to 0.5 feet.
2. Intertidal data (DCT) from 2002 were excluded.

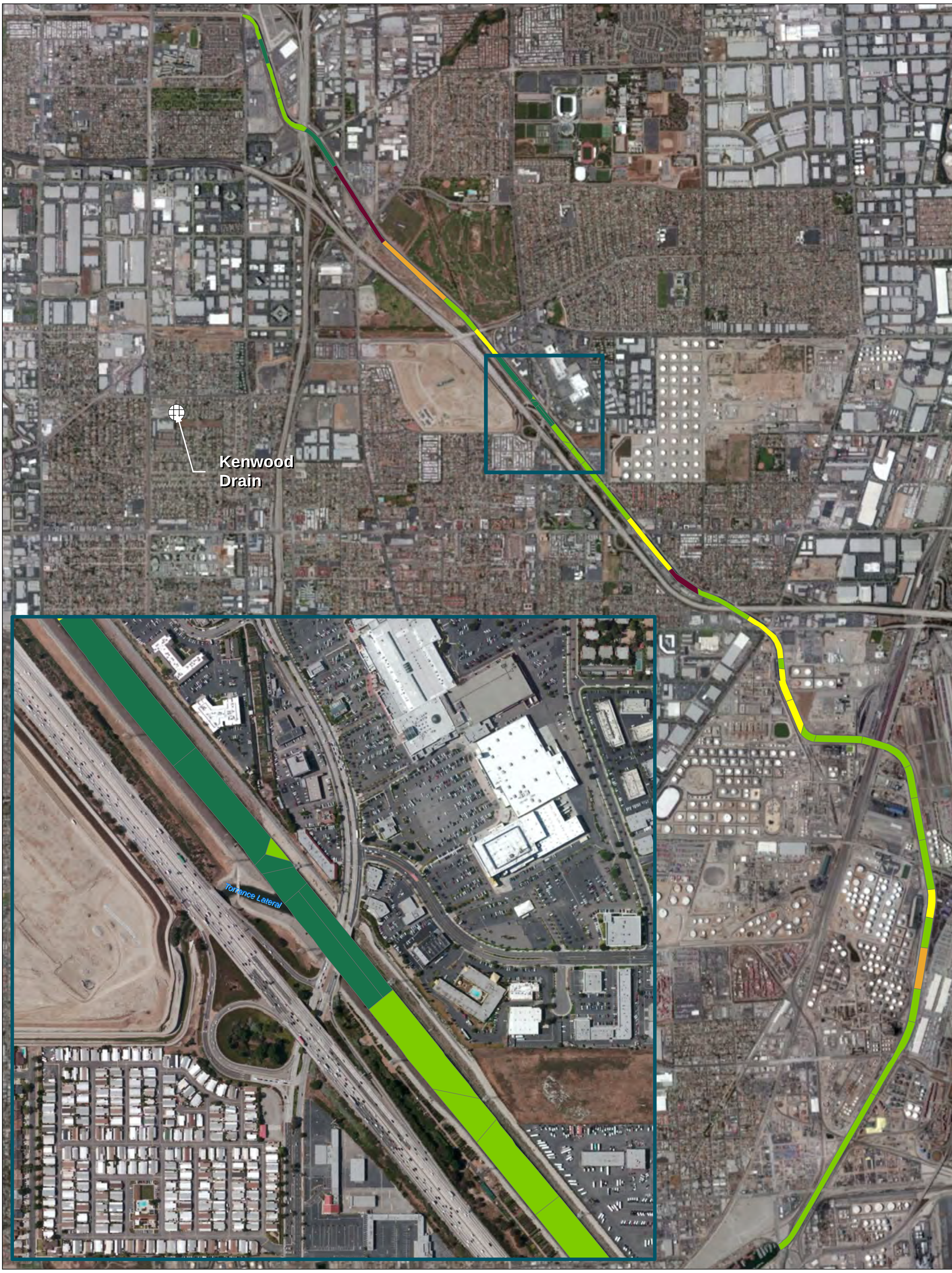
Feet

0 2,500 5,000

Figure 4g

Thiessen Polygons Showing Surface Concentrations of Chromium, 2002 and 2011 Data

Dominguez Channel Estuary



LEGEND

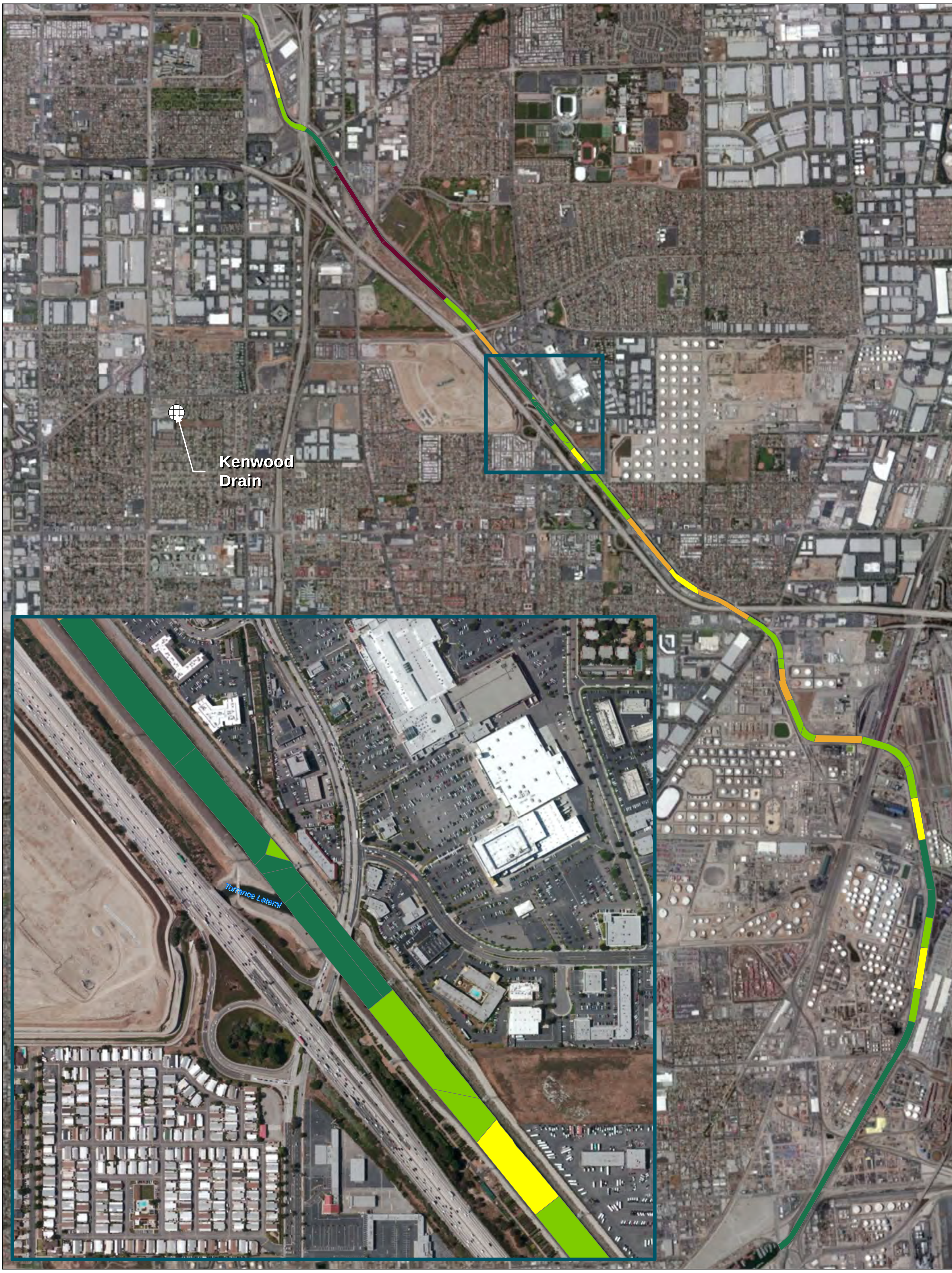
Copper (mg/kg, 2002 and 2011 Surface Data)

- 6.7 - 34 (ERL = 34)
- 34.1 - 100
- 101 - 200
- 201 - 270 (ERM = 270)
- 271 - 400

NOTES:
1. Surface samples collected at 0 to 0.5 feet.
2. Intertidal data (DCT) from 2002 were excluded.

Feet
0 2,500 5,000

Figure 4h
Thiessen Polygons Showing Surface Concentrations of Copper, 2002 and 2011 Data
Dominguez Channel Estuary



LEGEND

Zinc (mg/kg, 2002 and 2011 Surface Data)

- 35 - 150 (ERL = 150)
- 151 - 410 (ERM = 410)
- 411 - 500
- 501 - 600
- 601 - 817

NOTES:
1. Surface samples collected at 0 to 0.5 feet.
2. Intertidal data (DCT) from 2002 were excluded.

Feet
0 2,500 5,000

Figure 4i
Thiessen Polygons Showing Surface Concentrations of Zinc, 2002 and 2011 Data
Dominguez Channel Estuary

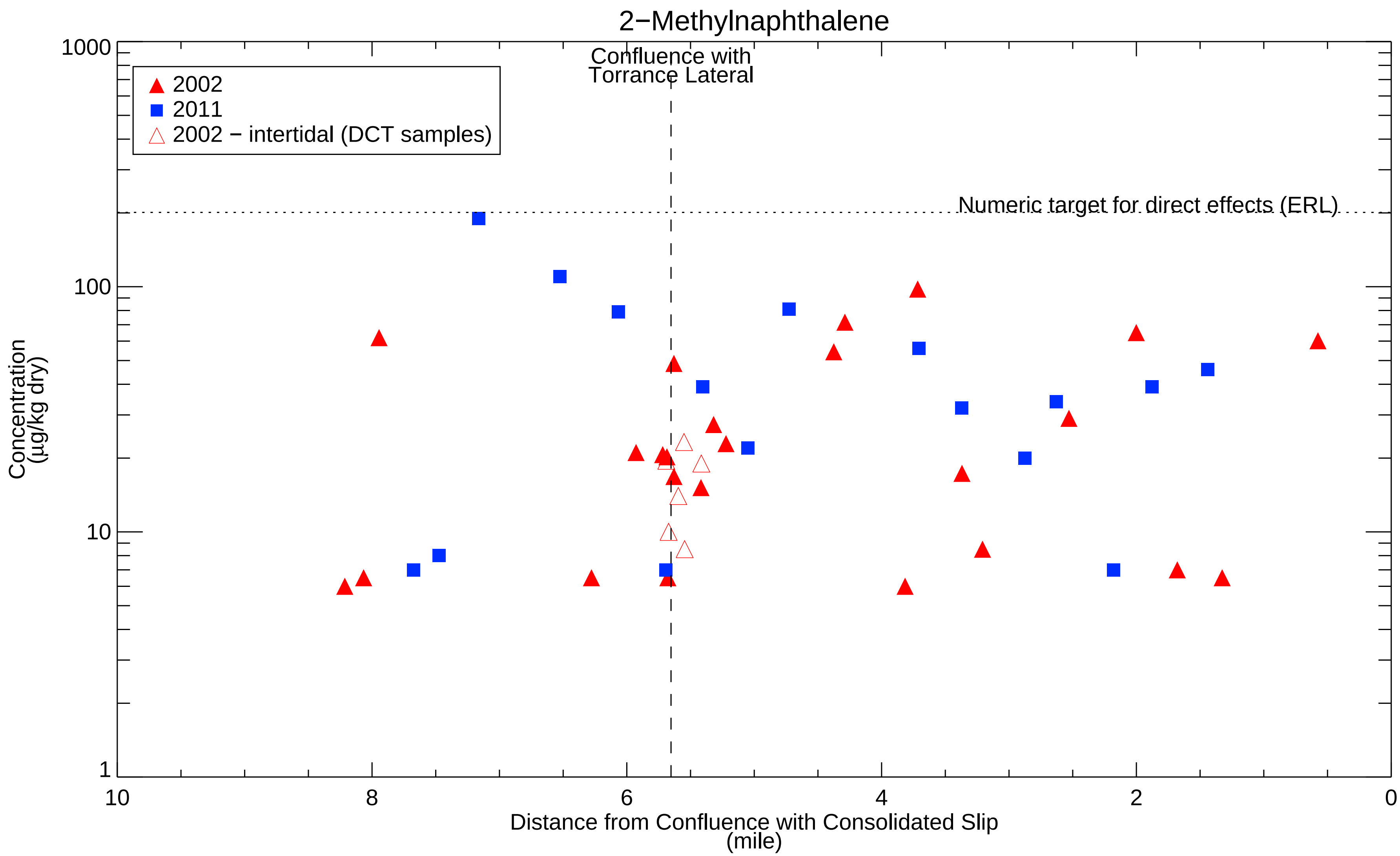


Figure 5a

Concentrations of 2−Methylnaphthalene in Surface Sediment from Dominguez Channel Estuary (0 to 0.5 ft)

Torrance Lateral (TL), Kenwood Drain (KD), and Dominguez Channel Upstream of Estuary Above Vermont Ave (DCU) data from 2002 are not shown.
Non−detects set to half reporting limit (not shown as different symbols; MDL not available). Duplicates averaged.
Databases = Sed_DBcomb_NDhalfMDL_tot_20140229_alignTOC_20140301.bin, Sed_DBcomb_NDhalfMDL_indv_20140229.bin

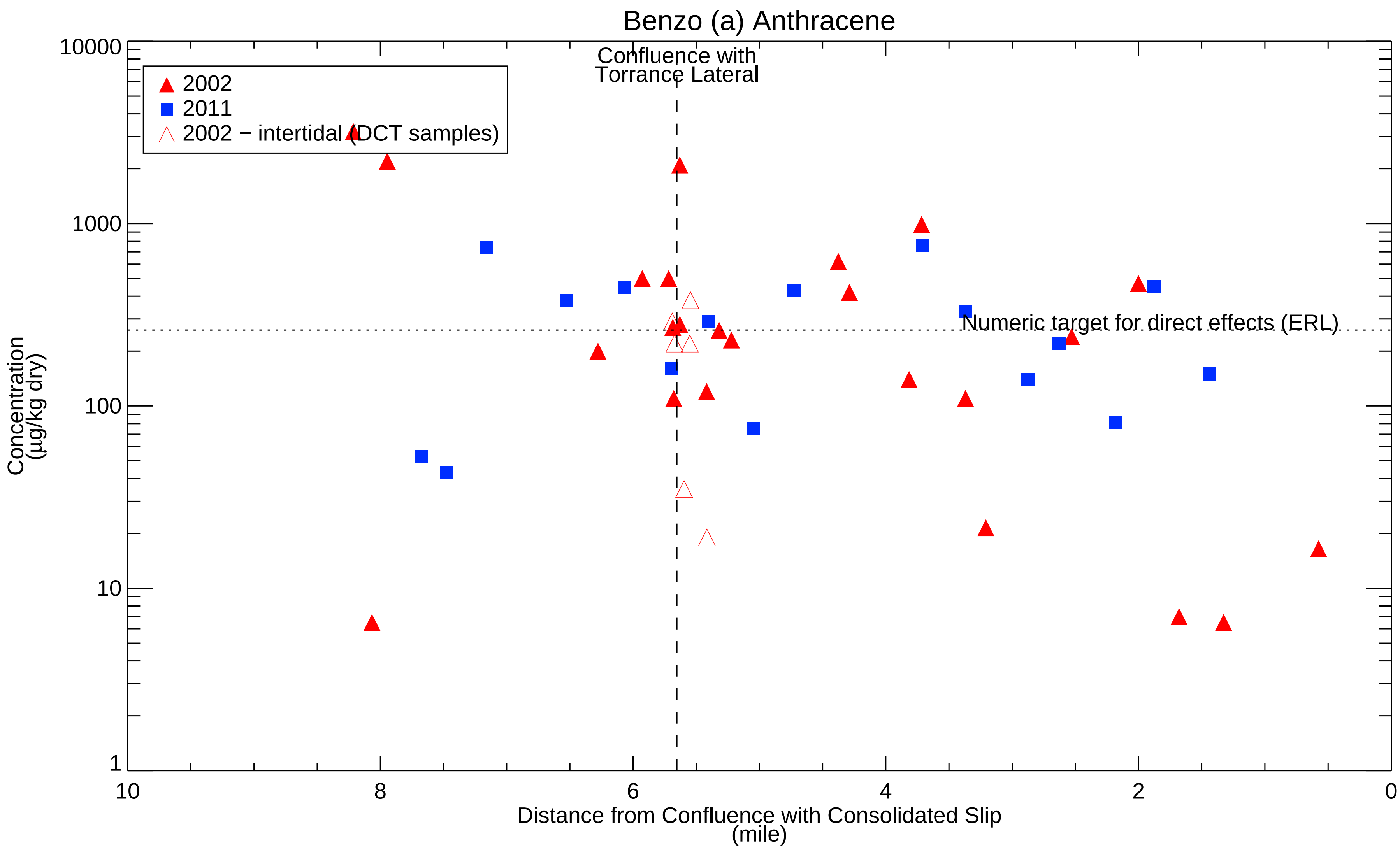


Figure 5b

Concentrations of Benzo (a) Anthracene in Surface Sediment from Dominguez Channel Estuary (0 to 0.5 ft)

Torrance Lateral (TL), Kenwood Drain (KD), and Dominguez Channel Upstream of Estuary Above Vermont Ave (DCU) data from 2002 are not shown.
Non−detects set to half reporting limit (not shown as different symbols; MDL not available). Duplicates averaged.
Databases = Sed_DBcomb_NDhalfMDL_tot_20140229_alignTOC_20140301.bin, Sed_DBcomb_NDhalfMDL_indv_20140229.bin

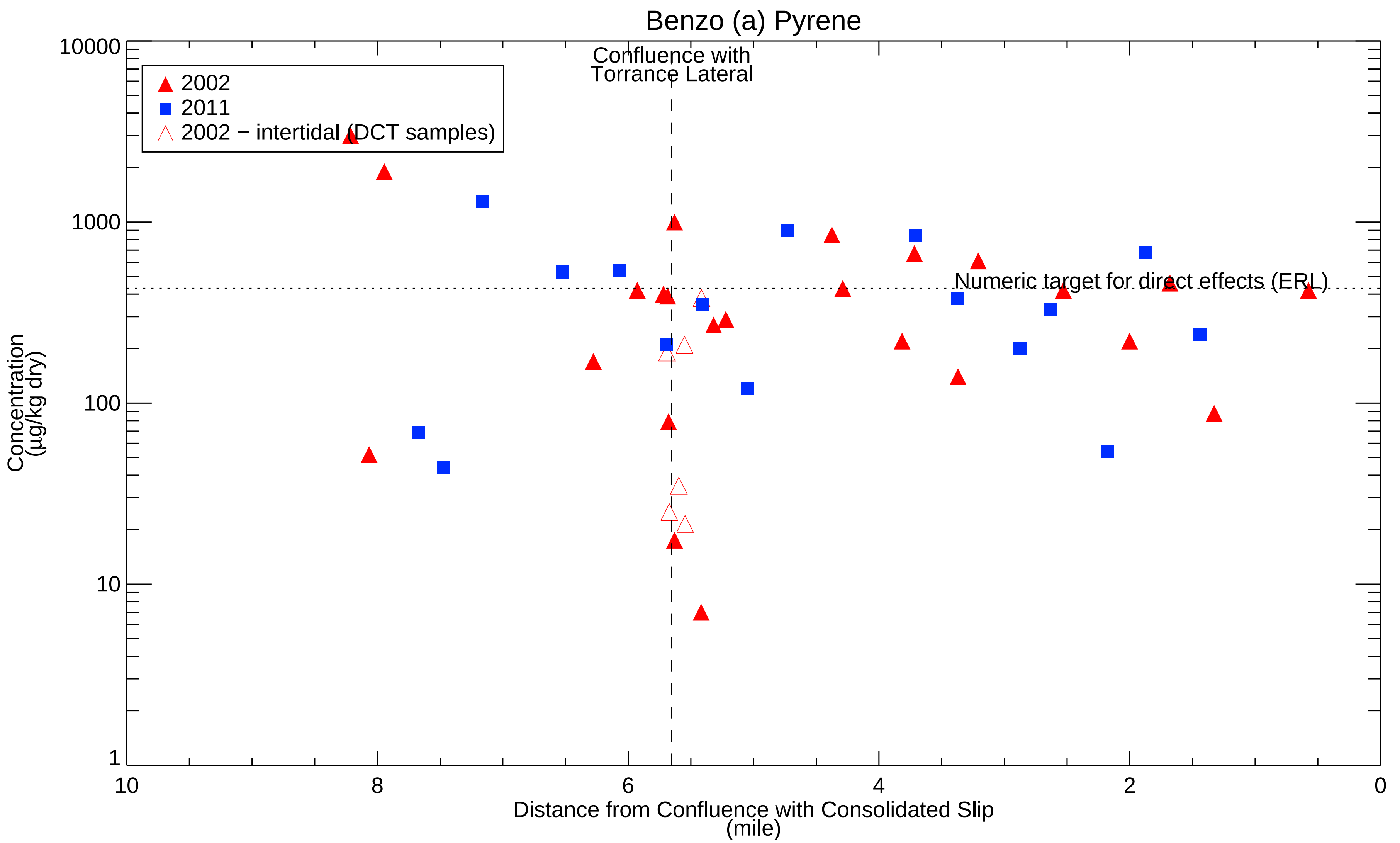


Figure 5c

Concentrations of Benzo (a) Pyrene in Surface Sediment from Dominguez Channel Estuary (0 to 0.5 ft)

Torrance Lateral (TL), Kenwood Drain (KD), and Dominguez Channel Upstream of Estuary Above Vermont Ave (DCU) data from 2002 are not shown.
Non−detects set to half reporting limit (not shown as different symbols; MDL not available). Duplicates averaged.
Databases = Sed_DBcomb_NDhalfMDL_tot_20140229_alignTOC_20140301.bin, Sed_DBcomb_NDhalfMDL_indv_20140229.bin

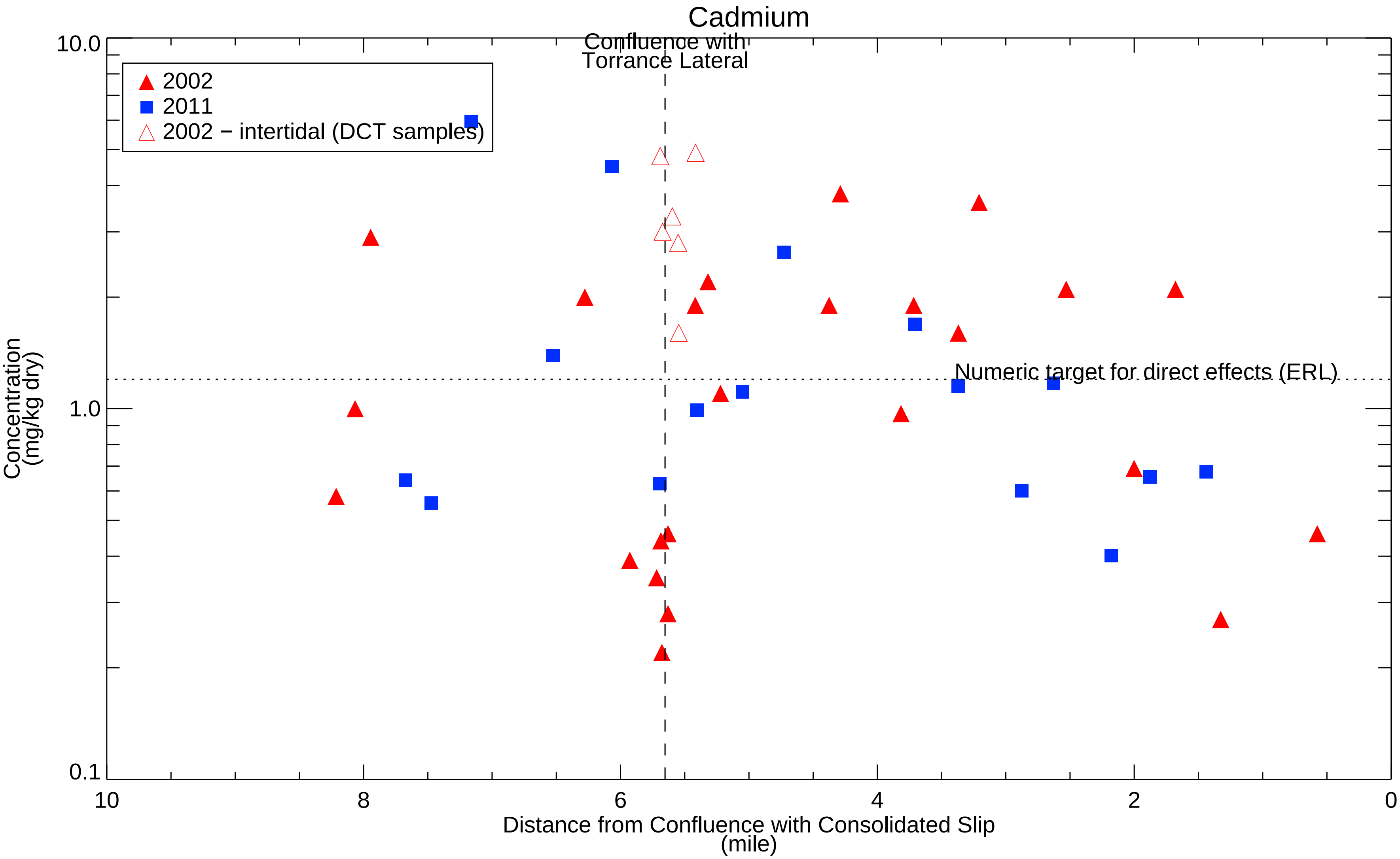


Figure 5d

Concentrations of Cadmium in Surface Sediment from Dominguez Channel Estuary (0 to 0.5 ft)

Torrance Lateral (TL), Kenwood Drain (KD), and Dominguez Channel Upstream of Estuary Above Vermont Ave (DCU) data from 2002 are not shown.
Non−detects set to half reporting limit (not shown as different symbols; MDL not available). Duplicates averaged.
Databases = Sed_DBcomb_NDhalfMDL_tot_20140229_alignTOC_20140301.bin, Sed_DBcomb_NDhalfMDL_indv_20140229.bin

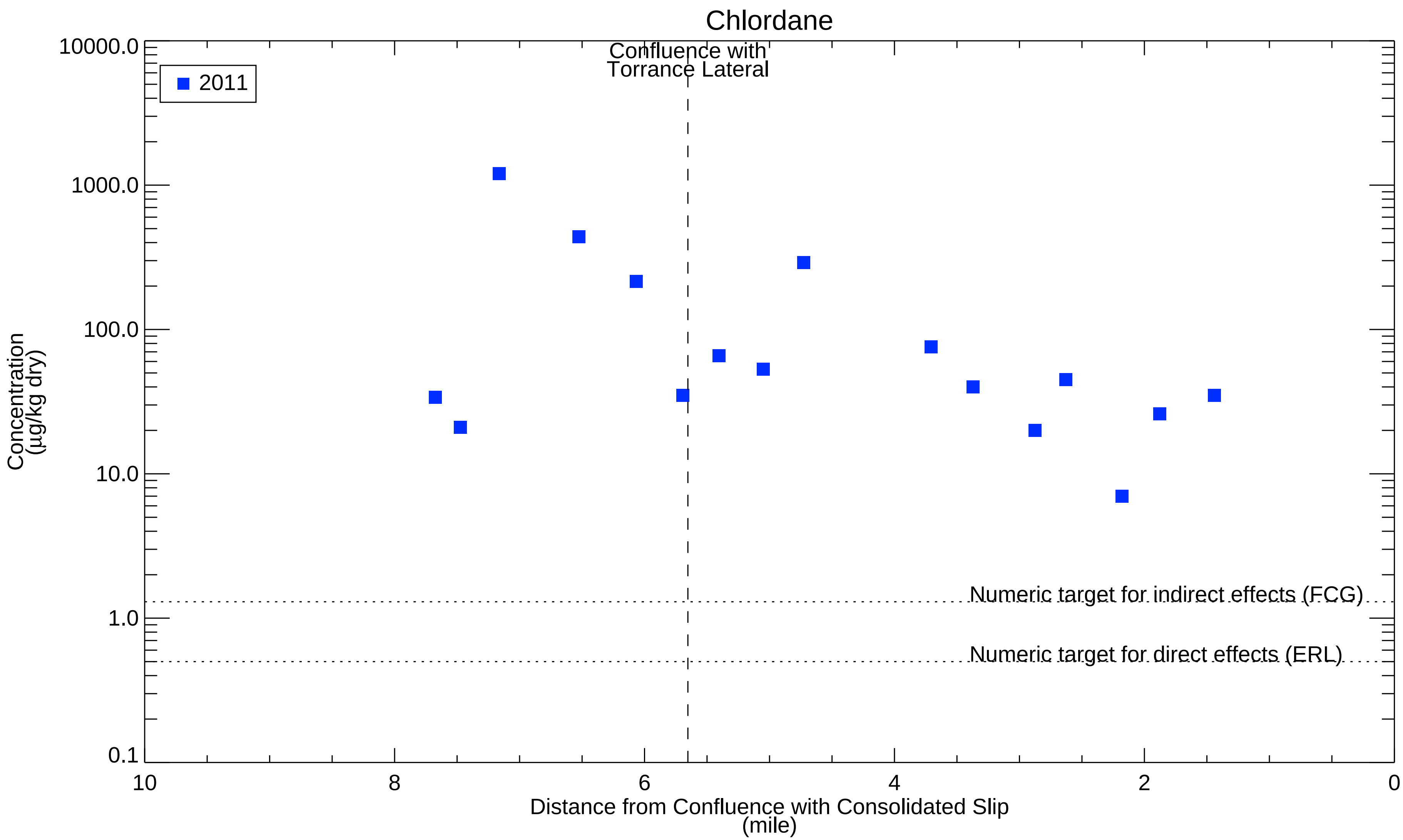


Figure 5e

Concentrations of Chlordane in Surface Sediment from Dominguez Channel Estuary (0 to 0.5 ft)

Torrance Lateral (TL), Kenwood Drain (KD), and Dominguez Channel Upstream of Estuary Above Vermont Ave (DCU) data from 2002 are not shown.
Non−detects set to half reporting limit (not shown as different symbols; MDL not available). Duplicates averaged.
Databases = Sed_DBcomb_NDhalfMDL_tot_20140229_alignTOC_20140301.bin, Sed_DBcomb_NDhalfMDL_indv_20140229.bin

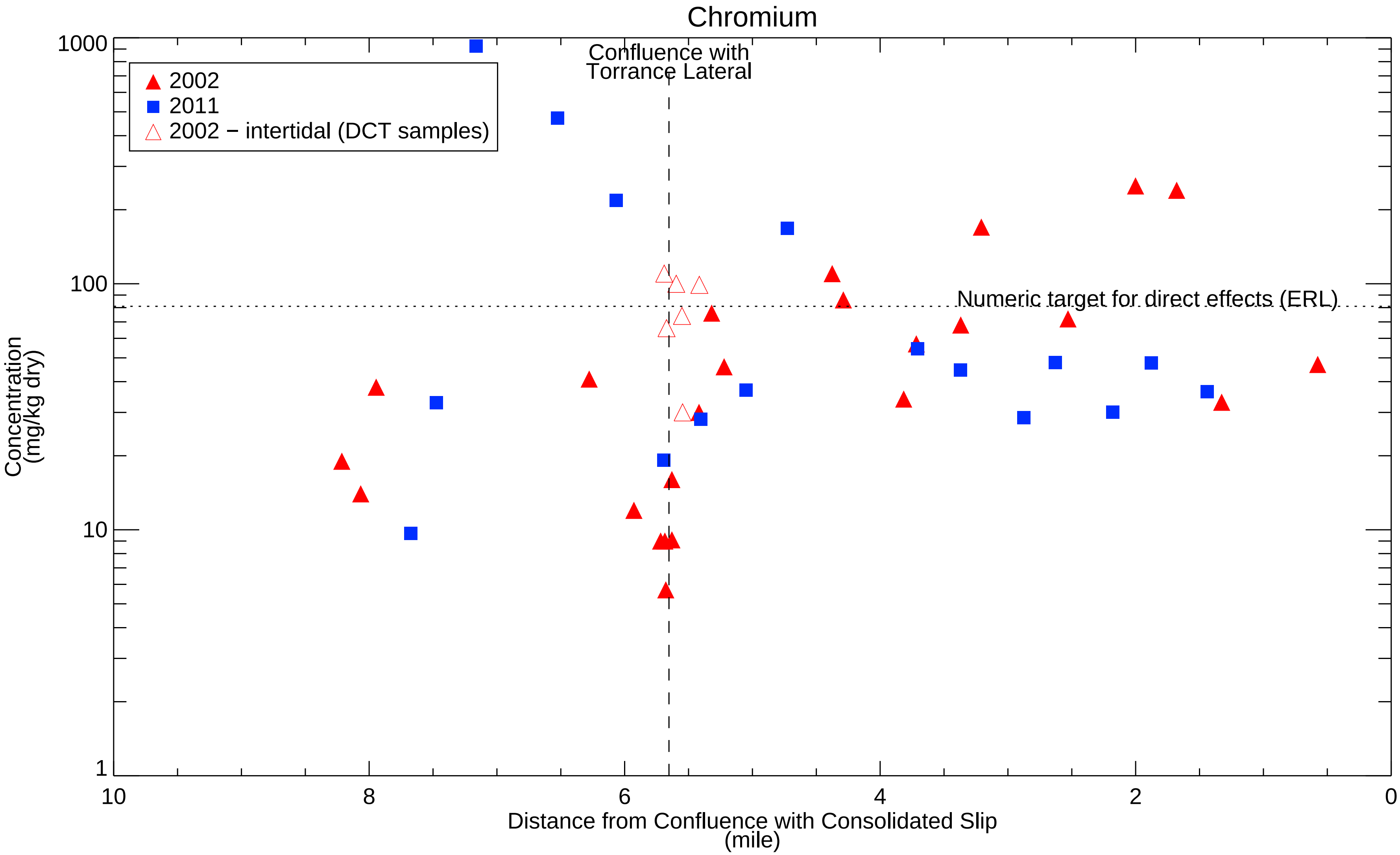


Figure 5f

Concentrations of Chromium in Surface Sediment from Dominguez Channel Estuary (0 to 0.5 ft)

Torrance Lateral (TL), Kenwood Drain (KD), and Dominguez Channel Upstream of Estuary Above Vermont Ave (DCU) data from 2002 are not shown.
Non−detects set to half reporting limit (not shown as different symbols; MDL not available). Duplicates averaged.
Databases = Sed_DBcomb_NDhalfMDL_tot_20140229_alignTOC_20140301.bin, Sed_DBcomb_NDhalfMDL_indv_20140229.bin

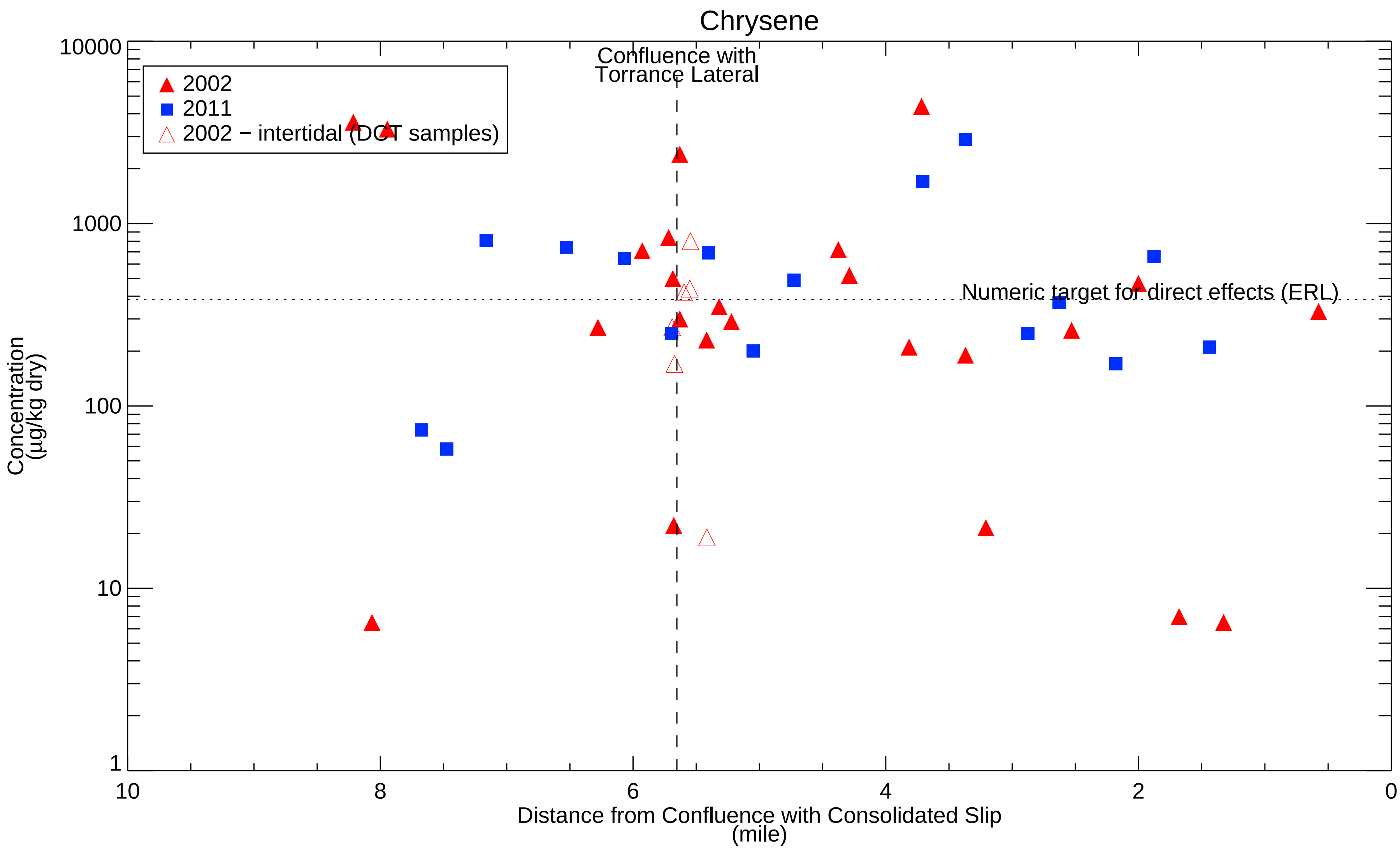


Figure 5g

Concentrations of Chrysene in Surface Sediment from Dominguez Channel Estuary (0 to 0.5 ft)

Torrance Lateral (TL), Kenwood Drain (KD), and Dominguez Channel Upstream of Estuary Above Vermont Ave (DCU) data from 2002 are not shown.
Non−detects set to half reporting limit (not shown as different symbols; MDL not available). Duplicates averaged.
Databases = Sed_DBcomb_NDhalfMDL_tot_20140229_alignTOC_20140301.bin, Sed_DBcomb_NDhalfMDL_indv_20140229.bin

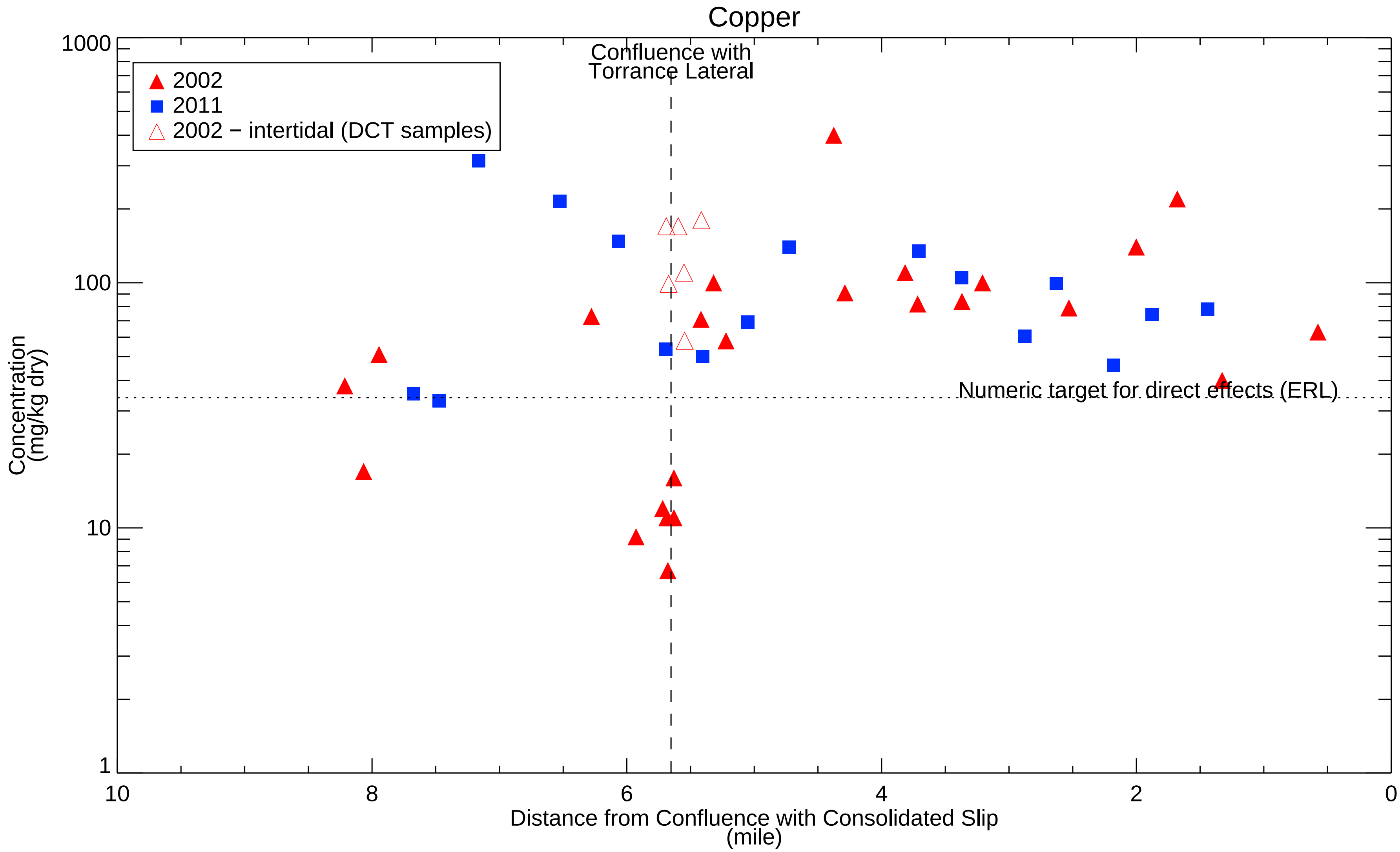


Figure 5h

Concentrations of Copper in Surface Sediment from Dominguez Channel Estuary (0 to 0.5 ft)

Torrance Lateral (TL), Kenwood Drain (KD), and Dominguez Channel Upstream of Estuary Above Vermont Ave (DCU) data from 2002 are not shown.
Non−detects set to half reporting limit (not shown as different symbols; MDL not available). Duplicates averaged.
Databases = Sed_DBcomb_NDhalfMDL_tot_20140229_alignTOC_20140301.bin, Sed_DBcomb_NDhalfMDL_indv_20140229.bin

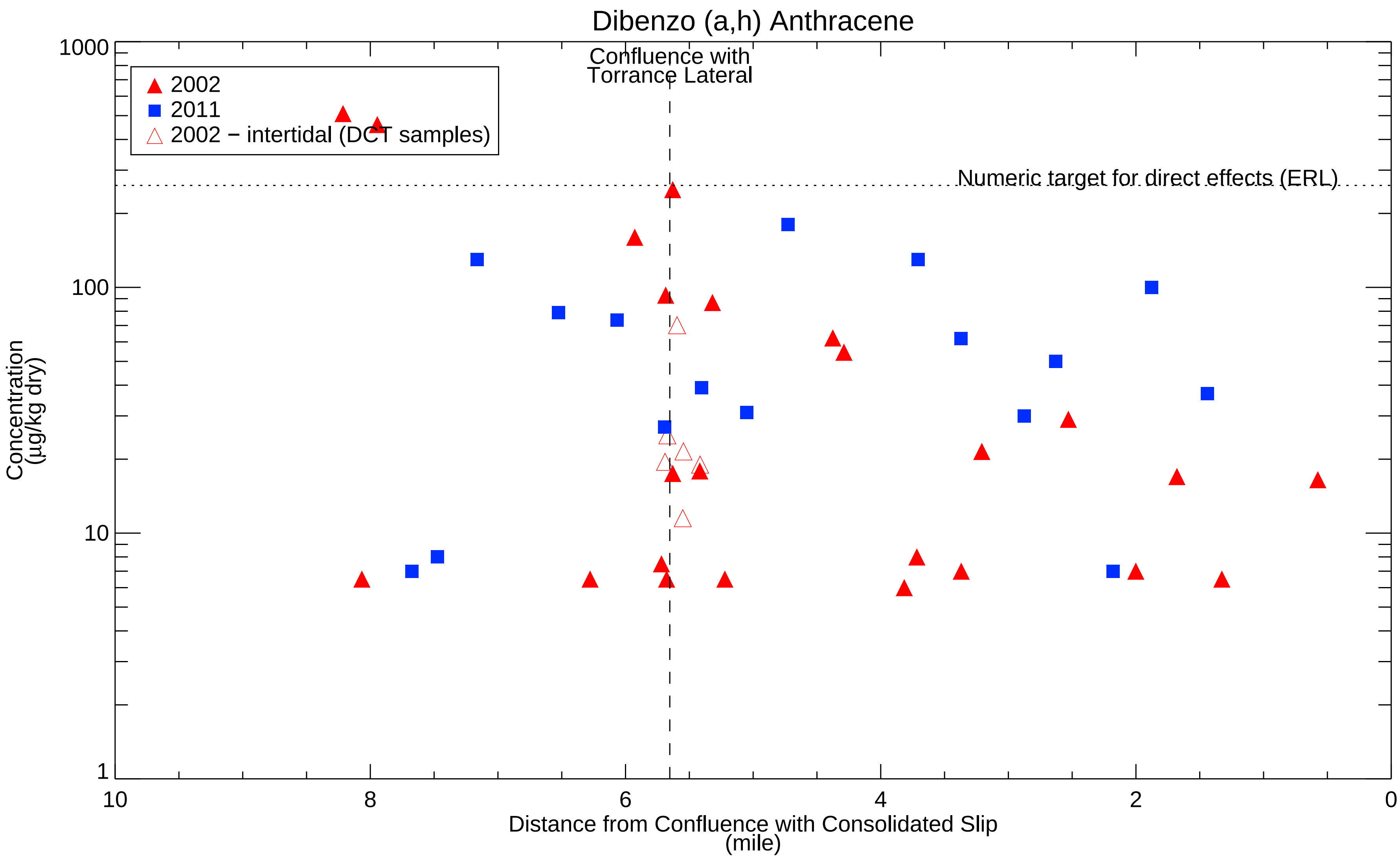


Figure 5i

Concentrations of Dibenzo (a,h) Anthracene in Surface Sediment from Dominguez Channel Estuary (0 to 0.5 ft)

Torrance Lateral (TL), Kenwood Drain (KD), and Dominguez Channel Upstream of Estuary Above Vermont Ave (DCU) data from 2002 are not shown.
Non−detects set to half reporting limit (not shown as different symbols; MDL not available). Duplicates averaged.
Databases = Sed_DBcomb_NDhalfMDL_tot_20140229_alignTOC_20140301.bin, Sed_DBcomb_NDhalfMDL_indv_20140229.bin

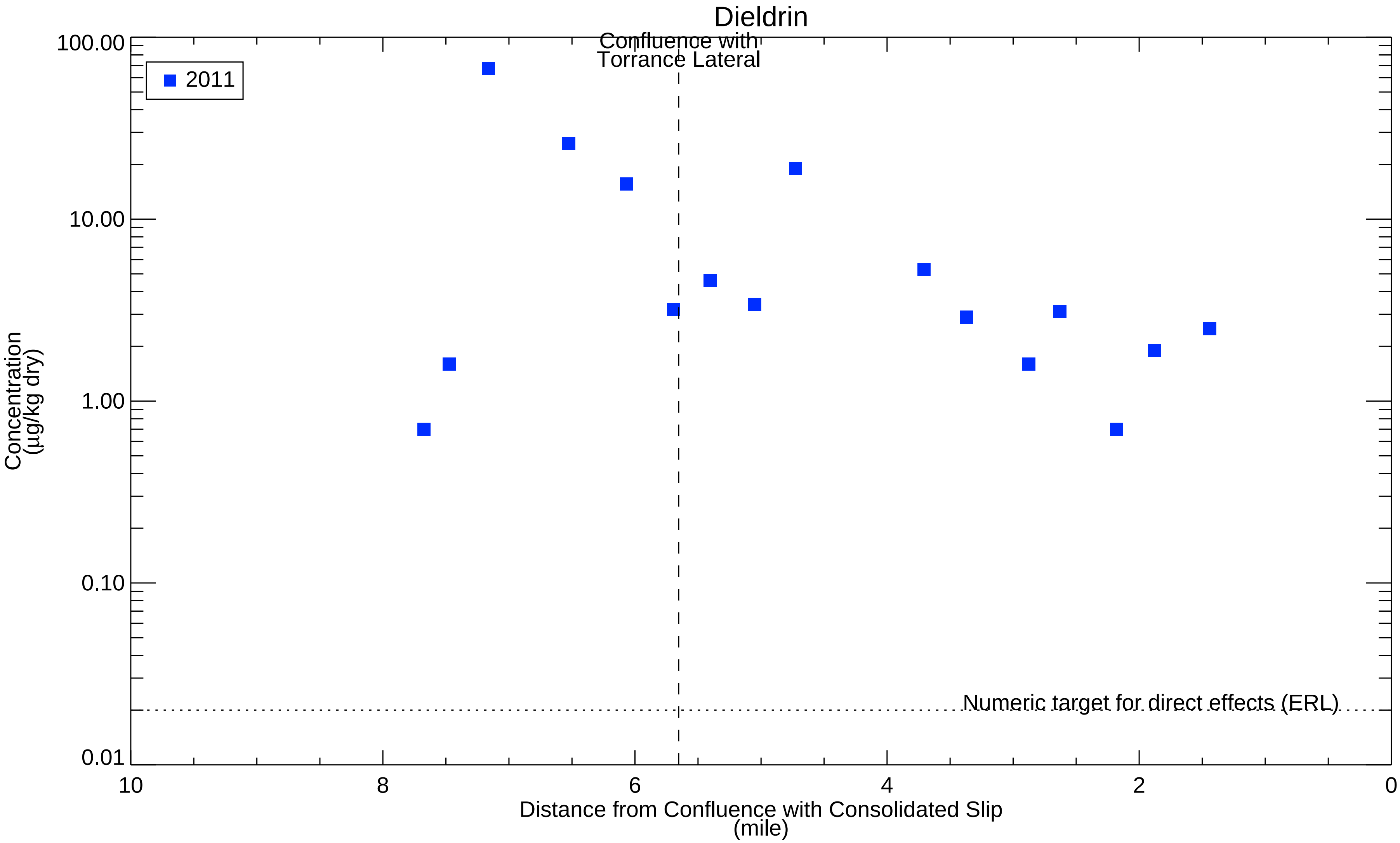


Figure 5j

Concentrations of Dieldrin in Surface Sediment from Dominguez Channel Estuary (0 to 0.5 ft)

Torrance Lateral (TL), Kenwood Drain (KD), and Dominguez Channel Upstream of Estuary Above Vermont Ave (DCU) data from 2002 are not shown.
Non−detects set to half reporting limit (not shown as different symbols; MDL not available). Duplicates averaged.
Databases = Sed_DBcomb_NDhalfMDL_tot_20140229_alignTOC_20140301.bin, Sed_DBcomb_NDhalfMDL_indv_20140229.bin

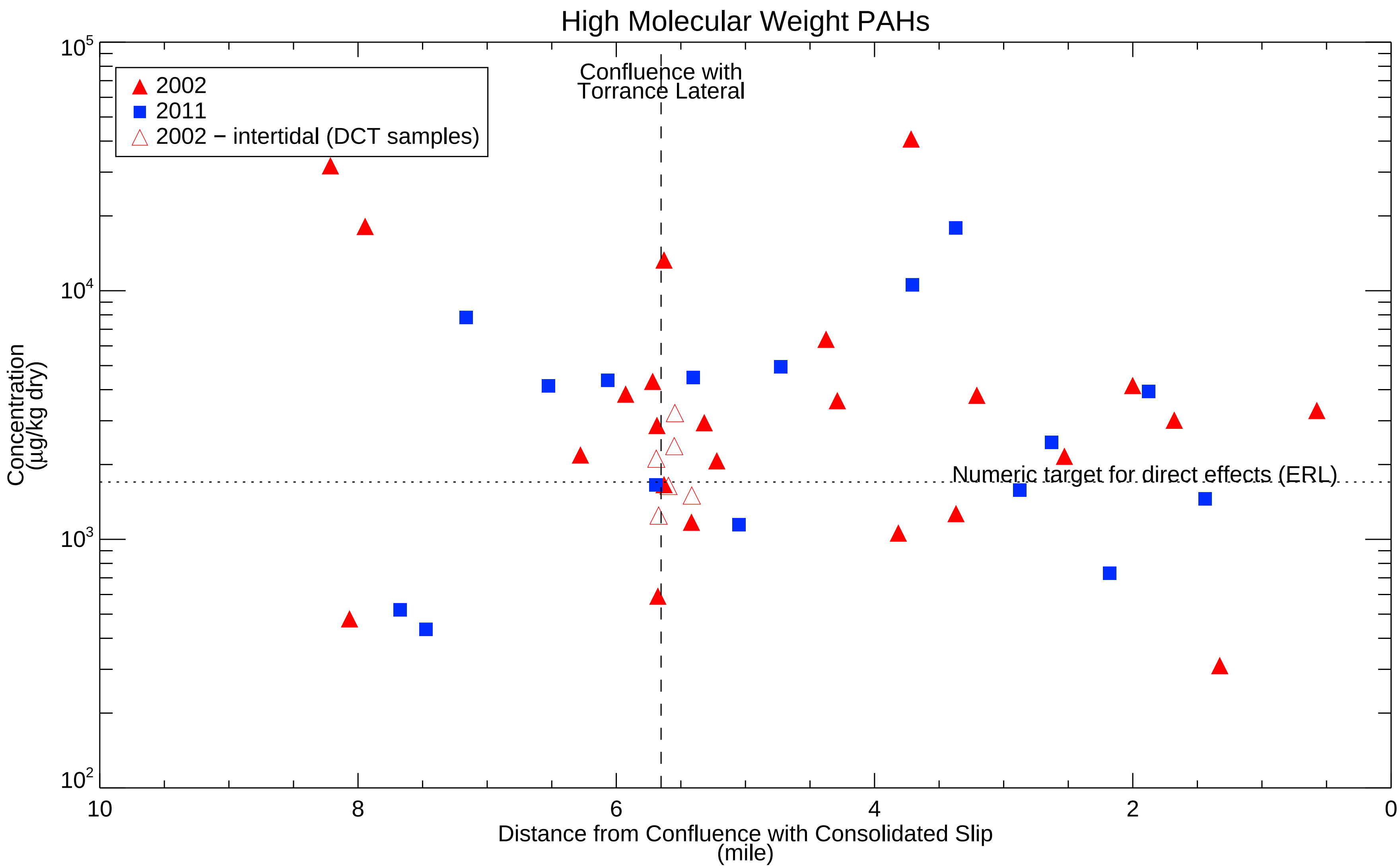


Figure 5k

Concentrations of High Molecular Weight PAHs in Surface Sediment from Dominguez Channel Estuary (0 to 0.5 ft)

Torrance Lateral (TL), Kenwood Drain (KD), and Dominguez Channel Upstream of Estuary Above Vermont Ave (DCU) data from 2002 are not shown.
Non−detects set to half reporting limit (not shown as different symbols; MDL not available). Duplicates averaged.
Databases = Sed_DBcomb_NDhalfMDL_tot_20140229_alignTOC_20140301.bin, Sed_DBcomb_NDhalfMDL_indv_20140229.bin
PAHs included: Benzo (a) Anthracene, Benzo (a) Pyrene, Benzo (e) Pyrene, Chrysene, Dibenzo (a,h) Anthracene, Fluoranthene, Perylene, Pyrene

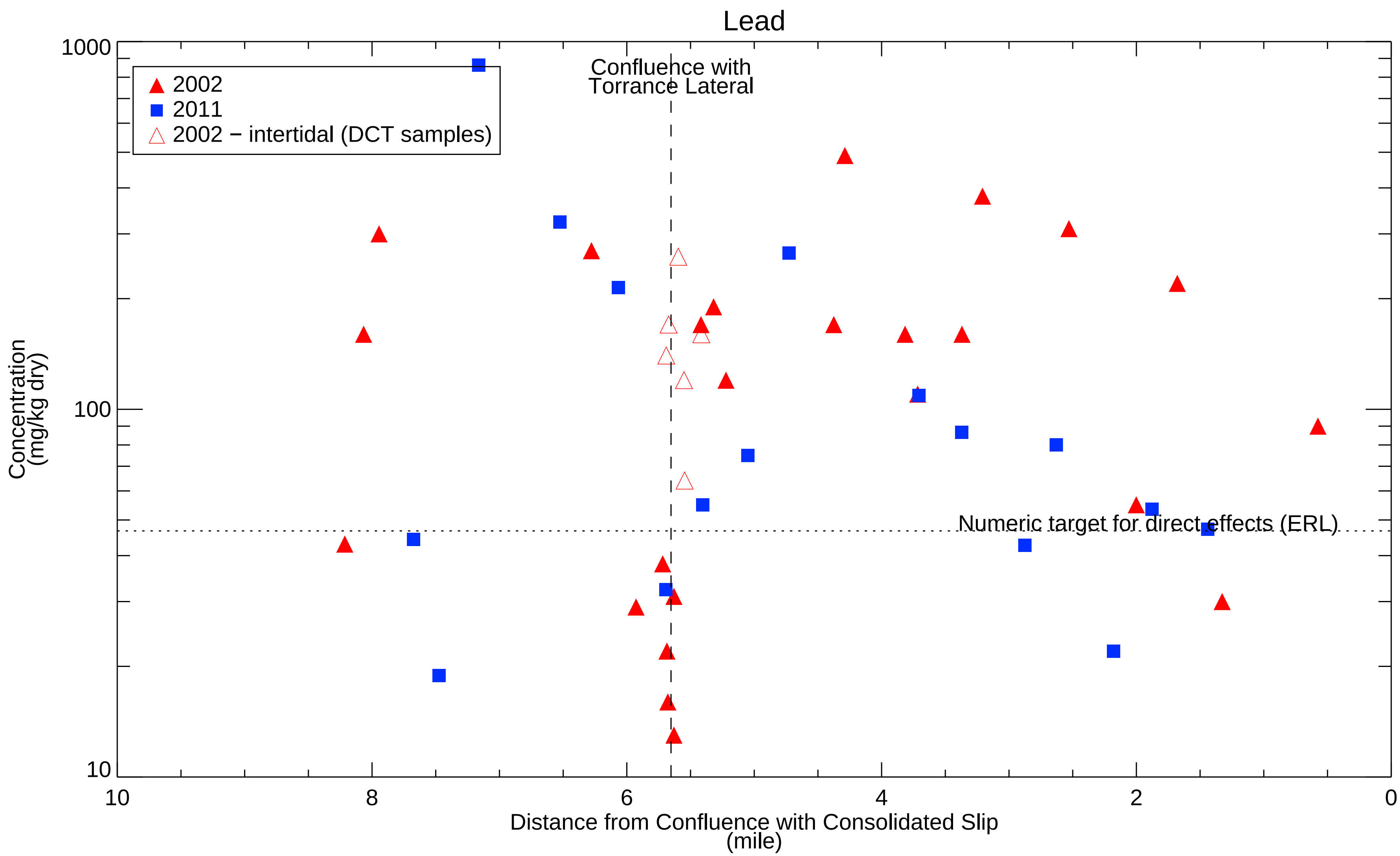


Figure 5l

Concentrations of Lead in Surface Sediment from Dominguez Channel Estuary (0 to 0.5 ft)

Torrance Lateral (TL), Kenwood Drain (KD), and Dominguez Channel Upstream of Estuary Above Vermont Ave (DCU) data from 2002 are not shown.
Non−detects set to half reporting limit (not shown as different symbols; MDL not available). Duplicates averaged.
Databases = Sed_DBcomb_NDhalfMDL_tot_20140229_alignTOC_20140301.bin, Sed_DBcomb_NDhalfMDL_indv_20140229.bin

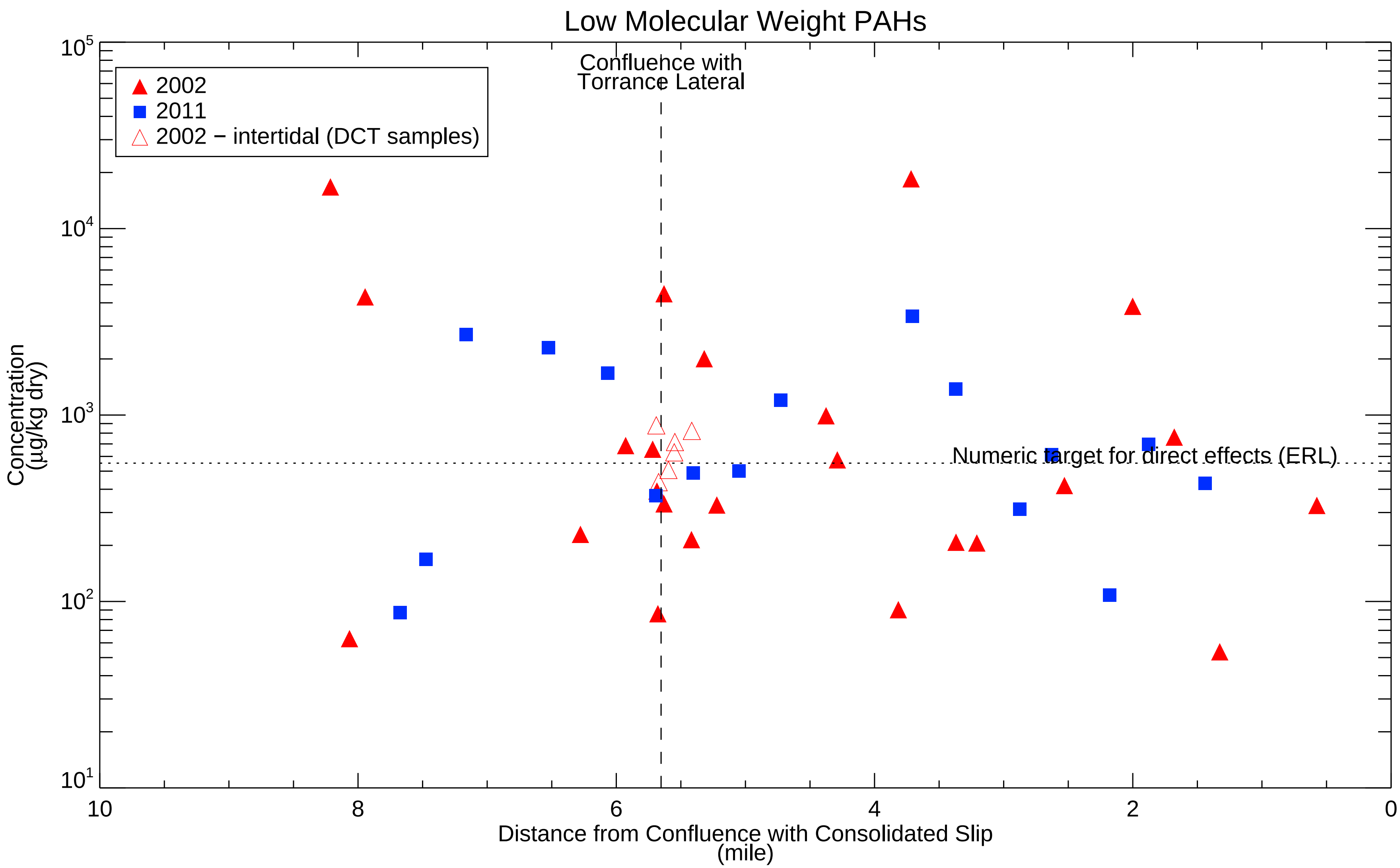


Figure 5m

Concentrations of Low Molecular Weight PAHs in Surface Sediment from Dominguez Channel Estuary (0 to 0.5 ft)

Torrance Lateral (TL), Kenwood Drain (KD), and Dominguez Channel Upstream of Estuary Above Vermont Ave (DCU) data from 2002 are not shown.
Non−detects set to half reporting limit (not shown as different symbols; MDL not available). Duplicates averaged.
Databases = Sed_DBcomb_NDhalfMDL_tot_20140229_alignTOC_20140301.bin, Sed_DBcomb_NDhalfMDL_indv_20140229.bin
PAHs included: Acenaphthene, Anthracene, Biphenyl, Fluorene, Naphthalene, Phenanthrene, 1−Methylnaphthalene, 2−Methylnaphthalene, 1−Methylphenanthrene, 2,6−Dimethylnaphthalene

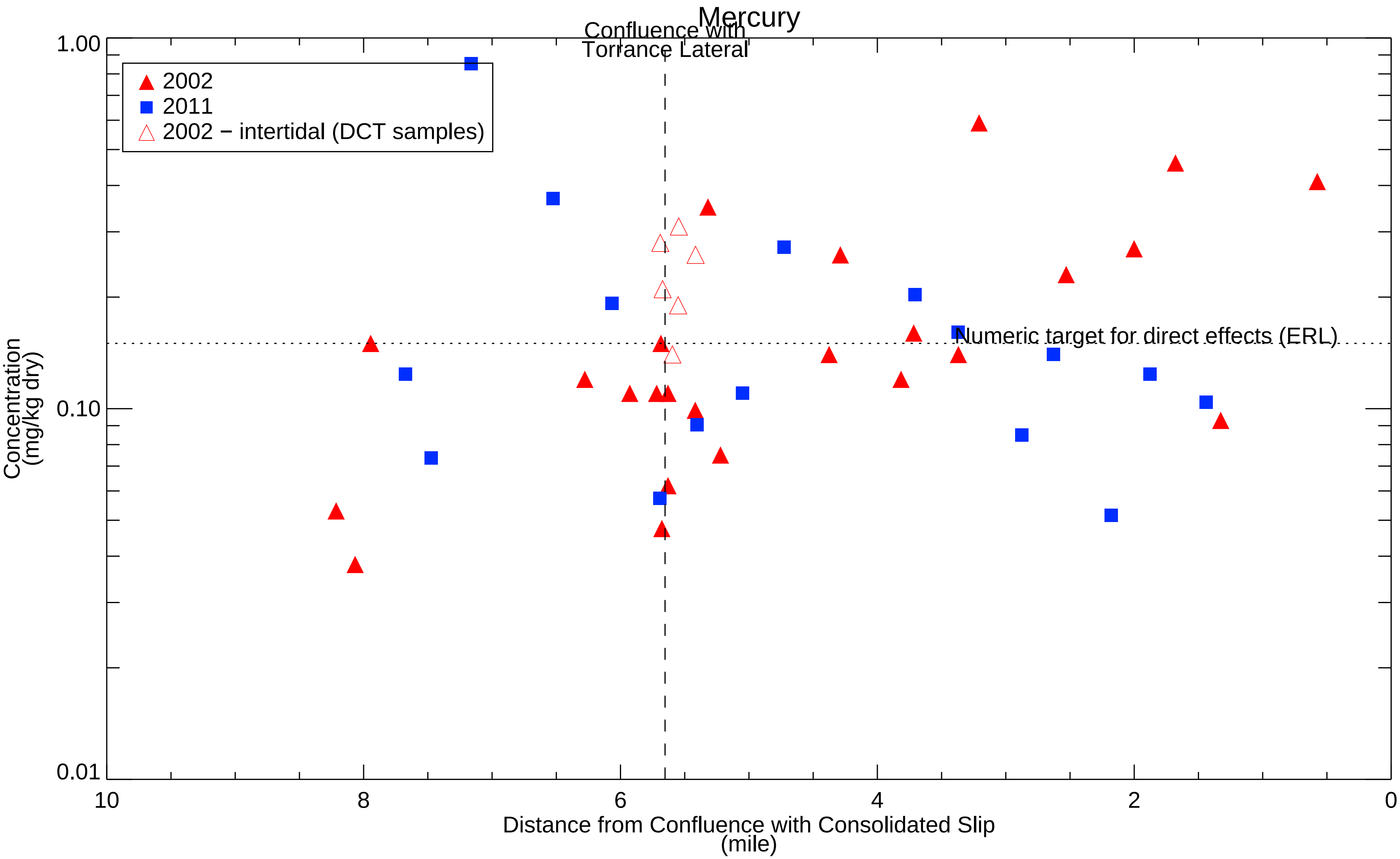


Figure 5n

Concentrations of Mercury in Surface Sediment from Dominguez Channel Estuary (0 to 0.5 ft)

Torrance Lateral (TL), Kenwood Drain (KD), and Dominguez Channel Upstream of Estuary Above Vermont Ave (DCU) data from 2002 are not shown.
Non−detects set to half reporting limit (not shown as different symbols; MDL not available). Duplicates averaged.
Databases = Sed_DBcomb_NDhalfMDL_tot_20140229_alignTOC_20140301.bin, Sed_DBcomb_NDhalfMDL_indv_20140229.bin

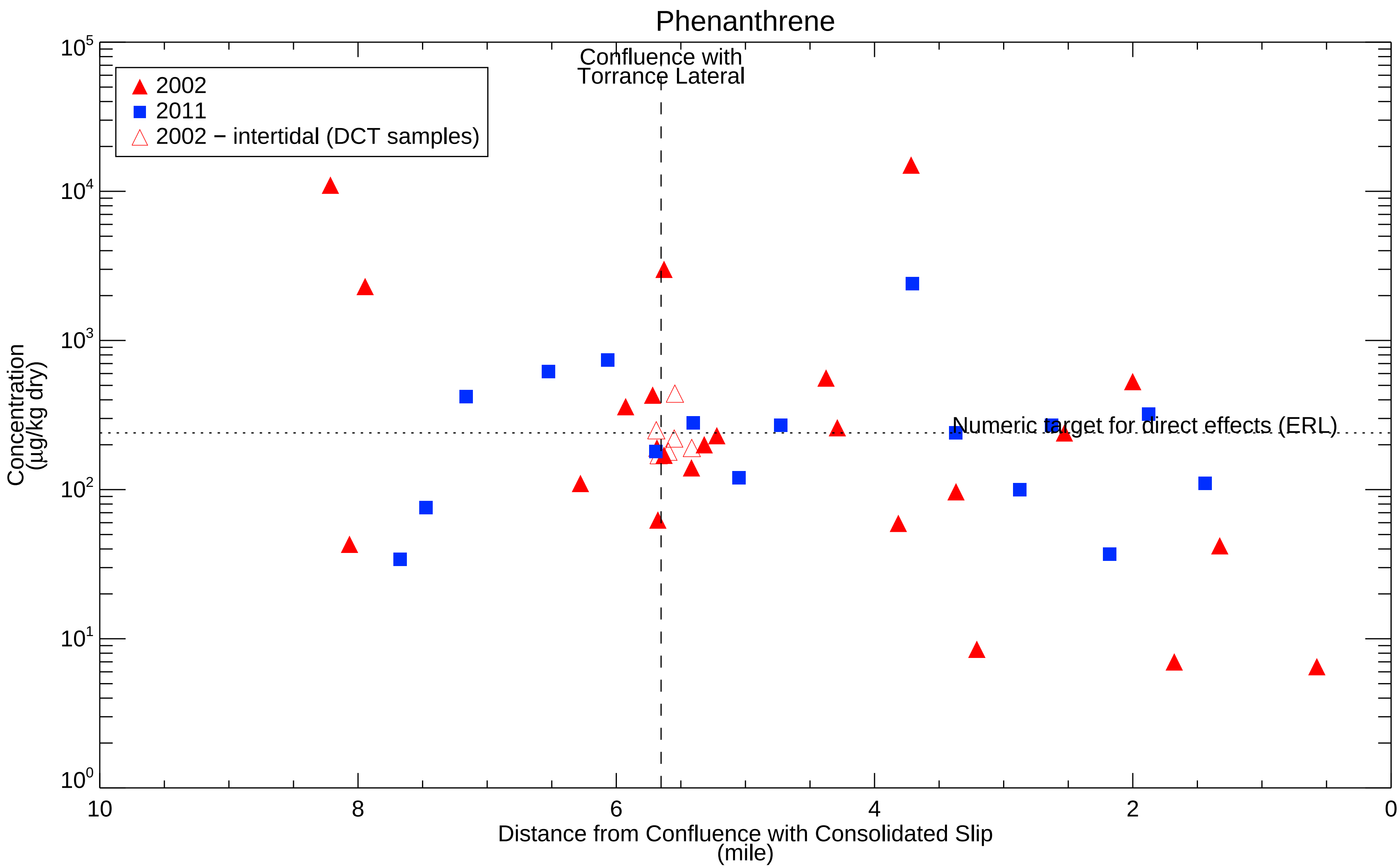


Figure 5o

Concentrations of Phenanthrene in Surface Sediment from Dominguez Channel Estuary (0 to 0.5 ft)

Torrance Lateral (TL), Kenwood Drain (KD), and Dominguez Channel Upstream of Estuary Above Vermont Ave (DCU) data from 2002 are not shown.
Non−detects set to half reporting limit (not shown as different symbols; MDL not available). Duplicates averaged.
Databases = Sed_DBcomb_NDhalfMDL_tot_20140229_alignTOC_20140301.bin, Sed_DBcomb_NDhalfMDL_indv_20140229.bin

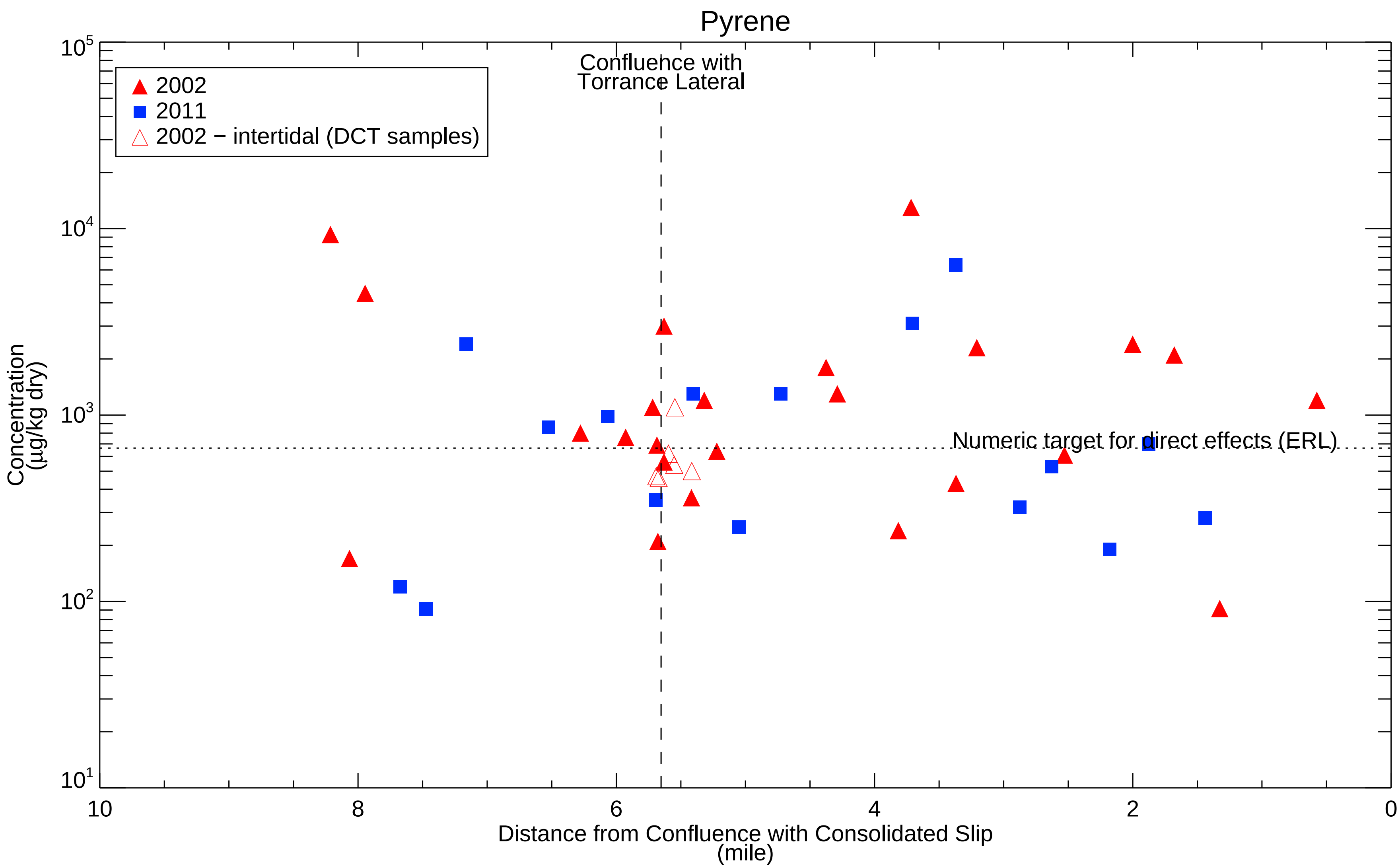


Figure 5p

Concentrations of Pyrene in Surface Sediment from Dominguez Channel Estuary (0 to 0.5 ft)

Torrance Lateral (TL), Kenwood Drain (KD), and Dominguez Channel Upstream of Estuary Above Vermont Ave (DCU) data from 2002 are not shown.
Non−detects set to half reporting limit (not shown as different symbols; MDL not available). Duplicates averaged.
Databases = Sed_DBcomb_NDhalfMDL_tot_20140229_alignTOC_20140301.bin, Sed_DBcomb_NDhalfMDL_indv_20140229.bin

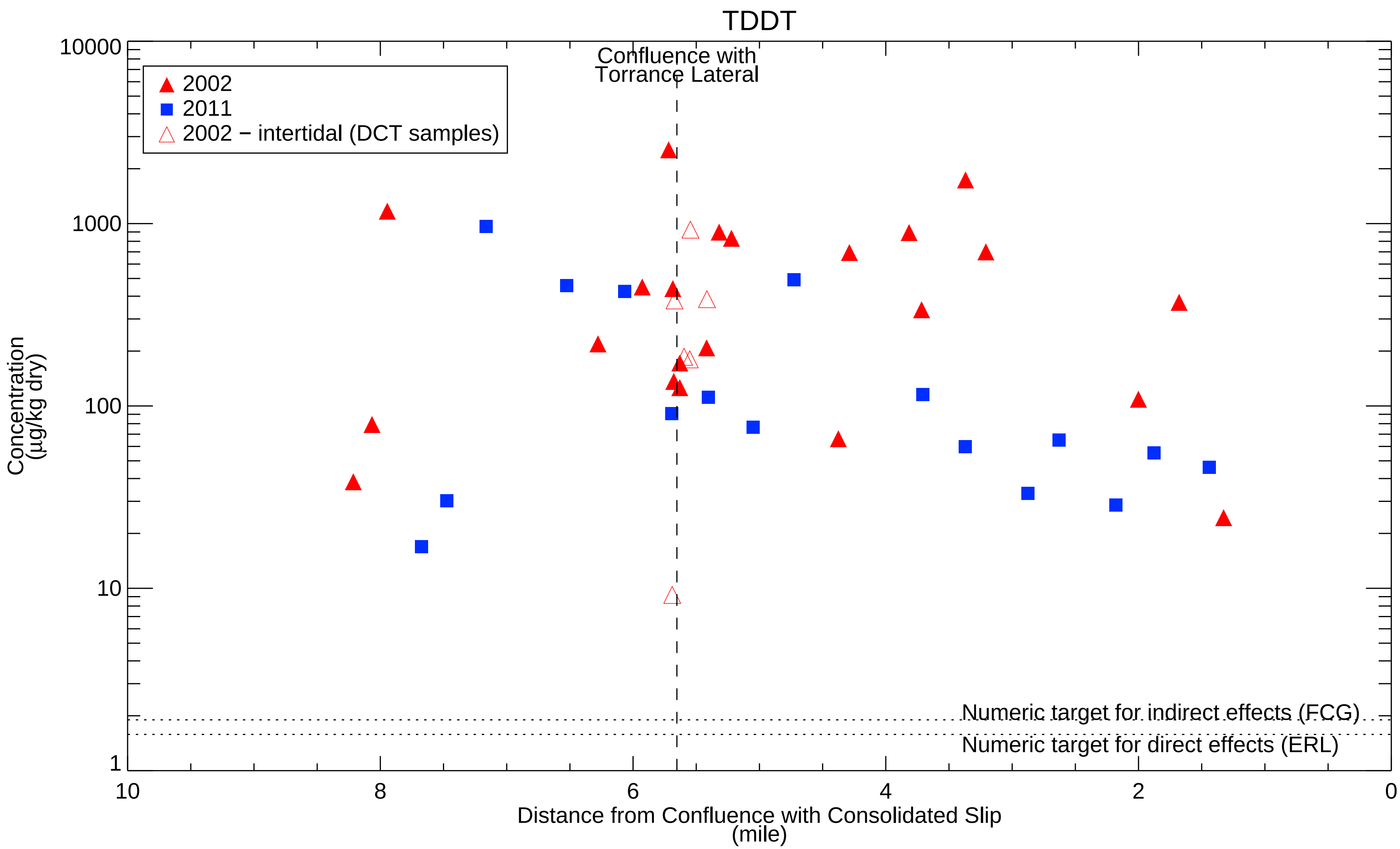


Figure 5q

Concentrations of TDDT in Surface Sediment from Dominguez Channel Estuary (0 to 0.5 ft)

Torrance Lateral (TL), Kenwood Drain (KD), and Dominguez Channel Upstream of Estuary Above Vermont Ave (DCU) data from 2002 are not shown.
Non−detects set to half reporting limit (not shown as different symbols; MDL not available). Duplicates averaged.
Databases = Sed_DBcomb_NDhalfMDL_tot_20140229_alignTOC_20140301.bin, Sed_DBcomb_NDhalfMDL_indv_20140229.bin

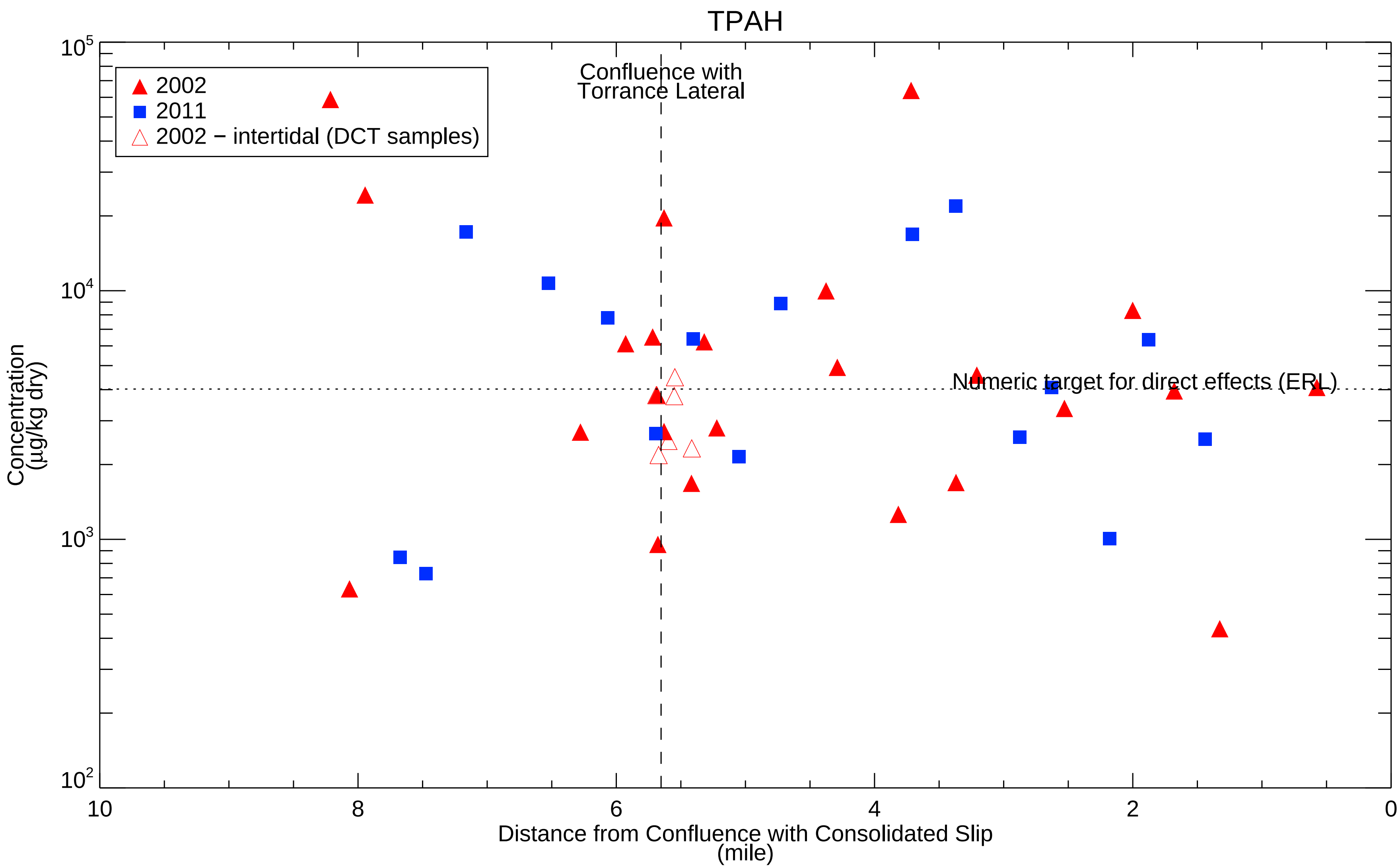


Figure 5r

Concentrations of TPAH in Surface Sediment from Dominguez Channel Estuary (0 to 0.5 ft)

Torrance Lateral (TL), Kenwood Drain (KD), and Dominguez Channel Upstream of Estuary Above Vermont Ave (DCU) data from 2002 are not shown.
Non−detects set to half reporting limit (not shown as different symbols; MDL not available). Duplicates averaged.
Databases = Sed_DBcomb_NDhalfMDL_tot_20140229_alignTOC_20140301.bin, Sed_DBcomb_NDhalfMDL_indv_20140229.bin

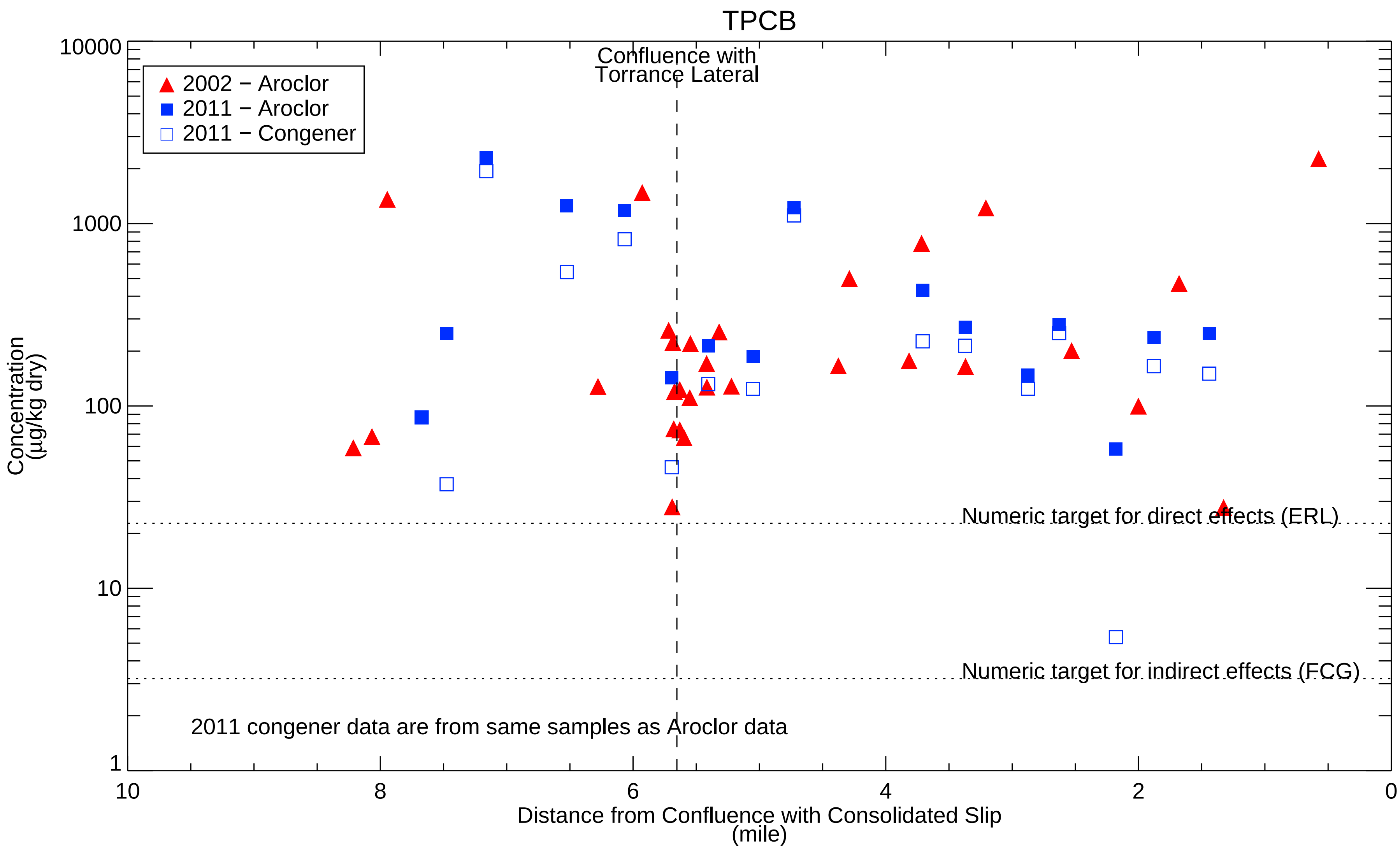


Figure 5s

Concentrations of TPCB in Surface Sediment from Dominguez Channel Estuary (0 to 0.5 ft)

Torrance Lateral (TL), Kenwood Drain (KD), and Dominguez Channel Upstream of Estuary Above Vermont Ave (DCU) data from 2002 are not shown.
Non−detects set to half reporting limit (not shown as different symbols; MDL not available). Duplicates averaged.
Databases = Sed_DBcomb_NDhalfMDL_tot_20140229_alignTOC_20140301.bin, Sed_DBcomb_NDhalfMDL_indv_20140229.bin

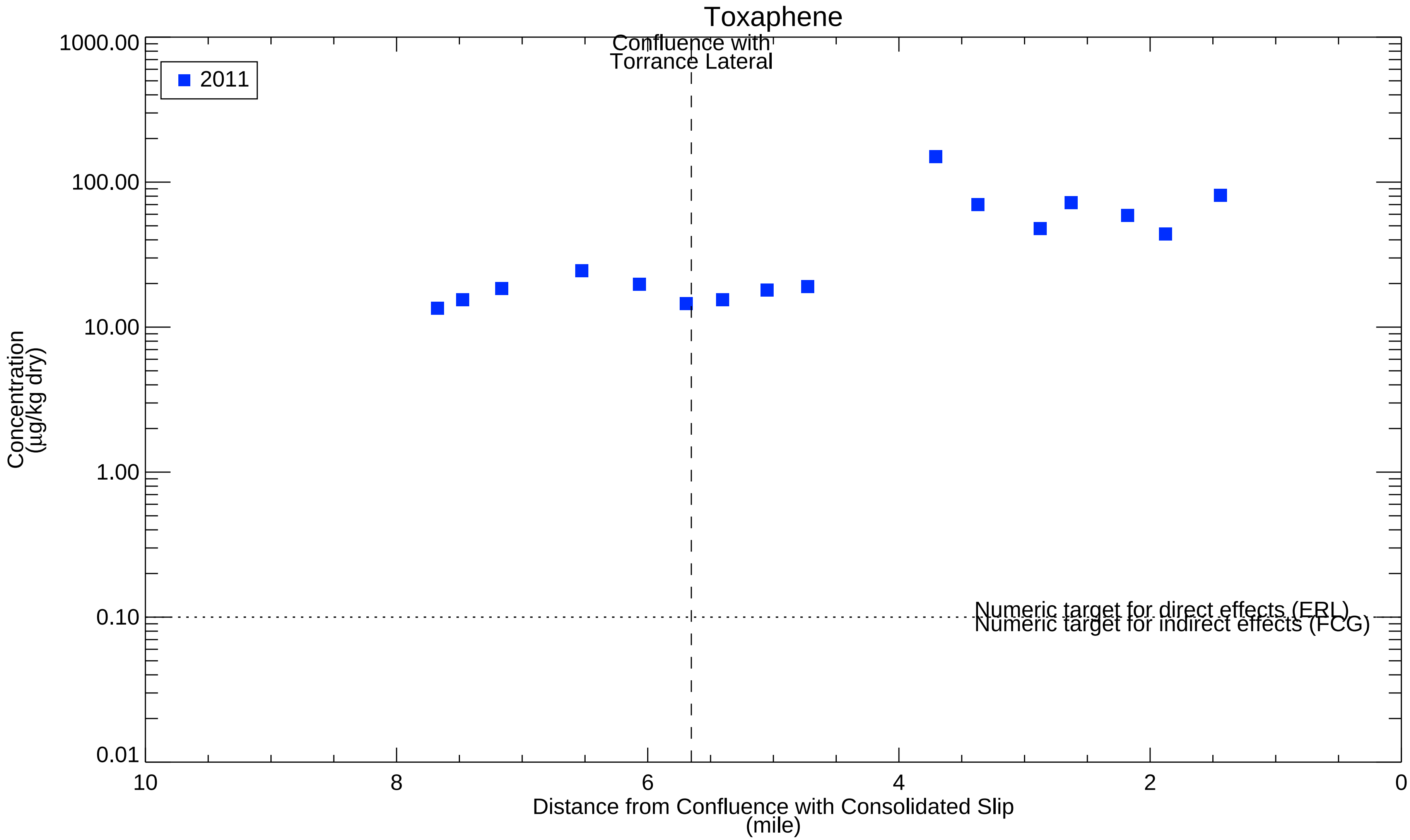


Figure 5t

Concentrations of Toxaphene in Surface Sediment from Dominguez Channel Estuary (0 to 0.5 ft)

Torrance Lateral (TL), Kenwood Drain (KD), and Dominguez Channel Upstream of Estuary Above Vermont Ave (DCU) data from 2002 are not shown.
Non−detects set to half reporting limit (not shown as different symbols; MDL not available). Duplicates averaged.
Databases = Sed_DBcomb_NDhalfMDL_tot_20140229_alignTOC_20140301.bin, Sed_DBcomb_NDhalfMDL_indv_20140229.bin

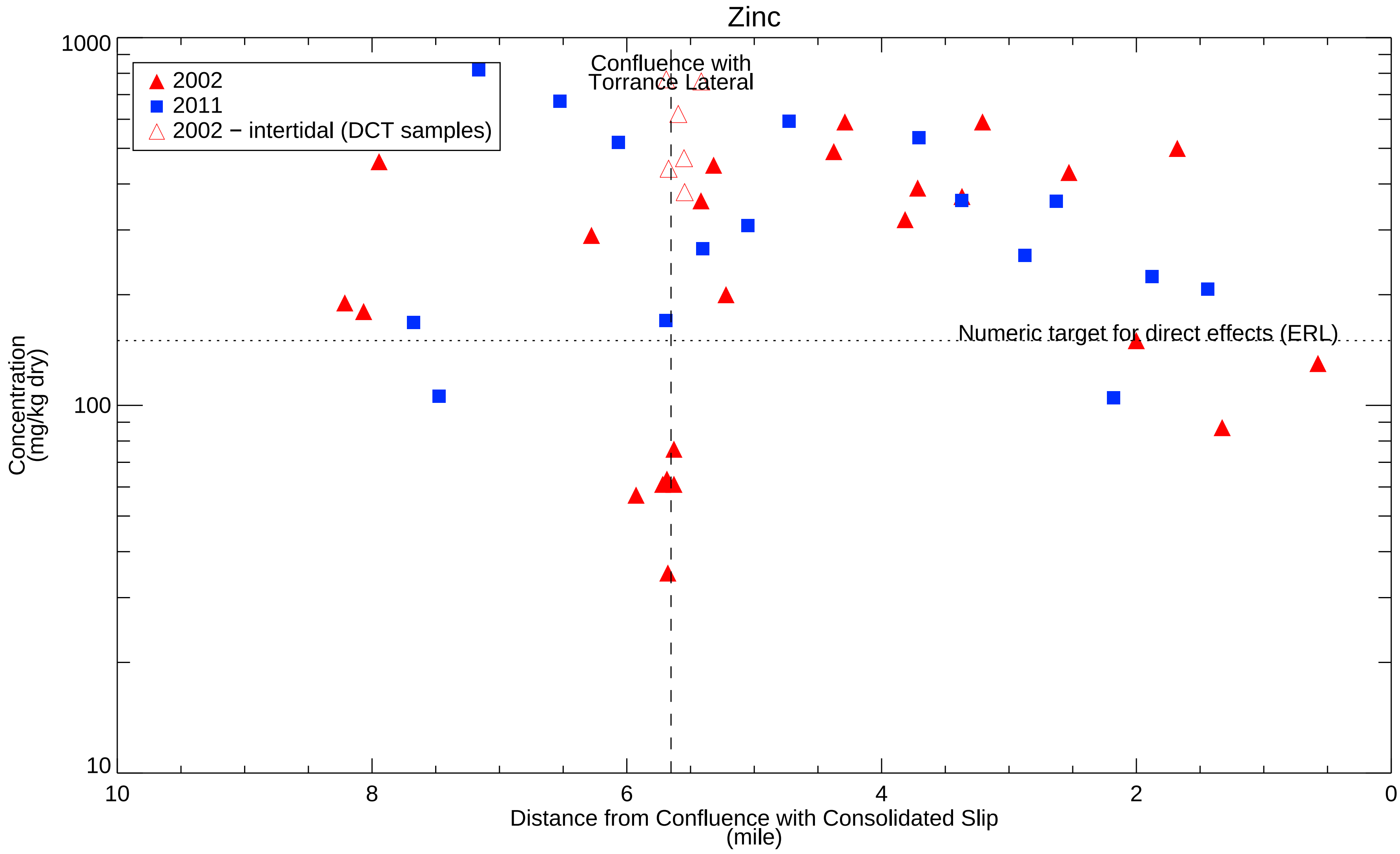


Figure 5u

Concentrations of Zinc in Surface Sediment from Dominguez Channel Estuary (0 to 0.5 ft)

Torrance Lateral (TL), Kenwood Drain (KD), and Dominguez Channel Upstream of Estuary Above Vermont Ave (DCU) data from 2002 are not shown.
Non−detects set to half reporting limit (not shown as different symbols; MDL not available). Duplicates averaged.
Databases = Sed_DBcomb_NDhalfMDL_tot_20140229_alignTOC_20140301.bin, Sed_DBcomb_NDhalfMDL_indv_20140229.bin

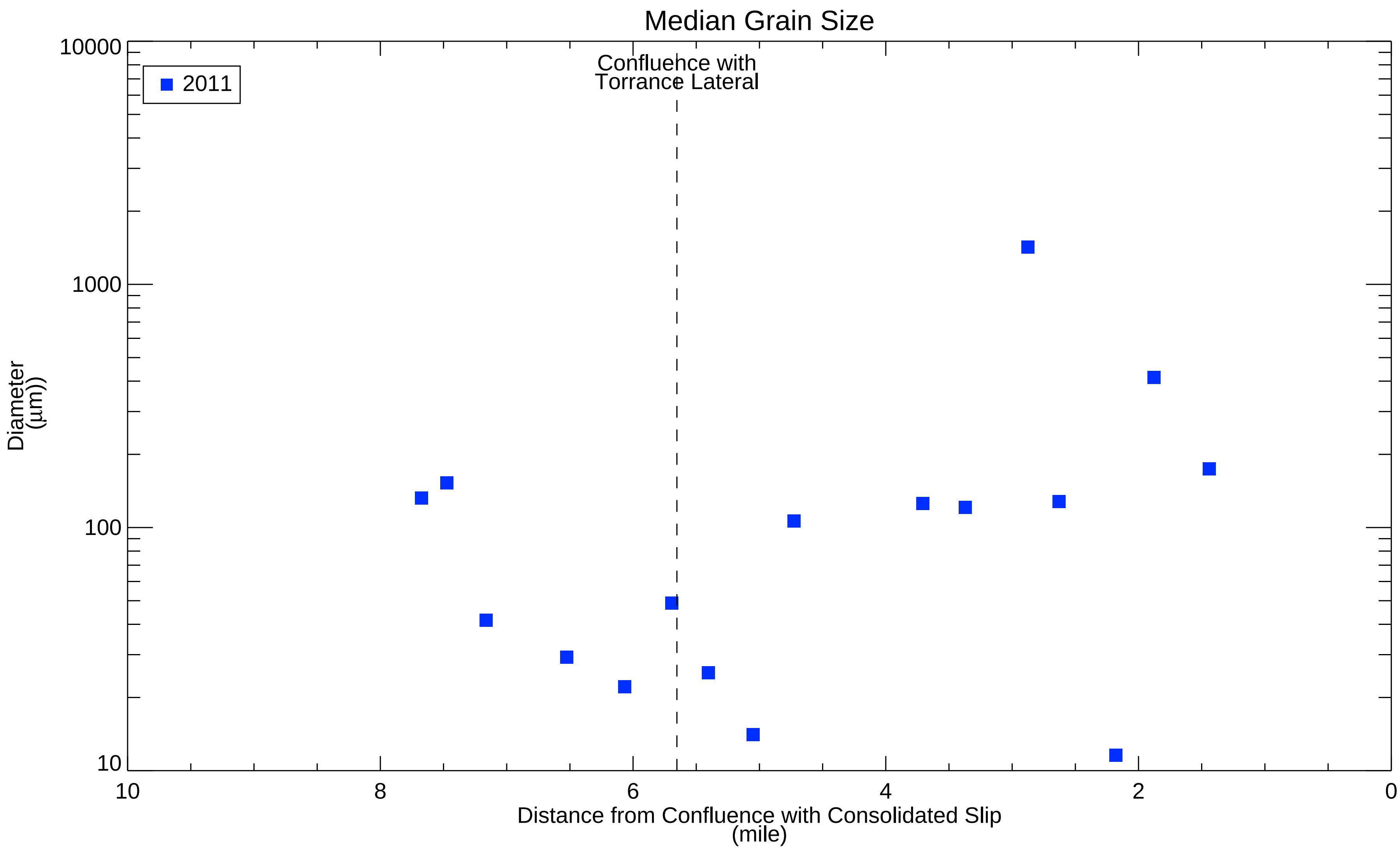


Figure 5v

Concentrations of Median Grain Size in Surface Sediment from Dominguez Channel Estuary (0 to 0.5 ft)

Torrance Lateral (TL), Kenwood Drain (KD), and Dominguez Channel Upstream of Estuary Above Vermont Ave (DCU) data from 2002 are not shown.
Non−detects set to half reporting limit (not shown as different symbols; MDL not available). Duplicates averaged.
Databases = Sed_DBcomb_NDhalfMDL_tot_20140229_alignTOC_20140301.bin, Sed_DBcomb_NDhalfMDL_indv_20140229.bin

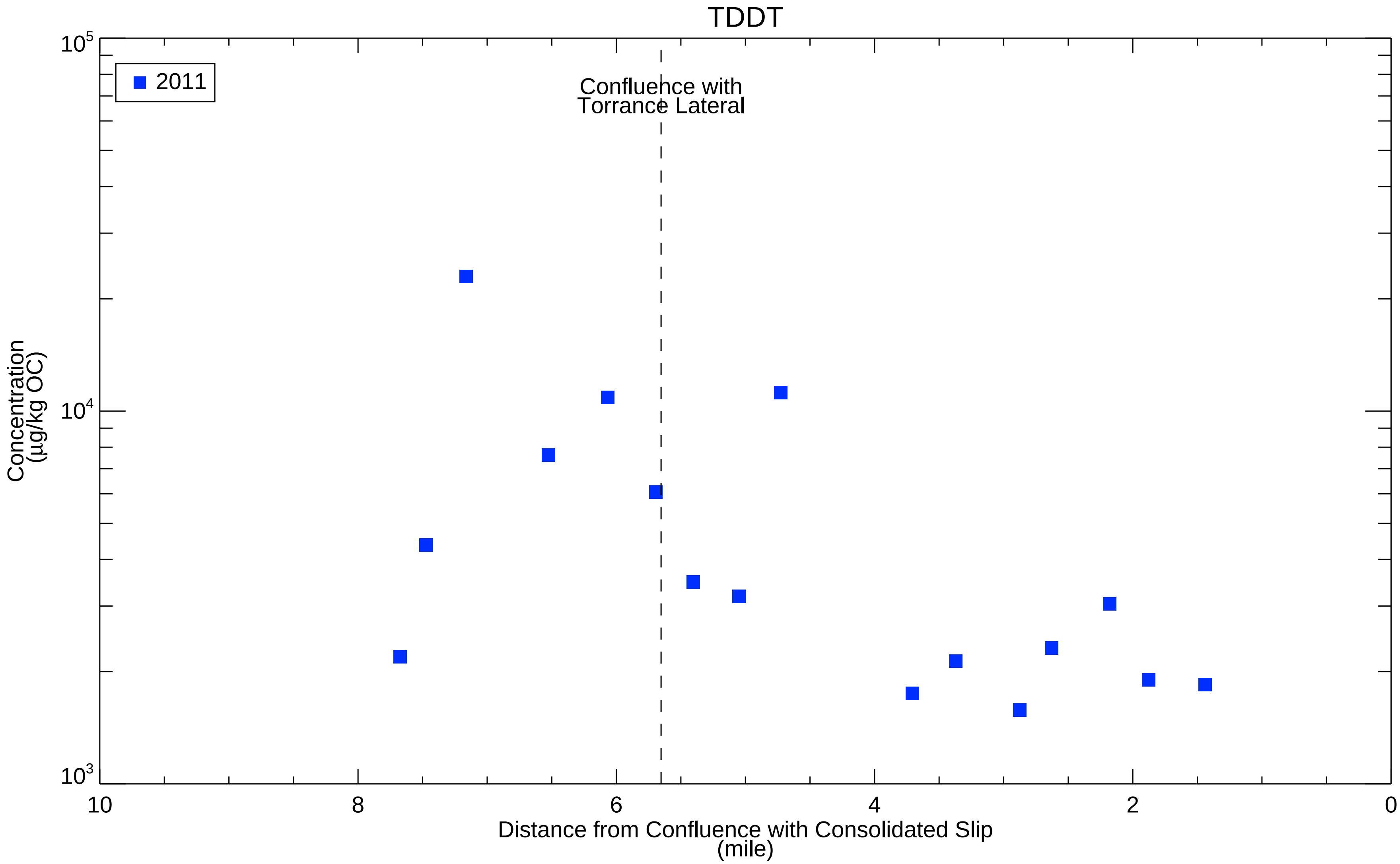


Figure 6a

Carbon−Normalized Concentrations of TDDT in Surface Sediment from Dominguez Channel Estuary (0 to 0.5 ft)

Torrance Lateral (TL), Kenwood Drain (KD), and Dominguez Channel Upstream of Estuary Above Vermont Ave (DCU) data from 2002 are not shown.
Non−detects set to half reporting limit (not shown as different symbols; MDL not available). Duplicates averaged.
Databases = Sed_DBcomb_NDhalfMDL_tot_20140229_alignTOC_20140301.bin, Sed_DBcomb_NDhalfMDL_indv_20140229.bin

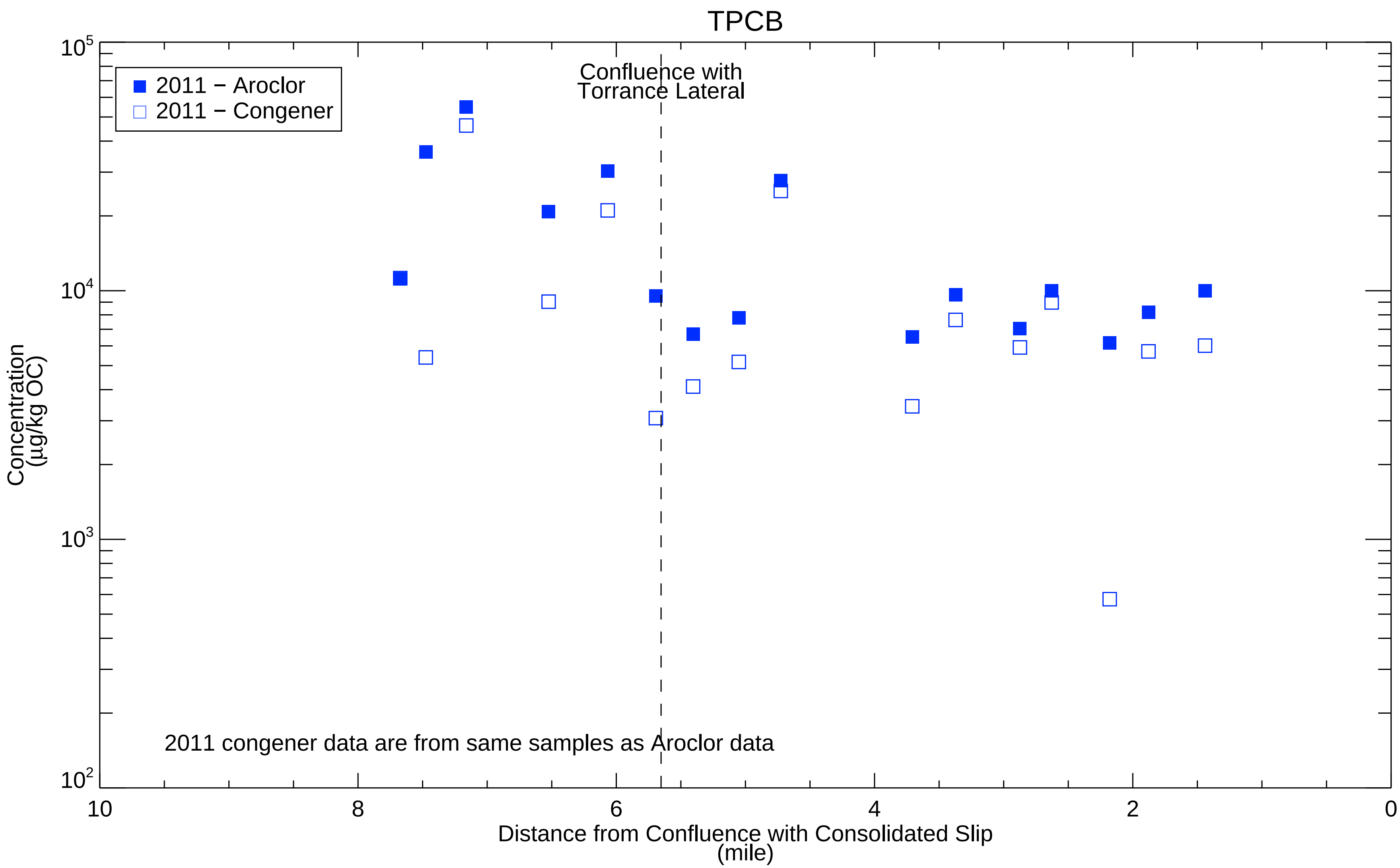


Figure 6b

Carbon−Normalized Concentrations of TPCB in Surface Sediment from Dominguez Channel Estuary (0 to 0.5 ft)

Torrance Lateral (TL), Kenwood Drain (KD), and Dominguez Channel Upstream of Estuary Above Vermont Ave (DCU) data from 2002 are not shown.
Non−detects set to half reporting limit (not shown as different symbols; MDL not available). Duplicates averaged.
Databases = Sed_DBcomb_NDhalfMDL_tot_20140229_alignTOC_20140301.bin, Sed_DBcomb_NDhalfMDL_indv_20140229.bin

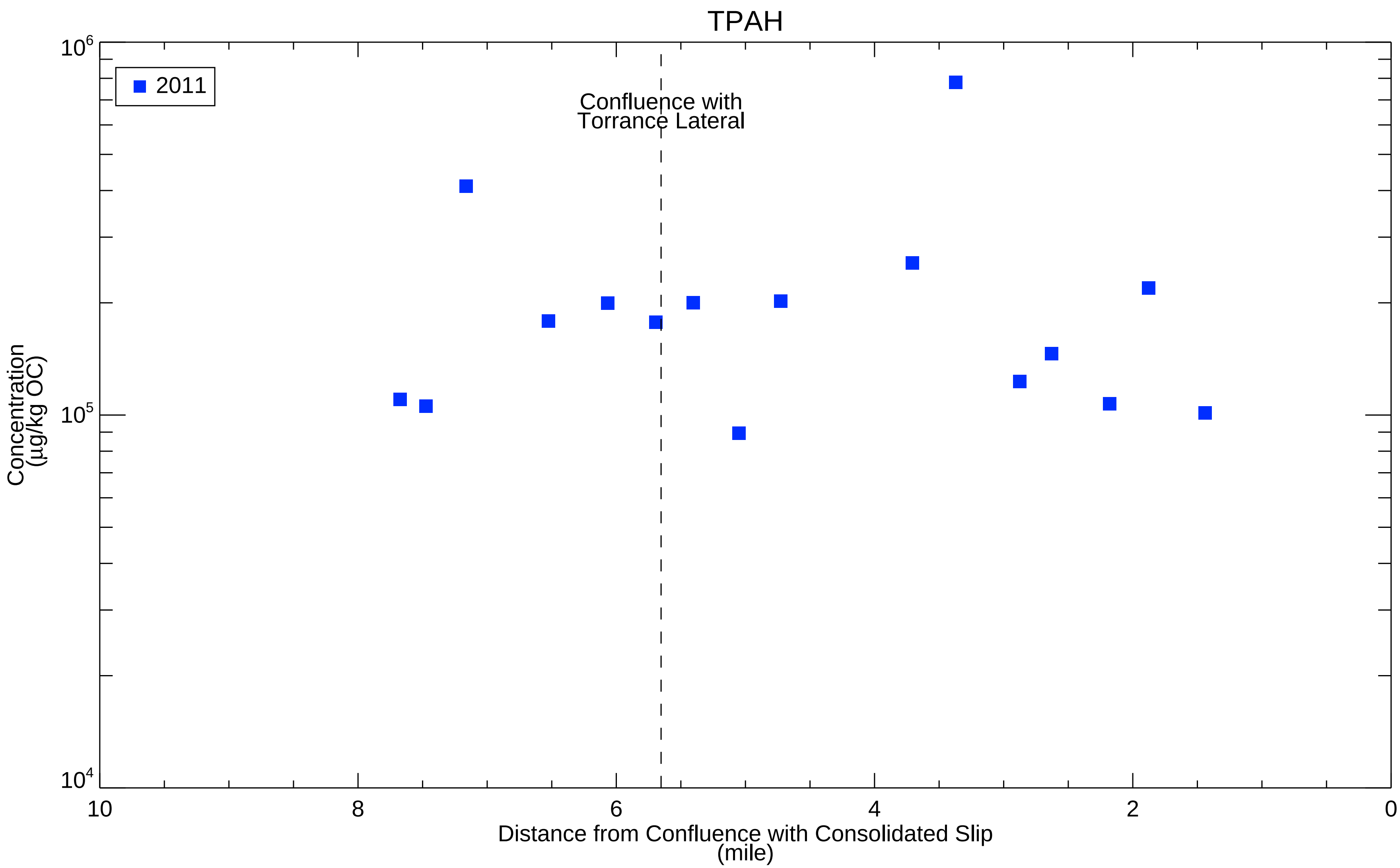


Figure 6c

Carbon−Normalized Concentrations of TPAH in Surface Sediment from Dominguez Channel Estuary (0 to 0.5 ft)

Torrance Lateral (TL), Kenwood Drain (KD), and Dominguez Channel Upstream of Estuary Above Vermont Ave (DCU) data from 2002 are not shown.
Non−detects set to half reporting limit (not shown as different symbols; MDL not available). Duplicates averaged.
Databases = Sed_DBcomb_NDhalfMDL_tot_20140229_alignTOC_20140301.bin, Sed_DBcomb_NDhalfMDL_indv_20140229.bin

APPENDIX A
PROBABILITY PLOTS OF CONCENTRATIONS IN DCE SURFACE SEDIMENT

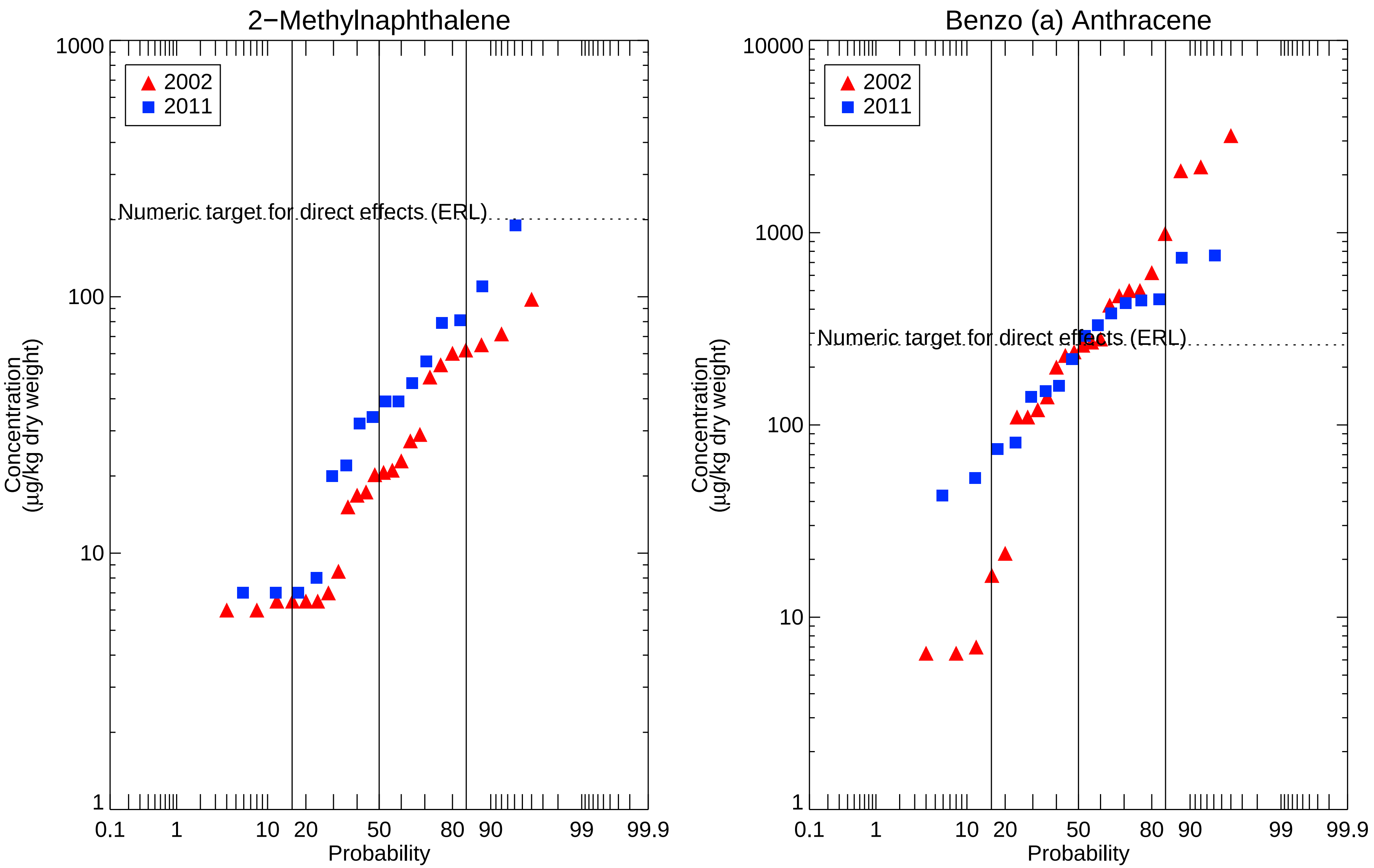


Figure A−1

Probability Plots of 2−Methylnaphthalene and Benzo (a) Anthracene Concentrations in Dominguez Channel Estuary Sediment (0 to 0.5 ft)

Torrance Lateral (TL), Kenwood Drain (KD), Dominguez Channel Upstream of Estuary Above Vermont Ave (DCU), and intertidal (DCT) data from 2002 not shown.
Non−detects set to half the reporting limit (not shown as different symbols; MDL not available).
2011 congener data are from same samples as Aroclor data. Duplicates from original sample results were averaged.
Databases = Sed_DBcomb_NDhalfMDL_tot_20140229.bin

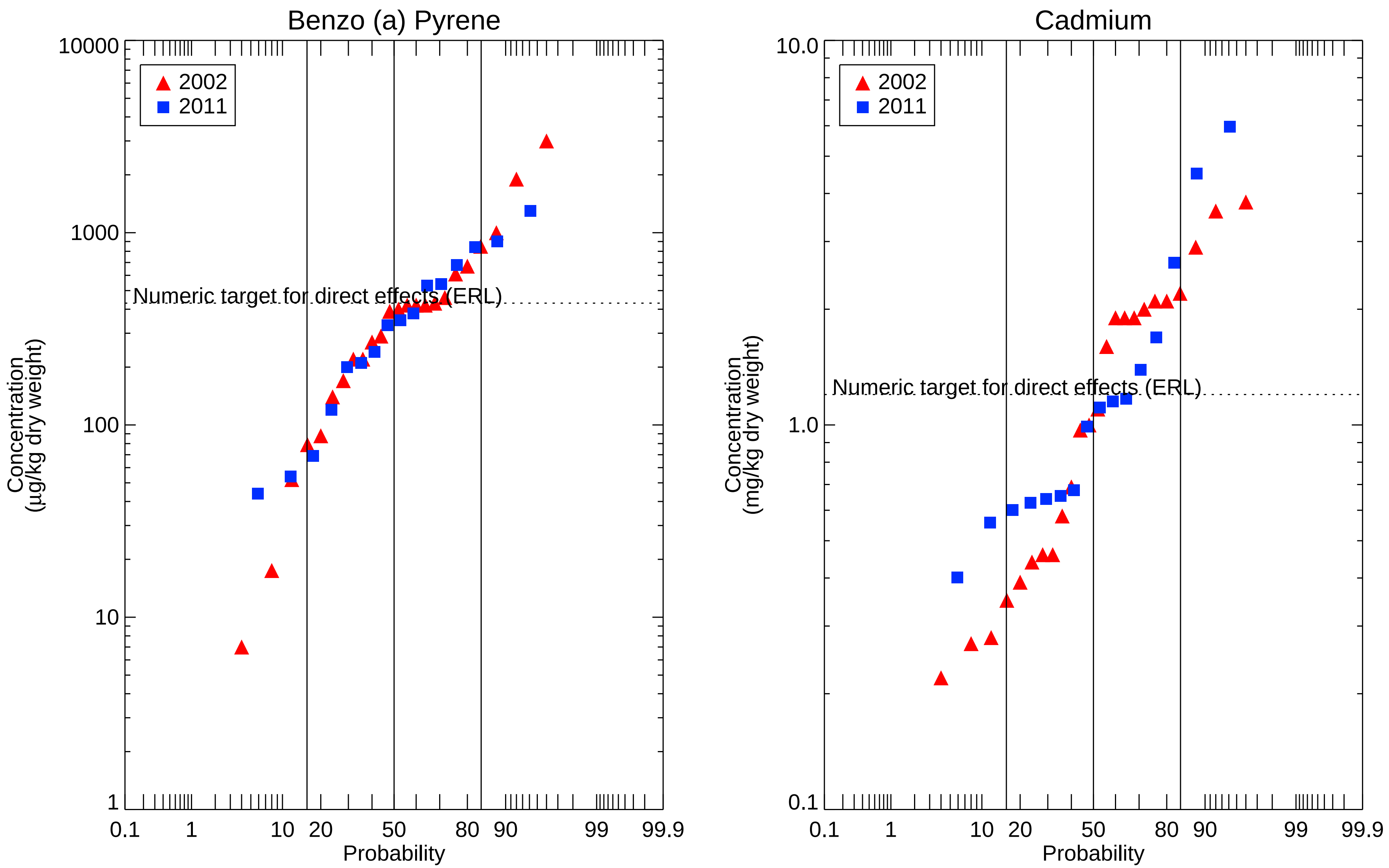


Figure A−2

Probability Plots of Benzo (a) Pyrene and Cadmium Concentrations in Dominguez Channel Estuary Sediment (0 to 0.5 ft)

Torrance Lateral (TL), Kenwood Drain (KD), Dominguez Channel Upstream of Estuary Above Vermont Ave (DCU), and intertidal (DCT) data from 2002 not shown.
Non−detects set to half the reporting limit (not shown as different symbols; MDL not available).
2011 congener data are from same samples as Aroclor data. Duplicates from original sample results were averaged.
Databases = Sed_DBcomb_NDhalfMDL_tot_20140229.bin

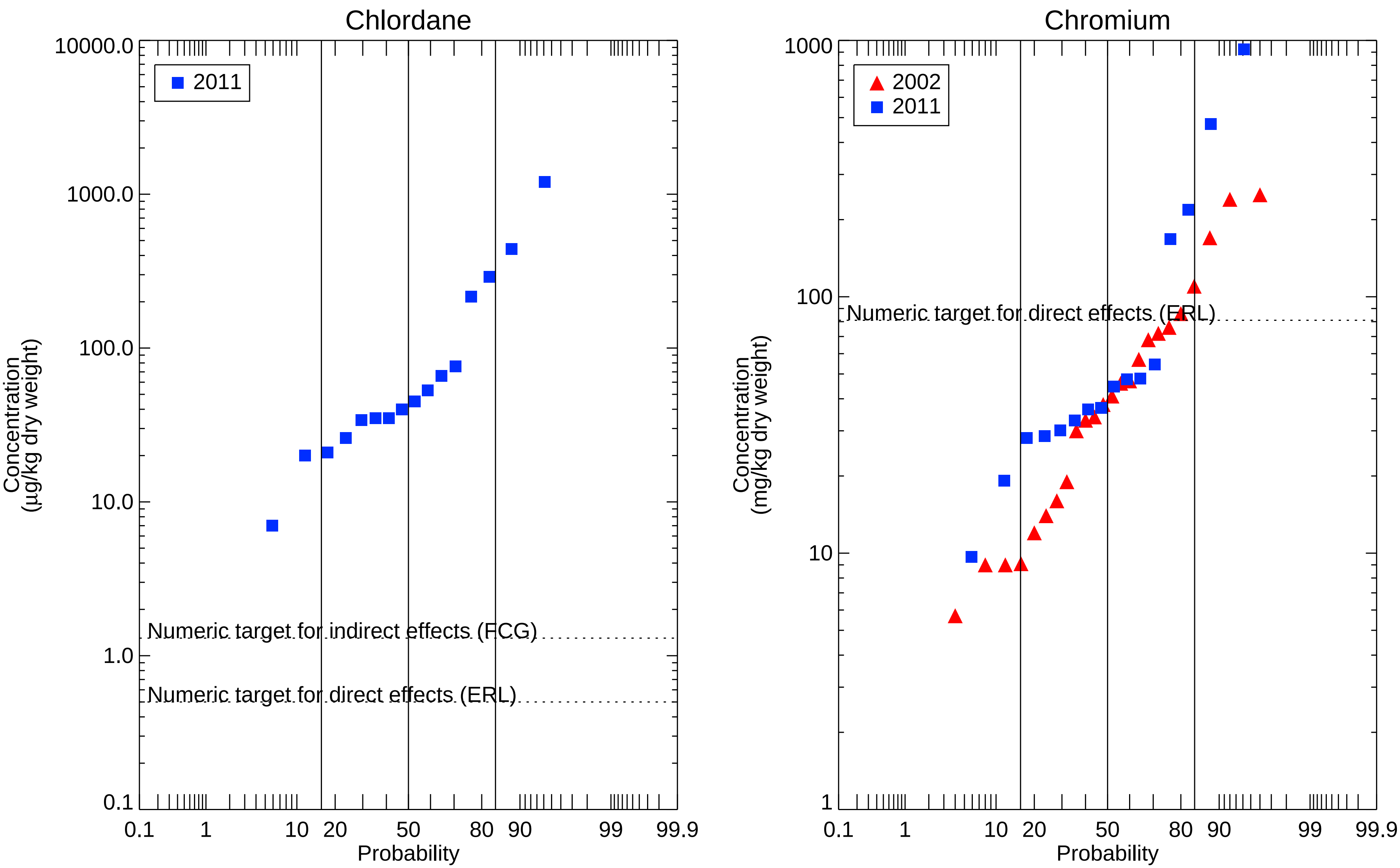


Figure A−3

Probability Plots of Chlordane and Chromium Concentrations in Dominguez Channel Estuary Sediment (0 to 0.5 ft)

Torrance Lateral (TL), Kenwood Drain (KD), Dominguez Channel Upstream of Estuary Above Vermont Ave (DCU), and intertidal (DCT) data from 2002 not shown.
Non−detects set to half the reporting limit (not shown as different symbols; MDL not available).
2011 congener data are from same samples as Aroclor data. Duplicates from original sample results were averaged.
Databases = Sed_DBcomb_NDhalfMDL_tot_20140229.bin

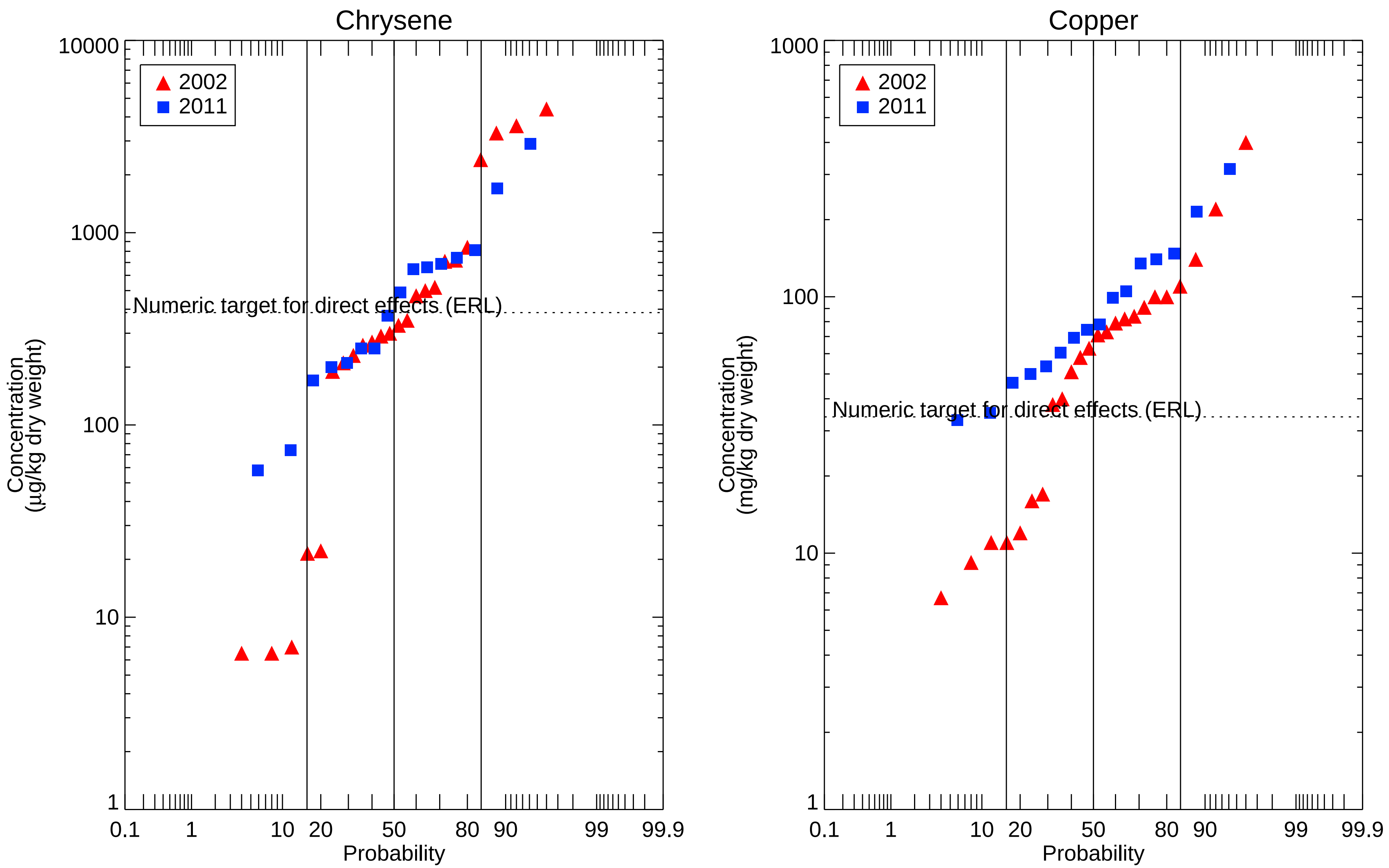


Figure A−4

Probability Plots of Chrysene and Copper Concentrations in Dominguez Channel Estuary Sediment (0 to 0.5 ft)

Torrance Lateral (TL), Kenwood Drain (KD), Dominguez Channel Upstream of Estuary Above Vermont Ave (DCU), and intertidal (DCT) data from 2002 not shown.
Non−detects set to half the reporting limit (not shown as different symbols; MDL not available).
2011 congener data are from same samples as Aroclor data. Duplicates from original sample results were averaged.
Databases = Sed_DBcomb_NDhalfMDL_tot_20140229.bin

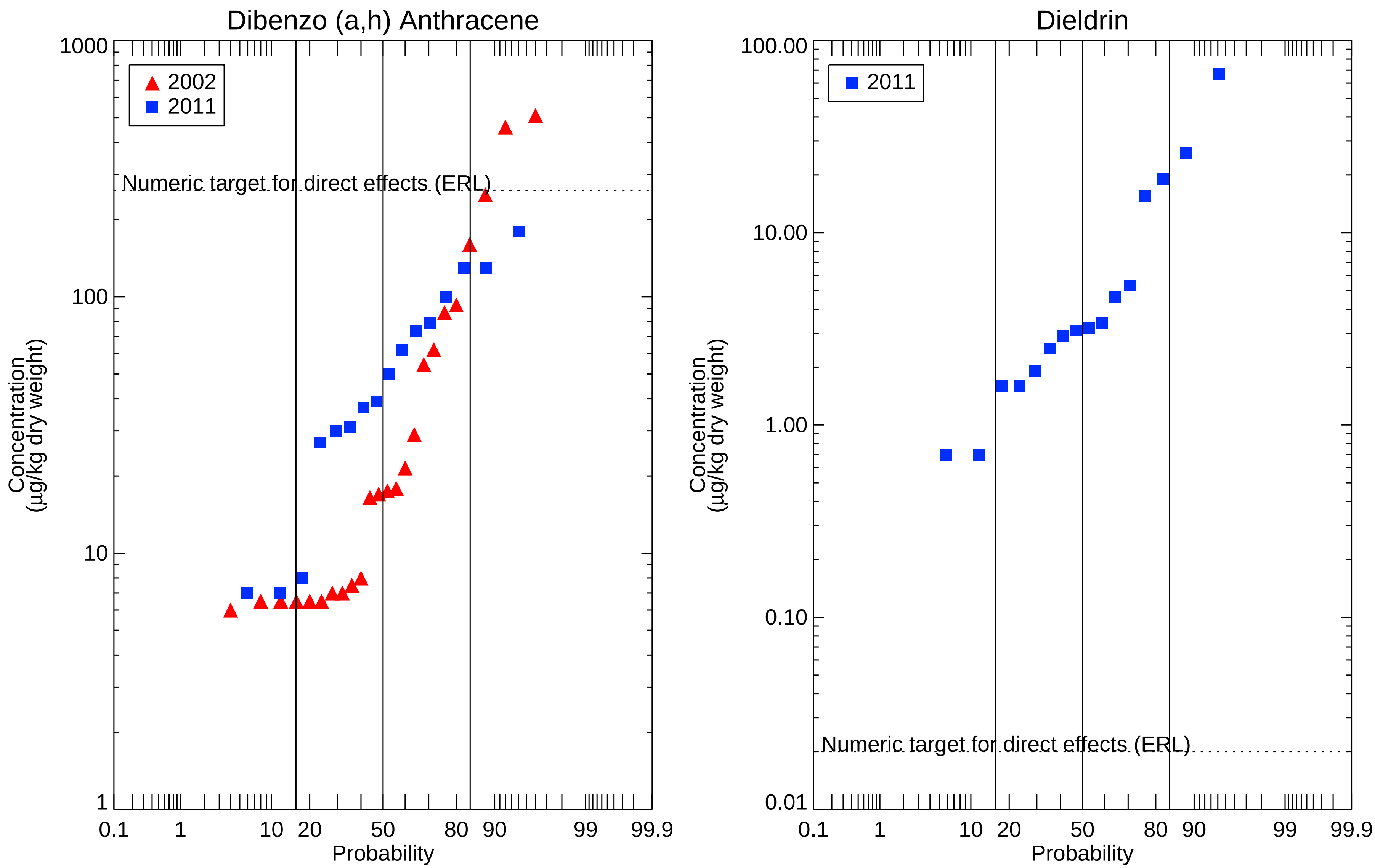


Figure A−5

Probability Plots of Dibenzo (a,h) Anthracene and Dieldrin Concentrations in Dominguez Channel Estuary Sediment (0 to 0.5 ft)

Torrance Lateral (TL), Kenwood Drain (KD), Dominguez Channel Upstream of Estuary Above Vermont Ave (DCU), and intertidal (DCT) data from 2002 not shown.
Non−detects set to half the reporting limit (not shown as different symbols; MDL not available).
2011 congener data are from same samples as Aroclor data. Duplicates from original sample results were averaged.
Databases = Sed_DBcomb_NDhalfMDL_tot_20140229.bin

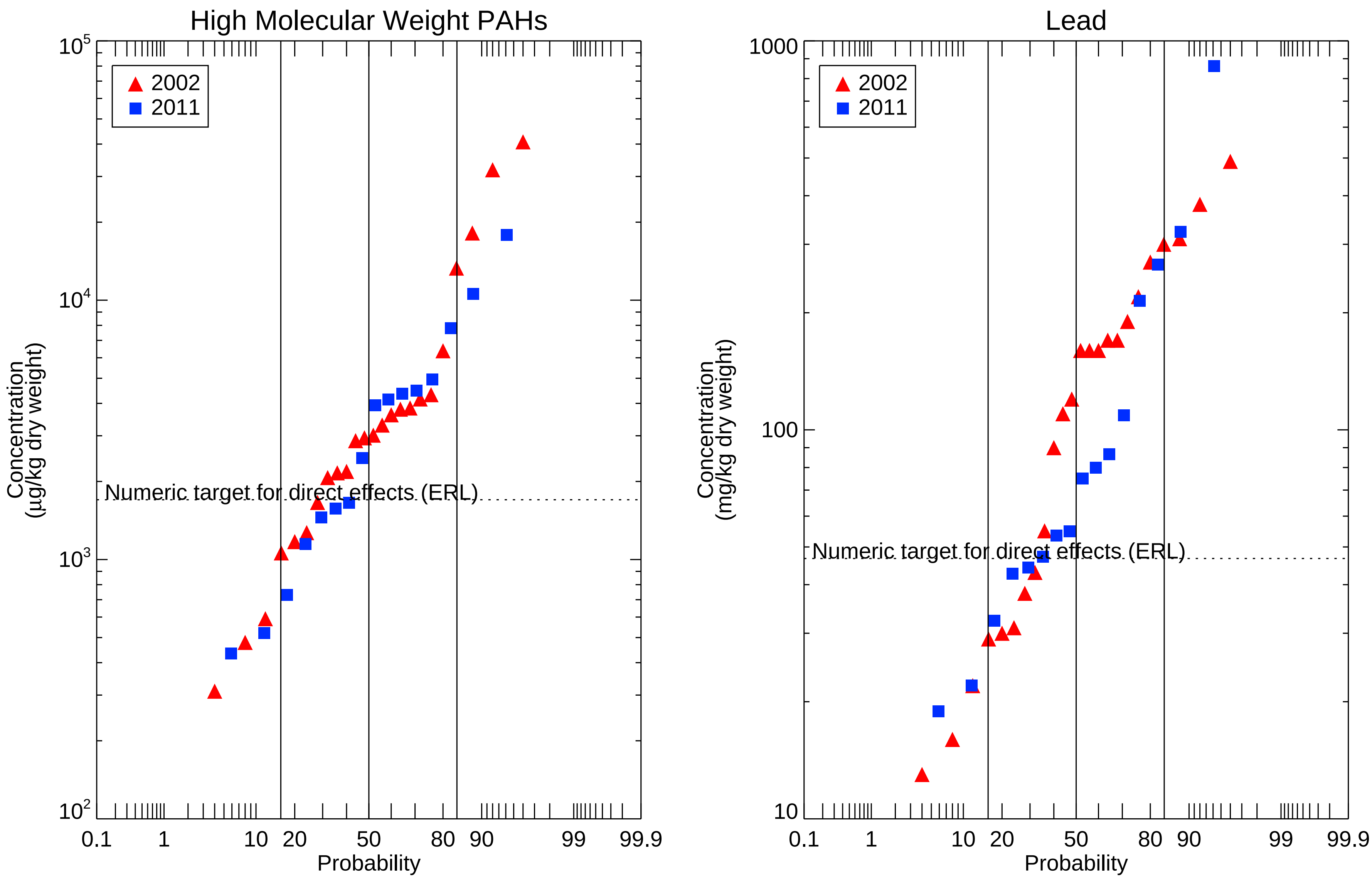


Figure A−6

Probability Plots of High Molecular Weight PAHs and Lead Concentrations in Dominguez Channel Estuary Sediment (0 to 0.5 ft)

Torrance Lateral (TL), Kenwood Drain (KD), Dominguez Channel Upstream of Estuary Above Vermont Ave (DCU), and intertidal (DCT) data from 2002 not shown.
Non−detects set to half the reporting limit (not shown as different symbols; MDL not available).
2011 congener data are from same samples as Aroclor data. Duplicates from original sample results were averaged.
Databases = Sed_DBcomb_NDhalfMDL_tot_20140229.bin

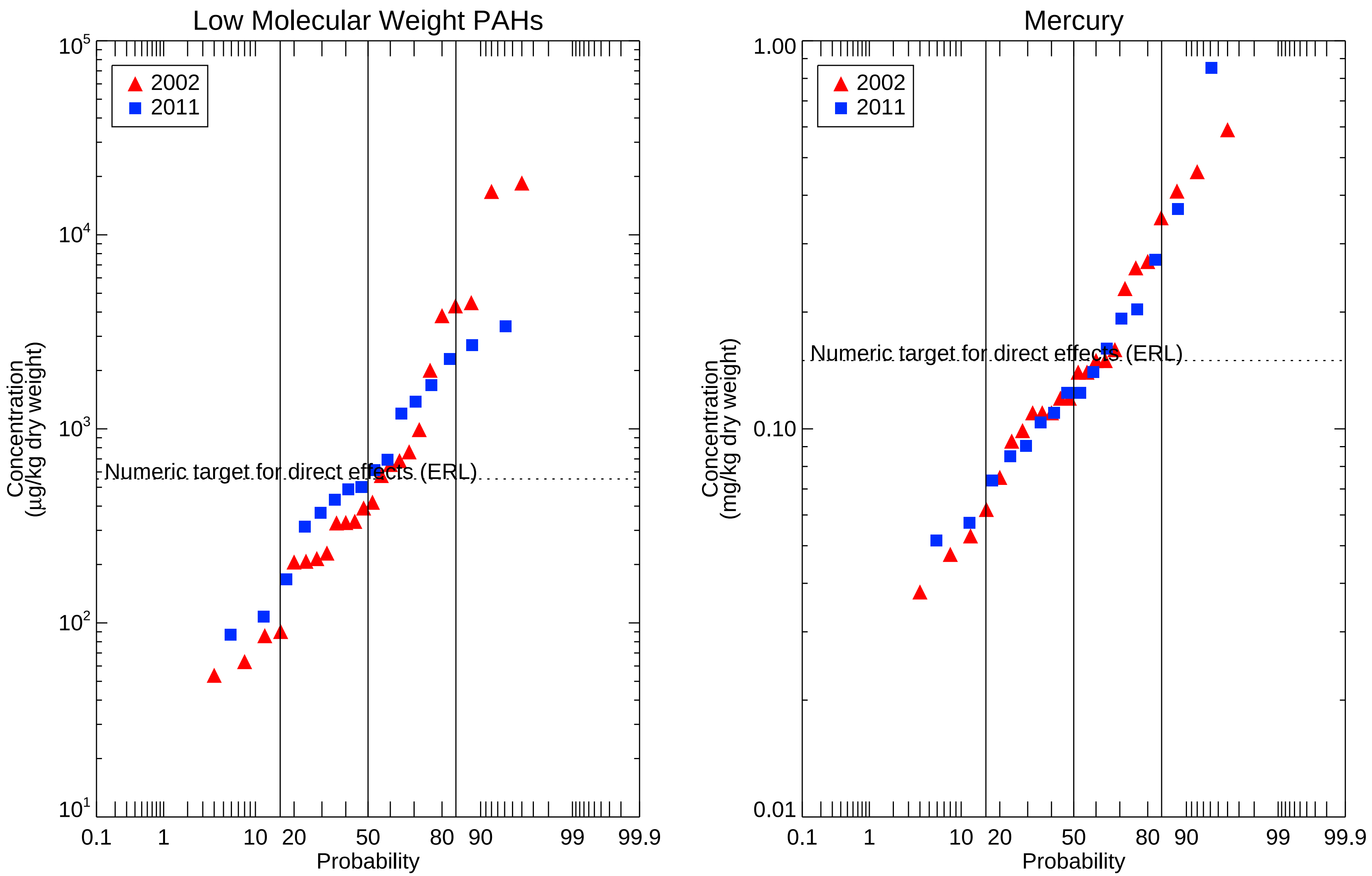


Figure A−7

Probability Plots of Low Molecular Weight PAHs and Mercury Concentrations in Dominguez Channel Estuary Sediment (0 to 0.5 ft)

Torrance Lateral (TL), Kenwood Drain (KD), Dominguez Channel Upstream of Estuary Above Vermont Ave (DCU), and intertidal (DCT) data from 2002 not shown.
Non−detects set to half the reporting limit (not shown as different symbols; MDL not available).
2011 congener data are from same samples as Aroclor data. Duplicates from original sample results were averaged.
Databases = Sed_DBcomb_NDhalfMDL_tot_20140229.bin

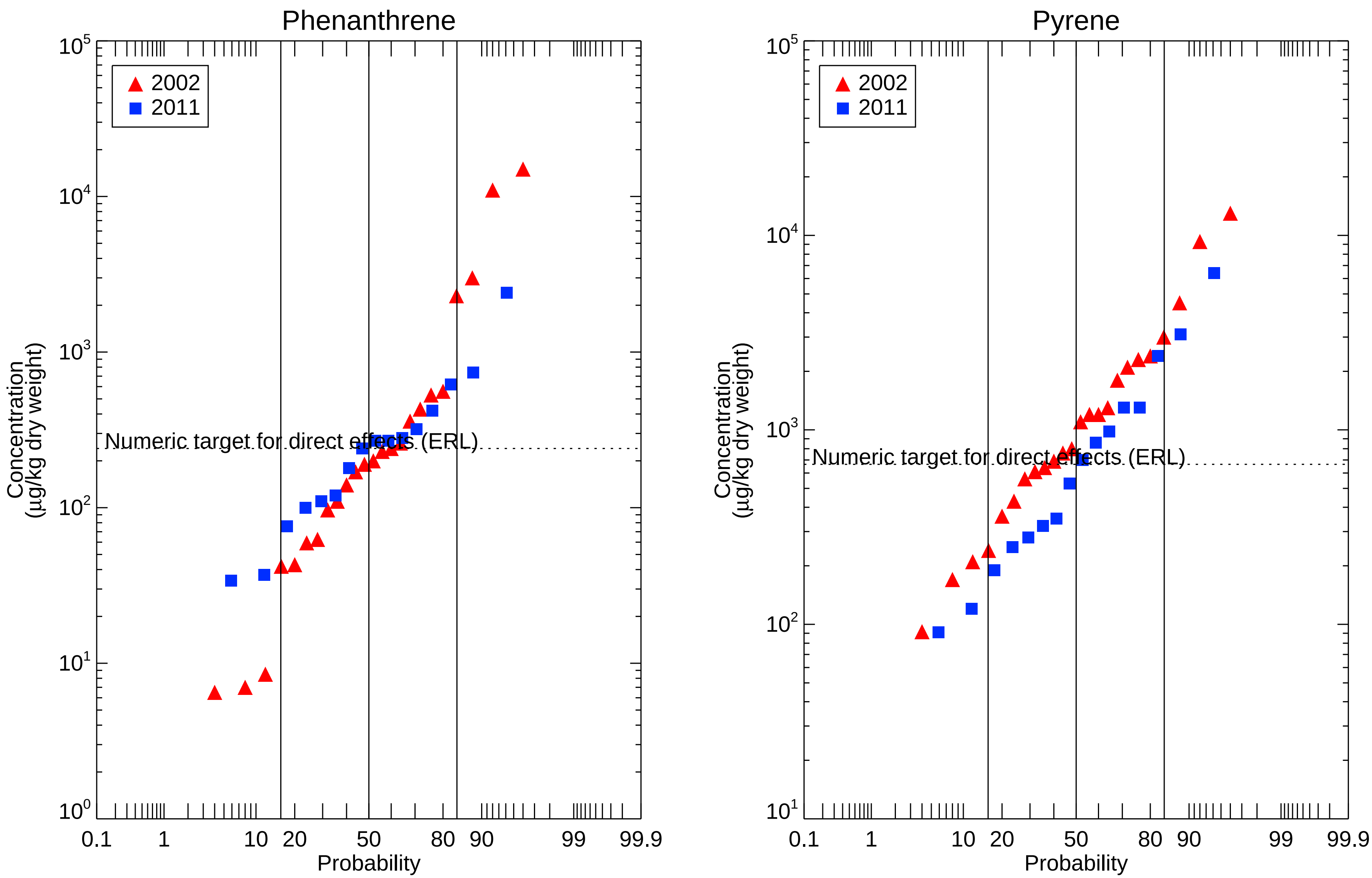


Figure A−8

Probability Plots of Phenanthrene and Pyrene Concentrations in Dominguez Channel Estuary Sediment (0 to 0.5 ft)

Torrance Lateral (TL), Kenwood Drain (KD), Dominguez Channel Upstream of Estuary Above Vermont Ave (DCU), and intertidal (DCT) data from 2002 not shown.
Non−detects set to half the reporting limit (not shown as different symbols; MDL not available).
2011 congener data are from same samples as Aroclor data. Duplicates from original sample results were averaged.
Databases = Sed_DBcomb_NDhalfMDL_tot_20140229.bin

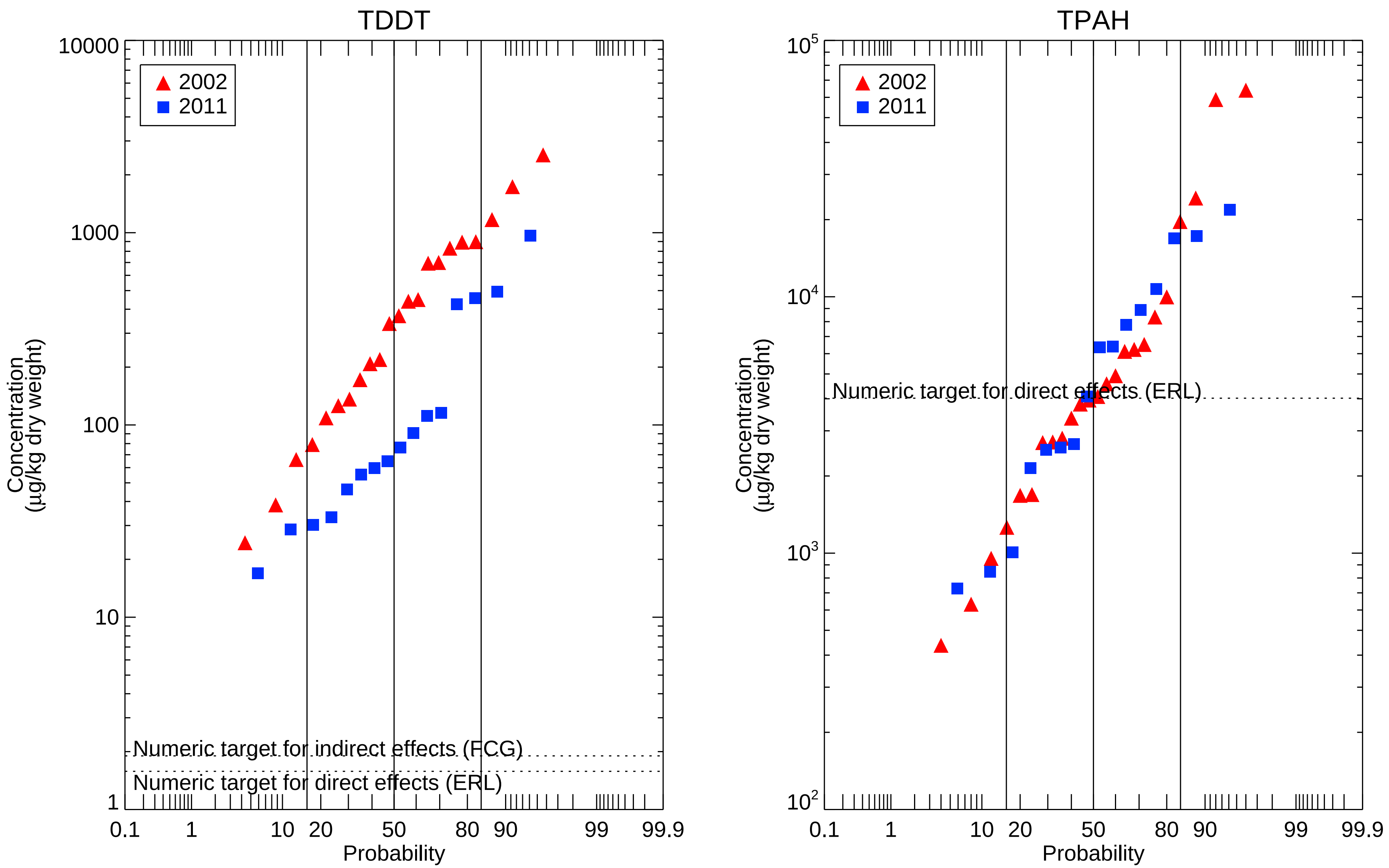


Figure A−9

Probability Plots of TDDT and TPAH Concentrations in Dominguez Channel Estuary Sediment (0 to 0.5 ft)

Torrance Lateral (TL), Kenwood Drain (KD), Dominguez Channel Upstream of Estuary Above Vermont Ave (DCU), and intertidal (DCT) data from 2002 not shown.
Non−detects set to half the reporting limit (not shown as different symbols; MDL not available).
2011 congener data are from same samples as Aroclor data. Duplicates from original sample results were averaged.
Databases = Sed_DBcomb_NDhalfMDL_tot_20140229.bin

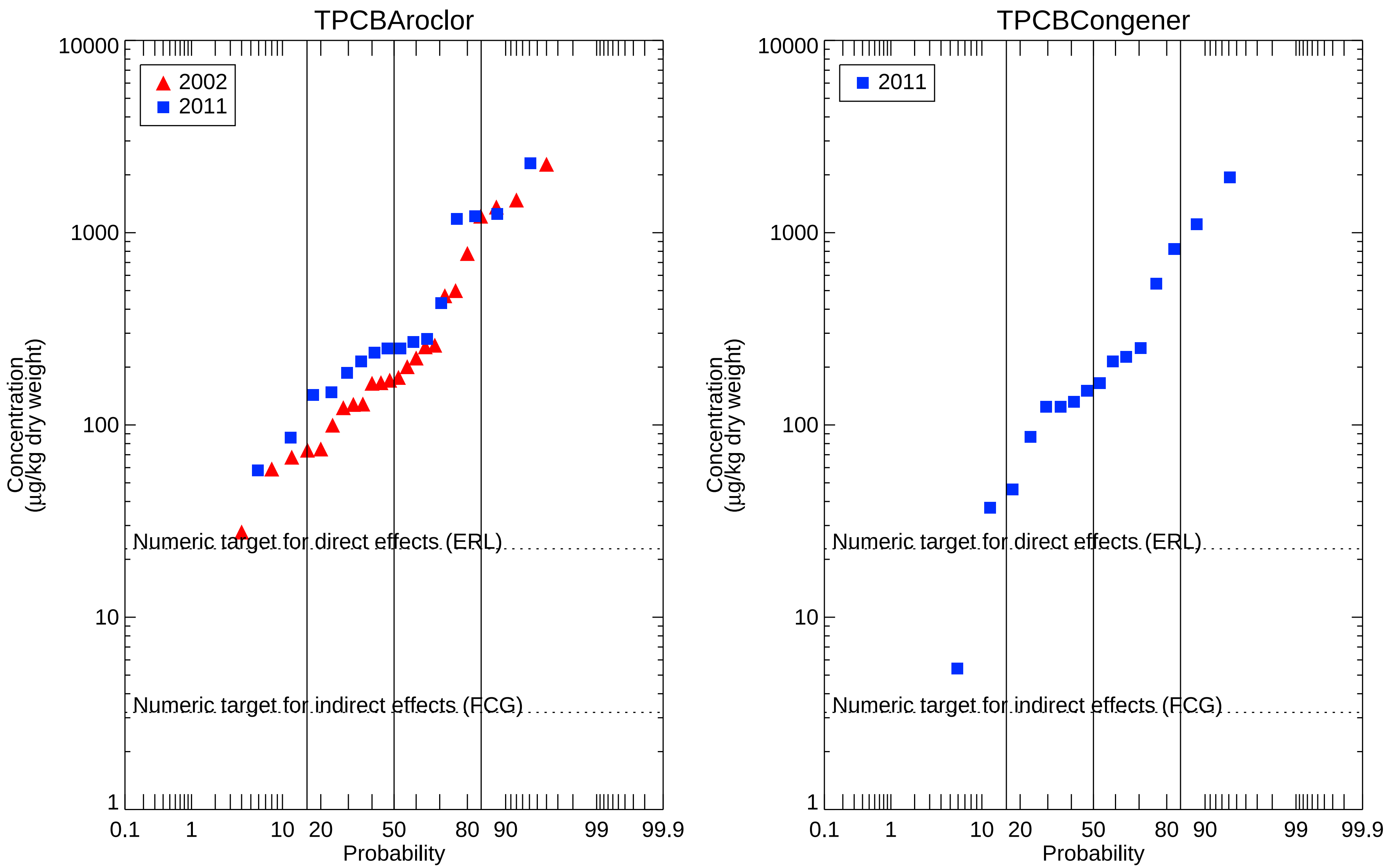


Figure A−10

Probability Plots of TPCBAroclor and TPCBCongener Concentrations in Dominguez Channel Estuary Sediment (0 to 0.5 ft)

Torrance Lateral (TL), Kenwood Drain (KD), Dominguez Channel Upstream of Estuary Above Vermont Ave (DCU), and intertidal (DCT) data from 2002 not shown.
Non−detects set to half the reporting limit (not shown as different symbols; MDL not available).
2011 congener data are from same samples as Aroclor data. Duplicates from original sample results were averaged.
Databases = Sed_DBcomb_NDhalfMDL_tot_20140229.bin

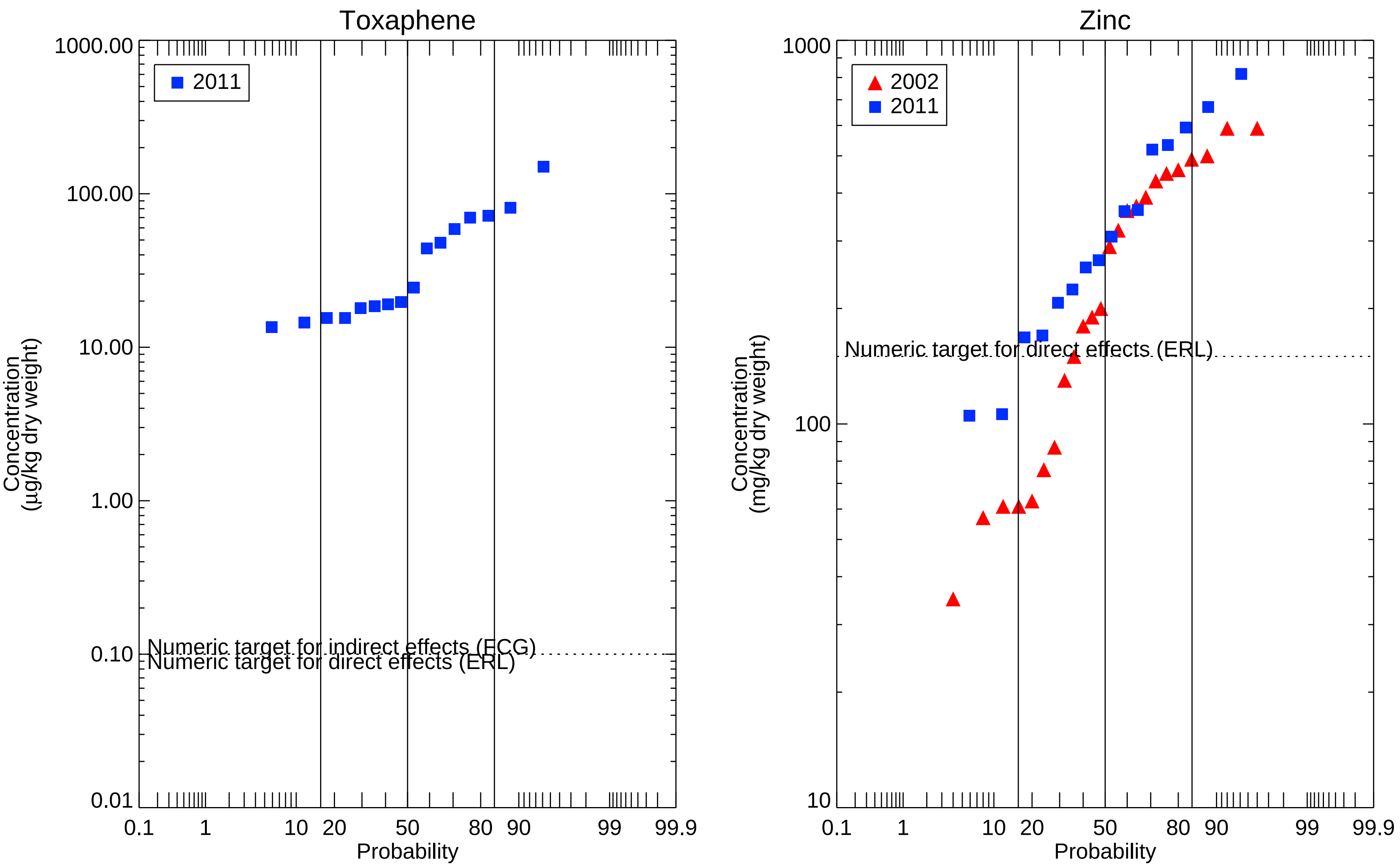


Figure A−11

Probability Plots of Toxaphene and Zinc Concentrations in Dominguez Channel Estuary Sediment (0 to 0.5 ft)

Torrance Lateral (TL), Kenwood Drain (KD), Dominguez Channel Upstream of Estuary Above Vermont Ave (DCU), and intertidal (DCT) data from 2002 not shown.
Non−detects set to half the reporting limit (not shown as different symbols; MDL not available).
2011 congener data are from same samples as Aroclor data. Duplicates from original sample results were averaged.
Databases = Sed_DBcomb_NDhalfMDL_tot_20140229.bin

APPENDIX B
SPATIAL PLOTS OF CONCENTRATIONS IN DCE SEDIMENT AT ANY DEPTH

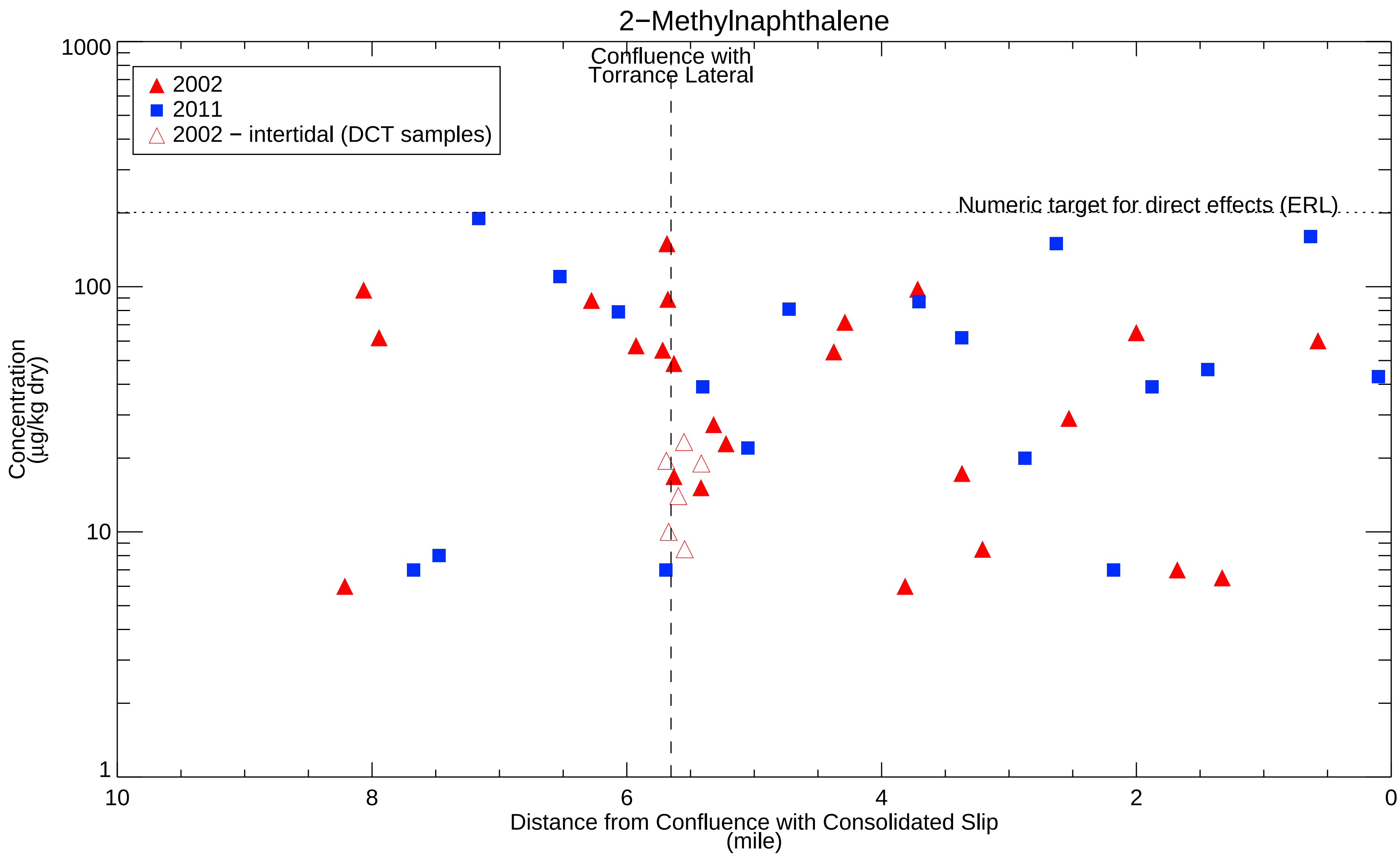


Figure B−1

Concentrations of 2−Methylnaphthalene in Sediment from Dominguez Channel Estuary (Maximum Regardless of Depth)

Torrance Lateral (TL), Kenwood Drain (KD), and Dominguez Channel Upstream of Estuary Above Vermont Ave (DCU) data from 2002 are not shown.
Non−detects set to half reporting limit (not shown as different symbols; MDL not available). Duplicates averaged.
Databases = Sed_DBcomb_NDhalfMDL_tot_20140229_alignTOC_20140301.bin, Sed_DBcomb_NDhalfMDL_indv_20140229.bin

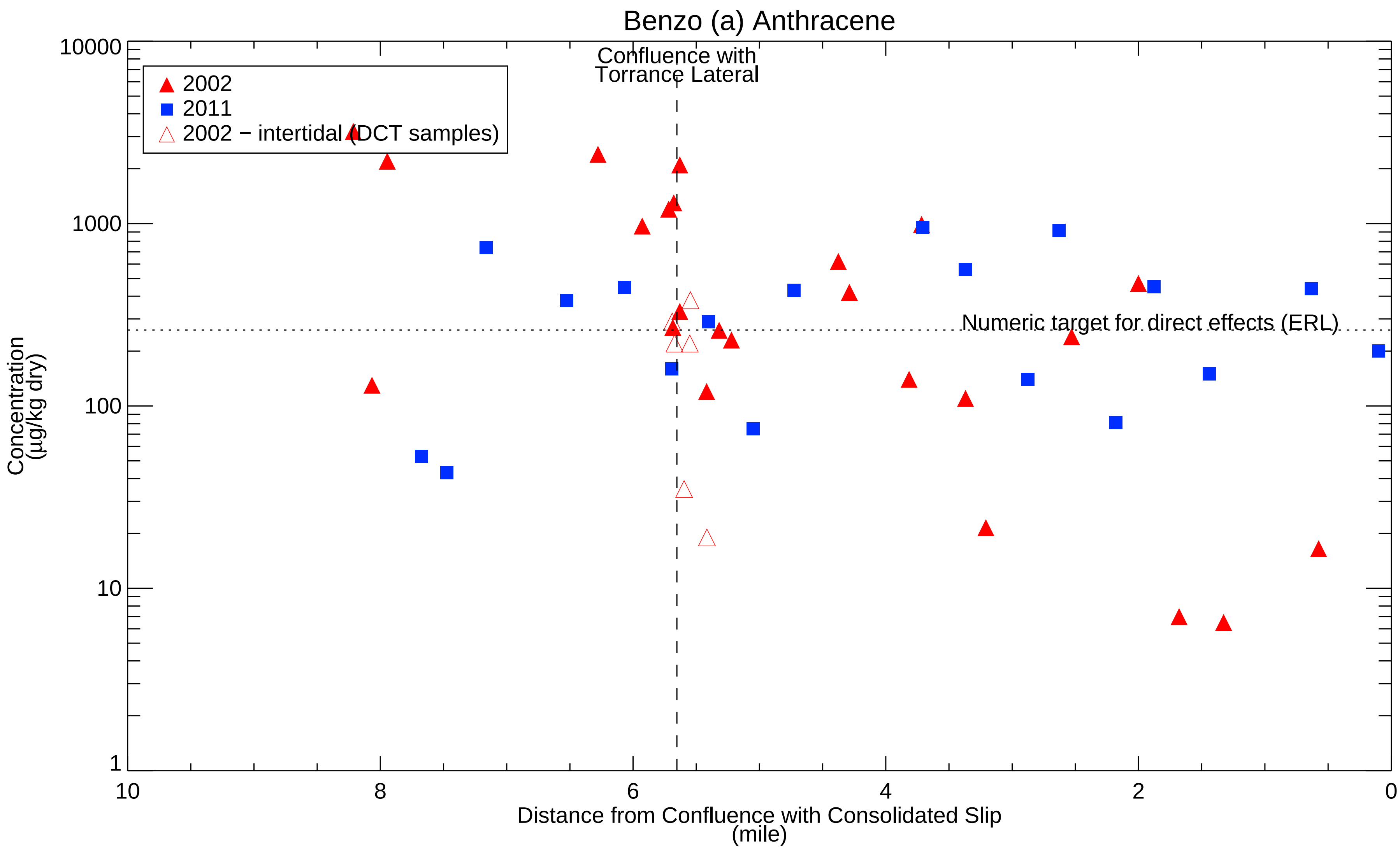


Figure B−2

Concentrations of Benzo (a) Anthracene in Sediment from Dominguez Channel Estuary (Maximum Regardless of Depth)

Torrance Lateral (TL), Kenwood Drain (KD), and Dominguez Channel Upstream of Estuary Above Vermont Ave (DCU) data from 2002 are not shown.
Non−detects set to half reporting limit (not shown as different symbols; MDL not available). Duplicates averaged.
Databases = Sed_DBcomb_NDhalfMDL_tot_20140229_alignTOC_20140301.bin, Sed_DBcomb_NDhalfMDL_indv_20140229.bin

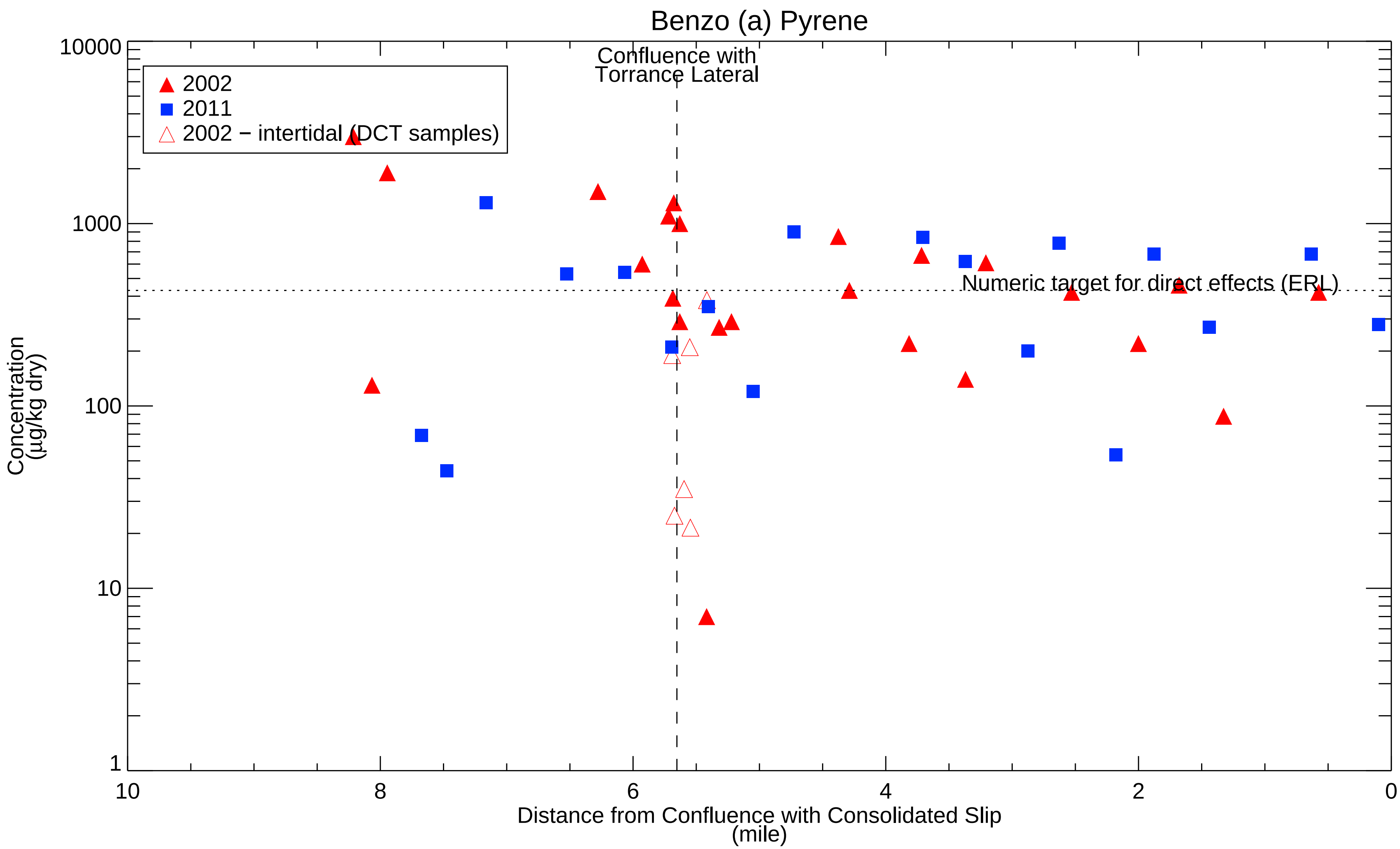


Figure B−3

Concentrations of Benzo (a) Pyrene in Sediment from Dominguez Channel Estuary (Maximum Regardless of Depth)

Torrance Lateral (TL), Kenwood Drain (KD), and Dominguez Channel Upstream of Estuary Above Vermont Ave (DCU) data from 2002 are not shown.
Non−detects set to half reporting limit (not shown as different symbols; MDL not available). Duplicates averaged.
Databases = Sed_DBcomb_NDhalfMDL_tot_20140229_alignTOC_20140301.bin, Sed_DBcomb_NDhalfMDL_indv_20140229.bin

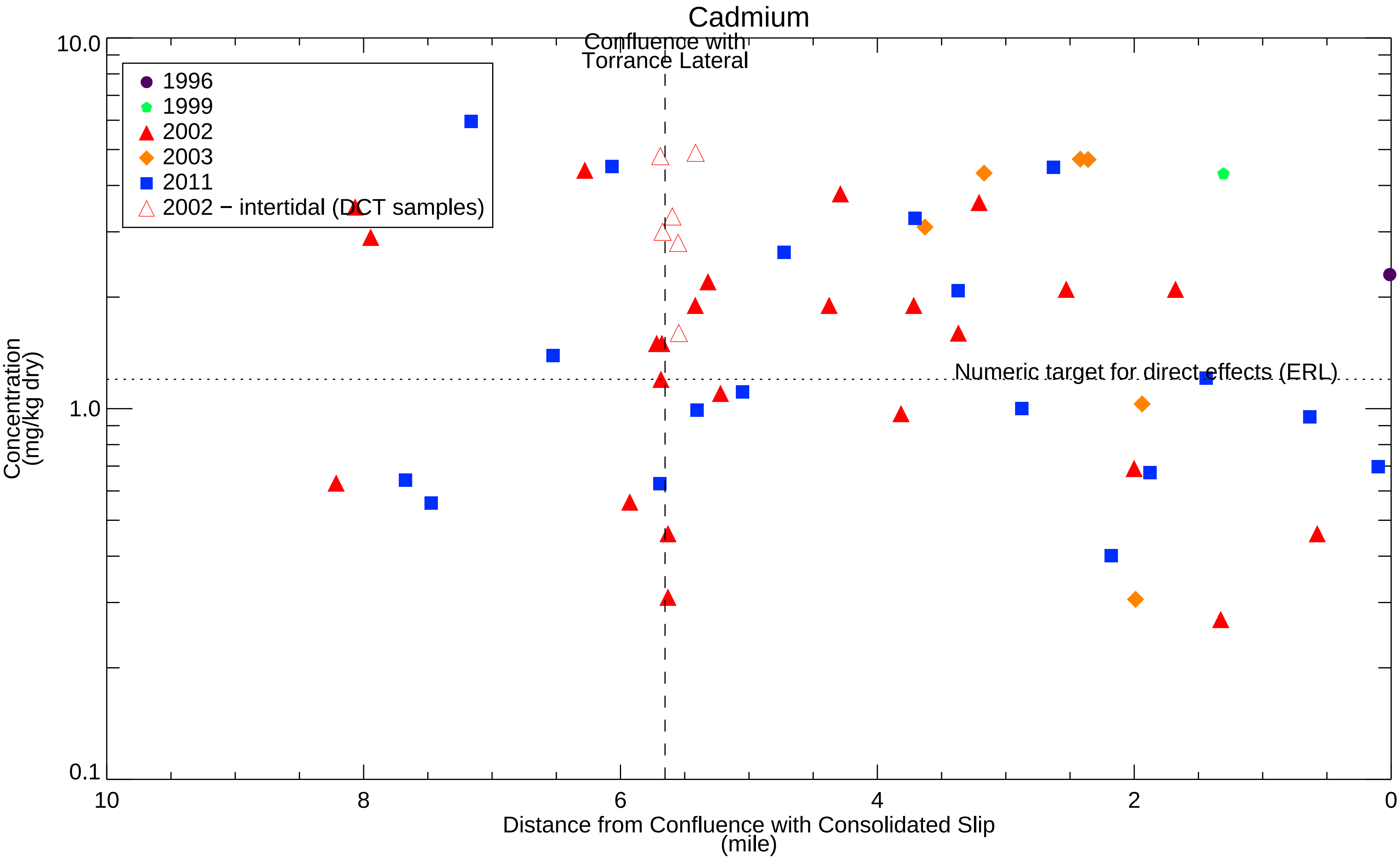


Figure B−4

Concentrations of Cadmium in Sediment from Dominguez Channel Estuary (Maximum Regardless of Depth)

Torrance Lateral (TL), Kenwood Drain (KD), and Dominguez Channel Upstream of Estuary Above Vermont Ave (DCU) data from 2002 are not shown.
Non−detects set to half reporting limit (not shown as different symbols; MDL not available). Duplicates averaged.
Databases = Sed_DBcomb_NDhalfMDL_tot_20140229_alignTOC_20140301.bin, Sed_DBcomb_NDhalfMDL_indv_20140229.bin

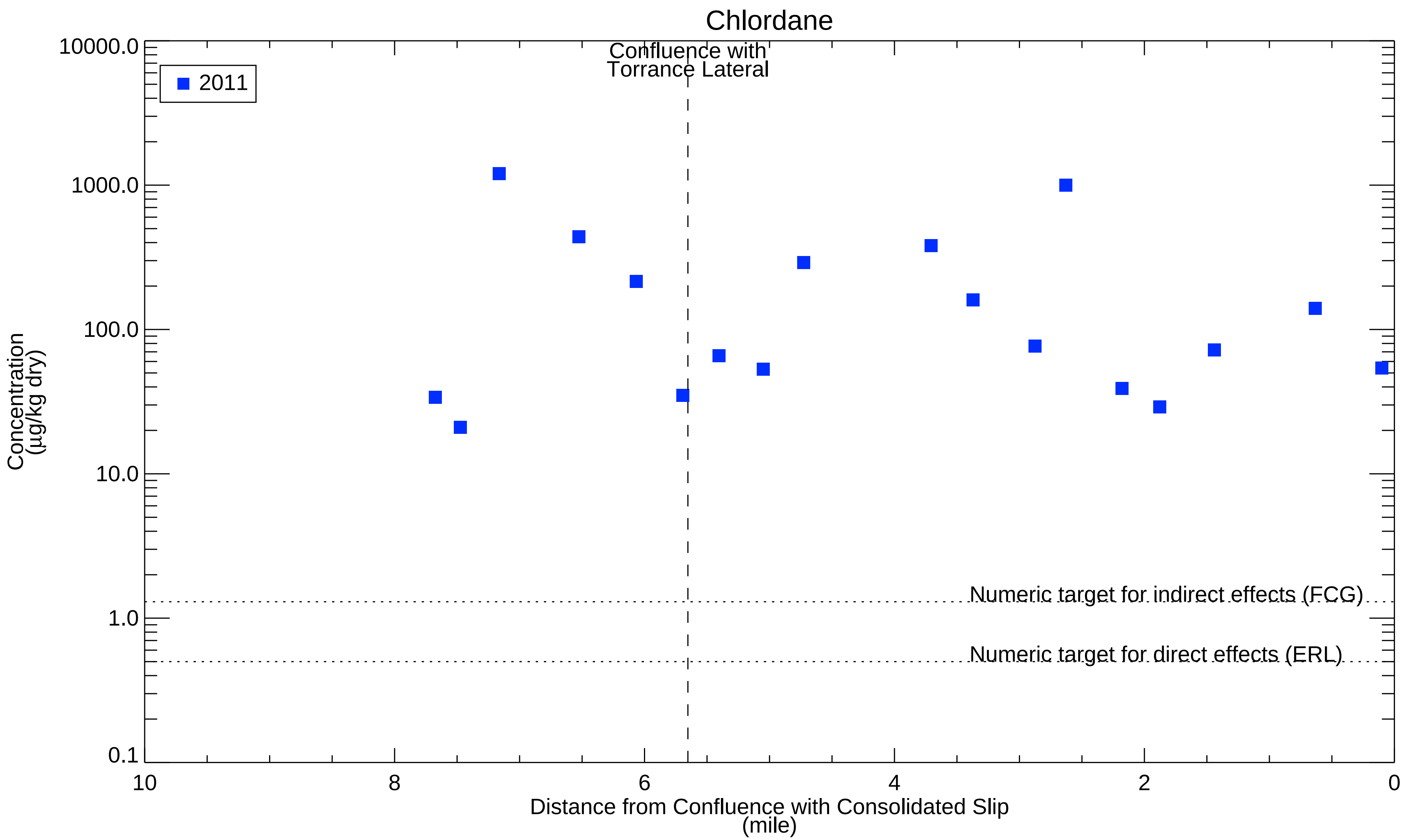


Figure B−5

Concentrations of Chlordane in Sediment from Dominguez Channel Estuary (Maximum Regardless of Depth)

Torrance Lateral (TL), Kenwood Drain (KD), and Dominguez Channel Upstream of Estuary Above Vermont Ave (DCU) data from 2002 are not shown.
Non−detects set to half reporting limit (not shown as different symbols; MDL not available). Duplicates averaged.
Databases = Sed_DBcomb_NDhalfMDL_tot_20140229_alignTOC_20140301.bin, Sed_DBcomb_NDhalfMDL_indv_20140229.bin

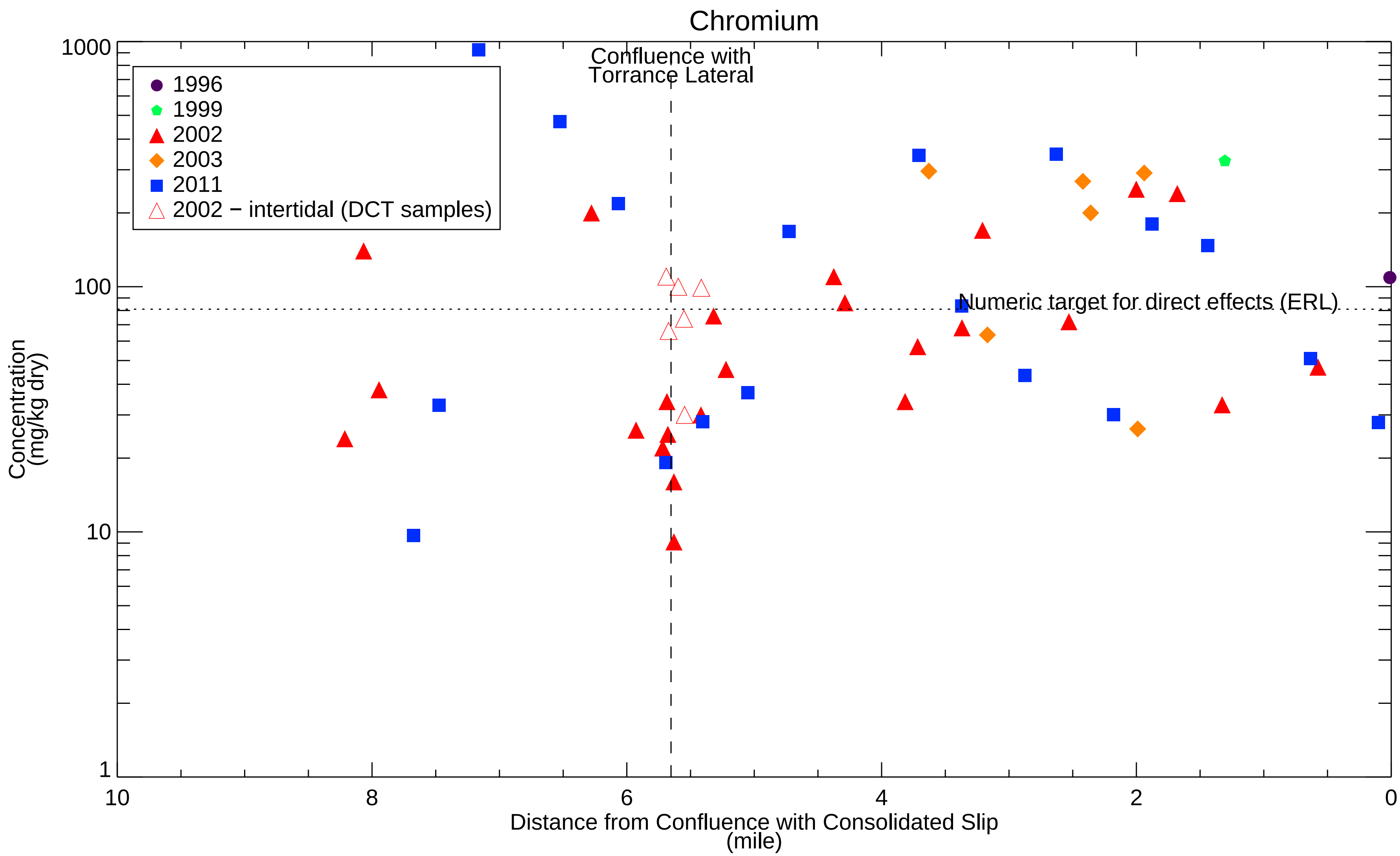


Figure B−6

Concentrations of Chromium in Sediment from Dominguez Channel Estuary (Maximum Regardless of Depth)

Torrance Lateral (TL), Kenwood Drain (KD), and Dominguez Channel Upstream of Estuary Above Vermont Ave (DCU) data from 2002 are not shown.
Non−detects set to half reporting limit (not shown as different symbols; MDL not available). Duplicates averaged.
Databases = Sed_DBcomb_NDhalfMDL_tot_20140229_alignTOC_20140301.bin, Sed_DBcomb_NDhalfMDL_indv_20140229.bin

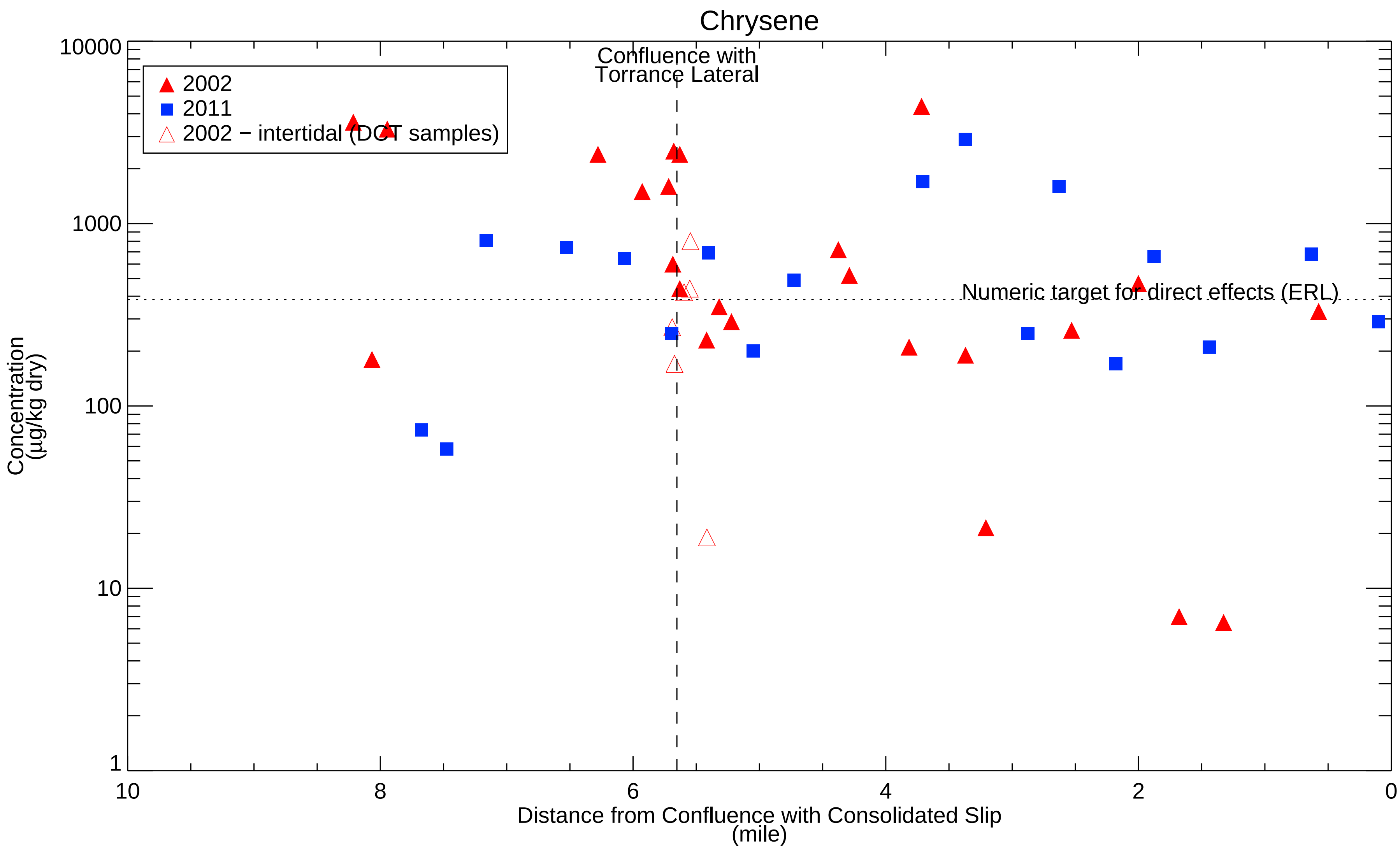


Figure B−7

Concentrations of Chrysene in Sediment from Dominguez Channel Estuary (Maximum Regardless of Depth)

Torrance Lateral (TL), Kenwood Drain (KD), and Dominguez Channel Upstream of Estuary Above Vermont Ave (DCU) data from 2002 are not shown.
Non−detects set to half reporting limit (not shown as different symbols; MDL not available). Duplicates averaged.
Databases = Sed_DBcomb_NDhalfMDL_tot_20140229_alignTOC_20140301.bin, Sed_DBcomb_NDhalfMDL_indv_20140229.bin

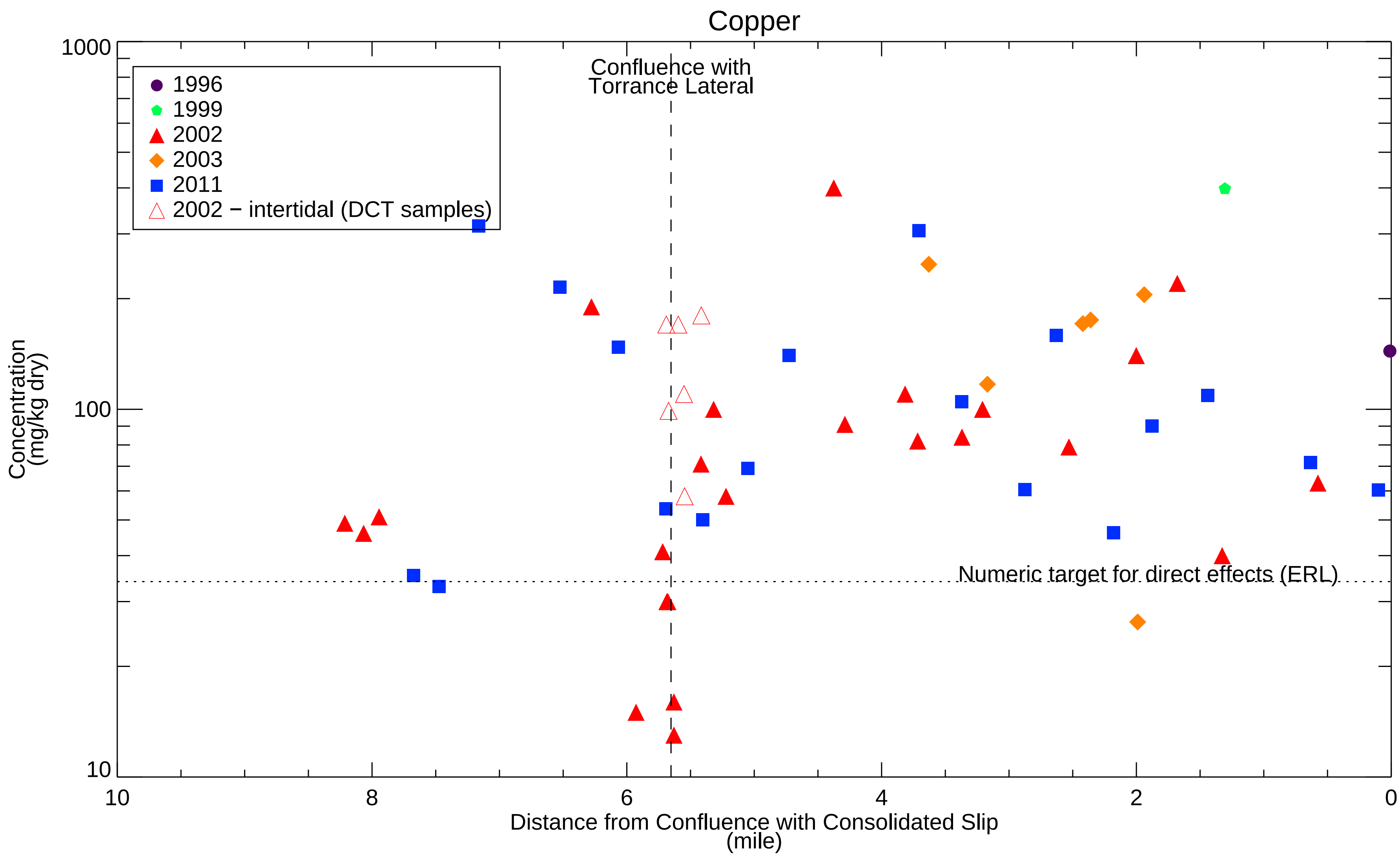


Figure B−8

Concentrations of Copper in Sediment from Dominguez Channel Estuary (Maximum Regardless of Depth)

Torrance Lateral (TL), Kenwood Drain (KD), and Dominguez Channel Upstream of Estuary Above Vermont Ave (DCU) data from 2002 are not shown.
Non−detects set to half reporting limit (not shown as different symbols; MDL not available). Duplicates averaged.
Databases = Sed_DBcomb_NDhalfMDL_tot_20140229_alignTOC_20140301.bin, Sed_DBcomb_NDhalfMDL_indv_20140229.bin

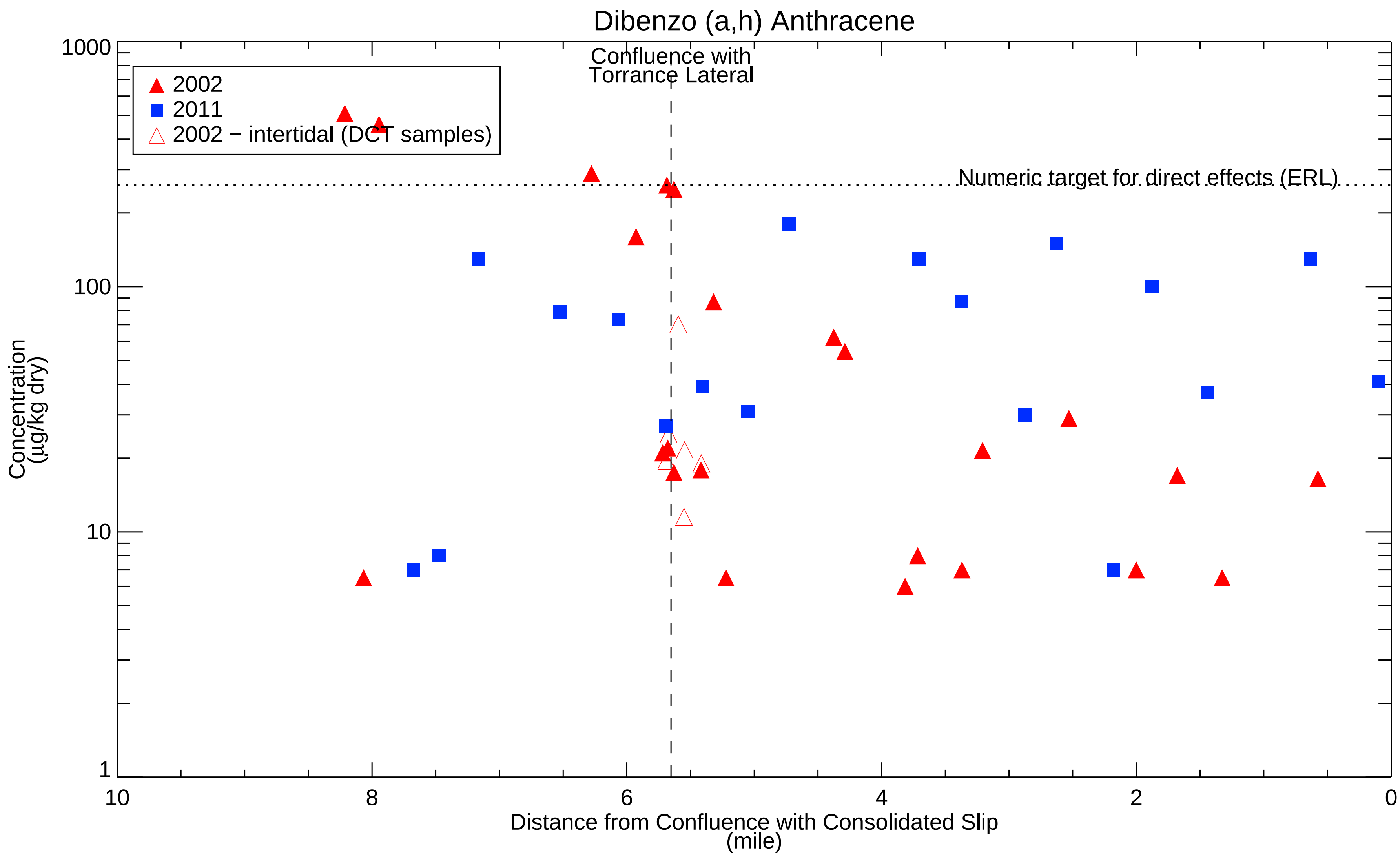


Figure B−9

Concentrations of Dibenzo (a,h) Anthracene in Sediment from Dominguez Channel Estuary (Maximum Regardless of Depth)

Torrance Lateral (TL), Kenwood Drain (KD), and Dominguez Channel Upstream of Estuary Above Vermont Ave (DCU) data from 2002 are not shown.
Non−detects set to half reporting limit (not shown as different symbols; MDL not available). Duplicates averaged.
Databases = Sed_DBcomb_NDhalfMDL_tot_20140229_alignTOC_20140301.bin, Sed_DBcomb_NDhalfMDL_indv_20140229.bin

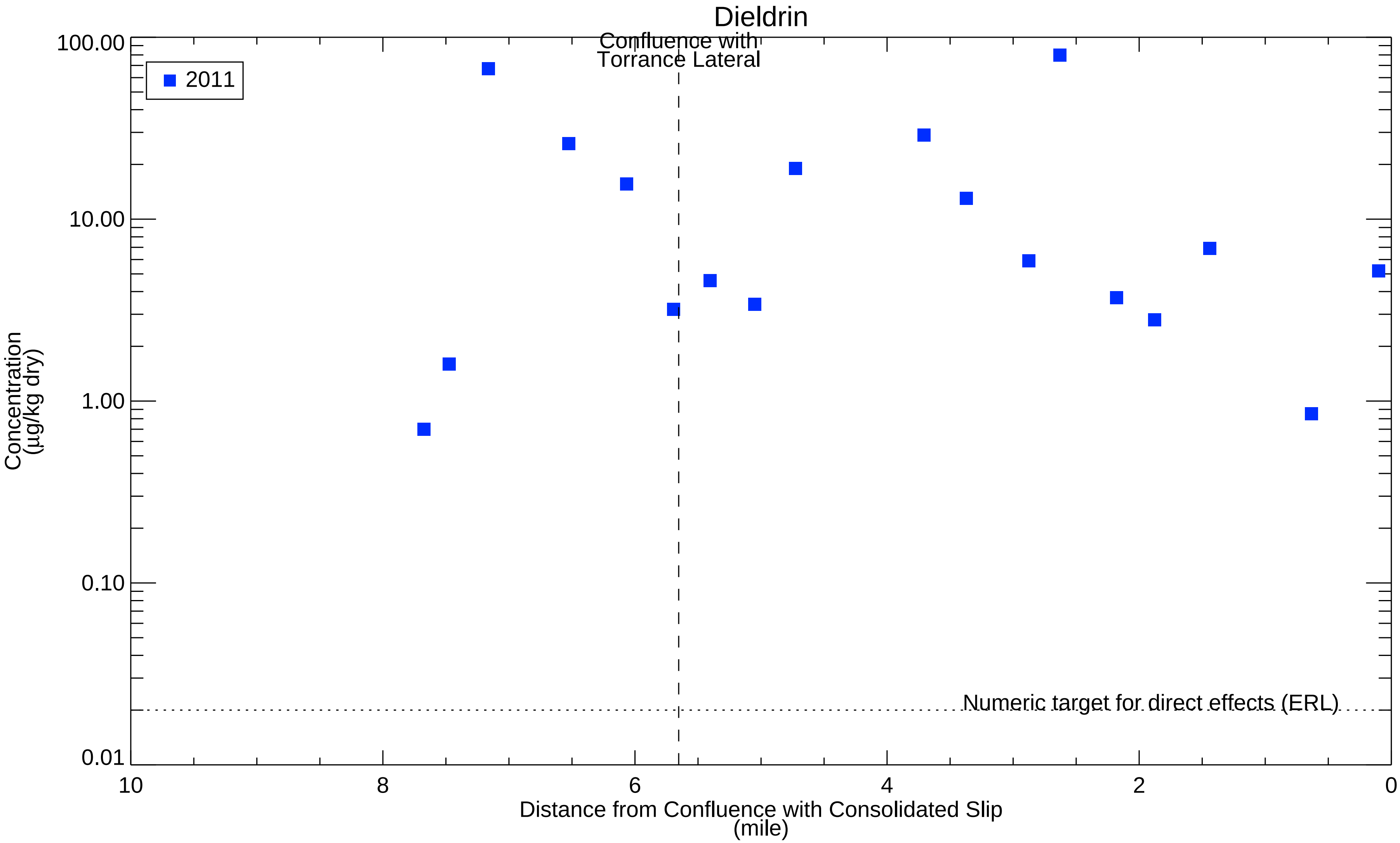


Figure B−10

Concentrations of Dieldrin in Sediment from Dominguez Channel Estuary (Maximum Regardless of Depth)

Torrance Lateral (TL), Kenwood Drain (KD), and Dominguez Channel Upstream of Estuary Above Vermont Ave (DCU) data from 2002 are not shown.
Non−detects set to half reporting limit (not shown as different symbols; MDL not available). Duplicates averaged.
Databases = Sed_DBcomb_NDhalfMDL_tot_20140229_alignTOC_20140301.bin, Sed_DBcomb_NDhalfMDL_indv_20140229.bin

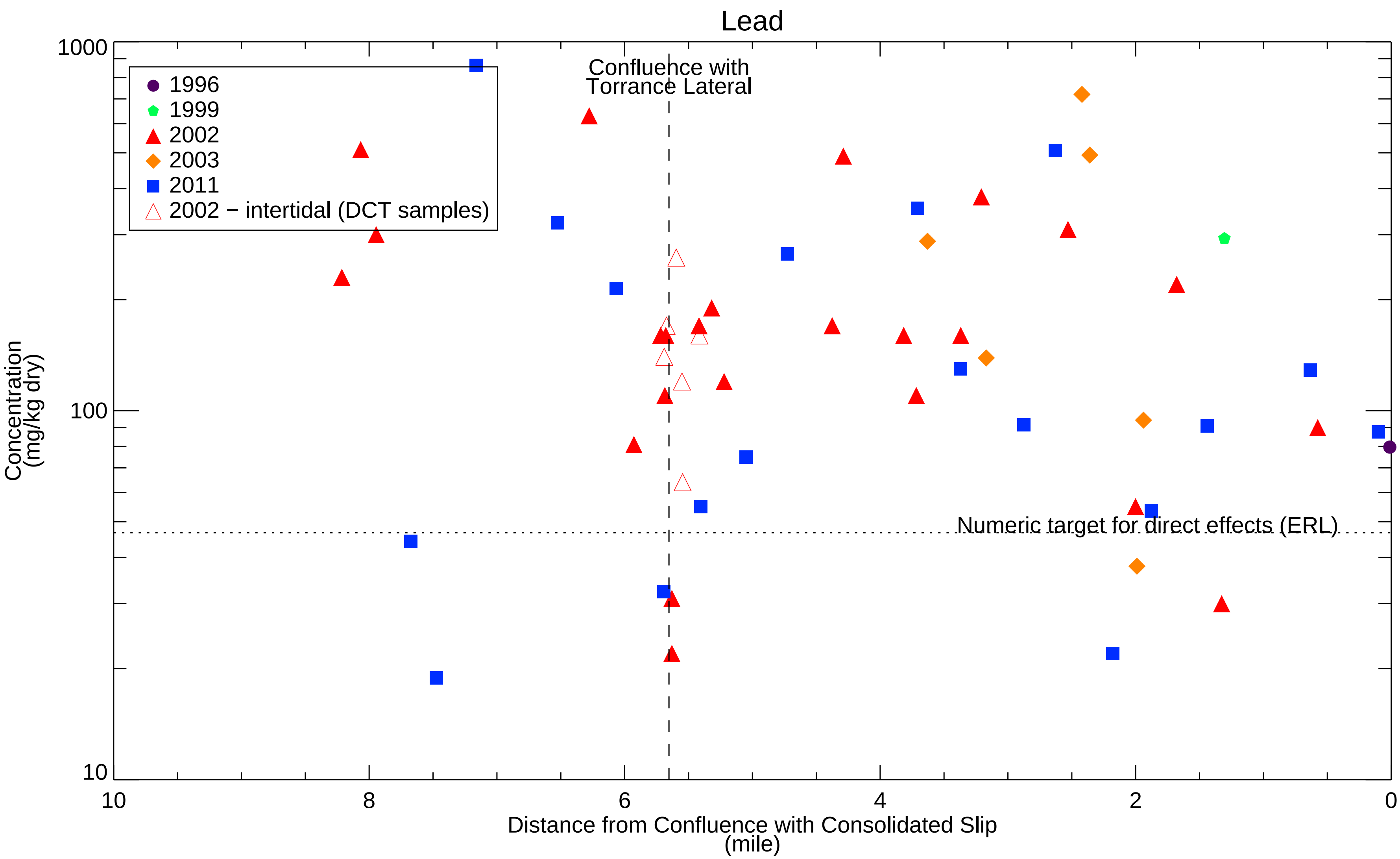


Figure B−11

Concentrations of Lead in Sediment from Dominguez Channel Estuary (Maximum Regardless of Depth)

Torrance Lateral (TL), Kenwood Drain (KD), and Dominguez Channel Upstream of Estuary Above Vermont Ave (DCU) data from 2002 are not shown.
Non−detects set to half reporting limit (not shown as different symbols; MDL not available). Duplicates averaged.
Databases = Sed_DBcomb_NDhalfMDL_tot_20140229_alignTOC_20140301.bin, Sed_DBcomb_NDhalfMDL_indv_20140229.bin

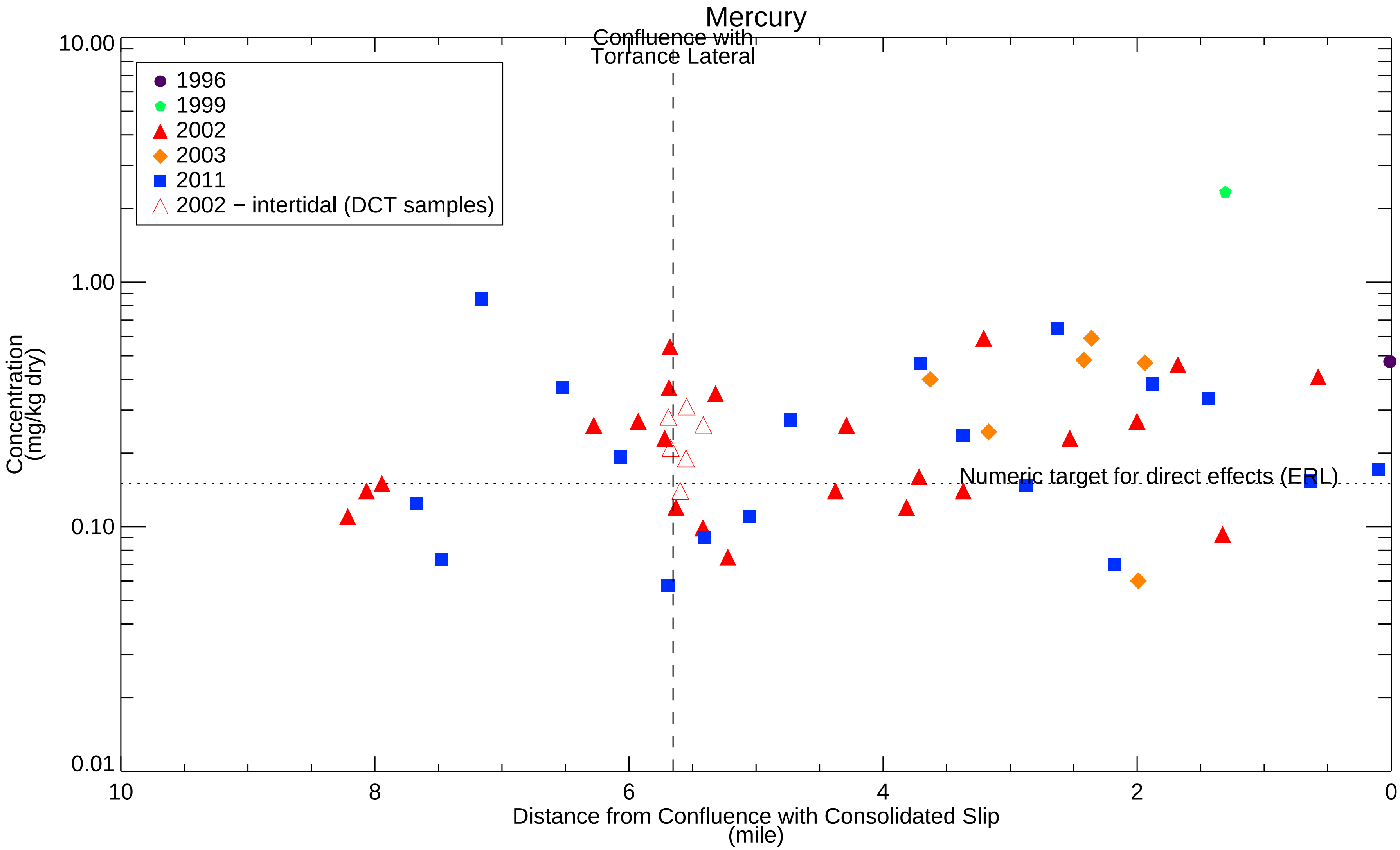


Figure B−12

Concentrations of Mercury in Sediment from Dominguez Channel Estuary (Maximum Regardless of Depth)

Torrance Lateral (TL), Kenwood Drain (KD), and Dominguez Channel Upstream of Estuary Above Vermont Ave (DCU) data from 2002 are not shown.
Non−detects set to half reporting limit (not shown as different symbols; MDL not available). Duplicates averaged.
Databases = Sed_DBcomb_NDhalfMDL_tot_20140229_alignTOC_20140301.bin, Sed_DBcomb_NDhalfMDL_indv_20140229.bin

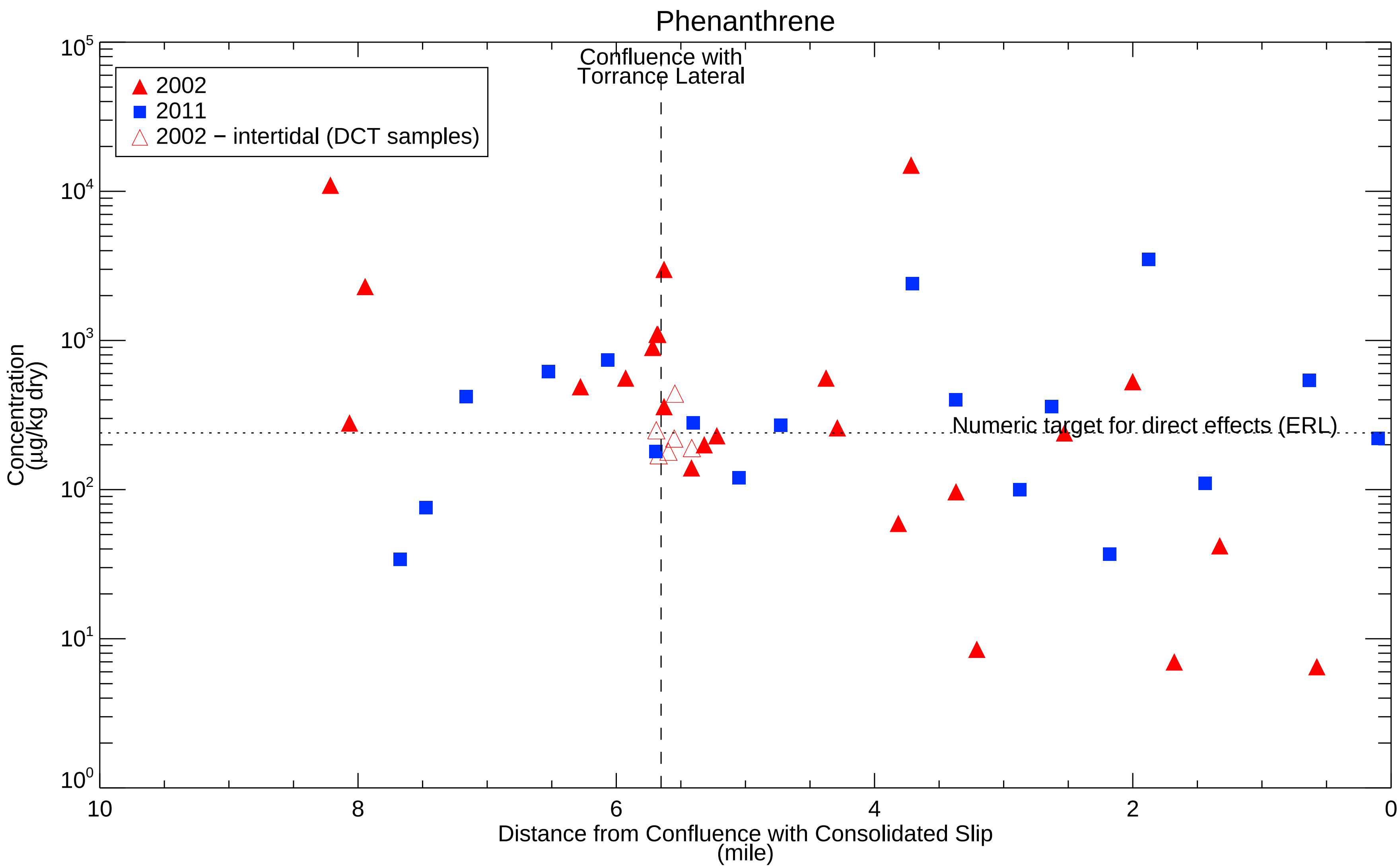


Figure B−13

Concentrations of Phenanthrene in Sediment from Dominguez Channel Estuary (Maximum Regardless of Depth)

Torrance Lateral (TL), Kenwood Drain (KD), and Dominguez Channel Upstream of Estuary Above Vermont Ave (DCU) data from 2002 are not shown.
Non−detects set to half reporting limit (not shown as different symbols; MDL not available). Duplicates averaged.
Databases = Sed_DBcomb_NDhalfMDL_tot_20140229_alignTOC_20140301.bin, Sed_DBcomb_NDhalfMDL_indv_20140229.bin

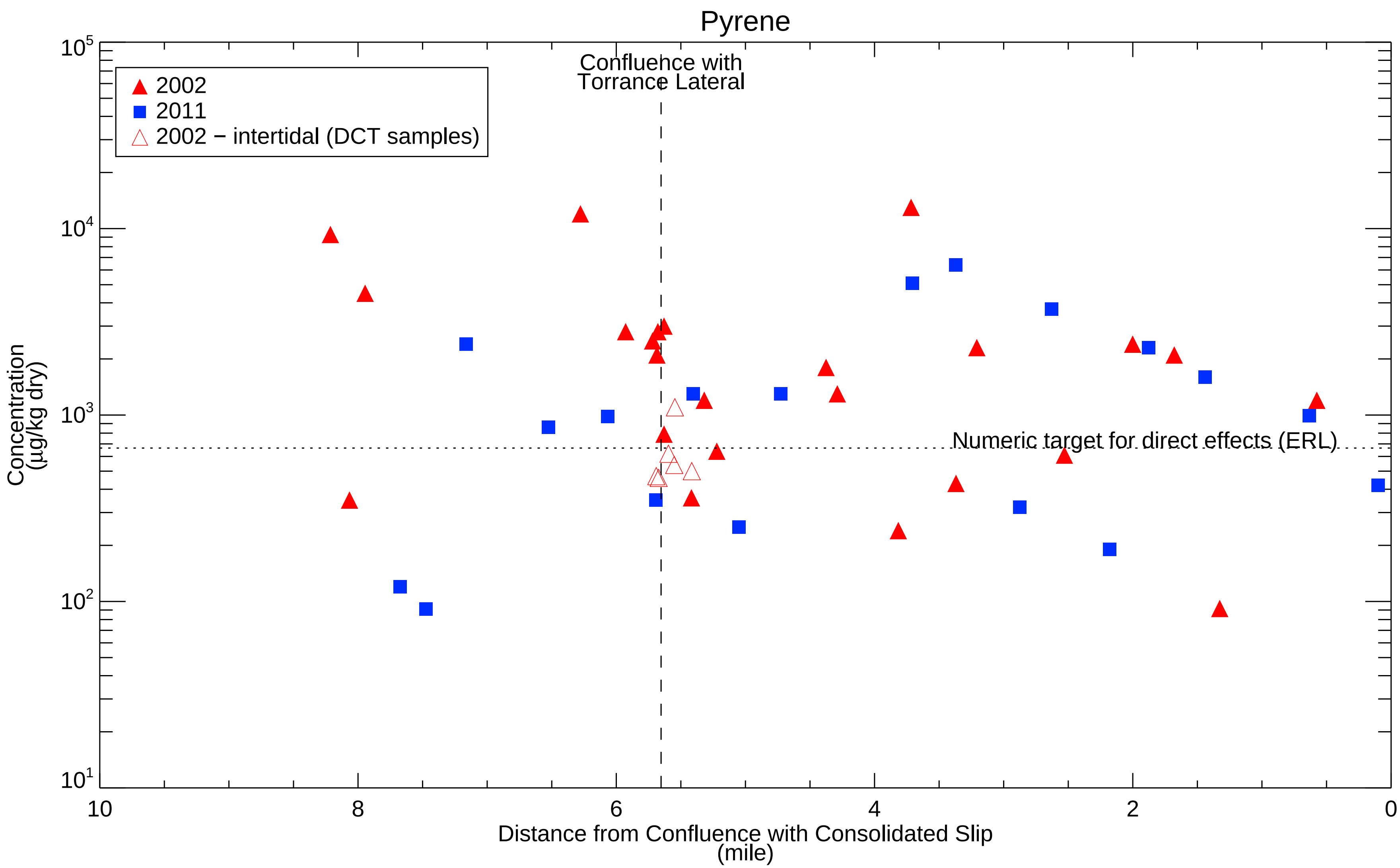


Figure B−14

Concentrations of Pyrene in Sediment from Dominguez Channel Estuary (Maximum Regardless of Depth)

Torrance Lateral (TL), Kenwood Drain (KD), and Dominguez Channel Upstream of Estuary Above Vermont Ave (DCU) data from 2002 are not shown.
Non−detects set to half reporting limit (not shown as different symbols; MDL not available). Duplicates averaged.
Databases = Sed_DBcomb_NDhalfMDL_tot_20140229_alignTOC_20140301.bin, Sed_DBcomb_NDhalfMDL_indv_20140229.bin

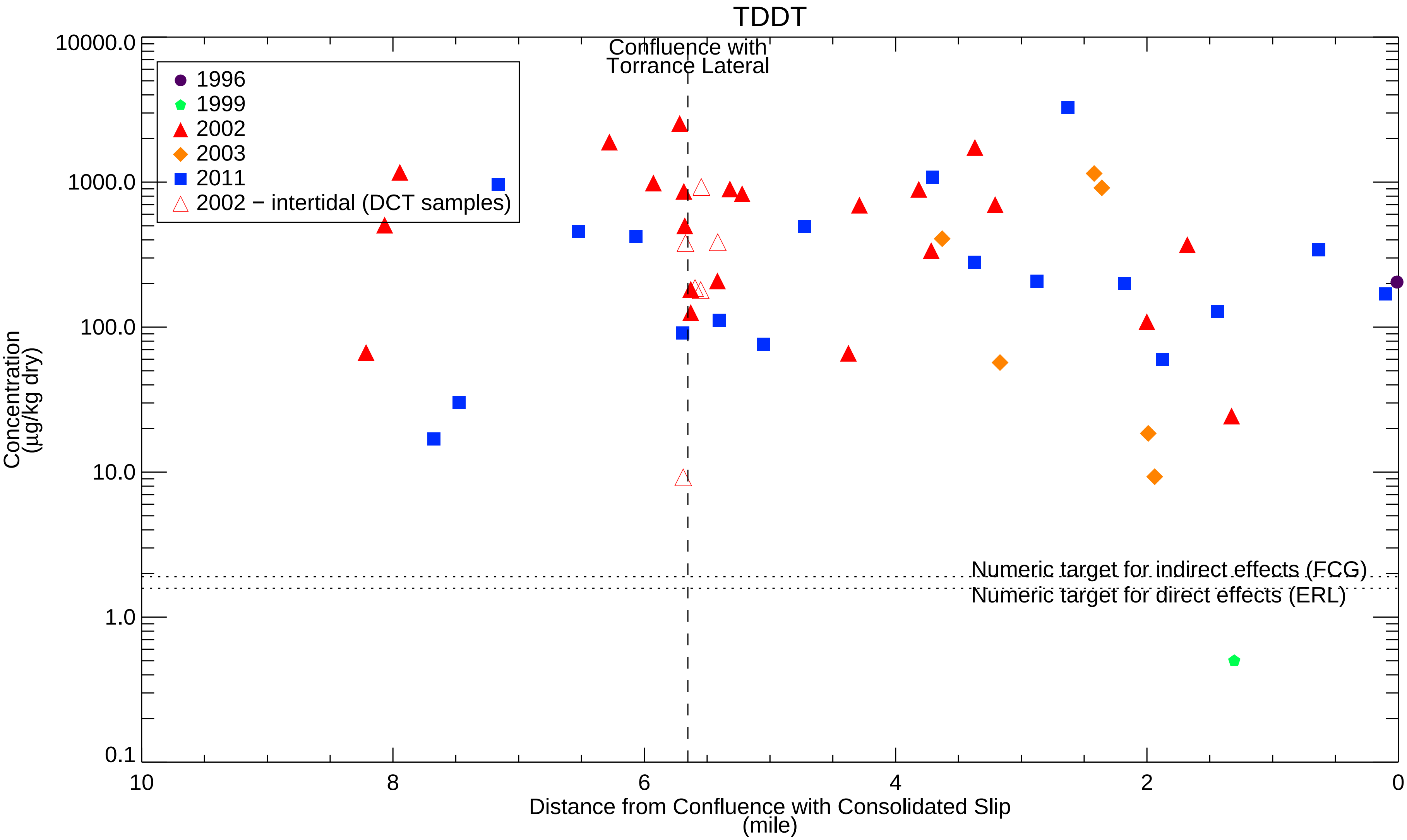


Figure B−15

Concentrations of TDDT in Sediment from Dominguez Channel Estuary (Maximum Regardless of Depth)

Torrance Lateral (TL), Kenwood Drain (KD), and Dominguez Channel Upstream of Estuary Above Vermont Ave (DCU) data from 2002 are not shown.
Non−detects set to half reporting limit (not shown as different symbols; MDL not available). Duplicates averaged.
Databases = Sed_DBcomb_NDhalfMDL_tot_20140229_alignTOC_20140301.bin, Sed_DBcomb_NDhalfMDL_indv_20140229.bin

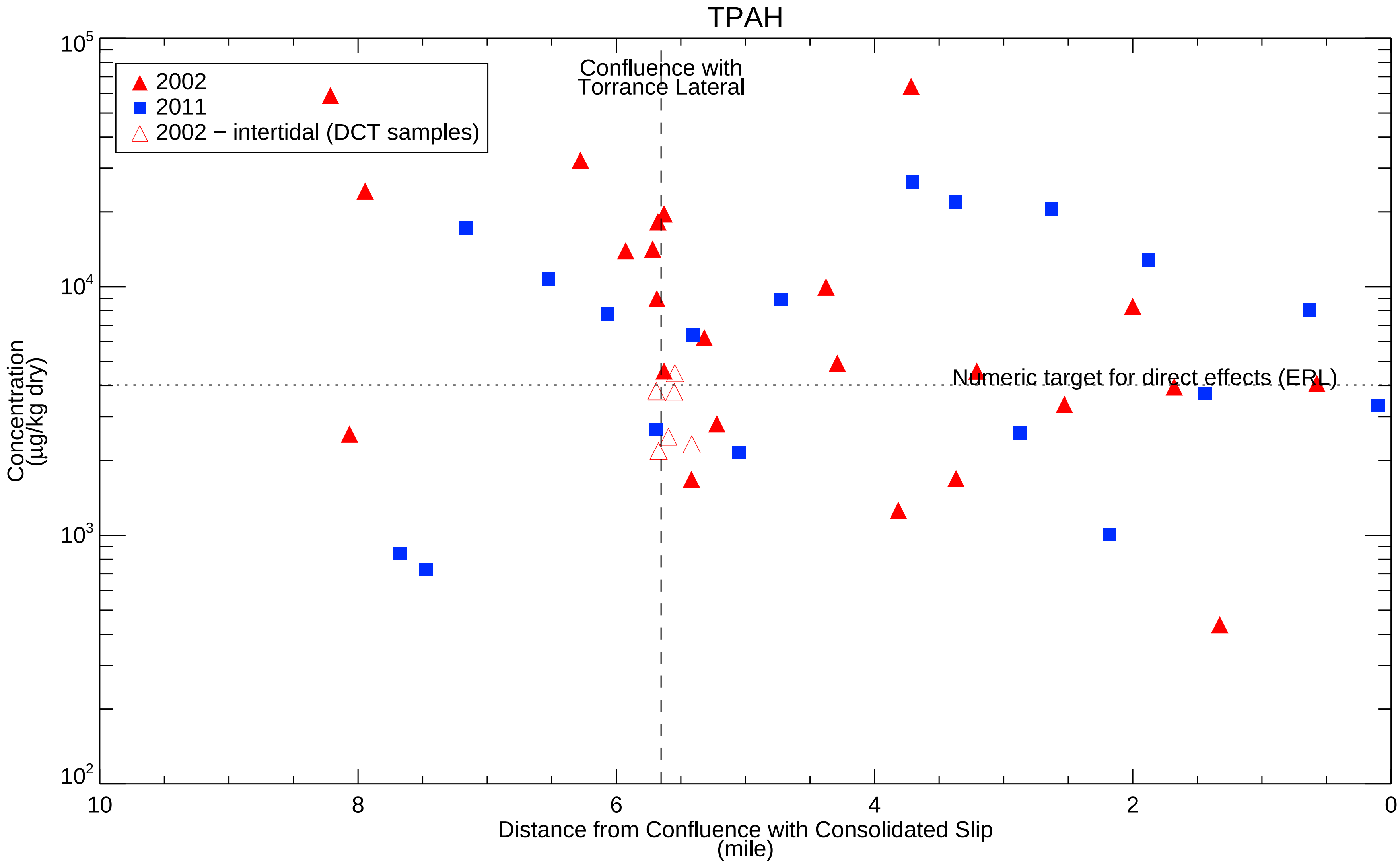


Figure B−16

Concentrations of TPAH in Sediment from Dominguez Channel Estuary (Maximum Regardless of Depth)

Torrance Lateral (TL), Kenwood Drain (KD), and Dominguez Channel Upstream of Estuary Above Vermont Ave (DCU) data from 2002 are not shown.
Non−detects set to half reporting limit (not shown as different symbols; MDL not available). Duplicates averaged.
Databases = Sed_DBcomb_NDhalfMDL_tot_20140229_alignTOC_20140301.bin, Sed_DBcomb_NDhalfMDL_indv_20140229.bin

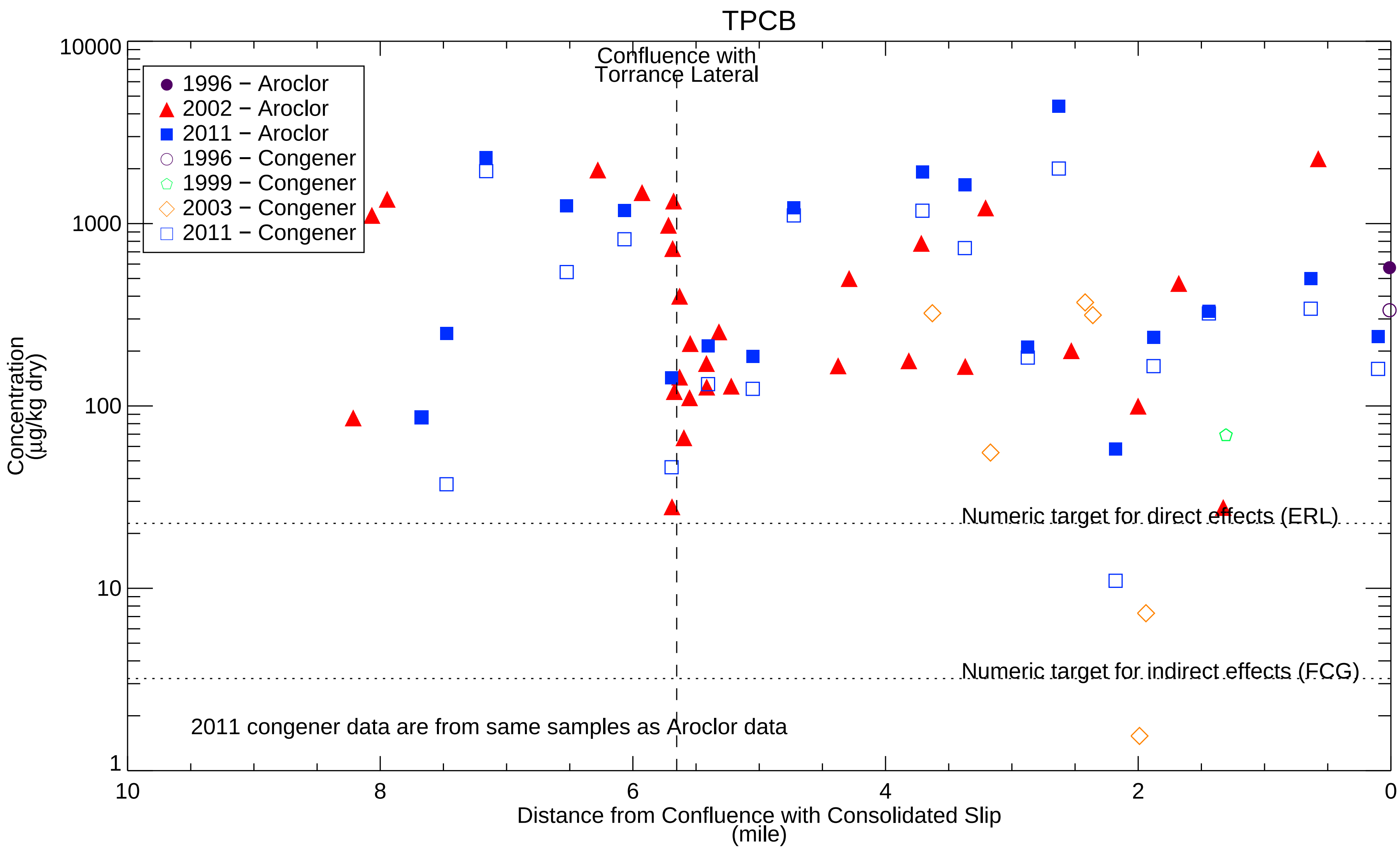


Figure B−17

Concentrations of TPCB in Sediment from Dominguez Channel Estuary (Maximum Regardless of Depth)

Torrance Lateral (TL), Kenwood Drain (KD), and Dominguez Channel Upstream of Estuary Above Vermont Ave (DCU) data from 2002 are not shown.
Non−detects set to half reporting limit (not shown as different symbols; MDL not available). Duplicates averaged.
Databases = Sed_DBcomb_NDhalfMDL_tot_20140229_alignTOC_20140301.bin, Sed_DBcomb_NDhalfMDL_indv_20140229.bin

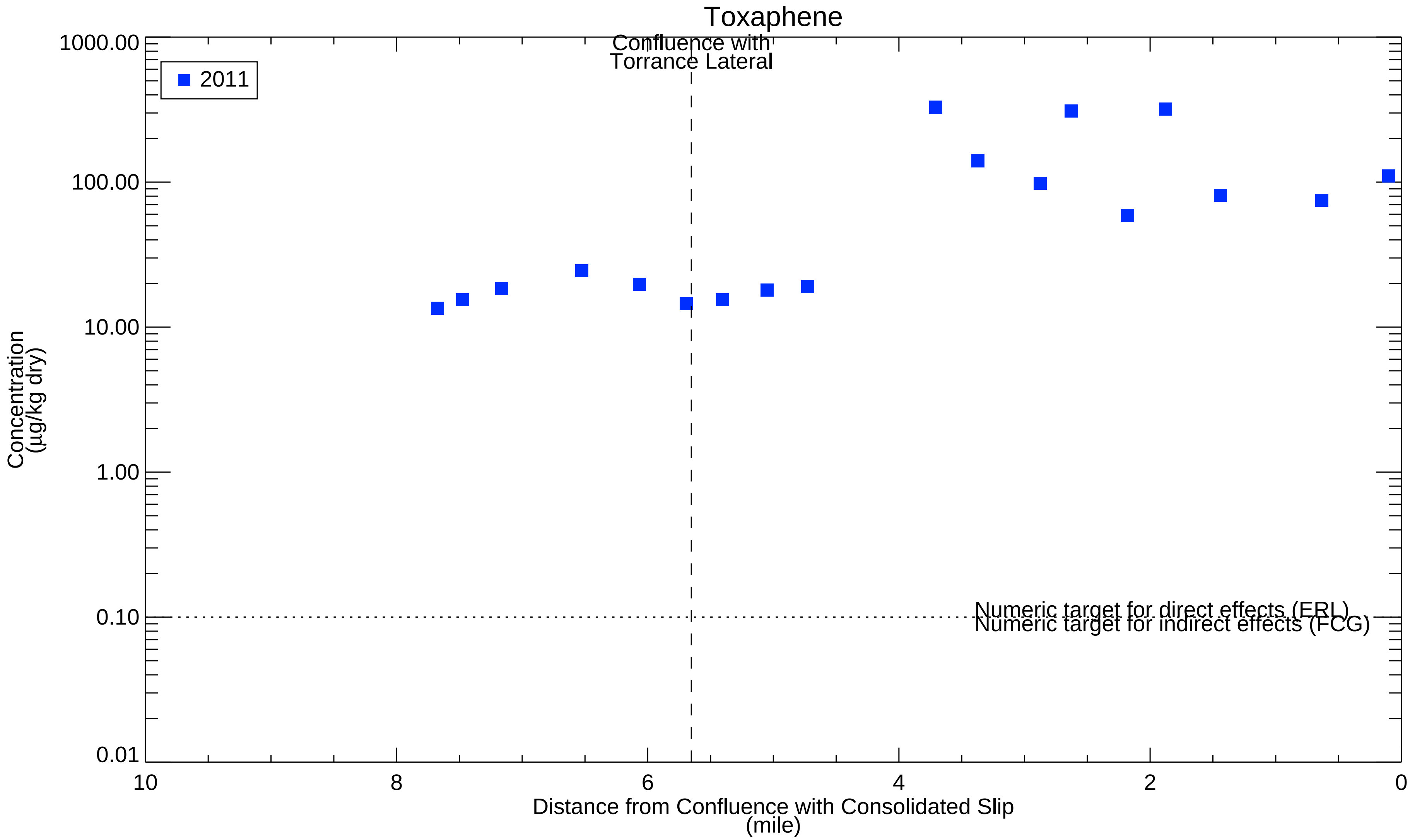


Figure B−18

Concentrations of Toxaphene in Sediment from Dominguez Channel Estuary (Maximum Regardless of Depth)

Torrance Lateral (TL), Kenwood Drain (KD), and Dominguez Channel Upstream of Estuary Above Vermont Ave (DCU) data from 2002 are not shown.
Non−detects set to half reporting limit (not shown as different symbols; MDL not available). Duplicates averaged.
Databases = Sed_DBcomb_NDhalfMDL_tot_20140229_alignTOC_20140301.bin, Sed_DBcomb_NDhalfMDL_indv_20140229.bin

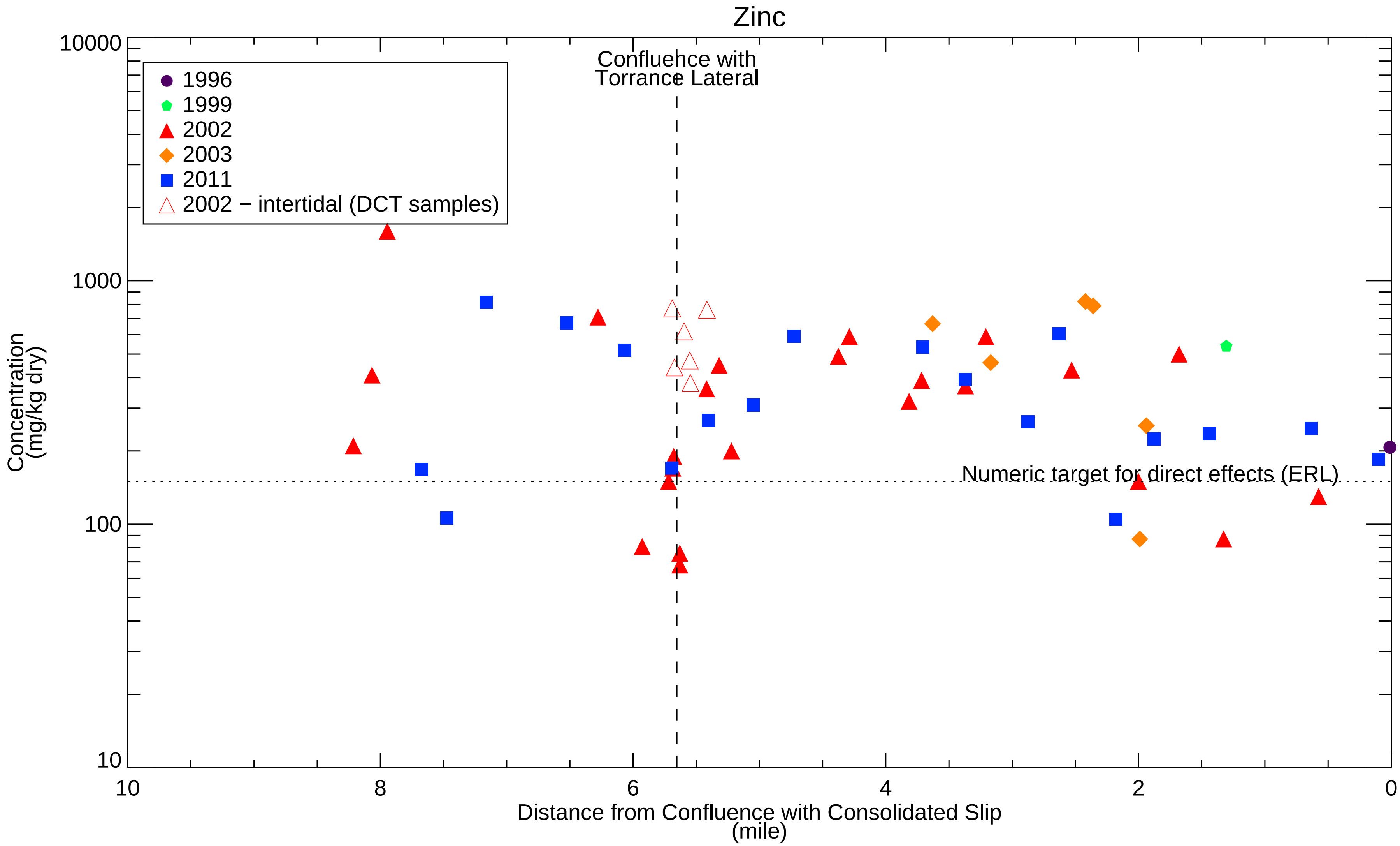


Figure B−19

Concentrations of Zinc in Sediment from Dominguez Channel Estuary (Maximum Regardless of Depth)

Torrance Lateral (TL), Kenwood Drain (KD), and Dominguez Channel Upstream of Estuary Above Vermont Ave (DCU) data from 2002 are not shown.
Non−detects set to half reporting limit (not shown as different symbols; MDL not available). Duplicates averaged.
Databases = Sed_DBcomb_NDhalfMDL_tot_20140229_alignTOC_20140301.bin, Sed_DBcomb_NDhalfMDL_indv_20140229.bin

APPENDIX B
PRINCIPLES FOR EVALUATING REMEDIAL OPTIONS FOR CONTAMINATED SEDIMENT SITES

Principles for Evaluating Remedial Options for Contaminated Sediment Sites

Steven C. Nadeau (snadeau@honigman.com) and Megan C. McCulloch (Honigman Miller Schwartz and Cohn LLP, Detroit, MI), Todd S. Bridges (U.S. Army Engineer Research and Development Center, Vicksburg, MS)

ABSTRACT: The complexity inherent in contaminated sediment sites requires that they undergo a detailed evaluation of site conditions and sediment management options in order to optimize the effectiveness of their potential remediation and risk reduction. Experiences gained at numerous sediment sites over the last 20 years can be tapped by Project Managers in the form of lessons learned. This knowledge should be integrated into the decision-making process as recommended by the U.S. EPA Contaminated Sediment Remediation Guidance For Hazardous Waste Sites (2005). This paper will review risk management principles for complex contaminated sediment sites and several of the key risk-based decision-making factors necessary to realistically evaluate the potential risk reduction associated with each remedial option.

INTRODUCTION

Contaminated sediment is pervasive across the United States. In 2004, U.S. EPA identified 96 watersheds as containing "areas of probable concern," defined as areas where fish and benthic organisms may be frequently exposed to contaminated sediment (U.S. EPA 2004). As of September 2005, through U.S. EPA's Superfund program, remedies have been selected for over 150 contaminated sediment sites, of which over 65 are large enough to be tracked at the national level (U.S. EPA 2008). Investigations are on-going at over 50 other contaminated sediment sites (U.S. EPA 2008).

Sediment sites pose challenging technical problems and addressing these problems consumes an enormous amount of resources. There are over 11 Superfund "mega" sites where the cost of the sediment remedy exceeded $50 million (U.S. EPA 2008). A number of other sites are expected to become "mega" sites as site investigations are completed and remedies are selected for them. An example of the high cost of remediating contaminated sediment is the Fox River's Operable Units 2 – 5, where the sediment remedy was estimated to cost $390 million in the Amended Record of Decision (U.S. EPA and WDNR 2007). Moreover, the cost estimate for remediating approximately 75 million cubic yards of contaminated sediment within Great Lakes Areas of Concern ranged from $1.5 billion to $4.5 billion, depending on the types of remedies selected (Great Lakes Regional Collaboration 2005).

Due to the number, size, and high cost of sediment sites across the U.S., efficient and effective remediation of these sites will require a decision-making process that integrates the key lessons learned from the remediation efforts at numerous sediment sites over the last 20 years and the application of risk-management principles in a comprehensive remedy evaluation process. Key considerations in remedy evaluation and selection are discussed and key questions to consider when evaluating and selecting remedies are presented.

RISK MANAGEMENT PRINCIPLE #1: SOURCE CONTROL

The first principle for managing risks associated with contaminated sediment sites is to "Control Sources Early" (U.S. EPA 2002). Identifying and controlling sources prior to conducting remediation is critical to the effectiveness of any sediment cleanup (U.S. EPA 2005). Without source control, the site may become recontaminated.

The risk of recontamination is not theoretical. A 2007 survey of recently completed contaminated sediment remedial actions identified 20 sites in which sediment had become recontaminated (Nadeau and Skaggs 2007). Common sources of recontamination are combined sewer overflows, storm sewer outfalls, other point sources, other sediment sources, including upstream sources and unremediated nearby sediments, runoff, atmospheric deposition, and contaminated groundwater advection (U.S. EPA 2002; U.S. EPA 2005; Nadeau and Skaggs 2007). Thus, prior to initiating any sediment cleanup, project managers should identify and control existing sources, consider whether there is a potential for recontamination and factor that potential into the remedy selection process. Table 1 identifies key questions to consider regarding source control.

TABLE 1. Key source control questions to consider during site evaluation and remedy evaluation and selection (from Evison 2008).

- What steps have been taken to identify sources and are these steps sufficient?
- Have continuing sources been identified?
- Will all continuing sources be controlled prior to remediation?
- If not, should remediation proceed and what accommodations/expectations/plans exist about those sources?

A VALUABLE TOOL: CONCEPTUAL SITE MODEL

A conceptual site model (CSM) represents the current understanding of the site conditions by incorporating information about contaminant sources, transport pathways, exposure pathways and receptors (U.S. EPA 2005). The CSM not only summarizes much of the information related to site risks to human and ecological receptors, it identifies the nature and source of the risk. This identification of the site's risk drivers can be used to evaluate which of the proposed remedial alternatives would effectively mitigate site risks to human and ecological receptors by addressing the site elements that are creating the risks (U.S. EPA 2005). Therefore, the value of a CSM for evaluating the potential effectiveness of remedial alternatives should not be underestimated. Table 2 identifies key questions to consider regarding the CSM.

TABLE 2. Key CSM questions to consider during site evaluation and remedy evaluation and selection (adapted from Evison 2008).

- Have the following data been collected and evaluated in developing the conceptual site model?
  -- Sources of contaminants of concern
  -- Human exposure pathways
  -- Human receptors
  -- Biota exposure pathways
  -- Ecological receptors
  -- Contaminant transport pathways
- If not, why not?
- What are the principal contaminants of concern and exposure pathways driving unacceptable risk at the site?
- Which exposure pathways are relatively unimportant and can be excluded from further consideration?

STABILITY OF CONTAMINANTS IN SEDIMENT

A key component of the CSM is its representation of the stability of contaminants in sediment (U.S. EPA 2002; U.S. EPA 2005). Although sediment moves over time in most aquatic environments, the most important consideration is whether movement of the contaminants in sediment is occurring at a scale and rate that poses risks to human health and ecological receptors (U.S. EPA 2005). Thus, it is important to evaluate the stability of contaminants in sediment and how it affects risk rather than just the movement and/or stability of sediment without reference to risk. Table 3 identifies key questions to consider regarding the stability of contaminants in sediment.

TABLE 3. Key stability of contaminants in sediment questions to consider during site evaluation and remedy evaluation and selection (adapted from Evison 2008).

• Have the appropriate lines of evidence been evaluated on the potential stability of the contaminants present in the sediment (as opposed to sediment stability per se)?
• Does contaminant fate and transport through in-place sediment potentially pose an unacceptable risk to human health and ecological receptors? Is movement of contaminated sediment (surface and subsurface) or of contaminants alone occurring or may occur at scales and rates that will significantly change their current contribution to human health and ecological risk? -- Are they contributing to risk now? -- Are they likely to contribute to risk in the future?
• If yes, can in-situ remedies (e.g., capping, MNR) be designed to adequately reduce risk to human health and ecological receptors?

EVALUATING REMEDIAL ALTERNATIVES AND SELECTING A REMEDY

There are several key concepts that should be applied when evaluating remedial alternatives and selecting a remedy. These concepts are discussed below.

Remedial Action Objectives. To develop and evaluate remedial alternatives, a description should be developed of what risk reduction the cleanup is expected to accomplish (U.S. EPA 2005). These general statements, remedial action objectives (RAOs), are derived from the understanding of exposure pathways, receptors, and risks gained during development of the CSM and from risk assessments. RAOs should reflect objectives that are achievable from remediation of the site. Some goals, such as lifting a fish consumption advisory, may require watershed level actions that are outside the scope of the site cleanup and may not be achievable on a short-term or even a long-term basis regardless of the subject site's remediation success (U.S. EPA 2005). From the RAOs, contaminant-specific risk-based remediation goals and sediment cleanup levels should be developed (U.S. EPA 2002; U.S. EPA 2005).

Comparative Net Risk. U.S. EPA recommends using a risk management process "to select a remedy designed to reduce the key human and ecological risks" (U.S. EPA 2005). Considerations in the risk management process for contaminated sediment sites include (U.S. EPA 2005; Nadeau 2008):

- There is no presumptive remedy for any contaminated sediment site, regardless of the contaminant or level of risk;
- Risks must be characterized over appropriate timeframes;
- Management goals must be framed within a realistic time period;
- Risk management actions must be linked to reduction of significant human and ecological risks;

- Ecological risks are characterized at a level of assessment appropriate for the site;
- All implementation and residual risks of the remedial alternatives must be considered.

An approach recommended by U.S. EPA and the National Academy of Sciences Committee on Remediation of PCB-Contaminated Sediments that incorporates these considerations is comparative net risk evaluation (CNRE) (NRC 2001; U.S. EPA 2005). Use of CNRE ensures that on a site-specific basis decision-makers consider, at the remedy selection stage, not only the benefits of a remedial approach, but also the residual risks associated with the approach and the risks associated with implementing the remedial approach (U.S. EPA 2005; Nadeau 2008). This differs from the traditional approach of either considering implementation risks at the remedy implementation stage or assuming that remedial approaches will be 100% effective on implementation thereby bypassing any consideration of residual risk. CNRE is consistent with the National Oil and Hazardous Substances Pollution Contingency Plan's (NCP) 9 criteria (40 CFR §300.430(e)(9)(iii)), which require evaluation and balancing of short-term and long-term risks and benefits, including residual risk. Failure to account for implementation risks and residual risk during the remedy evaluation stage can skew remedy selection and result in a less effective and less protective remedy than anticipated, a result neither regulators nor the responsible parties should find acceptable.

Specific Remedy Implementation Risks. Each remedy has its own uncertainties and potential implementation risks. For MNR, the risk present at the time of remedy selection should decrease with time (U.S. EPA 2005). The implementation risks associated with MNR are mostly related to continued exposure to contaminants while natural processes work to reduce contaminant bioavailability. Institutional controls may be useful to address risks to human health during MNR implementation (e.g., fish consumption advisories) (U.S. EPA 2005).

For capping, the risk due to direct exposure to contaminated sediment should decrease rapidly as the cap is placed (U.S. EPA 2005). Implementation risks may include contaminant releases during placement of the cap, impacts on the community (e.g., noise, accidents, residential or commercial disruption), construction-related risks to workers during transport and placement of cap materials, and disruption of the benthic community (U.S. EPA 2005). Cap design and placement techniques may be useful in mitigating some construction-related implementation risks (U.S. EPA 2005).

During dredging, risks to human health and ecological receptors may increase due to increased exposure to contaminants resuspended and released to the surface water (U.S. EPA 2005; NRC 2007; Bridges *et al.* 2008). For example, during the 1995 Non-Time Critical Removal Action (NTCRA) in the Grasse River, caged fish deployed along the perimeter of a set of 3 silt curtains for 6 weeks showed several-fold increases in PCB concentrations compared to those observed in the pre-dredging period (NRC 2007). Lessons learned from the 1995 NTCRA and dredging projects at other sites over 10 additional years did not prevent a similar impact to Grasse River fish during the 2005 Remedial Options Pilot Study dredging (NRC 2007). PCB concentrations increased substantially in fish during the 2005 dredging pilot (NRC 2007).

In addition to the effects of releases at the site, resuspended and released contaminants may be transported downstream from the site. For example, at the Fox River Deposit 56/57 dredging project, 2.2% of the mass of contaminants dredged were released downstream (Steuer 2000).

Although there are no standardized best management practices for environmental dredging, lessons learned from other similar sites may yield some useful techniques for reducing resuspension and releases during dredging (U.S. EPA 2005; NRC 2007). Of late, the effectiveness of silt curtains in controlling releases has been questioned (Bridges *et al.* 2008), as evidenced by the Grasse River fish examples. Because some contaminant release and transport during dredging is inevitable, it must be considered during the alternatives evaluation (U.S. EPA 2005).

Other dredging implementation risks may include impacts on the community (e.g., noise, accidents, residential or commercial disruption), construction-related risks to workers during sediment removal and handling, and disruption of the benthic community (U.S. EPA 2005). Implementation risks are site-specific and remedy-specific and must be considered during remedy evaluation and selection (U.S. EPA 2005). Failure to adequately consider implementation risks may skew remedy selection and result in a less protective remedy than anticipated.

Residual Risk. Residual risk is the risk to human health and ecological receptors from contaminated materials or residuals that remain after remedial action has been concluded (U.S. EPA 2005). All remedial approaches leave some contaminants in place after remedial actions are complete (U.S. EPA 2005). The source of residual risk varies for each remedial approach and should be evaluated on a site-specific basis.

For MNR, residual risk is generally related to the possibility that clean sediment overlying buried contaminants may move to such an extent that unacceptable risk is created or that groundwater flow, bioturbation, or other mechanisms may move buried contaminants to the surface in an amount and at a rate that could cause unacceptable risk to human health or ecological receptors (U.S. EPA 2005). Institutional controls and monitoring may be used to address residual risk. Table 4 identifies key questions to consider regarding residual risk following a MNR remedy.

TABLE 4. Key questions to evaluate residual risk from a MNR remedy (adapted from Evison 2008).

- What evidence is there that the system is recovering? Is the pattern of recovery expected to change in the future? If so, how will it change? Will the change result in unacceptable risk?
  -- If the change may result in an unacceptable risk, can institutional controls reduce human health risks?
- Is the rate of recovery sufficient to reduce risk within an acceptable time frame?
  -- If no, can the recovery process be accelerated by engineering means?
  -- If no, can human health risks be addressed by institutional controls?
- Are groundwater flow, bioturbation, or other mechanisms likely to move contaminants to the surface at a rate and concentration that may pose an unacceptable risk?
- Can a monitoring plan be designed to evaluate risk reduction and protectiveness?

For capping, residual risk is generally related to (1) the possibility of cap erosion or disruption exposing contaminants; (2) the potential for contaminants to migrate through the cap; and (3) risks from contaminants remaining in uncapped areas (U.S. EPA 2005). As with MNR, whether erosion or contaminant migration through the cap poses an unacceptable risk depends on the amount and rate of contaminant exposure due to those processes (U.S. EPA 2005). Cap monitoring, maintenance, and design and institutional controls may be used to address residual risk. Table 5 identifies key questions to consider regarding residual risk following capping.

TABLE 5. Key questions to evaluate residual risk from a capping remedy (adapted from Evison 2008).

- Is erosion or disruption of the cap likely to occur in a way that may pose an unacceptable risk?
  -- If likely, can cap design, maintenance, or institutional controls reduce risk to an acceptable level?
- Is contaminant migration through the cap likely to occur at a rate that may pose an unacceptable risk?
  -- If likely, can activated carbon or other material be incorporated into the cap to reduce risk to an acceptable level?
- Is NAPL migration through the cap likely to occur at a rate that may pose an unacceptable risk?
  -- If likely, can an impervious material or reactive material be incorporated into the cap to reduce risk to an acceptable level?
- Is gas migration through the cap likely to occur at a rate that may pose an unacceptable risk?
  -- If likely, can the cap be designed to reduce risk to an acceptable level?
- Can the monitoring plan be designed to detect significant erosion or contaminant movement before unacceptable risk occurs?

For dredging, residual risk is primarily related to residuals, i.e., contaminated sediments remaining in the aquatic environment after the completion of dredging. (U.S. EPA 2005; NRC 2007; Bridges *et al*. 2008). Because residuals will occur to some degree with every dredging project (NRC 2007), they should be considered during remedy evaluation and selection (U.S. EPA 2005). There are two types of residuals, undisturbed and generated, both of which are important. Undisturbed residuals are contaminated sediments found at the post-dredge sediment surface that have been uncovered, but not fully removed as a result of the dredging operation (Patmont and Palermo 2007; Bridges *et al*. 2008). Generated residuals are contaminated sediments that are dislodged or suspended by the dredging operation and are subsequently redeposited on the bottom either within or adjacent to the dredging footprint (Patmont and Palermo 2007; Bridges *et al*. 2008). A series of dredging project results has shown that generated residuals ranged from 2 to 9% of the contaminant mass from the last production pass (Patmont and Palermo 2007). Lessons learned from previous dredging projects indicate that residuals are likely to be higher in areas where there are debris, rocks, bedrock, and/or hardpan as well as in areas with low dry density sediment (e.g., “fluff”) (U.S. EPA 2005; NRC 2007).

Residuals are not inconsequential. For example, during the 2005 Remedial Options Pilot Study at the Grasse River, the average surficial concentration of PCBs increased substantially immediately following dredging (NRC 2007). The increase occurred despite removing approximately 80% of the PCB mass in the dredging footprint (NRC 2007). Thus, mass removal did not equate to risk reduction in this more modern-day pilot (NRC 2007). Table 6 identifies key questions to consider regarding residual risk from dredging.

TABLE 6. Key questions to evaluate residual risk from a dredging remedy (adapted from Evison 2008).

- Is it likely that resuspension will pose an unacceptable risk?
- Is it likely that releases will pose an unacceptable risk?
- Is it likely that residuals will pose an unacceptable risk?
- If residuals are estimated to exceed cleanup levels, should an engineered cap be considered as an alternative to dredging?
- If residuals are estimated to exceed cleanup levels, can cleanup levels be achieved with backfill? If so,

how is the backfill intended to function? -- If it is intended as a dilution layer - Is the added material going to change the amount of contaminant mass that is bioavailable? - Would thin layer placement without dredging be more appropriate? -- If it is intended as a cap - Has it been evaluated for erosion potential? - Has it been evaluated for the effects of groundwater advection? - Would engineered capping be more appropriate? • Can the monitoring plan be designed to ensure the backfill is functioning as designed?

Selecting A Remedy. Once the remedial alternatives have been evaluated, a risk-based decision-making process should be applied to select a remedy or combination of remedies that will effectively reduce risks to human health and ecological receptors (U.S. EPA 2005). This risk-based decision-making process includes the 9 criteria from the NCP and complies with the NCP (U.S. EPA 2005; Evison 2008). Table 7 identifies key remedy selection considerations.

TABLE 7. Key remedy selection principles (adapted from U.S. EPA 2005 and Evison 2008).

• There is no presumptive remedy for any contaminated sediment site, regardless of the contaminant or level of risk. • Risk management goals should be developed that can be evaluated within a realistic time period, acknowledging that it may not be practical to achieve all goals in the short term. • Evaluate uncertainties concerning the predicted effectiveness of various remedial alternatives and the time frames for achieving cleanup levels, remedial goals, and remedial action objectives. • Use realistic time frames for remedy design, implementation and completion, and incorporate risks associated with remedy implementation when comparing on-going risks • The effectiveness of in-situ (capping and MNR) and ex-situ (dredging) alternatives should be evaluated under the conditions present at the site. There should not be a presumption that removal of contaminated sediments from a water body will be more effective or permanent than capping or MNR. • Contaminants that are deeply buried, have no significant migration pathway to the surface, and are unlikely to be exposed in the future may not need removal because they do not necessarily contribute to site risks. • No remedy is perfect. A combination of sediment management options may be the most effective way to manage risk. • Developing accurate cost estimates is an essential part of evaluating alternatives. An important risk management function is to compare and contrast the cost and benefits of various remedies.

CONCLUSION

Contaminated sediment sites pose difficult challenges due to complex technical issues. Addressing these sites requires applying risk-management principles within a risk-management framework to remedy evaluation and selection. To be effective, this risk management framework must include consideration of implementation risks and residual risk at the remedy evaluation and selection phase. U.S. EPA's "Contaminated Sediment Remediation Guidance for Hazardous Waste Sites" provides such a framework.

REFERENCES

Bridges, T., S. Ells, D. Hayes, D. Mount, S. Nadeau, M. Palermo, C. Patmont, and P. Schroeder. 2008. *The Four Rs of Environmental Dredging: Resuspension, Release, Residual, and Risk*. ERDC/EL TR-08-4. U.S. Army Corps of Engineers, Engineer Research and Development Center. February 2008.

Evison, L. 2008. "Decision Tool for Remedy Evaluation". Presented at *Optimizing Decision-Making and Remediation at Complex Contaminated Sediment Sites Conference*, January 8-10, 2008, New Orleans, Louisiana. Conference jointly sponsored by U.S. Environmental Protection Agency, U.S. Navy Space and Naval

Warfare Systems Center, U.S. Army Corps of Engineers – Engineer Research and Development Center, and Sediment Management Work Group.

Great Lakes Regional Collaboration. 2005. *Strategy To Restore And Protect The Great Lakes*. December 2005.

Nadeau, S. and M. Skaggs. 2007. "Analysis of Recontamination of Completed Sediment Remedial Projects." Paper D-050 in *Proceedings, 4th International Conference on Remediation of Contaminated Sediments*, January 22-25, 2007, Savannah, GA. Battelle Press, Columbus, OH:

Nadeau, S. 2008. "Applying the Principles of Comparative Net Risk and Risk Management to Sediment Sites." Presented at *Optimizing Decision-Making and Remediation at Complex Contaminated Sediment Sites Conference*, January 8-10, 2008, New Orleans, LA. Conference jointly sponsored by U.S. Environmental Protection Agency, U.S. Navy Space and Naval Warfare Systems Center, U.S. Army Corps of Engineers – Engineer Research and Development Center, and Sediment Management Work Group.

NRC. 2001. *A Risk-Management Strategy for PCB-Contaminated Sediments*. National Research Council. National Academies Press, Washington, DC.

NRC. 2007. *Sediment Dredging at Superfund Megasites: Assessing the Effectiveness*. National Research Council. National Academies Press, Washington, DC.

Patmont, C., and M. Palermo. 2007. "Case Studies of Environmental Dredging Residuals and Management Implications." Paper D-066 in *Proceedings, 4th International Conference on Remediation of Contaminated Sediments*, January 22-25, 2007, Savannah, GA. Battelle Press, Columbus, OH.

Steuer, J. 2000. *A Mass-Balance Approach for Assessing PCB Movement During Remediation of a PCB-Contaminated Deposit on the Fox River, Wisconsin*. USGS Water Resources Investigation Report 00-4245.

U.S. EPA. 2002. *Principles for Managing Contaminated Sediment Risks at Hazardous Waste Sites*. OSWER Directive 9285.6-08. February 2002.

U.S. EPA. 2004. *The Incidence and Severity of Sediment Contamination in Surface Waters of the U.S., National Sediment Quality Survey: Second Edition*. EPA-823-R-04-007. November 2004.

U.S. EPA. 2005. *Contaminated Sediment Remediation Guidance for Hazardous Waste Sites*. OSWER Directive 9355.0-85.

U.S. EPA and WDNR. 2007. *Record of Decision Amendment, Lower Fox River and Green Bay Superfund Site*. U.S. Environmental Protection Agency and Wisconsin Department of Natural Resources. June 2007.

U.S. EPA. 2008. "Contaminated Sediments in Superfund." http://www.epa.gov/superfund/health/conmedia/sediment/index.htm. Website last visited January 14, 2009.