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Two Total Maximum Daily Loads for Chlordane in Clear Creek

For Segments 1101 and 1102

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TEXAS NATURAL RESOURCE CONSERVATION COMMISSION

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Introduction

Section 303(d) of the Clean Water Act requires all states to identify waters that do not meet, or are not expected to meet, applicable water quality standards. For each listed water body that does not meet a standard, states must develop a total maximum daily load (TMDL) for each pollutant that has been identified as contributing to the impairment of water quality in that water body. The Texas Natural Resource Conservation Commission (TNRCC) is responsible for ensuring that TMDLs are developed for impaired surface waters in Texas.

In simple terms, a TMDL is a quantitative plan that determines the amount of a particular pollutant that a water body can receive and still meet its applicable water quality standards. In other words, TMDLs are the best possible estimates of the assimilative capacity of the water body for a pollutant under consideration. A TMDL is commonly expressed as a load, with units of mass per unit of time, but may be also be expressed in other ways. TMDLs must also estimate how much the pollutant load needs to be reduced from current levels in order to achieve water quality standards.

The Total Maximum Daily Load Program, a major component of Texas' statewide watershed management approach, addresses impaired or threatened streams, reservoirs, lakes, bays, and estuaries (water bodies) in or bordering the state of Texas. The primary objective of the TMDL Program is to restore and maintain the beneficial uses (such as drinking water, recreation, support of aquatic life, or fishing) of impaired or threatened water bodies.

Section 303(d) of the Clean Water Act and the U.S. Environmental Protection Agency's (EPA) implementing regulations (40 Code of Federal Regulations, Section 130) describe the statutory and regulatory requirements for acceptable TMDLs. The TNRCC guidance document, *Developing Total Maximum Daily Load Projects in Texas* (GI-250, 1999), further refines the process for Texas. This TMDL document has been prepared in accordance with these guidelines, and is composed of the following six elements:

- Problem Definition
- Endpoint Identification
- Source Analysis
- Linkage Between Sources and Receiving Water
- Margin of Safety
- Pollutant Load Allocation

This TMDL document was prepared by the TMDL Team in the Strategic Assessment Division of the Office of Environmental Policy, Analysis, and Assessment of the Texas Natural Resource

Conservation Commission. It was adopted by the Texas Natural Resource Conservation Commission on January 17, 2001. Upon adoption, the TMDL became part of the state Water Quality Management Plan. The Texas Natural Resource Conservation Commission will use this document in reviewing and making determinations on applications for storm water permits and in its nonpoint source pollution abatement programs.

Background Information

These TMDLs address the contamination of fish tissue by chlordane in portions of two classified segments of Clear Creek in Harris, Galveston, Fort Bend, and Brazoria Counties in southeast Texas. Chlordane here refers to technical chlordane (CAS 12789-03-6), a mixture of chlorinated hydrocarbons including cis-chlordane, trans-chlordane, cis-nonachlor, trans-nonachlor, heptachlor, octachlordane, chlordene isomers, and other compounds.

Chlordane is a legacy pollutant, a term used to describe substances whose use has been banned or severely restricted by the U.S. Environmental Protection Agency (EPA). Because of their slow rate of decomposition, many of these substances frequently remain at elevated levels in the environment for many years after their widespread use has ended. No additional loading of legacy pollutants is allowed or expected due to the EPA restrictions. Gradual declines in environmental legacy pollutant concentrations occur as a result of natural attenuation processes.

EPA guidance (*Draft Guidance for Water Quality-Based Decisions: The TMDL Process, Second Edition*, EPA 841-D-99-001, 1999) on the development of TMDLs offers flexibility in addressing particular situations and unusual circumstances, allowing States the discretion to adopt different approaches where appropriate. The guidance states that the allowable pollutant load "must be expressed in a manner ... that represents attainment and maintenance of water quality standards." The guidance allows for the use of a surrogate target for situations where "no .... quantifiable pollutant load can be used to .... express the TMDL."

In preparing these TMDLs for legacy pollutants, the TNRCC has refined the typical loading allocation approach of a TMDL, which limits the amount of a pollutant that can be added to an impaired water body. Because these legacy pollutants are already restricted, and no significant additional loading is expected, these TMDLs do not specifically attempt to quantify allowable loads for these contaminants. The ultimate goal of these TMDLs is the reduction of fish tissue contaminant concentrations to levels that constitute an acceptable risk to consumers, allowing TDH to remove the bans on fish consumption and the beneficial use to be restored to these water bodies.

Problem Definition

Clear Creek was included on the State of Texas 1998, 1999, and 2000 §303(d) lists (see corresponding *State of Texas Clean Water Act Section 303(d) List and Schedule of Development of Total Maximum Daily Loads*, SFR-58) as a result of the issuance of a fish consumption advisory by the Texas Department of Health (TDH) on November 18, 1993. TDH advised against consuming fish from Clear Creek upstream and west of State Highway 3. The fish consumption advisory was issued following determinations of unacceptable human health risk due to elevated concentrations of chlordane and volatile organic chemicals including dichloroethane and trichloroethane in fish tissue. The impacted portions of Clear Creek and their watersheds lie within Harris, Galveston, Fort Bend, and Brazoria counties in the San-Jacinto-Brazos Coastal Basin (see Figure 1).

- Segment 1102 (Clear Creek Above Tidal) extends from Rouen Road in Fort Bend County to a point 100 meters upstream of FM 528 in Galveston/Harris County, where it meets segment 1101. The fish consumption advisory applies to the entire 47 kilometer length of segment 1102.
- Segment 1101 (Clear Creek Tidal) extends downstream from 100 meters upstream of FM 528 to its confluence with Clear Lake 2.0 miles downstream of El Camino Real in

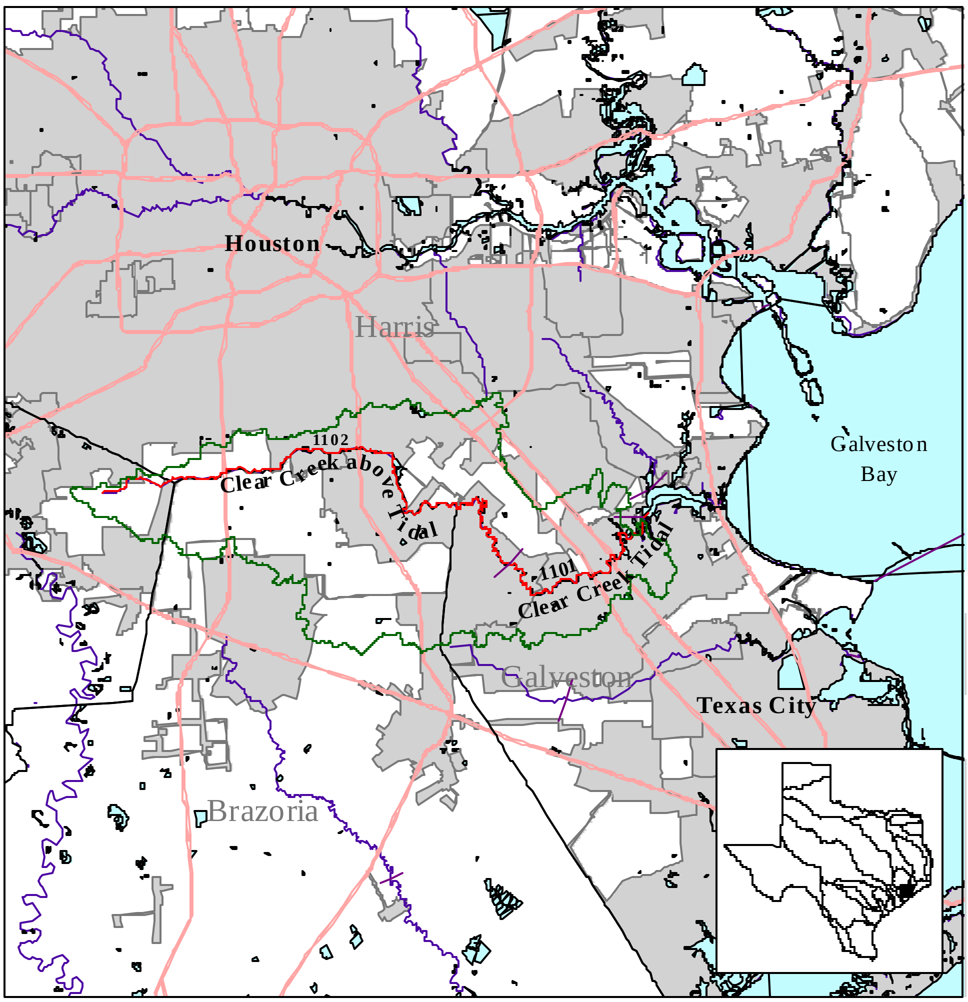

Figure 1. Study Area -- Clear Creek Watershed.

Galveston/Harris County. The fish consumption advisory applies to the upper 15 kilometers of Segment 1101, to State Highway 3 in Webster.

Organochlorine insecticides such as chlordane were widely used in the U.S. prior to EPA restriction, and are common environmental contaminants (Moore and Ramamoorthy 1984; Schmitt *et al*. 1985, 1990; Smith *et al.* 1988; USGS 2000). Chlordane is a frequent cause of fish consumption advisories in the U.S. (EPA 1999b), and elevated concentrations are often found in game fish tissue (Kuehl et al. 1994). Fish consumption can be a primary route of human exposure to chlordane (Humphrey 1987; Fiore *et al*. 1989), which can cause a variety of adverse health effects (Longnecker *et al.* 1997). Risk assessments that resulted in the fish consumption bans in these waters were made on the basis of a carcinogenic risk of liver cancer and a noncarcinogenic risk of adverse liver effects due to fish tissue contaminant levels (see TDH 1993).

Endpoint Identification

The ultimate goal of this TMDL is the reduction of chlordane concentrations in fish tissue to levels that constitute an acceptable risk to fish consumers, allowing TDH to remove chlordane from the fish consumption advisory. The allowable load of chlordane is based on fish tissue concentrations.

EPA (1997a) provides guidance for assessing contaminant data for risk assessment. This guidance and TDH assumptions were used to develop target values for tissue contaminant levels that result in an acceptable risk level. EPA (1997a) presents equations for calculating the maximum allowable fish consumption rate given consumer body weight, contaminant concentration, an acceptable cancer risk level, and the contaminant risk values for carcinogenic and noncarcinogenic risk. A cancer potency value (q_1*) is the risk value for carcinogens. The oral reference dose (RfD) is the risk value used to protect against chronic exposure by noncarcinogens.

The consumption rate and consumer body weight were set at the TDH constants of 30 grams of fish per day (0.03 kg/d) for a 70-kg adult, and at 15 grams of fish per day (0.015 kg/d) for a 15- and 35-kg child, both over a 30-year time period. TDH uses an acceptable cancer risk level of 1 x 10^{-4}, adjusted to 2.33 x 10^{-4} to account for the use of the 30-year time period. Cancer potency and chronic RfD values (Table 1) were obtained from EPA (1997a) and the EPA IRIS database.

Equations in EPA guidance (1997a) were solved to calculate the maximum allowable concentration of contaminant in tissue (1) at a given cancer risk level, and (2) based on the noncarcinogenic health effects of a contaminant:

(1) $$C_m = (ARL)(BW) / (C_{lim})(q_1^*)$$

(2) $$C_m = (RfD)(BW) / (C_{lim})$$

where

C_m = maximum allowable concentration of contaminant in tissue (mg/kg)
ARL = acceptable cancer risk level = 2.33 x 10^{-4}
BW = consumer body weight (kg)
C_{lim} = allowable fish consumption rate (kg/d)
q_1* = cancer slope factor for given contaminant (see Table 2)
RfD = oral reference dose for given contaminant (see Table 2).

Substituting adult and child consumption rates and body weights used by TDH, the maximum tissue contaminant concentrations that can be consumed within an acceptable level of risk were calculated (see Table 2).

Table 1. Maximum fish tissue concentrations (mg/kg) for individual contaminants that can be ingested by consumers of given body weights, within the acceptable cancer risk level (ARL) used by TDH, and without causing adverse noncarcinogenic health effects. Carcinogenic (q_1*) and noncarcinogenic (RfD) risk values were obtained from EPA 1997a and the EPA IRIS database.

	Carcinogenic Risk ARL = 2.33 x 10^{-4}			Noncarcinogenic Risk		
	Maximum Fish Tissue Concentration (mg/kg)					
		Consumer Body WT.			Consumer Body WT.	
Contaminant	**q_1***	**15-kg**	**35-kg / 70-kg**	**RfD**	**15-kg**	**35-kg/70-kg**
Total Chlordane	0.35	0.67	1.5	5 x 10^{-4}	0.5	1.1

For chlordane, the target concentration that will achieve an acceptable noncarcinogenic risk is less than that needed for an acceptable carcinogenic risk. Both target concentrations for a 15-kg child are less than those of a 35-kg child and 70-kg adult (see Table 1). The noncarcinogenic values for a 15-kg child are therefore most protective, and these values become the endpoint targets for chlordane in Clear Creek (Table 2). Other contaminants do not contribute substantially to risk.

Table 2. Most protective endpoint target for fish tissue contamination in each §303(d) list water body that will allow removal of the TDH fish consumption ban.

Segment	**Primary Endpoint Target**
Clear Creek Tidal (1101)	≤ 1.1 mg/kg chlordane in fish tissue for adults ≤ 0.5 mg/kg chlordane in fish tissue for children
Clear Creek above Tidal (1102)	≤ 1.1 mg/kg chlordane in fish tissue for adults ≤ 0.5 mg/kg chlordane in fish tissue for children
All Water bodies	Removal of fish consumption bans

The TDH has the authority and jurisdiction for the decision to issue or remove fish consumption advisories and bans. Subsequent risk assessments by TDH may result in no change to an advisory, removal of the advisory, or a prohibition from taking of fish. The ultimate endpoint target for all water bodies is the protection of all groups and the complete removal of the fish consumption advisories.

Source Analysis

Production and use of legacy pollutants has been banned or severely restricted by the EPA. Because of their past heavy and widespread use, strong affinities for sorption to sediment organic matter and tissue, and slow rates of decomposition, these substances and/or their degradation products frequently remain at elevated levels in the environment for many years after widespread use has ended (Moore and Ramamoorthy 1984; Smith *et al.* 1988; Jones and de Voogt 1999; USGS 2000).

Chlordane was introduced in 1948, and was used extensively as a broad spectrum insecticide to control soil insects on agricultural crops, as a home lawn and garden insecticide, as a fumigating agent, and for termite control (EPA 1980; Dick 1982; Dearth and Hites 1991). EPA suspended use of chlordane on food crops in 1978, and phased out other above-ground uses over the following five years (EPA 1997b; Mattina *et al.* 1999). All uses except underground application for termite control were banned in 1983 (Mattina *et al.* 1999). Manufacture and domestic sales were halted in 1987, and use of existing stores was allowed until April 1988 when all sale and use were terminated (Dearth and Hites 1991; EPA 1997b; Mattina *et al.* 1999).

Organochlorine insecticides have entered aquatic systems as a result of direct application to a water body, drift from aerial spraying, urban and agricultural runoff, spills, industrial and municipal wastewater discharges, and erosion of contaminated soils (Dick 1982; Smith *et al.* 1988; Van Metre *et al.* 1998). Studies that have examined the relationship between land use and contamination by legacy pollutants suggest that problems can originate from both urban and agricultural land uses, although determination of a specific source can be very difficult (Tate and Heiny 1996; Munn and Gruber 1997; Webster *et al.* 1998). Numerous studies have associated organochlorine pesticide residues in tissue and sediment with urban land uses (Stamer *et al.* 1985; Arruda *et al.* 1987; Smith *et al.* 1988; Pereira *et al.* 1996; Mattina *et al.* 1999; Black *et al.* 2000).

Linkage Between Sources and Receiving Waters

The time required for the reduction of legacy pollutant tissue concentrations to endpoint levels is a function of their persistence and fate in the environment. Organochlorine insecticides are extremely hydrophobic, and their affinity for sorption to soil and sediment, along with their tendency to partition into the lipid of aquatic organisms, determine their transport, fate, and distribution (Smith *et al.* 1988).

Numerous studies have documented the long-term persistence of organochlorine pesticides and their degradation products in soil. Pesticide residue concentrations in soils can span several orders of magnitude, and are a reflection of application history and loss rates (Lichtenstein *et al.* 1971; Harner *et al.* 1999). Heavily used pesticides will be present in higher concentrations years later. Degradation rates of organochlorine residues are highly variable, and soil half-lives of as much as 20 to 35 years have been reported (Nash and Woolson 1967; Dimond and Owen 1996; Mattina *et al.* 1999).

The primary method of transport of legacy pollutants into aquatic systems is by erosion of soil and attached contaminants (Munn and Gruber 1997). Aquatic sediments act as a reservoir for hydrophobic pesticides in aquatic systems (Moore and Ramamoorthy 1984). Contaminants may be present in sediment at concentrations that are orders of magnitude higher than in the water column, where they are typically very low or undetectable (see Smith *et al.* 1988). These contaminants degrade slowly, and may be present for long periods of time (Oliver *et al.* 1989; EPA 1999b). Van Metre *et al.* (1998) analyzed sediment core samples from 11 reservoirs, including White Rock Lake in Dallas, and determined mean sediment half-life to be 7.7 to 17 years for chlordane.

Sediments may act as long-term sources of contamination through desorption of contaminants, and as a result of the resuspension of sediment particles by disturbances (Oliver *et al.* 1989; Baker *et al.* 1991; Zaranko *et al.* 1997; Maher *et al.* 1999). Sediment-associated contaminants can be a long-term source of chronic toxicity to organisms that live or feed in contact with the sediments, and provide a source for the introduction of contaminants into the food web (Reynoldson 1987; Farrington 1991; Larsson 1986).

Organochlorine insecticides are highly lipophilic and rapidly accumulate in the tissue of aquatic organisms. Contaminant concentrations are found in fish tissue at levels considerably higher than that of the water column and sediments (Smith *et al.* 1988; Rinella *et al.* 1993; EPA 1997a, 1999b). Fish tissue contaminant concentrations can vary within the same water body (Stow *et al.* 1995; Lamon and Stow 1999), and among different fish species, size classes within a fish species, and various tissues within a fish (Swackhamer and Hites 1988; EPA 1997a).

A large number of factors have been found to influence contaminant uptake, accumulation, and elimination in fish and other aquatic organisms. Characteristics of fish species and their environments are very important to uptake and elimination processes (Swackhamer and Hites 1988). Fish characteristics include lipid content, age, length, weight, diet and feeding habits, reproductive status, contaminant transfer from females to young, growth dilution, metabolism, and other species-specific physiological factors. Environmental factors include contaminant levels in food items, trophic position and length of the food chain, habitat use and movement, seasonal variation in contaminant availability, water column contaminant concentration, and sediment contaminant concentration and bioavailability. The relative importance of these factors is much debated, and research has found the effects of many of them to be interrelated (Smith *et al.* 1988; Farrington 1991; Pritchard 1993; Jones and de Voogt 1999; Sijm *et al.* 2000).

Characteristics of the contaminants also affect their tissue concentrations. These factors include differences in isomer and residue bioavailability, equilibrium time, and susceptibility to uptake, biotransformation, and elimination. Schmitt *et al.* (1985) found that changes in tissue concentrations over time vary with differences in chlordane isomers.

The time necessary for a contaminant to reach equilibrium in tissue is variable, hard to determine, and generally very long. Stable organic compounds with low aqueous solubility, such as many legacy pollutants, generally exhibit the longest equilibrium times. Time to equilibrium is also a function of fish size, with larger fish accumulating contaminants at a slower rate (Smith *et al.* 1988).

Once equilibrium is reached, the time necessary for a contaminant to be eliminated from tissue is also long, often on the order of years, and variable, generally increasing with the hydrophobicity and lipophilicity of the compound (Larsson 1986). Contaminant elimination may occur through respiration, metabolism, egestion, growth dilution, and transfer to eggs or young (Sharpe and Mackay 2000). Elimination rates can also be affected by the form of the contaminant (Niimi and Oliver 1983; Sijm *et al.* 1992; de Boer *et al.* 1994). Delorme *et al.* (1999) suggest that hydrophobic contaminants may not remobilize from fish tissue unless severe nutritional stress occurs.

In addition to generally excluding the effects of contaminated sediment and food, most studies of contaminant uptake and elimination are relatively short-term laboratory experiments (de Boer *et al.* 1994; Sijm *et al.* 2000). Long-term field studies have generally found that elimination rates are considerably longer than in those measured in laboratory studies (de Boer *et al.* 1994; Delorme *et al.* 1999). The interval between bioconcentration and elimination may be too short in laboratory studies to allow equilibrium within all tissues, allowing elimination to proceed much faster than in a field situation. Published uptake and elimination rates derived from laboratory studies may not reflect field conditions, limiting their use for the prediction of contaminant behavior (Swackhamer and Hites 1988; de Boer *et al.* 1994).

Margin of Safety

The margin of safety is required in a TMDL in order to account for any uncertainty about the pollutant load and its association with water quality. The margin of safety may be an explicit component that leaves a portion of the assimilative capacity of a water body unallocated, or an implicit component established through the use of conservative analytical assumptions (EPA 1999a).

These TMDLs use an implicit margin of safety. EPA (1997a) guidance on the assessment of contaminant data for use in fish advisories contains an extensive discussion of the assumptions and uncertainties present in the calculation of fish consumption limits. Conservative assumptions and calculations are used throughout the guidance to provide a margin of safety for the various uncertainties. Strict criteria exist concerning the types of studies and the data required to support assumptions and calculations. Numeric adjustments are made for the extrapolation of study results from animals or humans to the general population, and to provide a conservative upper bound on cancer risk values and a conservative RfD for noncarcinogens. Adjustments are designed to provide a safe margin between observed toxicity and potential toxicity in a sensitive human.

EPA assumes no safe threshold for exposure to carcinogens. Any exposure is assumed to pose some cancer risk. Noncarcinogenic effects occur with chronic exposure over a significant period of time. The oral reference dose (RfD) is defined in EPA (1997a) as "an estimate (with uncertainty perhaps spanning an order of magnitude) of a daily exposure to the human population (including sensitive subgroups) that is likely to be without an appreciable risk of deleterious effects during a lifetime." Calculated RfDs reflect the assumption that, for noncarcinogens, a threshold exists below which exposure does not cause adverse health effects. RfD calculations use modifying and uncertainty factors to account for variables such as the variability of responses in human populations, differences in responses between animal study species and humans, and gaps in available data. The RfD is calculated so there is little probability of an adverse health effect due to chronic exposure to concentrations below the RfD (EPA 1997a).

Use of the most protective target concentration for single contaminants provides additional assurance that protection from both carcinogenic and noncarcinogenic effects will be achieved. Because the goal of this TMDL is removal of fish consumption bans through reduction of the consumption risk, the margin of safety inherent in the EPA guidance, combined with the conservative use of endpoint targets, will provide an adequate margin of safety for the protection of human health. The decline of tissue contaminant concentrations to within an acceptable level of risk will allow TDH to remove the fish consumption bans, which effectively restores the fish consumption use to these water bodies. The margin of safety is required in a TMDL in order to account for any uncertainty about the pollutant load and its association with water quality. These TMDLs use an implicit margin of safety, which is established through the conservative analytical assumptions in the EPA guidance on risk assessment and fish consumption, as well as the use of the most protective endpoint targets. These steps will provide an adequate margin of safety for the protection of human health and restoration of the fish consumption use in these water bodies.

Pollutant Load Allocation

Restrictions on the use of legacy pollutants generally have resulted in a slow but steady decline in environmental residues (Smith *et al.* 1988). Contaminant levels in lake sediment cores have shown good agreement with production and usage histories of the parent compounds, with peak concentrations appearing at the times of peak use (Ricci *et al.* 1983; Oliver *et al.* 1989; Van Meter and Callender 1997; Van Metre *et al.* 1998). Higher concentrations generally appeared deeper in the cores, indicating that input and accumulation were decreasing with time. Although residues continue to persist in deeper parts of the cores, burial by more recently deposited sediments may result in effective removal of the contaminants from bioavailability to aquatic life (Ricci *et al.* 1983).

Decreases in fish and human tissue concentrations of organochlorine insecticides have been observed where no major additional inputs are occurring (see Moore and Ramamoorthy 1984; Brown *et al.* 1985; Hovinga *et al.* 1992; Bremle and Larsson 1998). Reviews of tissue data collected from a variety of water bodies in northern Europe between 1967 and 1995 have found a significant decrease in organochlorine concentrations over time (Skåre *et al.* 1985; Bignert *et al.* 1998). Fish tissue concentrations of total DDT, chlordane, and dieldrin have declined across the U.S. since uses of these substances were discontinued (Schmitt *et al.* 1990; USGS 2000).

Continuing decreases in environmental legacy pollutant levels are expected, although the necessary time frame is subject to debate. Within the context of these TMDLs, legacy pollutants are considered background sources that reflect the site-specific application history and loss rates of the subject area. All continuing sources of pollutant loadings occur from nonpoint source runoff , leaching, or erosion of the various sinks that may exist within the watersheds. No authorized point source discharges of these pollutants are allowed by law. Therefore, any contribution from point source discharges would be the result of illegal disposal of these contaminants by customers of the treatment systems.

Continuing natural attenuation of these pollutants is expected via degradation and metabolism of the contaminants, burial of contaminated sediment through natural sedimentation in the urban lakes, and scouring and redistribution of sediments in the river.

Natural attenuation is generally a preferred option for the elimination of legacy pollutants. More drastic alternatives, such as sediment removal by dredging, can result in considerable habitat disturbance and destruction, and sediments resuspended during dredging further expose aquatic life to contaminants and the potential for additional uptake, cause abrasive damage to gills and sensory organs of fish and invertebrates, and interfere with fish prey selection (O'Brien 1990; Waters 1995). More drastic alternatives such as dredging or eradication of contaminated fish communities and restocking (O'Meara *et al.* 2000) are generally better justified at heavily contaminated sites impacted by point source discharges and major spills.

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