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# Organochlorine Pesticides in the Johnson Creek Basin, Oregon, 1988–2002



Scientific Investigations Report 2004-5061

U.S. Department of the Interior
U.S. Geological Survey

**Cover.**—**Left**, Agricultural land in the upper Johnson Creek Basin, **Right**, Pasture and recent urban development in the middle Johnson Creek Basin, **Bottom**, Johnson Creek 1 mile above its confluence with the Willamette River.

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# Conversion Factors

| Multiply | By | To obtain |
|---|---|---|
| **Length** | | |
| micrometer (μm) | 0.00003937 | inch (in) |
| **Mass** | | |
| microgram (μg) | 0.00000003527 | ounce (oz avoirdupois) |
| milligram (mg) | 0.00003527 | ounce |
| gram (g) | 0.03527 | ounce |
| **Concentration, By Volume** | | |
| micrograms per liter (μg/L) | 1 | parts per billion (ppb) |
| milligrams per liter (mg/L) | 1 | parts per million (ppm) |

# Organochlorine Pesticides in the Johnson Creek Basin, Oregon, 1988–2002

*By* Dwight Q. Tanner *and* Karl K. Lee

## Abstract

Organochlorine pesticides were detected in unfiltered samples from Johnson Creek that were collected during a storm in March, 2002. Total DDT (the sum of DDT and its metabolites), as well as dieldrin, potentially exceeded Oregon chronic, freshwater criteria at all four Johnson Creek stream-sampling sites. The total DDT criterion was also potentially exceeded at a storm drain at SE 45th Avenue and Umatilla Street.

The concentration of total DDT in water samples has decreased by an order of magnitude since previous sampling was done on Johnson Creek in 1989–1990. This decrease was probably due to the movement of these compounds out of the basin and to degradation processes. Concentrations and loads of the organochlorine pesticides were largest at the most upstream sampling site, Johnson Creek at Palmblad Road, which has historically been primarily affected by agricultural land cover. Concentrations and loads were smaller at downstream locations, and there were only a few detections from storm drains.

For the purposes of assessing trends in total DDT concentration in Johnson Creek, data for total suspended solids (TSS) were examined, because TSS is often correlated with DDT concentrations, and TSS data are collected routinely by regulatory agencies. As an intermediate step, linear regression was used to relate TSS (measured in the recent study) and turbidity (measured both in the earlier and in the recent studies). For 77 samples, TSS (in mg/L [milligrams per liter]) = 0.88 x Turbidity (in nephleometric turbidity units). The $r^2$ value was 0.82.

The TSS concentration (measured, or estimated by the regression) was compared to the concentration of total DDT using linear regression. The TSS concentration associated with meeting the Oregon water-quality criterion for total DDT was 15 to 18 mg/L in the lower and middle part of the basin and 8 mg/L in the upper reaches of the basin. This TSS/DDT relationship is based on only one storm and may not be valid for other conditions of streamflow and runoff. Dieldrin concentration was not well correlated with TSS.

Organochlorine compounds also were detected in significant concentrations in Kelley Creek, an important tributary to Johnson Creek, but quality-control considerations made it difficult to interpret some of the data. It does appear, however, that some of the metabolites of DDT were positively associated with TSS. The high concentrations of the DDT metabolites and dieldrin were correlated with agricultural areas.

## Introduction

Johnson Creek is a free-flowing stream in the Portland metropolitan area that has historically supported native fish populations, but it has a recent history of high pesticide concentrations (mostly organochlorine compounds), both in the water column and in streambed sediments. The U.S. Geological Survey (USGS), in cooperation with local jurisdictions, began an assessment of the hydrologic conditions in the Johnson Creek Basin and in March 2002 sampled Johnson Creek and storm drains for organochlorine compounds. In addition to the March 2002 sampling, samples were taken at several other sites in the basin by other agencies.

## Background

Unfiltered stream samples were collected during storms in 1989 and 1990 at multiple sites in the Johnson Creek Basin. These samples contained high total dichlorodiphenyltrichloroethane (DDT) as well as high dieldrin concentrations. (In this report, the term "total DDT" means the sum of the concentrations of DDT and its metabolites, dichlorodiphenyldichloroethylene (DDE) and dichlorodiphenyldichloroethane (DDD). Likewise, the term "DDX" refers generally to the occurrence of any combination of the DDT compounds and their metabolites.) The highest concentrations of total DDT from Johnson Creek samples for both the December 1989 and January 1990 storms were from the site at Regner Road at river mile (RM) 15.8 (fig. 1), where the peak concentrations were 0.86 µg/L (micrograms per liter) and 0.255 µg/L, respectively. The highest dieldrin concentrations were also at the Regner Road site, where the concentrations during the same two storms were 0.060 µg/L and 0.035 µg/L. DDX, as well as lindane and dieldrin, were detected at low concentrations in a storm drain (outfall) at SE 100th and Knapp during the January 1990 storm (Edwards, 1992).

Organochlorine compounds also were detected in unfiltered samples from Johnson Creek at Palmblad (RM 17.2) in 1994 (Harrison and others, 1995). In the 1994 study, of the 33 sites in the Willamette River Basin where pesticide analyses were done, total DDT and dieldrin were detected most frequently at Johnson Creek at Palmblad Road, with maximum concentrations of both compounds of about 0.02 µg/L.

DDT also has been detected in streambed sediments. Samples taken during low flow in August 1988 at nine sites on Johnson Creek indicated that the largest concentration of total DDT was at the most upstream sample site, Hogan Road, at RM 17.4 (Edwards and Curtiss, 1993). In a 1992 study of 14 sites in the Willamette River Basin, streambed sediment at the Hogan Road site had the highest concentrations of total DDT and dieldrin (Harrison and others, 1995).

Semipermeable membrane devices (SPMDs) were used in a study of the Lower Columbia River Basin (McCarthy and Gale, 1999), which included one site on Johnson Creek. The purpose of this study was to better understand the partitioning of organic compounds into lipids, as occurs in aquatic organisms. Levels of several organochlorine compounds, including DDX and dieldrin, were somewhat elevated in the SPMDs in 1997 and 1998 at the sampling site on Johnson Creek at Milwaukie (RM 0.7) compared to other sites in the Lower Columbia River Basin.

The organochlorine compounds DDT and dieldrin were some of the first organic pesticides developed. Their production has decreased because their use has become regulated or banned in the United States. The agricultural uses of chlordane, DDT, and dieldrin were banned in the early 1970s (U.S. Environmental Protection Agency, 1985), but chlordane was used for termite control until the late 1980s. Although there are no records to indicate the usage of these pesticides in the Johnson Creek Basin, annual use in the United States peaked in the mid-1960s for DDT (70,000 tons) and for aldrin/dieldrin (9,000 tons) (Smith and others, 1988, p. 27). Organochlorine compounds in general have a low solubility in water and a high environmental persistence (Witkowski and others, 1987).

Polychlorinated biphenyls (PCBs) are synthetic compounds that were widely used in electrical transformers in the 1960s and 1970s, but were banned in 1979. PCBs are almost insoluble in water and persist in the environment, so they can become concentrated in suspended-sediment particles.

Johnson Creek, one of the few free-flowing streams in the Portland metropolitan area, is a significant resource (Woodward-Clyde, 1995) and is the subject of a number of protective measures. Chinook salmon and steelhead, listed as protected under the Endangered Species Act, inhabit the creek. Johnson Creek was included in the State of Oregon, Department of Environmental Quality (ODEQ), 303(d) List of Impaired Waters in 1998 for DDT, dieldrin, fecal coliform bacteria, and temperature. In 2002, PCBs and polycyclic aromatic hydrocarbons were added to the 303(d) list (Oregon Department of Environmental Quality, 2003a). The ODEQ is in the process of developing Total Maximum Daily Load (TMDL) allocations for total DDT, dieldrin, temperature, and bacteria.

## Purpose and Scope

In 1998, the U.S. Geological Survey (USGS) entered into a cooperative study with the City of Portland, Bureau of Environmental Services, to study hydrologic conditions in the Johnson Creek Basin. The primary focus of the original study was to better understand ground-water-caused flooding problems in the basin and to provide streamflow and water-quality data that would be of use to the public and to resource managers. The study was expanded in subsequent years to include support from the Cities of Gresham and Milwaukie, and Clackamas and Multnomah Counties. Monitoring of the quantity and quality of surface water and ground water has led to a better understanding of the hydrology in the basin. The study was further expanded in 2002 to include intensive sampling for specific water-quality parameters to provide additional data for development of TMDLs for total DDT, dieldrin, and bacteria in the basin.

This report contains previously unreported organochlorine-pesticide data from four stream sites and two storm drains, all sampled during a storm from March 11 to March 13, 2002. These results are compared with those from other organochlorine-compound samplings over the past decade. The interpretations of these data were used to
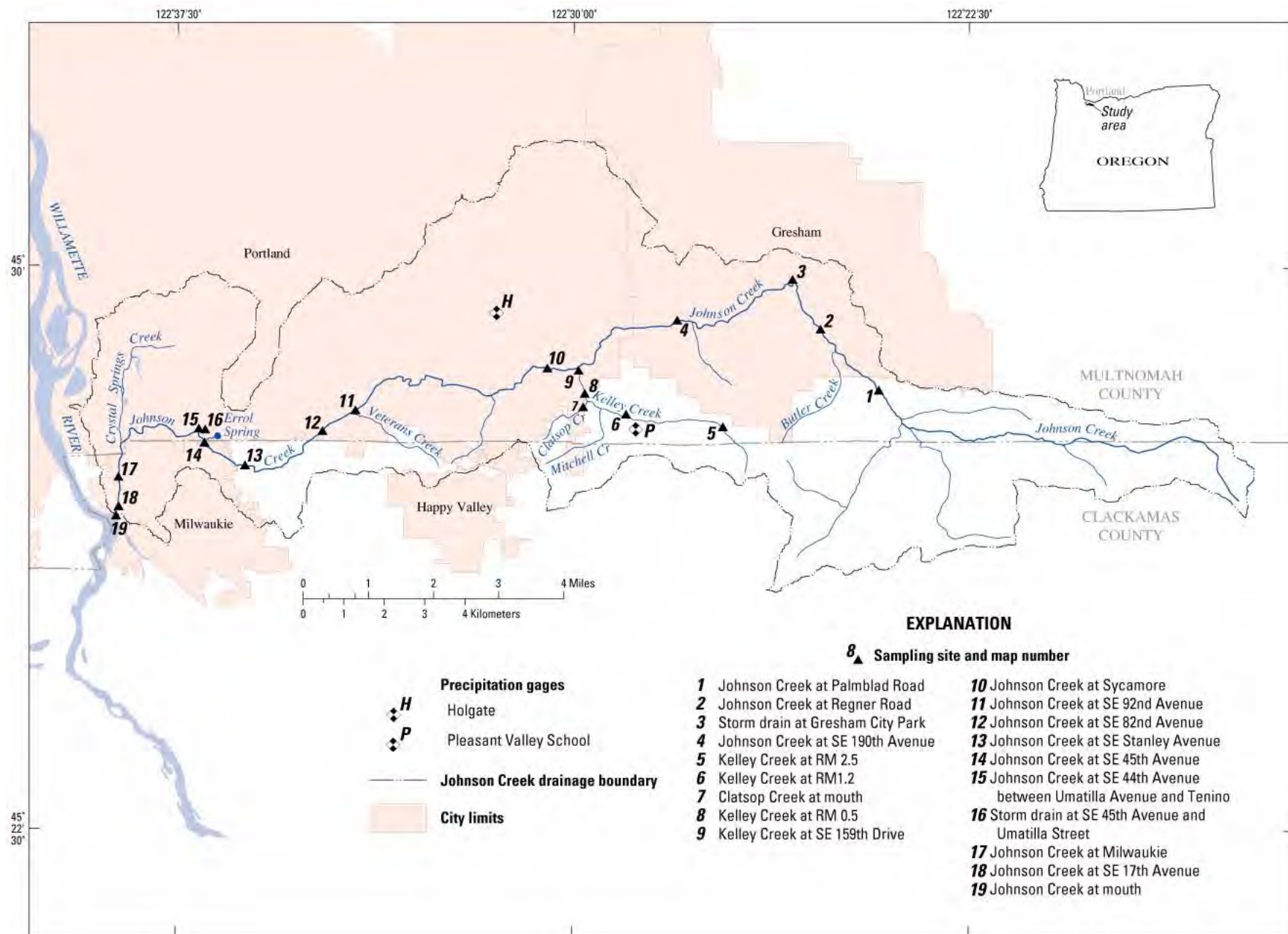
**Figure 1.** Sampling locations, Johnson Creek Basin, Oregon. RM, river mile.

EXPLANATION

$8_{\blacktriangle}$ Sampling site and map number

**Precipitation gages**

*H* Holgate

*P* Pleasant Valley School

— Johnson Creek drainage boundary

City limits

1 Johnson Creek at Palmblad Road
2 Johnson Creek at Regner Road
3 Storm drain at Gresham City Park
4 Johnson Creek at SE 190th Avenue
5 Kelley Creek at RM 2.5
6 Kelley Creek at RM1.2
7 Clatsop Creek at mouth
8 Kelley Creek at RM 0.5
9 Kelley Creek at SE 159th Drive
10 Johnson Creek at Sycamore
11 Johnson Creek at SE 92nd Avenue
12 Johnson Creek at SE 82nd Avenue
13 Johnson Creek at SE Stanley Avenue
14 Johnson Creek at SE 45th Avenue
15 Johnson Creek at SE 44th Avenue
      between Umatilla Avenue and Tenino
16 Storm drain at SE 45th Avenue and
      Umatilla Street
17 Johnson Creek at Milwaukie
18 Johnson Creek at SE 17th Avenue
19 Johnson Creek at mouth

help determine the movement and trends of organochlorine compounds in the basin and how their occurrence relates to total suspended solids (TSS), land use, and to possible source areas.

In addition to the March 2002 sampling, samples were taken at several other sites on both Johnson Creek and Kelley Creek (a tributary to Johnson Creek) by other agencies. Samples were taken from Johnson Creek from November 2001 to January 2002 by the ODEQ and from Kelley Creek from January 2002 to January 2003 by the City of Portland. Both the ODEQ and City of Portland data are used in this report to provide nonstorm organochlorine-compound data to be used in conjunction with the storm samples taken by the USGS.

## Study Area Description

The Johnson Creek Basin is located in northwest Oregon in Clackamas and Multnomah Counties (fig. 1). Johnson Creek flows through the cities of Gresham, Portland and Milwaukie, where it flows into the Willamette River. The creek is about 24 miles long and drains an area of 54 square miles. The headwaters as well as the several tributaries on the south side of the basin originate in a group of volcanic hills (Trimble, 1963). The largest south-side tributary is Kelley Creek. Few tributaries flow into Johnson Creek from the relatively flat area north of Johnson Creek because of permeable deposits left by the Missoula Floods after the last Ice Age (Waitt, 1985). The primary north-side tributary is Crystal Springs Creek. The relatively high and constant flow of Crystal Springs Creek is indicative of regional ground-water discharge. Being in a rapidly-developing urban area, Johnson Creek has been adversely affected by urbanization (Laenen, 1980). Channel simplification, rock lining of the stream channel, establishment of a network of storm drains, and paving of once-pervious areas may have affected both runoff volume and response to precipitation events. Urban development in recent years has resulted in the conversion of agricultural lands to residential uses, particularly in the southern and eastern part of the Johnson Creek Basin.

## Acknowledgments

## Study Design and Methods

Johnson Creek was sampled by the USGS and other agencies from 1988 to 2002 (table 1, fig. 1). In addition to the sites shown in table 1, the City of Portland took samples on Kelley Creek at RM 2.5, 1.2, 0.5, 0.0 and on Clatsop Creek (a tributary to Kelley Creek). Several of the sites on Johnson Creek sampled in 2001–02 had been sampled in previous studies, making it possible to compare data trends over time.

Land cover data were used to characterize the contributing area to the sampling sites in the Johnson Creek Basin (fig. 2, table 2). Data for land cover, which reflects land use, were obtained from the Metro Data Resource Center, Portland, Oregon (Steve Erickson, written commun., 2003). The land cover data were published in 1998, and were the result of updating 1992 land cover data based on 1998 Landsat Thematic Mapper imagery, aerial photography and digital orthophotos. The 1998 land cover used the same classification scheme as the previous edition. The 16 classifications were barren/sparsely vegetated, 2 agricultural types, 9 forest types, 3 shrub types, and meadow/grass. These classifications were grouped for this study into five classifications: (1) barren/sparsely vegetated (referred to as "urban" in this report), (2) agricultural, (3) closed-canopy forest, (4) scattered and open-canopy forest and shrub, and (5) meadow and grass. The land-cover data were used to relate spatial differences in organochlorine compounds in the basin to the vegetation types. Present land cover is not expected to be the same as land cover decades ago when organochlorine compounds discussed in this report were in use, but recovery of historical land use/land cover data (if it exists) was beyond the scope of this report.

## Hydrologic Data

Stream discharge data used in this study were from the following USGS gaging stations: Johnson Creek at Regner Road (station 14211400), Johnson Creek at Sycamore (station 14211500), Johnson Creek at Milwaukie (station 14211550), and Kelley Creek at 159th Drive, (station 14211499), (fig. 1, table 1). Daily stream-flow data for the 2002 water year were published by the

**Table 1.**    Sampling sites and data sources for organochlorine compounds, Johnson Creek Basin, Oregon, 1988–2002.

[Sample media are unfiltered water, unless otherwise specified. Map ID refers to the number on figure 1. Abbreviations: USGS, U.S. Geological Survey; ODEQ, Oregon Department of Environmental Quality; N/A, not applicable; SPMD, semipermeable membrane device; QA, quality assurance; SED, in addition to a water sample, a streambed sediment sample was collected in low-flow conditions of 1988. Source: (1) Harrison and others, 1995; (2) Oregon Department of Environmental Quality; (3) This publication; (4) Edwards, 1992; (5) McCarthy and Gale, 1999]

| Map ID | Site Name | USGS site number | Johnson Creek river mile | Dates sampled | Sampling agency | Sample type | Source |
|---|---|---|---|---|---|---|---|
| 1 | Johnson Creek at Palmblad Road | 452823122240900 | 17.2 | 1994<br>2001<br>2002 | USGS<br>ODEQ<br>USGS | spring and fall<br>winter<br>storm | (1)<br>(2)<br>(3) |
| 2 | Johnson Creek at Regner Road | 452910122251500 | 15.8 | 1989/90 | USGS | storms | (4) |
| 4 | Johnson Creek at SE 190th Avenue | N/A | 12.6 | 2001/02 | ODEQ | winter | (2) |
| 9 | Kelley Creek at SE 159th Drive | 14211499 | 10.6 | 1989/90 | USGS | storms | (4) |
| 10 | Johnson Creek at Sycamore | 14211500 | 10.2 | 1989/90<br>2002 | USGS<br>USGS | storms<br>storm | (4)<br>(3) |
| 11 | Johnson Creek at SE 92nd Avenue | 452806122340300 | 5.8 | 1988<br>2001/02 | USGS<br>ODEQ | SED only<br>storm | (4) |
| 12 | Johnson Creek at SE 82nd Avenue | 452717122344000 | 5.5 | 1989/90 | USGS | SED | (4) |
| 13 | Johnson Creek at SE Stanley Avenue | 452722122361100 | 3.6 | 1989/90 | USGS | storms | (4) |
| 14 | Johnson Creek at SE 45th Avenue | 452743122365400 | 3.2 | 2001/02<br>2002 | ODEQ<br>USGS | storm, QA<br>storm | (2)<br>(3) |
| 15 | Johnson Creek at SE 44th Avenue between Umatilla Avenue and Tenino | 452750122370000 | 3.0 | 1990 | USGS | SED | (4) |
| 17 | Johnson Creek at Milwaukie | 14211550 | 0.7 | 1989/90<br>1997<br>1998<br>2002 | USGS<br>USGS<br>USGS<br>USGS | storms<br>SPMD, low flow<br>SPMD, high flow<br>storm | (4)<br>(5)<br>(5)<br>(3) |
| 18 | Johnson Creek at SE 17th Avenue | N/A | 0.3 | 2001/02 | ODEQ | storm | (2) |
| 3 | Storm Drain in Gresham City Park | 452951122254600 | N/A | 2002 | USGS | storm | (3) |
| 16 | Storm Drain at SE 45th Avenue and Umatilla Street | 452750122365300 | N/A | 2002 | USGS | storm | (3) |

U.S. Geological Survey (2003). Discharge was determined for the Palmblad Road and 45th Avenue sites by developing a temporary stream-stage/discharge rating during the winter of 2001–02 (methods described in Rantz and others, 1982). Water-surface elevation observations were associated with discharge measurements (U.S. Geological Survey, 2003) to develop a rating for each site. During the storm of March 2002, the water-surface elevations at the time of sampling were determined by measuring down from a point on the bridge and related to discharge using the rating. The rating-derived discharge was used in conjunction with the instantaneous flow data at nearby streamflow-gaging stations to estimate discharge at the time of sampling. The discharge associated with samples taken by the ODEQ was estimated by comparison with flow at nearby gages. For samples taken on Kelley Creek, discharge data were available only at the gage at the mouth of the creek. No flow estimates were made for the upstream or tributary sites on Kelley Creek. Discharge data for the storm drains were from continuous flow meters. These data were provided by the Cities of Gresham and Portland.

Precipitation data used in this report were provided by the City of Portland Hydra rainfall network (City of Portland, Bureau of Environmental Services, 2002a and 2002b). This network consists of tipping-bucket rain gages located throughout the Portland metropolitan area. The Holgate rain gage (fig. 1) was selected as a representative
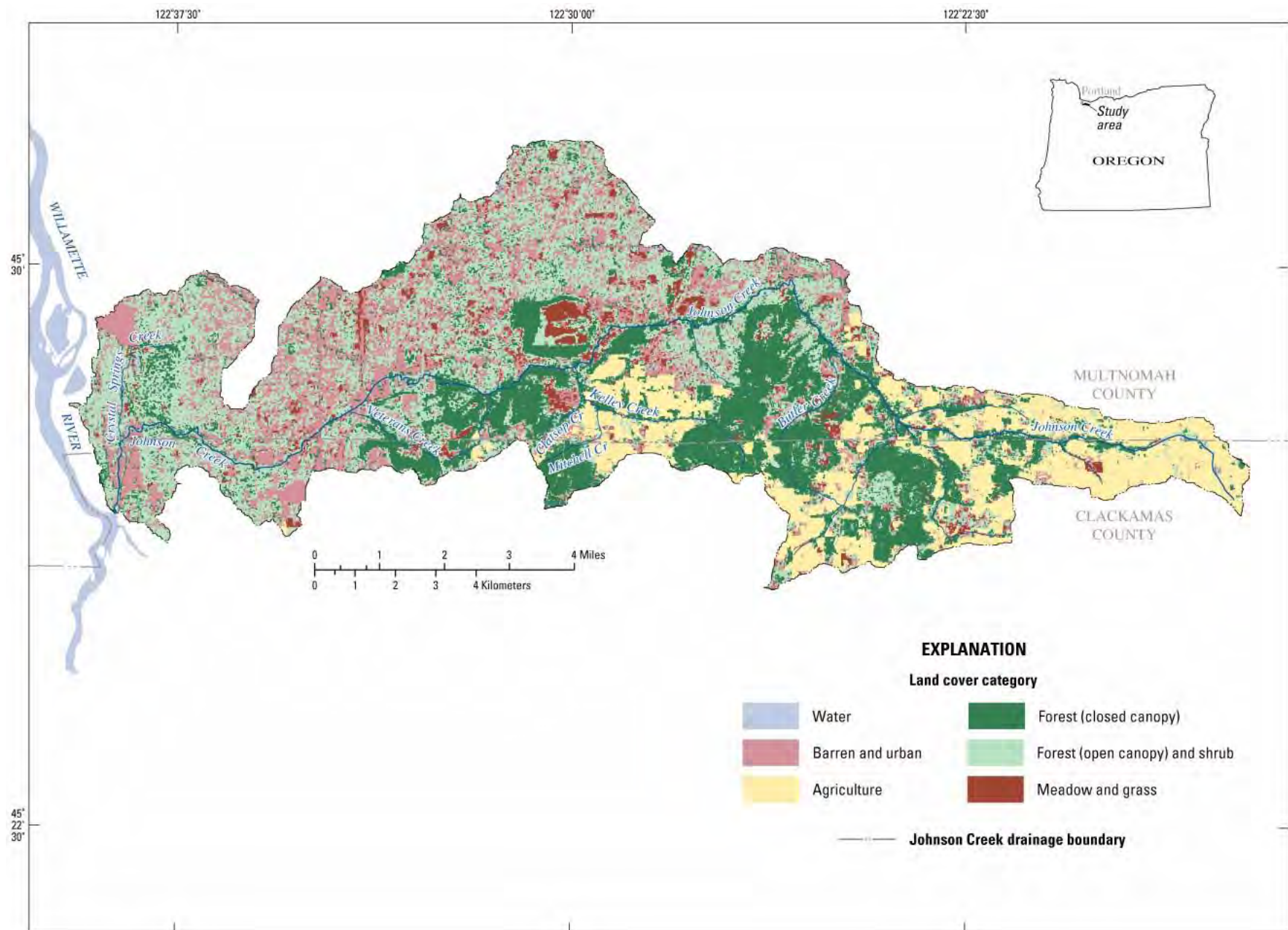
**Figure 2.**    Land cover categories, Johnson Creek Basin, Oregon.

**Table 2.** Drainage area and land cover for sampling sites, Johnson Creek Basin, Oregon, 1988–2002.

[Map ID refers to the number on figure 1. Abbreviation: NA, not applicable. Drainage area and land cover data were not available for the storm drains. The urban land cover category was called "barren/sparsely vegetated" in the original data set]

| Map ID | Site Name | Johnson Creek river mile | Drainage area (square miles) | Land cover, in percent | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | Urban | Agriculture | Forest (closed canopy) | Forest (scattered and open canopy), shrub | Meadow and grass |
| 1 | Johnson Creek at Palmblad Road | 17.2 | 12.5 | 7 | 50 | 25 | 14 | 4 |
| 2 | Johnson Creek at Regner Road (station 14211400) | 15.8 | 15.4 | 8 | 42 | 30 | 16 | 4 |
| 4 | Johnson Creek at SE 190th Avenue | 12.6 | 19.8 | 11 | 33 | 30 | 21 | 5 |
| 10 | Johnson Creek at Sycamore (station 14211500) | 10.2 | 26.8 | 12 | 31 | 31 | 21 | 5 |
| 11 | Johnson Creek at SE 92nd Avenue | 5.8 | 42.6 | 21 | 20 | 25 | 28 | 6 |
| 12 | Johnson Creek at SE 82nd Avenue | 5.5 | 44.4 | 21 | 19 | 26 | 28 | 6 |
| 13 | Johnson Creek at SE Stanley Avenue | 3.6 | 46.0 | 23 | 18 | 25 | 28 | 6 |
| 14 | Johnson Creek at SE 45th Avenue | 3.2 | 47.2 | 23 | 18 | 24 | 29 | 6 |
| 15 | Johnson Creek at SE 44th Avenue between Umatilla Avenue and Tenino St. | 3.0 | 47.3 | 23 | 18 | 24 | 29 | 6 |
| 17 | Johnson Creek at Milwaukie (station 14211550) | 0.7 | 53.2 | 24 | 16 | 23 | 32 | 5 |
| 18 | Johnson Creek at SE 17th Avenue | 0.3 | 53.6 | 24 | 16 | 23 | 32 | 5 |
| 19 | Johnson Creek at mouth | 0.0 | 53.9 | 24 | 16 | 23 | 32 | 5 |
| 5 | Kelley Creek at RM 2.5 | NA | 0.63 | 2 | 11 | 75 | 10 | 2 |
| 6 | Kelley Creek at RM 1.2 | NA | 2.63 | 5 | 41 | 43 | 9 | 2 |
| 7 | Clatsop Creek at mouth | NA | 0.34 | 24 | 8 | 32 | 22 | 14 |
| 8 | Kelley Creek at RM 0.5 | NA | 4.18 | 8 | 37 | 41 | 11 | 3 |
| 9 | Kelley Creek at SE 159th Drive (station 14211499) | NA | 4.69 | 9 | 37 | 39 | 11 | 4 |

site in the Johnson Creek Basin. Data from the rain gage located at Pleasant Valley School were used in the Kelley Creek analysis.

## Sample Collection and Analysis

For the USGS sampling in March 2002, unfiltered samples for organochlorine-compound analysis were collected as grab samples. Samples were collected directly into 1-liter amber glass bottles that had been cleaned and then baked at 450°C to remove impurities. For each grab sample, the bottle was placed underwater near the center of the stream (or storm drain) and filled to the top. Because the waterways were narrow and the flow was turbulent and well-mixed, the typical procedure of obtaining depth- and width-integrated samples was not employed. Additionally, grab sampling was chosen because it is the sampling method used by other agencies (including ODEQ) for sampling Johnson Creek. Therefore, the methodologies used for gathering data will be comparable when setting TMDLs.

Water samples for TSS were collected in the same manner using 1-liter, wide-mouth, plastic bottles. Samples for both organochlorine compounds and TSS were maintained at 4°C during shipment to the laboratories.

The USGS National Water Quality Laboratory (NWQL) in Lakewood, Colorado, analyzed the samples from the March 11–13, 2002, storm for organochlorine pesticides and total PCBs using a modification of the method described in Wershaw and others (1987). For the usual method (NWQL Schedule 1389), samples are extracted in hexane and analyzed by gas chromatography/ electron capture detection (GC/ECD). This method was modified to enable the added analyses for the $o,p'$ isomers of DDT, DDE, and DDD (instead of only the $p,p'$ isomers). Glassware was triple rinsed with methanol, hexane, and acetone to minimize interferences. Information concerning the organochlorine compounds analyzed is summarized in table 3.

Several designations were used by the NWQL to indicate minimum levels of detection for the particular analytical methods. A laboratory reporting level (LRL) was used for most of the organochlorine compounds (table 3). These values reflect the 99% probability (based on data collected nationwide in water year 2002) of reporting a false negative result. Because detection levels are statistically based, the LRL can change from year to year. A subjective, minimum reporting level (MRL) was used for chlordane, toxaphene, and total PCB. The MRL does not have the statistical foundation that the LRL has. If a concentration was measured by the laboratory as being less than the LRL or the MRL, or if the concentration was too small to quantify, the value was reported as a nondetection or "less than" value. The laboratory used an "E" remark code to identify an estimated concentration. This code was used when the identification of a compound was qualitatively confirmed but the concentration was estimated because there was greater-than-usual uncertainty about the measurement.

The ODEQ laboratory analyzed samples for organochlorine compounds and total PCB in 2001 and 2002. Chlorinated pesticides were analyzed using EPA method 8081, and total PCB was analyzed using EPA method 8082. These methods use methylene chloride extraction followed by an electron capture detection analysis. The ODEQ laboratory measured turbidity using a Hach[TM] 2100-AN turbidity meter with formazin as the primary standard. The turbidity meter was always used in ratio mode, and the light source had a tungsten filament and used a filter supplied by Hach.

TSS and turbidity were analyzed by the City of Portland, Bureau of Environmental Services (Peter Abrams, written commun., 2002). TSS was analyzed using method 2450 D, "Total suspended solids dried at 103–105°C" (American Public Health Association and others, 1998). The water sample was filtered through a glass-fiber filter of a known weight, and the residue and filter were dried to a constant weight. The weight of the residue from a given sample volume represents the concentration of the TSS. Turbidity was analyzed using method 2130–B, the nephleometric method, (American Public Health Association, 1998), which compares the light scattering characteristics of the sample with those of a standard. The instrument used was a Orbeco-Hellige[TM] digital direct-reading turbidity meter, Model 965–10A, using white light. The turbidimeter was not operated in the ratio mode and formazin standards were used to calibrate the instrument.

Although both the ODEQ and City of Portland laboratories used formazin standards for turbidity measurements, the Hach[TM] 2100-AN and Orbeco-Hellige[TM] turbidity meters may not provide comparable data because of the difference in mode of operation (Gray and Glysson, 2002). No direct data quality comparisons were available for the two laboratories.

## Quality Assurance

The goal of the quality assurance (QA) segment of this study was to quantify the extent to which the laboratory analytical data represent stream conditions and to maximize their utility for managing the watershed. To achieve this goal, QA checks and measures were made both in the field and in the laboratory (table 4). In the field, "blank" samples for pesticide analysis were prepared for submission to both the USGS laboratory and the ODEQ laboratory. The field blanks were prepared by pouring certified organic-free water into the sample bottle under the sampling conditions (outdoors, near the stream-sampling site), to determine if environmental conditions,

**Table 3.**    Organochlorine compounds analyzed in unfiltered water samples, Johnson Creek Basin, Oregon, 2002, and Oregon water quality criteria.

[DDD, dichlorodiphenyldichloroethane; DDE, dichlorodiphenyldichloroethylene; DDT, dichlorodiphenyltrichloroethane; CAS, Chemical Abstracts Service registry number; USGS, U.S. Geological Survey; --, not applicable. LRL, laboratory reporting level, MRL, minimum reporting level; bolded criteria are those smaller than or equal to the reporting level. The source of the water quality criteria is: Oregon Department of Environmental Quality, 2003b, "Water Quality Criteria Summary," table 20, http://www.deq.state.or.us/wq/wqrules/340Div41Tbl20.pdf, accessed 2/11/03]

| Analyte | CAS | USGS parameter code | Reporting level type | Reporting level ($\mu$g/L) | Chronic freshwater criteria ($\mu$g/L) | Acute freshwater criteria ($\mu$g/L) |
|---|---|---|---|---|---|---|
| aldrin | 309–00–2 | 39330 | LRL | 0.001 | -- | 3.0 |
| chlordane, technical | 57-74-9 | 39350 | MRL | .10 | **0.0043** | 2.4 |
| o,p'-DDD (o,p'-DDT metabolite)[1] | 53–19–0 | -- | -- | -- | -- | -- |
| p,p'-DDD (p,p'-DDT metabolite) | 72–54–8 | 39360 | LRL | .001 | -- | -- |
| o,p'-DDE (p,p'-DDT metabolite)[1] | 3424–82–6 | -- | -- | -- | -- | -- |
| p,p'-DDE (o,p'-DDT metabolite) | 72–55–9 | 39365 | LRL | .001 | -- | |
| o,p'-DDT[1] | 789–02–6 | -- | -- | -- | -- | -- |
| p,p'-DDT | 50–29–3 | 39370 | LRL | .002 | -- | -- |
| Total DDT[2] | -- | -- | -- | -- | **.001** | 1.1 |
| dieldrin | 60–57–1 | 39380 | LRL | .001 | .0019 | 2.5 |
| endosulfan I (α-endosulfan, Thiodan) | 959–98–8 | 39388 | LRL | .002 | .056 | .22 |
| endrin | 72–20–8 | 39390 | LRL | .002 | .0023 | .18 |
| lindane (γ-HCH, *gamma*-hexachlorocylohexane, γ-BHC) | 58–89–9 | 39340 | LRL | .0007 | .08 | 2.0 |
| heptachlor (Velsicol 104) | 76–44–8 | 39410 | LRL | .002 | .0038 | .52 |
| heptachlor epoxide (heptachlor metabolite) | 1024–57–3 | 39420 | LRL | .001 | -- | -- |
| p,p'-methoxychlor (Marlate) | 72–43–5 | 39480 | LRL | .002 | .03 | -- |
| mirex (dechlorane) | 2385–85–5 | 39755 | LRL | .001 | **.001** | -- |
| toxaphene | 8001–35–2 | 39400 | MRL | 1.0 | **.0002** | .73 |
| total PCB (polychlorinated biphenyl) | 1336–36-3 | 39516 | MRL | .10 | **.014** | 2.0 |

[1]Analysis for the *o,p'* isomers were not standard procedures for the USGS National Water Quality Laboratory, and the results of these analyses are not stored in the main NWIS database. These data are on file at the USGS Portland office and are in an alternate NWIS database.

[2] "Total DDT" in this context refers to the sum of six analytes: *o,p'*-DDD, *p,p'*-DDD, *o,p'*-DDE, *p,p'*-DDE, *o,p'*-DDT, and *p,p'*-DDT. For any given environmental sample, one, several, or all of these compounds may have been analyzed.

sample bottles, or laboratory procedures were introducing contamination to the water sample. Two field blanks were submitted to the USGS laboratory, one from Johnson Creek at Sycamore, and one from the storm drain at Gresham City Park. One field blank was submitted to the ODEQ laboratory, from the storm drain at Gresham City Park. No organochlorine compounds were detected in any of the field blanks (table 4), indicating that no measurable contamination had occurred.

Several QA activities were performed at Johnson Creek at SE 45th Avenue on March 11, corresponding to the sample time of 16:00 hours. At this time and place, streamflow was on the rising limb of the hydrograph (fig. 3) and organochlorine-compound concentrations were also beginning to increase. One large grab sample was taken from the stream in a glass carboy and split into four repli-

cate subsamples (two each for the USGS and ODEQ laboratories). For this procedure, a teflon cone-splitter was used, a device specially made to obtain representative subsamples from a single container of water (Capel and Larson, 1996). The purpose of replicate samples was to determine the variability in the results due to sample preparation and laboratory analysis, within and among laboratories.

The concentrations of organochlorine compounds in the two replicates for the USGS laboratory were very similar to each other (table 4). In both replicates, only three compounds were detected (dieldrin, *p,p'*-DDE, and *p,p'*-DDT), and for each of these compounds, one replicate sample differed from the other by less than 0.001 µg/L. Two of the replicate samples were also submitted to the ODEQ laboratory (table 4), and in addition to the three

**Table 4.** Quality control data for the U.S Geological Survey (USGS) and Oregon Department of Environmental Quality (ODEQ) laboratories,

[DDD, dichlorodiphenyldichloroethane; DDE, dichlorodiphenyldichloroethylene; DDT, dichlorodiphenyltrichloroethane; PCB, polychlorinated biphenyls; <, not

| Sample type | Site number | Sample date and time | Analyzing laboratory | Aldrin (μg/L) | Chlordane (μg/L) | *p,p′*-DDD (μg/L)L | *o,p′*-DDD (μg/L) | *p,p′*-DDE (μg/L) | *o,p′*-DDE (μg/L) | *p,p′*-DDT (μg/L) | *o,p′*-DDT (μg/L) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Field blank | 14211500 | 3/11/02 12:38 | USGS | <0.0011 | <0.1000 | <0.0015 | <0.001 | <0.0011 | <0.001 | <0.0019 | <0.001 |
| Field blank | 452951122254600 | 3/11/02 14:18 | USGS | <.0011 | <.1000 | <.0015 | <.001 | <.0011 | <.001 | <.0019 | <.001 |
| | | 3/11/02 14:18 | ODEQ | <.0010 | <.010 | <.0010 | NA | <.0010 | NA | <.0020 | NA |
| Field replicate | 452743122365400 | 3/11/02 16:20 | USGS | <.0011 | <.1000 | <.0015 | <.001 | .0012 | <.001 | E .0017 | <.001 |
| Field replicate | 452743122365400 | 3/11/02 16:21 | USGS | <.0011 | <.1000 | <.0015 | <.001 | .0015 | <.001 | .0019 | <.001 |
| Field replicate | 452743122365400 | 3/11/02 16:20 | ODEQ | <.0011 | <.011 | <.0011 | NA | .0036 | NA | .0085 | NA |
| Field replicate | 452743122365400 | 3/11/02 16:21 | ODEQ | <.0011 | <.011 | <.0011 | NA | .0032 | NA | .0048 | NA |
| Field replicate spike with expected concentration = 0.054 μg/L | 452743122365400 | 3/11/02 16:25 | USGS | .0218 | <.1000 | .026 | .0253 | .026 | .0212 | .0267 | .0265 |
| Field replicate spike with expected concentration = 0.052 μg/L | 452743122365400 | 3/11/02 16:24 | USGS | .023 | <.1000 | .0278 | .0262 | .0276 | .0227 | .0285 | .028 |
| Field replicate spike with expected concentration = 0.054 μg/L | 452743122365400 | 3/11/02 16:25 | ODEQ | .0434 | <.011 | .1446 | NA | .0502 | NA | .0812 | NA |
| Laboratory blank | NA | | USGS | <.0011 | <.1000 | <.0015 | <.001 | <.0011 | <.001 | <.0019 | <.001 |
| Laboratory blank | NA | | USGS | <.0011 | <.1000 | <.0015 | <.001 | <.0011 | <.001 | <.0019 | <.001 |
| Laboratory blank | NA | | USGS | <.0011 | <.1000 | <.0015 | <.001 | <.0011 | <.001 | <.0019 | <.001 |
| Laboratory blank | NA | | USGS | <.0011 | <.1000 | <.0015 | <.001 | <.0011 | <.001 | <.0019 | <.001 |
| Laboratory blank | NA | | ODEQ | <.0010 | <.010 | .0022 | NA | <.0010 | NA | <.0020 | NA |
| Laboratory spike | NA | | USGS | 49.5 | NS | 71.6 | 68.8 | 66.9 | 57.5 | 72.4 | 71.2 |
| Laboratory spike | NA | | USGS | 45.79 | NS | 68.6 | 71.02 | 66.72 | 57.42 | 71.61 | 70.53 |
| Laboratory spike | NA | | USGS | 49.23 | NS | 63.29 | 61.9 | 61.87 | 52.3 | 64.82 | 63.7 |
| Laboratory spike | NA | | USGS | 52.82 | NS | 67.27 | 69.3 | 66.4 | 56.59 | 70.41 | 68.6 |

Johnson Creek Basin, March 10–13, 2002.

detected at indicated concentration;  µg/L, micrograms per liter; NA, not applicable; nd, not detected; E, estimated; NS, not spiked]

| Dieldrin (µg/L) | Endo-sulfan 1 (µg/L) | Endrin (µg/L) | Hepta-chlor (µg/L) | Hepta-chlor Epoxide | Lindane (µg/L) | *p,p* Meth-oxychlor (µg/L) | *o,p* Meth-oxychlor (µg/L) | Mirex (µg/L) | Cis-Nonachlor (µg/L) | Oxy-chlordane (µg/L) | Toxa-phene (µg/L) | Total PCB (µg/L) | Alpha HCH-d6 Surrogate recovery (%) | Isodrin Surrogate recovery (%) | Nonachlor Surrogate recovery (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| <0.0011 | <0.0015 | <0.0019 | <0.0015 | <0.0011 | <0.0007 | <0.0019 | <0.001 | <0.0011 | <0.001 | <0.001 | <1.000 | <0.1000 | 72 | 63 | 54 |
| <.0011 | <.0015 | <.0019 | <.0015 | <.0011 | <.0007 | <.0019 | <.001 | <.0011 | <.001 | <.001 | <1.000 | <.1000 | 80 | 58 | 53 |
| <.0010 | <.0010 | <.0010 | <.0010 | <.0010 | <.0010 | <.0040 | NA | NA | NA | NA | <.010 | nd | NA | NA | NA |
| .0026 | <.0015 | <.0019 | <.0015 | <.0011 | <.0007 | <.0019 | <.001 | <.0011 | <.001 | <.001 | <1.000 | <.1000 | 74 | 63 | 49 |
| .003 | <.0015 | <.0019 | <.0015 | <.0011 | <.0007 | <.0019 | <.001 | <.0011 | <.001 | <.001 | <1.000 | <.1000 | 75 | 66 | 52 |
| <.0011 | .0076 | .0057 | <.0011 | <.0011 | <.0011 | <.0043 | NA | NA | NA | NA | <.011 | nd | NA | NA | NA |
| .0082 | .0064 | <.0011 | <.0011 | <.0011 | <.0011 | <.0042 | NA | NA | NA | NA | <.011 | nd | NA | NA | NA |
| .0306 | .0227 | .0295 | .023 | .0254 | .0267 | .0192 | .027 | .0216 | .0298 | .0038 | <1.000 | <.1000 | 60 | 101 | 41 |
| .0331 | .0246 | .0315 | .024 | .0268 | .0285 | .0208 | .0292 | .0236 | .0323 | .0149 | <1.000 | <.1000 | 65 | 110 | 44 |
| .0674 | .05 | .0659 | .0334 | .0404 | .0457 | .0891 | NA | NA | NA | NA | <.011 | nd | NA | NA | NA |
| <.0011 | <.0015 | <.0019 | <.0015 | <.0011 | <.0007 | <.0019 | <.001 | <.0011 | <.001 | <.001 | <1.000 | <.1000 | 100 | 59 | 68 |
| <.0011 | <.0015 | <.0019 | <.0015 | <.0011 | <.0007 | <.0019 | <.001 | <.0011 | <.001 | <.001 | <1.000 | <.1000 | 96 | 49 | 51 |
| <.0011 | <.0015 | <.0019 | <.0015 | <.0011 | <.0007 | <.0019 | <.001 | <.0011 | <.001 | <.001 | <1.000 | <.1000 | 70 | 49 | 47 |
| <.0011 | <.0015 | <.0019 | <.0015 | <.0011 | <.0007 | <.0019 | <.001 | <.0011 | <.001 | <.001 | <1.000 | <.1000 | 81 | 63 | 54 |
| <.0010 | <.0010 | <.0010 | <.0010 | <.0010 | <.0010 | <.0040 | NA | NA | NA | NA | <.010 | nd | NA | NA | NA |
| 75.5 | 47.8 | 65.1 | 56.97 | 63.5 | 63.4 | 61.9 | 72.4 | 65.95 | 85.1 | 63.4 | NS | NS | 91 | 119 | 63 |
| 67.63 | 46.14 | 60.2 | 54.97 | 61.22 | 60.97 | 40.25 | 64.58 | 59.79 | 77.53 | 65.06 | NS | NS | 91 | 111 | 53 |
| 62.87 | 40.33 | 62.75 | 53.24 | 54.96 | 55.74 | 51.24 | 62.7 | 58.52 | 75.3 | 42.2 | NS | NS | 75 | 118 | 53 |
| 70.23 | 43.69 | 68.28 | 57.65 | 59.51 | 60.03 | 56.59 | 68.3 | 62.73 | 83.2 | 66.9 | NS | NS | 81 | 123 | 55 |
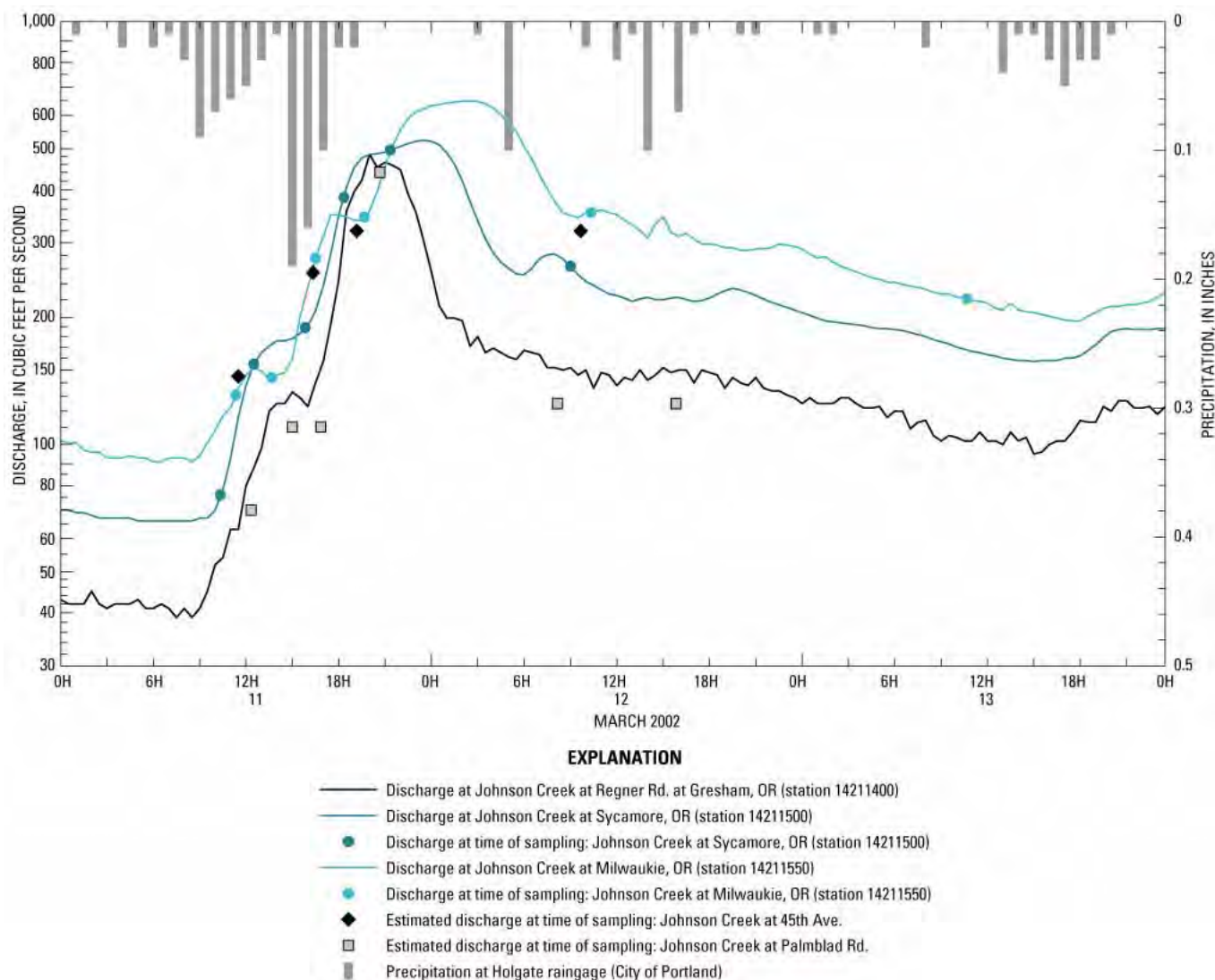
**Figure 3.**    Stream hydrographs, times of sample collection, and precipitation, Johnson Creek Basin, Oregon, March 11–13, 2002.

compounds detected at the USGS laboratory, there were small detections of endosulfan I and endrin. For these samples from the same site and time, the ODEQ laboratory detected *p,p*'-DDT at an average of 3.7 times larger and *p,p*'-DDE at an average of 2.5 times larger than the USGS laboratory. For the replicate samples analyzed for dieldrin at the ODEQ lab, the concentrations were very different: in one sample dieldrin was not detected (<0.001µg/L), and the dieldrin concentration of the other sample at the same time and place was 0.008 µg/L.

Replicate field "spikes" also were prepared for the QA sampling at the SE 45th Avenue site on March 11. A solution containing a known volume and concentration of the analytes was introduced ("spiked") into a native water sample. By calculating the amount of the spiked material recovered during analysis, an assessment can be made of the influence of the native water's matrix on laboratory analyses. Two spiked samples were submitted to the USGS

laboratory and one was submitted to the ODEQ laboratory for organochlorine-compound analysis, along with the stream samples. The laboratory results are shown in table 4. A summary of the spike recoveries for the USGS laboratory shows that about 40% to 60% of the spike compounds were recovered (table 5). The spike recoveries of DDX and dieldrin, the focus of this report, were in the 50% range. The ODEQ laboratory also analyzed one of these spiked samples, and the recoveries of organochlorine compounds were higher and in some cases more variable than the recoveries from the USGS laboratory. The ODEQ laboratory's recoveries ranged from 62% to 268%. Of special interest for this report are the high recoveries for *p,p*'-DDD (268%) and for *p,p*'-DDT (138%). These discrepancies in spike recovery between the USGS and ODEQ laboratories are consistent with the lower concentrations measured by the USGS laboratory for the USGS/ODEQ replicate sample (described above), and may indicate a low

**Table 5.**    Summary of spike recoveries, U.S. Geological Survey (USGS) and Oregon Department of Environmental Quality (ODEQ) laboratories, Johnson Creek Basin, March 10–13, 2002.

[Spike recovery was calculated as percent recovery of added spike material. Expected concentrations, where available, are in table 4; DDD, dichlorodiphenyldichloroethane; DDE, dichlorodiphenyldichloroethylene; DDT, dichlorodiphenyltrichloroethane]

| | Spike recovery, in percent | | | |
| Compound | USGS field spikes (average of 2) | USGS lab spikes (average of 2) | ODEQ field spike | ODEQ lab spike |
|---|---|---|---|---|
| *p,p*'- DDT | 50 | 70 | 138 | 136 |
| *p,p*'- DDE | 49 | 65 | 87 | 97 |
| *p,p*'- DDD | 52 | 68 | 268 | 160 |
| dieldrin | 56 | 69 | 117 | 100 |
| aldrin | 43 | 49 | 80 | 77 |
| endosulfan 1 | 45 | 44 | 80 | 84 |
| endrin | 59 | 64 | 117 | 94 |
| lindane | 53 | 60 | 85 | 80 |
| heptachlor | 45 | 56 | 62 | 81 |
| heptachlor epoxide | 50 | 60 | 75 | 80 |
| *p,p*'-methoxychlor | 38 | 52 | 165 | 231 |
| *o,p*'-DDT | 52 | 69 | | |
| *o,p*'-DDE | 42 | 56 | | |
| *o,p*'-DDD | 50 | 68 | | |
| mirex | 43 | 62 | | |

bias in the USGS laboratory and a high bias for the ODEQ laboratory. However, analyte concentrations were not corrected based on spike recoveries because spike recoveries are not rigorously quantitative. Instead, the spike recoveries can be used as indications that the reported values may be lower or higher than the true concentrations.

In addition to the field QA procedures, there were also QA efforts as part of the routine procedures for laboratory analysis. In both the USGS and ODEQ laboratories, aliquots of organic-free water (laboratory blanks) were analyzed along with the environmental samples. The samples analyzed by the USGS laboratory were in sets containing about 12 samples each. The March 2002 samples were analyzed in four sample sets, with one laboratory blank and one laboratory spike (described below) per set (table 4). As was the case with the USGS field blanks, there were no detections of compounds analyzed for in the laboratory blanks, indicating that there was no reason to expect laboratory contamination. However, *p,p*'-DDD was detected at a concentration of 0.002 µg/L in the ODEQ laboratory blank. (The detection level of this constituent for the ODEQ laboratory was 0.001 µg/L).

Laboratory spikes also were prepared and analyzed at the laboratories. For laboratory spikes, organic-free blank water was spiked with known concentrations of the analytes. Laboratory spikes were added to blank water rather than to native stream water, avoiding interference

(matrix effects) from sediment particles or other compounds that may exist in the native water. This provides a direct test of laboratory bias or contamination. For the USGS laboratory, the average recovery of each constituent (with one exception, endosulfan I) of the four laboratory spikes was larger than the average of the two field spikes. For the DDT compounds and dieldrin, the USGS laboratory spikes were recovered, on the average, at about 70 percent.

For the ODEQ laboratory, the recoveries of the constituents in the laboratory spike were sometimes larger and sometimes smaller than the corresponding constituent in the field spike (table 5). For DDX and dieldrin, the recovery in the laboratory spike was closer to 100% (the optimal recovery) than the field spike. Based on those two samples, it may be possible to hypothesize that matrix effects in the field spike biased the ODEQ laboratory away from 100% recovery.

At the USGS laboratory, three surrogate compounds were mixed with each native sample before analysis. Surrogate compounds have a similar chemical structure to the analytes, but are not expected to be found in the environment. Surrogate recoveries indicate the general efficiency of the laboratory analysis for the particular analytical group. The concentration of these surrogates, when compared to the expected concentration, was used to calculate the percent recovery of each surrogate compound. The surrogate compounds were isodrin (parameter code 90571,

CAS number 465–73–6), alpha-HCH–d6 (parameter code 99777), and PCB 207 (parameter code 99780 and CAS number 52663–79–3). The median recoveries were about 60 percent, about 70 percent, and about 50 percent, respectively (fig. 4). These recoveries were within the same approximate range as the USGS field spikes and laboratory spikes (table 5). The recovery of the alpha-HCH-d6 surrogate most closely reflects the method's performance for the constituents of interest in this report—DDT and its metabolites and dieldrin (Duane Wydoski, USGS National Water Quality Laboratory, written commun., 2003). For each surrogate compound, the sample with the smallest recovery (shown as the lower point on for each compound on fig. 4) was from the same sample—Johnson Creek at Palmblad on March 11, 2002, at 15:00 hours, indicating a consistently low recovery of compounds in this sample.
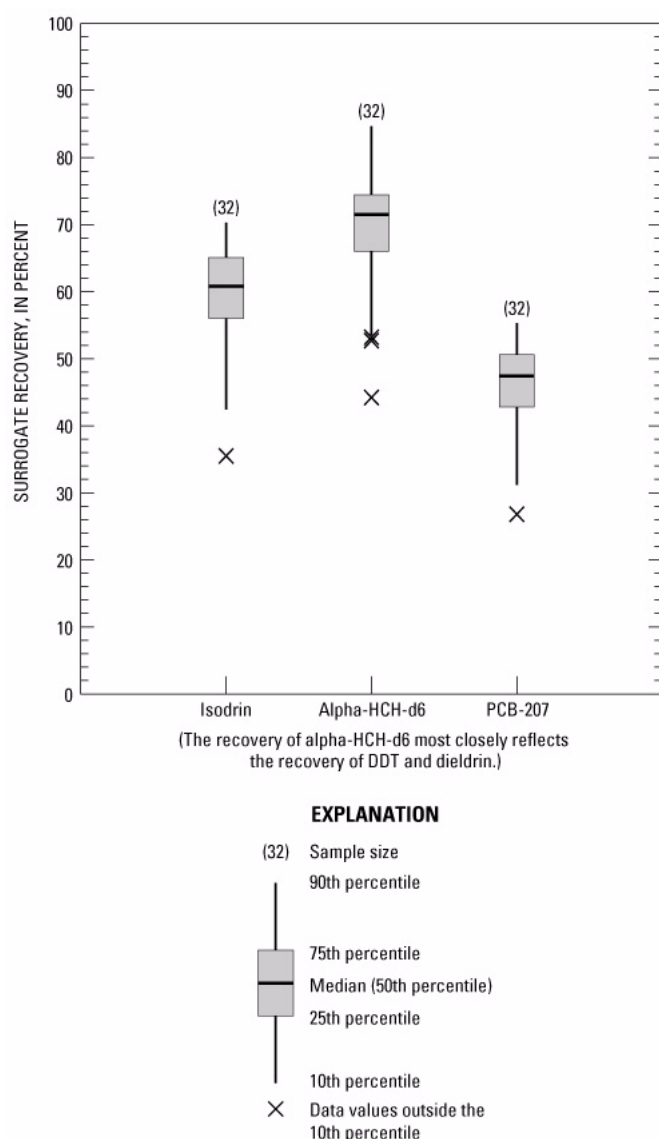


**Figure 4.** Surrogate recoveries by the USGS laboratory, samples of Johnson Creek Basin, Oregon, March 2002.

To summarize the quality-assurance efforts, the field and laboratory blanks indicated no contamination, with the exception of the detection of *p,p'*-DDD at a low concentration in the ODEQ laboratory blank. Field spikes, replicates, laboratory spikes, and USGS surrogates all indicated that the USGS laboratory may be biased toward reporting lower-than-real values for organochlorine compounds and that the ODEQ laboratory may be biased toward reporting higher-than-real values for these compounds.

## Results

Water-quality results presented here include several elements. The hydrologic conditions of March 11–13, 2002, are described to provide context for the samples taken during that storm event. Next, the occurrence of organochlorine compounds during the March 2002 storm, as well as in samples taken by ODEQ during nonstorm periods, is discussed. Results are compared to water-quality standards. Instantaneous loads were computed to assess the flux of pesticides in the basin. The relation of sediment parameters (TSS and turbidity) is explored; this relation provides a means of comparing current sediment-pesticide associations with sediment and pesticide data collected a decade ago. Finally, samples taken from Kelley Creek, a tributary to Johnson Creek, in 2002 and 2003 provided an indication of both spatial and temporal differences in pesticide concentrations.

### Hydrologic Conditions during Storm Sampling

The storm of March 11 and 12, 2002 (fig. 5), was a typical winter storm, with a peak flow at the Milwaukie gage of about 650 cubic feet per second (ft$^3$/s). The peak discharge at the Milwaukie gage on March 11 had been exceeded four times since October 2001. The peak at the Sycamore gage was 524 ft$^3$/s, corresponding to a recurrence interval of less than 1 year (Wellman and others, 1993). The goal was to sample on the rising and falling limbs of the hydrograph, and also to sample near the peak discharge. Since organochlorine compounds are associated with suspended sediment, which is usually transported to the greatest degree near the storm peak, sampling throughout the hydrograph would best describe the instantaneous loading and transport of organochlorine compounds during a given storm event.

Figure 3 depicts the storm hydrographs for Johnson Creek, precipitation during the storm, and times of sample collection. Discharge from the gaging station at Gresham (RM 15.8) is shown along with the estimated discharge at Palmblad Road (RM 17.2) at the time of each of the six samples. Precipitation data are also shown for the Holgate rain gage (City of Portland, Bureau of Environmental Services, 2002a). The most intense precipitation preceded the
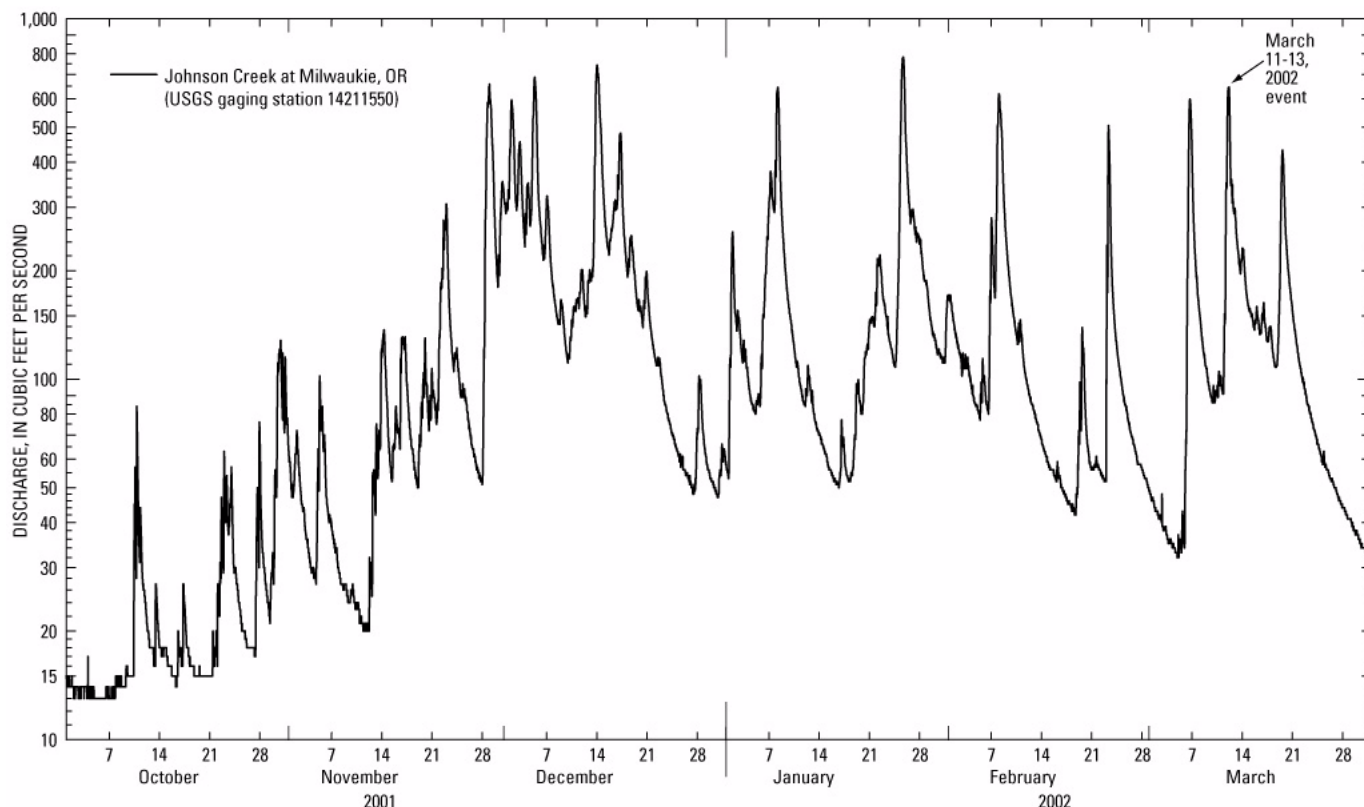
**Figure 5.** Stream hydrograph of Johnson Creek at Milwaukie, Oregon, October 2001 through March 2002.

storm peak by several hours. The six samples at Palmblad Road were well distributed over the stream hydrograph.

The storm hydrograph and discharge associated with each sample time for Johnson Creek at Sycamore are also shown in figure 3. Because the samples were collected at the stream-gaging station, the discharge at the time of sampling corresponds exactly to the storm hydrograph line. The hydrograph at the Sycamore gage was similar in shape to that at the Gresham gage, but the peak discharge at Sycamore was larger, of longer duration, and occurred slightly later than at Gresham. A small secondary peak at Sycamore in the morning of March 12 corresponds to a subsequent rainfall event. Five of the six samples at the Sycamore gage were taken on the rising limb of the hydrograph. A sample was taken near the peak discharge.

Three of the four samples at the SE 45th Avenue site were taken on the rising limb of the hydrograph (fig. 3). The discharge at the time of sampling prior to the peak and after the peak was approximately half the peak discharge.

The peak at Johnson Creek at Milwaukie was larger and occurred later than the upstream sites (fig. 3). The peak discharge occurred shortly after midnight and no samples were taken near the peak of the hydrograph. As with the samples taken at the SE 45th Avenue site, the discharge at the time of sampling prior to the peak and following the peak was about half the peak discharge.

The flow hydrographs of the two storm drains located at Gresham City Park and at SE 45th Avenue and Umatilla Street indicate a typical urban-runoff response (fig. 6). The catchment for both sites consists of rooftops, streets, and landscaped areas. The Gresham site drains part of the downtown core of the city of Gresham, whereas the 45th Avenue site primarily receives water from a mix of residential and industrial areas. In contrast to the stream sites, in which several hours of precipitation led to a rapid rise with a distinct single peak followed by a gradual recession, runoff in the storm drains rose and fell rapidly in response to precipitation.

The flow responses of the two storm drains to the precipitation event of March 11 were fairly similar (fig. 6). The data-recording interval at the Gresham site was 2 hours, whereas the recording interval at the SE 45th Avenue site was 15 minutes, so the Gresham hydrograph has fewer data points. Some differences in the hydrology of the two catchments are evident from the respective hydrographs. The base flow of the Gresham storm drain is minimal, but the base flow at the SE 45th Avenue site is about 1 $ft^3$/s. The base-flow component at the SE 45th Avenue site is due to interception of spring discharge in the area. Errol Spring, located 0.2 miles east of the SE 45th Avenue sampling site, does not flow into the storm drain, but it is indicative of springs that emanate from the hillside north
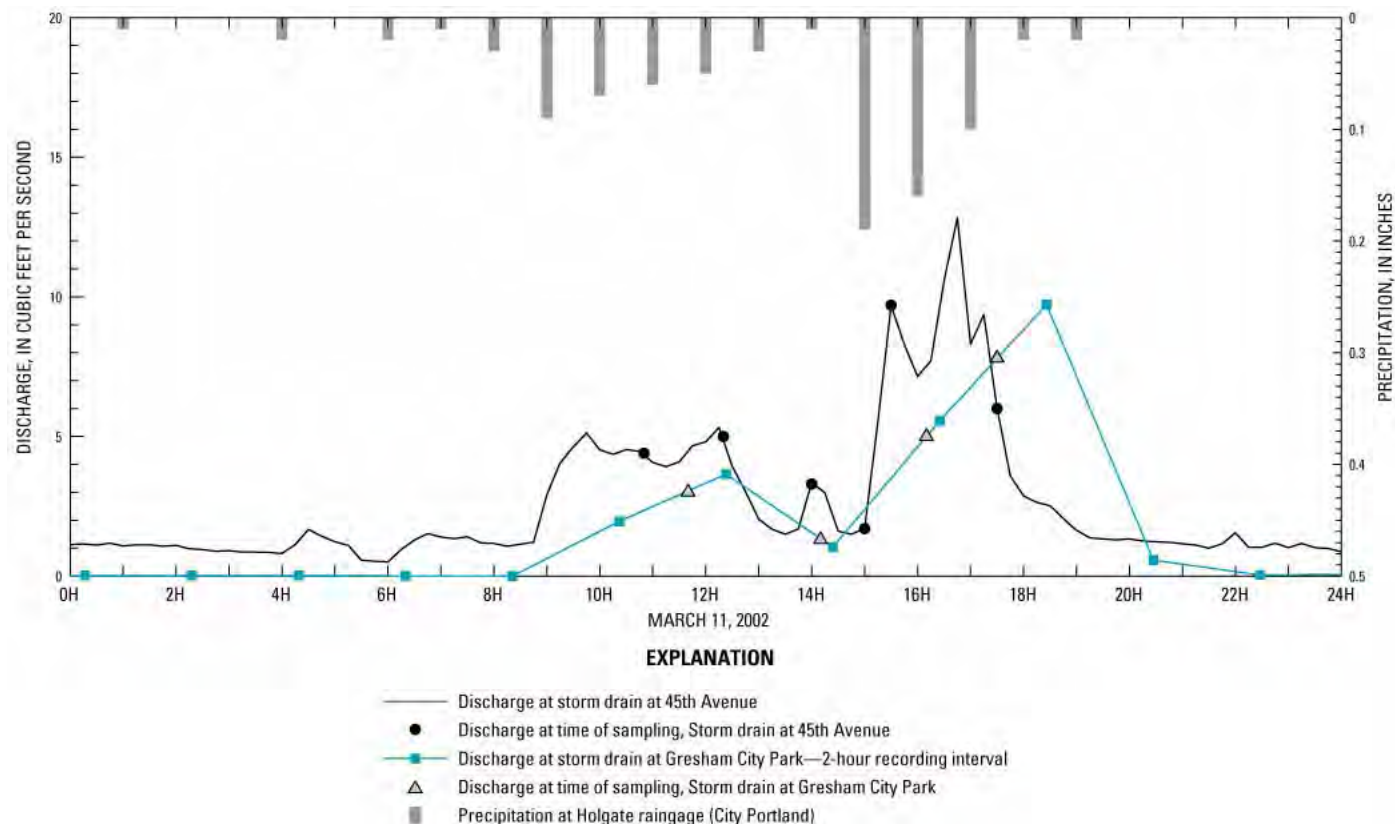
**Figure 6.**    Discharge at storm drains, times of sample collection, and precipitation, Johnson Creek Basin, Oregon, March 11, 2002.

of the storm drain. The occurrence of spring flow in this storm drain is substantiated by flow measurements made in 1988, 1999, and 2000 (U.S.Geological Survey, 1989, 2000, 2001). Based on the peak discharge at both storm drains early on March 11 of about 5 ft$^3$/s, followed by a peak of about 10 ft$^3$/s at each site, the catchment of both sites may be of similar size, although the dimension of each catchment was not determined. The effect of ground-water discharge at the 45th Avenue site, which amounts to about 10 percent of the peak discharge, was not explored, but factors such as the contributing area to the springs and age of these waters may have an effect on the data.

The samples taken from both storm drains were fairly well distributed on the flow hydrograph (fig. 6). Based on both the precipitation and flow data, samples were taken near the peak discharge at each site.

## Occurrence of Organochlorine Pesticides and Compliance with Criteria

The analysis of whole-water samples from the storm of March 11–13, 2002 (table 6), was the primary source of data for both this section and the following section concerning loads. In addition to organochlorine pesticides, analyses were done for total PCB, turbidity, and TSS. Also discussed in these sections are organochlorine-pesticide

data from ODEQ sampling and analysis from December 2001 and January 2002 (table 7). The ODEQ data set includes 11 samples from 5 sites on Johnson Creek, data that are useful for helping to assess the occurrence of organochlorine pesticides in the basin, particularly during non-storm periods.

The USGS laboratory, under a special agreement, quantified the *o,p'* isomers (as well as the more standard *p,p'* isomers) of DDT, DDE and DDD (table 6), whereas the ODEQ laboratory quantified only the *p,p'* isomers of DDT, DDE and DDD (table 7). Of the 32 samples analyzed by the USGS, 22 contained at least 1 of the DDX compounds, and only 4 contained 1 of the *o,p'* DDX compounds (table 6). The concentration of *o,p'* isomers of three of these four samples was less than 6% of the total concentration, and the *o,p'* component of the other sample was 20% of the total DDT. Due to the small component of the *o,p'* isomers, the data from the USGS laboratory (where the full analysis was done) were treated the same as the data from the ODEQ laboratory (where the analysis was limited to the *p,p'* isomers). In this report, the term "total DDT" refers to the sum of all DDT + metabolite concentrations, including all analyzed isomers.

Organochlorine pesticides were detected from the March 2002 sampling at five of the six sites (table 6). There were no detections of any of the analytes in samples

from the storm drain in Gresham City Park. DDX compounds were detected at every other site. There were single detections of the following compounds: chlordane and endosulfan I at Palmblad Road, *p,p'*-methoxychlor at Milwaukie, and total PCB at the storm drain at SE 45th and Umatilla Street. The highest concentration of total DDT was 0.07 μg/L at the Palmblad site on March 11 at 20:40 hours, during the peak of the storm. Dieldrin was detected in every stream water sample, but not in any of the samples from the storm drains. The sample with the highest total DDT concentration also had the highest concentration of dieldrin (0.02 μg/L) and the only detection of chlordane (an estimated value of 0.1 μg/L). The relatively high concentrations of both total DDT and dieldrin at the Palmblad Road site may reflect the historical agricultural land use in the upper watershed. This is consistent with findings at Kelley Creek, described later in the report, showing high organochlorine compound concentrations in the part of the stream draining areas that are now predominately agricultural and may have also been agricultural in the past.

For the ODEQ samples of December 5 and 19, 2001, and January 9, 2002, organochlorine compounds were detected in every sample (table 7). Both DDX compounds and dieldrin were detected in every sample. Endosulfan I was detected at every site, and overall there were one or more detections of aldrin, endrin, and heptachlor. The highest concentration of total DDT was 0.008 μg/L at the SE 190th Avenue site on December 5, 2001. The highest dieldrin concentration was 0.008 μg/L at the Palmblad Road site, also on December 5, 2001.

Although both dieldrin and DDX compounds were detected in numerous samples by the USGS and ODEQ, the concentrations of these compounds were not well correlated, especially at the lower concentrations (fig. 7). For the March 2002 storm-event sampling, several stream samples had detections of dieldrin but not DDX. Only samples from the storm drain at SE 45th Avenue indicated the occurrence of DDX and not dieldrin. The dieldrin concentration of most of the March 2002 samples was between 30% and 100% of the total DDT concentration (table 6). Samples taken by the ODEQ on December 5, 2001, and January 9, 2002, contained fairly similar concentrations of dieldrin and total DDT; however, samples taken on December 19, 2001, had dieldrin concentrations generally more than twice that of total DDT (table 7).

Two previous studies indicated generally lower concentrations of dieldrin relative to total DDT. Dieldrin concentrations, relative to total DDT, were smaller for samples taken during storms in 1989–90 (Edwards, 1994). Analyses using semipermeable membrane devices in 1997 and 1998 (McCarthy and Gale, 1999) found that the dieldrin concentration in Johnson Creek at Milwaukie was one-third to two-thirds that of total DDT.

The lack of correlation of dieldrin to total DDT may be attributable to the chemical characteristics of these compounds. Dieldrin is more soluble in water than DDT

(Smith and others, 1988, p. 29). Although the source of both dieldrin and DDX in the stream may be soil erosion, resulting in introduction of contaminated sediments to the stream, more dieldrin may be in the dissolved state relative to DDX. This could result in persistence of dieldrin in the stream even during nonstorm periods. The highly variable relation of dieldrin to total DDT may be dependent on sediment concentration and the time of exposure of contaminated sediments in the stream, differences in degradation of these compounds, and (or) geographical differences in their application.

Overall, the concentrations of both total DDT and dieldrin were lower in the 2001–02 samples than in the 1989–90 samples. Differences in storm magnitude and antecedent conditions may cloud the comparison of organochlorine-compound concentrations in 1989–90 to those of 2001–02. The December 1989 storm was of slightly greater magnitude; the recurrence interval was 1.25 years (Wellman and others, 1993) compared to a recurrence interval of less than 1 year for the March 2002 storm. The storm of January 1990 was slightly smaller than the March 2002 storm. Despite the small difference in peak discharges, the difference in organochlorine-pesticide concentrations was substantial. The total DDT concentration of every sample taken in 1989–1990 (shown in table 8) was equal to or greater than 0.05 μg/L, but only one sample in 2001–02 had a higher concentration (table 6). For dieldrin, the concentration of every sample from 1989–90 was greater than 0.01 μg/L, but the 2001–02 data indicate that only 2 of 34 samples contained concentrations above 0.01 μg/L. For both DDT and dieldrin, the decrease may be due to degradation, deposition, or transport out of the basin.

The data suggest that decreases in total DDT (which includes the parent compound DDT plus the degradation products DDD and DDE) from 1989 to 2002 may possibly have been due more to transport of these compounds out of the basin than to degradation. In natural systems, DDT is biotransformed into DDD and DDE (Smith and others, 1988, p. 31). For both the recent samples and those taken more than 10 years before, the concentration of the parent compound DDT is one-half to two-thirds of the total DDT concentration (tables 6 and 8). Therefore, degradation has not taken place to a great extent, and transport may be the dominant process.

The State of Oregon promulgated water-quality criteria for 11 of the 18 compounds that were analyzed by the USGS (table 3). The Oregon criteria were based on guidelines established by the U.S. Environmental Protection Agency (1986). The criteria considered in this report were the chronic criteria for the protection of freshwater aquatic life. The chronic freshwater standard was based on a 96-hour (4-day) average concentration. In this study, there were insufficient data to determine the average over a 96-hour period, so it was considered that a criterion was *potentially* exceeded if the numerical value was exceeded

**Table 6.**   Organochlorine-compound and streamflow data, Johnson Creek Basin, Oregon, March 11–13, 2002.

[USGS, U.S. Geological Survey; ft$^3$/s, cubic feet per second; NTU, nephelometric turbidity units; mg/L, milligrams per liter; µg/L, micrograms per liter; <, not dichloroethylene; DDT, dichlorodiphenyltrichloroethane; E, estimated]

| Map ID | Site name | USGS site number | Date | Time | Discharge (ft$^3$/s) | Turbidity (NTU) | Total suspended solids (mg/L) | Aldrin (µg/L) | Chlordane (µg/L) | *p,p'* - DDD (µg/L) | *o,p'* DDD (µg/L) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Johnson Creek at Palmblad Road | 452823122240900 | 20020311 | 1220 | 70 | 85 | 64 | <0.001 | <0.1 | <0.002 | < 0.001 |
| | | | 20020311 | 1500 | 110 | 260 | 186 | <.001 | <.1 | <.002 | <.001 |
| | | | 20020311 | 1650 | 110 | 300 | 202 | <.001 | <.1 | <.002 | <.001 |
| | | | 20020311 | 2040 | 440 | 800 | 1190 | <.001 | *E0.1 | *.002 | <.001 |
| | | | 20020312 | 810 | 125 | 80 | 48 | <.001 | <.1 | <.002 | <.001 |
| | | | 20020312 | 1550 | 125 | 65 | 41 | <.001 | <.1 | <.002 | <.001 |
| 10 | Johnson Creek at Sycamore | 14211500 | 20020311 | 1020 | 75 | 21 | 10 | <.001 | <.1 | <.002 | <.001 |
| | | | 20020311 | 1230 | 156 | 55 | 57 | <.001 | <.1 | <.002 | <.001 |
| | | | 20020311 | 1550 | 190 | 55 | 33 | <.001 | <.1 | <.002 | <.001 |
| | | | 20020311 | 1820 | 380 | 230 | 266 | <.001 | <.1 | <.002 | <.001 |
| | | | 20020311 | 2120 | 500 | 300 | 321 | <.001 | <.1 | *E.001 | <.001 |
| | | | 20020312 | 900 | 266 | 110 | 84 | <.001 | <.1 | <.002 | <.001 |
| 14 | Johnson Creek at SE 45th Avenue at Portland. Discharge estimated—continuous data not available | 452743122365400 | 20020311 | 1130 | 145 | 38 | 30 | <.001 | <.1 | <.002 | <.001 |
| | | | 20020311 | 1620 | 255 | 65 | 84 | <.001 | <.1 | <.002 | <.001 |
| | | | 20020311 | 1910 | 320 | 120 | 125 | <.001 | <.1 | <.002 | <.001 |
| | | | 20020312 | 940 | 320 | 200 | 123 | <.001 | <.1 | <.002 | <.001 |
| 17 | Johnson Creek at Milwaukie | 14211550 | 20020311 | 1120 | 131 | 27 | 22 | <.001 | <.1 | <.002 | <.001 |
| | | | 20020311 | 1341 | 144 | 45 | 28 | <.001 | <.1 | <.002 | <.001 |
| | | | 20020311 | 1630 | 276 | 70 | 80 | <.001 | <.1 | <.002 | <.001 |
| | | | 20020311 | 1940 | 345 | 90 | 106 | <.001 | <.1 | <.002 | <.001 |
| | | | 20020312 | 1020 | 354 | 200 | 123 | <.001 | <.1 | <.002 | <.001 |
| | | | 20020313 | 1040 | 221 | 50 | 26 | <.001 | <.1 | <.002 | <.001 |
| 3 | Storm Drain at Gresham City Park | 452951122254600 | 20020311 | 1140 | 3 | 26 | 23 | <.001 | <.1 | <.002 | <.001 |
| | | | 20020311 | 1410 | 1 | 34 | 18 | <.001 | <.1 | <.002 | <.001 |
| | | | 20020311 | 1610 | 5 | 50 | 63 | <.001 | <.1 | <.002 | <.001 |
| | | | 20020311 | 1730 | 8 | 60 | 86 | <.001 | <.1 | <.002 | <.001 |
| 16 | Storm Drain at SE 45th Avenue and Umatilla Street | 452750122365300 | 20020311 | 1050 | 4 | 60 | 49 | <.001 | <.1 | <.002 | <.001 |
| | | | 20020311 | 1220 | 5 | 75 | 77 | <.001 | <.1 | <.002 | <.001 |
| | | | 20020311 | 1400 | 3 | 39 | 31 | <.001 | <.1 | <.002 | <.001 |
| | | | 20020311 | 1500 | 2 | 28 | 18 | <.001 | <.1 | <.002 | <.001 |
| | | | 20020311 | 1530 | 10 | 160 | 301 | <.001 | <.1 | <.002 | <.001 |
| | | | 20020311 | 1730 | 6 | 85 | 86 | <.001 | <.1 | <.002 | <.001 |

detected at indicated level; * indicates detections of organochlorine compounds; DDD, dichlorodiphenyldichloroethane; DDE, dichlorodiphenyl-

| p,p'-DDE (μg/L) | o,p'-DDE (μg/L) | p,p'-DDT (μg/L) | o,p'-DDT (μg/L) | Dieldrin (μg/L) | Endo-sulfan I (μg/L) | Endrin (μg/L) | Lindane (μg/L) | Hepta-chlor (μg/L) | Hepta-chlor-epoxide (μg/L) | p,p'-methoxy-chlor (μg/L) | Mirex (μg/L) | Toxa-phene (μg/L) | Total PCB (μg/L) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *0.004 | <0.001 | *0.006 | < 0.001 | *0.003 | <0.002 | <0.002 | <0.0007 | <0.002 | <0.001 | <0.002 | <0.001 | <1 | <0.1 |
| *.006 | <.001 | *.009 | <.001 | *.005 | *E.001 | <.002 | <.0007 | <.002 | <.001 | <.002 | <.001 | <1 | <.1 |
| *.011 | *.001 | *.021 | <.001 | *.016 | <.002 | <.002 | <.0007 | <.002 | <.001 | <.002 | <.001 | <1 | <.1 |
| *.029 | *.003 | *.036 | *.001 | *.021 | <.002 | <.002 | <.0007 | <.002 | <.001 | <.002 | <.001 | <1 | <.1 |
| *.003 | <.001 | .003 | <.001 | *.007 | <.002 | <.002 | <.0007 | <.002 | <.001 | <.002 | <.001 | <1 | <.1 |
| *.002 | <.001 | *.003 | <.001 | *.005 | <.002 | <.002 | <.0007 | <.002 | <.001 | <.002 | <.001 | <1 | <.1 |
| <.001 | < .001 | <.002 | <.001 | *.003 | <.002 | <.002 | <.0007 | <.002 | <.001 | <.002 | <.001 | <1 | <.1 |
| *.002 | <.001 | *.002 | <.001 | *.005 | <.002 | <.002 | <.0007 | <.002 | <.001 | <.002 | <.001 | <1 | <.1 |
| *.002 | <.001 | *E.002 | <.001 | *.004 | <.002 | <.002 | <.0007 | <.002 | <.001 | <.002 | <.001 | <1 | <.1 |
| *.006 | <.001 | *.006 | *.003 | *.005 | <.002 | <.002 | <.0007 | <.002 | <.001 | <.002 | <.001 | <1 | <.1 |
| *.006 | <.001 | *.009 | *E.001 | *.007 | <.002 | <.002 | <.0007 | <.002 | <.001 | <.002 | <.001 | <1 | <.1 |
| *.004 | <.001 | *.005 | <.001 | *.006 | <.002 | <.002 | <.0007 | <.002 | <.001 | <.002 | <.001 | <1 | <.1 |
| <.001 | <.001 | <.002 | <.001 | *.002 | <.002 | <.002 | <.0007 | <.002 | <.001 | <.002 | <.001 | <1 | <.1 |
| *.001 | <.001 | *E.002 | <.001 | *.003 | <.002 | <.002 | <.0007 | <.002 | <.001 | <.002 | <.001 | <1 | <.1 |
| *.002 | <.001 | *E.002 | <.001 | *.003 | <.002 | <.002 | <.0007 | <.002 | <.001 | <.002 | <.001 | <1 | <.1 |
| *.005 | <.001 | *.008 | <.001 | *.008 | <.002 | <.002 | <.0007 | <.002 | <.001 | <.002 | <.001 | <1 | <.1 |
| <.001 | <.001 | <.002 | <.001 | *.002 | <.002 | <.002 | <.0007 | <.002 | <.001 | <.002 | <.001 | <1 | <.1 |
| <.001 | <.001 | <.002 | <.001 | *.002 | <.002 | <.002 | <.0007 | <.002 | <.001 | <.002 | <.001 | <1 | <.1 |
| *.001 | <.001 | *.004 | <.001 | *.003 | <.002 | <.002 | <.0007 | <.002 | <.001 | *.004 | <.001 | <1 | <.1 |
| *.002 | <.001 | *.002 | <.001 | *.003 | <.002 | <.002 | <.0007 | <.002 | <.001 | <.002 | <.001 | <1 | <.1 |
| *.005 | <.001 | *.007 | <.001 | *.006 | <.002 | <.002 | <.0007 | <.002 | <.001 | <.002 | <.001 | <1 | <.1 |
| *.002 | <.001 | *.003 | <.001 | *.005 | <.002 | <.002 | <.0007 | <.002 | <.001 | <.002 | <.001 | <1 | <.1 |
| <.001 | <.001 | <.002 | <.001 | <.001 | <.002 | <.002 | <.0007 | <.002 | <.001 | <.002 | <.001 | <1 | <.1 |
| <.001 | <.001 | <.002 | <.001 | <.001 | <.002 | <.002 | <.0007 | <.002 | <.001 | <.002 | <.001 | <1 | <.1 |
| <.001 | <.001 | <.002 | <.001 | <.001 | <.002 | <.002 | <.0007 | <.002 | <.001 | <.002 | <.001 | <1 | <.1 |
| <.001 | <.001 | <.002 | <.001 | <.001 | <.002 | <.002 | <.0007 | <.002 | <.001 | <.002 | <.001 | <1 | <.1 |
| <.001 | <.001 | <.002 | <.001 | <.001 | <.002 | <.002 | <.0007 | <.002 | <.001 | <.002 | <.001 | <1 | <.1 |
| <.001 | <.001 | *.003 | <.001 | <.001 | <.002 | <.002 | <.0007 | <.002 | <.001 | <.002 | <.001 | <1 | <.1 |
| <.001 | <.001 | *E.002 | <.001 | <.001 | <.002 | <.002 | <.0007 | <.002 | <.001 | <.002 | <.001 | <1 | <.1 |
| <.001 | <.001 | <.002 | <.001 | <.001 | <.002 | <.002 | <.0007 | <.002 | <.001 | <.002 | <.001 | <1 | <.1 |
| *E.001 | <.001 | *.017 | <.001 | <.001 | <.002 | <.002 | <.0007 | <.002 | <.001 | <.002 | <.001 | <1 | <.1 |
| <.001 | <.001 | *E.001 | <.001 | <.001 | <.002 | <.002 | <.0007 | <.002 | <.001 | <.002 | <.001 | <1 | *E.1 |

**Table 7.** Organochlorine-compound and streamflow data collected and analyzed by Oregon Department of Environmental Quality, Johnson Creek, Oregon, 2001–02.

[<, not detected at indicated concentration; NA, not available; NTU nephelometric turbidity units; ft$^3$/s, cubic feet per second; mg/L, milligrams per liter; μg/L micrograms per liter; DDD, dichlorodiphenyl-dichloroethane; DDE, dichlorodiphenyldichloroethylene; DDT, dichlorodiphenyltrichloroethane; * indicates detections of organochlorine compounds]

| Map ID | Site name | Sample date and time | Estimated discharge (ft$^3$/s) | Turbidity (NTU) | Total suspended solids (mg/L) | Aldrin (μg/L) | p,p'-DDD μg/L | p,p'-DDE (μg/L) | p,p'-DDT (μg/L) | Dieldrin (μg/L) | Endosulfan (μg/L) 1 | Endrin (μg/L) | Heptachlor (μg/L) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Johnson Creek at Palmblad Road | 12/5/01 12:00 | 180 | 58 | 40 | NA | <0.0010 | *0.0034 | *0.0031 | *0.0077 | *0.0043 | NA | <0.0010 |
| 1 | Johnson Creek at Palmblad Road | 12/19/01 12:25 | 80 | 27 | 10 | <0.0010 | <.0010 | *.003 | <.0010 | *.007 | *.004 | NA | NA |
| 4 | Johnson Creek at SE 190th Avenue | 12/5/01 11:25 | 260 | 84 | 87 | NA | NA | *.0047 | *.0036 | *.0066 | *.0048 | NA | *.0011 |
| 4 | Johnson Creek at SE 190th Avenue | 12/19/01 11:50 | 100 | 31 | 19 | NA | NA | *.0014 | NA | *.0051 | *.0028 | NA | NA |
| 4 | Johnson Creek at SE 190th Avenue | 1/9/02 12:10 | 100 | 26 | 15 | <.0010 | *.002 | *.0022 | *.0028 | *.006 | *.0024 | <0.0010 | <.0010 |
| 11 | Johnson Creek at SE 92nd Avenue | 12/19/01 11:10 | 150 | 42 | 16 | NA | NA | *.0012 | NA | *.0043 | NA | NA | NA |
| 11 | Johnson Creek at SE 92nd Avenue | 1/9/02 11:40 | 160 | 37 | 21 | <.0011 | *.0012 | *.0024 | <.0020 | *.0052 | *.0022 | <.0010 | <.0010 |
| 14 | Johnson Creek at SE 45th Avenue | 12/19/01 10:40 | 160 | 42 | 20 | NA | NA | *.0019 | *.0025 | *.0064 | NA | NA | *.0013 |
| 14 | Johnson Creek at SE 45th Avenue | 1/9/02 11:15 | 160 | 32 | 20 | *.0013 | *.0025 | NA | *.0024 | *.0054 | *.0022 | <.0010 | <.0010 |
| 18 | Johnson Creek at SE 17th Avenue | 12/19/01 10:00 | 180 | 50 | 20 | NA | NA | *.0024 | *.0028 | *.0053 | NA | NA | NA |
| 18 | Johnson Creek at SE 17th Avenue | 1/9/02 10:40 | 180 | 34 | 22 | <.0010 | *.0013 | *.0015 | *.002 | *.0053 | *.0022 | <.0010 | <.0010 |
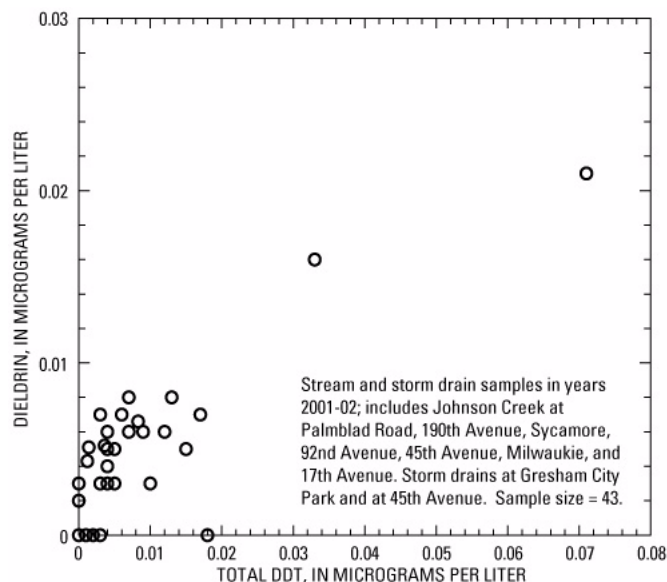
**Figure 7.** The relation between the concentrations of total DDT and dieldrin, Johnson Creek Basin, Oregon, 2001–02.

even once. However, because the samples covered the course of a short-duration storm (1–3 days), with the organochlorine-compound concentrations rising and falling with stream discharge, it is likely that the 96-hour-average organochlorine-compound concentrations were less than the average of the concentrations sampled, and therefore that the criteria were not exceeded. Of the 11 compounds for which criteria have been established, 5 (chlordane, total DDT, mirex, toxaphene, and PCBs) had criteria less than or equal to the reporting level. Any detection of these compounds was considered to be an potential exceedance of the chronic freshwater criterion.

In 2001 and 2002, chronic freshwater criteria were potentially exceeded for chlordane, total DDT, dieldrin, and total PCB (fig. 8). The total DDT and dieldrin standard was potentially exceeded at most of the sites and times. These results illustrate the ubiquity and long life of DDX and dieldrin in the environment. According to the U.S. Environmental Protection Agency (1986), they also indicate long-term effects of the organochlorine compounds on aquatic organisms, including fish and benthic invertebrates.

As noted in table 3, the chronic freshwater criterion promulgated by the State of Oregon for dieldrin is 0.0019 μg/L. Recently, the U.S. Environmental Protection Agency (2002), has changed their recommended value for this criterion to 0.056 μg/L. If the State of Oregon follows this recommendation and changes their criterion for dieldrin, none of the samples from the March 2002 storm would have had concentrations that exceeded the criterion.

The occurrences of chlordane and PCBs may be the result of agricultural uses and urban settings in the basin, respectively. Because there was only one detection of each compound in the March 2002 sample, the association of pesticide occurrence with land cover is not conclusive. The only potential exceedance for chlordane was at the Palmblad Road site, which may be related to the fact that much of the agriculture in the Johnson Creek Basin is upstream of this site. Fifty percent of the land cover in the area upstream from this site is agricultural (table 2). Past uses for chlordane include insect control on fruit and vegetable crops, as well as termite control in urban areas. The only potential exceedance for total PCB was in the storm drain at SE 45th Avenue, which may be due to the urban land uses upstream of this sampling site.

## Loads of Organochlorine Pesticides

The discussion of organochlorine pesticides to this point has focused on concentrations, which is appropriate for evaluating the occurrence of organochlorine pesticides and the comparisons to guidelines or criteria. However, for understanding the flux of organochlorine pesticides in the Johnson Creek Basin, and assessing possible sources and sinks, the load of the organochlorine pesticides must be considered. Load is calculated as organochlorine-pesticide concentration multiplied by stream discharge. Stream-discharge data were not available for all organochlorine-pesticide samples, and only when both quantities were measured was a load calculated.

Figures 9 and 10 show the total DDT and dieldrin loads, respectively, and the discharge hydrographs for the streamflow-gaging site nearest each sampling site. Loads are represented as bars on each graph, and as such are instantaneous observations. The load of the entire storm was not calculated due to incomplete organochlorine-pesticide data over the storm hydrograph. The discharges used for load calculation at the Palmblad Road and SE 45th Avenue sites were estimated as described above in the hydrologic data section. It should be noted that there are two y-axes on figures 9 and 10. The right y-axis of each graph is discharge, and the same scale is used for each graph. The left y-axis of each graph represents load.

Several factors contribute to uncertainty when comparing organochlorine-pesticide loads over the storm event of March 11–13, 2002. First, samples were taken at a small number of points (a maximum of six) over the discharge hydrograph at each site. Second, comparison of loads to the discharge hydrograph does not imply that the peak load is simultaneous with the peak stream discharge. Third, the source (contributing area) of streamflow at a given time on the hydrograph changes, resulting in changes in the proportions of contributing-area land uses. For example, samples taken at the SE 45th Avenue and Milwaukie sites in the afternoon of March 11, while on a rapid rise in discharge, likely represented flow derived primarily from nearby urban areas and to a lesser extent from the upper basin, whereas subsequent flow might have a higher

**Table 8.**    Organochlorine-compound, streamflow and turbidity data, Johnson Creek Basin, Oregon, 1989–90.

[Data are from Edwards, 1992. Discharge and turbidity data for the sample times shown were estimated from measurements that were taken at slightly different times. ft$^3$/s, cubic feet per second; NTU, nephelometric turbidity units; µg/L, micrograms per liter; DDD, dichlorodiphenyldichloroethane; DDE, dichlorodiphenyldichloroethylene; DDT, dichlorodiphenyltrichloroethane]

| Site number and name | Date | Time | Discharge (ft$^3$/s) | Turbidity (NTU) | p,p'- DDD (µg/L) | p,p'- DDE (µg/L) | p,p'- DDT (µg/L) | Dieldrin (µg/L) |
|---|---|---|---|---|---|---|---|---|
| 452910122251500, Johnson Creek at Regner Road | 12–04–89 | 17:30 | 450 | 600 | 0.070 | 0.160 | 0.630 | 0.060 |
| | 12–04–89 | 21:00 | 600 | 530 | .020 | .060 | .150 | .030 |
| | 12–04–89 | 23:50 | 460 | 290 | .010 | .020 | .040 | .020 |
| | 01–25–90 | 16:50 | 103 | 155 | .033 | .042 | .180 | .020 |
| | 01–25–90 | 21:45 | 103 | 400 | .020 | .034 | .085 | .035 |
| | 01–26–90 | 01:15 | 103 | 160 | .013 | .019 | .042 | .029 |
| 14211499, Kelley Creek at 159th Drive | 12–04–89 | 20:30 | 260 | 260 | .010 | .050 | .080 | .050 |
| | 01–25–90 | 21:05 | 85 | 190 | .011 | .029 | .044 | .028 |
| 14211500, Johnson Creek at Sycamore | 12–04–89 | 18:00 | 600 | 560 | .010 | .010 | .100 | .010 |
| | 12–04–89 | 21:25 | 830 | 320 | .050 | .060 | .170 | .040 |
| | 12–05–89 | 00:00 | 825 | 390 | .010 | .030 | .080 | .030 |
| | 01–25–90 | 18:15 | 250 | 220 | .011 | .026 | .045 | .020 |
| | 01–25–90 | 22:30 | 457 | 205 | .017 | .028 | .066 | .018 |
| 45271712234400, Johnson Creek at SE 82nd Avenue | 12–04–89 | 22:15 | 750 | 360 | .010 | .020 | .040 | .020 |
| | 01–25–90 | 22:10 | 360 | 190 | .011 | .020 | .042 | .017 |
| 452722122361100, Johnson Creek at Stanley Avenue | 12–05–89 | 00:00 | 750 | 420 | .010 | .040 | .100 | .030 |
| | 01–25–90 | 22:15 | 400 | 270 | .012 | .020 | .040 | .016 |
| 452750122370000, Johnson Creek at SE 44th Avenue | 01–25–90 | 23:15 | 400 | 200 | .090 | .010 | .060 | .010 |
| 14211550, Johnson Creek at Milwaukie | 12–04–89 | 20:15 | 600 | 520 | .010 | .030 | .070 | .020 |
| | 12–05–89 | 01:30 | 826 | 420 | .010 | .040 | .110 | .030 |
| | 01–25–90 | 21:00 | 345 | 190 | .010 | .013 | .025 | .012 |
| | 01–26–90 | 01:55 | 530 | 200 | .015 | .018 | .048 | .015 |
| | 01–26–90 | 08:15 | 315 | 145 | .011 | .011 | .028 | .013 |

proportion of contributions from predominantly agricultural areas upstream. Even at the Sycamore site, the samples taken on the rising limb of the hydrograph may represent a greater proportion of flow from nearby areas than the upper watershed. The loads calculated from samples taken in the morning of March 12, following the peak, indicated that, although the peak load had passed the Palmblad Road site and returned to a background level, the load at the downstream sites was still elevated.

## Total DDT

Total DDT loads for the March 2002 storm were calculated for four sampling sites (fig. 9). The maximum instantaneous load of total DDT at the Palmblad Road site was 76 grams per day, coinciding with the timing of the peak discharge. Before and after the peak of total DDT and discharge, there was a small, but measurable load of total DDT at each sampling time, which may represent a background level of total DDT at the Palmblad Road site.

The peak total DDT load attenuated between the Palmblad Road site (fig. 9A) and the Sycamore site (fig. 9B) downstream, while peak stream discharge increased. The large total DDT load at the Palmblad Road site indicates a source in the upper Johnson Creek Basin, the land use within which is largely agricultural (fig. 2 and table 2). Although no sample was taken at the peak discharge of 524 ft$^3$/s at the Sycamore site, a sample was taken 2 hours prior to the peak at a discharge of 496 ft$^3$/s. The load of
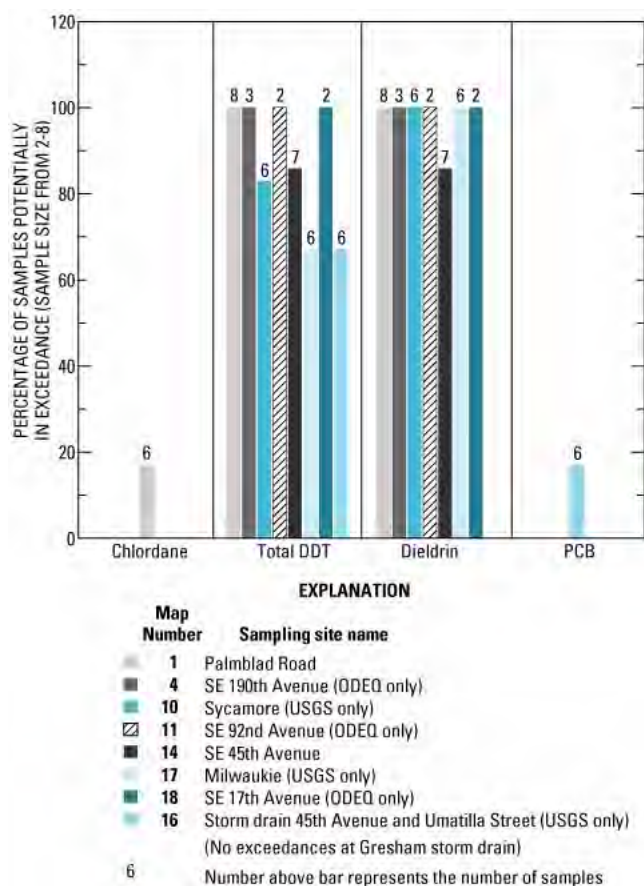
**Figure 8.** Potential exceedances of Oregon water quality criteria, Johnson Creek Basin, Oregon, 2001–02.

this sample was 21 grams per day. The samples taken at the Palmblad Road and Sycamore sites in the morning of March 12 indicate the total DDT load may attenuate fairly rapidly at the upper site. About 10 hours after the peak discharge at the Sycamore gage, the load of total DDT was about 5 grams per day, or about one-quarter of the peak load. Again, due to the small number of samples, it was not possible to calculate a total-storm load for each site.

No samples were taken at the SE 45th Avenue or Milwaukie sites (fig. 9C) during the peak streamflow (which probably coincided approximately with the maximum total DDT concentration), so calculation of the peak total DDT load downstream of the Sycamore gage could not be determined. The highest load measured was 10 hours after the peak and was about 10 grams per day. The similarity in loads at the SE 45th Avenue and Milwaukie sites, based on samples taken at nearly the same time, indicates that there was little input of total DDT between the two sites. Although DDX was detected in the storm drain at SE 45th Avenue (located between the stream-sampling location at SE 45th Avenue and the Milwaukie gage), the discharge from the drain was less than 3 percent of the

stream discharge, adding little in terms of load to the stream.

## Dieldrin

Dieldrin was detected in every stream (non-storm-drain) sample in the March 2002 storm (fig. 10). As was the case for total DDT, the highest instantaneous load of dieldrin, 23 grams per day, occurred at the Palmblad Road site near the peak in discharge (fig. 10A). Again, this suggests a historical agricultural source of dieldrin in the Johnson Creek Basin. The peak load at Sycamore was about 8 grams per day (fig. 10B), smaller than that at Palmblad Road. The largest measured loads at SE 45th Avenue and at Milwaukie were about 6 and 5 grams per day, respectively (fig. 10C). However, as noted above, no samples were taken near the peak streamflow at either site, so the peak load of dieldrin at the SE 45th Avenue and Milwaukie sites probably was not documented.

## Relation of Total Suspended Solids to Turbidity

To compare recent water-quality results (including comparisons of organochlorine-pesticide concentrations to a sediment parameter) with previous studies, it was necessary to determine the relationship between TSS and turbidity (fig. 11). The 1989–90 study (Edwards, 1992) included only turbidity measurements, and the sampling of 2001 and 2002 included both turbidity and TSS data.

An analysis was made of all samples for which both TSS and turbidity were measured. This data set comprised 78 samples, including samples collected from Johnson Creek and storm drains March 11–13, 2002 by the USGS and analyzed by the City of Portland Bureau Environmental Services (BES) laboratory (table 6); samples taken and analyzed by the ODEQ on Johnson Creek in 2001–02 (table 7); and samples collected by the City of Portland from Kelley Creek in 2002–03 (table 9). There may have been a bias resulting from the use of different turbidity instruments by the ODEQ and BES laboratories, but the magnitude and direction of any such bias is unknown.

A linear regression was done on the turbidity values to estimate TSS. Of the 78 values, one high value (a peak value at Johnson Creek at Palmblad Road, March 11, 2002 at 20:40) was not used. If used, this high value would have had undue influence on the regression and would have skewed the relation of TSS to turbidity, particularly at low TSS concentrations. For the purposes of this study, the relation at low TSS concentrations was of primary importance. Of the 77 remaining samples, the relation was determined to be TSS (in mg/L [milligrams per liter]) = 0.88 x turbidity (in nephleometric turbidity units). The regression line was forced through the origin, and had an r$^2$ of 0.82. A plot of the residuals indicated the residuals were fairly well balanced about zero. This equation was applied to the
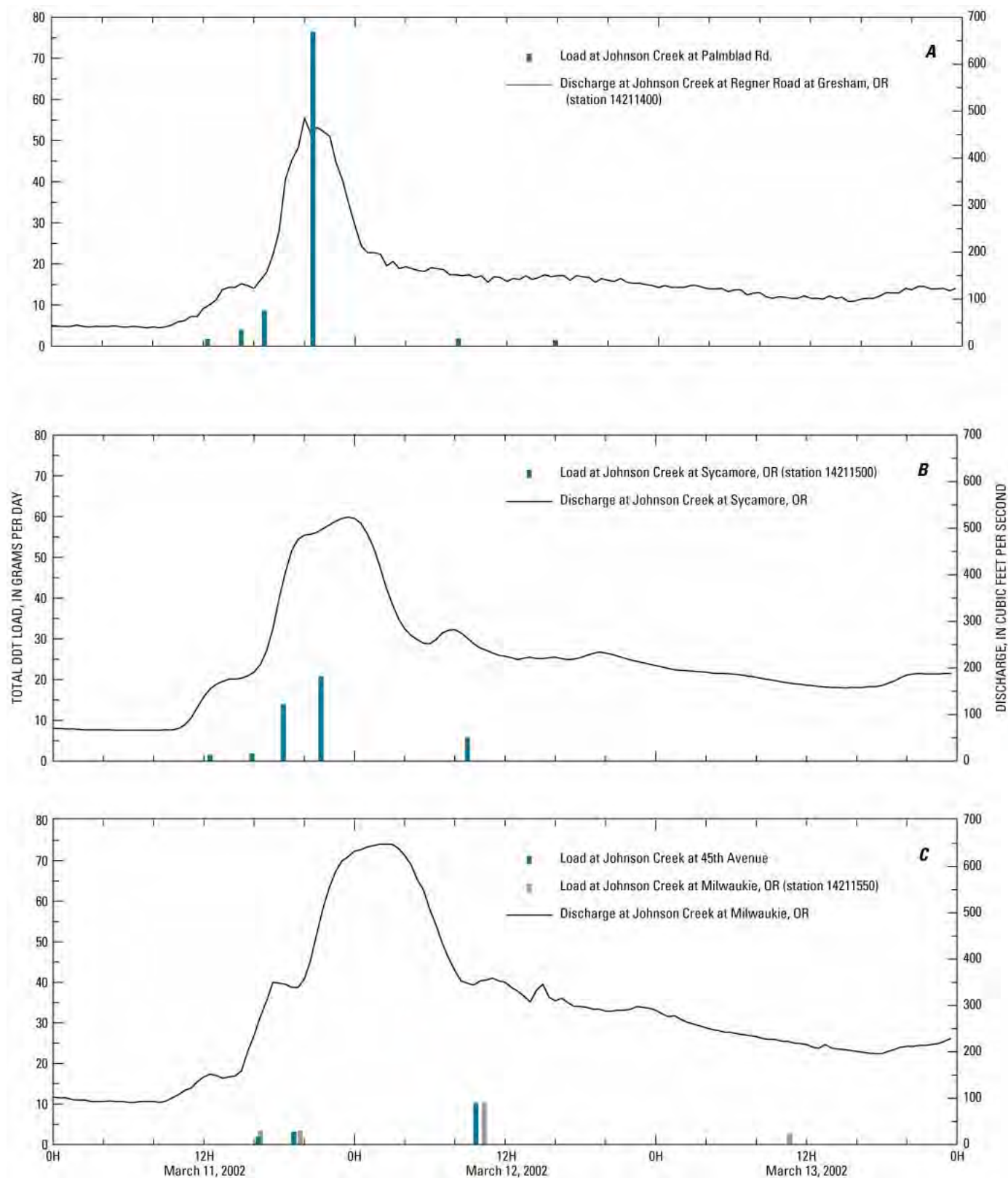
**Figure 9.**    Total DDT loads and streamflow hydrographs, Johnson Creek Basin, Oregon, March 11–13, 2002. A, upper basin site; B, middle basin site; C, lower basin sites.
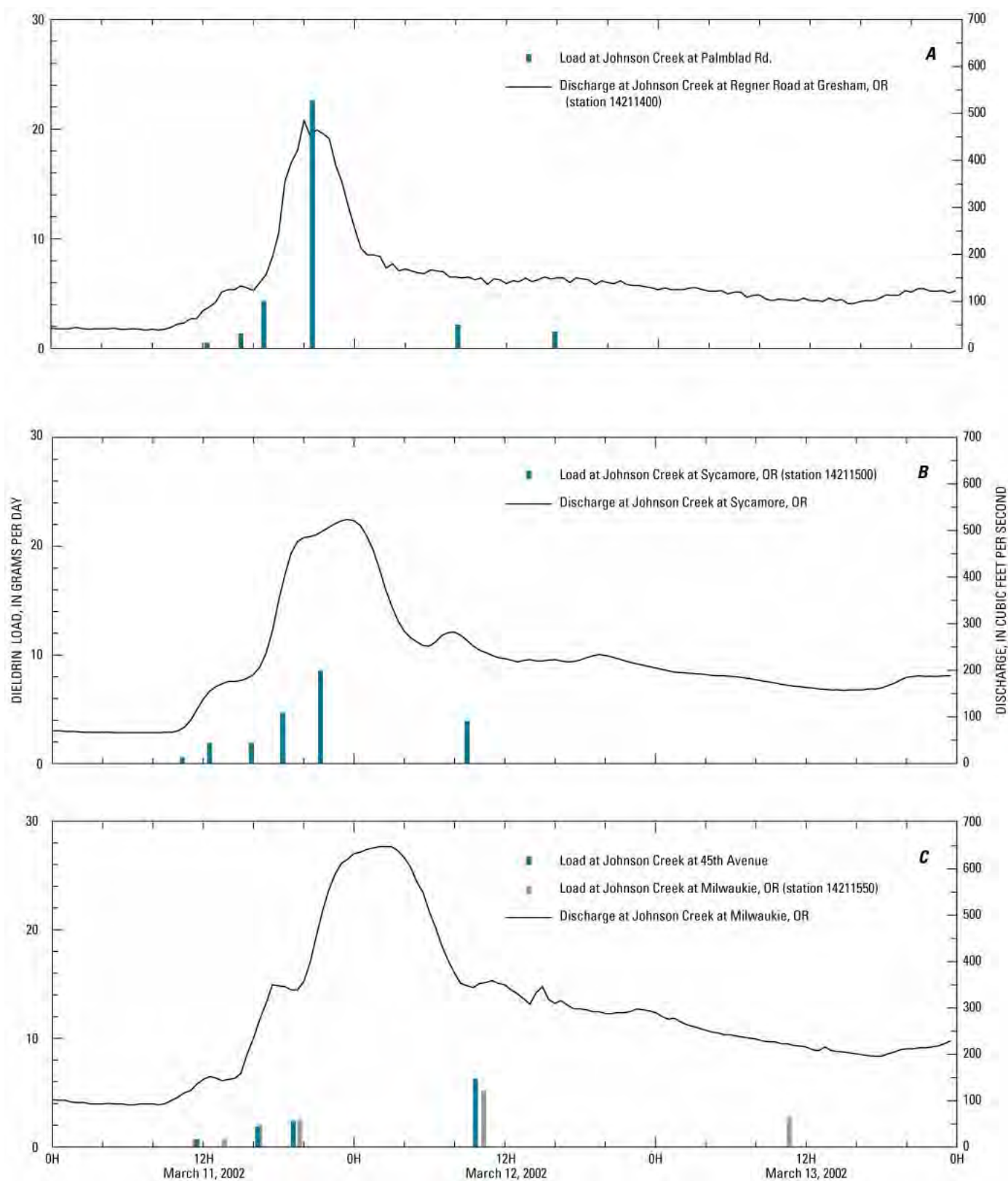
**Figure 10.**    Dieldrin loads and streamflow hydrographs, Johnson Creek Basin, Oregon, March 11–13, 2002. A, upper basin site; B, middle basin site; C, lower basin sites.
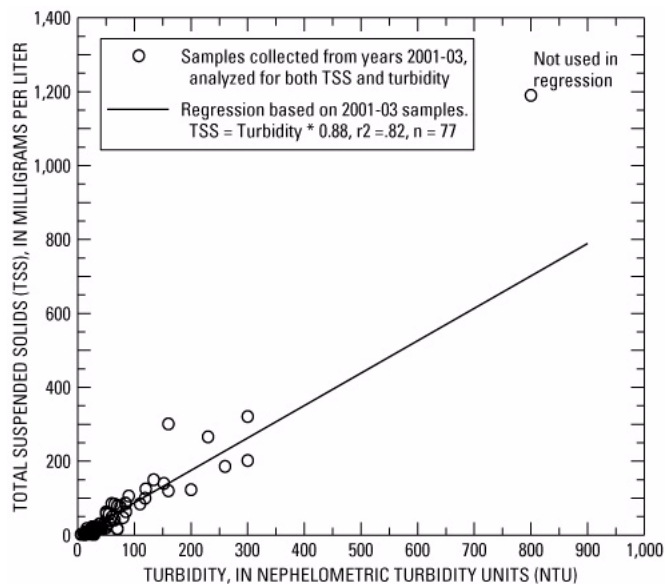
**Figure 11.**    The relation between total suspended solids and turbidity, Johnson Creek and Kelley Creek, Oregon, 2001–03.

1989–90 samples for which a turbidity was measured, to derive an estimated TSS concentration.

## Relation of Organochlorine Pesticides to Total Suspended Solids

The relationship between organochlorine compounds and total suspended solids (either measured or estimated) was explored for the data sets from the 1989–90 and 2001–02 time periods. Both the USGS and ODEQ data were used for this analysis. Total DDT and TSS were positively correlated, and there was a decrease in total DDT relative to TSS from the 1989–90 period to the 2001–02 period (fig. 12). The relation of total DDT and TSS was more linear in 2001–02 than 1989–90 probably because most of the recent samples were from a single storm event, whereas the 1989–90 samples were from two high-flow events.

The total DDT/TSS relation in the upper Johnson Creek Basin is shown in figure 12A. The older data are from the Regner Road site (RM 15.8) and the newer data are from the Palmblad Road site (RM 17.2). The land cover upstream of each of these sites is similar, although the area upstream from the Palmblad Road site has a slightly larger agricultural percentage (table 2, fig. 2). The data point representing a TSS value of 1,190 mg/L is shown on the graph, but it was not used in the regression because the primary interest was in determining the minimum threshold concentration of TSS that would be associated with exceedance of the Oregon chronic water-quality criterion for total DDT. For the Palmblad Road site, the TSS value that would correspond to the total DDT water-quality criterion of 0.001 µg/l was 8 mg/L TSS (table 10).

The correlation coefficient for the regression was 0.78. Based on these data, if TSS could be limited to this concentration, the Oregon chronic freshwater criterion for total DDT would not be exceeded.

Similar data are shown in figure 12B for Johnson Creek at Sycamore (RM 10.2). For the 2002 data, the correlation coefficient was 0.89 and, using the regression equation, if the TSS were less than 18 mg/L at this site, then the Oregon chronic freshwater criterion for total DDT would not be exceeded (table 10).

The relation between total DDT and TSS in the lower part of the Johnson Creek Basin is portrayed in figure 12C. Data from three sites were combined for the regression displayed for the total DDT/TSS relation: Johnson Creek at SE 45th Avenue (RM 3.2), Johnson Creek at Milwaukie (RM 0.7), and Johnson Creek at SE 17th Avenue (RM 0.3). Data were combined because there were only small differences in stream discharge (fig. 3), land cover (table 2), and total DDT load (fig. 9). For the 1989–90 sampling, similar land cover enabled grouping the samples at SE Stanley Avenue (RM 3.6) and at SE 44th Avenue (RM 3.0) with those at the Milwaukie gage. The correlation coefficient for 2001–02 was only 0.28, meaning that a relatively small portion of the variation was explained by the regression. One reason is that, as stated earlier, the peak of the March 2002 storm was not fully sampled in the lower part of the basin. Another reason for the poor relation is that concentrations of total DDT were low, with 3 of the 14 samples being below the detection level. (Nondetections were treated as zero values for this analysis.) Using the resulting regression, a TSS of less-than or equal to 15 mg/L would need to be maintained in the lower basin to meet the Oregon chronic freshwater criteria for total DDT (table 10). As stated before, however, the confidence in this relation is not high.

Relative to TSS, there was up to an order-of-magnitude decrease in the concentrations of total DDT for 2001–02 when compared to data from 1989–90. That is, for a given TSS concentration, the concentration of total DDT in 2001–02 was up to 10 times smaller than in 1989–90. This trend of decreased total DDT for a given mass of sediment over a decade timespan has also been observed in the Yakima River Basin, Washington (Rinella and others, 1999).

The decrease over time of total DDT relative to TSS in the Johnson Creek Basin may have been due to several factors. First, some DDX may have been transported through the river system. These compounds were applied to plants and to the soil surface and some of the pesticide may have left the basin associated with sediment export during streamflow. Second, disturbance of noncontaminated soils may have in effect diluted the concentration of total DDT relative to TSS. Third, DDX may have degraded, although as indicated in the discussion of DDX concentrations, the persistence of the parent compound

**Table 9.** Organochlorine-compound and other water-quality data collected and analyzed by the City of Portland, Oregon, Kelley Creek, 2002–03.

[Map ID refers to the number on figure 1; ft$^3$/s, cubic feet per second; mg/L, milligrams per liter; µg/L, micrograms per liter; NA, not available; NTU, nephelometric turbidity units; <, not detected at indicated concentration; E, estimated below minimum detection level; DDD, dichlorodiphenyldichloroethane; DDE, dichlorodiphenyldichloroethylene; DDT, dichlorodiphenyltrichloroethane]

| Map ID | Site Name | Date and time | Discharge (ft$^3$/s) | Turbidity (NTU) | Total suspended solids (mg/L) | Aldrin (µg/L) | Chlorpyrifos (µg/L) | p,p'-DDD (µg/L) | p,p'-DDE (µg/L) | p,p'-DDD + p,p'-DDE, rounded (µg/L) | Dieldrin (µg/L) | Endirn (µg/L) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 5 | Kelley Creek at RM 2.5 | 1/7/02 9:55 | NA | NA | 20 | <0.0003 | E0.00026 | 0.0009 | E0.0001 | 0.001 | 0.0015 | E0.00065 |
| 5 | Kelley Creek at RM 2.5 | 3/6/02 9:20 | NA | NA | 135 | E.00019 | .0017 | .0004 | .0023 | .003 | .0008 | E.00005 |
| 5 | Kelley Creek at RM 2.5 | 6/4/02 9:07 | NA | NA | 17 | E.00002 | E.0003 | <.00039 | <.00039 | 0 | <.0004 | <.00078 |
| 5 | Kelley Creek at RM 2.5 | 9/5/02 9:55 | NA | 29 | 2 | E.00002 | E.00027 | E.00001 | .0011 | .001 | E.0003 | E.00007 |
| 5 | Kelley Creek at RM 2.5 | 12/12/02 13:34 | NA | 21 | 3 | <.0013 | NA | <.0013 | E.00024 | .0002 | E.00026 | <.0013 |
| 5 | Kelley Creek at RM 2.5 | 1/29/03 9:15 | NA | 18 | 8.2 | <.0012 | NA | <.0012 | E.000096 | .0001 | E.00069 | <.0012 |
| 6 | Kelley Creek at RM 1.2 | 1/7/02 10:35 | NA | NA | 15 | <.0003 | .0015 | .0023 | .0031 | .005 | .0145 | .0159 |
| 6 | Kelley Creek at RM 1.2 | 3/6/02 9:45 | NA | NA | 139 | .0006 | .0060 | .0083 | .0200 | .028 | .0240 | .0134 |
| 6 | Kelley Creek at RM 1.2 | 6/4/02 9:33 | NA | NA | 3 | E.00003 | .0196 | <.0003 | .0034 | .004 | .0142 | .1320 |
| 6 | Kelley Creek at RM 1.2 | 9/5/02 10:35 | NA | 20 | 8.9 | .0016 | .0302 | .0048 | .0104 | .015 | .0337 | .1078 |
| 6 | Kelley Creek at RM 1.2 | 12/12/02 13:50 | NA | 16 | 3 | <.0012 | NA | .0018 | .0034 | .005 | .0150 | <.0012 |
| 6 | Kelley Creek at RM 1.2 | 1/29/03 9:33 | NA | 50 | 57.7 | <.0012 | NA | .0017 | .0059 | .008 | .0074 | <.0012 |
| 7 | Clatsop Creek (tributary) | 1/7/02 11:20 | NA | NA | 19 | <.0003 | E.00045 | .0010 | .0004 | .001 | .0015 | .0101 |
| 7 | Clatsop Creek (tributary) | 3/6/02 10:10 | NA | NA | 161 | .0011 | .0053 | .0019 | .0014 | .003 | .0016 | .0333 |
| 7 | Clatsop Creek (tributary) | 6/4/02 9:50 | NA | NA | 3.2 | <.0002 | <.001 | <.0003 | <.0003 | 0 | <.0003 | .0178 |
| 7 | Clatsop Creek (tributary) | 9/5/02 11:20 | NA | 6.3 | 2.8 | .0008 | E.00087 | E.00013 | E.00002 | .0002 | .0031 | .0554 |
| 7 | Clatsop Creek (tributary) | 12/12/02 14:37 | NA | 16 | 18 | <.0012 | NA | E.00091 | E.00014 | .001 | <.0012 | <.0012 |
| 7 | Clatsop Creek (tributary) | 1/29/03 9:53 | NA | 30 | 22 | <.0012 | NA | <.0012 | E.0001 | .0001 | E.00049 | <.0012 |

**Table 9.** Organochlorine-compound and other water-quality data collected and analyzed by the City of Portland, Oregon, Kelley Creek, 2002–03.—Continued

[Map ID refers to the number on figure 1; ft$^3$/s, cubic feet per second; mg/L, milligrams per liter; µg/L, micrograms per liter; NA, not available; NTU, nephelometric turbidity units; <, not detected at indicated concentration; E, estimated below minimum detection level; DDD, dichlorodiphenyldichloroethane; DDE, dichlorodiphenyldichloroethylene; DDT, dichlorodiphenyltrichloroethane]

| Map ID | Site Name | Date and time | Discharge (ft$^3$/) | Turbidity (NTU) | Total suspended solids (mg/L) | Aldrin (µg/L) | Chlorpyrifos (µg/L) | p,p'-DDD (µg/L) | p,p'-DDE (µg/L) | p,p'-DDD + p,p'-DDE, rounded (µg/L) | Dieldrin (µg/L) | Endirn (µg/L) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 8 | Kelley Creek at RM 0.5 | 1/7/02 10:00 | NA | NA | 24.4 | <0.0003 | 0.0042 | 0.0019 | 0.0020 | 0.004 | 0.0133 | 0.0127 |
| 8 | Kelley Creek at RM 0.5 | 3/6/02 10:34 | NA | NA | 157 | .0021 | .0072 | .0051 | .0130 | .018 | .0158 | .1038 |
| 8 | Kelley Creek at RM 0.5 | 6/4/02 10:11 | NA | NA | 2.8 | <.0003 | .0067 | <.0004 | <.00039 | 0 | .0090 | .0775 |
| 8 | Kelley Creek at RM 0.5 | 9/5/02 10:00 | NA | NA | 1 | .0007 | .0009 | .0009 | .0010 | .002 | .0113 | .0708 |
| 8 | Kelley Creek at RM 0.5 | 12/12/02 14:05 | NA | 12 | 1 | <.0012 | NA | E.0005 | E.001 | .002 | .0073 | <.0012 |
| 8 | Kelley Creek at RM 0.5 | 1/29/03 10:28 | NA | 21 | 15 | <.0011 | NA | E.00055 | E.001 | .002 | .0058 | <.0011 |
| 9 | Kelley Creek at SE 159th Drive, station 14211499 | 1/7/02 11:40 | 63 | NA | 18 | <.0003 | .0014 | .0015 | .0019 | .003 | .0118 | .0168 |
| 9 | Kelley Creek at SE 159th Drive, station 14211499 | 3/6/02 10:50 | 190 | NA | 154 | .0025 | .0046 | .0065 | .0128 | .019 | .0163 | .1025 |
| 9 | Kelley Creek at SE 159th Drive, station 14211499 | 6/4/02 10:33 | .51 | NA | 2.8 | <.00026 | .0053 | <.00037 | <.00037 | 0 | .0073 | .0691 |
| 9 | Kelley Creek at SE 159th Drive, station 14211499 | 9/5/02 11:40 | .18 | 5.7 | 2 | .0007 | .0078 | .0007 | .0010 | .002 | .0072 | .0543 |
| 9 | Kelley Creek at SE 159th Drive, station 14211499 | 12/12/02 14:20 | 1.7 | 11 | 2 | E.00013 | NA | E.0004 | E.00074 | .001 | .0053 | <.0013 |
| 9 | Kelley Creek at SE 159th Drive, station 14211499 | 1/29/03 10:10 | 19 | 22 | 16 | <.0012 | NA | E.00038 | E.00098 | .001 | .0043 | <.0012 |
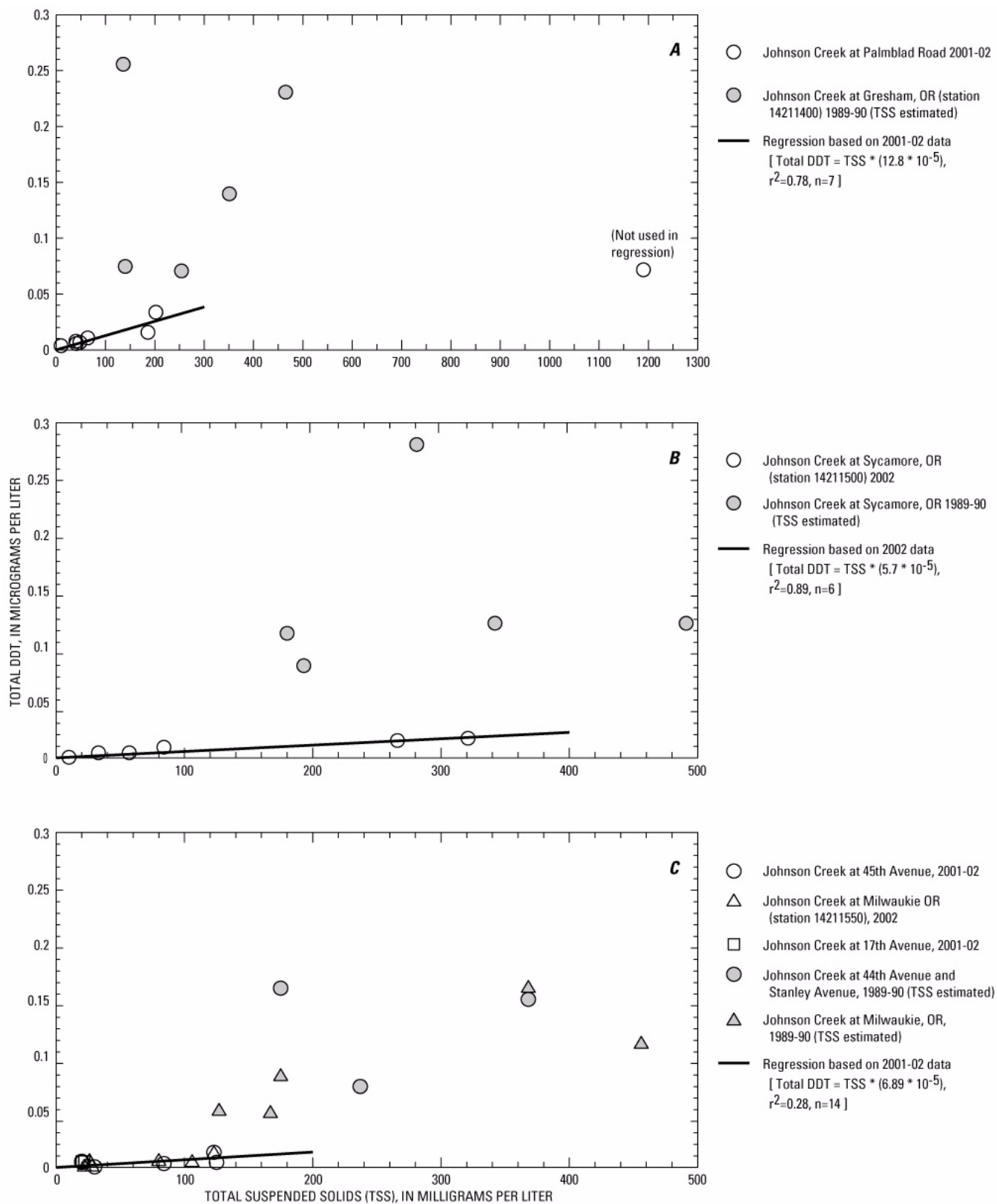
**Figure 12.**    The relation between total DDT and total suspended solids, Johnson Creek Basin, Oregon, 1989–2002. A, upper basin sites; B, middle basin site; C, lower basin sites.

**Table 10.**    Maximum concentration of total suspended solids associated with the exceedance of the water-quality criterion for total DDT, Johnson Creek Basin, Oregon.

[Map ID refers to the number on figure 1; mg/L, milligrams per liter; TSS, total suspended solids; DDT, dichlorodiphenyltrichloroethane]

| Map ID | Site name | Johnson Creek river mile | Sample size for regression | Total suspended solids maximum concentration (mg/L) | Correlation coefficient of linear regression, TSS versus total DDT |
|---|---|---|---|---|---|
| 1 | Johnson Creek at Palmblad Road | 17.2 | 7 | 8 | 0.78 |
| 10 | Johnson Creek at Sycamore | 10.2 | 6 | 18 | .89 |
| 14 | Johnson Creek at SE 45th Avenue | 3.2 | | | |
| 17 | Johnson Creek at Milwaukie | 0.7 | [1]14 | 15 | .28 |
| 18 | Johnson Creek at SE 17th Avenue | 0.3 | | | |

[1]Combined samples from sites (Map ID) 14, 17, and 18.

DDT indicates degradation may not be a dominant process controlling the decrease of DDX in the Johnson Creek Basin.

In general, the TSS concentrations were smaller in the 2001–02 data set than the estimates of TSS in 1989–90. The decrease in TSS may have been due to the nature of the 2002 storm that was sampled—it was not as large a storm as the December 1989 storm and was similar in magnitude to the January 1990 storm. Other factors, such as precipitation intensity and geographic distribution of precipitation and differences in the distribution of bare ground or otherwise erodible soils in the basin, could significantly affect the delivery of sediments (either contaminated or noncontaminated) to the stream. In addition, changes in land use, such as conversion of agricultural lands to residential development, may have affected the TSS concentration during a given storm.

As discussed earlier in this report, dieldrin was not well correlated to total DDT, and one explanation for this is the difference in the solubility of DDX and dieldrin in water. Using similar methods as in the above section, dieldrin concentrations in the Johnson Creek Basin over the past decade were compared to TSS concentrations. In general, the dieldrin concentration was less for a given TSS concentration in 2001–02 than in 1989–90 (tables 6 and 8). For the 2001–02 data set, the correlation between dieldrin and TSS is weak, so no direct estimator for dieldrin can be made based on TSS. The absence of a relationship between dieldrin and TSS indicates that controlling sediment in the stream may not control dieldrin in Johnson Creek.

## Organochlorine Pesticides in Kelley Creek

Unfiltered water samples were collected from Kelley Creek (a tributary to Johnson Creek) and Clatsop Creek (a tributary to Kelley Creek) at five locations on 6 days between January 2002 and January 2003. The sampling locations are shown in figure 1 and land cover data are listed in table 2 and shown in figure 2. Listed from upstream to downstream, the sampling sites are Kelley Creek at RM 2.5, Kelley Creek at RM 1.2, Clatsop Creek near the mouth, Kelley Creek at RM 0.5, and the mouth of Kelley Creek (USGS gaging station number 14211499). Few flow data were available for Kelley Creek. The USGS gage was located at the mouth of the creek, which was the location of the most downstream sampling. No flow data were available for the sampling locations upstream of the gage site.

Although these samples were not part of the USGS cooperative study, discussion of them is included for several reasons: Kelley Creek has the largest drainage area of any tributary to Johnson Creek, the results (table 9) provide insight into the occurrence of organochlorine pesticides in this basin relative to land cover, and some of the results can be compared to samples collected from Kelley Creek by the USGS in 1989–90 that contained DDX (table 8).

The sampling and analysis were done by the City of Portland Bureau of Environmental Services and their contractors. Analytical data were available for several compounds, but due to quality-control considerations only two of the DDT metabolites and dieldrin are discussed here. Analytical problems occurred with several of the samples, as indicated by high laboratory-spike recoveries (140–

476%) for certain constituents. For this reason, of the six DDT and metabolite compounds analyzed in 2002–03 (*p,p*'-DDT, *p,p*'-DDE, *p,p*'-DDD, *o,p*'-DDT, *o,p*'-DDE, and *o,p*'-DDD) only *p,p*'-DDE and *p,p*'-DDD [hereafter combined and referred to as "*p,p*'-DDE + *p,p*'-DDD"] are discussed in this section. For these reasons, this analysis should be considered more of a qualitative comparison of the occurrence of organochlorine compounds through time and space in Kelley Creek.

Samples were collected from Kelley Creek in 2002 on January 7, March 6, June 4, September 5, and December 12, and on January 29, 2003, under a variety of stream-flow conditions (fig. 13). The samples collected on January 7, 2002, and March 6, 2002, are considered medium- to high-flow samples; the discharge at the mouth of Kelley Creek was 60 ft$^3$/s and 200 ft$^3$/s, respectively. These samples were collected during storm periods, with more than 1 inch of precipitation at the Pleasant Valley School rain gage over the 3 days prior to the sampling on each day (City of Portland, Bureau of Environmental Services, 2002b). Samples from June and September 2002, were collected during low-flow conditions. The discharge at the mouth of the creek was less than 1 ft$^3$/s and no precipitation fell for several days prior to the sampling. The sample collected on December 12, 2002, reflected a fairly dry antecedent condition. Prior to the sampling, 0.9 inch of precipitation fell in the 3 days, but the flow (less than 2 ft$^3$/s at the mouth of the Kelley Creek) had not exceeded this level for more than 2 days over the past 5 months. The sampling of January 29, 2003, was done when the flow at the mouth of the creek was about 20 ft$^3$/s, medium in the range of flows associated with samples over the previous year, and occurred after several days of inter-mittent rain, with 0.2 inches over the previous 3 days.

In general, as with other samples in the Johnson Creek Basin, *p,p*'-DDE + *p,p*'-DDD concentrations were positively correlated with TSS, although as a whole, the 2002–03 data are scattered. When the sample results were separated by site (fig. 14), several patterns emerged. The samples collected from the most upstream location, Kelley Creek at RM 2.5, and from the mouth of Clatsop Creek had the lowest concentrations of *p,p*'-DDE + *p,p*'-DDD rela-tive to TSS of any sites sampled in the Kelley Creek Basin. The land cover upstream of both of these locations is pri-marily forest (fig. 2, table 2). The forest and meadow and grass areas comprise 87 percent and 68 percent of the areas upstream of the Kelley Creek at RM 2.5 and Clatsop Creek sites, respectively. Also significant is the low agricultural component, only 11 percent and 8 percent, respectively. The areas upstream of these two sites have the lowest per-centage of agricultural and highest percentage of forested lands relative to others in the Johnson Creek Basin. Clat-sop Creek has a more urban component than the upper Kelley Creek area. Recently disturbed lands associated with urban development, in conjunction with steep slopes, may account for the relatively high TSS concentration dur-ing the March 2002 sampling, but regardless, neither area upstream of the sampling sites appears to be a significant source of *p,p*'-DDE + *p,p*'-DDD. The highest concentra-tion observed at both of these sites was 0.003 μg/L, each during the March 2002 sampling. Of the total of 12 sam-ples at these 2 locations, 6 were less than 0.001 μg/L of *p,p*'-DDE + *p,p*'-DDD, and 4 were at the 0.001 μg/L con-centration. Several of the individual values were reported as estimates.

In contrast to the upper Kelley Creek Basin and Clat-sop Creek, the middle portion of Kelley Creek, defined as the part of the basin between RM 2.5 and RM 1.2, was a significant source of *p,p*'-DDE + *p,p*'-DDD. The agricul-tural component upstream of RM 1.2 was 41 percent, simi-lar to the agricultural component of land cover in the upper Johnson Creek Basin. The primary type of agriculture in this area is currently (and possibly historically) in-ground and container nurseries. The combined concentration of *p,p*'-DDE + *p,p*'-DDD at Kelley Creek at RM 1.2 for each of the six samplings was equal to or greater than 0.004 μg/L, with a maximum concentration of *p,p*'-DDE + *p,p*'-DDD of 0.028 μg/L for the March 2002 event. All six sam-ples exceeded the freshwater criterion for total DDT. In addition to the organochlorine pesticides noted above, dieldrin and endrin exceeded the freshwater chronic toxi-city criteria in the Kelley Creek site at RM 1.2, based on instantaneous concentrations (table 9).

Concentrations in the lower part of the Kelley Creek Basin, represented by samples at RM 0.5 and at the mouth of Kelley Creek, may be indicative of a dilution effect of organochlorine-compound- and sediment-laden waters coming from the middle basin. Both locations were down-stream from Clatsop Creek. The distribution of land-cover types becomes increasingly urban. However, upstream agricultural and forest components still contribute, and the distribution of land cover at the mouth of the creek was similar to that of the Johnson Creek Basin upstream from Regner Road. The concentration of *p,p*'-DDE + *p,p*'-DDD at RM 0.5 and at the mouth appeared to be less than at RM 1.2 for a given concentration of TSS (fig. 14): of the 12 samples, 2 did not contain *p,p*'-DDE or *p,p*'-DDD at con-centrations greater than the detection level, and the maxi-mum combined concentration was 0.019 μg/L, again occurring during the March 2002 sampling. Without stream discharge data, it was not possible to determine if additional loading of these organochlorine compounds occurs downstream from RM 1.2.

Dieldrin data collected in 2002–03 in the Kelley Creek Basin also indicated spatial trends. As with the *p,p*'-DDE + *p,p*'-DDD analysis, dieldrin concentrations were relatively low at the sites on Kelley Creek at RM 2.5 and on Clatsop Creek (table 9). The average concentration of the six samples at each site (using estimated values as-is and setting less-than values to zero) at Kelley Creek at RM 2.5 and Clatsop Creek was 0.0007 and 0.0011 μg/L,
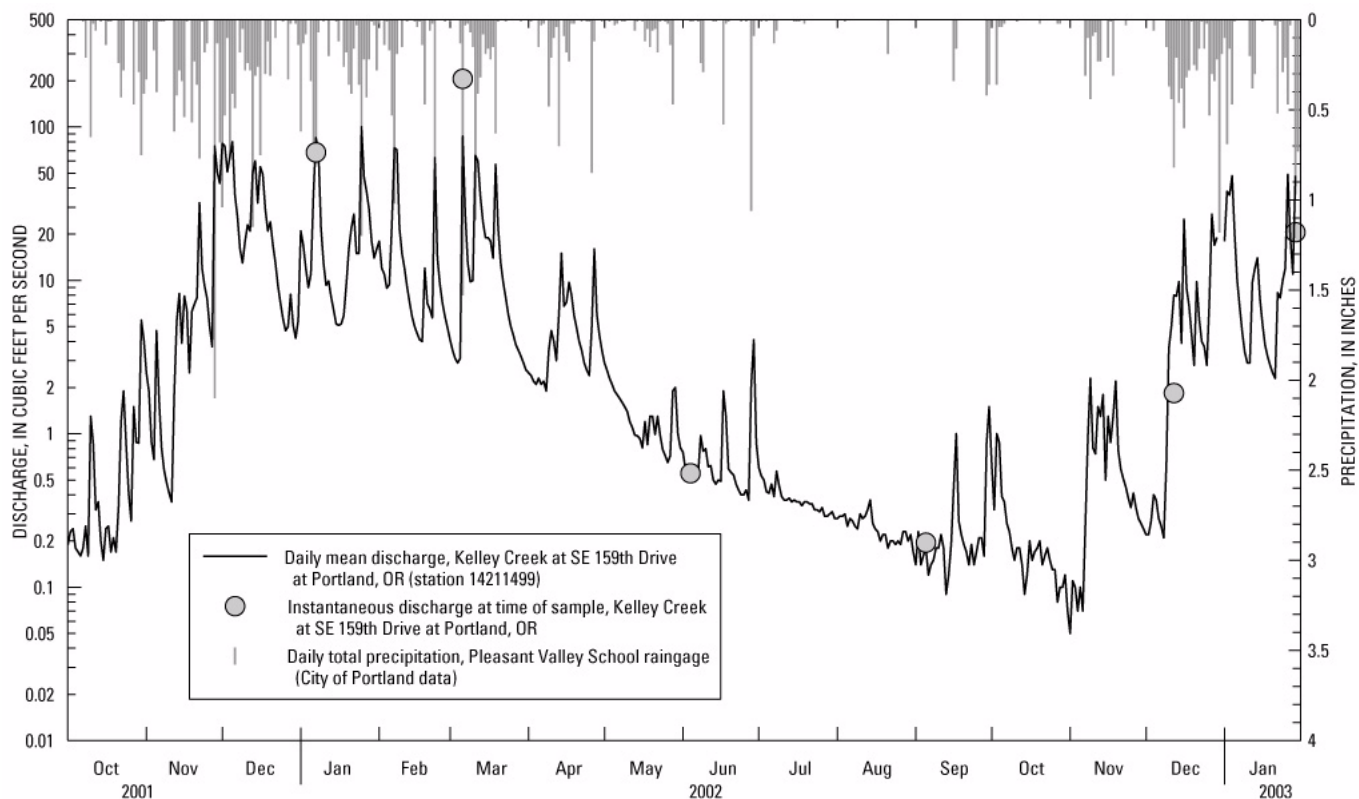
**Figure 13.**    Daily mean discharge and discharge at time of sampling at Kelley Creek, Oregon, and daily total precipitation, October 2001 to January 2003.

respectively. In contrast, the average concentration in Kelley Creek at RM 1.2 was more than 20 times higher, at 0.0181 µg/L. Average concentrations of dieldrin at RM 0.5 and at the mouth of Kelley Creek were 0.0104, and 0.0087 µg/L respectively. The sharp increase at RM 1.2 compared to RM 2.5 indicated a likely source between these two locations. Load comparisons could not be done with these data due to lack of flow data at all but the site at the mouth of the creek. Although p,p'-DDE + p,p'-DDD was cor-related to TSS, no such relation could be developed for dieldrin.

Dieldrin concentrations in Kelley Creek, when com-pared to the concentration of p,p'-DDE + p,p'-DDD, were higher than observed at sites on Johnson Creek. The diel-drin concentration of several samples was higher than that of p,p'-DDE + p,p'-DDD, compared to the general trend observed on Johnson Creek, where the dieldrin concentra-tion was less than half of the total DDT. The reason for this is unknown.

In addition to spatial differences in the distribution of p,p'-DDE + p,p'-DDD in the Kelley Creek Basin, some evidence indicates a decrease in these compounds relative to TSS over time. Samples taken in 1989 and 1990 at the mouth of Kelley Creek indicate a higher concentration of p,p'-DDE + p,p'-DDD relative to TSS than samples taken in 2002–03 (tables 8 and 9, fig. 14). The TSS concentra-tions for the 1989–90 samples were estimated using meth-

ods described above. Although the difference in pesticide concentration relative to a similar TSS concentration for these two samples indicate about a twofold decline, other factors such as the magnitude of the storms, antecedent conditions, and position on the flow hydrograph may have an effect on the comparability of the results.

## Implications for Future Study

A major shortcoming of the present study is that it contains only data from a single storm, which is not opti-mal for predicting the concentrations and loads of contam-inants under various other conditions. A future monitoring program to estimate organochlorine-pesticide loads in Johnson Creek and its tributaries could be accomplished by installing continuous streamflow and turbidity monitors in conjunction with additional sampling for TSS/sediment and organochlorine-compounds. An alternate method of measuring and expressing suspended solids is suspended-sediment concentration. This method is reliable regardless of the amount of sand-size material in the samples (Gray and others, 2000), and for future studies use of this tech-nique could be considered.

Four USGS streamflow-gaging sites already exist (fig. 1, table 1) and discharge data from these sites are
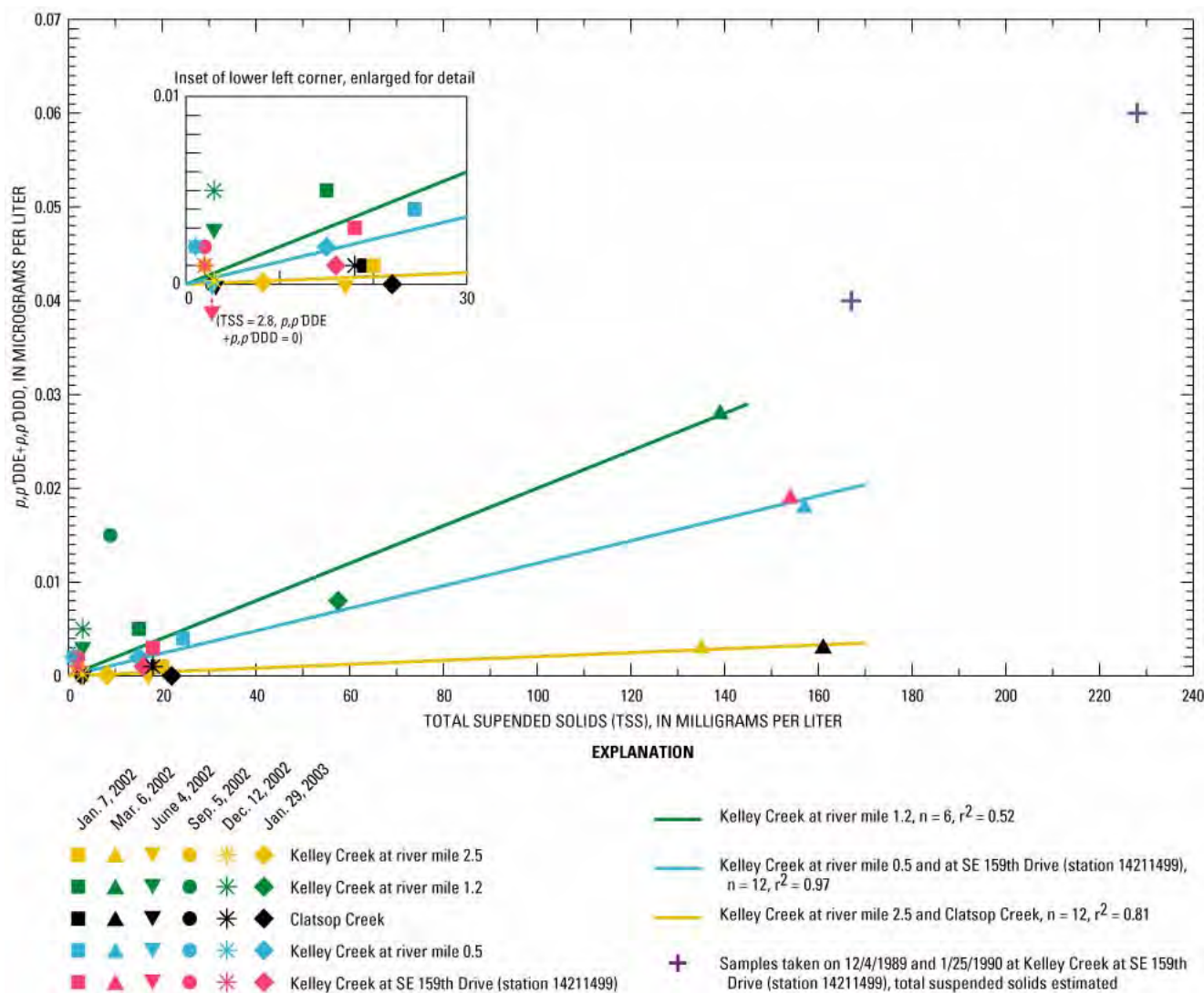
**Figure 14.** The relation between *p,p'*-DDE + *p,p'*-DDD concentration and total suspended solids, Kelley Creek, Oregon, 1989–90 and 2001–03.

necessary to calculate the load of any constituent. Turbidity can be used as a surrogate to predict the concentrations of TSS or suspended sediment, which in turn could be used to predict total DDT or fecal-indicator bacteria because these constituents are often sorbed to or associated with the sediment particles. Provided that it is done carefully, the measurement of turbidity is straightforward and inexpensive compared to the sampling and analysis for organochlorine compounds. Continuously deployed turbidimeters are becoming more reliable and accurate, and when added to present-day stream-gaging stations in the basin, the turbidity data could be available in real-time along with the streamflow data. A turbidity monitoring program should include documented, consistent techniques and instruments, along with sound data-management and storage procedures. There may be a need for auto-samplers to automatically sample for organochlorine pesticides and sediment during storm

events. Some existing TMDLs for organochlorine pesticides target turbidity as the surrogate constituent for regulation, for reasons mentioned above. Therefore, monitoring of turbidity may have the added benefit of evaluating compliance to State of Oregon regulations.

A monitoring program could be designed to concentrate on the upland areas, including Johnson Creek upstream of Palmblad Road, and the middle Kelley Creek Basin. The data in this report showed that organochlorine-pesticide concentrations were highest in the upper Johnson Creek Basin, both in samples from 2002 and samples from 1989–90. The lack of discharge data, except at the mouth of Kelley Creek, and quality-assurance problems in the laboratory analyses made it difficult to understand the loading of organochlorine compounds in Kelley Creek. Finer definition of the occurrence, loading, and possible source areas of organochlorine pesticides could be accomplished if more streamflow, turbidity, and organochlorine-

pesticide data were collected. Additional data on the occurrence of dieldrin are needed because this study indicated that it is not reasonable to predict dieldrin concentrations based on TSS.

Fish tissue analysis for organochlorine compounds would be helpful to determine the health risk associated with fish consumption by humans and wildlife. A previous study of Johnson Creek using semipermeable membrane devices to simulate bioaccumulation showed that organochlorine compounds such as DDT and dieldrin were accumulated in those devices in Johnson Creek (McCarthy and Gale, 1999).

Structural measures (for example, wetlands or off-channel settling ponds) could be used to trap sediment, and consequently reduce mobilization of organochlorine compounds in the stream. Evaluating these measures was not part of the scope of the present report, but they were described in an earlier work (Edwards, 1994). Steeply sloped areas with the historical use of organochlorine compounds are potential source areas for organochlorine compounds. If structural measures were implemented in some of these areas, a water-quality monitoring program would be needed to evaluate their effectiveness.

## Summary and Conclusions

Unfiltered water samples were collected from several sites in the Johnson Creek Basin and analyzed to better understand the extent of organochlorine-compound contamination, explore the relationship of certain organochlorine compounds to total suspended solids, and assess the changes in organochlorine-compound concentrations over time. Four to six samples were taken at each of four sites on Johnson Creek during a storm in March 2002 and analyzed by the USGS National Water Quality Laboratory. In addition, two storm drains were sampled multiple times. Samples taken by the Oregon Department of Environmental Quality (ODEQ) at five sites on 3 days in winter, 2001–02 also were analyzed, providing organochlorine-pesticide data for nonstorm periods. In addition, samples were taken at five stream sites in the Kelley Creek Basin (a tributary to Johnson Creek) by the City of Portland on 6 days in 2002–03. Samples collected by ODEQ were analyzed by their laboratory, and samples from Kelley Creek were analyzed by private laboratories.

Quality-control data from laboratory blanks, replicate samples, and organic-chemical surrogates analyzed by both the USGS and ODEQ laboratories indicated that the data quality was within acceptable ranges. Although the USGS laboratory appeared to have a low bias and the ODEQ laboratory appeared to have a high bias with respect to organochlorine-compound concentrations, the data were usable for assessments of potential source areas and loading. Samples analyzed by the private laboratory

may have been subjected to some contamination or interference; for this reason, only some of those analytical results were discussed in this report.

Organochlorine pesticides were detected at five of six sites sampled by the USGS in March 2002 and at all sites sampled by the ODEQ in 2001 and 2002. State of Oregon chronic freshwater criteria were potentially exceeded for total DDT, dieldrin, chlordane, and total PCB. (The water-quality data did not cover a long enough time period—4 days—to determine if an exceedance did occur). Total DDT, composed of hydrophobic compounds, is commonly associated with sediment in the stream. There was a positive correlation between concentration of total DDT with turbidity (the sediment parameter analyzed in the 1989–90 sampling), as well as with total suspended solids (the sediment parameter analyzed in the 2001–03 sampling). The 2001–03 sampling included analyses for both turbidity and TSS, providing a relation between these two sediment measures, and a common basis (estimated TSS) for comparison to the 1989–90 data. The concentrations of total DDT relative to TSS has decreased markedly from a decade ago. In general, total DDT concentration was an order of magnitude less in 2002 compared to 1989–90. A statistically significant relation could not be established between dieldrin and TSS.

Loads of total DDT and dieldrin were calculated as organochlorine-pesticide concentration multiplied by stream discharge and were investigated to assess possible sources and sinks of the compounds. The largest instantaneous loads of total DDT and dieldrin occurred at the Palmblad Road site (76 grams per day and 23 grams per day, respectively). These loads indicate a possible source of organochlorine pesticides in the drainage basin upstream of the Palmblad Road site, which has 50% agricultural land cover, the highest percentage agricultural land cover of any sampled site. This land was probably agricultural land in the past, and the historical use of now-banned organochlorine pesticides in combination with soil erosion from current practices may be responsible for the current loads of these compounds.

Regression equations developed for estimating total DDT based on TSS concentration allowed the calculation of threshold TSS concentrations associated with the exceedance of the freshwater criteria for total DDT. At the Palmblad Road site, a TSS concentration larger than 8 mg/L could result in the exceedance of the standard, while a TSS concentration larger than 18 mg/L and 15 mg/L could result in exceedance of the standard at the Sycamore and Milwaukie sites, respectively. Again, this indicates a potential upstream source of DDX, with DDX-contaminated sediments mixing with uncontaminated sediments lower in the basin.

Samples from Kelley Creek, a tributary to Johnson Creek, illustrated spatial and temporal trends in $p,p'$-DDE $+ p,p'$-DDD. Results for the Kelley Creek samples were treated separately in this report due to possible quality-

assurance problems. Due to this shortcoming, comparisons made among the Kelley Creek sites in 2002–03, as well as comparison with data collected in 1989–90 were considered qualitative. Neither the headwaters of Kelley Creek (upstream of RM 2.5), nor Clatsop Creek (a tributary to Kelley Creek) appeared to be sources of $p,p$'-DDE + $p,p$'-DDD or of dieldrin. Samples taken at RM 1.2 had elevated $p,p$'-DDE + $p,p$'-DDD and dieldrin concentrations indicating a source of those compounds in the middle reaches (between RM 2.5 and RM 1.2). Samples taken at RM 0.5 and at the mouth of the creek indicate possible dilution of higher concentrations from this middle reach. The concentration of $p,p$'-DDE + $p,p$'-DDD relative to TSS appears to have decreased since the sampling in 1989–90, based on a very limited amount of data.

Future studies in the Johnson Creek Basin could include continuous monitoring of streamflow and turbidity, and additional sampling for organochlorine compounds. Further studies of the agricultural areas upstream of the Palmblad Road site and in the Kelley Creek Basin would be useful, especially as some of these areas undergo changes in land use.

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