A PCE PLUME DISCHARGING TO A RIVER: INVESTIGATIONS OF FLUX, GEOCHEMISTRY, AND BIODEGRADATION IN THE STREAMBED

by

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Abstract

A tetrachloroethene (PCE) groundwater plume emanates from beneath a dry cleaner facility and discharges to a 60 m-long reach of the Pine River in Angus, Ontario, Canada. The streambed and near-stream zone were shown to be a dynamic and unique environment that modified the distribution, concentration, and composition of the plume. The plume and hydrogeology were characterized using a Waterloo Profiler, mini-profilers, bundle multilevel samplers, driveable multilevel samplers, Ground Penetrating Radar surveys (of the streambed), streambed temperature mapping (to identify discharge zones), drivepoints, and sediment coring. Low hydraulic conductivity silt, clay, and peat deposits underlying the sandy streambed deposits caused the plume to discharge over a large area of the streambed and extend across the full width (11 to 14 m) of the river at some locations. Spatial variations in the geology resulted in groundwater fluxes that varied from 0.03 to at least 446 L/m^2d. Although no appreciable biodegradation of the plume occurred in the upgradient aquifer, anaerobic biodegradation in the top 2.5 m of the streambed dramatically altered the plume composition by transforming PCE primarily to cis-1,2-dichloroethene (cDCE) and vinyl chloride (VC) and to a lesser extent trichloroethene (TCE), 1,1-dichloroethene (11DCE), trans-1,2-dichloroethene (tDCE), ethene, and ethane. The degree of biodegradation was spatially variable at a depth of 0.3 m in the streambed, but overall, the streambed reduced the total mass of PCE discharging to the river by 54 to 59% resulting in large accumulations of chlorinated degradation products and no appreciable mineralization. The high concentrations of volatile organic compounds (VOCs) that remained represented a potential hazard to benthic and hyporheic aquatic life. The VOC concentrations were spatially variable, with up to 5529 μg/L found at one location and no VOCs detected 3.5 m away, while at another location, 3639 μg/L of PCE was reduced to 125 μg/L and almost completely transformed to cDCE over a vertical distance of only 0.15 m. Transformation of PCE generally occurred over relatively short vertical distances (< 0.45 m) and was associated with sharp changes in redox conditions. The degree of biodegradation was highly correlated with the redox conditions and the magnitude of fluxes because the low hydraulic conductivity deposits that caused the low fluxes were also organic-rich and strongly reducing. High amounts of dechlorination (i.e. production of ethene and ethane) occurred where fluxes were very low and sulfate reducing to methanogenic conditions existed. Virtually no biodegradation occurred in high flux areas where water was anaerobic to nitrate reducing. A new method of calculating groundwater fluxes based on streambed temperature measurements and testing of mini-piezometers was developed and used to create a conceptual flow model that was based on the magnitude and direction of the fluxes. Five types of flow behavior were identified: 1) short-circuits and springs, 2) high discharge, 3) low to moderate discharge, 4) no discharge and 5) recharge. This flow model provided a valuable framework for interpreting and characterizing the complex patterns of redox conditions, biodegradation, and mass discharges. Despite high VOC concentrations in the streambed, an estimated 24.9x10^3 L/d of contaminated groundwater flowing to the river, and an estimated total mass of 3.2 to 4.0 g/d of PCE and 2.8 to 4.2 g/d of cDCE discharging to the river, VOCs were rarely detected in surface water (summer river flows were typically 1.4 to 2 m^3/s). PCE was detected at concentrations ≤ 3.1 μg/L and on one occasion was as high as 23.2 μg/L whereas no cDCE or VC was detected in surface water. This occasional detection of PCE may have occurred because PCE was associated with high groundwater discharge zones whereas cDCE was associated with low groundwater discharges. In general, high VOC concentrations in the streambed were not associated with the high groundwater discharge zones. This study demonstrates the complex interaction of hydrogeologic, geochemical, and biochemical processes that occur in streambeds and the resulting fine scale spatial variability in plume discharge.

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Dedication

This thesis is dedicated to my wife, Bernadette Hughes Conant. Without her love, support, encouragement, guidance, and patience, this work could never have been completed.

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CHAPTER 1.

INTRODUCTION

When the phrase "groundwater/surface-water interactions" is used in the context of streams and rivers, different scientific disciplines may associate quite different processes and meanings to it. For example, hydrologists and civil engineers tend to think of mechanisms related to stream-flow generation on a drainage-basin scale and what affect this interaction has on base flows and flooding events. Hydrogeologists commonly think about how these interactions affect the quantity and quality of groundwater supplies, conjunctive water use, bank storage of water, and perhaps gain or loss of surface water along reaches of rivers. Ecologists associate this type of interaction with maintaining flows in rivers or with hyporheic zone exchange (the hyporheic zone is generally described as the portion of the streambed where mixing of groundwater and surface water occurs) and their potential affects on biological assemblages and community structures, usually in pristine (i.e. uncontaminated) conditions. Each discipline has tended to investigate individual aspects of this interaction that are on a scale relevant to the particular questions or problems they have identified. Because groundwater/surface-water interactions is not the main focus of any of those disciplines, there is not a comprehensive and full understanding of the hydrological, chemical, and biological processes occurring in streambeds and near rivers. Efforts have been made to understand and summarize the geochemistry and flow in this dynamic zone as it relates to the ecology, nutrient cycling, and fate of nitrates (Brunke and Gonser, 1997; Dahm et al., 1998; Huggenberger et al., 1998). However, the question of how near-stream processes affect the fate and transport of groundwater contaminated with organic compounds that discharge into rivers or streams has not been addressed in any comprehensive way.

Groundwater contaminant plumes discharging to rivers and streams is a topic of ecological concern in the United States (USEPA, 2000). A National Priorities List characterization study estimates that 51% of 1218 hazardous waste sites impact surface water (USEPA, 1991) and at many of these sites chlorinated volatile organic compounds (VOCs) are migrating by groundwater flow to streams and rivers. Despite the relatively common occurrence of chlorinated VOC plumes discharging to streams, no study has been published that characterizes and examines in a comprehensive way the role the streambed may play in attenuating VOC concentrations prior to the plume discharging into a river. This lack of research may reflect a general perception that even if high concentration VOC groundwater plumes reach a river, they will be rapidly attenuated in the surface water either by dilution or volatilization. If resulting concentrations of VOCs in the surface water column are much lower than freshwater aquatic life guidelines, it may be interpreted to mean the plume does not result in any adverse exposures to aquatic life. In this context, several questions arise. What is the overall impact of groundwater plumes on rivers and streams? Is aquatic life in the surface-water column the only receptor of interest or should we be concerned about benthic and hyporheic aquatic life that are exposed to contaminants in the streambed? Are either the concentrations or the total mass of contaminants attenuated within the streambed and, if so, to what extent and under what conditions? How and where do groundwater plumes really discharge into rivers and what role do subsurface conditions play in resulting discharge patterns? Can the flow and biogeochemical processes occurring in a streambed be generalized into specific types of behaviors? Are current monitoring techniques sufficient to characterize these processes or are new ones needed? Such questions take on particular relevance at sites where remedial actions have not been taken or monitored natural attenuation (MNA) is being proposed as a remedial alternative for a plume. In these instances, groundwater plumes flow toward and will likely reach their natural points of discharge which are often rivers or streams.

To begin answering some of these questions, a comprehensive approach is required that characterizes the hydrogeology and water quality on a fine scale. A field investigation was undertaken to characterize a tetrachloroethene (PCE) groundwater plume discharging to the Pine River, in Angus, Ontario, Canada. The goal of this study was to determine the factors that control how and where the plume discharges, the extent to which the plume is attenuated in the streambed, and the primary processes responsible for the observed attenuation (e.g. biodegradation, hyporheic mixing, or sorption). The hope was also to develop a comprehensive conceptual model that explains the range of observed behaviors and advances our overall understanding of groundwater/surface-water interactions as they relate to discharging plumes.

This dissertation presents the findings from this investigation in three main chapters. Chapter 2 describes the geology, groundwater flow paths, and resulting contaminant distribution at the site and characterizes the contaminant concentrations within the streambed and in surface water. Chapter 3 focuses on delineating and quantifying groundwater discharge zones in the streambed. In this chapter, existing methods for determining discharge are reviewed and a new and simple method is presented for quantifying and mapping fluxes that combines streambed temperature measurements and fluxes determined from hydraulic testing of mini-piezometers. A new flux-based conceptual flow model that consists of 5 different types of discharge behavior is also presented. Chapter 4 examines the relationship between groundwater flux, redox conditions, and the degree of biodegradation that occurs in the streambed. Distinct biogeochemical conditions were found to be associated with each of the 5 different types of groundwater discharge described in the conceptual flow model in Chapter 3. Chapter 5 summarizes the main conclusions of the previous 3 chapters and discusses the transferability of these findings to other sites and overall implications of this work.

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CHAPTER 2.

THE POTENTIAL FOR A PCE GROUNDWATER PLUME TO CONTAMINATE A RIVER: THE ROLE OF THE STREAMBED AND NEAR-RIVER ZONE

2.1 ABSTRACT

An investigation of a tetrachloroethene (PCE) groundwater plume emanating from beneath a dry cleaner and discharging to a 60 m-long reach of river showed that the near-river zone substantially modified the distribution, concentration, and composition of the plume prior to discharging into the surface water. The plume and hydrogeology were characterized using the Waterloo profiler, mini-profiler, conventional and driveable multilevel samplers, Ground Penetrating Radar surveys (of the streambed), streambed temperature mapping (to identify discharge zones), drivepoint piezometers, and sediment coring and testing. The complex contaminant distribution observed beneath the river was caused by: 1) the contaminant distribution in the plume prior to entering the near-river zone; 2) the geological heterogeneity beneath the river; 3) biodegradation; and 4) sorption to high foc deposits. Plan-view mapping of interstitial-water concentrations at a depth of 0.3 m in the streambed showed that the plume extended over the full width of the river (11-14 m) at some locations, and had a different internal concentration distribution and composition than observed in vertical cross-section along the riverbank. Low-hydraulic-conductivity silty-clay deposits underneath the fluvial sands of the streambed caused much of this spreading. Extensive anaerobic biodegradation in the top 2.5 m of the streambed caused approximately 54% of the area of the plume to consist solely of PCE transformation products, primarily cis-1,2-dichloroethene and vinyl chloride. High concentration areas (up to 5529 μg/L) within the streambed represent potential adverse exposure locations for benthic and hyporheic aquatic life. The highest concentration areas of the streambed did not correspond to high groundwater discharge zones and these areas appear to be retarded remnants in low discharge zones which reflect past high concentration plume discharges. Despite high streambed concentrations, contaminants were rarely detected in the surface water due to rapid dilution in the river, but low concentrations of PCE ($\leq$23.2 μg/L) were detected at and down stream of high groundwater discharge locations. Surface water sampling immediately above the streambed gave no indication of cDCE or VC discharging to the river or of the high concentrations that aquatic life could be exposed to in the streambed.

2.2 INTRODUCTION

A National Priorities List characterization study estimates that 51% of 1218 hazardous waste sites impact surface water (USEPA 1991) and at many of these sites chlorinated volatile organic compounds (VOCs) are migrating by groundwater flow to streams and rivers. Despite this relatively common occurrence, few published studies have characterized VOC plumes in detail to examine the processes that control how they discharge to a river. Some studies (Norman et al., 1986; Avery, 1994; Hess et al., 1989) examined VOC groundwater plumes discharging to rivers using widely spaced and limited numbers of seepage meters and piezometers (i.e. less than about 24 each), but did not map the concentrations in the streambed. Others have mapped plan-view distributions of VOCs in streambeds using larger numbers of diffusion samplers (Vroblesky et al., 1991 and 1996; Savoie et al., 1999; Lyford et al., 1999) but have presented relatively little information concerning the hydrological and geological controls on flow or the fine-scale vertical concentration distribution of the groundwater plume responsible for the observed streambed concentrations. Two studies describe the advection, biodegradation, and adsorption processes related to a VOC plume migrating toward a creek in a freshwater tidal wetland in vertical cross-section (Lorah et al., 1997; Lorah and Olsen, 1999), but do not discuss the spatial variation of contaminants in plan view within the streambed.

The literature lacks holistic field studies that relate the upgradient plume to resulting streambed concentration distributions. It is not clear to what extent conditions within the streambed will modify a contaminant plume prior to its discharge to the surface water and this is especially difficult to assess if data regarding the upgradient plume is lacking. The area beneath and adjacent to a river or stream is potentially a very complex geological, hydrological, and biochemical zone (Huggenberger et al., 1998; Brunke and Gonser, 1997; USEPA, 2000) and conditions within this zone can be considerably different than those found further away from the stream. Studies of uncontaminated sites show that conditions in the streambed may be spatially and temporally variable and subject to large hydraulic and geochemical gradients (Brunke and Gonser, 1997; Dahm et al., 1998; Hendricks and White, 1991 and 1995). As the plume passes through this zone it is hypothesized that the geometry of the plume and chemical composition of the plume will change and these changes will affect the potential of the plume to contaminate the streambed and surface water.

The ecological effects of VOC groundwater plumes on rivers are often only characterized by analyzing the surface water quality down stream of the area of contaminant discharge. Dilution of VOC plume discharges by surface water flow and additional attenuation by volatilization, sorption, and degradation in the river (Rathbun, 1998) often result in low or undetectable concentrations in surface water. However, little has been done to assess if high concentrations of VOCs will occur in the streambed (with the possible exception of the semi-quantitative concentration results from diffusion sampler investigations mentioned earlier), even though these concentrations could be harmful to benthic and hyporheic aquatic life residing there. Ecologists consider the streambed, hyporheic zone (the hyporheic zone is defined as the portion of the substream deposits that contain some portion of surface water or is a mixture of groundwater and surface water), and near-stream groundwater/surface-water transition zone a unique habitat that plays an important role in the aquatic food-web and provides other ecological services related to the health of a stream (Hynes, 1970; Gibert et al., 1994; Boulton et al., 1998; Ward et al., 1998). Although sediment sampling methods have been used to try to evaluate the toxic effects of contaminants on aquatic life (USEPA, 1992), many of these methods are not well suited for evaluating VOC contamination and samples are rarely collected with the knowledge of exactly where a plume discharges. The result is a lack of understanding of the potential concentration exposures that may occur in a streambed.

This investigation was designed to provide a comprehensive field study of the behavior of a tetrachloroethene (PCE) dissolved-phase groundwater plume discharging to a river and integrates geology, hydrology, and the contaminant distribution observed in the aquifer to evaluate how they relate to the plan-view interstitial water concentration distributions in the streambed. The study site is located in Angus, Ontario, Canada, approximately 75 km north-northwest of Toronto (Figure 2-1a) and 5.5 km north of the University of Waterloo research site on Canadian Forces Base (CFB) Borden (Figure 2-1b). The area is primarily residential, with scattered commercial properties and open lots (Figure 2-1c). The Angus site was chosen because it had a high-concentration single-contaminant groundwater plume that was flowing in a geologically simple aquifer toward a relatively small river which could be fairly easily instrumented. A 60 m wide by 4 to 6 m thick, dissolved-phase PCE groundwater plume extends 195 m down gradient to the Pine River from a dense non-aqueous phase liquid (DNAPL) source of PCE beneath a dry-cleaning facility (Figure 2-1c). The groundwater at the site has likely been contaminated since at least the 1970s. Although researchers have characterized the contaminant distribution (Pitkin, 1994; Pitkin and Cherry, 1994; Beneteau, 1996; Writt, 1996; Levenick, 1998; Beneteau et al., 1999; Guilbeault, 1999) and geology of the aquifer (Pitkin, 1994; Writt, 1996) to the east of the river, very little is known about the groundwater flow, geology, and contaminant distribution beneath and immediately adjacent to the Pine river. This study used conventional and innovative sampling approaches and techniques to characterize the streambed, the areas adjacent to the river, and the upgradient aquifer. A particular emphasis was put on determining whether high groundwater concentrations in the aquifer resulted in high interstitial concentrations within the streambed or if attenuation processes reduced concentrations prior to discharge to the surface water.

2.3 BACKGROUND

2.3.1 Site Hydrogeology and The Groundwater Plume

Geological information regarding the site is contained in a report by Writt (1996) and in regional mapping reports. Physiographic mapping of the unconsolidated materials indicate that the site is part of the surficial regional sand sheet known as the Camp Borden Sand Plain (Chapman and Putnam, 1984) and is mapped as glaciolaustrine deposits of transitional to shallow water lacustrine sands (Burwasser and Cairns, 1974). The unconsolidated thickness at the site is approximately 61 m (Burwasser and

Ford, 1974). Based on 6 cores of unconsolidated deposits collected at the site, Writt (1996) divided the stratigraphy of the top 15 m of the deposits (i.e. where the PCE contamination is present) into 5 sand layers and one silty-clay aquitard layer. He concluded that the 5 sand layers were deposited in a braided channel to a braided-meandering transition channel environment. The sand deposits east of the river consist primarily of fine to very fine sands. Intervals of medium sand are also present occasionally, and coarse sand and fine gravel intervals occur very infrequently. The aquitard is approximately 1 to 1.5 m thick with the bottom 0.1 to 0.3 m consisting of a thin peat (or interlayered clay and peat) deposit which is overlain by a silty-clay that grades upward into silty very-fine sand. Writt suggested that the silt and clay of the aquitard were deposited by either an abandoned channel or a small peripheral lake. The aquitard is absent in the vicinity of the dry-cleaner, which allowed some of the PCE DNAPL spilled to penetrate and accumulate in the deeper sands, resulting in a dissolved-phase plume that travels within the sandy confined aquifer toward the river. When the current study was initiated, it was not clear whether the aquitard or aquifer extended beneath or beyond the river.

Prior to the current study, very little information existed regarding piezometric water levels and groundwater flow directions within the confined and unconfined aquifers in the area between the dry cleaner and the Pine River. Water level information was only available from conventional 0.051 m inside diameter (ID) monitoring wells and drive points installed at 5 locations (Pitkin, 1994; Beneteau, 1996). These installations were not designed to map groundwater flow directions and were primarily used to collect water quality samples. Groundwater was inferred to flow northwest from the dry cleaner based on the plume location.

The Waterloo Groundwater Profiler [described by Pitkin (1999)] was used to delineate the PCE plume and a total of 38 vertical profiles of the water quality were obtained along 4 transect lines (Pitkin, 1994; Writt, 1996). Initial interpretation of the data indicated one narrow (5 to 10 m wide) high concentration (>10,000 µg/L) "core" of the plume [terminology from Cherry (1996)] appeared to extend from the dry cleaner to the river (Writt, 1996) and was located within a 60 m wide lower-concentration "fringe" that generally exceeded 1000 μg/L. The highest PCE concentration in the plume was 43,318 μg/L found 19 m west-northwest of the dry cleaner along profiler Transect 1 at B1. High concentrations of PCE were also found far from the dry cleaner building with 22,376 μg/L observed 171 m down gradient (and 41 m from the river) on profiler Transect 4 at AP24 and at a depth of 9 m below ground surface (bgs). Six shallow mini-piezometers (AMP1 though AMP6) had also been installed in the streambed by Pitkin (1994) using the method of Lee and Cherry (1978) and then sampled in July 1993. Contamination was only detected at AMP3 located approximately 29 m north of the King Street bridge (see Figure 2-2) where 221 μg/L of PCE and 9.9 μg/L of trichloroethene (TCE) were found. Although this early work demonstrated some of the complexity of the plume, it did not fully define the lateral edges of the plume or the location of the front of the plume and no other information was available about where and how the plume discharged to the river.

Prior testing of groundwater samples had consisted almost exclusively of analyses for PCE and TCE. It was not known if other PCE degradation products besides TCE were present in the aquifer or what the redox conditions were in the aquifer. The maximum concentration of TCE detected in water samples by Writt (1996) was 6.7 μg/L. TCE was usually found in samples containing the highest PCE concentrations suggesting it might have been an impurity in the PCE that was spilled. If it was not an impurity, the low levels suggest degradation of PCE to TCE in the aquifer is insignificant. TCE concentrations from Pitkin (unpublished data) were generally similar except for one elevated concentration of 190 μg/L detected at AP11. It was not known if PCE was being degraded beyond TCE to products not being analyzed. However, analyses of the dissolved-phase PCE from the site for ^{37}Cl and ^{13}C isotopes (Beneteau, 1996; Beneteau et al., 1999) suggested that biodegradation of PCE was not occurring in the plume at this site.

From this review of existing hydrogeological information, it was not clear whether the aquitard, aquifer, or plume extended beneath or beyond the river or whether the geochemical conditions in the aquifer were the same in the aquifer and near the river. Moreover, previous studies had not analyzed the surface water for VOCs to determine the effect of the groundwater plume on surface water concentrations.

2.3.2 The Pine River

The Pine River drains a basin that is approximately 348 km^2 in area and discharges into the Nottawasaga River in Angus, approximately 2.3 km down stream of the study site (Figure 2-1b). The surface water quality of the Pine River upstream of the site is a high-quality cold-water habitat that supports a wide diversity of aquatic life and benthic taxa (Jones, 1999) including salmon and trout. Daily discharge for the river at the Water Survey Division of Environment Canada gauging station in Everett (15 km upstream of the site), averaged 2.12 m^3/s and had base flows generally less than 1 m^3/s between 1967 and 1998. The station at Everett represents only the upper 195 km^2 (56%) of the drainage basin, so flows at Angus are higher. An investigation by Beebe (1997) at a location 150 m down stream of the King Street bridge estimated summer base flows of 1 to 2 m^3/s. The 100-year flood flow at Angus is estimated to be between 99.8 and 101.4 m^3sec^{-1} (Burkard, 1990).

In the vicinity of the Angus site, the Pine river is a moderately to highly sinuous, low gradient river, that meanders northward through a broad floodplain. The channel has a low width to depth ratio, a high entrenchment ratio, and general slope of 0.0007 m/m (Beebe, 1997) and is classified as an E5 stream type using the Rosgen Classification of Natural Rivers (Rosgen, 1996). This study focused on a 60 m long, relatively straight portion of the Pine River located immediately downstream of the King Street bridge (Figure 2-1c). At the site, the nearly vertical stream banks are generally about 1.2 to 2.5 m high and consist of silt, clay and peat deposits. The river is 11 to 14 m wide and the average river channel depth in the summer is 0.5 m with a maximum depth of about 1.1 m. The channel is primarily fine sand but some woody debris and a few logs are present (mostly beyond 34 m down stream) where a gentle 16 m long riffle begins. Existing logs were left in place but new accumulations of debris (manmade or natural) were periodically removed in order to minimize long-term changes in river flow patterns and streambed deposition. Erosion and deposition of streambed sands occurred throughout the year. Sediment transport measurements made from the King Street bridge by Burkard (1990) showed that bedload transport constitutes 25.6 to 73.3 % of the total transport during the year. In her study, bedload transport rates ranged from 0.0023 to 0.0222 kilograms per meter width of river per second (kg/m/s) and suspended sediment measurements ranged between 12.7 and 78.9 mg/L, and total suspended load for the entire river was observed to be between 0.0186 to 0.3915 kg/s.

2.4 FIELD METHODS

Field investigations were performed between 1996 and 1999 in response to a growing understanding of the hydrogeological system and plume discharge area. Reconnaissance work was followed up with more comprehensive and detailed investigations that focused primarily on characterizing plume concentrations beneath the river. Field investigations characterized the geology, streambed sediments; plume concentrations beneath and upgradient of the river; groundwater flow; and surface water concentrations.

2.4.1 Geology and Streambed Sediment Characterization

The techniques used to characterize geology and streambed sediment at the site included: coring and testing of geological deposits, Ground Penetrating Radar (GPR), and visual mapping of sediments. Cores of unconsolidated deposits were collected at 19 locations. Cores SC7 to SC13 were all collected within 1.7 to 4.5 m of the river except for SC9 and SC13, which were 15 m and 34 m east of the river, respectively (Figure 2-2). All cores were collected with 0.051 m ID aluminum piston core barrels, in 1.52 m long sections, down to depths of between 7.62 to 12.2 m below land surface, using the method described by Starr and Ingleton (1992). Riverbed cores RC1 to RC12 (Figure 2-3) were collected by hand using a hammer or sledge hammer to drive the aluminum core tubes approximately 1.3 to 1.8 m into the riverbed deposits. Cores RC1 to RC4 were collected on March 16 and 17, 1998, and RC5 to RC12 were collected on October 16, 1998, one day after a GPR survey of the riverbed. Total recoveries of sediments for RC1 to RC12 generally ranged from 71 to 92 percent. Corrected thicknesses and depths of stratigraphic contacts were calculated for each riverbed core based on incremental recovery data obtained while advancing the core. The holes created by the coring at SC7 to SC13 were sealed using a bentonite grout tremmied into place and at RC1 to RC12 the holes were immediately plugged by driving in a larger outside diameter (OD) bentonite-filled PVC pipe into the hole.

All the geological materials collected were logged and classified. Samples of some of the deposits were also tested for hydraulic conductivity, porosity, bulk density, fraction of organic carbon (foc) content, radiocarbon date, and for contaminant concentrations (both total sediment and interstitial water concentrations). Hydraulic conductivities were determined for subsamples of the cores (about 0.05 m long) by performing falling-head permeameter tests using the method described by Sudicky (1986) and results were adjusted to a 10° C groundwater temperature using water density and viscosity measurements tabulated in Marsily (1986). The porosity and bulk density of each permeameter sample was also determined by using weight to volume calculations. Hydraulic conductivity and porosity was determined for 178 subsamples from riverbed cores RC1 to RC12 and 48 subsamples from SC12.

Foc analyses were performed on 52 subsamples from cores SC12, SC13, RC1, RC2, RC4, and RC11. At least 3 grams of sediments were collected and finely crushed (< 200 mesh) for each sample. Total organic carbon analyses (TOC is synonymous with foc if it expressed as a percentage) were performed on 25 samples by the University of Guelph Soil and Nutrient Laboratory (Guelph, Ontario) using a Leco Induction furnace and the method described by Tabatabi and Bremner (1970) which reportedly has a detection limit of about 0.05%. This type of method is thought to be less appropriate for determining very small values of total organic carbon (Krom and Berner, 1983). Therefore, another 34 samples suspected to have low foc values were analyzed by the University of Waterloo Organic Geochemistry Laboratory (Waterloo, Ontario) using a Lindburg quartz tube furnace and the method described by Churcher and Dickout (1987) which has a detection limit of 0.008%. Duplicates and laboratory blanks were also sent for analysis and some samples were analyzed by both laboratories.

Only one sample of the subsurface deposits was submitted for age dating. Wood fragments found in core SC12 (located 2.9 m east of the river) at a depth of 4.65 m bgs were radiocarbon (^{14}C) dated by the University of Waterloo Environmental Isotope Laboratory using the beta counting method described by Aravena et al. (1997).

PCE and TCE concentrations were determined for 41 sediment samples collected from cores SC11 and SC12. An average vertical sampling spacing of about 0.37 m (ranging between 0.1 to 0.9 m) was used for both SC11 and SC12. Sediment cores were cut open lengthwise in the field, wrapped in aluminum foil, and immediately subsampled using a stainless-steel mini-corer that can collect up to 10 cubic centimeters of the deposits. The subsample was extruded into a vial containing 15 mL of methanol and stored at 4°C for at least a week with periodic shaking to improve extraction. The vials were eventually centrifuged and samples of the methanol were extracted with pentane and analyzed for PCE and TCE using a Hewlett Packard 5890 Series II plus gas chromatograph equipped with a Ni^{63} electron capture detector (ECD) and a DB-624 megabore capillary column. The detection limits for the method was between 0.23 and 2.30 micrograms of PCE per gram of dry sediment (µg/g) and between 0.22 and 2.22 µg/g for TCE. Concentrations represent total contaminant mass in the sample (i.e. mass sorbed on the sediment solids plus the mass in the interstitial pore water).

Streambed soil cores from RC1 to RC4 were subjected to a new method of liquid extraction with sediment subcoring referred to as the "LESS" core sampling technique. This method was designed to simultaneously determine both the interstitial pore water and total contaminant concentrations from which sorbed concentrations could be determined. Aluminum core tubes containing sediments were immediately capped, laid on their sides, and 0.021 m OD holes were drilled though the aluminum walls on a 0.15 m vertical spacing for sampling. A neoprene stopper fitted with a 0.0032 m OD stainless steel sampling tube was immediately inserted into the drilled hole and formed a water tight seal. Attached to the end of the tube that was placed into the wet sediment was a 0.0254 m long porous stainless-steel sampling tip (i.e. a 0.45 μm porous cup manufactured by Mott Corporation, Farmington, Connecticut). A small glass syringe was then attached to the other end of the tube to extract water from the core and fill three 5 mL glass vials for analyses. The porous tip was then removed and the sediment where the water had been extracted was subcored using the mini-corer and placed in a vial containing methanol. A total of 25 sediment samples were analyzed for PCE, TCE, and cis-1,2-dichloroethene (cDCE) using a new direct methanol injection method on the same Hewlett Packard 5890 Series II plus gas chromatograph previously described. This new method was specifically developed for analyzing this set of samples and improved the detection limits by about a factor of 100. The direct methanol injection method resulted in minimum detection limits of 0.006, 0.002, and 0.109 μg/g (per dry weight of sediment) for PCE, TCE and cDCE, respectively. Water samples could be collected from only 11 of the 25 locations because some deposits were too fine to obtain water using a syringe. Water samples from the sediments were analyzed for PCE, TCE, cDCE, trans-1,2-dichloroethene (tDCE), 1,1-dichloroethene (11DCE), and vinyl-chloride (VC), using the methods described in the plume delineation section.

To obtain information on the geology beneath the streambed, two GPR surveys were performed using a pulseEKKO IV GPR system (Sensors and Software, Inc. Mississauga, Ontario, Canada) with a pair of unshielded slab-antennae, mounted on a 0.01 cm thick plywood sheet in the bottom of a small inflatable raft. GPR traces were obtained every 0.1 m across nearly the full width of the river on transects between 10.1 and 12.4 m long that were spaced 1 to 2 m apart. Locations along each transect were determined by a measuring tape extended above the river between survey stakes located on either side of the river. Transect designations are used throughout this chapter to identify sampling locations in the riverbed. An example of the naming convention is as follows, location 8-8W 4.5 m indicates that the transect is approximately 8 m downstream (north) of the King Street bridge (shown in Figure 2-3) and the point is 4.5 m west of stake 8 (on the east bank) toward stake 8W (on the west bank). A Sokkia SET4E Total Station and SDR33 Datalogger were used to survey the elevations and locations of the stakes, all land based instrumentation and sampling locations, and other riverbed installations.

GPR has been successful in delineating and characterizing river bottom sediment structures and their thickness at other sites (Naegeli et al., 1996; Beres and Haeni, 1991; Haeni, 1996); therefore, a preliminary GPR survey was performed on May 15, 1998, to determine the usefulness of GPR at this site. GPR measurements were made across the river along 6 transects (4-4W, 6-6W, 8-8W, 16-16W, 18-18W, and 20-20W) and along one 18.3 m long land based line starting near stake 20 and extending eastward in 0.2 m increments. The transects were first performed using 100 megahertz (MHz) antennae placed 0.62 m apart and then all river transects were repeated using 200 MHz antennae placed 0.46 m apart. The second GPR survey performed on October 15, 1998, consisted of 16 transects across the Pine River located between (and including) transects 4-4W and 24-22W (see Figure 2-3 and 2-6 for transect lines). Only the 200 MHz antennae was used this time because of its better resolution.

The surficial geology of the streambed was visually mapped in July 1997, August 1998, and February 1999, as part of streambed temperature surveys (see Chapter 3). Observations were typically made on a 1 by 2 m grid extending from approximately transect -4 - -4W (under the King Street bridge) northward to as far as transect 60-60W. Notes regarding depth of water and notable obstructions (e.g. logs or manmade debris) were also made at each location.

2.4.2 Water Level Monitoring and Stream Gauging

To obtain a better understanding of groundwater/surface-water interactions, ground water flow directions, and river stage/discharge relationships, several drivepoint piezometers, mini-piezometers, dataloggers and staff gauges were installed and monitored at the site. A total of 41 drivepoint piezometers, were installed at 20 locations (DP1 to DP20). The drivepoint piezometers generally consisted of #50-mesh, stainless-steel screens 0.026 m OD and 0.28 m long, attached to either a 0.0213 or 0.0267 m OD, schedule 80 black-iron pipe like those depicted in Harvey et al. (2000). A 0.0095 m ID polyethylene sampling tube was attached to each drive point and extended up through the iron pipe to the surface. An electric percussion hammer was used to drive the iron pipe with the attached drivepoints to depths between 2.49 to 8.04 m bgs. In 1996, at locations DP1 to DP9 nests of shallow (2.49 to 3.99 m bgs), intermediate (5.20 to 5.97 m bgs), or deep (7.28 to 8.04 m bgs) piezometers were installed. In July 1998, the remaining 14 piezometers (DP10 to DP20) were installed and included and pairs of shallow and deep installations at DP10, DP14, and DP17.

In June 1996, three pairs of mini-piezometers were installed in the streambed, one shallow (about 0.6 m deep) and one deep (about 1.2 m deep) at locations SP1, SP2, and SP3 (see Figure 2-2). Each mini-piezometer consisted of a 0.0095 m, ID polyethylene tube, with a 0.1 m long screen and was installed using the method of Lee and Cherry (1978). In November 1996, the mini-piezometers were vandalized and so this type of installation was not pursued further. A new type of streambed piezometer was subsequently designed and 34 were installed (designated SP4 to SP37). Each piezometer consisted of a 0.75 m long, 0.021 m OD, schedule 80 PVC-pipe, with a 120 μm stainless-steel mesh wrapped around a 0.1 m long perforated section of the pipe. The screened interval was recessed such that the mesh was flush with the outside of the PVC pipe. The bottom of each piezometer was capped with a threaded steel bolt, and a threaded male elbow connector was attached to the top of the PVC and connected to a 1.1 m long section of 0.0127 m OD polyethylene tube. Piezometers were pushed by hand or hammered into the streambed to a depth of 0.65 to 0.70 m without the need for making an oversized borehole. All the streambed and drivepoint piezometers were developed by surging and pumping. Streambed piezometers were capped to prevent flow of water in or out of the tubes since the tubes were underwater and designed to lay flat on top of the streambed.

Hydraulic head measurements and slug testing of piezometers SP4 through SP34 were performed between November 3 to 6, 1998 except for SP34 and SP35 which were tested on December 10, 1998. Prior to each slug test, the hydraulic head difference between the river and the piezometer was measured to within 0.001 m using a potentiomanometer similar to that described by Winter et al. (1988). The Hvorslev (1951) falling-head slug-test method was used to determine hydraulic conductivity, which could then be used in vertical groundwater flux calculations.

Monitoring of water levels in piezometers began soon after the first piezometers were installed in 1996 but when the last 14 were installed in July 1998, monthly water level measurements were made in all land based piezometers for a period of 13 months. At this time, drivepoint well AW1, with a 0.032 m ID and a 0.56 m long screen, was installed to a depth of 7.24 m bgs in the confined aquifer at a location approximately 3.8 m east of the river. Water levels in AW1 were monitored to within 0.005 m on a 15 minute interval starting in July 9, 1998, and ending November 17, 1999, using a Solinst Model 3001, M5 Levelogger™ (Solinst Limited Canada, Georgetown, Ontario).

Manual measurements of stream stages at Angus began in 1996 with the installation of steel-pipe staff gauges SG-1 to SG-6 (Figure 2-2). In September 1996, SG-3 was destroyed and in June 1999, SG-1A was installed. Between March 1998 and June 1999, a Solinst, Model 3001, M5 Levelogger™ was placed in a stilling well in the river at PRP1 (Figure 2-3) and recorded stream stage on a 15 minute interval. Discharge was measured 8 times at the site using a Swoffer Model 2100-STDX flow meter. A stage/discharge relationship was developed for the site using this data.

2.4.3 Streambed Temperature Measurements

Streambed temperatures have been used at other sites to qualitatively identify areas of groundwater discharge (upwelling) into surface water or surface water infiltration (downwelling) into the streambed deposits (Bilby 1984; White et al., 1987; Hendricks and White 1988; Sillman and Booth, 1993; Maddock et al., 1995). The theory behind using temperature contrasts as an indication of discharge has been summarized by Lapham (1989). In northern temperate climates, high groundwater discharge areas in streambed tend to be relatively cold zones in the bed during the summer and relatively warm zones in the bed during the winter. Temperature monitoring included, plan-view mapping of streambed temperatures in winter and monitoring of groundwater and surface-water temperatures. Groundwater and surface water were monitored using waterproof StowAway® TidbiT® -5°C to +37°C range temperature loggers (Onset Computer Corporation, Pocasset Massachusetts). River water temperatures were monitored at a 15 minute interval starting on August 4, 1997 and ending November 17, 1999. Groundwater temperatures in the confined aquifer at the base of drivepoint well AW-1 were monitored on 15 minute to 1 hour intervals starting on July 9, 1998 and ending November 17, 1999. Measurements were accurate to within about 0.1 to 0.2°C. Streambed temperatures were measured using a Barnant Model 600-8525 Handheld Thermister Thermometer (Barnant Company, Barrington, Illinois) equipped with a stainless steel YSI Model 418 reusable temperature probe (YSI Incorporated, Yellow Springs, Ohio). The probe was accurate to within 0.1 °C. The probe was fixed to the end of a 1.8 m long, 0.009 m OD stainless steel tube and was inserted to a depth of 0.2 m at each measurement location. Measurements were generally made on a 1 m spacing along transects located perpendicular to the river flow. The mapping of streambed temperatures was performed between July 28 and 29, 1998 and consisted of 383 measurements for the reach of river extending from transect -4 - -4W under the King Street bridge down stream to transect 44-44W. See Chapter 3 for additional discussions regarding measuring streambed temperatures.

2.4.4 Plume Delineation

Sampling devices used to characterize and delineate the subsurface water quality at the site included: the Waterloo Groundwater profiler, mini-profiler, bundle multilevel samplers, "driveable" multilevel samplers, drivepoint piezometers, and mini-piezometers. Water samples collected from these devices were analyzed for VOCs at the University of Waterloo. Water samples for PCE and TCE analysis were extracted using pentane and run using a Hewlett Packard 5890 Series II gas chromatograph equipped with a Ni^{63} electron capture detector (ECD), an autosampler, a HP 6890 Series integrator, and a DB-624 megabore capillary column. Minimum detection limits for PCE and TCE were typically 0.7 and 0.9 µg/L. Analyses for cDCE, tDCE, 11DCE, and vinyl chloride (VC) were performed using a headspace method. The samples were analyzed using a Hewlett Packard 5890 Series II gas chromatograph equipped with a HNU photoionization detector (PID) with a fused silica capillary NSW-PLOT column. Samples prior to June 1998, were manually injected into the PID while those after that date were injected using an automated Hewlett Packard 7694 Headspace Sampler. The minimum detection limits for the manual and the automated methods were cDCE (7.8 and 1.0 µg/L), tDCE (1.9 and 1.4 µg/L), 11DCE (3.2 and 1.4 µg/L) and VC (0.7 and 0.8 µg/L), respectively. Analyses for ethene and ethane were performed using a headspace method and samples were manually injected into a Hewlett Packard 5790A gas chromatograph equipped with a flame ionization detector (FID), a GS-Q megabore capillary column, and a Hewlett Packard 3396 Series II Integrator. Headspace concentrations were converted to water concentrations using Henry's law. Minimum detection limits for ethene and ethane were typically 0.5 µg/L. Each set of samples analyzed typically included laboratory blanks, field and laboratory duplicates, trip blanks and equipment blanks.

The Waterloo Groundwater profiler (referred to as the "profiler" in this chapter) was used at 33 locations to collect approximately 381 groundwater samples as part of the current study. The profiler is a direct push method of obtaining detailed vertical profiles of water quality in unconsolidated materials. The method involved the driving of a 0.038 m OD, multi-port, stainless-steel sampling tip into the subsurface materials to sequential depths using either a hand-operated jackhammer or an Enviro-Core™ XD drill rig. A single stainless-steel sampling tube is connected to the sampling tip and a peristaltic pump and sampling manifold are attached to collect water in glass vials. The stainless-steel tube is then back flushed with deionized water prior to and during advancement of the tip to the next sampling depth.

Table 2-1 contains information regarding the depth, number of samples, types of analyses and date of sampling for each of the 33 profiling locations. Thirteen of these profile locations (AP40 to AP52), were done during July and August 1996, along profiler transects 5 and 6 which parallel the east and west sides of the Pine River, respectively (see Figure 2-2). These profiles were within 4 m of the river and used to characterize the western edge of the plume. A total of 175 water samples were collected typically using a 0.5 m vertical spacing. Another 10 locations (AP96-1 to AP96-10) consisting of about 81 samples were profiled in the upgradient plume area to further characterize the PCE plume cores and delineate the lateral edges. In November and December 1997, three locations, AP53 to AP55 (Levenick, 1998) consisting of 21 samples were profiled near previously profiled locations AP25 to AP27 (Writt, 1996) about 29 to 37 m east of the river, along transect 4 (Figure 2-2). All samples from the 34 locations were analyzed for PCE and TCE, and samples from AP52 to AP55 were also analyzed for PCE degradation products.

Between August and November 1996, 8 locations (PRP1 to PRP8) consisting of 106 samples were profiled in the riverbed at distances of between 18 to 36 m downstream of the King Street bridge (see

Figure 2-3). A single flight of scaffolding was setup on temporary wooden or concrete blocks on the riverbed and an electric jack hammer was used to drive the tip into the subsurface to a maximum depth of 8.5 m. The sampling interval was generally between 0.1 and 0.5 m. VOC samples were collected in a sampling manifold in the same manner as previously described. The only difference was the use of an additional 2 to 6 m of stainless-steel tubing to reach the sampling equipment set up on the shore. Upon completion of each hole, the profiling equipment was removed using a battery operated winch, and a 0.048 m OD PVC pipe was driven into the hole and capped until the hole and pipe could be tremmie grouted with bentonite.

A newly developed "mini-profiler" was also used to obtain vertical profiles and horizontal distribution of the groundwater contamination in the streambed. The mini-profiler is a 0.0064 m OD, 0.003 m ID stainless-steel tube, 2.6 m in length, having a 0.01 m long screen, located 0.025 m above the drive tip. The mini-profiler was a soil vapor probe described by Hughes et al. (1992) that was modified to collect water. Vertical profiles of water quality were obtained in the same manner as with the Waterloo profiler, but the mini-profiler could be advanced and withdrawn from the streambed by hand (without scaffolding or a hammer) and the small holes were not grouted. About 104 water samples were collected generally using a vertical spacing of 0.15 m down to a maximum depth of 2.10 m below the streambed. The mini-profiler was used for vertical profiling at PRP7R, PRP8R, PRP9R, and PRP10 to PRP17 and most of these locations are located along transects 6-6W, 18-18W, and 30-26W (Figure 2-3). All locations were sampled in August or October 1997, except PRP17 which was sampled in June 1998. In August 1998, the mini-profiler was used at 80 locations to map the horizontal extent of the plume at a depth of 0.3 m below the streambed. Samples were collected on approximately a 2 by 4 m grid starting at transect -4 - -4W (beneath the King Street bridge) and ending at transect 44 - 44W, with two additional samples collected on transect 52 - 52W. Sampling was also repeated at 6 of the 80 locations to assess the reproducibility of the sampling method during the sampling event. A 1.8 m long mini-profiler was attached to a 2.9 m long section of teflon tubing that was connected directly to the sampling manifold mounted in the bow a small boat. Mounting equipment on a boat eliminated the need for extra tubing to reach the shore which meant decontaminating between sampling events was easier. Samples collected during horizontal and vertical mini-profiling were analyzed for PCE and 7 degradation products.

In January 1999, because of concerns about potential changes in the concentration and position of the PCE plume, 12 bundle multilevel samplers, designated BML1 to BML12, were installed along the banks of the river. BML1 to BML10 were installed in a row on the east ride of the river and roughly parallel to transect 5 and within 3.4 m to 10 m of the river. BML11 and BML12 were installed on the west side of the river, in the vicinity of AP47 and AP49, respectively. See Figure 2-2 for BML locations. The BMLs were constructed in a similar manner to those used by Mackay et al. (1986) and described by Bianchi-Mosquera and MacKay (1992). Each BML consisted of a 9.97 m long PVC center stalk with 8 to11 teflon sampling tubes (0.0032 m OD and 0.0016 m ID) bundled to it, each with a Nitex screen placed over the end of the tube. The sampling ports had a vertical spacing of 0.5 m and were placed 4.5 to 9.5 m below the top of the center stalk. The BMLs were installed using an Enviro-Core™ XD drill rig which vibrated in a temporary casing with an aluminum knock-out tip. The bottom part of each hole was allowed to collapse around the BML but the top 4.27 to 5.50 m of each hole (above the top port) was sealed using a bentonite grout. In March 1999, approximately 106 groundwater samples were collected from the BML samplers and analyzed for PCE, TCE, 11DCE, tDCE, cDCE, VC, ethene, and ethane.

In this study, two new types of driveable multilevel samplers (MLS) were developed that eliminated the need for a temporary casing to install the device and minimized the possibility of vertical groundwater flow along the installation. The MLS sampling ports were flush with the outside of a stainless steel or PVC drive pipe that was driven directly into the streambed using an electric jack hammer. The stainless-steel type were modified multilevel sampling devices used by Barbaro (1999) and de Oliveira

(1997). The device consisted of a 3.055 m long, 0.0335 m OD (0.0254 ID) schedule 40 stainless-steel pipe fitted with a drive tip and it had 9 sampling ports spaced 0.3 m vertically along its length. Each port was attached to a separate 0.0032 m OD stainless-steel sampling tube extending up inside the larger pipe. The larger pipe was then filled with wax to provide internal support while driving the device. The other type of driveable multilevel consisted of a 0.014 m ID, 0.042 m OD PVC pipe which was 1.52 m in length with 10 sampling ports spaced 0.15 m vertically along the pipe and terminating in a solid stainless-steel drive tip. The ports consisted of Mott 0.0254 m long 0.45 μm porous tips soldered to 0.0032 m OD stainless-steel tubes which were placed into machined slots along the outside of the pipe and PVC welded (sealed) into place. In October 1998, pairs of stainless steel and PVC type driveable multilevel samplers (MLS1 to MLS20) were permanently installed at 10 locations (see Figure 2-3). The MLS samplers were installed in a line along transects 6-6W and 16-16W and extended to a maximum depth of 5.5 m below the streambed. Sampling of 41 MLS sampler points occurred in November 1998, and 139 points were sampled in March 1999. All the MLS water samples were analyzed for PCE and its degradation products.

In the initial part of the study, some of the water level monitoring points (drivepoint piezometers) were sampled for groundwater quality. On June 25, 1996 drivepoint nests DP1 to DP6 and streamed mini-piezometer pairs SP1, SP2, and SP3 were sampled for PCE and it's degradation products. Between November 8 and 11, 1996, water samples were also collected from drivepoint nests at DP1, DP7, DP8, DP9, and a streambed piezometer pair at SP1.

2.4.5 Surface Water Sampling

Between June 25, 1996 and March 17, 1999, 71 surface water samples were collected from various locations within the study reach and analyzed for VOCs. The majority of water samples were collected by hand as grab samples from just a few centimeters above the streambed. For VOC sampling, an open 40 mL or 25 mL glass vial was inverted and pushed down through the water to the desired depth. The vial was then turned over to release the air, allowing it to fill with river water before being lifted to the surface where it was immediately capped with a teflon lined septum and plastic cap. Other samples were collected prior to profiling the streambed at a location using a peristaltic pump and sampling manifold and placing either a Waterloo Profiler tip or a mini-profiler tip to the desired height just above the streambed. Samples were collected just above the streambed to improve the likelihood of detecting contaminated groundwater discharge since it would have been subject to less mixing and turbulent dispersion in the surface water. The method of lifting the vial up through the river water prior to capping was not believed to have resulted in a significant mixing of the sample with water higher up in the river.

Two main surface water sampling events occurred on June 27, 1996 and October 7 and 9, 1996, when the river levels were relatively low at 184.72 and 184.50 m, respectively. For each sampling event, one group was collected upstream of the projected plume discharge area and the other two groups were collected either within or downstream of the projected plume discharge area. These samples were collected prior to installing the transect stakes used for determining locations so a description of the sampling locations is provided. In June, samples were collected at about 2.5 m from the east bank, in the center of the river, and 2.5 m from the west bank at locations 0, 65, and 113 m downstream of the King Street bridge. Those collected at distances of 65 m and 113 m were labeled with the suffixes "-SP2" and "-DS", respectively. In October, samples were collected at distances of about 0, 23, and 54 m down stream. The two samples collected at the bridge were from the east side and center of the river (the sample from the west side broke during transport). The 4 samples at a distance of 23 m downstream were at locations PRP1, PRP2, PRP3, and PRP4. At a distance of 54 m three samples were collected on the east side, center, and west side of the river in line with SP1. Three other samples were collected at this time at PRP5, PRP6, and SP2 located about 36, 35, and 66 m downstream of the bridge, respectively. Later samples were typically collected either prior to profiling at a location or before sampling a MLS location or along specific transects.

2.5 RESULTS AND DISCUSSION

2.5.1 Geology

Prior to investigating the geology near the river, it was hypothesized that either no hydraulic connection existed between the confined aquifer and the river (Figure 2-4a) or that the river had eroded down through the aquitard and established a good connection with the underlying confined aquifer (Figure 2-4b). If no hydraulic connection had been established, then the plume could travel beneath the river without discharging to it (Figure 2-4a) but, if Figure 2-4b was the case, the plume would discharge completely to the river near the east bank and not extend beyond the groundwater divide in the center of the river. Early investigations in the Pine River and immediately adjacent to it showed low hydraulic conductivity "semi-confining deposits" and high hydraulic conductivity sandy streambed deposits unique to the near river environment, and deeper deposits that were part of the aquifer sands to the east. The result was near-stream geology that was more complex than shown in Figure 2-4.

2.5.1.1 Semi-Confining Deposits

Coring and the GPR surveys showed that the 1.5 m thick silty-clay aquitard that exists to the east of the river was absent in the immediate vicinity of the river and that semi-confining deposits were present instead of the aquitard. The semi-confining deposits at the site consisted of about a 5 m thick sequence of finely-bedded silts, peat, and clay that contain infrequent sand stringers. The semi-confining deposits are likely swamp or overbank type deposits laid down in association with a river or lake. The deposits extend from ground surface down to an elevation of around 181.2 m in cores SC7 to SC12. The semi-confining deposits were also found beneath the river at shallow depths at core locations RC1, RC2, RC7, RC9, RC11, and RC12. Under the river, the semi-confining deposits ranged from a gray to darker-gray silt with a small amount of clay to a gray to olive-gray clay or silty clay. These deposits contained less peat and wood material and tended to be more clay rich than semi-confining deposits found at cores SC11 and SC12. Figure 2-5b is a cross-section of the geology along the line shown in

Figure 2-5a which starts near the dry cleaner and passes roughly along the axis of the PCE plume to the Pine River. The figure shows semi-confining deposits lie over aquifer sand layer 2, and unconformably contacts both sand layer 3 and the aquitard at about 30 m east of the river. Initially it was thought that the aquitard had been eroded away by the Pine River in the past when the outlet for the river was much lower and then replaced with the semi-confining deposits as the outlet level rose. However, the radiocarbon date for the base of the semi-confining deposits at SC12 was 9350 ± 90 years before present which is older that the 6880 ± 80 age (Karrow, 1999) obtained for the base of the aquitard at B2 (located about 144 m away at a 2 m higher elevation than the SC12 sample). It is assumed that this wood accurately reflects the age of the deposits and is not older wood from upstream that was rafted downstream and redeposited. Thus some, but perhaps not all, of the semi-confining deposits were already in place before the aquitard was deposited. It is not known how far these low hydraulic conductivity semi-confining deposits extend beyond the river to the west, but in the immediate area of the river they play an important role in determining how and where the groundwater plume discharges into the river. The occurrence and distribution of these deposits beneath the river are discussed in more detail in the following sections.

Table 2-2 summarizes the maximum, minimum, geometric mean (K_G), arithmetic mean (K_A) and harmonic mean (K_H) hydraulic conductivities and the average porosity for the semi-confining deposits and other deposits at the site. The semi-confining deposits had hydraulic conductivities that were equal to or lower than those reported for the aquitard by Writt (1996). Falling head permeameter tests on 3 silt samples at the base of the semi-confining deposits at SC12 resulted in hydraulic conductivity values between 2.66×10^{-5} cm/s and 2.21×10^{-4} cm/s and porosities between 41 and 48%. Ten permeameter tests on samples collected from 5 locations beneath the river had a geometric mean hydraulic conductivity (K_G) of 1.12×10^{-4} cm/s and were as low as 2.36×10^{-5} cm/s with an average porosity of 62.6%. Slug testing of streambed piezometers screened in the silty clays of the semi-confining deposits had vertical hydraulic conductivities (K_v) ranging between 9.34×10^{-4} cm/s and 4.44×10^{-6} cm/s.

2.5.1.2 Streambed Surficial Geology and Streambed Sands

Mapping of the surficial geology of the streambed was undertaken to characterize the site geology and to help infer preferential flow paths to the river. A map of the streambed surficial geology (top 0.1 m of deposits) for February 1999 is shown in Figure 2-6. Geomorphology, topography, and composition of the riverbed may vary both seasonally and in response to floods because of river erosion and deposition of sediments (primarily sand). For instance, over a 6 month period, the topography of streambed sands was observed to vary by at least 0.45 m at one location along transect 18-18W. Nonetheless, the pattern of deposits in Figure 2-6 was quite similar to the July 1997 and August 1998 distribution of deposits (not shown). Because of these shifting sands, the semi-confining deposits typically only out crop beneath the river as very small areas along the stream banks and they correspond to the silt-with-clay-or-peat zone and the sand-and-silt-with-clay-or-peat zones labeled as zones 1A and 1, respectively in Figure 2-6). Within 30 m of the King Street bridge, 56.3% of the area of the streambed consisted of fine to very-fine sand and 13.7 % consisted of sand and gravel with or without cobbles and boulders. Downstream of transect 30-30W in the area of the gentle riffle, the streambed material was coarser, consisting of 20.5% sand and 48.7% of sand and gravel with, or without, cobbles and boulders. In both stretches of the river, about 30 % of each area consisted of fluvially deposited sand and silt that were commonly found along the edges of the river.

The thickness and characteristics of the fluvial sand deposits that overlie the semi-confining deposits were determined by coring and GPR surveys. In general, the top portions of riverbed cores RC1 to RC12 consisted of tan colored, clean and uniform, fine-to-very-fine sand deposits, about 0.10 to 0.54 m thick, likely representing deposition within the past year. This layer was usually underlain by either similar grain-sized gray-tan sands or by a finer gray-tan sand which in some areas contained numerous shell fragments and a small amount of silt. This lower sand layer occasionally contained woody debris such as small pieces of sticks or bark or peat like materials which were typically present as beds less than 0.02 m thick. The 167 permeameter tests on the sandy streambed materials resulted in a K_G of 1.53×10^{-2} cm/s and an average porosity of 39.6%, which are similar to the values obtained for the aquifer sands of layers 1 and 2 in this study (Table 2-2). At the 6 river core locations where semi-confining deposits were found, 0.15 to 1.25 m of sandy materials lie unconformably on top of the semi-confining deposits. This contact was typically very sharp and these sands had hydraulic conductivities 32 to 382 times greater than the underlying semi-confined deposits. Therefore, vertical flow of groundwater from the aquifer up through the streambed at these locations will be restricted and controlled by the semi-confining deposits and so the distribution of the overlying surficial sands and gravels of the streambed will not be reliable indicators of increased or preferential groundwater flow paths.

2.5.1.3 Absence of Semi-Confining Deposits Beneath the River

The presence or absence of the semi-confining deposits at depth determined where preferential groundwater flow paths from the underlying contaminated confined aquifer occurred. Shallow coring indicated the river had eroded at least 1.5 m below the current streambed level at some places, and replaced the semi-confining deposits with higher hydraulic conductivity sandy deposits. GPR was used to map the interface between the surficial sands and the underlying clayey semi-confining deposits to a depth of 3 m. Reflection of GPR signals off of the top of the semi-confining layer were strong, but radar signals did not penetrate much below it where clay in the deposits attenuated the signal. Deeper penetration of the radar signals in an area typically meant greater thicknesses of sand or other deposits that contain relatively little clay which could represent preferred groundwater flow paths to the river (e.g. geological windows).

The 16 GPR transects surveyed in October 1998, indicated that the semi-confining deposits extended from the east bank to about a third of the way across the river (approximately 4.0 to 4.5 m) in transects 14-14W through 24-22W. GPR and coring showed that less than about 0.80 m of sand overlies the semi-confining deposits in those areas. In the center of the river, the surficial sands and silty sands become considerably thicker (i.e. 2.5 to over 3.1 m thick). The GPR reflectors in these deeper deposits were hummocky and wavy which suggests a sequence of bedded sands or sand and silts with individual bed thicknesses of about 0.15 m. The cross-sectional areas of these sandy deposits are somewhat "u-shaped" and are consistent with the infilling of an older and deeper river channel incised into the semi-confining deposits. The former channel is clearly visible along several GPR transects including 16-16W (Figure 2-7a). These deposits are deep enough to intersect the underlying aquifer at an elevation of approximately 180.8 to 181.4 m. The depth axis in Figure 2-7 is based on a single radar velocity of 0.055 meters per nanosecond (m/ns) for saturated sands, and a topography correction has been applied to each trace to compensate for the water portion of the section which had a velocity of 0.033 m/ns.

Geological interpretation of the GPR transects were aided by coring of the deposits and by relative hydraulic conductivities inferred by the inability (or ability) to pump water samples from the MLS, Waterloo profiler, or mini-profiler sample locations and the color and silt content of the pumped water. In Figures 2-7b the clayey semi-confining deposits can be clearly seen extending out under the river from the east. Slightly higher hydraulic conductivity layers within and adjacent to the semi-confining deposits have been inferred to be silty-sand deposits based on the profiler and multilevel sampler pumping results. Some of these silty deposits are within the "u-shaped" former channel deposits. Between MLS8 and MLS10 a narrow continuous sandy zone (i.e. a geological window) is present that connects the confined sand layer 2 with the river and may serve as a preferential groundwater flow path. However, thin layers of silty-sand deposits may extend across the full width of the river just above the confined aquifer (note the question marks in Figures 2-7b), and could restrict vertical flow along that path. Geological interpretation of GPR records were complicated by "multiples" (i.e. multiple signal echoes from reflections off of the water/sediment and air/water interfaces) which occasionally obscure real stratigraphic reflectors within the streambed. It was also difficult to distinguish sand layers from silty-sand layers on the GPR records, so the fluvial deposits at depth (i.e. greater than the 1.8 m maximum depth of streambed coring) may be either sand and/or silty sands.

In the southern transects near the bridge (4-4W to 14-14W), the semi-confining deposits were less apparent in the GPR records because they were either absent or did not extend very far under the river, or the deposits contained less clay (e.g. RC7 on transect 10-10W). The radar signals penetrated deep into the deposits and the hummocky and chaotic configuration of reflectors suggest bedded sands or possibly cross-bedded sands and gravels. Diffraction patterns were occasionally observed indicating the possible presence of cobbles, boulders, logs, or manmade obstructions. The apparent lack of the semi-confining deposits suggests that the flow up from the confined aquifer is unrestricted, and the deposits across nearly the full width of the river could constitute a preferred flow path. The GPR transect and geological interpretation shown for transect 6-6W (Figures 2-7c and 2-7d, respectively) are representative of the deposits along the southern portion of the river.

2.5.2 Groundwater Flow and Discharge Through the Streambed

Groundwater flow at the site was determined using water level data and also was inferred from streambed temperature measurements, site geology, and distribution of contaminants. For the area east of the river, the sandy confined aquifer (i.e sand layers 1, 2 and 3) was the main groundwater flow system of interest because the dissolved phase PCE plume travels almost exclusively through it to reach the edge of the river. Figure 2-8a shows the potentiometric surface for drivepoints screened in the confined aquifer as measured on November 5, 1998, which corresponds to the lowest monthly water level conditions observed between July 1998, and August 1999. The direction of groundwater flow was very similar throughout the 13-month period with maximum observed changes in water levels at these piezometers of between 0.23 to 0.40 m. In Figure 2-8a, groundwater flow is generally horizontal toward the river from both sides, indicating that the river is a location of groundwater discharge and that the plume should not flow past the river as was hypothesized in Figure 2-4a except possibly in the area of DP9. Deep piezometer DP9-3 consistently had the lowest head observed in the confined aquifer and so the potentiometric contours are concentric around that location and form what resembles a cone of depression around a pumping well (Figure 2-8a). This location may be near an area of local discharge from the confined aquifer to the overlying unconfined system. Some groundwater flow from the east side of the river maybe able to flow beneath the river to the DP9 area but not beyond.

At most locations in the confined aquifer the flow was essentially horizontal since vertical hydraulic gradients between pairs of intermediate and deep piezometers screened within the confined aquifer were often non-detectable. Small vertical gradients (generally upward) within the confined aquifer near the river were measurable on occasion, but they did not display a consistent spatial or temporal pattern. Drawdown caused by daily pumping of the Angus Plaza water supply well (located 90 m north west of AW1 in Figure 2-8a) may have contributed to this inability to resolve these gradients near the river. Water levels at AW1 varied about 0.02 to 0.04 m during the time required to take a typical set of monthly water level measurement and varied about 0.1 m over an entire day.

Monitoring of water levels with Leveloggers™ was done to characterize seasonal differences in vertical flow potential between the confined aquifer and the river and determine if reversals in flow direction occurred. Figure 2-9a shows the relative locations of the Leveloggers™ in the river and the confined aquifer at well AW1. Figure 2-9b is a graph showing water levels measured between July 1998 and June 1999. During this time the minimum flow in the Pine River was 1.39 m^3/s, the maximum flow was 6.89 m^3/s, and the median flow was 2.29 m^3/s. During that time the water levels in AW1 ranged from 185.71 to 186.39 m (i.e. varied by 0.68 m) and the river stage ranged from 184.43 to 185.27 m (i.e. varied by 0.84 m). Figure 2-9c shows the vertical hydraulic gradient between the AW1 well screen and the bottom of the river (a vertical distance of 3.64 m) is always upward at between 0.29 and 0.42 m/m indicating groundwater discharges to the river even during the modest spring runoff in March 1999. Likewise, water levels in piezometers screened in the confined aquifer near the river in this study were observed to always be 0.5 to 1.5 m higher than those measured in the top of the semi-confining deposits or in the river. Some of the deep piezometers near the river would have been flowing artesian wells for either part or all of the year if they had not been capped. The lack of gradient reversals during flooding suggests that surface water does not flow down into the underlying aquifer as bank storage [such as that observed by Squillace (1996)], except possibly during more rapid and extreme flooding situations than observed in Figure 2-9c. During flooding events, increases in river stage are accompanied by increases in the aquifer water level, but the response in the aquifer lags slightly in time and is not quite as large resulting in short periods (1 to 3 days) of lower hydraulic gradients as seen in the graph (Figure 2-9c).

Vertical hydraulic head differences and flow within shallow streambed deposits were also investigated. Six sets of water level measurements made at mini-piezometer pairs at SP1, SP2, and SP3 from June 18 to November 9, 1996, resulted in vertical head differences ranging from 0 to 0.004 m and vertical gradients ranging between 0 (no flow) to 0.0067 m upward. Upward flow occurred even when the river stage was higher (elevation 185.1 m) during the November 9, 1996, measurements. However, it was not clear if the small head differences might be an artifact of the Lee and Cherry (1978) installation technique, where the holes created to install the mini-piezometers in silty and clayey materials may not have collapsed properly around the tube and could result in a poor seal between the screen and the overlying river. Water level measurements piezometers made with the potentiomanometer in the new type of piezometers (SP4 to SP37), also indicated upward flow of water at each location in November 1998. The lowest head difference between these piezometers and the river was 0.002 m, the median difference was 0.01 m, and highest difference was 0.233 m (at SP34, located at 28-28W 2.0m). The vertical head gradients between the center of the piezometer screen and the top of the streambed ranged from 0.003 m/m to 0.405 m/m. These upward gradients suggest downwelling of surface water into the deeper streambed deposits is not common during low river flow conditions.

The spatial pattern of groundwater discharge through the streambed is shown qualitatively by streambed temperatures measured at a depth of 0.2 m in July 1998 (Figure 2-10). During this mapping, surface water temperatures ranged between 16.5 and 20.5 °C while the groundwater temperature in the confined aquifer was constant at 9.8 °C. Cooler temperatures in the streambed (9.9 to 14 °C) indicate areas of higher groundwater discharge and higher temperatures (17 to 19 °C) indicated areas of low groundwater discharge. Darcy flux calculations made at piezometer locations SP4 to SP37 were consistent with this pattern. For example, the lowest flux of 5.1×10^{-5} liters per square meter of streambed per day (L/m^2d) occurred at SP31 where the streambed temperature was higher (16.7 °C) and the highest estimated flux, 7060 L/m^2d, occurred at SP34 where the temperature was warm (10.3 °C). Groundwater appears to discharge preferentially in three areas, the south central discharge area, the west central discharge area, and the eastern shore discharge area. All three areas are within 32 m of the King Street bridge, and none are in the riffle area down stream of that distance. The location of these discharge areas are generally consistent with the pattern of concentric potentiometric contours near the river that show this upper portion of the river to be an area of focused discharge (Figure 2-8a). The south central and west central discharge zones also align with the preferential pathways inferred from the geological investigations. The eastern-shore discharge area occurs where a tree and a section of stream bank extend into the river and it is thought that erosion and scouring associated with the water flowing under it has reduced the thickness of the semi-confining deposits or perhaps created a geological window at this location. See Chapter 3 for a further examination of the relationship between streambed temperatures and discharge.

2.5.3 Contaminant Plume

2.5.3.1 The Upgradient Groundwater Plume

To understand the source of the contamination found beneath the river, it was necessary to characterize the upgradient land-based plume traveling toward the river. A plan-view distribution of maximum PCE concentrations based on the present sampling effort and data from Pitkin (1994), Writt (1996), Levenick (1998) and Guilbeault (1999) is shown in Figure 2-8b and differs from earlier interpretations. Three main findings were made about the overall plan-view distribution of PCE in the aquifer. First, using new data from profiling along transects 2 and 3 and drawing the plume to be consistent with newly mapped groundwater flow directions, there was now a physical basis for concluding there are two separate high-concentration (>10,000 µg/L) cores of the PCE plume and not just one as had been previously thought. Second, profiling along the east bank of the river (transect 5) and sampling of drivepoints DP1, DP7 and DP8, and the BML installations, showed that the northern edge of the PCE plume intersects the river approximately 21 m further to the south than previously projected by Writt (1996). The plume position in Figure 2-8b was consistent with the groundwater flow near the river, which showed the plume should curve toward the river as it is depicted in Figure 2-8a. However, sampling of piezometer nests at DP1 to DP6 and SP1 to SP3 along the eastern side of the river (where the PCE plume was initially projected to be located by Writt) did not detect any PCE, but did detect low levels of PCE degradation products at a few locations. The presence of PCE degradation products to the north of the current location suggests the plume may have occupied that location at an earlier time and the contaminants are remnants of that occupation. The PCE degradation products detected included 25 µg/L of cDCE at DP1-2, 4.4 µg/L of TCE at DP2-2, 0.9 µg/L of TCE at DP3-1, and 5.3 µg/L of tDCE at SP3-D. Third, profiling performed in July 1996, on the west side of the river along transect 6 parallel to the river, indicated the entire plume discharged to the river. A possible exception was the detection of 2.5 µg/L of PCE at AP47 on the west bank of the river at a depth of 2.5 m bgs. Analyses of water samples collected from drivepoint piezometers DP9-2 and DP9-3 on November 8, 1996, detected

5.1 and 26.3 μg/L, respectively. However, analyses of 20 methanol-preserved sediment samples collected from core SC11 (2.4 m south of AP47) in June 1997 failed to confirm the presence of PCE (or TCE) in the semi-confining deposits or underlying sand aquifer on the west side of the river. In March 1999, 2.1 μg/L of PCE was detected at a depth of 5.55 m at BML11 (about 5.1 m south and 3 m deeper than the AP47 detection). Even though small amounts of contamination appear to have reached the far bank, the overwhelming majority of the contamination must be discharging up through the streambed. However, the presence of PCE beneath the far bank of the river suggests that the groundwater flow paths beneath the river may be influenced by preferential discharge up through the semi-confining deposits near DP9.

The PCE plume in the confined aquifer was characterized in cross-section beneath the stream bank immediately adjacent to the east edge of the Pine River to obtain a better understanding of the complex concentration distribution about to reach the river. The plume still contained the high concentrations of PCE observed further upgradient and was located almost exclusively in the confined aquifer. Plume concentrations varied vertically by factors of 100 to 1000 over distances of less than 1 to 2 m. PCE concentrations for the Waterloo Profiler Transect 5 performed in 1996 and the BML1 to BML10 transect sampled in 1999 are shown at a 1:1 scale in Figures 2-11b and 2-11c, respectively. The PCE groundwater plume along transect 5 was generally 5 to 7 m thick and approximately 45 m wide. Peak concentrations in the plume (>1000 μg/L) were found in a continuous band within the confined aquifer, that was 1.0 to 1.5 m thick along almost the full width of the plume. The two highest concentrations for the transect were 8707 μg/L at AP40 and 6643 μg/L at AP43. The two plume cores (>10,000 μg/L) shown in Figure 2-8b were either not intersected by the sampling array or were not present. If a 5000 μg/L concentration is used to define a core, then a two-core pattern is observed at approximately the right locations in the north and south ends of the plume and the cores are separated by a lower concentration area around AP45, AP41, and AP46. Only in this area between AP45 and AP46 did the plume extend up into the semi-confining deposits, as indicated by the positions of the 1 and 10 µg/L contours in Figure 2-11b. This flow up into the semi-confining deposits may be the result of the eastern shore discharge area (Figure 2-10). However, analyses of 21 methanol-preserved sediment samples collected from core SC12 (3.1 m south of AP45) in June 1997 indicated that PCE was present only in the confined aquifer sands and neither PCE nor TCE were in the semi-confining deposits at that location.

The concentration distribution of PCE was also examined in vertical cross-section beneath the eastern bank of the river a second time when the BML locations were sampled in March 1999 (Figure 2-11c). The purpose of this sampling was to see if the PCE concentration distribution had changed appreciably since 1996 and determine if PCE degradation products were present in the confined aquifer. The results of PCE analyses are projected onto the same cross-section line as transect 5 to aid in comparison. The plume in Figures 2-11b and 2-11c are similar, but the overall PCE concentrations in 1999 are lower and the plume is slightly thinner and appears to have shifted vertically upward. The plume has approximately the same width but is now only 4 to 5 m thick. The plume looks thinner partly because no BML sampling ports were placed to sample the semi-confining deposits. The continuous band of greater than 1000 µg/L of PCE seen in 1996 is discontinuous in the BML transect, and the highest PCE concentration was 2699 µg/L at BML6-5. These changes in the plume may be an artifact of how the sampling array intersected the plume, or may be a result of seasonal variations in the flow direction or depletion or changes in dissolution of the DNAPL source. The large reduction in plume concentrations are not thought to be a result of anaerobic biodegradation since only minor amounts of PCE degradation products were observed along the BML cross-section. Low concentrations of cDCE (<14.5 µg/L) and TCE (< 9.5 µg/L) were detected in the top 2 to 4 points in the aquifer at BML7, BML9, and BML10 and 26.8 µg/L of TCE was found at the top most point in the aquifer at BML1. Moreover, the geochemical conditions in the confined aquifer are not particularly reducing and are anaerobic with little or no nitrate reduction (see Chapter 4 for further discussion of the geochemistry). The decline in concentration in the aquifer are consistent with previous findings where concentrations from Waterloo profiling performed at AP53, AP54, and AP55 in 1997 (Levenick, 1998), were considerably lower than those observed at immediately adjacent profile locations AP25, AP26, and AP27 performed in 1995 (Writt, 1996).

Another reason for obtaining the vertical cross-section of PCE concentrations shown in Figure 2-11b and 2-11c was to estimate the mass of PCE discharging through the eastern edge of the river. Mass discharge was calculated as follows. The areas of the plume enclosed between adjacent concentration contours were measured using AutoCad®, and these areas were assigned the average concentration value of the two enclosing contours and then multiplied by the appropriate specific discharge (Darcy flux) for the area. For areas inside of 1000 µg/L contours there is no upper contour, so an average of the peak concentration from each profile was used as the upper concentration in the calculations. The average specific discharge for aquifer sand layers 1 and 2 near the river was estimated to be 0.171 m/d and was 0.001 m/d for the semi-confining layer, based on values of K_G and measured gradients. Over the entire cross-sectional area of the plume, approximately $24.9x10^3$ to $28.5x10^3$ L/d of contaminated water was flowing toward the river. For transect 5, approximately 19.7 grams of PCE per day (g/d) was flowing toward the river in 1996. For the BML transect, approximately 7.7 g/d of PCE was traveling toward the river in 1999. In both instances, a relatively small cross-sectional area of the plume contained most of the mass discharge. For example, for transect 5 about 15.7% of the plume area is enclosed by the 1000 µg/L contour but it accounts for 78.5% of the mass. The PCE mass discharge in 1999 was less than half of that observed in 1996 and both are less than the 58.5 to 146.2 g/d estimated for Transect 4 in 1995 (Writt, 1996). Mass discharge estimates by Guilbeault (1999) for half of the width of the plume near the dry cleaner were 21.7 g/d for part of Transect 2 using data collected in 1993 (Pitkin, 1994) and 39.7 g/d for part of the plume along the dry-cleaner building using profiles done in

1997 (Guilbeault 1999). The apparent decline in mass discharge over time is consistent with the decline in concentrations discussed earlier. The mass discharge estimates from the previous studies have been temperature adjusted to 10 °C to more accurately reflect in situ hydraulic conductivity values.

Extrapolation of concentration and groundwater flux data laterally into areas where there is no information adds a degree of uncertainty to mass discharge estimates that is potentially large and very difficult to quantify, especially since such large concentration differences occur over such short distances. One particular concern is that both the BML samplers and transect 5 profiling seemed to have missed the two cores (>10,000 µg/L) of the PCE plume. Assuming each core was only 2 m wide and 1 m high and located within an existing 1000 µg/L contour, this unaccounted for additional flux would be about 6.2 g/d, which would represent an 80% increase in mass discharge for the BML transect and a 31% increase for Transect 5. Locating high concentration cores of a plume is critical part of accurately estimating total mass discharge (Cherry, 1996), and this has been previously noted for other dissolved-phase plumes down gradient of DNAPL source areas (Rivett et. al., 1994; LeSieur, 1999; and Guilbeault, 1999). Recognizing and identifying these cores are important for determining the mass loading to rivers and locations of maximum concentration exposures in the streambeds.

2.5.3.2 Contamination of Interstitial Water in the Streambed

Plan-view mapping of interstitial water concentrations in the streambed using the mini-profiler in August 1998 showed that the PCE plume had been modified in both size and shape. The concentration and composition of the plume had also been substantially modified by anaerobic biodegradation. Anaerobic biodegradation (rather than abiotic degradation) is believed to be the main PCE transformation mechanism at the site because of the relatively large amount of cDCE produced in comparison to 11DCE and tDCE, which is indicative of a microbiologically mediated process

(Wiedemeier et al., 1999). To directly compare the contaminated area of the streambed to the PCE concentrations found in the confined aquifer, total VOCs detected in the streambed (i.e. PCE and its anaerobic degradation products TCE, cDCE, tDCE, 11DCE, VC, ethene and ethane) were converted to equivalent PCE concentrations. Equivalent PCE concentrations represent minimum pre-transformation PCE concentrations since they do not account for any PCE that has been completely mineralized to CO_2, chloride, and water. The equivalent PCE concentrations are shown in Figure 2-11a at the same 1:1 scale as the PCE concentration cross-sections in the adjacent aquifer along Profiler Transect 5 and the BML transect shown in Figures 2-11b and 2-11c.

The plan-view area of contamination in the streambed delineated by the 1 µg/L equivalent PCE contour in Figure 2-11a is 469 m^2 or about 2.3 to 3.2 times larger than in the two cross-sections. The area enclosed by the 10 µg/L contour in Figure 2-11a is about 2.9 to 3.8 times those in the cross sections. The plume has a similar north-south dimension in both the streambed and aquifer, but is typically much wider in the streambed than its thickness in the aquifer. This widening is not consistent with the narrowing of flow lines and focussing of flow at the shoreline that is usually encountered when groundwater discharges to surface water. In fact, at some locations the plume appears to discharge over the full width of the river, which has also been observed where other VOC plumes discharge to rivers (Norman et al., 1986; Savoie et al., 1999; Lyford et al., 1999). The highest equivalent PCE concentration found during the plan-view mapping was at 16-16W 7.0 m where 10,323 µg/L was detected (Figure 2-11a) that consisted of 5529 µg/L of degradation products (no PCE) of which 83.5% were cDCE. The plume is also shown in cross section as equivalent PCE concentrations for MLS installations along 6-6W and 16-16W sampled in March 1999 (Figures 2-12a and 2-12b), and Waterloo Profiling along 24-22W performed in 1996 (Figure 2-13). Along transect 6-6W, where the semi-confining deposits extend only a short way beneath the river, the plume discharges across about 70% of the width of the river. In cross-sections 16-16W and 24-22W, where the semi-confining deposits extend out under the river, the plume discharges over nearly the complete width of the river. Because these cross sections are shown at a 1:1 scale, the extent of horizontal spreading of the plume in the streambed is clearly apparent when the horizontal width in the streambed is compared to the vertical height of the plume in the aquifer beneath the eastern riverbank. Even with this spreading, the equivalent PCE concentrations in the streambed changed by a factor of 100 to 10000 over lateral distances of less than 1 to 3.5 m, which is similar to the variations in PCE concentrations observed within the aquifer.

Both the distribution of equivalent PCE in plan-view in the riverbed and the distribution in the aquifer in cross-sections were contiguous areas of contamination. The equivalent PCE concentration distribution in the riverbed was not a series of isolated, individual contaminant discharge points as might occur if the upgradient aquifer plume had isolated sections or if discharge was restricted to only discrete locations. Although three areas of preferred groundwater discharge were indicated in plan view by streambed temperature measurements, these areas do not cause the plume to split up into isolated sections. Both the aquifer and riverbed concentration distributions also had relatively few, if any, "holes" (where uncontaminated areas are completely surrounded by contaminated areas). The only holes observed were in the PCE plume at AP41 on Transect 5 (Figure 2-11a) where the low concentrations may have been below detection limits. A hole in the equivalent PCE plume was also found at MLS9 in the cross-section along Transect 16-16W (Figure 2-12b), even though no holes were found in the earlier plan-view sampling results for the equivalent PCE plume in the riverbed (Figure 2-11a).

Of all the factors that could affect the PCE plume in the streambed, biodegradation caused the most dramatic change in the plume characteristics. After traveling about 195 m to reach the river with very little or no biodegradation of PCE, the plume suddenly undergoes significant anaerobic biodegradation as it travels through the top 2.5 m of the streambed. The streambed has the ability to biodegrade the

PCE whereas the underlying and adjacent confined sand aquifer apparently does not. Figures 2-14a, 2-14b, and 2-14c, show the distribution of PCE, cDCE, and VC in the streambed in August 1998. Peak concentrations of PCE, cDCE, and VC observed in the streambed were 1433 μg/L, 4619 μg/L, and 823 μg/L, respectively. At approximately 54% of the locations detecting VOCs in the streambed, PCE had been completely transformed to PCE degradation products. In terms of area, the part of the plume still containing PCE was also only 54% (coincidentally) of the total VOC plume area and was limited to 3 separate and distinct areas. PCE appears to have been primarily transformed to cDCE (Figure 2-14b) with little or no accumulation of TCE (i.e only five locations had TCE concentrations exceeding 7.8 μg/L). Further biodegradation of cDCE to VC appears to be limited to an area associated with the highest equivalent PCE concentrations in Figure 2-11a. Biodegradation of VC to ethene and ethane (not shown) also occurred within the footprint of the VC plume resulting in maximum concentrations of 100.7 and 76.8 μg/L, respectively. The concentration of contaminants in the streambed was spatially variable and large changes could occur on a scale of meters to centimeters both vertically and horizontally. For example, 3639 μg/L of PCE with about 557 μg/L of degradation products were found at PRP8R at a depth of 1.2 m, but at a depth of 1.05 m the PCE concentration was only 125.6 μg/L and degradation products now totaled about 3377 μg/L which consisted of about 90% cDCE. The geochemical conditions within the streambed and extent of biodegradation processes and relation to groundwater discharge are examined further in Chapter 4.

2.5.3.3 Differences between the upgradient plume and streambed concentrations

The internal distribution, composition, and concentration of the plume in the streambed were similar in some ways to those in the aquifer but significantly different in other ways and the differences were not particularly predictable. The fact that extensive biodegradation occurs in the streambed (Figures 2-14a 2-14b and 2-14c) but not in the aquifer is clearly the most significant difference. Another notable difference is that the equivalent PCE concentration distribution within the streambed enclosed by the

100 and 1000 μg/L contours (Figure 2-11a) do not precisely resemble the distributions seen in cross-section in the aquifer (Figures 2-11b and 2-11c). At some locations concentrations are either much lower or much higher than would have been anticipated by looking at the two cross-sections of concentrations in the aquifer. Of the two cross-sections, the BML results are a better match to the plan-view concentration distribution, except that high concentrations at BML8 (2097 μg/L) to the north are not found in the streambed. The streambed sampling also did not locate where the northern plume core discharges to the river and failed to detect concentrations greater than 100 μg/L in the area where it was projected to discharge. Even the deeper profiling in this area seemed to miss the core and high concentrations (8707 μg/L) observed at AP40. Maximum concentrations of PCE detected at PRP5, PRP6, PRP12, and PRP13 were 2794, 7.3, 841, and 214 μg/L, respectively, with little evidence of degradation products. However, the discharge area for the southern plume core (shown in Figure 2-8b) may have been found at 16-16W 7.0 m where an equivalent PCE concentration of 10,323 μg/L was detected (Figure 2-11a). Given the close spacing of water sampling locations used near and beneath the river, it is surprising that Transects 4 and 5 and later sampling of the BMLs and MLSs failed to detect the southern core. Concentrations can change by as much as 100 to 1000 over distances of 2 m or less in the aquifer, so perhaps the core still managed to pass through this dense monitoring network undetected.

The geology beneath the streambed was thought to be responsible for the difference between the concentration distributions observed in plan-view (Figure 2-11a) relative to those in the aquifer (Figure 2-11b and 2-11c). For example, the large total area and width of the plume that was observed in the streambed is likely because the plume has to discharge up through lower hydraulic conductivity semi-confining deposits beneath the river. Flow through these deposits requires either larger areas and/or higher gradients to transmit equal quantities of water through them than was the case in the aquifer deposits. Low hydraulic conductivity layers and anisotropy of geological deposits have been shown to cause this type of widening of groundwater discharge areas for flow to a lake Guyonnett (1991). Preferential discharge of water from the confined aquifer up into the unconfined aquifer and river near DP9 also contributed to the plume spreading across the whole width of the river and reaching the western shore.

Based on the previous water levels and the principle of using VOCs as a tracer for groundwater flow emanating from the east, conceptual models for the cross-sectional groundwater flow beneath the river were developed and are shown in Figures 2-15a, 2-15b, and 2-15c. Figure 2-15a represents the situation along 6-6W where a large geological window allows a vertical flow divide to occur relatively near the middle of the geological window and so the plume discharges primarily to the eastern half of the river. Figure 2-15b depicts the situation along 16-16W where the geological window is small and offset to the west, meaning the flow divide is also offset to the west and thus the plume must discharge across most of the river. Figure 2-15c shows the situation along 24-22W where the combination of semi-confining deposits and preferential discharge through the semi-confining deposit near DP9 allow the plume to reach the far side of the river. In Figure 2-15c the groundwater flow divide in the confined aquifer occurs beneath the western bank and the clean water from the west discharges up through the semi-confining deposits near DP9 and eventually reaches the river laterally through the unconfined deposits.

2.5.3.4 Concentrations in the streambed versus groundwater discharge

An examination of streambed concentrations versus preferred discharge locations and pathways showed that high concentrations did not occur where groundwater discharges were high. Using the streambed temperatures in Figure 2-10 to infer the magnitude of groundwater discharge through a riverbed, plots of PCE (Figure 2-14) and total VOCs as equivalent PCE (Figure 2-11a) versus streambed temperature (i.e. discharge) were created and shown Figure 2-16a and 2-16b. No clear relationship was found between streambed temperature and total VOC concentrations as equivalent PCE. High concentrations were found essentially over the full range of temperatures, with some of the highest concentrations occurring where temperatures were high and the discharge was presumably low. The plot of PCE concentration versus streambed temperature also showed considerable scatter, but many of the higher concentrations were associated with low temperatures where groundwater discharges are presumably high. Because the high concentration portion of the plume in the aquifer upgradient of the river was thought to be traveling through preferred high discharge pathways toward the river, it was initially thought that high concentrations would be associated with high groundwater discharge areas in the streambed, but they were not. For example, in Figures 2-12a and 2-12b and 2-13 the plume is not restricted to what appear to be the preferential groundwater flow pathway (geologic windows) in each case and high concentrations (>1000 μg/L) are shown to extend into lower hydraulic conductivity semi-confining deposits. The presence of high concentrations in those deposits may, to a certain extent, be an artifact of extrapolating contours into areas having no water quality data. However, results of sediment analyses from cores RC1 and RC2 show that high concentrations of PCE, TCE, and cDCE are present in the low hydraulic conductivity deposits.

There are at least two possible reasons why the highest equivalent PCE concentrations are associated with the low hydraulic conductivity deposits and low discharge areas. The most likely reason is that the high concentrations observed in the highly-sorptive low-hydraulic-conductivity deposits may be remnants of older high-concentration plume water that has not yet migrated all the way through these deposits. The plume has likely been discharging to the river since the 1970s when the first documented release occurred at the dry cleaner (the average time required for groundwater to travel from the dry cleaner to the river through the confined sand aquifer is approximately 1.1 to 3.9 years). Concentrations of PCE of 27000 and 21000 μg/L were first detected in 1992 approximately 80 m east of the river in samples from domestic drivepoint wells at 47 and 46 King Street located north and south of the intersection with Water Street, respectively (see building locations in Figure 2-8a). The peak concentration in the plume was likely as high, if not higher, prior to this time and was at least 22,376 μg/L at AP24 (41 m east of the river) as of 1995. As noted in the previous sections, concentrations and mass fluxes appear to have declined somewhat over time and the location of plume discharge to the river may have shifted southward by about 21 m. For several decades, the semi-confining deposits streambed were likely exposed to relatively high concentrations of PCE (>10,000 μg/L), which means the high concentrations had ample time to penetrate the deposits and expand the volume of contaminated deposits beyond the confines of any preferential flow paths or geological windows (see Figures 2-12b and 2-13). A slow release of contaminants from these deposits could explain why an equivalent PCE concentration of 10,323 μg/L was detected at 16-16W 7.0 m but equally high concentrations were not detected in the upgradient sand aquifer (Figures 2-11b and 2-11c).

An alternate explanation for why the high groundwater discharge locations in the streambed do not correlate with high concentrations of contaminants is that the two types of locations simply do not line up (i.e. do not fall along the same flow paths). The locations of high concentration plume cores and high hydraulic conductivity pathways in the upgradient plume flowing toward the river do not necessarily have to connect directly with the geological windows and high discharge areas in the streambed. Even if the geologic windows are areas of very large amounts of discharge, some portions of the plume in the aquifer will still discharge through the semi-confining deposits. Without all the detailed upgradient plume characterization work, there would have been an inability to properly interpret the plume concentrations in the streambed or understand the significance of the 10,323 μg/L concentration that was detected or recognize the apparent lack of a northern core.

2.5.4 Sediment Concentrations and Contaminant Partitioning

Streambed sediments and deeper deposits were investigated for 3 main reasons: 1) to characterize sediment contamination caused by the discharging plume; 2) to determine to what extent the contaminants should be expected to sorb to the deposits; and 3) to estimate retardation of the contaminants as they are transported through these deposits. Analyses of sediment samples from river cores RC1 to RC4 indicated that the VOC plume resulted in significant contamination of both the streambed sands and semi-confining deposits. The 14 sand and silty-sand streambed samples had concentrations that ranged from none detected to 16.14 µg/g for PCE and from 0.02 to 0.63 µg/g for TCE. No cDCE was detected in those samples. The 11 samples of semi-confining deposits from RC1 and RC2 had concentrations that ranged from none detected to 81.02 µg/g for PCE, 0.08 to 2.07 µg/g for TCE, and none detected to 7.19 µg/g for cDCE. Samples collected from the sands of the confined aquifer at SC12 were generally less contaminated than both the streambed sands and the semi-confining deposits and concentrations ranged from none detected to 1.33 µg/g for PCE. No TCE was detected in the samples from SC12 and the samples were not analyzed for cDCE.

The extent to which the streambed and subsurface materials become contaminated is a function of the interstitial water concentration and the distribution coefficient (K_d) for the material. K_d can be a function of many different factors that affect sorption (Luthy et al., 1997), but in materials that contain greater than 0.1% foc, K_d can be approximated by the product of the foc of the material and the organic carbon-water partitioning coefficient (K_{oc}) for the contaminant (Schwarzenbach and Westall, 1981; Chiou et al., 1983), which is 364 mL/g for PCE (Mabey et al., 1982). Foc values for the streambed sands ranged from 0.027 to 4.49 % and in the semi-confining deposits under the river it was between 1.69 and 7.18 %, but were much lower for the aquifer sands where they ranged between 0.007 to 0.039% (See Table 2-3). The average K_d for sand layer 2, the semi-confining deposits beneath the river, and the streambed sands were 0.106, 16.75, and 2.07 mL/g, respectively. When K_d values were calculated using the foc data for sands in core RC4, it closely matched the in situ-Kd values obtained by the LESS core sampling. Estimating K_d from foc and the LESS core sampling results both seem to be valid methods at this site, and suggest that the streambed sands that were sampled had sufficient time to reach chemical equilibrium with the contamination. Using the K_d values (Table 2-3), porosity, and bulk density of the sands, it was estimated that the transport of PCE through the streambed sands will be retarded by a factor of between 1.4 and 67.1 (with a mean value of 3.22) relative to the advection of water. Retardation values of between 21.5 and 88.1 are estimated for the semi-confining deposits beneath the river (Table 2-3).

The relatively high K_d values and retardation factors for the streambed deposits (compared to the aquifer) have important implications for the fate and transport of the plume. Since the plume has been migrating to the river for decades, the semi-confining deposits have likely accumulated (adsorbed) many kilograms of VOC contamination. Because of the high retardation factors and low hydraulic conductivities, the contaminants may not have been able to completely migrate through (break through) the semi-confining deposits at all locations beneath the river or attain steady-state concentration profiles within those deposits. Average linear vertical flow velocities calculated for the SP4 to SP37 piezometer locations using the slug testing and potentiomanometer data resulted in the streambed sands and silty sands having vertical velocities of 0.01 m/d to 13.8 m/d with an average value of 0.78 m/d, while the silty-clays of the semi-confining deposits had velocities of 0.016 to 5.1×10^{-5} m/d. Even if the upgradient plume source of PCE at the dry cleaner is remediated, the low velocities and high retardation factors for the semi-confining deposits could cause the plume to take decades to hundreds of years to flush completely clean under natural conditions. The rate of this cleanup may be shorter depending on the rate of biodegradation. The high foc deposits will remain as a long-term source of contaminants beneath the river as they slowly desorb. It should be acknowledged that contaminated deposits can be eroded, transported down stream, and redeposited. Because of the relatively high K_d values for some of the streambed deposits, the contaminants may not have sufficient time to desorb their contaminants while suspended in the surface water prior to being redeposited and buried. Hence, contaminated sediment may be detectable further down stream even though contaminated groundwater does not discharge at those locations. It is not known to what extent this type of contaminant transport has occurred at the site, but sediment transport is significant at the site (Burkard, 1990).

2.5.5 Surface Water Concentrations

Surface water sampling has traditionally been one method of characterizing the effects of discharging groundwater plumes on surface water and so 71 samples were collected as part of this study. The first two major surface water sampling events in June and October 1996 (consisting of 23 samples) resulted in non-detectable levels for all VOCs except for 3 samples containing PCE. Those 3 samples had concentrations less than 1.6 μg/L and were located within or down stream of the plume discharge area (Table 2-4). Additional sampling over the next few years confirmed these findings with only 5 of 48 samples containing PCE and 5 containing TCE (Table 2-4). The highest PCE concentration was 23.2 μg/L observed at location PRP12, adjacent to the eastern bank approximately 30 m down stream of the bridge. This location was immediately down stream of a 0.05 m diameter underwater spring which was sampled at the same time and was found to be discharging groundwater containing 666 to 806 μg/L of PCE and 1.0 to 3.75 μg/L of TCE. For the other samples that detected contamination, PCE and TCE concentrations were less than 3.1 and 3.2 μg/L, respectively. None of the 71 surface water analyses detected 11DCE, cDCE, tDCE, VC, ethene or ethane. The lack of cDCE in the surface water is somewhat surprising since the cDCE plume was larger and had higher concentrations than the PCE plume (Figures 2-14b and 2-14a, respectively). Possible explanations are that either the cDCE plume mass fluxes are low even though the concentrations are high or the cDCE biodegrades rapidly in the top 0.3 m of the streambed or in the aerobic surface water. The detection of TCE in the surface water was also surprising since plume and streambed concentrations were so low. The TCE is likely an artifact of incomplete decontamination of the mini-profiler during the August 1997 sampling, since TCE was only found in the samples collected at that time and was present in equipment blanks (Table 2-4).

To determine if PCE concentrations should have been detectable in the surface water, average surface water concentrations were calculated using PCE mass discharge estimates and observed ranges of stream flows for the Pine River. For the purpose of this calculation, the PCE mass discharge obtained for transect 5 and the BML transect were instantaneously and completely mixed with the river and it was assumed that there were no losses due to attenuation within the streambed. Using the higher PCE mass flux from Transect 5, the estimated PCE concentration in surface water for a low river flow condition (1.39 m^3/s) was 0.16 μg/L and for the highest estimated flow associated with the surface water concentration data shown in Table 2-4 (3.95 m^3/s) the concentration was 0.06 μg/L. Even if the PCE mass flux was 4 times higher than estimated, PCE would not be detectable in the surface water when fully mixed (assuming the 0.7 μg/L detection limit for the analyses). These calculated concentrations are consistent with the large number of non-detect observations for surface water reported in Table 2-4, particularly since biodegradation of PCE in the streambed substantially reduces the PCE mass discharge prior to entering the river. However, PCE was detected at some locations meaning the assumptions have over simplified the situation. First of all, the PCE plume does not uniformly discharge over the full width of the river, but is irregular in shape, concentration, and in rate of discharge, which results in a complex PCE source loading term for the surface water (see Chapter 4 for further details). Secondly, mixing in the river is not instantaneous and, as a rule of thumb for turbulent mixing for a point source release, concentrations should become vertically uniform at a downstream distance of 50 times the streambed depth (i.e. about 25 m at this site) and become horizontally uniform at about 100 to 300 channel widths downstream (Rutherford, 1994). The surface water samples containing PCE were collected at or immediately down stream of high concentration PCE discharge locations in the streambed. Figure 2-14d shows all the locations where PCE were detected in the surface water during this study. The PCE is found within or downstream of the streambed PCE discharge locations (Figure 2-14a) except for the 3.1 and 1.6 μg/L concentrations at

PRP9 and PRP4, which may be an artifact of insufficient decontamination of the profiler sampling equipment.

2.5.6 Potential Adverse Ecological Effects of the Discharging Plume

Potential adverse ecological effects of the discharging plume were evaluated by comparing observed concentrations to established water quality criteria and guidelines for protecting aquatic life. All PCE and TCE concentrations in the surface water (Table 2-4) are considerably lower than established freshwater aquatic life guidelines (Table 2-5). USEPA ambient water quality criteria for PCE in freshwater is set at 5280 μg/L for acute toxicity and 840 μg/L for chronic toxicity (USEPA 1986) and the values for TCE are even higher. The interim Canadian water quality guidelines for the protection and maintenance of freshwater aquatic life (which are long-term no-effect levels) issued by the Canadian Council of Ministers of the Environment (CCME) (Canadian Council of Ministers of the Environment, 1993) are 110 and 20 μg/L for PCE and TCE, respectively. Low levels of PCE and TCE in surface water may or may not trigger regulatory actions depending on the state and local regulations or specific remediation goals for ecological end points such as those used by the U.S. Department of Energy (USDOE) (Efroymson et al., 1997) shown in Table 2-5. The low concentrations in Table 2-4 may represent statistically significant increases in contaminants above background levels. In Canada this increase might be considered a violation under the Fisheries Act (Government of Canada, 1993) and in the United States, at RCRA sites, it might preclude being able to apply for Alternate Concentration Limits for the discharging groundwater (USEPA, 1987).

In contrast to conditions in the surface water, the benthic and hyporheic zone aquatic life in the streambed can be exposed to very high concentrations of contaminants in the discharging groundwater. Analyses of groundwater in the confined aquifer along transect 5 showed about 36% of the area of the plume headed toward the river contained concentrations higher than the CCME guideline for PCE.

Interstitial water collected from the streambed mapping in 1998 showed 8 out of 53 locations that detected VOC contamination contained PCE concentrations exceeding CCME guidelines and the USEPA chronic toxicity guideline was exceeded at one location. Three locations had TCE concentrations that exceeded the CCME guidelines. Vertical profiling of the interstitial water in the top 1.2 m of the streambed found concentrations that were higher than the USEPA's PCE chronic toxicity concentration level at 4 of 17 locations (e.g. at PRP3, PRP8R, PRP12, PRP15).

The transformation of PCE to TCE, cDCE, tDCE, 11DCE, and VC in the streambed represent multiple "new" potential hazards that would not have been adequately characterized by sampling the aquifer along transect 5 and the BML transect on the stream bank. Chronic toxicity and CCME guidance levels have not been established for many of the compounds including VC, even though it is a known human carcinogen. VC was never detected in the surface water, but is of concern because VC concentrations up to 1860 µg/L were detected in the interstitial water of the streambed. Both VC and cDCE were detected at concentrations higher than USDOE preliminary remediation goals.

The discharge of contaminated groundwater at the river has resulted in contaminated streambed sediments that could be contacted and potentially ingested by aquatic life. Even though the contaminants are quite volatile and have low bioconcentration factors, chronic (i.e. long-term) exposures are still possible in the streambed because the dissolved-phase groundwater plume emanates from a relatively constant and continuous DNAPL source. Even if contaminated sediments are eroded away and transported down stream, the clean materials that are redeposited in their place will be subsequently contaminated by the continued discharge of the groundwater plume. Neither the USEPA or CCME have established freshwater guidelines for PCE or it's degradation products in sediments, however, the concentrations of some sediment samples exceed ecological toxicity screening criteria (EPA, 1996) and that would trigger further ecological evaluations. Likewise, PCE and cDCE concentrations in some of the sediment samples exceeded USDOE preliminary remediation goals and would likely trigger further actions if these guidelines were applicable.

Other potentially significant exposure scenarios to be considered are high concentration discharges at springs and seeps. For example, an underwater spring at transect 30-30W 1.85 m had a concentration almost equal to USEPA chronic toxicity guideline and on two occasions small minnows were observed swimming in the spring discharge. Springs and seeps located at or above the shore line, can potentially result in direct terrestrial and human exposures to contaminated water. It should be noted that to determine ecological “impacts" requires that the receptor communities be evaluated, but that work was beyond the scope of this study. Concentrations that exceed guidelines represent a “potential hazard” and are of concern, but does not prove that aquatic life has been impacted at the site.

2.6 CONCLUSIONS

This study provides the first comprehensive assessment of a PCE plume discharging into a river and shows that the near-stream zone substantially modifies the distribution, concentration, and composition of the plume prior to its reaching the surface water. The complex concentration distribution observed in the streambed was caused by: the contaminant distribution in the plume prior to entering the near-stream zone; geologic heterogeneity beneath the river and its affect on groundwater flow; biodegradation within the streambed; and sorption to high foc deposits. High concentrations of VOCs (100 to 5529 μg/L) were found in interstitial water at a depth of 0.3 m in streambed deposits over 24% (113 m^2) of the area of the plume beneath the river. Concentrations varied by a factor of 100 to 1000 over lateral distances of 1.5 to 3.5 m, which was similar to vertical variations in the upgradient plume. At several locations VOC concentrations in the streambed may represent a hazard to benthic and hyporheic aquatic life because they either exceed Canadian no adverse effect levels or USEPA acute or chronic toxicity guidelines. Of particular concern were the fate of two plume cores (>10,000 μg/L of

PCE) found in the upgradient aquifer because they may result in localized areas of adverse ecological exposure and could account for up to half of the total mass of contaminants discharging to the river. The cores were very small in cross-sectional area (less than 15 m^2) and only one of the two was found in the river. It is not certain where or if the second core has reached the top of the streambed.

The plume travels 195 m from the dry cleaner to the edge of the river without undergoing any significant biodegradation, but organic-rich deposits within the top 2.5 m of the streambed caused complete transformation of PCE to degradation products in some locations. Anaerobic biodegradation of PCE changed the composition (and toxicity) of the plume beneath the river and resulted primarily in the production of cDCE and VC and, to a lesser extent, TCE, 11DCE, tDCE, ethene, and ethane. The degree of biodegradation in the streambed was not uniform, and approximately 54% of the plan-view area of the VOC plume consisted solely of PCE degradation products. The pattern of total VOCs expressed as equivalent PCE concentrations in the streambed did not closely resemble the cross-sectional distribution in the aquifer. The plume maintained a similar north-south dimension in the streambed but the area was about 2.3 to 3.2 times larger and extended over the full width of the river at some locations. This spreading was caused by low-hydraulic-conductivity silty-clay semi-confining deposits beneath the river that directed groundwater discharge further out into the river, and by preferential discharge through these deposits that occurs near DP9 on the opposite side of the river. High-hydraulic-conductivity geological windows through the semi-confining deposits resulted in preferential groundwater discharge zones in the streambed but these areas did not coincide with the high concentration areas or cores of the discharging plume. The highest concentration area in the streambed was associated with low groundwater discharge and may represent a sorbed or retarded high concentration remnant of the plume that has yet to travel all the way through the low hydraulic conductivity deposits. Investigations of the plume in the aquifer upgradient of the river is useful but may not provide an accurate characterization of what the plume will look like in the streambed. Despite the relatively large area of VOCs discharging through the streambed, rapid dilution by the relatively large flow in the river caused the VOCs to be rarely detected in surface water. Low concentrations of PCE (usually less than 3.2 µg/L but once as high as 23.2 µg/L) were detected at or down stream of high groundwater discharge locations. This study demonstrates that to fully and accurately characterize the potential adverse ecological effects of a discharging plume, one must investigate the interstitial water quality of the streambed and not rely solely on surface water samples which, in this case, gave no indication of the large amounts of cDCE or VC in the streambed.

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Table 2-1 Waterloo Profiler and mini-profiler sampling summary

Location[1]	Depth interval sampled (m)	Number of water samples versus attempts[2]	Maximum PCE conc. in profile (µg/L)	Analyses performed on water sample	Date of Profiling	Comments[5]
AP40	1.5 - 10.0	12/18	8706.9	E	07/17/96	Stainless steel sampling tube broke at 7.0 m bgs
AP40b	7.0 - 11.5	10/10	3724.5	E	07/24/96	Continuation of AP40 located 38 cm away
AP41	1.5 - 10.0	14/18	1821.9	E	07/17/96	
AP42	1.5 - 10.0	11/18	5256.0	E	07/18/96	
AP43	1.5 - 10.0	10/18	6643.4	E	07/18/96	
AP44	1.5 - 10.0	11/18	5887.8	E	07/22/96	
AP45	1.5 - 12.0	16/22	1478.5	E	07/23/96	
AP46	1.5 - 10.0	13/17	2625.6	E	07/24/96	No sample at 7m, may have missed peak conc.
AP47	1.5 - 10.0	13/18	2.6	E	07/25/96	
AP48	1.5 - 10.0	14/18	ND	E	07/25/96	
AP49	1.5 - 10.0	10/18	ND	E	07/31/96	3 samples froze and broke before analyzed
AP50	1.5 - 10.0	13/18	ND	E	08/01/96	
AP51	1.5 - 10.0	12/18	ND	E	08/01/96	
AP52	1.5 - 9.0	16/22	84.5	E, P, F	08/28/96	
AP53	3.05 - 10.06	7/10	1163.0	E, P, F	11/20/97	
AP54	4.88 - 12.20	10/10	7304.7	E, P, F	12/18/97	Two samples froze and broke before analyzed
AP55	4.88 - 9.14	4/5	108.9	E, P, F	12/19/97	Too shallow, didn't reach peak conc. zone
AP96-1	3.05 - 6.10	11/11	3.0	E	06/04/96	
AP96-2	3.05 - 6.10	9/11	3.1	E	06/04/96	
AP96-3	3.35 - 6.10	8/9	1.3	E	06/04/96	
AP96-4	4.0 - 11.0	10/14	1068.6	E	06/26/96	
AP96-5	5.0 - 11.0	12/12	25.0	E	06/26/96	Tube snapped some time before pulled out
AP96-6	5.0 - 12.0	12/16	>10000[3]	E	06/27/96	
AP96-7	6.5 - 12.0	12/12	>10000[4]	E	06/27/96	Lost tip and pipe down hole as pulling out
AP96-8	6.5 - 10.5	9/9	11.1	E	08/15/96	
AP96-9	6.5 - 10.5	9/9	1.0	E	08/15/96	
AP96-10	5.0 - 10.5	9/12	0.9	E	08/16/96	
PRP1	0.25 - 8.50	21/28	1961.8	E, P, F	08/07/96	
PRP2	0.10 - 7.00	16/24	1010.0	E, P, F	08/08/96	
PRP3	0.10 - 8.00	18/22	1939.4	E, P, F	08/09/96	
PRP4	0.1 - 6.5	13/20	559.7	E, P, F	08/28/96	
PRP5	0.1 - 6.0	18/21	2794.6	E, P, F	10/07/96	
PRP6	0.1 - 5.0	12/18	7.4	E, P, F	10/09/96	
PRP7	0.15 - 3.50	6/16	3808.4	E, P, F	11/07/96	
PRP7R	0.15 - 2.05	5/13	5001.2	E, P, F	08/12/97	mini-profiler

Location[1]	Depth interval sampled (m)	Number of water samples versus attempts[2]	Maximum PCE conc. in profile (µg/L)	Analyses performed on water sample	Date of Profiling	Comments[5]
PRP8	0.15 - 0.60	2/4	340.5	E, P, F	11/11/96	Water froze in line before finished sampling
PRP8R	0.15 - 2.10	8/14	3639.3	E, P, F	08/13/97	mini-profiler
PRP9	0.15 - 1.50	8/9	30.3	E, P, F	08/13/97	mini-profiler
PRP9R	0.75 - 1.63	3/3	103.1	E, P, F	08/14/97	mini-profiler
PRP10	0.15 - 1.35	8/13	24.1	E, P, F	08/14/97	mini-profiler
PRP11	0.15 - 1.65	3/4	ND	E, P, F	08/14/97	mini-profiler
PRP12	0.17 - 1.72	2/8	841.4	E, P, F	08/15/97	mini-profiler
PRP13	0.15 - 1.90	5/9	214.3	E, P, F	08/15/97	Both mini and Waterloo profilers used
PRP14	0.15 - 1.80	5/13	296.1	E, P, F	10/29/97	mini-profiler
PRP15	0.15 - 1.65	9/9	1438.1	E, P, F	10/30/97	mini-profiler
PRP16	0.15 - 2.00	9/9	6.9	E, P, F	10/31/97	mini-profiler
PRP17	0.33 - 1.50	4/5	572.1	E, P, F	06/24/98	mini-profiler

Notes:

[1] "AP" prefix means profile performed on land, "PRP" prefix means profile performed in Pine River

[2] Number of water samples that could be pumped versus the total number of depths where an attempt was made to collect a sample

[3] Exceeded calibration range, raw reading was 8868 µg/L, but actual PCE would have exceeded 10,000 µg/L based on other properly diluted samples with this magnitude of raw reading

[4] Exceeded calibration range, raw reading was 9313 µg/L, but actual PCE would have exceeded 10,000 µg/L based on other properly diluted samples with this magnitude of raw reading

[5] Samples collected with the Waterloo Groundwater Profiler unless specified otherwise

ND = PCE not detected

E = Analyses for PCE and TCE using the electron capture detector (ECD)

P = Analyses for cDCE, tDCE, 1,1-DCE, and VC using the photoionization detector (PID)

F = Analyses for ethene and ethane using the flame ionization detector (FID)

Table 2-2 Hydraulic conductivity, porosity, and bulk density determined for different types of deposits by testing core samples

Layer name	**Deposits**	**Hydraulic conductivity cm/s (at 10 °C)^A**					**Aniso-tropic ratio K_A/K_H**	**Average porosity %**	**Average bulk density^B g/cm^3**	**Cores sampled**	**No. of samples**	**Source of data**
		Maximum	**Minimum**	**K_A**	**K_G**	**K_H**						
1	Sand	3.74E-02	3.36E-02	3.59E-02	3.59E-02	3.58E-02	1.00	43.0^C	1.51	B1	3	Writt (1996)
1	Sand	2.07E-02	9.91E-03	1.25E-02	1.25E-02	1.24E-02	1.00	30.9	1.83	SC12	19	This study
2	Sand	2.28E-02	1.05E-03	1.07E-02	8.46E-03	5.47E-03	1.96	42.0^C	1.54	B1,B3,B4	13	Writt (1996)
2	Sand	2.39E-02	9.69E-03	1.47E-02	1.43E-02	1.36E-02	1.08	32.8	1.78	SC12	24	This study
3	Sand	7.88E-02	9.11E-03	3.00E-02	2.48E-02	2.05E-02	1.46	37.0^C	1.67	B1,B3,B4	17	Writt (1996)
4 (Aquitard)	Silty clay	2.06E-02	3.23E-04	3.67E-03	1.55E-03	9.75E-04	3.77	NA	NA	B1,B2,B3	8	Writt (1996)
5	Sand	5.26E-02	1.61E-03	1.84E-02	1.28E-02	8.09E-03	2.28	NA	NA	B5, B6	26	Writt (1996)
6	Sand	5.02E-02	1.05E-03	1.86E-02	1.30E-02	7.29E-03	2.55	NA	NA	B1,B2,B4, B5,B6	19	Writt (1996)
Semi-confining deposits (on land)	Silty clay	2.21E-04	2.66E-05	1.31E-04	9.49E-05	6.13E-05	2.14	44.3	1.48	SC12	3	This study
Semi-confining deposits (under river)	Silt, clay, and peat	4.29E-04	2.36E-05	1.89E-04	1.12E-04	7.62E-05	2.49	62.6	0.99	RC1, RC2, RC7, RC11, RC12	10	This study
Streambed Sands	Sand	3.89E-02	1.73E-03	1.68E-02	1.53E-02	1.34E-02	1.25	39.6	1.60	RC1 to RC12	167	This study

Notes:

[A] Hydraulic conductivity determined by permeameter tests

[B] Bulk denity calculated assuming a solids density of 2.65 g/cm^3

[C] graphially estimated value by Writt using an average K at 20 degrees C

K_A - Depth weighted arithmetic mean

K_G - Geometric mean

K_H - Depth weighted Harmonic mean

NA - Not estimated

Table 2-3 Results of foc testing of sediments and estimates of K_d and retardation of PCE for different types of deposits

Layer name	Deposits	Foc in percent				K_d for PCE^{A} mL/g			Retardation for PCE^{B}			Cores sampled	No. of samples
		Max.	Min.	Ave.	Mean	Max.	Min.	Ave.	Max.	Min.	Ave.		
1	Sand	0.029	0.007	0.018	0.019	0.106^{C}	0.025^{C}	0.064^{C}	1.63	1.15	1.38	SC12, SC13	11
2	Sand	0.039	0.020	0.029	0.029	0.142^{C}	0.073^{C}	0.106^{C}	1.77	1.40	1.57	SC12, SC13	4
Semi-confining deposits (on land)	Silty clay	5.88	0.379	3.227	3.33	21.40	1.38	11.75	72.3	5.60	40.1	SC12	4
Semi-confining deposits (under river)	Silt, clay, and peat	7.18	1.690	4.603	4.89	26.14	6.15	16.75	88.1	21.5	56.8	RC1, RC2, RC11	14
Streambed Sands	Sand	4.49	0.027	0.569	0.15	16.34	0.10	2.07^{D}	67.1	1.40	9.38^{E}	RC2, RC4, RC11	19

Notes:

[A] Kd is the distribution coefficient = Koc* foc [assuming a Koc of 364 mL/g for PCE (Mabey et al., 1982)]

[B] Retardation calculated using K_d, average bulk density, and average porosity for the particular layer (see Table 2-2)

[C] Calculated K_d may not be accurate (low) because foc is lower than the 0.1% necessary for the Koc*foc relationship to apply

[D] The average value is high, the mean K_d is 0.55 mL/g

[E] The average value is high, the mean retardation is 3.22

Table 2-4 Results of surface water sampling for VOCs

Date Sampled	**Sample Name^A**	**Method Collected**	**PCE µg/L**	**TCE µg/L**	**1,1DCE µg/L**	**tDCE µg/L**	**cDCE µg/L**	**VC µg/L**	**Ethene µg/L**	**Ethane µg/L**	**River Stage^B m**
06/25/96	**PR-EB**	Grab	ND	ND	ND	ND	ND	ND	ND	ND	184.72
06/25/96	**PR-CS**	Grab	ND	ND	ND	ND	ND	ND	ND	ND	184.72
06/25/96	**PR-WB**	Grab	ND	ND	ND	ND	ND	ND	ND	ND	184.72
06/25/96	**PR-EB-SP2**	Grab	ND	ND	ND	ND	ND	ND	ND	ND	184.72
06/25/96	**PR-CS-SP2**	Grab	ND	ND	ND	ND	ND	ND	ND	ND	184.72
06/25/96	**PR-WB-SP2**	Grab	ND	ND	ND	ND	ND	ND	ND	ND	184.72
06/25/96	**PR-EB-DS**	Grab	ND	ND	ND	ND	ND	ND	ND	ND	184.72
06/25/96	**PR-CS-DS**	Grab	ND	ND	ND	ND	ND	ND	ND	ND	184.72
06/25/96	**PR-WB-DS**	Grab	ND	ND	ND	ND	ND	ND	ND	ND	184.72
08/28/96	**PRP4-SW**	Profiler	**1.6**	ND	ND	ND	ND	ND	ND	ND	184.66
10/07/96	**PRP5-SW**	Profiler	**1.0**	ND	ND	ND	ND	ND	ND	ND	184.50
10/07/96	**Bridge East**	Grab	ND	ND	ND	ND	ND	ND	ND	ND	184.50
10/07/96	**Bridge Center**	Grab	ND	ND	ND	ND	ND	ND	ND	ND	184.50
10/07/96	**PRP1 SW**	Grab	ND	ND	ND	ND	ND	ND	ND	ND	184.50
10/07/96	**PRP2 SW**	Grab	ND	ND	ND	ND	ND	ND	ND	ND	184.50
10/07/96	**PRP3 SW**	Grab	ND	ND	ND	ND	ND	ND	ND	ND	184.50
10/07/96	**PRP4 SW**	Grab	ND	ND	ND	ND	ND	ND	ND	ND	184.50
10/07/96	**SP1 SW**	Grab	**1.5**	ND	ND	ND	ND	ND	ND	ND	184.50
10/07/96	**SP1 East**	Grab	ND	ND	ND	ND	ND	ND	ND	ND	184.50
10/07/96	**SP1 Center**	Grab	ND	ND	ND	ND	ND	ND	ND	ND	184.50
10/07/96	**SP1 West**	Grab	ND	ND	ND	ND	ND	ND	ND	ND	184.50
10/07/96	**SP2 SW**	Grab	ND	ND	ND	ND	ND	ND	ND	ND	184.50
10/09/96	**PRP6-SW**	Profiler	ND	ND	ND	ND	ND	ND	ND	ND	184.60
11/07/96	**PRP7-SW**	Profiler	ND	ND	ND	ND	ND	ND	ND	ND	184.73
11/09/96	**DP1 SW**	Grab	ND	ND	ND	ND	ND	ND	ND	ND	-
11/11/96	**PRP8 -SW**	Grab	ND	ND	ND	ND	ND	ND	ND	ND	184.74
08/12/97	**PRP7R-SW**	Mini-profiler	ND	**3.2**	ND	ND	ND	ND	ND	ND	184.49
08/13/97	**PRP8R-SW**	Mini-profiler	ND	**3.0**^{EQ}	ND	ND	ND	ND	ND	ND	184.69
08/13/97	**PRP9 SW**	Mini-profiler	**3.1**	**2.5**	ND	ND	ND	ND	ND	ND	184.69
08/14/97	**PRP10 SW**	Mini-profiler	ND	**1.0**	ND	ND	ND	ND	ND	ND	184.65
08/14/97	**PRP11 SW**	Mini-profiler	ND	ND	ND	ND	ND	ND	ND	ND	184.58
08/15/97	**PRP12 SW**	Mini-profiler	**23.2**	**2.9**	ND	ND	ND	ND	ND	ND	184.54
08/15/97	**PRP13 SW**	Mini-profiler	ND	ND	ND	ND	ND	ND	ND	ND	184.53
06/24/98	**PRP17 SW**	Grab	ND	ND	ND	ND	ND	ND	-	-	184.55
06/24/98	**6-6W 2.50 SW**	Grab	ND	ND	ND	ND	ND	ND	-	-	184.55
06/24/98	**6-6W 3.50 SW**	Grab	ND	ND	ND	ND	ND	ND	-	-	184.55
06/24/98	**6-6W 5.50 SW**	Grab	ND	ND	ND	ND	ND	ND	-	-	184.55
06/24/98	**6-6W 7.50 SW**	Grab	ND	ND	ND	ND	ND	ND	-	-	184.55
06/24/98	**6-6W 9.50 SW**	Grab	ND	ND	ND	ND	ND	ND	-	-	184.55
06/24/98	**6-6W 11.35 SW**	Grab	ND	ND	ND	ND	ND	ND	-	-	184.55
08/04/98	**-4 - -4W 8.0 SW**	Grab	ND	ND	ND	ND	ND	ND	ND	ND	184.46
08/05/98	**0-0W SW 2.35**	Grab	ND	ND	ND	ND	ND	ND	ND	ND	184.44
08/05/98	**0-0W SW 4.00**	Grab	ND	ND	ND	ND	ND	ND	ND	ND	184.44
08/05/98	**0-0W SW 6.00**	Grab	ND	ND	ND	ND	ND	ND	ND	ND	184.44
08/05/98	**0-0W SW 8.00**	Grab	ND	ND	ND	ND	ND	ND	ND	ND	184.44
08/05/98	**0-0W SW 10.0**	Grab	ND	ND	ND	ND	ND	ND	ND	ND	184.44
08/05/98	**0-0W SW 12.0**	Grab	ND	ND	ND	ND	ND	ND	ND	ND	184.44
08/05/98	**0-0W SW 14.0**	Grab	ND	ND	ND	ND	ND	ND	ND	ND	184.44
08/06/98	**12-12W SW 4.0**	Grab	ND	ND	ND	ND	ND	ND	ND	ND	184.50
08/07/98	**16-16W SW 5.0**	Grab	ND	ND	ND	ND	ND	ND	ND	ND	184.67
08/08/98	**24-24W SW 7.0**	Grab	ND	ND	ND	ND	ND	ND	ND	ND	184.57

Date Sampled	Sample Name[A]	Method Collected	PCE µg/L	TCE µg/L	1,1DCE µg/L	tDCE µg/L	cDCE µg/L	VC µg/L	Ethene µg/L	Ethane µg/L	River Stage[B] m
08/10/98	**32-32W SW 1.5**	Grab	**2.6**	ND	ND	ND	ND	ND	ND	ND	184.79
08/11/98	**40-40W SW 3.0**	Grab	ND	ND	ND	ND	ND	ND	ND	ND	184.59
08/12/98	**54-54W SW 2.00**	Grab	**1.1**	ND	ND	ND	ND	ND	ND	ND	184.60
08/12/98	**54-54W SW 4.00**	Grab	ND	ND	ND	ND	ND	ND	ND	ND	184.60
08/12/98	**54-54W SW 6.00**	Grab	ND	ND	ND	ND	ND	ND	ND	ND	184.60
08/12/98	**54-54W SW 8.00**	Grab	ND	ND	ND	ND	ND	ND	ND	ND	184.60
08/12/98	**54-54W SW 10.00**	Grab	ND	ND	ND	ND	ND	ND	ND	ND	184.60
08/12/98	**54-54W SW 12.00**	Grab	ND	ND	ND	ND	ND	ND	ND	ND	184.60
11/18/98	**MLS7-1**	Multilevel	ND	ND	ND	ND	ND	ND	ND	ND	184.59
11/20/98	**MLS18 SW**	Grab	ND	ND	ND	ND	ND	ND	ND	ND	184.60
11/20/98	**MLS3 SW**	Grab	ND	ND	ND	ND	ND	ND	ND	ND	184.59
03/09/99	**MLS3 SW**	Grab	ND	ND	ND	ND	ND	ND	ND	ND	184.82
03/10/99	**MLS7-1 SW**	Multilevel	ND	ND	ND	ND	ND	ND	ND	ND	184.75
03/11/99	**MLS17-1 SW**	Multilevel	ND	ND	ND	ND	ND	ND	ND	ND	184.69
03/13/99	**MLS1 SW**	Grab	ND	ND	ND	ND	ND	ND	ND	ND	184.71
03/14/99	**MLS9 SW**	Grab	ND	ND	ND	ND	ND	ND	ND	ND	184.60
03/15/99	**MLS11 SW**	Grab	ND	ND	ND	ND	ND	ND	ND	ND	184.58
03/16/99	**MLS13 SW**	Grab	ND	ND	ND	ND	ND	ND	ND	ND	184.59
03/16/99	**MLS15-1 SW**	Multilevel	**2.6**	ND	ND	ND	ND	ND	ND	ND	184.66
03/17/99	**MLS19 SW**	Grab	ND	ND	ND	ND	ND	ND	ND	ND	184.68
		Detection Limit[C]	0.7	0.9	3.2/1.4	1.9/1.4	7.8/1.0	0.7/0.8	0.5	0.5	

Notes:

[A] Sample name corresponds to a specific transect location, a profiling location, or multilevel sampler location. The "SW" added to locations simply indicates it was a surface water sample.

[B] The river stage measured at time of sampling or that same day. Elevation is relative to mean sea level.

[C] There are two detection limits for 1,1DCE, tDCE, cDCE, and VC. The first one listed is for samples collected before 6/98 and the other is for after.

[EQ] Compound was also found in equipment blank at a higher concentration than the reported sample results

ND = None detected (below detection limit)

- = Not sampled or information not available

Grab = grab sample using a VOC vial

Profiler = pumped using Waterloo Profiler

Mini-profiler = sample pumped using mini-profiler

Multilevel = Sample collected from MLS sampler port exposed above the streambed

Table 2-5 Summary of water quality and sediment criteria to protect freshwater aquatic life

Compound	**USEPA toxicity guidelines for freshwater**[A]		**Canadian criteria for no adverse effect for freshwater**[E]	**USDOE preliminary remediation goals for ecological endpoints**[F]	
	Acute[B] **µg/L**	**Chronic**[C] **µg/L**	**µg/L**	**Surface Water µg/L**	**Sediment µg/g**
PCE	5280	840	110	98	3.2
TCE	45000	21900	20	470	52.0
11DCE	11600[D]	-	-	25	3.5
cDCE	11600[D]	-	-	590[G]	0.4[H]
tDCE	11600[D]	-	-	590[G]	0.4[H]
VC	-	-	-	782	-

Notes:

[A] USEPA (1986). Because of insufficient data to develop criteria, the values presented represent lowest observed effect levels determined by EPA

[B] Acute toxicity exposure is defined for short term exposures

[C] Chronic toxicity exposure is defined for long term exposures

[D] the value for the summation of all three dichloroethylene isomers

[E] CCME (1993). Values are interim guidelines for long-term no-effect levels

[F] From Efroymson (1997). PRGs are upper concentration limits for specific chemicals in specific environmental media that are anticipated to protect human health or the environment

[G] Value is for "1,2-dichloroethene" and not specifically assigned to a particular isomer in water

[H] Value is for "1,2-dichloroethene" and not specifically assigned to a particular isomer in sediment

\- Insufficient data to set guideline or criteria

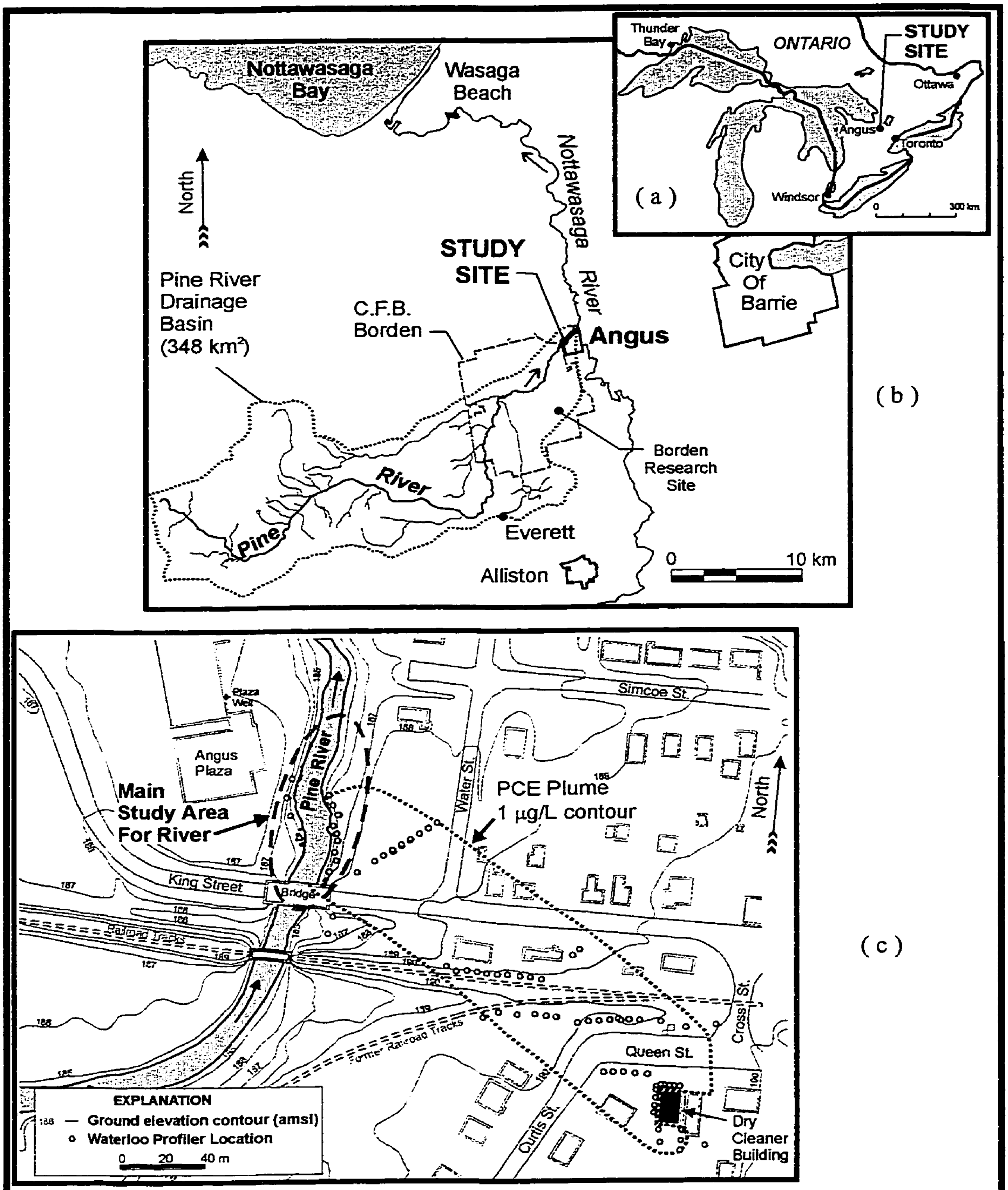


Figure 2-1. Site location map (a) within Ontario, (b) within the Pine River watershed, and (c) in the vicinity of the dry cleaning facility and showing the PCE groundwater plume. [Figure (b) was modified from Nottawasaga Valley Watershed Management Plan (1996)].

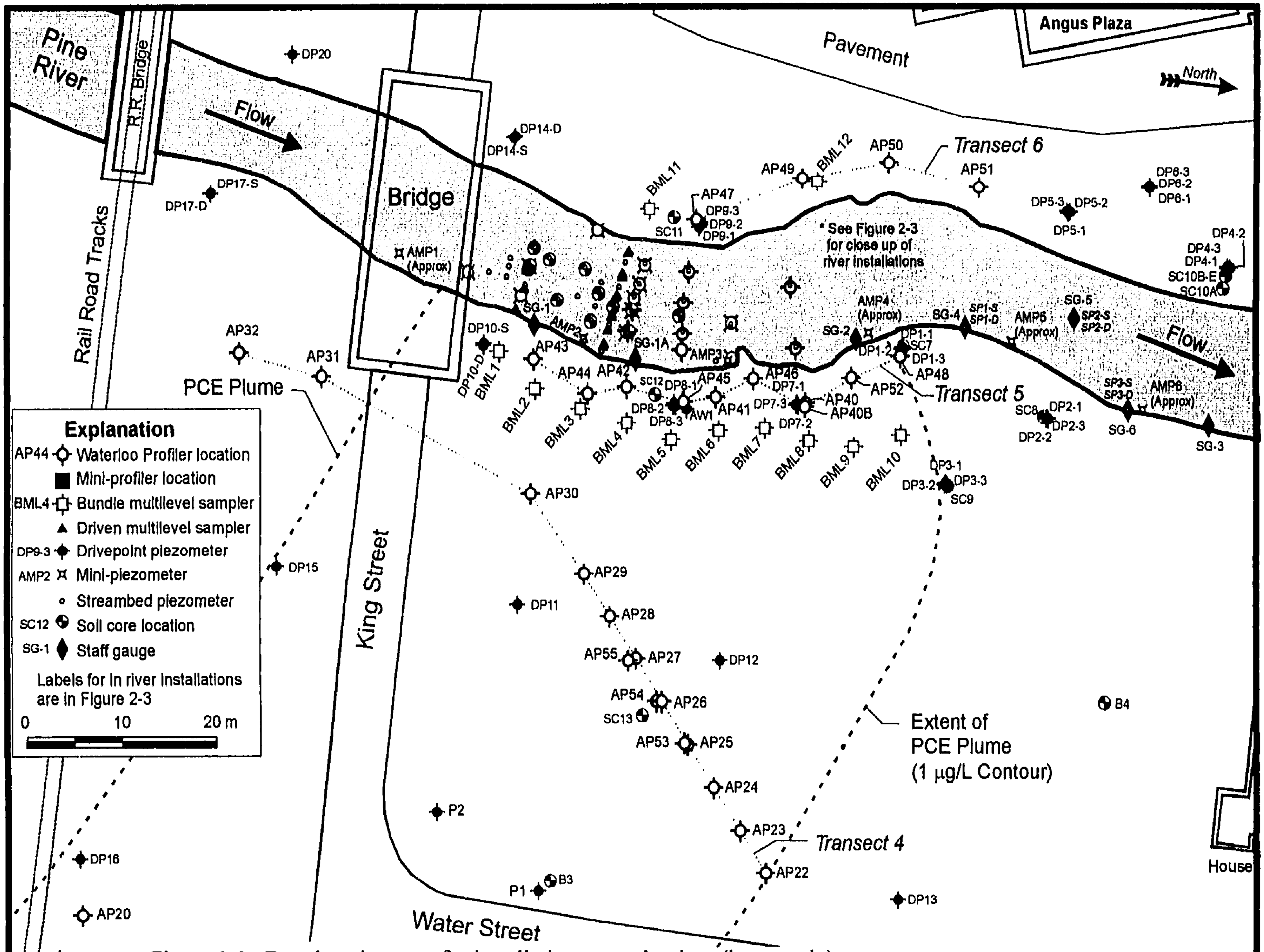


Figure 2-2. Data location map for installations near the river (large scale).

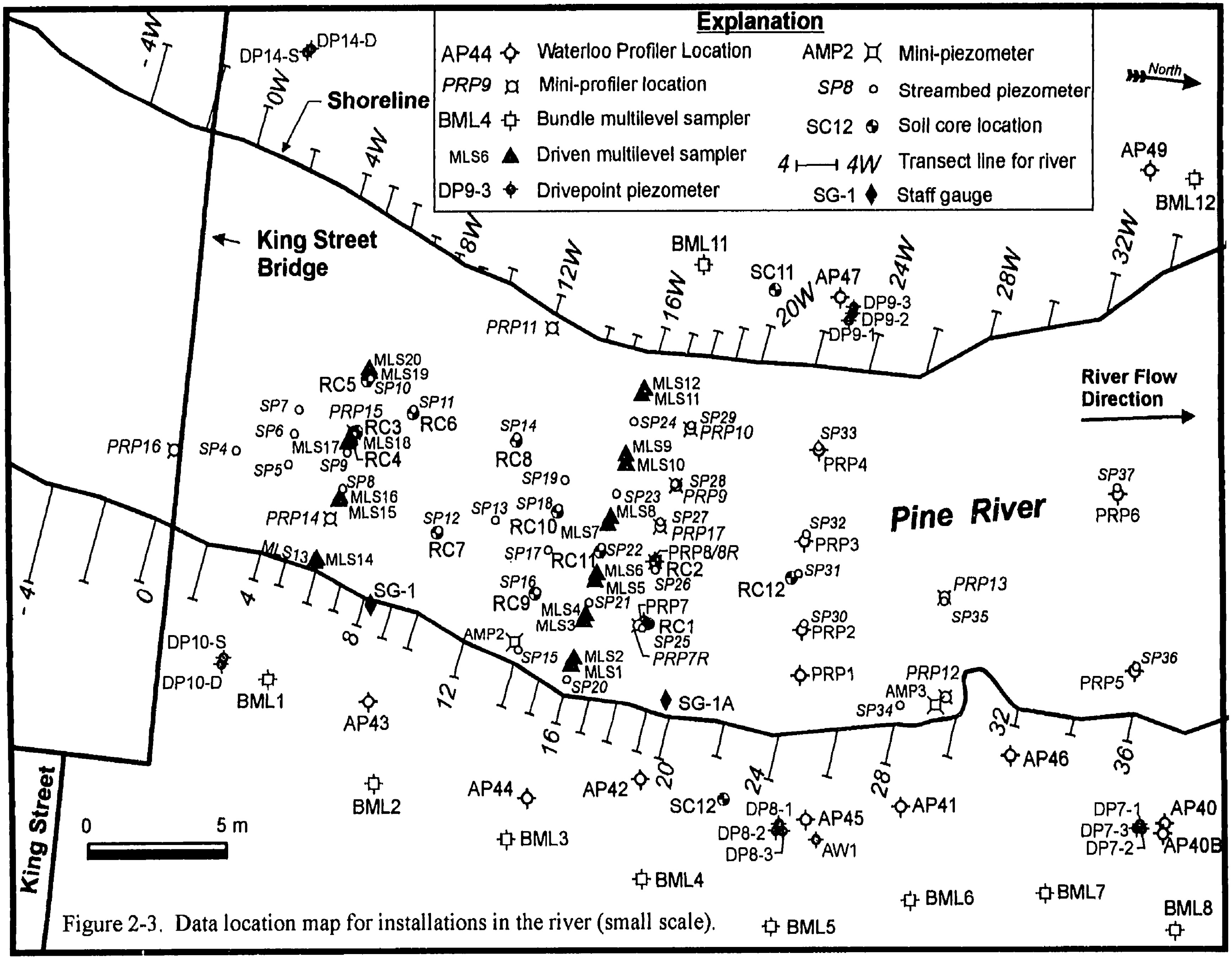


Figure 2-3. Data location map for installations in the river (small scale).

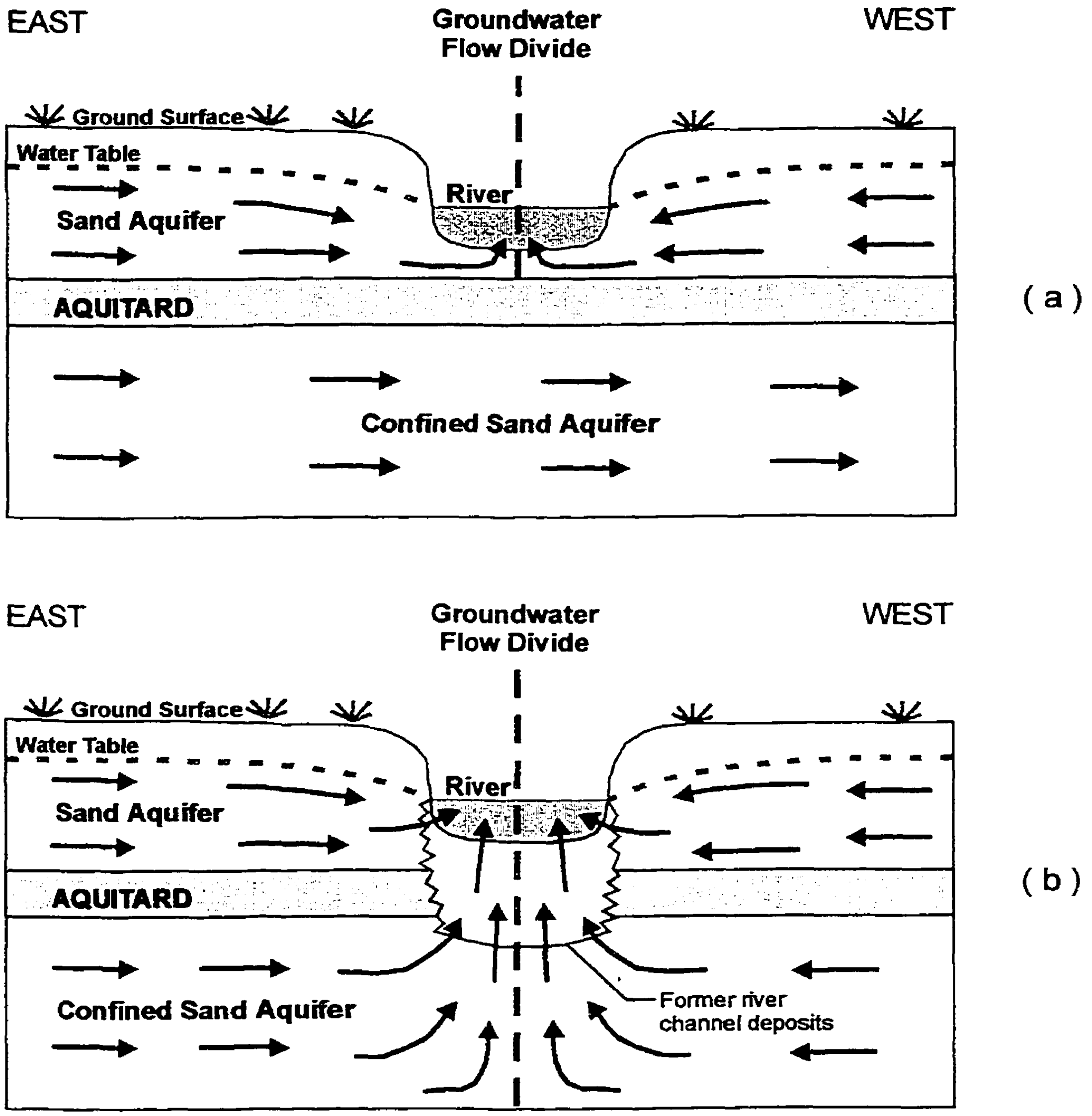


Figure 2-4. Schematic of hypothesized near river geology and groundwater flow direction. (a) The aquitard is still intact and groundwater in the confined aquifer does not discharge to the river and the flow divide is only in the unconfined system. (b) A former stream channel has eroded through the aquitard and groundwater flows up to the river from the confined aquifer and the groundwater flow divide is centered in the river (e.g. flow from the east must discharge to the east half of the river).

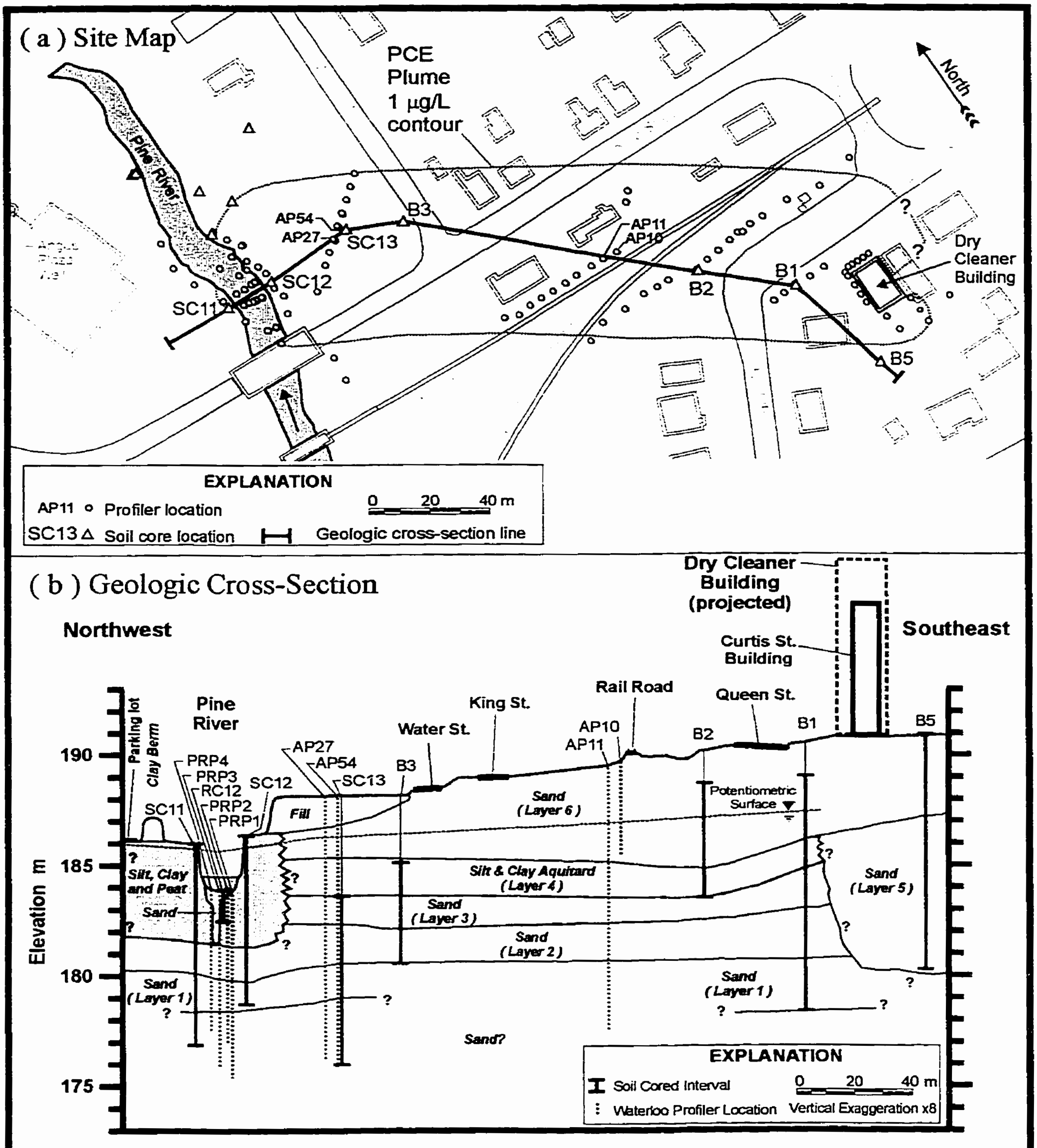


Figure 2-5. (a) Site map showing outline of PCE groundwater plume and line of geologic cross section. (b) Geological cross section from the dry cleaner to the Pine River. Stratigraphic layers are labeled in accordance with Writt (1996).

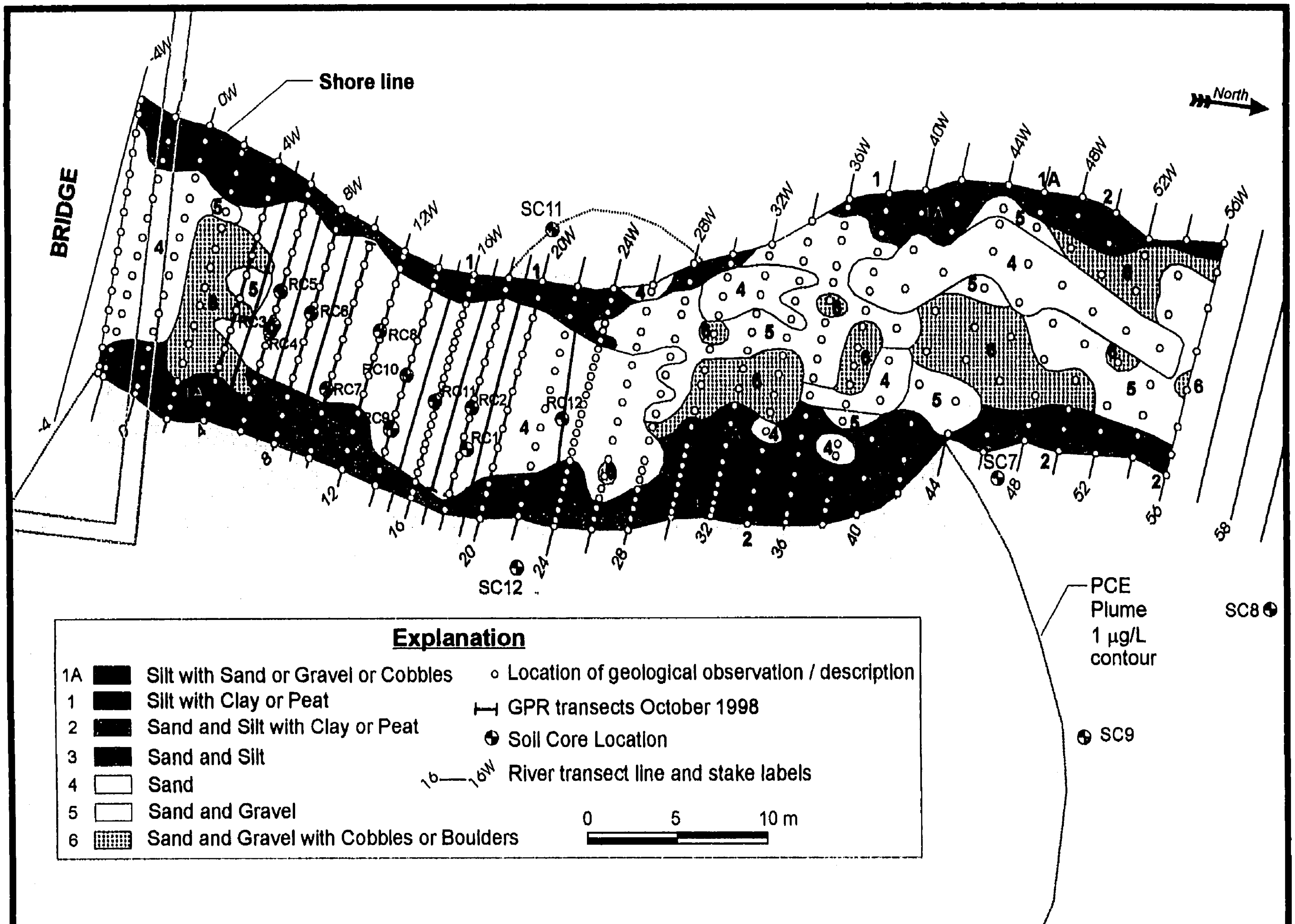


Figure 2-6. Surficial geology of streambed mapped February 18-20, 1999, shown with core locations and GPR survey transects performed in October 1998.

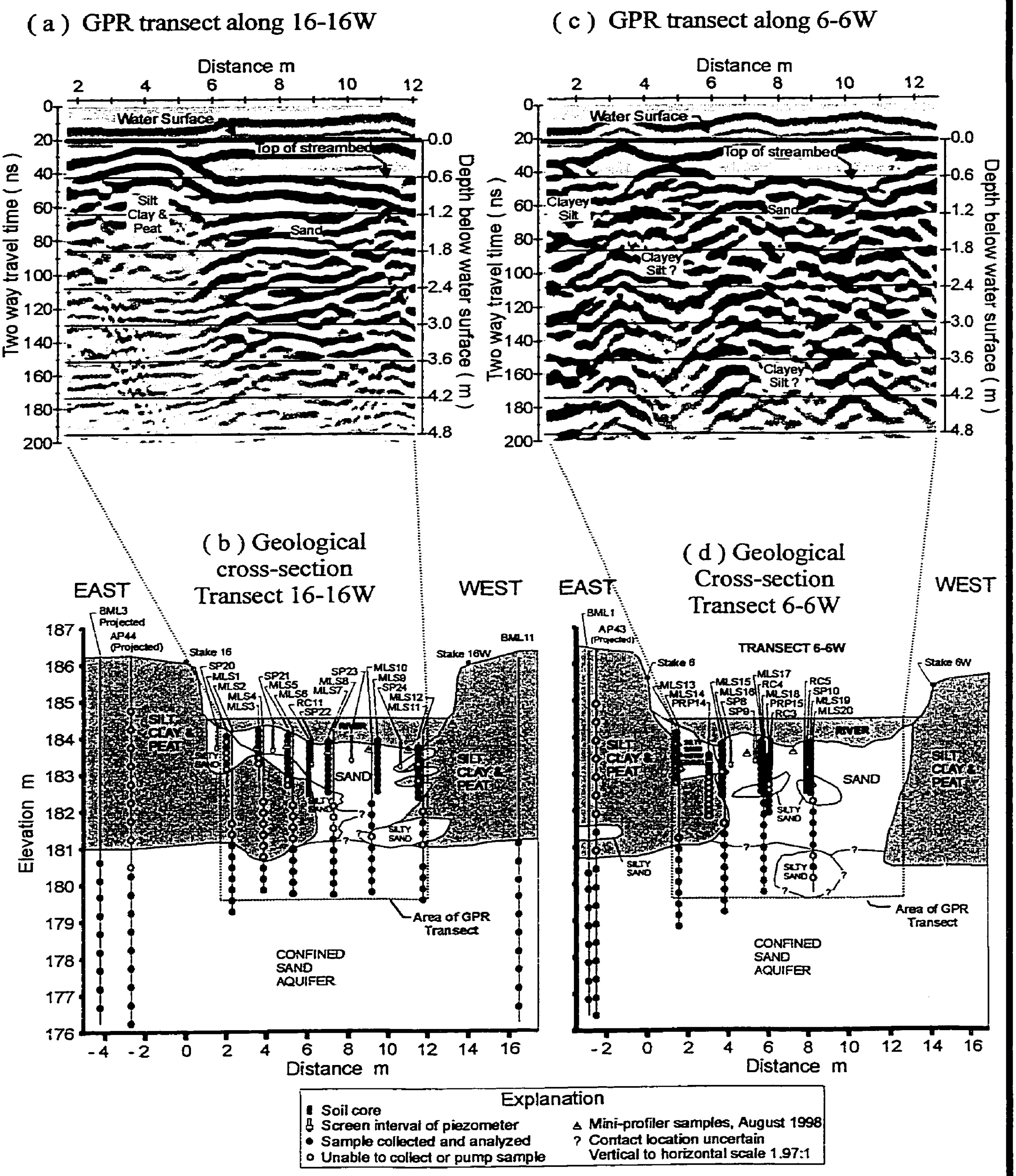


Figure 2-7. (a) GPR transect along river transect 16-16W, (b) Geologic cross-section along transect 16-16W, (c) GPR transect along 6-6W, (d) Geologic cross-section along 6-6. The GPR survey and river stage were measured on October 15, 1998.

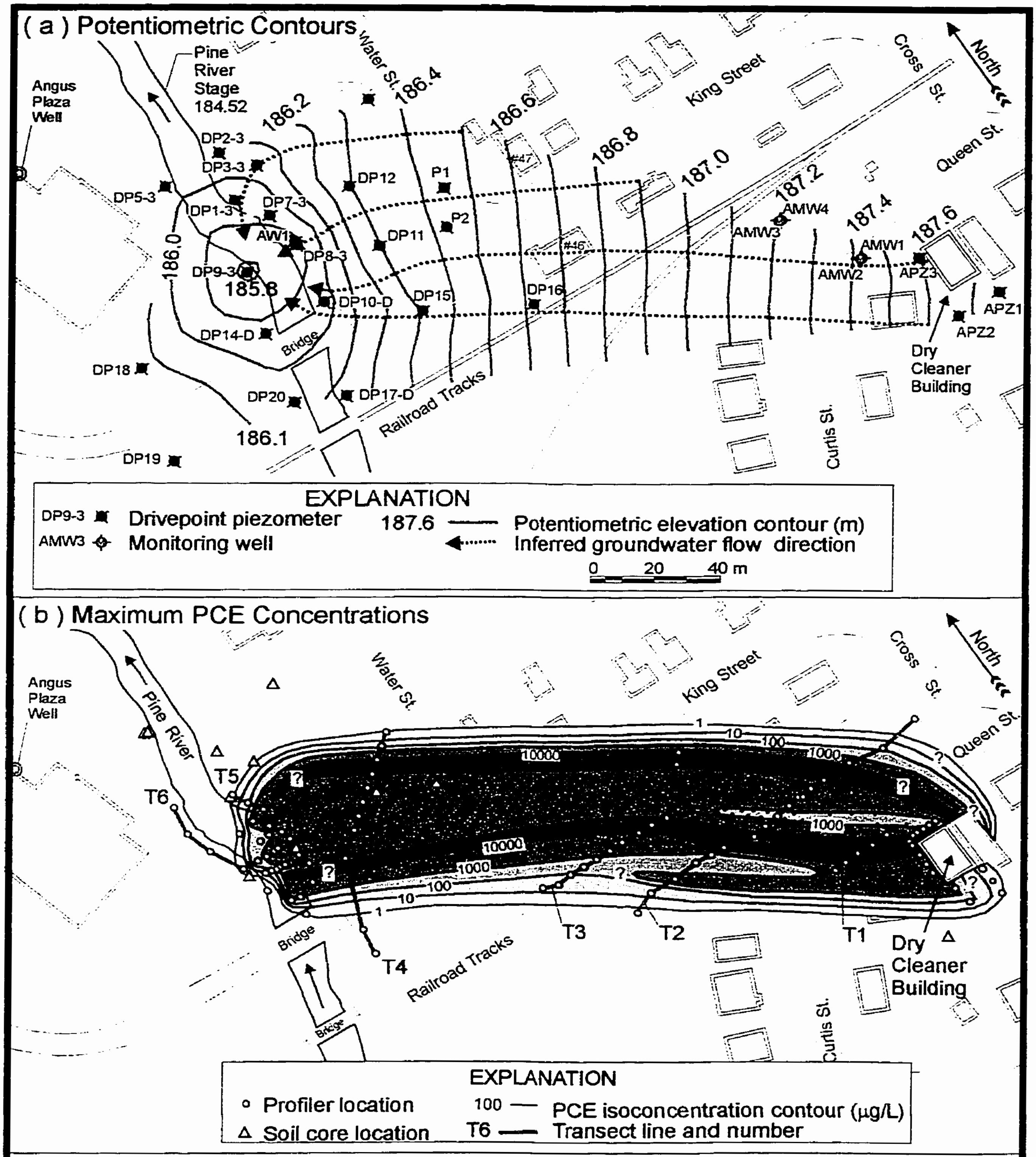


Figure 2-8. (a) Potentiometric contour map of seasonal low water levels in the confined aquifer on November 5, 1998, showing discharge to the river. (b) Contour map of maximum PCE concentrations in groundwater at each vertical profile location which shows two high concentration plume cores. Water quality data collected by Pitkin (1994), Writt (1996), Levenick (1998), Guilbeault (1999), and this study.

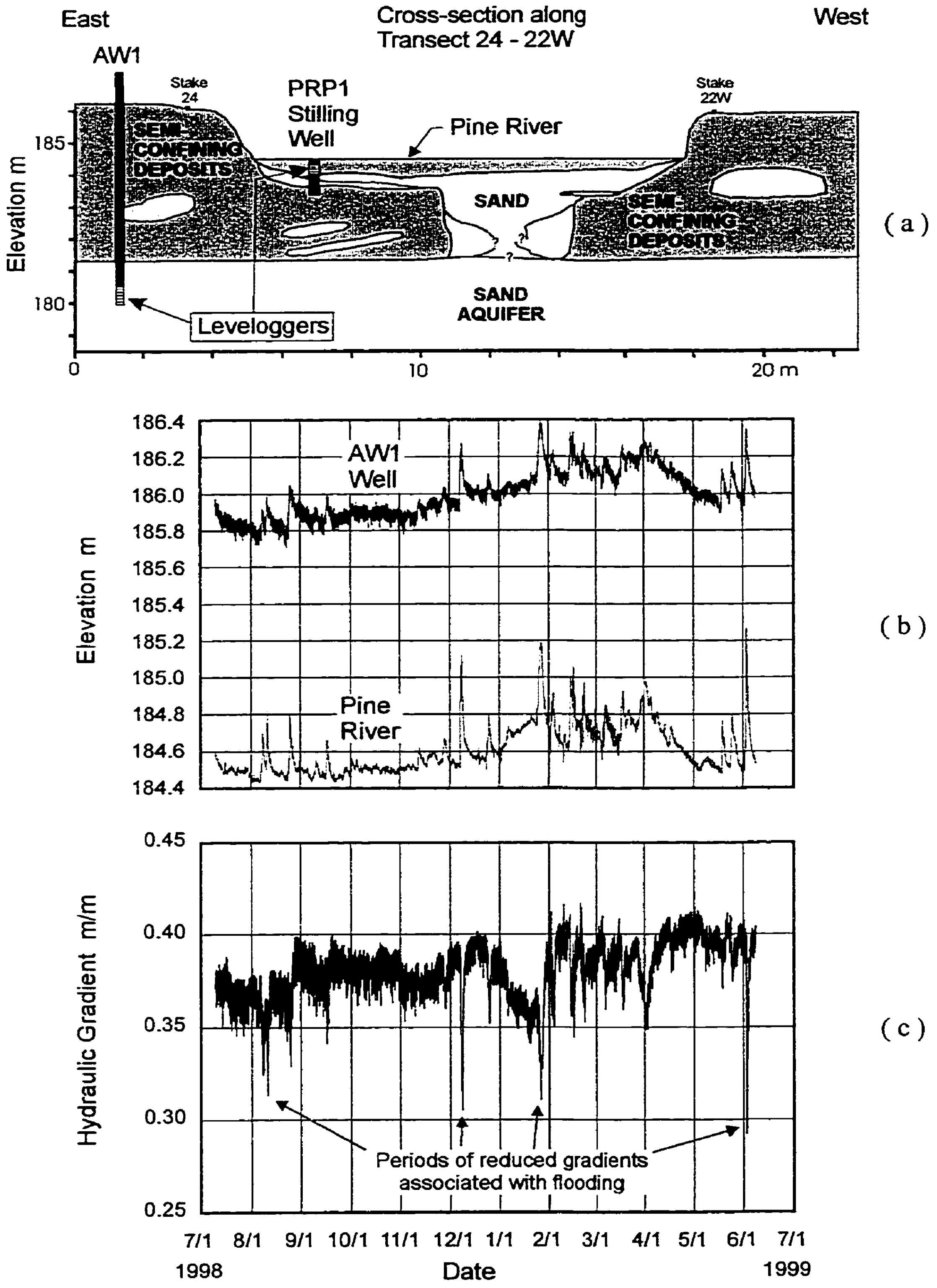


Figure 2-9. (a) Location of levelloggers that recorded water levels in the river at PRP1 and in the confined aquifer at AW1. (b) Water levels in river and AW1 from 7/1/98 to 7/1/99. (c) Upward hydraulic gradient between the river and AW1 during the same time period

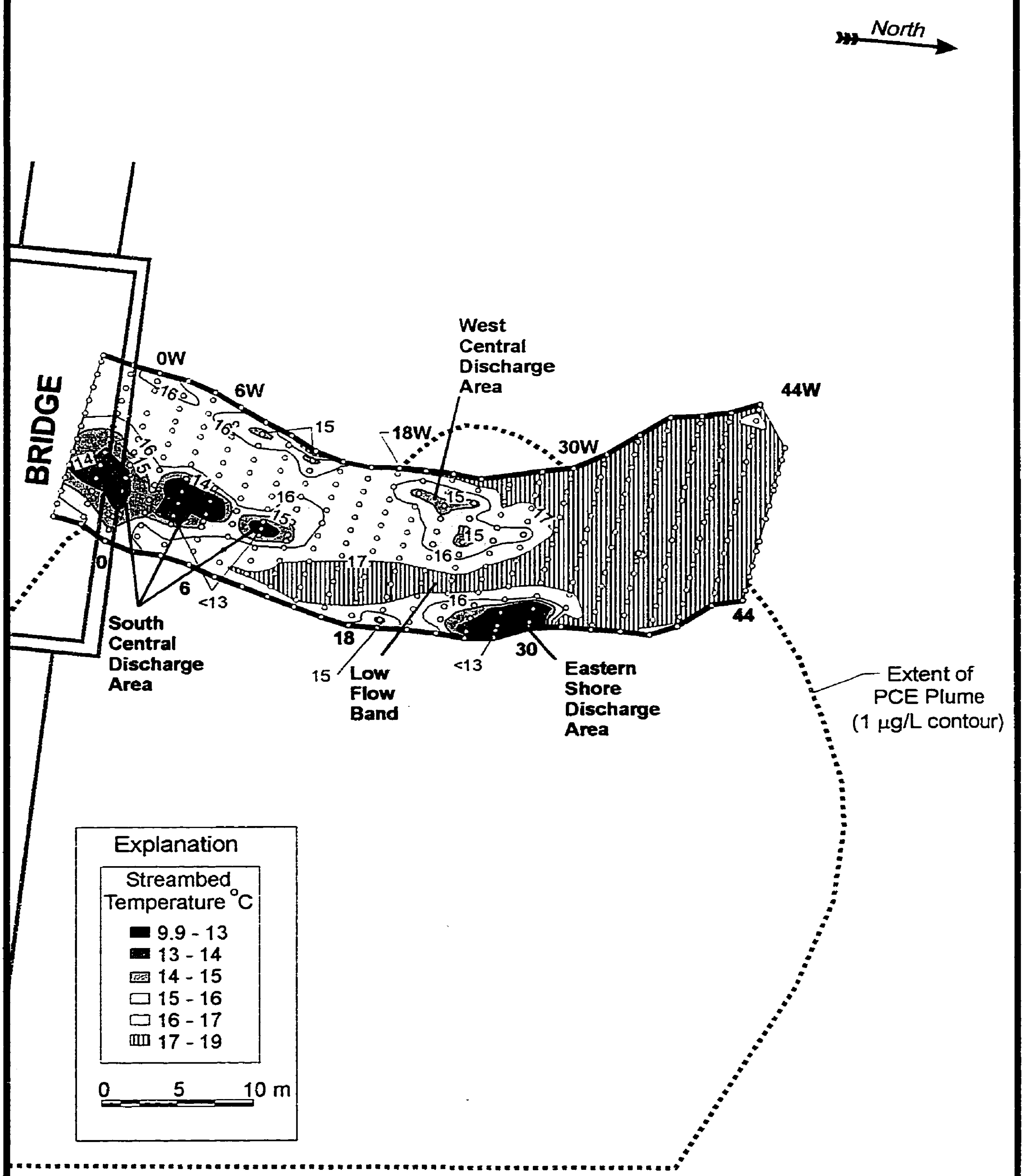


Figure 2-10. Summer streambed temperatures measured at a depth of 0.3 m on July 28 to 29, 1998, showing 3 high groundwater discharge locations. Open circles indicate locations of temperature measurements along transects.

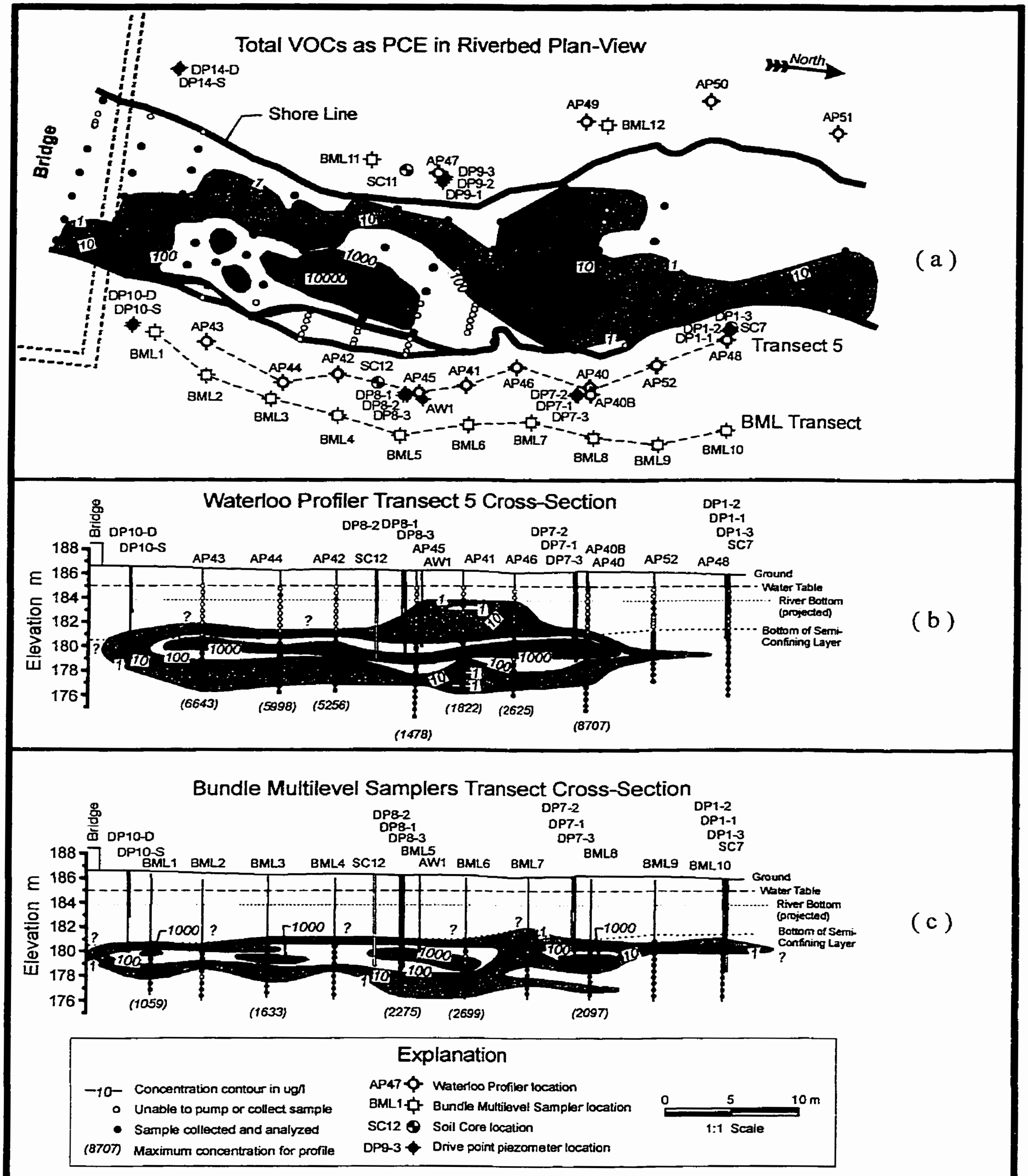
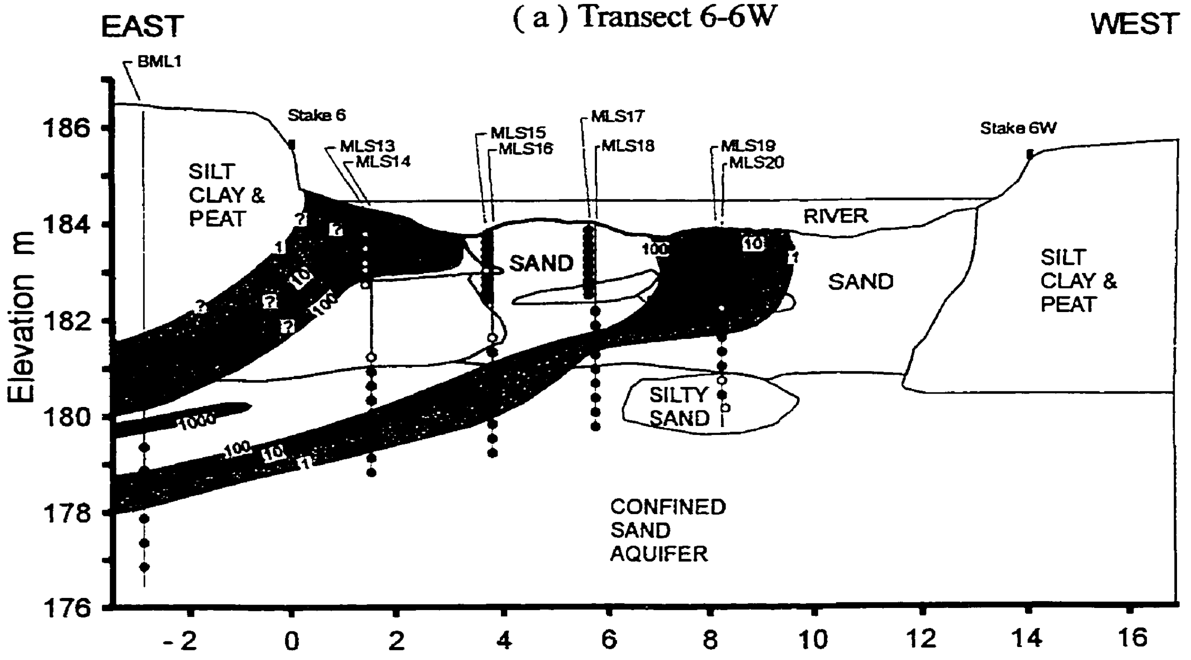


Figure 2-11. (a) Plan-view of total VOCs concentrations expressed as equivalent PCE in streambed at a depth of 0.3 m in August 1998. (b) Cross-section view of PCE concentrations along Transect 5 sampled with Waterloo Profiler in July-August 1996. (c) Cross-section view of PCE concentrations along BML transect sampled March 1999. Figures are at same 1:1 scale.

(a) Transect 6-6W



(b) Transect 16-16W

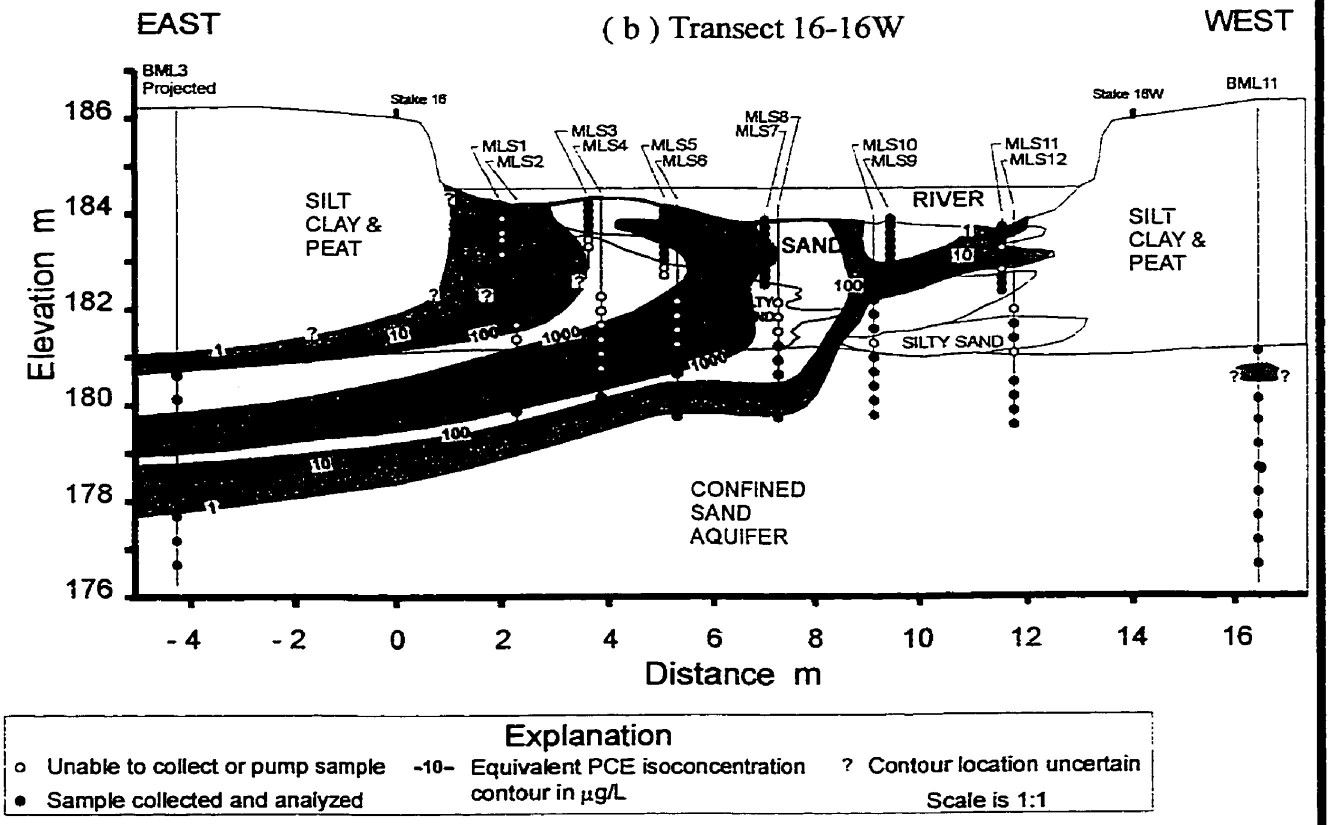


Figure 2-12. Total VOCs expressed as equivalent PCE concentrations (µg/L) for MLS and BML points sampled in March 1999 along (a) transect 6-6W and (b) transect 16-16W.

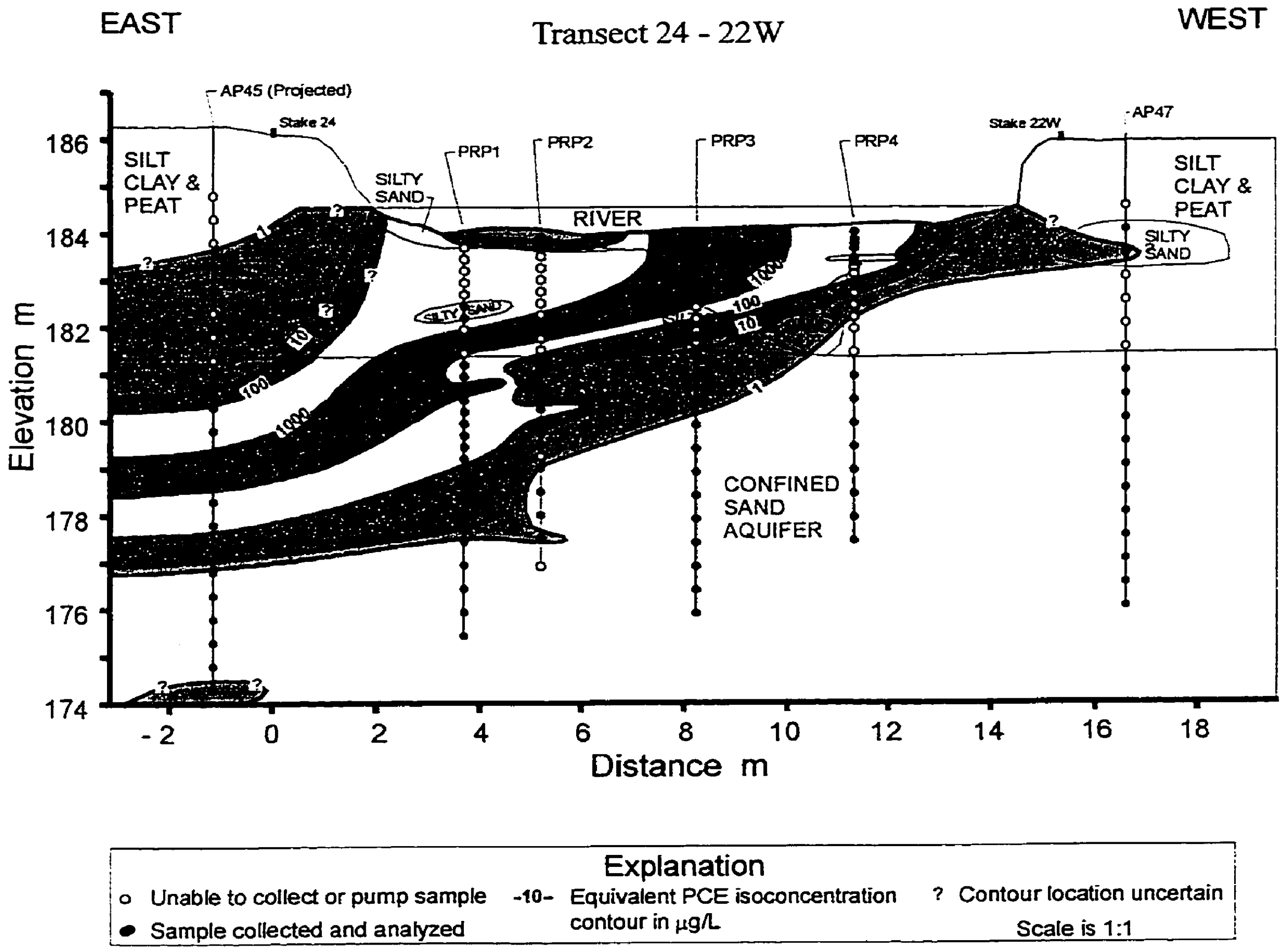


Figure 2-13. Total VOCs expressed as equivalent PCE concentrations (µg/L) for Waterloo Profiler points along transect 24-22W in July and August 1996.

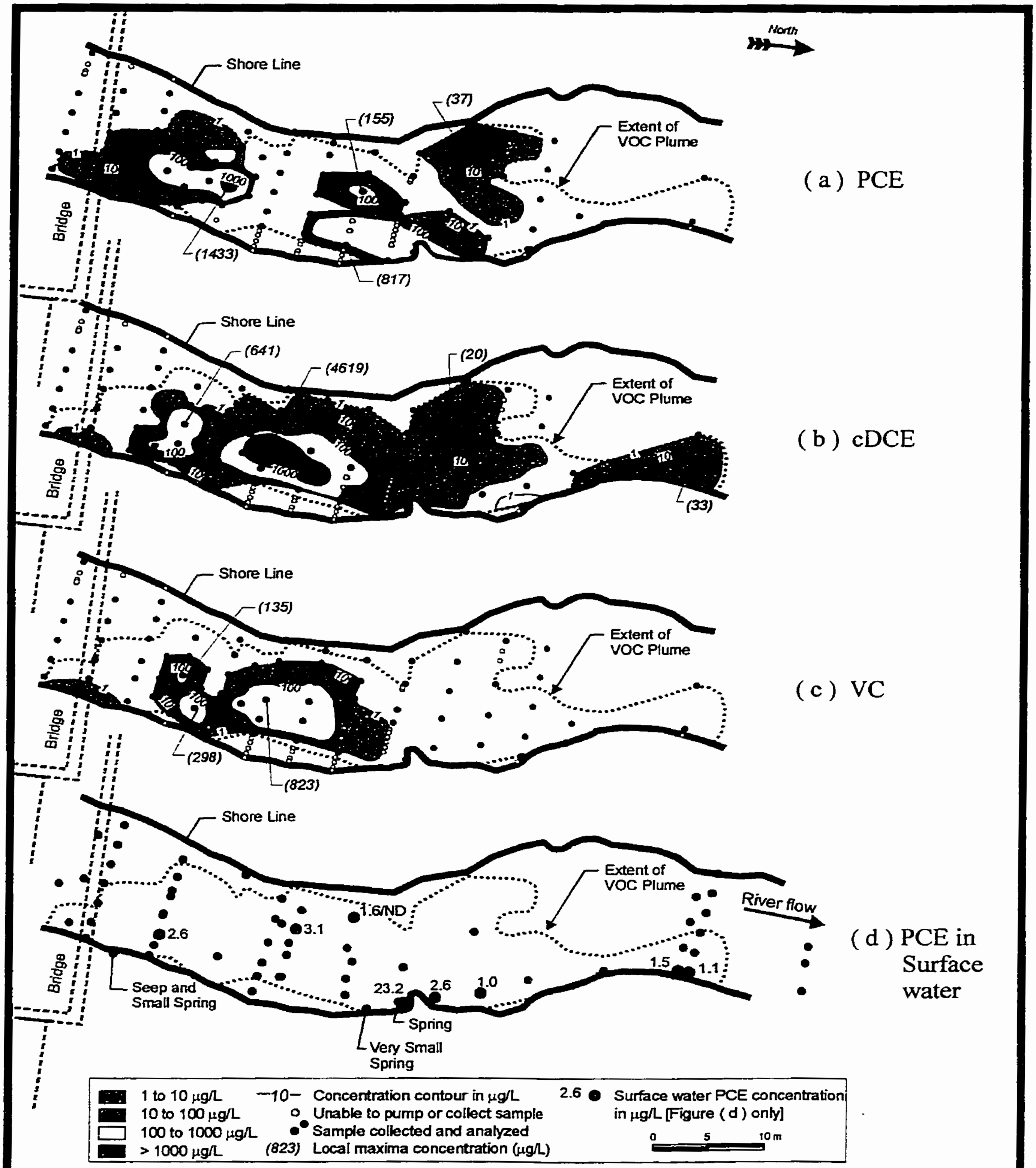


Figure 2-14 Plan-views of contaminant concentrations in the interstitial water of the streambed at a depth of 0.3 m in August 1998 for (a) PCE, (b) cDCE, and (c) VC. (d) Surface water PCE concentrations measured just above streambed (composite of all sampling dates). Note some locations in (d) were sampled multiple dates and some downstream locations not shown.

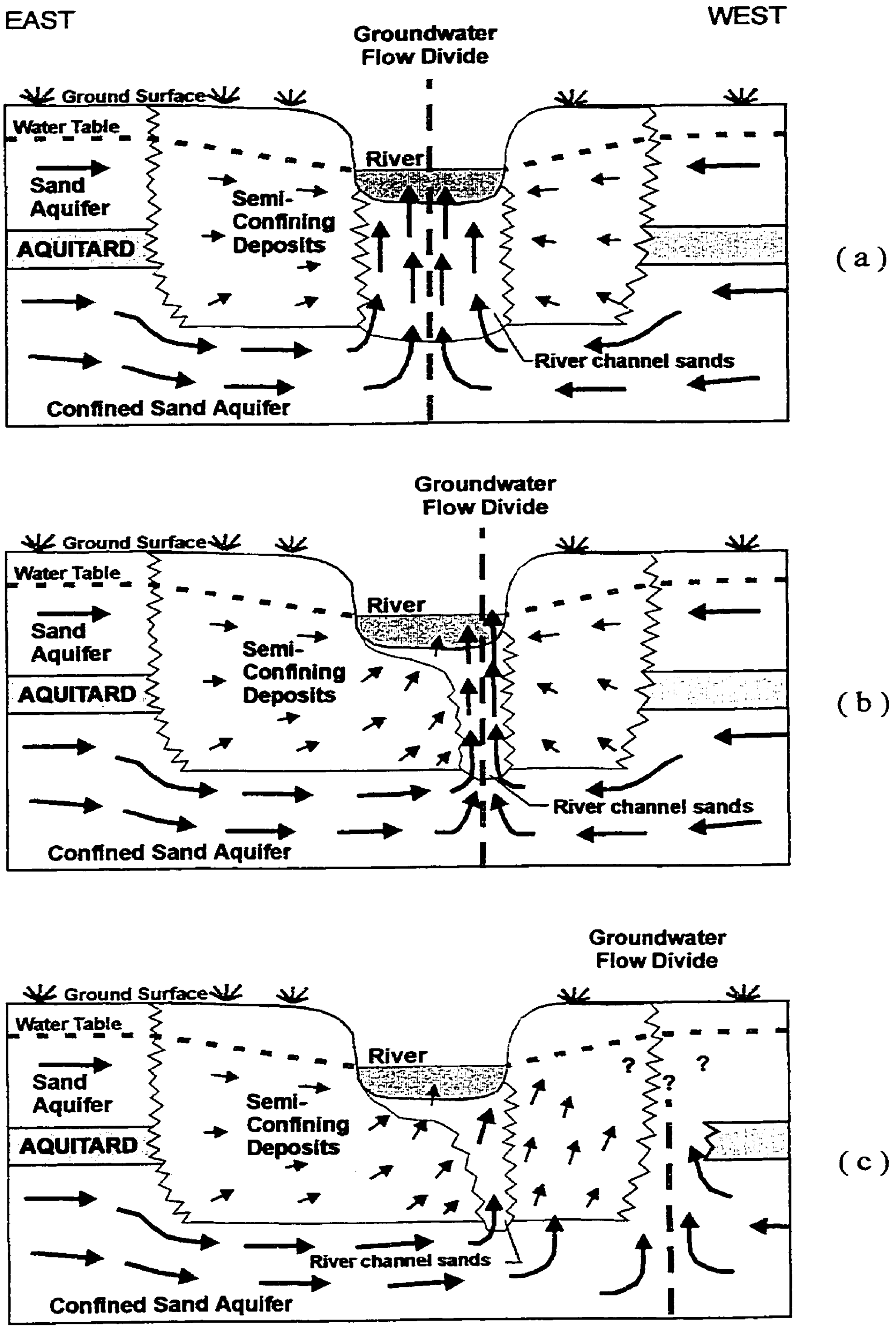


Figure 2-15. Schematics of near-stream geology and groundwater flow. (a) Former stream channel has eroded through semi-confining deposits and the flow divide is in the center of the river. (b) Geological window through semi-confining deposits with groundwater discharge from east offset to west side of river along with flow divide. (c) A preferential flow path beneath the west bank causes water from the east to flow beneath the river to far side. The location of divide in the unconfined deposits is not known.

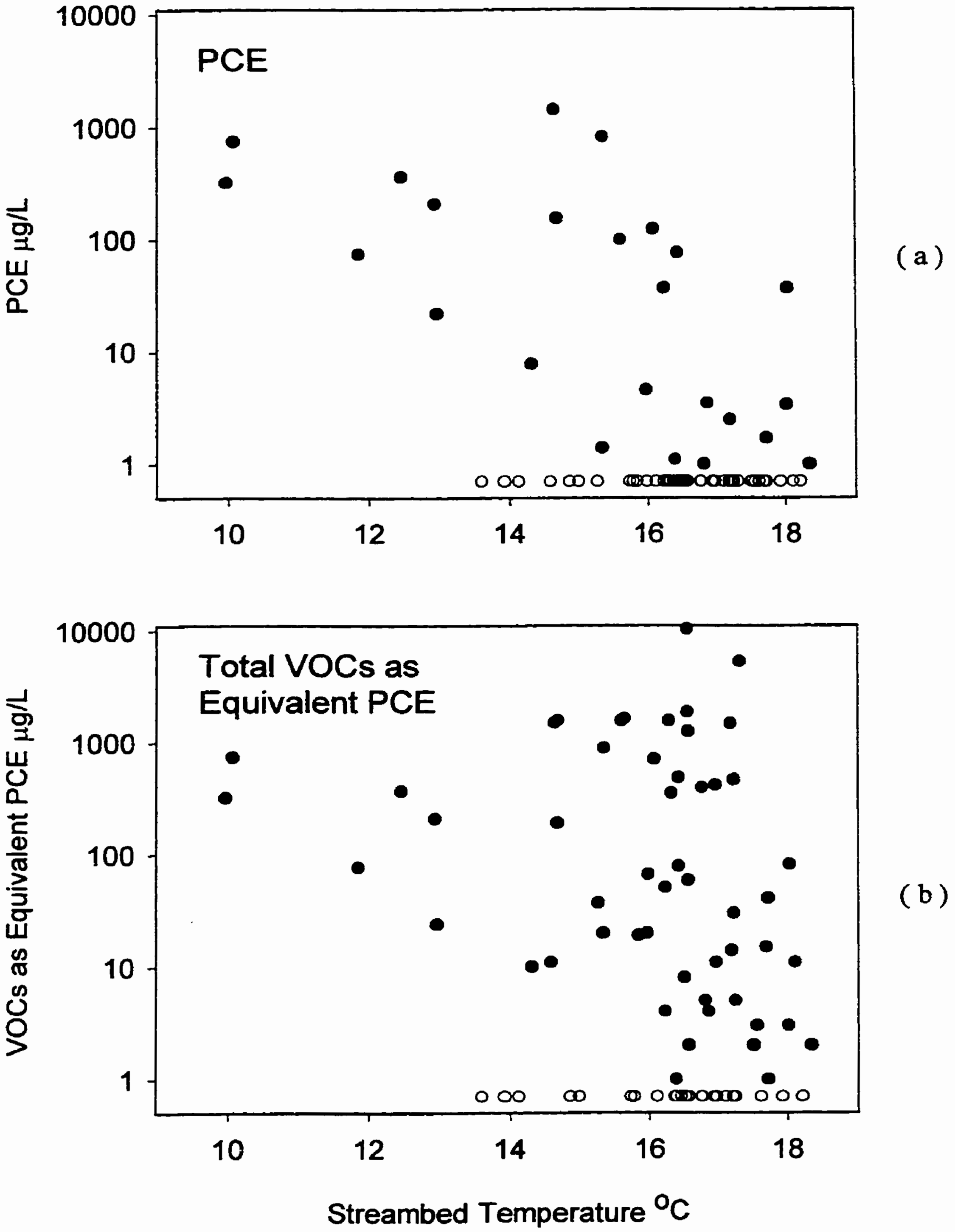


Figure 2-16. Streambed water concentrations (August 1998) versus streambed temperatures (July 1998) for (a) PCE and (b) total VOCs expressed as equivalent PCE. Closed circles indicate VOC contamination detected at the location. Open circles means no VOCs were detected and are plotted at the detection limit.

CHAPTER 3.

DELINEATING AND QUANTIFYING GROUNDWATER DISCHARGE ZONES IN A RIVERBED USING STREAMBED TEMPERATURES, MINI-PIEZOMETERS, AND PORE WATER SAMPLING

3.1 ABSTRACT

Streambed temperature mapping, hydraulic testing of mini-piezometers, and geochemical analyses of interstitial water of the streambed were used to delineate the pattern of groundwater discharge in a streambed and to develop a flux-based conceptual model for groundwater/ surface-water interaction where a tetrachloroethene (PCE) groundwater plume discharges to a river. Slug testing and potentiomanometer measurements at 34 streambed mini-piezometers showed that groundwater discharge ranged from 0.03 to 446 L/m^{2}d (but possibly as high as 7060 L/m^{2}d at one location) along a 60 m long by 11 to 14 m wide reach of river. Mapping of streambed temperatures at a depth of 0.2 m on a 1 by 2 m grid indicated that the reach was dominated by groundwater discharge and indicated 3 main areas of high groundwater discharge as well as areas of little or no discharge. Relatively little downwelling or hyporheic flow was observed at the site (less than 12% of the total area) and these areas were primarily identified using chloride concentrations to indicate the presence of surface water in the streambed. A new and simple empirical method was developed that related fluxes obtained at mini-piezometers to streambed temperatures. This relationship allowed flux to be calculated at the hundreds of finely-spaced temperature measurement locations where no piezometers were located. Complex but similar plan-view patterns of flux were derived for both summer and winter and showed that about 5 to 7% of the area accounted for about 21 to 24% of the total discharge. Using the quantitative flux data, a new conceptual model for groundwater discharge was developed that was consistent with field data and known mechanisms for flow within streambeds. Five different behaviors were identified based on the magnitude and direction of flux across the surface of the streambed and include: short-circuit discharge (e.g. high flow springs); high discharge (>200 L/m^{2}d) associated with preferential flow paths; low to moderate discharge (0 to 200 L/m^{2}d); no discharge (e.g. horizontal hyporheic or groundwater flow); and recharge (e.g. downwelling). Geological variations at depth played a key role in determining which type of flow behavior occurred in the streambed and where.

3.2 INTRODUCTION

Determining groundwater flow direction and flux is essential for evaluating the transport, fate and potential impact of groundwater plumes containing volatile organic compounds (VOCs) that discharge to rivers or streams. Groundwater flow paths in the vicinity of a river are influenced by several factors including: climate, hydrology, geology, geomorphology, and biology (Brunke and Gonser, 1997; Winter et al., 1998). These factors may result in very complex flow paths and flux patterns for discharging groundwater that vary spatially and temporally (Huggenberger et al., 1998; Baxter and Hauer, 2000). However, hydrogeological investigations of VOC plumes discharging to streams or rivers typically rely on relatively little and widely scattered data. Flux data are rarely collected on a fine scale (meters to centimeters) to fully characterize the complexity in the streambed over the full area of a discharging plume. Moreover, to accurately determine the contaminant mass flux through a streambed, the groundwater flux data likely needs to be collected on a scale comparable to the spatial variability in VOC concentrations in the streambed. Some of the techniques and equipment used to quantify groundwater discharge to a river include: installing seepage meters or heat flow meters, hydraulic testing of mini-piezometers, modeling of vertical streambed temperature profiles, performing tracer tests, measuring differences in stream flow, and using flow and chemical hydrograph separation methods. Unfortunately, to apply some of these methods on a centimeter to meter scale would require a large amount of equipment or time or both and would make the characterization too expensive. In some instances, installing a very large amount of equipment in the river will alter the flow in the system that is being monitored and provide erroneous results. Other methods may accurately quantify the total amount of groundwater discharging into the river but are unable to resolve the spatial distribution of flux through the streambed. There is a need for a method to map groundwater fluxes through a streambed that is simple, quantitative, unobtrusive (does not disturb the system), efficient, and fully characterizes the spatial variation. Either a new method or a new approach that combines existing methods is necessary.

Relatively few published studies have used multiple investigation tools to characterize groundwater/surface-water interactions, groundwater discharge, and the nature of VOC groundwater plume discharges to a stream or river on a fine scale. Seepage meters and mini-piezometers were used to characterize VOC plumes discharging to rivers (Avery, 1994; Norman et al., 1986; Hess et al., 1989). Passive PETREX sampling tubes have been used to map VOC plume discharges to creeks (Vroblesky et al., 1991) and in a marine coastal setting (Anderson and Church, 1998). Piezometers, "peeper" diffusion samplers, and geochemical sampling have been used to investigate a VOC plume discharging to a freshwater tidal wetland (Lorah et al., 1997; Lorah and Olsen, 1999). Diffusion samplers (Vroblesky et al., 1996) have been used to characterize VOC discharges to rivers (Savoie et al., 1999; Lyford et al., 1999; Vroblesky and Robertson, 1996) and to a lake (Savoie et al., 2000). Temporary water-sampling points, sediment sampling, and Ground Penetrating Radar (GPR) were used to characterize a chlorinated solvent plume discharging to a lake (Lendvay et al., 1998). In general, these studies have not mapped the groundwater flux through the streambed or lakebed in sufficient detail to allow an accurate estimate of contaminant flux to be made even if the plan-view extent of the plume in the streambed is relatively well defined.

Based on a review of groundwater flux mechanisms and available streambed characterization tools (summarized later), it was hypothesized that, if existing characterization methods were combined on a relatively fine scale, then both a qualitative and quantitative understanding of groundwater discharge into a river could be achieved. Temperature methods, hydraulic testing methods using piezometers, and measurement of pore water geochemistry (using permanent and temporary sampling devices) were all used to provide information regarding the magnitude and location of groundwater discharges in a streambed for a site where a tetrachlorethene (PCE) plume discharges to a river. It was hypothesized that indications of groundwater flux inferred from plan-view mapping of streambed temperatures could be empirically related to quantitative measurements of fluxes obtained by hydraulic testing of mini-piezometers to provide a simple, quantitative, and unobtrusive method to fully characterize the spatial variability of the groundwater discharge. It was also thought that this new method and an integrated approach would allow for the development of a conceptual model for groundwater discharge for the site that was based on the magnitude and direction of flow. The results of this study have important implications for the design and interpretation of streambed monitoring programs for discharging plumes and our overall understanding of groundwater discharge.

3.2.1 Concepts of Groundwater / Surface-Water Interactions

A summary of existing concepts for groundwater/surface-water interactions is provided below as background and a basis for appreciating the scale of observation necessary to characterize certain physical flow processes. In the past, large portions of a stream or river (i.e. entire reaches) have been conceptualized as: "gaining" where groundwater discharges into the surface water; "losing" where surface water flows down into the subsurface deposits; and "through flow" where groundwater enters the stream on one side of the river and the surface water exits the river and enters the subsurface on the other (Bear 1979, page 52). Another type of interaction is called the "zero exchange" (Woessner, 1998) or "parallel flow" reach (Woessner, 2000) where no vertical exchange of water occurs across the streambed. Vertical hydraulic gradients between the river and the underlying deposits are usually used to classify these reaches; however, the terminology does not provide an indication of the magnitude of the flux.

Groundwater/surface-water exchange can also occur on a scale of meters to centimeters as a result of variations in streambed topography. Topographic changes in the top of a streambed and in the elevation of the water surface can both result in surface water entering the streambed at "downwelling" zones and reemerging with groundwater at "upwelling" zones. Downwelling of surface water often occurs at the heads of riffles and subsequent upwelling of this water occurs at the downstream end of the riffle usually at the head of the next pool (Williams, 1993; Boulton, 1993; Harvey and Bencala, 1993). Surface water can also flow laterally into the adjacent stream banks at the head of a riffle, travel essentially parallel to the river in the stream bank as "substream flow", and then return to the stream at the end of the riffle (Harvey and Bencala, 1993). Small changes in streambed topography from a concave surface to a convex surface can also result in an interchange of water between the bed and the stream (Vaux, 1968). Even very small bedforms, such as triangularly shaped sediment sandwaves (ripples), can result in "convective bed transport" (Thibodeaux and Boyle, 1987; Savant et al., 1987) or "pumping" as it has also been referred to (Elliot and Brooks, 1997a and 1997b). Convective bed transport is the movement of surface water through and beneath the bedform as a result of pressure variations caused by the water flowing over the surface of the bedform. Migration of bedforms along the streambed can also trap and release surface water as interstitial fluid and this process is referred to as "turnover" (Elliot and Brooks, 1997a and 1997b). In instances where surface water is entering the streambed, it means that groundwater can not directly discharge into the stream at those locations and it is diverted elsewhere, potentially making it more difficult to locate groundwater discharge zones (Conant, 2000). Surface water displacing groundwater can also occur on a much larger scale of entire reaches during storm events or spring runoff when rapid and large increases in river stage relative to adjacent aquifer water levels can result in "bank storage" along long stretches of a river. During bank storage, surface water temporarily enters the adjacent banks and underlying streambed deposits and is released back to the river when the river stage drops (Todd, 1955; Squillace, 1996).

In the above discussions, water has been classified as either groundwater or surface water, but interstitial water in a streambed can be a mixture of the two. In many studies, a zone of interstitial water in the streambed and adjacent banks has been found to contain surface water or a mixture of groundwater and surface water that is referred to as the "hyporheic zone" (White 1993; Hendricks and White 1991; Triska et al., 1993; Williams 1989; Stanford and Ward, 1988). Ecologists consider this zone to be a unique ecotone which contains a distinct set of riverine biota that has adapted to this particular subsurface environment. Triska et al. (1989) divided this zone into an upper "surface" hyporheic zone containing more than 98% surface water and a lower "interactive" hyporheic zone containing between 10 and 98 % surface water, but there is no one set of hydrological, chemical, zoological and metabolic criteria that has been agreed upon to delineate the hyporheic zone (White 1993; Williams 1989; Hakencamp et al., 1993; Valett et al., 1993). Nonetheless, in most studies the hyporheic zone is spatially limited to no more than a few meters or centimeters from the river channel (Hill and Lymburner, 1998; Williams 1993; Triska et al., 1989 and 1993; Castro and Hornberger, 1991), yet in one highly permeable braided stream environment it was found 2 km away from the channel laterally (Stanford and Ward, 1988). In the instance of hyporheic mixing, groundwater discharge reaches the surface water of the stream channel in a diluted form.

There is a need for a conceptual model and investigative approach that acknowledges all these mechanisms and characterizes both the type and the magnitude of these fluxes. Despite the variety of mechanisms described above, the discharge of groundwater to a river is really only a function of two factors: the hydraulic gradient at the location and the hydraulic conductivity of the subsurface deposits. The challenge is to investigate a site on a scale that adequately characterizes the possible range and scales of discharge behavior.

3.2.2 Review of Methods For Measuring Groundwater Discharge

Many different methods of determining groundwater discharge were reviewed and assessed for possible use in this study. Since the intent was to use multiple techniques and to have a relatively large number of measurements using a small spacing, it was desirable to select methods that would not appreciably alter or disturb the flow over or within the streambed. Other desired features included being relatively inexpensive and resistant to flood damage or vandalism. The methods considered included seepage meters, Darcy flux calculations based on hydraulic conductivity and hydraulic head data from piezometers, geochemical sampling of natural waters, tracer tests, heat flow meters; temperature monitoring, and non-invasive geophysical methods. A summary and description of some of these investigation tools can be found in Carr and Winter (1980), EPA (1991, 1990, 2000) and Wolf et al. (1991).

Seepage meters are commonly used in lake studies and in some river studies to directly measure groundwater discharge flux at specific locations (Lee 1977; Lee and Cherry, 1978; Carr and Winter, 1980; Shaw and Prepas 1990a and 1990b; Avery, 1994). However, seepage meters can be difficult to use correctly (Blanchfield and Ridgeway, 1996; Belanger and Montgomery, 1992; Shaw and Prepas, 1989) and are not recommended in rivers where surface water flow velocities exceed 0.2 m/s (Lee and Cherry, 1978), and water quality samples collected from them may not be representative of the groundwater (Belanger and Mikutel, 1985). These devices were not used for this study because at low river stage the flow velocities were as high as 0.66 m/s and there was concern the devices would either be eroded away, vandalized, or the topography of the devices themselves would cause local disturbances in the water flow within the streambed (e.g. convective bed transport).

In river and stream studies, groundwater flux is often calculated using data from piezometers installed in shallow streambed deposits and Darcy's Law (Lee and Cherry 1978) and sometimes piezometers are used in conjunction with seepage meters (Lee and Hynes, 1977; Lee and Cherry 1978; Woessner and Sullivan, 1984; Cruickshank et al., 1988). The piezometers can be inexpensively installed and, if designed properly and used in moderate numbers, they will not appreciably disturb the flow in the river. Groundwater flux estimates can be made based on hydraulic conductivity measurements obtained from slug testing of the piezometers and measuring hydraulic head differences between the streambed and river. This method was included in this study because it can be quantitative and inexpensive.

Contrasts between the natural geochemistry of surface water and groundwater have also been used to delineate groundwater discharge areas, or calculate the degree of substream mixing using an end member mixing model (Mengis et al., 1999), or to map the lateral or vertical extent of the hyporheic zone (Williams 1989, Hendricks and White, 1991 and 1995; Plénet and Marmonier 1995). Interstitial water samples from the deposits beneath the stream are analyzed for parameters that are unique to either surface water or groundwater or is present at a substantially different concentration in one or the other. Ideally the parameter used should be relatively conservative and the respective concentrations in groundwater and surface water should be uniform. These types of investigations have used natural parameters such as chloride, isotopes such as O^{18} (Hinton et al., 1994) and deuterium (Turner and Macpherson, 1990), and radon (Yoneda et al. 1991). Analyses of the surface water and groundwater at the study site during the spring run-off showed that O^{18} contrast between the waters was too low for use in this study. Chloride, sodium, nitrate, specific conductance, and dissolved oxygen concentration contrasts were relatively high but only chloride was considered conservative enough to use as an indicator in this study.

In some studies, a tracer has been added to the surface water to assist in delineating the hyporheic zone. Tracers used include chloride (Castro and Hornberger, 1991; Triska et al., 1989 and 1993; Munn and Meyer 1988), and dyes (Vervier et al., 1993). Tracers have also been injected into the groundwater and the subsurface flow path monitored as it discharges to a stream (Harvey and Bencala, 1993), a drainage ditch (Meigs and Bahr, 1995), or lake (Lee et al., 1980). The amount of surface water tracer necessary for the large volume of flow in the river, possible problems obtaining regulatory approval, and large amount of subsurface monitoring equipment needed were deterrents to using a surface water tracer. However, because the spatial distribution of the PCE groundwater plume was so well characterized at the study site (see Chapter 2), PCE and its degradation products were effectively used as groundwater tracers in this study.

Natural temperature variations have also been successfully used to determine locations of groundwater discharge and to quantify fluxes. The theory underlying use of streambed temperatures as an indication of groundwater discharge flux in streambeds is summarized by Lapham (1989) and is based on the interaction between heat conduction processes and advection of water. Relationships between vertical streambed temperature distribution and the magnitude of groundwater flow are relatively well understood. For example, during summer the heat of the river water conducts downward into the river through the porous media while the cooler groundwater flowing upward carries the heat back out of the subsurface by advection. The resulting temperature distribution in the streambed is a function of these competing processes. Where discharge of water is very slow, the heat can penetrate deeper than where discharge is large, so sediments in low discharge zones should be warmer than those in high discharge zones areas (Figure 3-1). Where surface water downwells, the temperature in the streambed should be essentially the same as the surface water above. In northern temperate climates, groundwater temperatures tend to remain fairly constant and are about equal to the mean annual air temperature (about 10 °C), whereas surface water temperatures in streams and rivers can range from 0 °C in winter to over 20 °C in the summer. Areas of high groundwater discharge can be found in the bed of a lake or river by locating relatively cold zones in the bed during the summer or relatively warm zones in the bed during the winter. Streambed temperature has also been used qualitatively to identify areas of groundwater discharge (upwelling) into surface water or surface water infiltration (downwelling) into the streambed deposits (White et al., 1987; Hendricks and White 1988; Evans et al., 1995; Sillman and Booth, 1993; Maddock et al., 1995). Modeling vertical profiles of temperature in deposits beneath a stream has been performed to determine rates of vertical groundwater flow into surface water (Lapham, 1989; Fryar et al., 2000) or quantify surface water infiltrating into the subsurface deposits (Constantz and Thomas, 1996; Constantz, 1998; Sillman et al., 1995; Bartolino and Niswonger, 1999). Temperature methods were also selected for use in this study, because they are inexpensive, qualitative, and quantitative. Heat-flow meters that determine the velocity and direction of groundwater flow by introducing a pulse of heat and monitoring the temperature (Kerfoot, 1984; Ballard, 1996) were not used in this study because they are expensive, relatively large in size, and would disturb the system.

Geophysical investigations have been used to directly and indirectly indicate locations of groundwater discharge zones. A sediment probe which measures the conductance of sediments (i.e. pore water and solid material) while dragged through them has been used to directly locate groundwater discharge zones in lakes (Lee, 1985; Lee and Welch 1989; Vanek and Lee, 1991; Harvey et al.,1997) and wide rivers (Lee et al., 1997; Lee and Bianco, 1994). In cases where the conductance of the groundwater is sufficiently different than the surface water, it allows for the direct detection of the groundwater discharge. A preliminary survey with a sediment probe at the study site did not detect significant contrasts in conductance so this method was not pursued further. Other geophysical methods based on detecting electromagnetic (EM) anomalies of a plume were considered, but the method was not selected because the PCE groundwater plume did not have a uniform or strong EM signature. GPR (Naegeli et al., 1996; Beres and Haeni, 1991; Haeni, 1996; Lendvay et al., 1998) and Continuous Seismic Reflection (Haeni, 1996) have been used as a non-invasive ways of characterizing the geological materials beneath a river or lake and can be used to infer either potential preferential groundwater flow paths or barriers to flow. GPR had already been successfully used at this site and was quite useful for defining the extent of low hydraulic conductivity semi-confining deposits beneath the river (see Chapter 2).

3.2.3 Description of the Site

Field investigations focused on a 60 m long section of the Pine River in Angus, Ontario, Canada, where a dissolved-phase PCE groundwater plume discharges to the river (Figure 3-2). The hydrogeological instrumentation installed along this reach of river for this study are shown in Figure 3-3. Flow in the river at this location ranges from 1.4 to 2.0 m^3/s in the summer (see Chapter 2) with an estimated 100 year flood flow of 99.8 to 101.4 m^3/s (Burkard 1990). The specific reach of interest is relatively straight and approximately 11 to 14 m wide. In the summer the river has an average depth of 0.5 m with a maximum depth of about 1.1 m. The surficial geology of the streambed is primarily fine sand with downstream areas having accumulations of sand with gravel or cobbles. In many areas the surficial fluvial sands are underlain by semi-confining deposits consisting of up to 3.1 m of silts, clays, and peats. A GPR investigation and coring of the streambed showed that the semi-confining deposits are apparently absent near the center and western side of the stream. Below the semi-confining deposits are the very-fine to fine sands of a confined aquifer. See Chapter 2 and Writt (1996) for a further description of the geology at the site. PCE contaminated groundwater travels from beneath a dry cleaning facility 195 m away through this confined aquifer (Pitkin 1994; Writt, 1996; Guilbeault, 1999) and ultimately discharges through the streambed and into the river.

Hydrogeological investigations of the site (Chapter 2) concluded that this portion of the river is primarily a gaining reach and that the semi-confining deposits have a substantial influence on where the plume is able to discharge into the river. Water levels in the top of the confined aquifer versus those in the river indicate large upward hydraulic gradients (0.29 to 0.42 m/m) which means that the potential for upward flow at the site is strong and is apparently hindered by the low hydraulic conductivity deposits. In general, groundwater flows to the river from both sides which indicates the plume should discharge to the river, and water quality sampling of the aquifer on the opposite side of the river confirms this finding. However, the streambed is dominated by discharge from the east and minor amounts of PCE contamination were even observed to reach the far side of the river at one or two sampling points.

Sampling of the interstitial water of the streambed at 80 locations at a depth of 0.3 m in August 1998, showed that an area of about 469 m^2 was contaminated by the groundwater plume. This area was 2.9 to 3.2 times larger than the cross-sectional area of the plume in the aquifer beneath the east bank of the river. The area where the plume discharged not only contained PCE but also large amounts of products of anaerobic degradation of PCE including trichloroethene (TCE), cis-1,2-dichloroethene (cDCE), 1,1-dichloroethene (11DCE), trans-1,2-dichloroethene (tDCE), vinyl chloride (VC), ethene, and ethane. The concentrations in the streambed changed by a factor of 100 to 10,000 over a lateral distances of 1 to

3.5 m. Unless groundwater flux is determined on an equal or smaller lateral spacing, it is unlikely that accurate estimates of contaminant mass discharge can be obtained.

3.3 FIELD METHODS

3.3.1 Streambed Temperature Measurements

Temperature measurements were used to provide a qualitative indication of groundwater discharge locations in the riverbed. The investigations included monitoring of groundwater and surface-water temperatures, plan-view mapping of streambed temperatures in both winter and summer, and vertical profiling of streambed temperatures. Groundwater and surface water were monitored using waterproof StowAway® TidbiT® -5 °C to +37 °C range temperature loggers (Onset Computer Corporation, Pocasset, Massachusetts). River water temperatures were monitored at a 15 minute interval starting on August 4, 1997 and ending November 17, 1999. Groundwater temperatures in the confined aquifer at the base of drivepoint well AW-1 were monitored on 15 minute to 1 hour intervals starting on July 9, 1998, and ending November 17, 1999. Measurements were accurate to within about 0.1 to 0.2 °C.

By mapping the streambed temperatures in plan view at a uniform depth below the streambed, it was felt that a qualitative understanding of groundwater discharge patterns could be achieved. The streambed was mapped both in summer and winter when the difference in temperature between the groundwater and the surface water were the largest and patterns of discharge would be easiest to determine. Temperatures were measured using a Barnant Model 600-8525 Handheld Thermister Thermometer (Barnant Company, Barrington, Illinois) equipped with a stainless steel YSI Model 418 reusable temperature probe (YSI Incorporated, Yellow Springs, Ohio). The probe was accurate to within 0.1 °C. The probe was fixed to the end of a 1.8 m long, 0.009 m outside-diameter (OD) stainless-steel tube to aid in inserting it into the streambed, but the YSI probe was not very rugged and several were broken during the course of this study. The probe was inserted to a depth of 0.2 m at each location except at a very few locations where obstructions or cobbles or gravel limited the depth of installation to 0.15 m. Information collected at each location included streambed temperature, the time of the measurement, depth of the water, streambed geology, and notes regarding channel features or debris. The measurements were generally made on a 1 m spacing along transects located perpendicular to the river flow. The distance between each transect was about 2 m. By using a measuring tape extended between transect stakes on opposite banks (which were surveyed), the resulting measurement locations on the 1 m by 2 m grid were accurate to within about 0.1 m laterally. Transect locations are used to identify locations and an example of the naming convention is as follows. Location 6-6W 4.5 m indicates the transect is approximately 6 m downstream (north) of the King Street bridge (shown in Figure 3-3) and the point is 4.5 m west of stake 6 (on the east bank) toward stake 6W (on the west bank).

The summer mapping of streambed temperatures was performed on July 28 and 29, 1998, and consisted of about 383 measurements for the reach of river extending from transect -4 - -4W under the King Street bridge downstream to transect 44-44W. Streambed temperature measurements were also repeated along transects -4 - -4W, 10-10W, and 28-28W during the mapping to examine the reproducibility of the measurements over time. River stage elevations remained virtually constant at 184.52 to 184.49 m (all elevations are in meters above mean sea level) during mapping. Thus the discharge condition for groundwater was essentially constant suggesting that vertical groundwater flow remained unchanged during the mapping.

The winter mapping of streambed temperatures was performed between February 18 and 20, 1999, and consisted of 514 measurements for the reach of river extending from transect -4 - -2W under the King Street bridge downstream to transect 56-56W. Streambed temperature measurements were also repeated along transects 0-0W, 10-10W, and 14-14W during the mapping to examine the reproducibility of the measurements over time. River stage varied between an elevation of 184.58 to

184.78 m, which is similar to the summer stage conditions. The change in stage during the winter mapping may have changed vertical hydraulic gradients within the streambed, but it is not known to what extent, if any, that groundwater flow through the streambed was altered.

At various times during this investigation, vertical profiles of streambed temperatures were obtained using a multilevel temperature probe that could be driven into the desired depth. The probe consisted of 6 YSI model 401 temperature probes placed at a 0.1 m vertical spacing in milled slots along a 0.0254 m OD solid aluminum pipe and connected to the Barnart Thermister using a 10 channel switching box. Each thermometer tip was placed flush with the outside of the solid rod and a 0.01 m diameter space was milled around each thermometer tip to so as to keep the tip from touching the aluminum and to improve its contact with streambed water and sediments. The multilevel probe was generally driven 0.55 to 0.6 m into the streambed which allowed the top temperature probe to measure the surface water temperature. The probe was then left to equilibrate for 10 to 15 minutes before readings were taken. The multilevel probe could then be driven further into the streambed if desired. Vertical temperature profiles were measured at total of 18 locations, but not during the summer or winter plan-view mapping of streambed temperatures. A similar design for collecting multilevel temperatures with a driven probe was described by Comer and Grenney (1977).

3.3.2 Mini-piezometer installations and slug testing

A total of 34 streambed piezometers, designated SP4 to SP37 were installed to obtain groundwater flux information. Locations for the installations (see Figure 3-3) were chosen based on information obtained from the summer streambed temperature mapping and from other existing streambed monitoring data. Each piezometer consisted of a 0.75 m long, 0.021 m OD, schedule 80 PVC pipe, with a 120 μm stainless-steel mesh wrapped around a 0.1 m long perforated section of the pipe. The screened interval was recessed such that the mesh was flush with the outside of the PVC pipe. The bottom of each piezometer was capped with a threaded steel bolt, and a threaded male elbow connector was attached to the top of the PVC and connected to a 1.1 m long section of 0.0127 m OD polyethylene tube. To avoid creating an oversized borehole that would have to collapse or be sealed to prevent unwanted vertical flow along the annulus, piezometers were pushed by hand or driven into the streambed. The center of piezometer screens were installed at a depth of 0.49 to 0.70 m below the surface of the streambed. The piezometers were developed by surging and pumping and then capped to prevent flow of water in or out of the tubes since the tubes were underwater and designed to lay flat on the surface of the streambed.

Slug testing and hydraulic head measurement of all piezometers were performed between November 3 and 6, 1998, except for SP34 and SP35 which were tested on December 10, 1998. Prior to each slug test, the hydraulic head difference between the river and the piezometer was measured to within 0.001 m using a potentiomanometer similar to those described by Winter et al. (1988) and Lee and Cherry (1978). A slug testing apparatus, consisting of a 0.038 m inside-diameter (ID) clear Plexiglas reservoir tube mounted on a tripod, was used for each test. Falling-head slug tests were performed by instantaneously releasing water from the filled reservoir and measuring the water level decline using a Solinst Model 3001, M5 Levelogger™ (Solinst Limited Canada, Georgetown, Ontario, Canada). The hydraulic conductivity for each test was calculated using slug testing analyses methods (Hvorslev, 1951), and combined with the hydraulic head data to calculate the vertical groundwater flux at each piezometer location.

Since effective porosity is required to calculate average linear groundwater flow velocities, a time domain reflectometery (TDR) survey was performed on December 10, 1998, to determine the in-situ total water content of the top 0.2 m of the streambed at each of the 34 piezometer locations and at 21 additional streambed locations. A Tektronix Model 1502B Metallic TDR cable tester (Tektronix Inc., Beaverton, Oregon) was used along with a waterproof TDR probe and the data were analyzed using WATTDR which is a Wave Form Acquisition and Analyses Program (Redman, 1998) that uses the empirical relationship of Topp (1980) to relate water content to measured dielectric permittivity. Both measurements of porosity of repacked core samples (see Chapter 2) and the TDR results were used to estimate the effective porosity of streambed deposits.

3.3.3 Geochemical Indicators and Streambed Sampling

Chloride and VOCs (i.e. PCE and its 7 anaerobic degradation products) were used as geochemical indicators to determine if interstitial water found within the streambed represented groundwater, surface water, or a mixture of the two. Field investigations were designed to characterize the aquifer groundwater, the surface water, and the interstitial water of the streambed.

The lateral and vertical concentration distributions of chloride and PCE in groundwater adjacent to the Pine River was characterized using the Waterloo Groundwater Profiler method (Pitkin et al., 1999) and by installing and sampling bundled multilevel (BML) samplers similar to those described by Mackay et al. (1986) and Bianchi-Mosquera and Mackay (1992). In July and August 1996, the Waterloo Profiler was used to collect 175 samples for PCE and TCE analyses at locations AP40 to AP52 along the banks of the river as shown in Figure 3-3. In January 1999, 12 BML samplers were installed along the banks of the river (Figure 3-3) and subsequently sampled in March 1999. Each BML installation consisted of 7 to 11 sampling points with a 0.5 m vertical spacing. Approximately 106 groundwater samples were collected from the BML samplers and analyzed at the University of Waterloo for PCE, TCE, 11DCE, tDCE, cDCE, VC, ethene, and ethane using a Hewlett Packard Model 5890 Series II gas chromatographs equipped with either an electron capture detector (ECD) or a photoionization detector (PID) or using a Hewlett Packard Model 5790A gas chromatograph with a flame ionization detector (FID). These analyses methods are described in more detail in Chapter 2. All BML samples were also analyzed for chloride using an Orion Model 9617BN Combination Chloride electrode attached to an Orion Model 420A meter (Orion Research Inc., Boston, Massachusetts). Approximately 36 chloride samples from BML1, BML3, BML7 and BML11 were also sent to Philips Analytical Services (Halifax, Nova Scotia, Canada) for chloride analysis (USEPA Method 325.1) using a Roche Cobas Fara/BMC

Hitachi 911 Colorimetric Analyzer. Chloride concentrations determined using the electrode were within -22 % to 35 % of the laboratory determined amounts and on average were within -1.9 %.

Surface water concentrations of chloride and PCE were generally obtained from grab samples taken just above the top of the streambed. A summary of surface water analyses for PCE and its anaerobic degradation products for samples collected between 1996 and 1999 can be found in Chapter 2. A summary of chloride results can be found in Chapter 4.

The concentrations of chloride and VOCs in the interstitial water in the streambed were determined using the Waterloo Profiler, mini-profiler, and multilevel samplers. The mini-profiler was a soil vapor probe described by Hughes et al. (1992) that was modified to collect water. The mini-profiler is a 0.0064 m OD, 0.003 m ID stainless-steel tube, 1.8 m in length, having a 0.01 m long screen, located 0.025 m above the drive tip. The MLS samplers consisted of a stainless-steel type described by de Oliveira (1997) and Barbaro (1999) that was modified for driving into the ground and a new PVC type described in Chapter 2. Between July and November 1996, the Waterloo Profiler was used at 8 locations (PRP1 to PRP8) to vertically profile the water quality on a vertical interval of 0.1 to 1.0 m down to a maximum depth of 8.5 m. Locations PRP1 to PRP4 were installed essentially in a line along transect 24-22W. The mini-profiler was used at 11 locations (PRP7R, PRP8R, and PRP9 through PRP17) to vertically profile the water quality typically using a 0.15 m vertical interval down to maximum depth of 2.1 m. Four of the mini-profiler locations (PRP7R through PRP10) were installed in a line along transect 18–18W. Locations PRP7R through PRP13 were sampled between August 12 and 15, 1997. Locations PRP14 to PRP16 were sampled in October 1997, whereas location PRP17 was sampled in June 1998. In October 1998, a total of 20 driveable multilevel samplers (MLS1 to MLS20) were permanently installed at 10 locations. The sampling array had a vertical spacing of 0.15 to 0.30 m which extended to a maximum depth of 5.5 m. The MLS samplers were installed in a line along two transects, 6-6W and 16-16W. Sampling of 41 MLS sampler points occurred in November 1998, and all

139 MLS sampler points were sampled in March 1999. All water samples collected with the Waterloo Profiler, the mini-profiler, and MLS samplers for and PCE and its degradation products. These samples were also analyzed for chloride with the exception of the early Waterloo profiler sampling at PRP1 through PRP6.

The mini-profiler was also used to map the horizontal (plan-view) distribution of PCE and chloride concentrations in the streambed. Between August 4 and 12, 1998, water samples were collected at a depth of 0.3 m below the streambed at 80 locations using a mini-profiler. Samples were collected on approximately a 2 by 4 m grid starting at transect -4 - -4W (beneath the King Street bridge) and ending at transect 44 - 44W, with two additional samples collected on transect 52 - 52W. The intent was to collect samples during summer low flow river conditions and the first 2 days of sampling did occur when the river elevation was quite low, at 184.4 m. However, two rainfall events resulted in river stages rising to as high as 184.8 m on day 7 before dropping back to 184.5 m at the end of the sampling. Resampling of 7 locations showed that if vertical flow conditions had changed within the streambed, the concentration had not been appreciably affected by the fluctuations in river stage.

3.4 RESULTS AND DISCUSSION

3.4.1 Streambed Temperatures

During the summer streambed temperature mapping in July 1998, surface water temperatures varied diurnally, reaching a low of 16.5 °C and a high of 20.5 °C (Figure 3-4a) while the groundwater temperature in the confined aquifer stayed constant at 9.8 °C. Measured streambed temperatures ranged between 10.0 and 19.0 °C. Repeating streambed temperature measurements along three transects at different times during the mapping, showed temperatures were mostly reproducible to within about 0.3 °C with a maximum difference of 0.6 °C (except at one point where it was 1.7 °C) even though the surface water temperatures varied by 4.0 °C. Figure 3-4b shows streambed temperatures versus distance along transect -4 - -4W (under the bridge) and illustrates how reproducible measurements are even after 8.5 hours have elapsed and surface water temperatures have changed from 16.6 to 19.3 °C.

During the winter mapping in February 1998, surface water temperatures varied over a relatively small range (0 to 1.6 °C) during the three days of mapping (Figure 3-5a) while groundwater temperatures in the confined aquifer were constant at 10.7 °C. Measured streambed temperatures ranged between 0.4 and 9.3 °C. Repeating streambed temperature measurements along three transects at different times during the mapping, showed streambed temperatures were generally reproducible to within about 0.3 °C with a maximum difference of about 1.1 °C. Figure 3-5b shows streambed temperatures versus distance along transect 10 - 10W and illustrates how reproducible the measurements are even after 16.5 hours have elapsed and surface water temperatures have changed from 1.5 to 0 °C.

Figure 3-6 shows the results of the summer and winter mapping of streambed temperatures. Both maps show streambed temperatures that vary over a 9 °C range and have locations where temperatures varied by 2 °C or more over lateral distances of 1 m or less. Distinct areas of groundwater discharge are visible as relatively cool areas (less than 16 °C) in the summer map and as warmer areas (greater than 3 °C) in the winter map. Areas of higher groundwater discharge (i.e. temperatures less than 13 °C in summer and greater than 6 °C in winter) are very localized and range in size from about 0.5 to 8.8 m^2. The locations and shapes of the temperature anomalies in the two maps are remarkably similar. Most of the areas of higher discharge are observed within 34 m of the bridge and little indication of high groundwater discharge is found further downstream. Three main discharge areas are apparent from the temperature data. The "eastern-shore" discharge zone is about a 1 to 3.5 m wide area extending along the eastern shore at a distance of about 20 to 33 m downstream of the bridge. The "west-central" discharge zone is an irregular shape that is a 6.5 m wide area extending from the western shore toward the center of the river at a distance of about 19.5 m to 30 m downstream of the bridge. The elongated "south-central" discharge zone is located near the center of the river, and is about 10 m wide beneath the bridge where it occupies nearly the entire eastern half of the river, but narrows to about 3 to 4 m wide in the center of the river at a distance of 12 m downstream. In both maps there is also a "low-flow band" about 1.7 to 4 m wide that separates the eastern-shore and west-central discharge zones and separates part of the south-central discharge zone from the eastern shore. The low-flow band starts at a distance of about 11 m downstream from the bridge and connects with a larger area of low flow located downstream of the 34-34W transect.

Although the winter and summer maps have very similar patterns of temperature anomalies, the winter map shows more of the fine details of the discharge zone. For instance, the winter map shows slightly warmer streambed temperatures along nearly the entire western shore (indicating discharge) and a 1 m wide by 8 m long colder zone (low flow area) just downstream of the bridge and west of the south central discharge zone. The winter map was less subject to short-term and long-term transients in surface water temperatures. Not only did the stream temperature stay more constant during the winter mapping, but it had been between 0 and 2.7° C for the two months prior to the mapping, which included about 30 consecutive days at 0° C.

The effect of diurnal changes in surface water temperatures on vertical profiles of temperature in the streambed was examined because it can be used to help design and interpret streambed temperature mapping. For example, Figure 3-7a shows streambed temperatures changed 0.6 °C at a depth of 0.1 m but only 0.2 °C at a depth of 0.2 m over a 5 hour period at PRP9 on August 14, 1997, in response to the 1.1 °C change in surface water temperature shown in Figure 3-7b. For this reason, the probe was inserted to a depth of 0.2 m during the later plan-view mapping to lessen the effect of short-duration variations in surface water temperature during the 2 to 3 days of mapping. A probe depth of 0.1 m was too shallow and subject to unacceptable diurnal variations during a first attempt at mapping performed in 1997. A depth of 0.3 m would be less susceptible to temporal variations but it was too rough on the probe and it was difficult to insert it that deep everywhere. The technique developed to map the streambed temperatures in plan view provided good results which is evident from the similarity of repeated measurements along selected transects in summer and winter (Figures 3-4b and 3-5b). The multilevel temperature probe was not extensively used because it left holes that might not collapse completely which could then serve as preferential pathways for the discharge of contaminated groundwater and because it took too much time to obtain a set of stable readings.

3.4.2 Piezometers, Slug Testing and Darcy's Law Calculations

The use of piezometers, slug testing, and water level measurements to calculate groundwater discharge using Darcys Law is a relatively standard technique in hydrogeological investigations and is commonly described in textbooks such as Freeze and Cherry (1979). Horizontal and vertical hydraulic conductivities (K_h and K_v, respectively) were calculated using an anisotropic ratio for the deposits and the Hvorslev (1951) case G, variable-head and time-lag equations. An anisotropic ratio of 1.25 was used when calculating K_h and K_v values. The ratio was determined from 167 permeameter tests of streambed sands by dividing the arithmetic mean hydraulic conductivity by the harmonic mean value for the samples (see Chapter 2). At 5 locations, the slug tests could not be run for a long enough time to allow hydraulic conductivity to be calculated using the time-lag equation. Hydraulic conductivity values from the more complete set of variable-head analyses were used and corrected to 10 °C (to facilitate comparison) and are summarized in Table 1Q.

The slug tests resulted in an average K_h value for streambed sands of 1.62×10^{-2} cm/s and an average K_v of 1.24×10^{-2} cm/s which corresponded rather well to the average permeameter test values determined in Chapter 2 of K_h 1.68×10^{-2} cm/s (i.e. the arithmetic mean value K_A) and K_v of 1.34×10^{-2} cm/s (i.e. the harmonic mean value K_H). The hydraulic conductivities for streambed sand were in the range for fine sand and similar to the average hydraulic conductivity values (i.e. the geometric mean value K_G) of

$1.25\text{x}10^{-2}$ to $1.43\text{x}10^{-2}$ cm/s for the underlying aquifer. Testing of the piezometer and slug testing apparatus indicated that the three hydraulic conductivity values in Table 1Q which are higher than $2.2\text{x}10^{-2}$ cm/s may be lower than the actual in situ values for the deposits, because of head losses caused by the testing equipment. The slug testing results for the silts and clays of the semi-confining deposits resulted in an average K_h value of $2.98\text{x}10^{-4}$ cm/s and an average K_v value of $2.28\text{x}10^{-4}$ cm/s. These values are skewed to the high side of the range by one or 2 measurements but still are in the general range of the average permeameter test K_h value of $1.66\text{x}10^{-4}$ cm/s (i.e. the arithmetic mean value) and K_v of $7.61\text{x}10^{-5}$ cm/s (i.e. the harmonic mean value). Perhaps more representative values for the slug testing of the semi-confining deposits are the mean K_v of $6.90\text{x}10^{-6}$ cm/s and the minimum K_v value of $4.44\text{x}10^{-6}$ cm/s. The semi-confining deposits have hydraulic conductivities that are considerably lower than the underlying and overlying sands and limit the amount of vertical groundwater flux that can occur in an area.

The hydraulic head differences between the streambed and the river were measured at each piezometer using a potentiomanometer during conditions representative of low river flow conditions (see Table 3-1). The November 1998, hydraulic head measurements observed at SP4 to SP37 were measured during a uniformly low river stage condition of 184.50 to 184.54 m. The exception was that a river stage of 184.62 m occurred during measurements at SP34 and SP35 on December 10, because the river was still declining from a flood peak elevation of 185.12 m that occurred on December 7. In general, these levels compare well with the 184.49 to 184.52 m stage during the summer temperature mapping and the 184.58 to 184.78 m stage during the winter mapping. At all piezometers the observed head differences indicated upward flow of water but at some locations the difference was only 0.002 m over a vertical distance of 0.63 to 0.67 m. The median head difference was 0.01 m and the average difference was 0.023 m. The maximum head difference of 0.233 m occurred at SP34, located at 28-28W 2.0m. The vertical hydraulic gradients between the center of the piezometer screen and the top of the streambed ranged from 0.003 to 0.405 m/m (see Table 3-1). These observed hydraulic gradients were assumed to be representative of the conditions during the summer and winter mapping of streambed temperatures and are fairly representative of conditions during the low river stages that occur from May-February. However, the vertical gradients within the streambed would likely change in response to large flooding events and the spring run-off.

Porosity measurements of streambed deposits made using TDR ranged between 42.1 and 71.7 %. The average porosity for sand, silt, and clayey-silt were 44.5, 47.5, and 55.9 %, respectively. Measurements of porosity on repacked streambed samples during permeameter testing was 39.6 % for sand and 62.6 % for the clayey-silt (see Chapter 2). The somewhat higher porosities for the TDR results for the sands are believed to be a better representation of the less compacted shallow in-situ streambed deposits than the results of the permeameter testing method that requires tight repacking of the sample for testing. The porosity values representative of each location are shown in Table 3-1.

Vertical groundwater flux q_v was calculated at each piezometer location using Darcy's Law, K_v values, and vertical hydraulic gradients (see Table 3-1). Values of q_v ranged from 0.029 to 445.7 L/m^{2}d (liters per square meter of streambed, per day) with the exception of SP34 which had a q_v of 7060 L/m^{2}d. In general, the lowest flux values are associated with locations where clayey semi-confining deposits are believed to be present beneath the stream and where the low-flow band is indicated by the temperature mapping. The highest q_v values are associated with the three discharge areas indicated by the temperature mapping. The flux value at SP34 is much higher than any other value. Temperature mapping clearly shows SP34 in the center of the south-shore discharge area, but the surficial deposits at SP34 contain silts and clays which would tend to suggest low flux conditions. Near this location the streambed was also observed to have a high discharge arestian spring where the sand appeared to be "dancing" or "boiling". It is likely that the SP34 piezometer screen intersected a spring conduit or sand deposits within the silty-clay deposits, which would explain both the high gradient and hydraulic conductivity observed. To calculate the fluxes in Table 1Q, the deposits were assumed to be homogeneous between the screen location and the top of the streambed, which was reasonable based on investigations of the sandy streambed deposits; however, this assumption might not be true at SP34. It is unclear if the value of flux obtained at SP34 is a true representation of the actual flux at that location. It also should be remembered that each calculated hydraulic conductivity value is assumed to be representative of all the deposits between the piezometer screen and the river, but is essentially a point measurement which is representative of the deposits immediately adjacent to the screen. The results of permeameter testing (see Chapter 2) showed this assumption of representativeness was valid at 10 of the 12 core locations shown in Figure 3-3. At locations where hydraulic conductivities of the deposits varied significantly over the distance between the river and the piezometer screen, the screen was located where it was representative of the lowest hydraulic conductivity for the interval.

The average linear vertical groundwater velocity (v_v) for each piezometer location was calculated using K_v, hydraulic gradient, and porosities in Table 3-1. For the purpose of the calculation, porosities from TDR data were assumed to equal the effective porosity, which means the calculated velocities may be a little lower (e.g. 0 to 25 %) than is actually the case. Velocities ranged from $6.4\text{x}10^{-5}$ to 1.0 m/d, with the exception of location SP34 that was 13.81 m/d. Assuming the deposits at each location are uniform and 2 m thick, the time for water to travel vertically though the deposits would range from a maximum of about 86 years in the semi-confining deposits to 0.5 days in the sands and would take only 3.5 hours using the v_v for SP34. For comparison average linear horizontal velocities (v_h) in the aquifer sands east of the river ranged between 0.51 and 0.58 m/d.

3.4.3 Calculating Flux by Combining Streambed Temperature and Piezometer Data

The purpose of combining the streambed temperature data with the flux estimates made at piezometer locations was to develop a mathematical relationship between temperature and flux. The relationship could be used to calculate vertical flux where only temperature data were available, thereby converting the large amount of streambed temperature data into quantitative flux data. Using this relationship would avoid the time and expense of installing and slug testing hundreds of piezometers which otherwise would be needed to obtain the same amount of spatial resolution as the temperature data. The streambed's response to surface water temperature changes is likely to be relatively uniform across the site since much of the streambed is dominated by sandy deposits which also means the thermal properties of the subsurface materials would be relatively constant. These conditions meant a simple empirical relationship could be derived instead of using more complicated numerical and analytical approaches.

Groundwater flux values from Darcy's Law calculations using piezometer data were plotted against streambed temperatures determined for each piezometer location for the summer and winter mapping (Figure 3-8a and 3-8b, respectively). Streambed temperatures were not always measured exactly at the piezometer locations during the mapping so they were linearly interpolated from the nearest two measurements along the transects. The interpolated streambed temperatures were also used to temperature correct the hydraulic conductivity values from the slug testing results in Table 3-1 in order to better reflect the in-situ water viscosity conditions at the time of the temperature mapping. In both summer and winter there is a clear relationship between streambed temperature and flux. As anticipated, in summer the fluxes increase as streambed temperatures decrease and in winter the fluxes increase as streambed temperature increase. Vertical lines on Figures 3-8a and 3-8b also show the range of surface water and groundwater temperatures observed during the mapping since they represent the thermal boundary conditions for the system.

A second-order polynomial was fitted to the streambed temperature versus flux data in Figure 3-8a and 3-8b and the equations and least squares value (R^2) for each fit is shown. The fits do not include the very high flux data from piezometer SP34. The empirical relationship seems to provide a reasonable fit to the rest of the data between the temperature extremes. Some scatter in the data occurs for each curve and is probably an artifact of streambed temperatures responding to changes in surface water temperatures that occurred either prior to or perhaps during mapping. The scatter may also be a result of having to interpolate streambed temperatures to get temperatures at piezometer locations. Changes in surface water temperature are thought to cause the poorer polynomial fit for the summer data (R^2= 0.66) versus the winter data (R^2= 0.81) because larger variations in antecedent surface water temperatures occurred in summer in comparison to the winter. Some of the outlying points on the graphs have been labeled with the corresponding piezometer names. Most of the piezometer locations indicated as outliers (i.e. SP14, SP21, SP32) as well as SP34, have hydraulic conductivities higher than the reliable limit of the slug testing apparatus. If the high hydraulic conductivities calculated were a result of an undetected leak in the sampling apparatus, the true hydraulic conductivities and fluxes would be lower than the calculated value, meaning the points would likely fall closer to the fitted curve than shown in the figures.

The groundwater fluxes for the summer and winter conditions (Figure 3-9a and 3-9b, respectively) were calculated using the equations shown in Figures 3-8a and 3-8b and the streambed temperature measurements at each location in Figures 3-6a and 3-6b. The calculated fluxes for the summer data ranged between -24.8 and 577.0 L/m^{2}d and were between -10.3 and 587.1 L/m^{2}d for the winter. The range of flux values and general pattern of flux is nearly the same for the winter and summer survey. The three main discharge zones indicated by the temperature surveys (i.e. the southern-shore, west-central, and south-central discharge zones) and the low flow band are clearly visible in both Figures 3-9a and 3-9b. The winter flux pattern shows these discharge zones more distinctly than the summer data. In winter the south-central and west-central discharge zones are nearly connected and the low flow band is larger and wider than in the summer. The overall discharge during the winter is lower than in the summer because lower temperatures result in lower hydraulic conductivities in the streambed. A drop in temperature from 16 to 1 °C reduces the hydraulic conductivity by about 50 %. The effect of temperature on flux is more clearly seen when the size of the areas enclosed by the 0 and 50 L/m^{2}d contours (Figures 3-9a and 3-9b) are compared. The median discharge in summer is 61.9 L/m^{2}d which is about 34.4% higher than the median discharge in winter of 46.1 L/m^{2}d when only the area mapped during the summer survey is compared (transect -4 - -4W through 44-44W). The average discharge in summer is 83.8 L/m^{2}d, which is only 11.2 % higher than the 74.4 L/m^{2}d for the winter. The closer similarity between the average values compared to the median values is because the total discharge is dominated by high flux areas where temperatures remain relatively constant. For example, in summer an estimated 7.0 % (46 m^2) of the total area of the streambed enclosed by the 200 L/m^{2}d contour was responsible for 23.5% of the total discharge (52.5 m^3/d) for this 48 m long reach of river. In winter an estimated 4.6% (32.4 m^2) of the total area of the streambed enclosed by the 200 L/m^{2}d contour was responsible for 20.6% of the total discharge (44.0 m^3/d) along the same reach of river. The total groundwater discharge along this reach of river is similar to the estimated groundwater discharge of 1.1 to 1.5 m^3/d per linear meter of river reach calculated for a 14.7 km long portion of the Pine River (including the study reach) using stream flow gauging data obtained from the Department of Fisheries and Oceans (Brian Stephens, personal communication, 1998).

The empirical relationship developed to relate the streambed temperatures to flux resulted in a consistent pattern in discharge and is a useful tool to determine flux for most of the temperature ranges. The relationships did result in calculation of some negative fluxes, which indicates downwelling of surface water into the subsurface. This type of flow is physically possible and even reasonable for the riffle area located downstream of transect 34-34W where the negative values occurred. However, the negative values may also be an artifact of the difficulty that the equation has when fitting the low flux data in Figure 3-8a and 3-8b and then extrapolating the relationship for temperatures beyond those used to derive the equation. An important limitation to the empirical relationship occurs when streambed temperatures are nearly equal to either the groundwater or surface water temperature (i.e. the thermal boundary conditions). At or near the boundary conditions the ground water flux may become asymptotic and non-unique. For example, as flux increases the shallow streambed temperature at a location may become essentially equal to the groundwater temperature, and even if the flux is then doubled or tripled the temperature will remain the same. If the value of q_v at SP34 is correct then this point may be on this non-unique portion of the curve since the temperature was essentially equal to the groundwater temperature and the flux was so large. The same type of non-unique behavior can also occur when downwelling of surface water causes shallow streambed temperatures to equal surface water temperatures and, in that instance, doubling of the recharge flux rate would not alter the streambed temperature either. The empirical approach may also not be valid or applicable in areas where flow in the streambed is horizontal, since an underlying assumption of the method is that flow is vertical. Other underlying assumptions are that the groundwater temperatures in the underlying aquifer are essentially constant and that surface water temperatures are spatially uniform (although they can change temporally) within the river reach.

3.4.4 Geochemical Indicators in Water

Chloride was used as a geochemical indicator to distinguish areas of groundwater discharge from areas where surface water was present in the streambed. The average chloride concentration for 25 surface water samples collected between 1996 and 1999 was 14.1 mg/L and ranged from 12.8 to 17.4 mg/L. The relatively constant concentration of chloride was consistent with surface water samples collected from a location 213 m upstream of the site on approximately a monthly basis since 1966 as part of the Ontario Ministry of the Environment and Energy (MOEE) Water Quality Monitoring Program (MOEE, 1996). The 78 chloride analyses performed by MOEE between 1988 and 1996 averaged of 13.9 mg/L with a standard deviation of 3.6 mg/L. In contrast to the constant surface water concentrations, analyses of groundwater samples from the BML installations in March 1999, using the chloride probe indicated concentrations ranged between 34 and 237 mg/L on the east side of the river and between 17 and 280 mg/L on the west side of the river. The probe values were consistent with the laboratory analyses of 44 samples in the groundwater plume, which averaged 130.1 mg/L and varied from 36.8 to 207 mg/L. Figure 3-10b is a cross-section view showing the chloride concentrations detected in the BML samplers in the aquifer on the east side of the river in March 1999. Figure 3-10a shows the results of sampling the streambed interstitial water at a depth of 0.3 m in August 1998, which detected concentrations of 14.5 to 177 mg/L. The distribution of chloride concentrations in the streambed did not correspond very well with the concentration pattern in the aquifer because the source of chloride probably originates from road salting, agricultural activities, or septic tanks which have concentrations that vary in time and space. This variability means chloride concentrations could not be used to reliably infer flow paths from the aquifer into the streambed.

PCE and its degradation products were used as tracers for groundwater flow from the east since little or no VOCs were found to the west or in surface water. PCE was detected in surface water in only 8 of 71 samples and at concentrations of 3.1 µg/L or less with the exception of one sample that had 23.2 µg/L. TCE was detected in 5 samples at concentrations of 3.2 µg/L or less but thought to be from incomplete decontamination of sampling equipment. No other degradation products were detected in any of the samples. Concentrations of PCE in groundwater on the east side of the river varied between none detected and 8707 µg/L in samples collected using the Waterloo Profiler and BML samplers. A PCE concentration in the aquifer of 22,376 µg/L was also detected in the plume at a location within 41 m of the river (Writt, 1996). Figure 3-11b shows PCE concentrations in cross-section view for BML points in the aquifer. Sampling the shallow streambed interstitial water at a depth of 0.3 m in August 1998 (shown in Figure 3-11a) detected high concentrations of VOCs with a maximum concentration equivalent to 10,323 µg/L of PCE. The presence of VOCs in the streambed indicated that most of the groundwater discharge in the streambed along this reach of river originates from the aquifer on the east side of the river. Vertical profiles of VOC concentrations beneath the river collected with the Waterloo profiler, mini-profiler, and from sampling the MLS locations were used to resolve the groundwater flow paths from the aquifer up to the streambed. Groundwater discharge does not appear to be exactly vertically upward into the river even over the last 1.5 m of the flow path, but instead the plume travels obliquely upward at a 25 to 30 degree angle in order to discharge to the river (see Chapter 2).

Water samples from the streambed that contain chloride concentrations below the lowest observed groundwater concentrations of 17 and 34 mg/L (for the west and east side of the river, respectively) can be inferred to contain some portion of surface water while those detecting VOCs contain some portion of groundwater. Chloride analyses of the interstitial streambed water at a depth of 0.3 m in August 1998, showed only 9 of 76 samples within the 13.9 to 34 mg/L range and of those locations 32-32W 10.9 m and 36-36W 13.5 m were the only two containing VOCs (see Figure 3-10). At two locations, the samples were collected in an apparent downwelling zone just up stream of a partially buried log. In three other instances (including the two VOC detections), the samples were collected from deposits containing sand, gravel, and cobbles which may have been acting as preferential zones for downwelling and/or horizontal hyporheic flow. The four other water samples were collected above or just within the top of the low-hydraulic-conductivity semi-confining deposits where the interstitial water was likely isolated from discharging groundwater. Despite a rise in river stage during the August 1998, sampling event that could have caused surface water to flow into streambed deposits, there is little definitive evidence of hyporheic mixing at a depth of 0.3 m below the streambed. However, interpreting concentrations higher than 34 mg/L is problematic. For example, a chloride concentration of 59.4 mg/L in the streambed could represent pure groundwater or be a mixture of two parts 14.1 mg/L surface water and one part 150 mg/L groundwater. Because of the large range in both chloride and PCE concentrations in groundwater, no attempt was made to use them in an end-member mixing model to estimate relative percentages of groundwater and surface water in the interstitial water of the streambed.

One clear example of surface water penetrating to a depth of 0.6 m below the streambed was observed in sands above the semi-confining deposits at 18-18W 4.35 m (PRP7). In November 1996, Waterloo profiling at location PRP7 showed the 0.6 m of sands overlying the semi-confining deposits contained no VOCs and had less than 17.3 mg/L chloride at depths of 0.15, 0.30, and 0.45 m and only 29.6 mg/L at a depth of 0.6 m. Resampling the sands 0.25 m away with the mini-profiler at location PRP7R in

August 1997, showed almost the exact same concentrations of chloride with depth. Each sample also contained very low concentrations of VOCs (less than 8 μg/L) but this is believed to be from insufficient decontamination of sampling equipment. The water in the streambed may have originated as downwelling surface water with subsequent horizontal flow downstream within these sands which are geologically isolated from the underlying aquifer by the clay. Alternately, the surface water might have been entrapped surface water contained in newly deposited sands. On more than one occasion during this study the sands at the PRP7 location were observed to be eroded almost completely away right down to the top of the silty-clay semi-confining deposits, but later new sands were deposited in their place. Depending on how long the profiling occurred after redeposition, the small flux of groundwater flowing vertically up from silts and clays may not have had enough time to displace the entrained surface water and the interstitial water could be analogous to "turnover" water described by Elliot and Brooks (1997a).

3.4.5 Streambed Topography

Changes in the topography of the streambed and stream surface have been shown to result in downwelling of surface water into streambed deposits on both large and small scales. Evaluations of topographically induced flow patterns generally use many of the techniques described above in order to verify the flow. The horizontal and vertical spacing of measurements in this study were designed to detect larger scale topographic effects but were not intended to detect very small effects (e.g. 0.01 to 0.10 m deep flow paths) similar to those described by Thibodeaux and Boyle (1987), Savant et al. (1987) and Elliot and Brooks (1997b). The temperature surveys and flux calculations suggested possible downwelling in the river downstream of transect 34-34W, where a small drop in streambed and river stage creates a 16 m long riffle. The chloride analyses also indicated two localized downwelling areas because of buried logs or other obstructions. In general, topographic effects do not result in very much downwelling or hyporheic zone mixing, and overall, hyporheic mixing is seldom seen at this site, at least not at a depth of 0.3 m.

Streambed topographic measurements made during temperature mapping were also reviewed to identify possible preferential groundwater discharge zones. Upwelling of groundwater usually occurs at the base of deep pools, but there were no particularly deep pools at the site, and only minor variations in stream depth (see Figure 3-12). A comparison of flux versus depth showed no direct correlation. High discharge areas in Figures 3-9a and 3-9b were associated with both shallow and deep areas of the river in Figure 3-12. For example, the south-central discharge area spans both shallow and deep locations, yet an equally deep location immediately to the east was not a high discharge location.

3.5 CONCEPTUAL MODEL FOR GROUNDWATER DISCHARGE

The detailed groundwater flow and flux information obtained from using multiple characterization methods at this site were generalized into a conceptual model for discharge. This model focuses on quantifying flow across the streambed surface and is oriented more toward subdividing groundwater discharge behavior than to determining different types of surface water infiltration into the streambed. The model not only provides a framework for categorizing and evaluating discharges at other sites, but also provides a basis for eventually calculating contaminant mass fluxes to surface water and interpreting geochemical conditions within the streambed (see Chapter 4).

Five basic types of groundwater discharge behavior have been identified and are shown schematically in cross-section view in Figure 3-13. The 5 types are also summarized in a plan view in Figure 3-14 and summarized in Table 3-2. Type 1 behavior is the "short-circuit discharge"; Type 2 is the "high discharge" zone; Type 3 is the "low to medium discharge" zone; Type 4 is the "no discharge" zone; and Type 5 behavior is the "recharge" zone where surface water flows down into the streambed deposits. Types 1, 2, and 3 represent subdivisions of what has normally been defined as "gaining" stream zones. Type 4 includes the zero exchange reach (Woessner 1998) and parallel flow reach (Woessner, 2000) and horizontal groundwater and hyporheic flow. Type 5 essentially lumps together processes which previously have been referred to as "losing" stream zones, such as downwelling portions of substream flow and convective bed transport.

3.5.1 Type 1: Short circuit discharge

Type 1 discharge behavior, or short-circuit discharge zones are very localized points of high discharge such as artesian springs and "pipe" flow. At these locations natural (or man made) conduits exist in the subsurface deposits that essentially represent shortcuts that allow groundwater from depth to rapidly reach the surface water and short circuit the normal flow path though the porous media. A discussion of the formation and origin of springs can be found in text books such as Todd (1980, pages 47-50). The springs at the Angus site are thought to be the result of artesian flow along small scale geological heterogeneities in the low hydraulic conductivity semi-confining deposits such as sand stringers, fractures, root holes, or even man made holes. At spring locations "dancing" or "boiling" sand can be seen as the high discharge of groundwater fluidizes the streambed deposits. The size of these discharges are usually relatively small in sand and gravel unconsolidated deposits, and less than 0.05 m in diameter at Angus, which made them difficult to find.

Three springs were found at the site (see Figure 3-14), the largest of these was Spring A located 0.5 m south of 30-30W 1.85 m. The per-unit-area flows from these short circuits can be orders of magnitude greater than those from the other types of discharge. For example, using data from the nearby piezometer SP34 (presumed to have intersected a spring conduit), the vertical flux is at least 7060 L/m^2d. The artesian flow from a 0.038 m ID temporary casing at PRP1 (prior to grouting the borehole) where profiling pierced through the semi-confining deposits in the vicinity of the 30-30W spring, was estimated be about 31.8 L/min (45,850 L/d). Such high fluxes result in high flow velocities and short groundwater residence times within the streambed deposits on the order of minutes to hours. The nearby Spring C on the shoreline had a flow of less than 1 L/min and was considerably smaller than at Spring A. The on-shore spring B near the base of the King Street bridge also had much lower flows and was associated with a seep area that may have been created when bridge construction pierced the semi-confining deposits. Other springs may have been present beneath the river at the west-central and south-central discharge zones but were not identified visually or by using temperature measurements. The temperature of spring waters were between 9.9 and 10.2 °C and nearly identical to the deeper aquifer groundwater. Although, the total area of the streambed having Type 1 discharges between transects -4 - -4W and 56-56W was less than 0.0003%, Type 1 discharges can represent discrete points of high volume discharges of contaminated aquifer water directly into the surface water.

3.5.2 Type 2: High discharge

Type 2 discharge behavior, the "high discharge" zone, are areas of preferred groundwater flow where high hydraulic conductivity deposits in the streambed connect the underlying high-hydraulic-conductivity aquifer deposits directly to the river. Groundwater flows through these deposits as easily, or more easily, than the underlying aquifer deposits, generally resulting in high per-unit-area discharges. Channel lag deposits or sand and gravel deposits associated with a prior location of a river channel can also be preferential flow paths or serve as geological windows through surrounding lower hydraulic conductivity fluvial deposits. High hydraulic gradients can also cause high discharge upwelling at topographic changes in the streambed or river surface and at the base of pools. Type 2 discharge can occur over large areas of the streambed, depending on the geological setting. At these types of locations shallow streambed temperatures will correspond more closely to groundwater temperatures than to the surface water temperatures and vertical groundwater flow velocities will be similar to flow velocities in the aquifer.

High discharge zones were identified within the eastern-shore, west-central, and south-central discharge zones previously shown in Figure 3-6a and 3-6b. In winter, the zones make up about 3.8% of the area of the streambed between transects -4 - -4W and 56-56W. Groundwater discharge in these areas are greater than 200 L/m^{2}d and calculated to be as high as 587.1 L/m^{2}d (excluding Type 1 discharges within these areas). The velocity of water flowing vertically through these deposits is approximately 0.52 to 13.8 m/d. These fluxes and velocities are equal to or higher than the 160 to 200 L/m^{2}d flux and 0.51 to 0.58 m/d velocity for groundwater flowing horizontally through the confined aquifer toward the river. Figures 3-15a and 3-15b shows (in cross section) a high discharge area along transect 6 - 6W and the relationship between streambed temperature, observed flux (from piezometers), and flux calculated for summer and winter, respectively. The high discharge zone occurs at a distance of 5 to 6 m in both summer and winter and corresponds well to the location of observed temperature anomalies and where the semi-confining deposits are absent at depth (Figure 3-15c). The calculated fluxes correspond relatively well to the observed values obtained for piezometers SP8, SP9 and SP10 shown in Figure 3-15C. Both the path of the PCE plume and the observed temperature distribution are consistent with groundwater beneath the semi-confining deposits flowing out to a point of preferred discharge at a distance of 5 to 6 m across the stream.

3.5.3 Type 3: Low to medium discharge

Type 3 is the "low to medium discharge" zone, consisting of low to medium hydraulic conductivity deposits (relative to the aquifer deposit) or low hydraulic gradients or both. Lower fluxes areas may also be caused by thin silt layers within or below otherwise high hydraulic conductivity sand deposits, or sands underlain by semi-confining deposits, or fining upward sequences of sedimentary deposits such as those associated with meandering streams.

Low to medium discharge zones dominate the site and make up about 76% of the streambed. Groundwater discharge in these areas are between 0 and 200 L/m^{2}d, and most of this zone has fluxes between 0 and 50 L/m^{2}d. Vertical groundwater flow velocities range from approximately $5\text{x}10^{-5}$ to 0.5 m/d in this zone, so groundwater has a longer residence time in these areas than in Type 1 or 2 areas. An example of a low to medium discharge zone is shown in Figures 3-16a and 3-16b where the relationship between streambed temperature, observed flux from piezometers SP25 to SP29, and flux calculated along transect 18-18W is depicted for summer and winter, respectively. The streambed temperatures tend to be closer to the surface water temperatures than the groundwater temperatures. The calculated fluxes in winter correspond very well to observed fluxes (Figure 3-16b), but summer calculations somewhat over predict the low observed fluxes and under predict the higher observed fluxes (Figure 3-16a). In summer, the lowest observed fluxes (1.5 to 10.6 L/m^{2}d) occur at a distance of about 2 to 6 m where sediment coring and GPR show the semi-confining deposits are particularly clay rich, but fluxes increase to 115.8 L/m^{2}d at distance of 9.1 m (Figure 3-16c). In winter, higher streambed temperatures and higher calculated fluxes occur at about 12 m (Figure 3-16b) where a small geological window occurs (Figure 3-16c). The 162 L/m^{2}d value of flux calculated at a distance of 1.2 m may be associated with a weak spring or preferential pathway through the semi-confining deposits. The plume discharge is consistent with this pattern of groundwater discharge. The most concentrated part of the contaminant plume (about 6000 µg/L of VOCs expressed as PCE) discharges at PRP8R at a distance of 6.4 m while only trace amounts of contaminants are found at PRP7 and PRP7R at a distance of about 4.3 m where the clay-rich semi-confining deposits are present. Contaminants have longer residence times in the streambed along this transect than along 6-6W because they generally must pass through lower hydraulic conductivity deposits.

3.5.4 Type 4: No discharge

Type 4 "no discharge" occurs when the vertical hydraulic gradient between the streambed and river is essentially zero, meaning there is no driving force making the water in the streambed move vertically to discharge into the river. Zero exchange reaches (Woessner, 1998) or parallel flow reaches (Woessner, 2000) are examples of where either surface water or groundwater maybe flowing within the streambed parallel to the river but has no upward discharge component. Horizontal hyporheic flow also falls into this category. Type 4 flow may occur in geologically uniform deposits if there is no vertical gradient and groundwater flow is parallel to the stream channel. The flow can also occur where sandy streambed deposits are geologically isolated from underlying groundwater system by a very low hydraulic conductivity layer which causes essentially no groundwater flow to enter the shallow streambed deposits; hence, flow in these deposits is dictated by the horizontal hydraulic gradient of the river. Type 4 flow can also occur when the horizontal hydraulic gradient of the river is high enough to completely overwhelm the vertical gradient making water flow horizontally through streambed deposits. This type of horizontal flow is more likely to occur in very high hydraulic conductivity deposits like coarse sands and gravels than in lower hydraulic conductivity deposits.

Type 4 no-flow discharge behavior occurs at location PRP7 on transect 18-18W at 4.35 m (Figure 3-16c). At this location the semi-confining deposit isolates the streambed sands from the underlying sand aquifer. On two occasions near PRP7, surface water was detected to a depth of 0.45 m in the streambed and none or only trace levels of VOCs were detected and thought to be from incomplete decontamination of sampling equipment. At this location the interstitial water may have been the result of entrapment during deposition (e.g. "turn-over"), or horizontal hyporheic flow through the topographically high standing sand bar deposits. Other small scale horizontal flow zones may be present at the site as part of small scale topographically induced convective bed transport which were primarily inferred from the presence of very low chloride concentrations in streambed deposits. These topographically induced Type 4 zones are shown in Figure 3-14 and one of which is associated with a cobble bar on transects 34-34W and 36-36W. Streambed temperatures at Type 4 locations correspond closely to surface water temperatures because vertical flow of groundwater is essentially zero, although temperatures may also be influenced by transient effects and the duration and depth of horizontal migration of the surface water through the deposits. Overall Type 4 areas account for about 3 % of the area investigated.

3.5.5 Type 5: Recharge

Type 5 "recharge" behavior occurs when hydraulic gradients between the river and the streambed indicate downward flow of surface water (i.e. the river water is recharging, or flowing into, the subsurface deposits). Recharge occurs most commonly when the river stage is higher than the adjacent watertable and so the river will lose water to the subsurface deposits, which can be essentially entire reaches of rivers in some cases. Several other processes can cause recharge on a small-scale, including topographically induced downwelling, substream flow, and convective bed transport.

Recharge behavior was not directly observed at the site (i.e. all streambed piezometers showed upward flow), but it can be inferred. For example, recharge likely occurred upgradient of Type 4 areas in order for surface quality water to be present in the subsurface. Groundwater fluxes calculated using the streambed temperature mapping (Figures 3-9a and 3-9b) also suggested recharge could be occurring over a larger area of the riffle on the northern part of the site. Although the sand, gravel, and cobble deposits and hydraulic gradients of a riffle might be conducive of this type of behavior, it was not confirmed by geochemical or hydraulic measurements. So the Type 5 areas shown in this riffle zone in Figure 3-14 might also be Type 4 behavior instead. Type 5 recharge areas account for 9% or less of the area investigated.

3.6 CONCLUSIONS

Streambed temperature mapping, mini-piezometer installation and testing, and geochemical analyses of streambed interstitial water provided both a qualitative and quantitative understanding of groundwater discharge into a river from which a flux-based conceptual model for discharge through the streambed was developed. Vertical groundwater flux estimates calculated using Darcy's law, hydraulic conductivities obtained by slug testing, and water level data measured at 34 mini-piezometers showed the flux to range from 0.03 to 446 L/m^2d but could be as high as 7060 L/m^2d at one location. The distribution of low-hydraulic-conductivity clayey-silt semi-confining deposits played a key role in determining which areas were low flux versus high flux areas. Streambed temperature mapping showed summer and winter patterns of temperature that were consistent with the mini-piezometer flux results with high discharge locations being associated with relatively cool areas of the streambed in summer and the relatively warm areas of the streambed in winter. An empirical relationship was developed between streambed temperatures and the fluxes determined at mini-piezometers which allowed the large amount of finely-spaced streambed temperature data to be converted into flux data. The second-order polynomial fit was relatively good over the range of streambed temperatures observed, but the relationship becomes non-unique when streambed temperatures are essentially equal to either the surface water or groundwater temperatures (i.e. at very high and very low fluxes). The empirical fit was best ($R^2= 0.81$) during the winter when the streambed temperatures were the least affected by short-duration changes in surface water temperature. The geochemical data provided valuable information regarding the origin of the interstitial water in the streambed that could not be provided by the temperature mapping or hydraulic testing of the piezometers. Low concentrations of chloride were used to infer the presence of surface water in the streambed while PCE and its degradation products were used to infer the presence of groundwater from the east side of the river.

A conceptual model of groundwater discharge was developed that consisted of 5 basic types of behavior, which, unlike previous models, subdivides the behaviors based on the relative magnitude of fluxes. Type 1 behavior is the "short-circuit discharge", which are relatively localized, high-discharge springs. Type 2 is the "high discharge" zone (>200 L/m^2d), which represent upwelling zones and preferred groundwater flow paths through high hydraulic conductivity geological windows located within otherwise low hydraulic conductivity streambed deposits. High discharge zones represented only about 5 to 7% of the area of the streambed, but account for about 21 to 24% of the total discharge to the river at this site. Type 3 behavior is the "low to medium discharge" zone (0 to 200 L/m^2d), consisting of lower hydraulic conductivity deposits or low gradients or both and makes up about 76% of the streambed at this site. Type 4 behavior is the "no discharge" zone, where there is no vertical discharge of water. This type of behavior was relatively uncommon at this site and was directly observed as hyporheic flow and topographically induced convective bed transport at only at few locations. Type 5 behavior is the "recharge" zone where surface water flows down into the streambed deposits. This behavior was not directly observed at any mini-piezometer location but can be inferred to exist because surface water is present in the streambed. Both the conceptual model and empirical approach to calculating fluxes are useful tools that can be applied to characterize and interpret other sites, but care should be taken to recognize the underlying assumptions.

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Table 3-1. Hydraulic conductivity determined from slug testing of mini-piezometers and calculations of vertical flux and average linear groundwater velocity.

Name	Location (A)	Material at Screen (B)	K_h (C) cm/s	K_v (D) cm/s	Por. (F) %	Head Dif. (H) cm	Grad.(I) (-)	Vertical Flux (q_v) L/m^{2}d	Vertical Velocity (V_v) m/d
SP4	2-2W 5.23m	Sand	7.66x10^{-3}	5.86x10^{-3}	44.5 (G)	2.7	0.047	239.93	0.54
SP5	4-4W 4.09m	Sand	1.14x10^{-2}	8.76x10^{-3}	42.1	1.9	0.034	256.83	0.61
SP6	4-4W 5.11m	Sand	1.20x10^{-2}	9.22x10^{-3}	45.0	2.0	0.033	263.25	0.59
SP7	4-4W 5.95m	Sand	2.15x10^{-2}	1.65x10^{-2}	44.5 (G)	1.9	0.031	445.67	1.00
SP8	6-6W 4.09m (MLS16)	Sand	6.70x10^{-3}	5.12x10^{-3}	44.1	1.0	0.016	69.19	0.16
SP9	6-6W 5.29m (RC4, PRP15, MLS17)	Sand	2.01x10^{-2}	1.54x10^{-2}	52.2	1.5	0.024	321.62	0.62
SP10	6-6W 7.93m (RC5, MLS19)	Sand & Silt	1.22x10^{-3}	9.30x10^{-4}	47.5(G)	2.5	0.039	31.16	0.066
SP11	8-8W 7.55m (RC6)	Sand & Silt	1.33x10^{-3}	1.02x10^{-3}	47.5(G)	2.7	0.041	36.04	0.076
SP12	10-10W 4.20m (RC7)	Sand	1.11x10^{-2}	8.46x10^{-3}	47.4	0.3	0.005	33.72	0.071
SP13	12-12W 5.55m	Sand	6.55x10^{-3}	5.01x10^{-3}	46.1	0.4	0.007	28.39	0.062
SP14	12-12W 8.43m (RC8)	Sand	2.52x10^{-2} (E)	1.93x10^{-2} (E)	42.9	0.8	0.013	221.85	0.52
SP15	14-14W 2.01m	Sand & Silt	1.33x10^{-3}	1.02x10^{-3}	47.5(G)	2.3	0.036	31.64	0.067
SP16	14-14W 4.15m (RC9)	Sand & Silt	6.92x10^{-3}	5.29x10^{-3}	47.5(G)	0.4	0.006	27.72	0.058
SP17	14-14W 5.60m	Sand	1.87x10^{-2}	1.43x10^{-2}	42.9	0.2	0.003	36.98	0.086
SP18	14-14W 7.07m (RC10)	Sand	1.84x10^{-2}	1.41x10^{-2}	43.0	0.6	0.010	117.83	0.27
SP19	14-14W 8.04m	Sand	2.02x10^{-2}	1.54x10^{-2}	44.3	0.7	0.010	135.30	0.31
SP20	16-16W 1.52m (MLS1)	Silt & Clay	7.85x10^{-6}	6.01x10^{-6}	51.4	5.0	0.079	0.41	0.00080
SP21	16-16W 4.30m (MLS4)	Sand	1.83x10^{-2}	1.40x10^{-2}	45.2	0.6	0.009	103.91	0.23
SP22	16-16W 6.21m (RC11)	Sand	1.96x10^{-2}	1.50x10^{-2}	43.9	0.2	0.003	41.20	0.094
SP23	16-16W 8.12m	Sand	8.92x10^{-3}	6.83x10^{-3}	43.3	0.5	0.010	60.21	0.14
SP24	16-16W 10.60m	Sand & Silt	2.48x10^{-4}	1.90x10^{-4}	47.5(G)	2.6	0.044	7.28	0.015
SP25	18-18W 4.09m (RC1, PRP7)	Silt & Clay	1.22x10^{-3}	9.34x10^{-4}	55.9(G)	0.7	0.011	8.69	0.016

Name	Location (A)	Material at Screen (B)	K_h (C) cm/s	K_v (D) cm/s	Por. (F) %	Head Dif. (H) cm	Grad.(I) (-)	Vertical Flux (q_v) L/m^{2}d	Vertical Velocity (V_v) m/d
SP26	18-18W 6.13m (RC2, PRP8)	Silt & Clay	2.48×10^{-4}	1.90×10^{-4}	55.9(G)	0.7	0.012	1.95	0.0035
SP27	18-18W 7.74m (PRP17)	Sand	1.26×10^{-2}	9.64×10^{-3}	45.1	0.4	0.007	56.47	0.13
SP28	18-18W 9.11m (PRP9)	Sand	2.15×10^{-2}	1.64×10^{-2}	44.6	0.4	0.007	96.34	0.22
SP29	18-18W 11.14m (PRP10)	Sand & Silt	2.10×10^{-3}	1.61×10^{-3}	47.5(G)	4.3	0.069	96.23	0.20
SP30	24-22W 5.50m (PRP2)	Silt & Clay	5.80×10^{-6}	4.44×10^{-6}	55.9(G)	6.8	0.108	0.41	0.00074
SP31	24-22W 7.07m (RC12)	Silt & Clay	9.02×10^{-6}	6.90×10^{-6}	55.9(G)	0.3	0.005	0.029	0.000051
SP32	24-22W 8.44m (PRP3)	Sand	2.51×10^{-2} (E)	1.92×10^{-2} (E)	44.4	1.2	0.020	329.09	0.74
SP33	24-22W 11.39m (PRP4)	Sand & Silt	4.88×10^{-3}	3.73×10^{-3}	47.5(G)	1.9	0.031	98.83	0.21
SP34	28-28W 2.02m	Sand	2.63×10^{-2} (E)	2.02×10^{-2} (E)	51.1	23.3	0.405	7059.78	13.81
SP35	28-28W 5.92m (PRP13)	Sand & Silt	4.99×10^{-4}	3.82×10^{-4}	47.5(G)	5.4	0.084	27.81	0.059
SP36	36-36W 2.53m (PRP5)	Sand	1.23×10^{-2}	9.42×10^{-3}	43.9	0.6	0.010	78.79	0.18
SP37	34-34W 8.55m (PRP6)	Sand & Silt	7.10×10^{-4}	5.43×10^{-3}	71.7	1.0	0.016	7.45	0.010

Notes:

(A) Transect location and distance and names of adjacent soil cores or water sampling locations

(B) Materials at well screen determined from coring or inferred from surficial geology and GPR data

(C) Kh = horizontal hydraulic conductivity calculated using Hvorslev (1951) variable-head equation, an ansiotropic ratio of K_h/K_v = 1.248, and corrected to 10 °C

(D) Kv = vertical hydraulic conductivity calculated using Hvorslev (1951) variable-head equation, an ansiotropic ratio of K_h/K_v = 1.248, and corrected to 10 °C

(E) Hydraulic conductivity value above reliable limit for testing equipment, actual value could be higher

(F) Porosity from TDR measurements made immediately adjacent to the piezometer

(G) TDR porosity either not measured or not representative of deeper deposits so assigned average value for material

(H) Head difference measured between center of screen and top of streambed on Nov 3 to 6, 1998 except for SP34 and SP35 measured on Dec 10, 1998

(I) Vertical hydraulic gradient at the mini-piezometer location

Table 3-2. Summary of flow characteristics for the 5 different types of discharge behaviors of the conceptual flow model.

Flow Type	Origin of water	Temperature of Streambed Deposits	Vertical flux range (L/m^{2}d)	Vertical velocity range (m/d)	Residence time of water in streambed	Percent of Streambed Area[A]	Percent of total GW discharge[B]
1) Short-Circuit Discharge	GW	Same as GW	> 1[F] (L/min)	> 10	minutes to hours	~ 0.0002	3.8
2) High Discharge	GW	Close to GW	> 200	0.5 to 13.8	5 hours to 6 days	3.8	20
3) Low to Medium Discharge	GW	Between GW and SW	0 to 200	0.00005 to 0.5	6 days to 8 years	84.6	76.2
4) No Discharge	GW, SW, or a mixture	Close to SW	0	0[C]	Depends on length of flow path	3[E]	0
5) Recharge	SW	Same as SW	< 0	ND[D]	Depends on length of flow path	8.6[E]	-0.5

Notes:

[A] The total area is defined to be the area of river between transect -4 - -4W and 56-56W using the winter flux data

[B] The percent discharges are calculated for the area between transects -4 - -4W and 56-56W for winter data only

[C] No vertical flow but there could still be horizontal flow

[D] Vertical velocities were not determined for this type of flow but are likely quite low.

[E] The Type 4 and 5 areas are not exact and may include portions of the other area other

[F] The flux is the total for a spring so is expressed in liters per minute

GW = groundwater

ND = not determined

SW = surface water

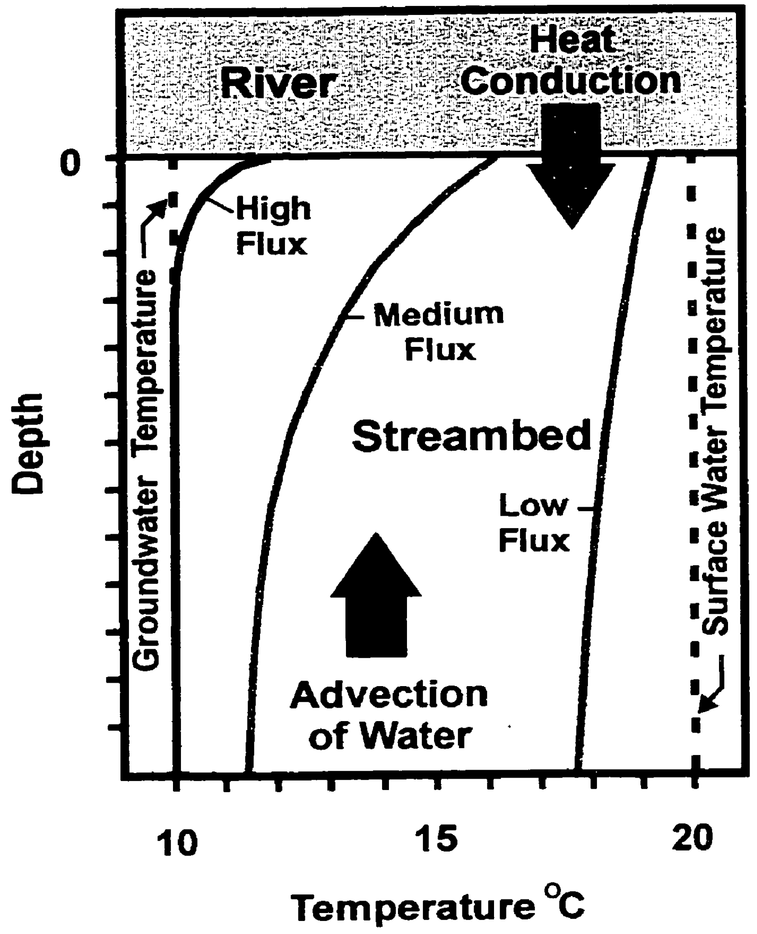


Figure 3-1. Schematic of temperature versus depth profiles in a streambed in the summer for high, medium, and low groundwater flux conditions. The distinctive profiles are a result of competing heat conduction and groundwater advection processes and will vary as surface water or groundwater temperatures change.

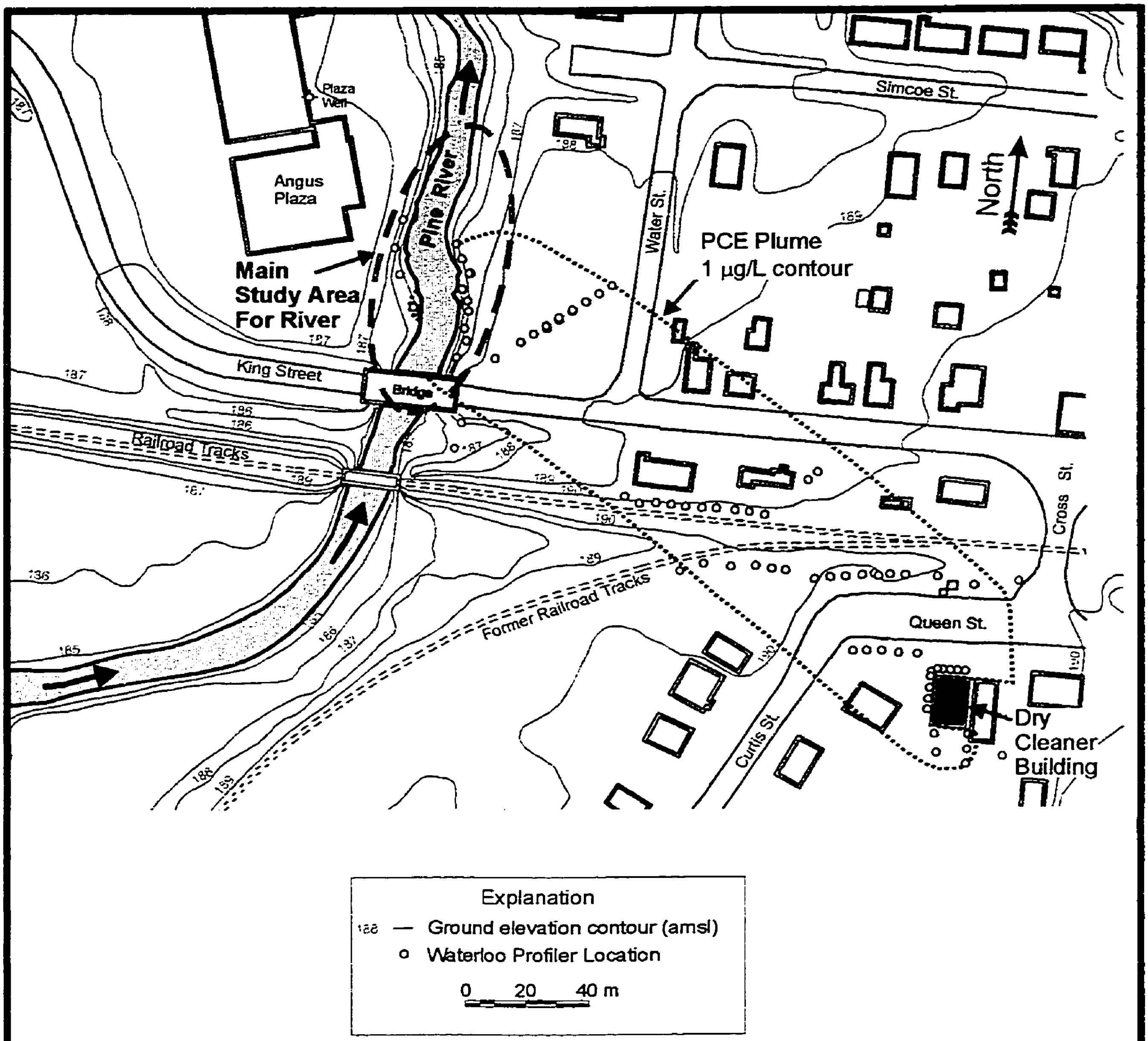


Figure 3-2. Map of dry cleaner site, Angus, Ontario, Canada, showing the location of the PCE plume (1 µg/L contour), land based Waterloo Profiler locations, ground elevation contours, and the main study area along the Pine River.

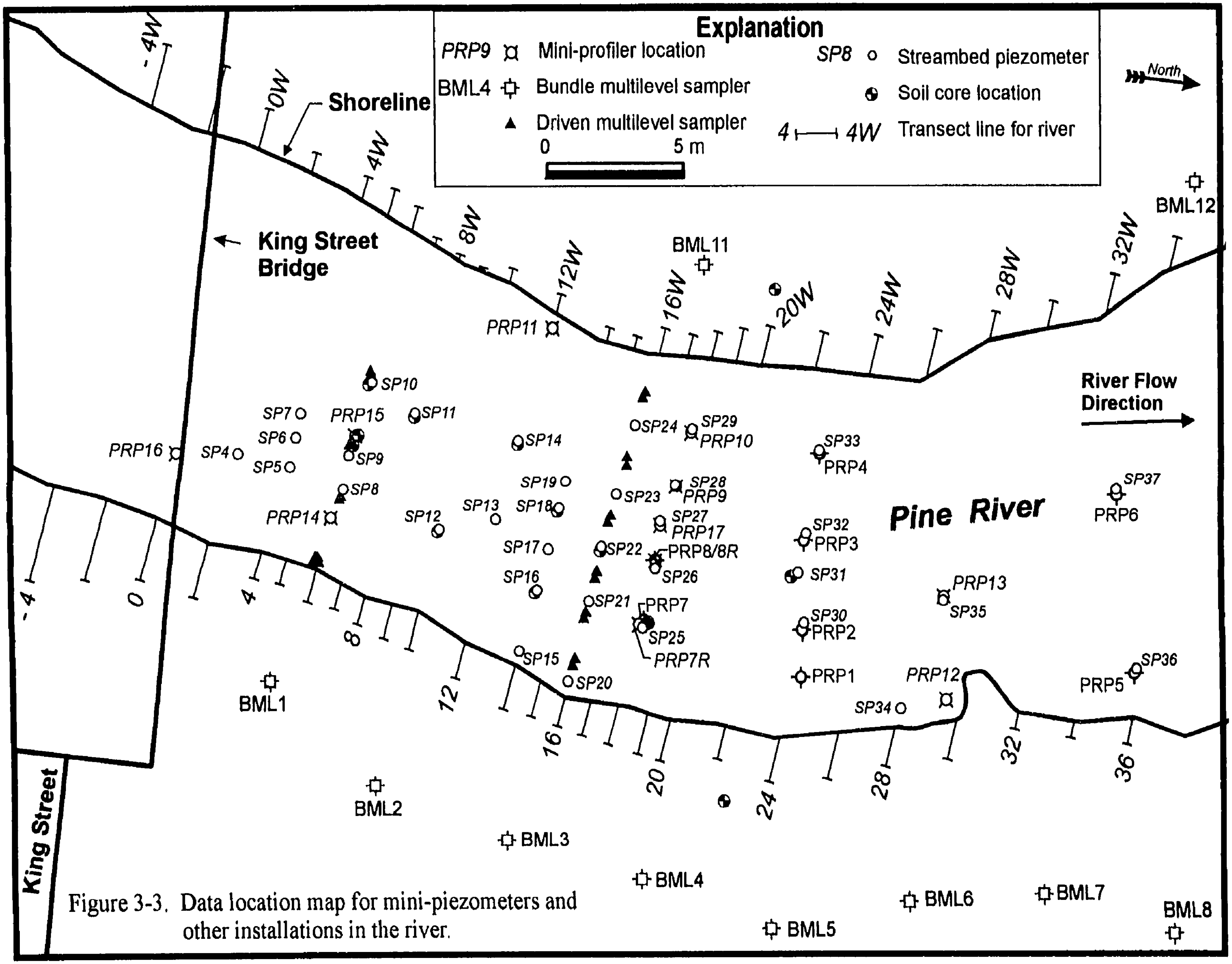


Figure 3-3. Data location map for mini-piezometers and other installations in the river.

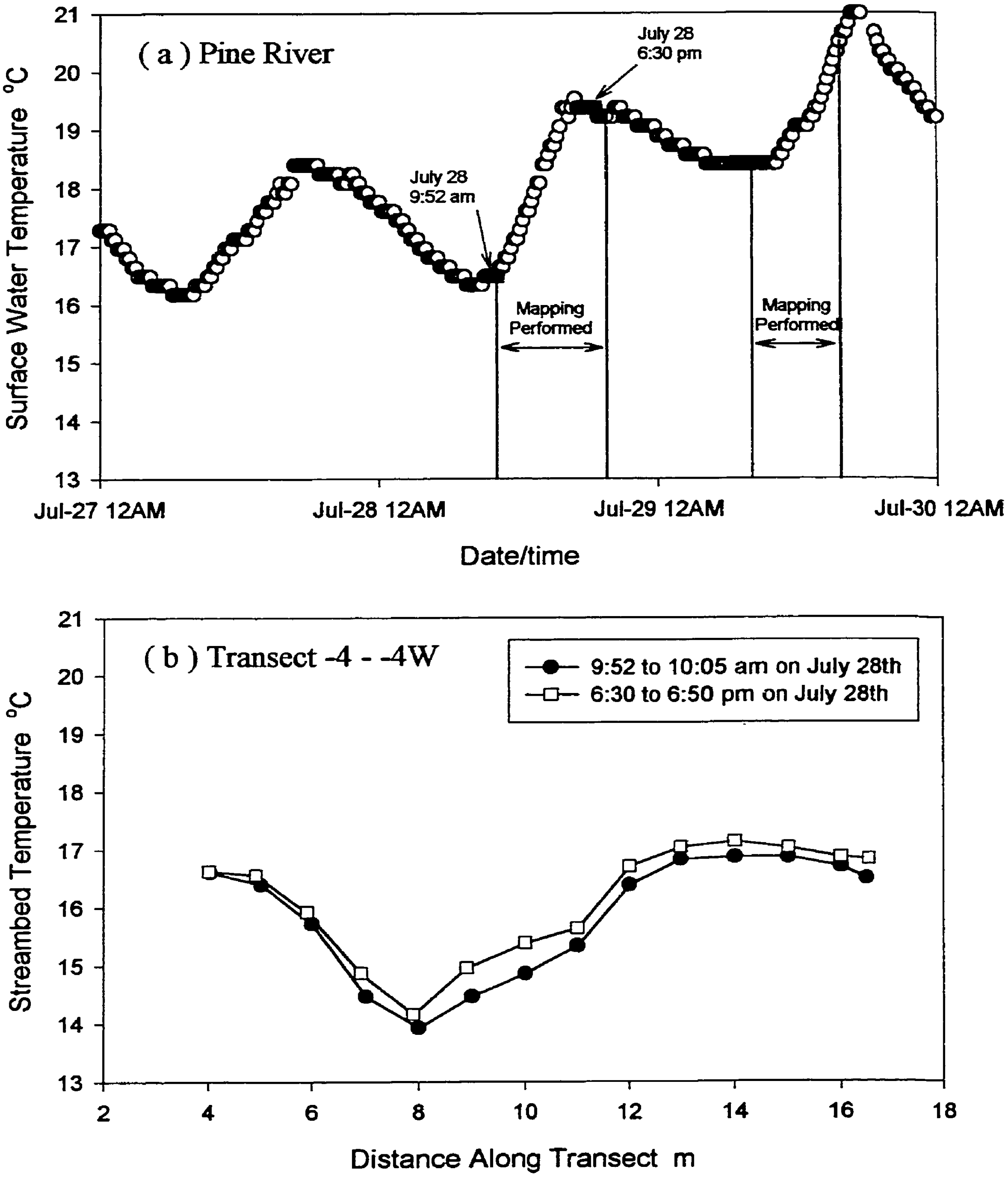


Figure 3-4. (a) Surface water temperatures versus time around the July 1998, mapping of streambed temperatures. The times as which streambed temperatures were measured along transect - 4 - -4W are shown. (b) Streambed temperatures measured along transect -4 - -4W at two different times during the July 1998, streambed mapping which showing good reproducibility during mapping.

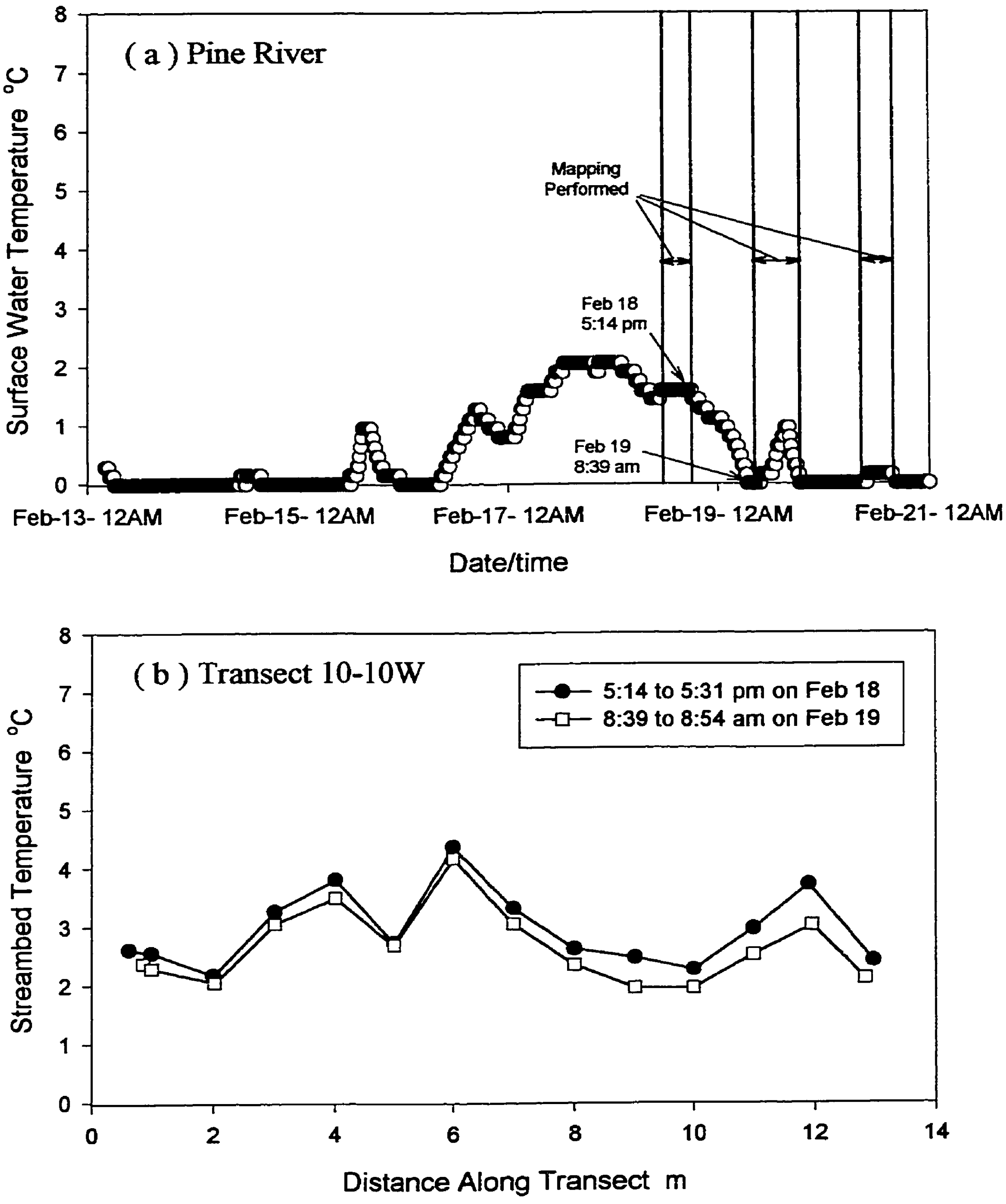


Figure 3-5. (a) Surface water temperatures versus time around the February 1999, mapping of streambed temperatures. The times as which streambed temperatures were measured along transect 10-10W are shown. (b) Streambed temperatures measured along transect 10-10W at two different times during the February 1999, streambed mapping which showing good reproducibility during mapping.

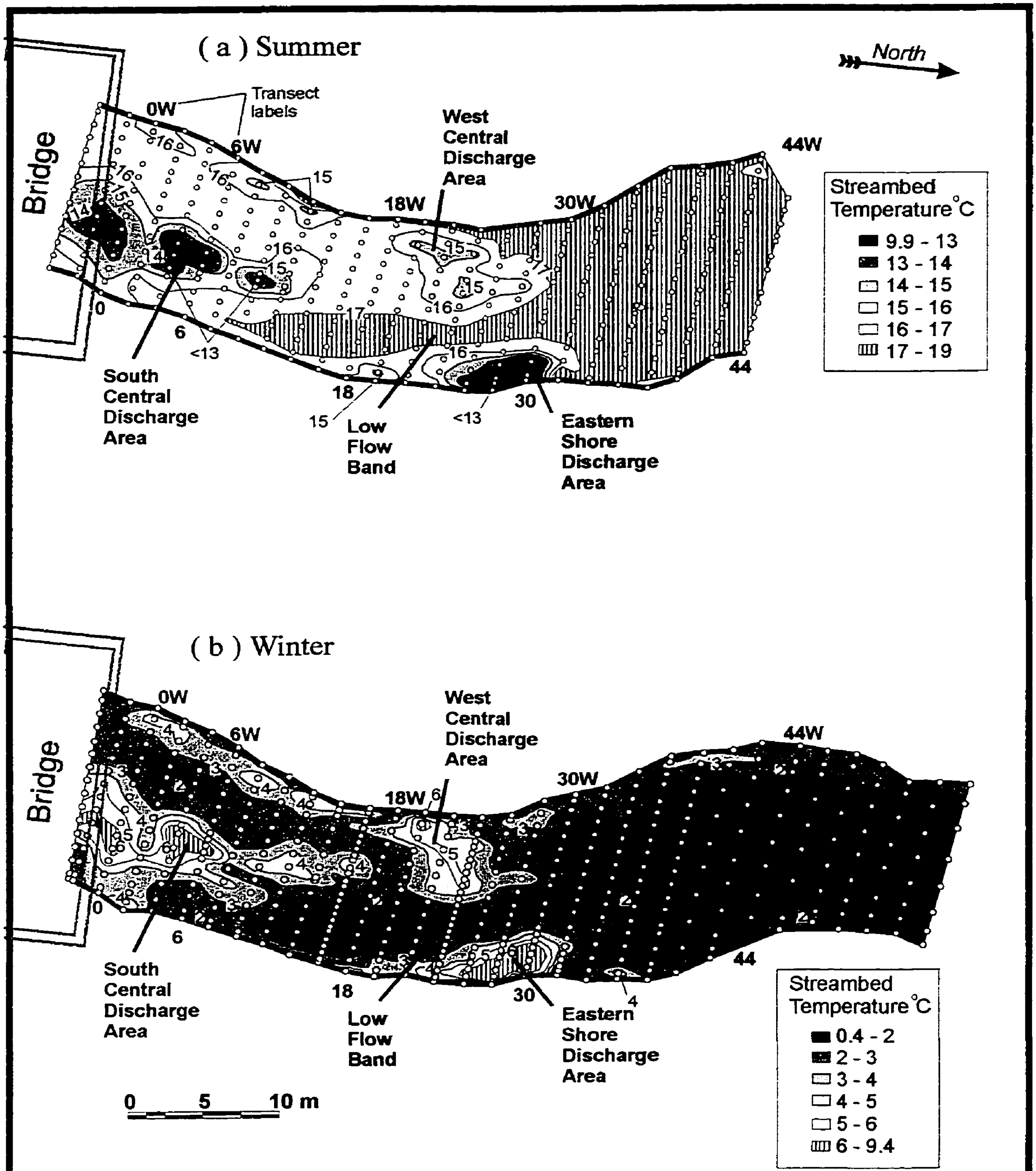


Figure 3-6. Streambed temperatures measured at a depth of 0.3 m in (a) summer on July 28 to 29, 1998 and (b) winter on February 18 to 20, 1999. Open circles indicate temperature measurement locations along transects. Areas of inferred high and low discharge are indicated.

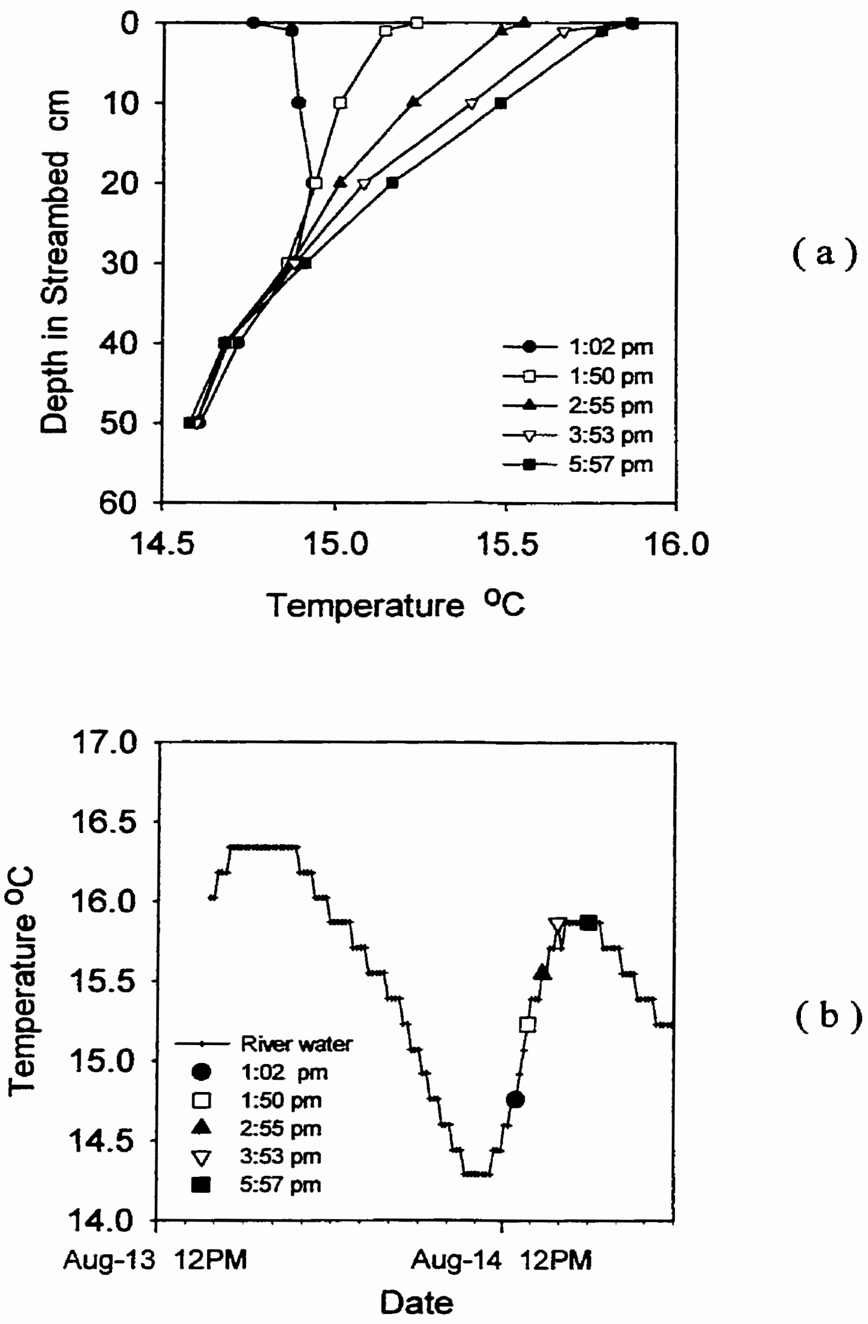
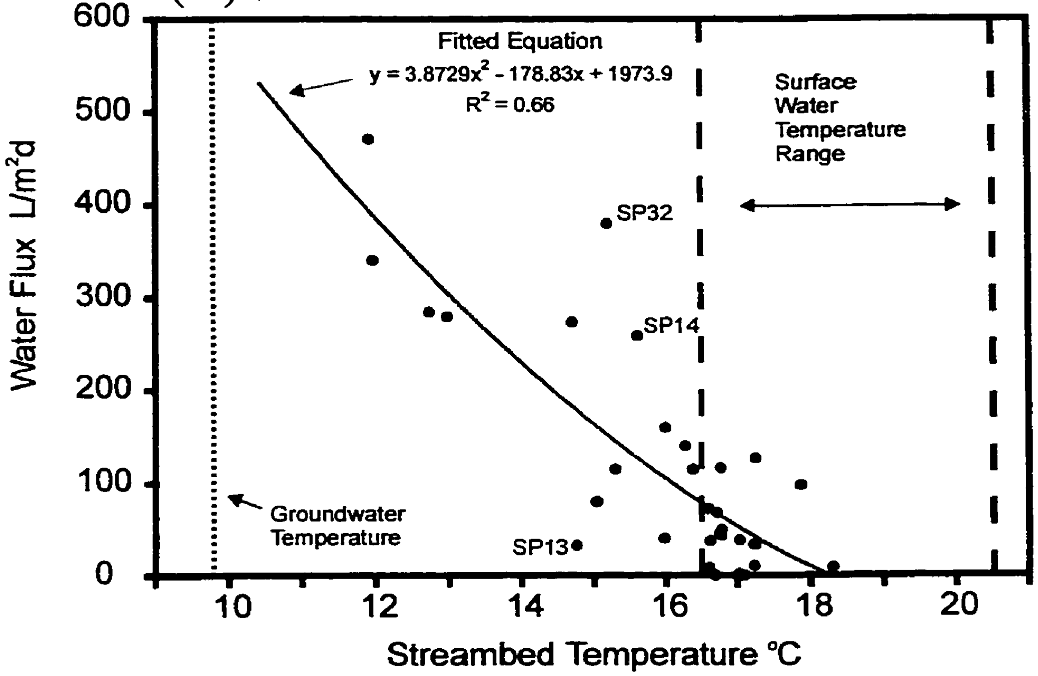


Figure 3-7. (a) Vertical profiles of streamed temperatures in sand at PRP9 measured at 5 different times on August 14, 1997. (b) Surface water temperatures measured before and during the time of the measurements at PRP9.

(a) Summer



(b) Winter

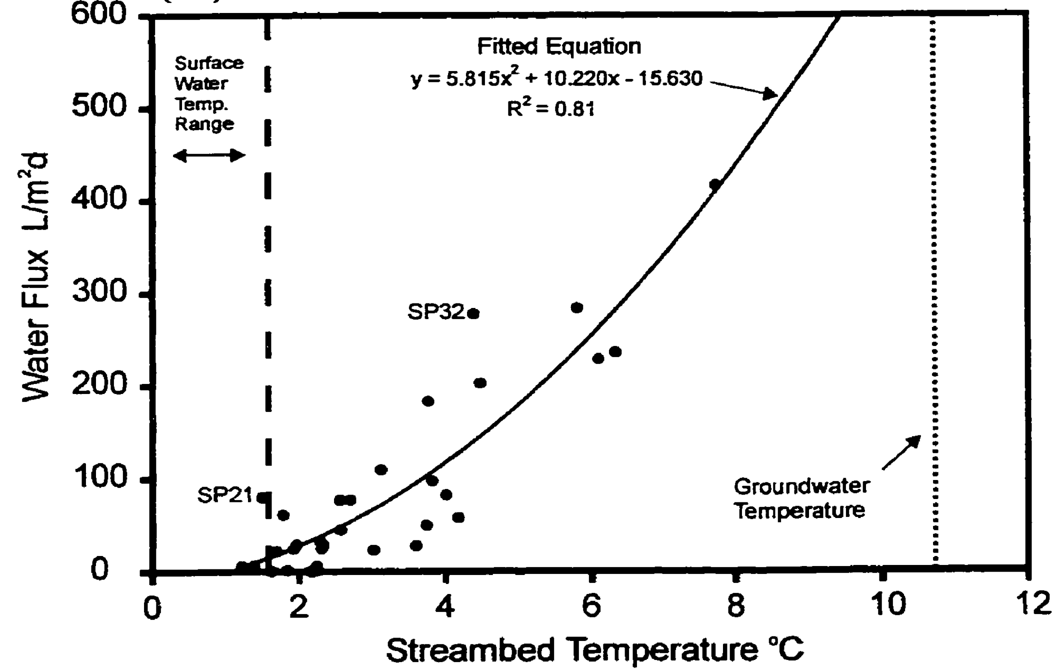


Figure 3-8. Darcy fluxes calculated from piezometer testing versus streambed temperatures at each piezometer location for (a) summer and (b) winter mapping conditions. The data in each graph has been empirically fitted with a second order polynomial and the equation shown. Fitted curve and graphs do not include high flux data for SP34. Names of outliers are shown on graphs.

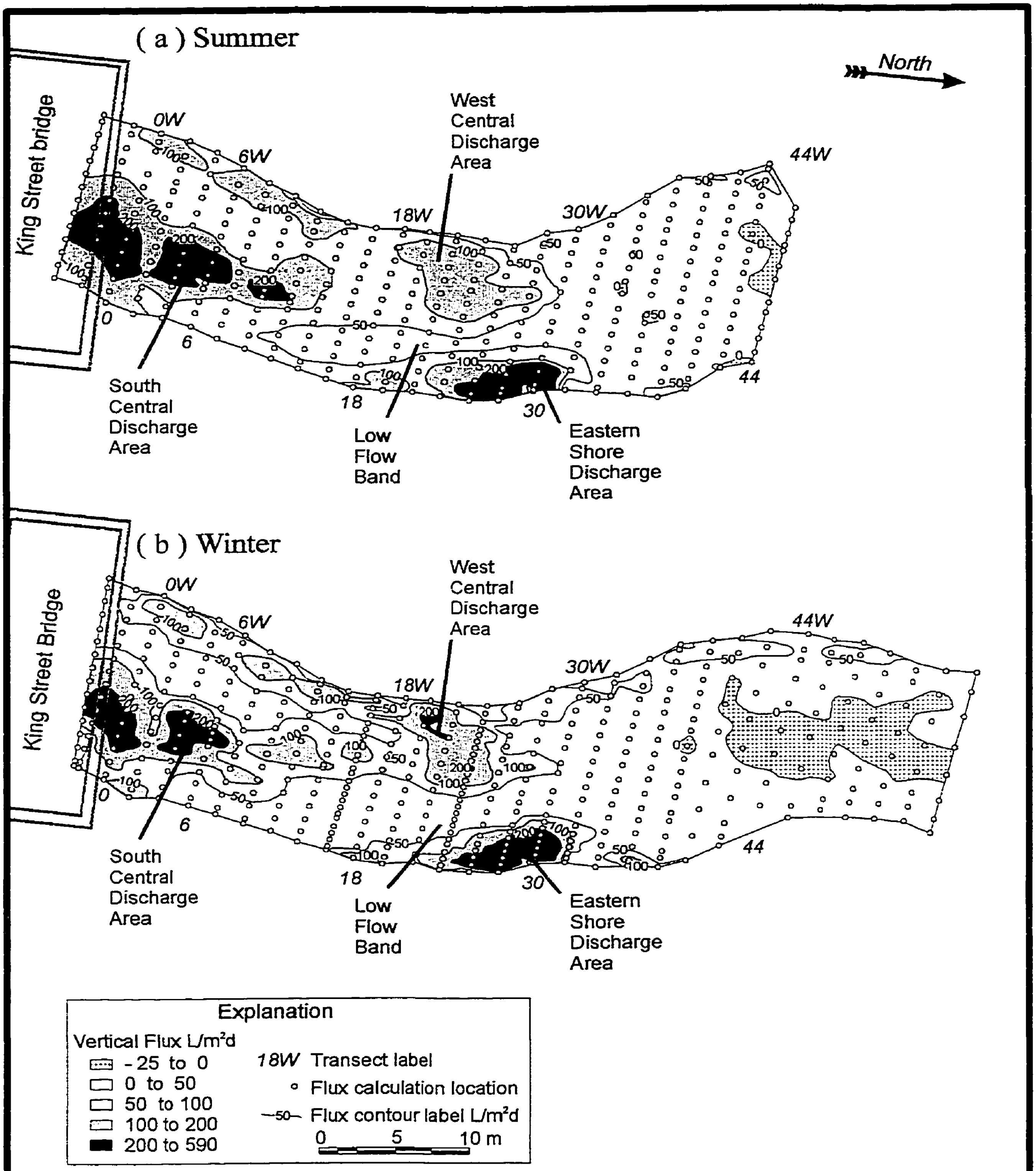


Figure 3-9. Plan-view contour maps of vertical water fluxes calculated using the empirical relationships for (a) summer (July 28 to 29, 1998) and (b) winter (February 18 to 20, 1999). Areas of high and low discharge inferred from temperature mapping are indicated.

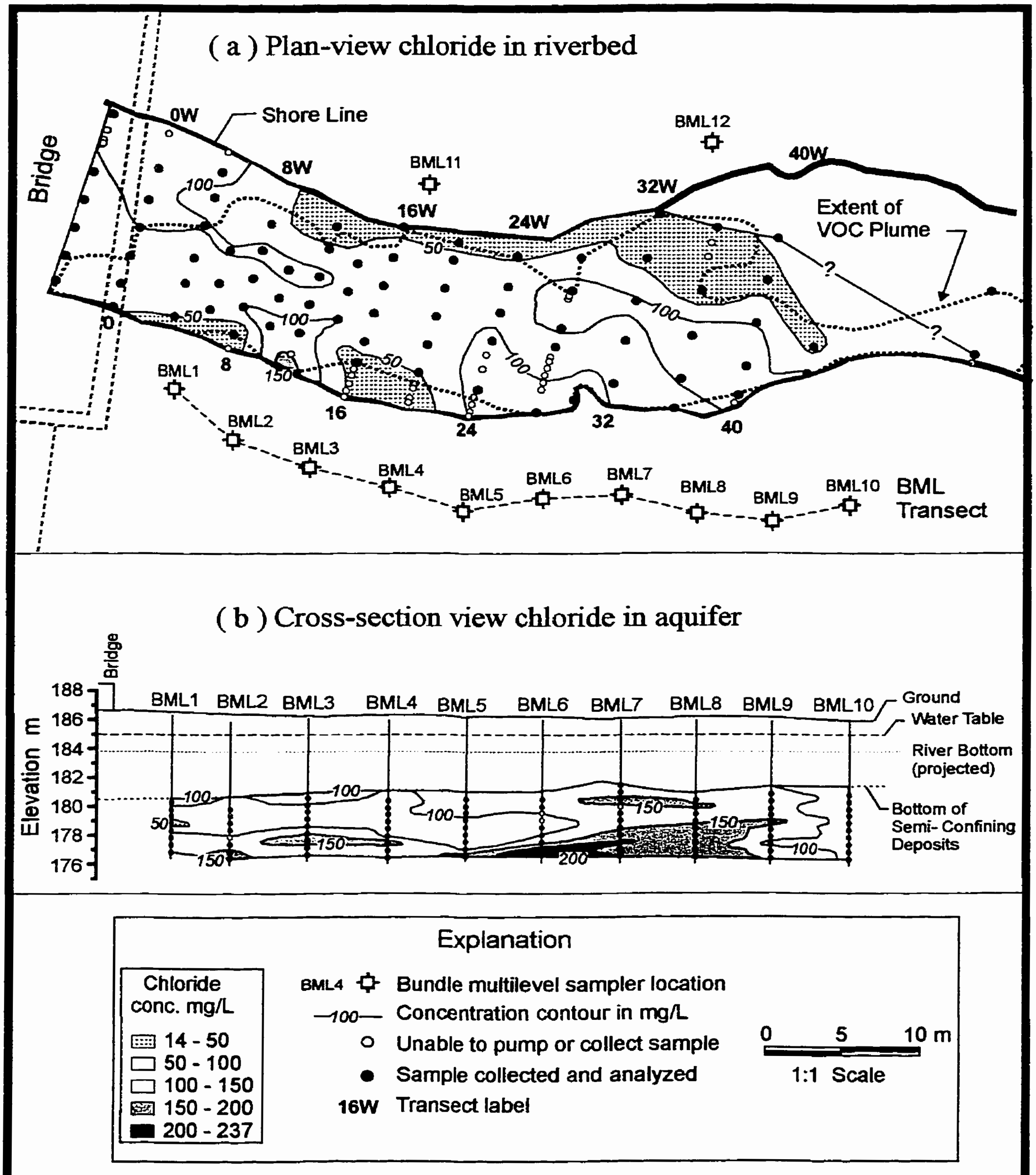
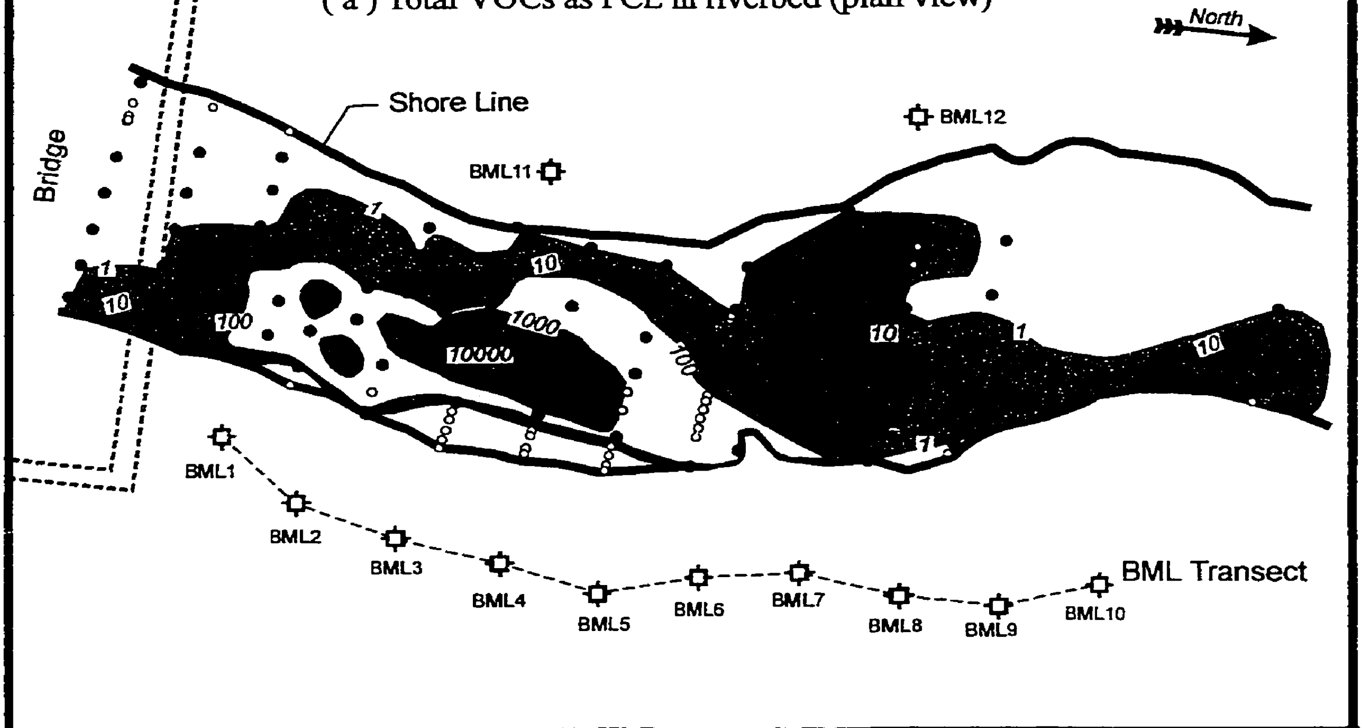


Figure 3-10. Concentrations of chloride (a) in plan view in the streambed at a depth of 0.3 m in August 1998, and (b) in cross-section view in the aquifer along the BML sampler transect east of the river in March 1999. Concentrations less than 34 mg/L in (a) may be indicative of surface water in the streambed.

(a) Total VOCs as PCE in riverbed (plan view)



(b) Bundle multilevel samplers transect (cross-section view)

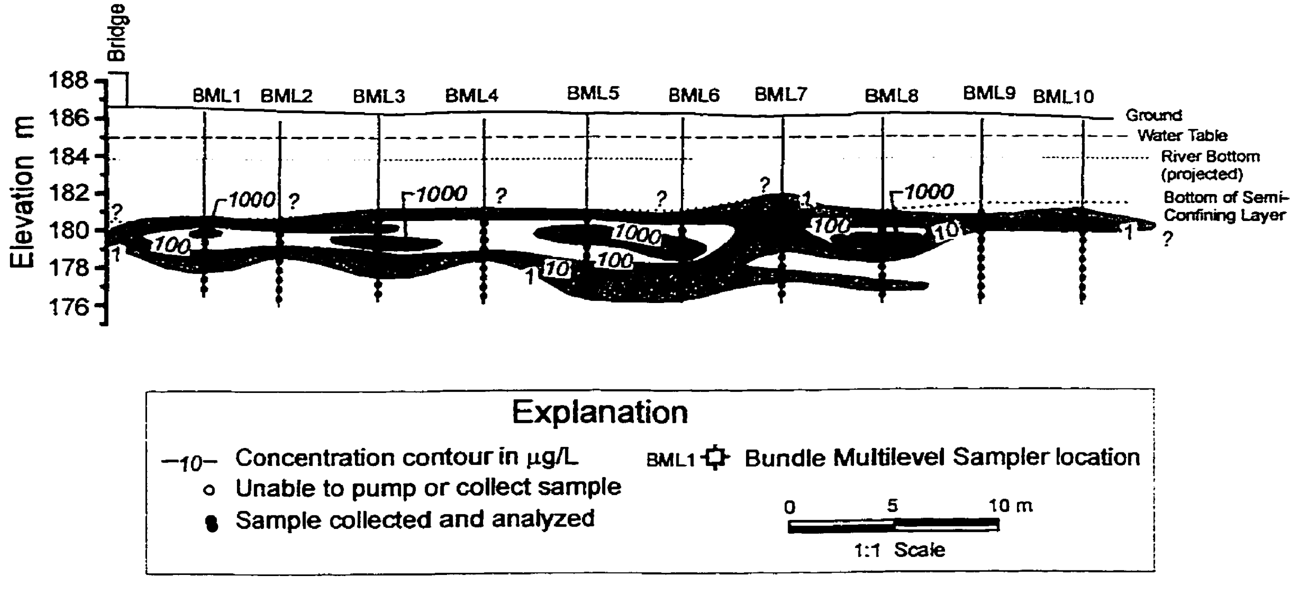


Figure 3-11. (a) Plan view of total VOCs concentrations expressed as equivalent PCE in streambed at a depth of 0.3 m in August 1998. Presence of VOCs indicates that the water originated as groundwater from the east (b) Cross-section view of PCE concentrations along BML transect sampled March 1999. Figures are at the same 1:1 scale.

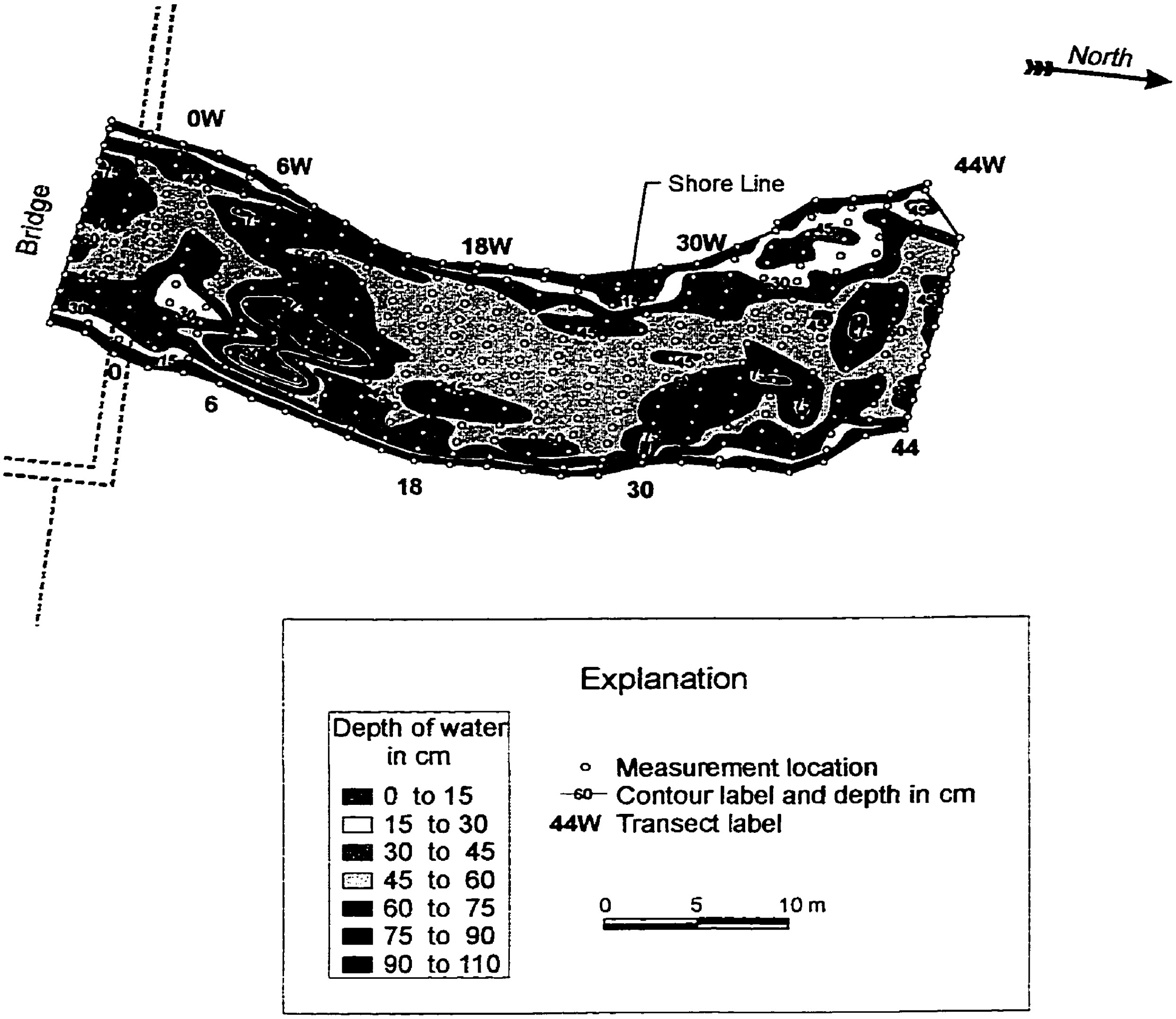


Figure 3-12. Plan view of streambed topography shown as depths of water on July 28 and 29, 1998. The river stage elevation was low at 184.49 to 184.52 m during measurements.

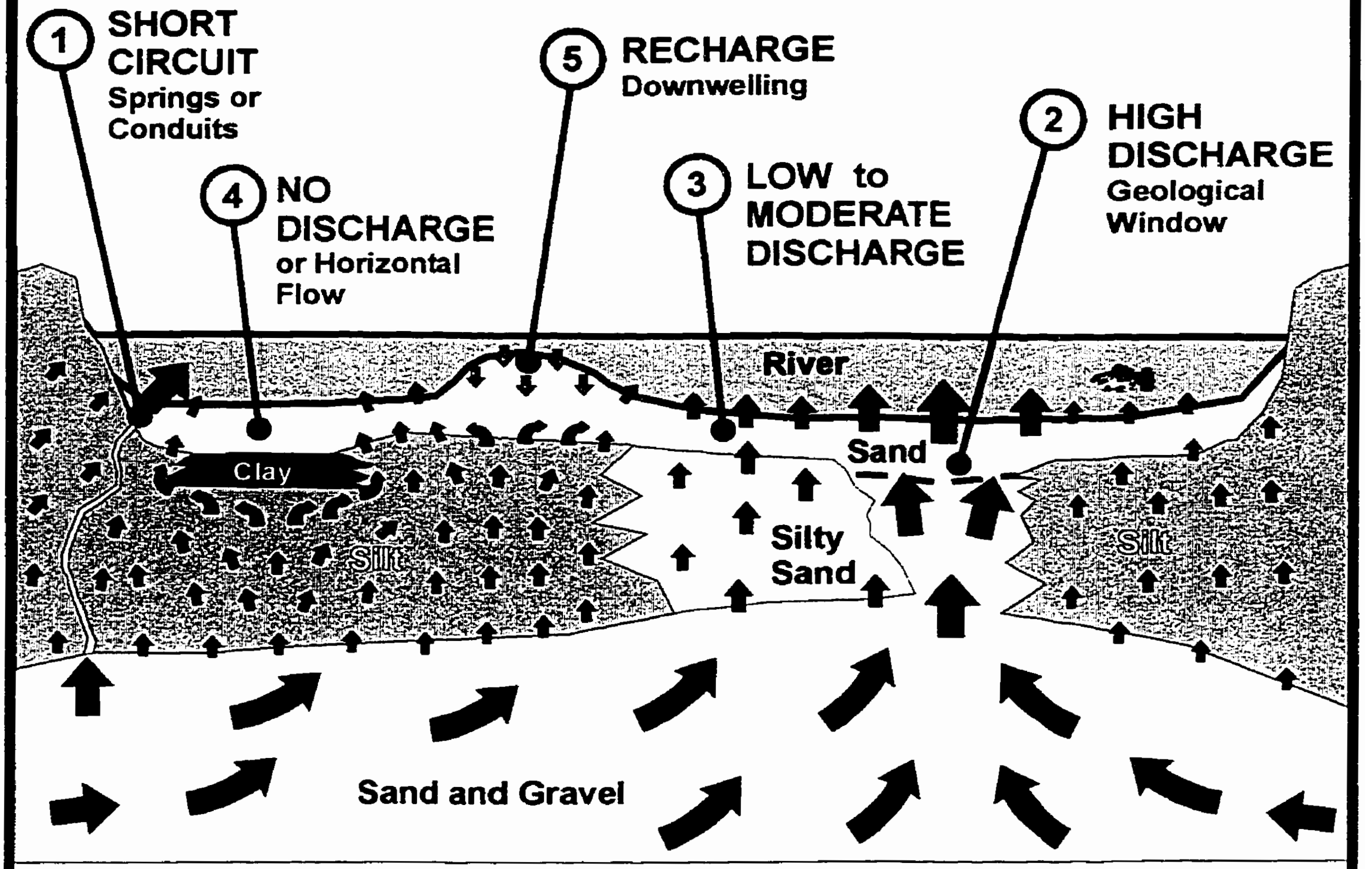


Figure 3-13. Conceptual model of 5 different types of flow beneath a river shown in cross section perpendicular to the direction of flow in the river. Arrows point in the direction of flow in the deposits and larger arrow sizes depict higher fluxes.

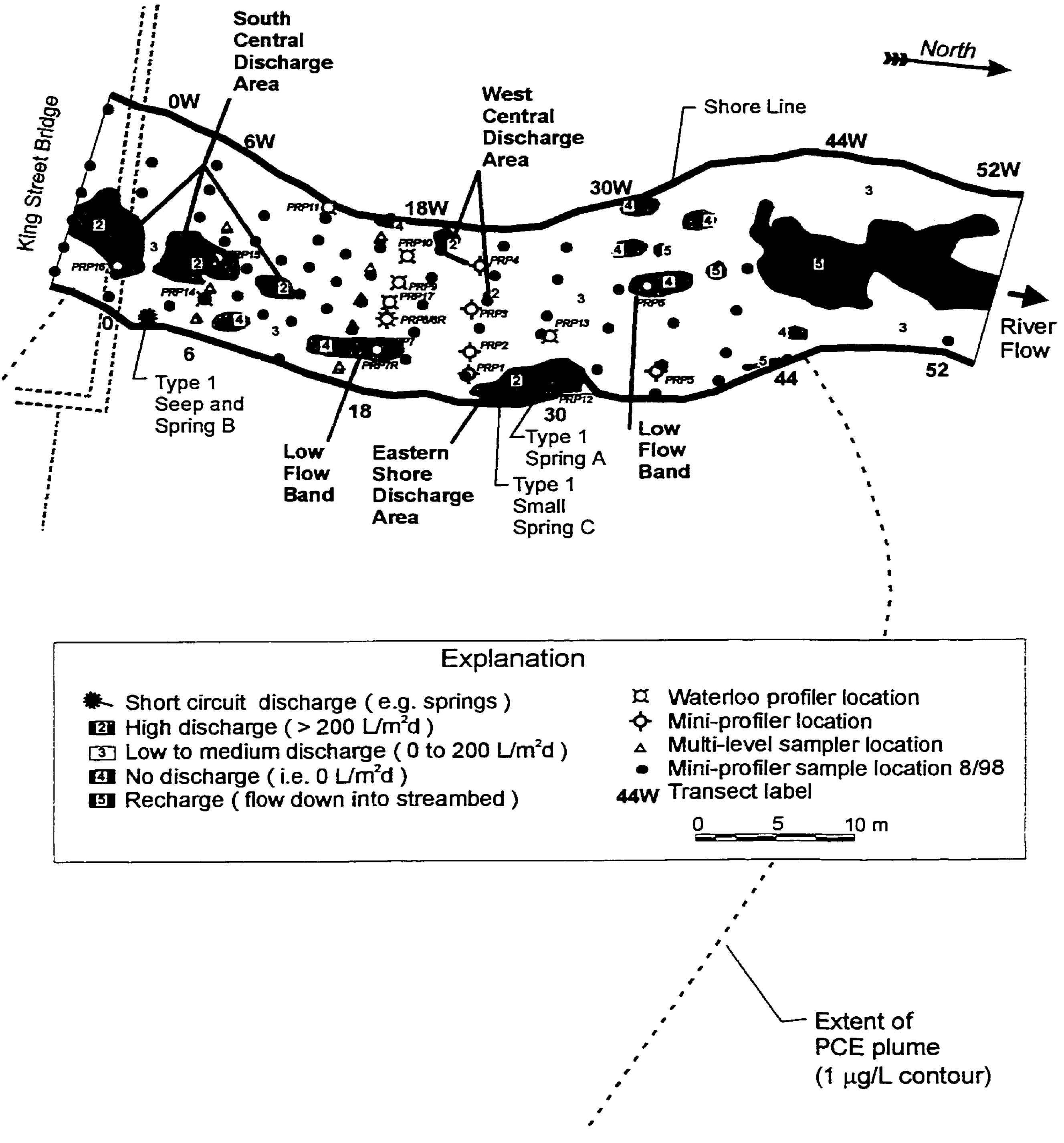


Figure 3-14. Plan-view of conceptual model for 5 different types of flow in streambed. The figure combines the behavior observed during the summer and winter mapping of fluxes and the geochemical data collected in summer. The maximum observed extent of Type 2 and Type 4 areas is shown hence the figure is a composite of conditions that have occurred over time. Type 4 areas may include Type 5 areas within them and vice versa but that were not delineated and are not shown.

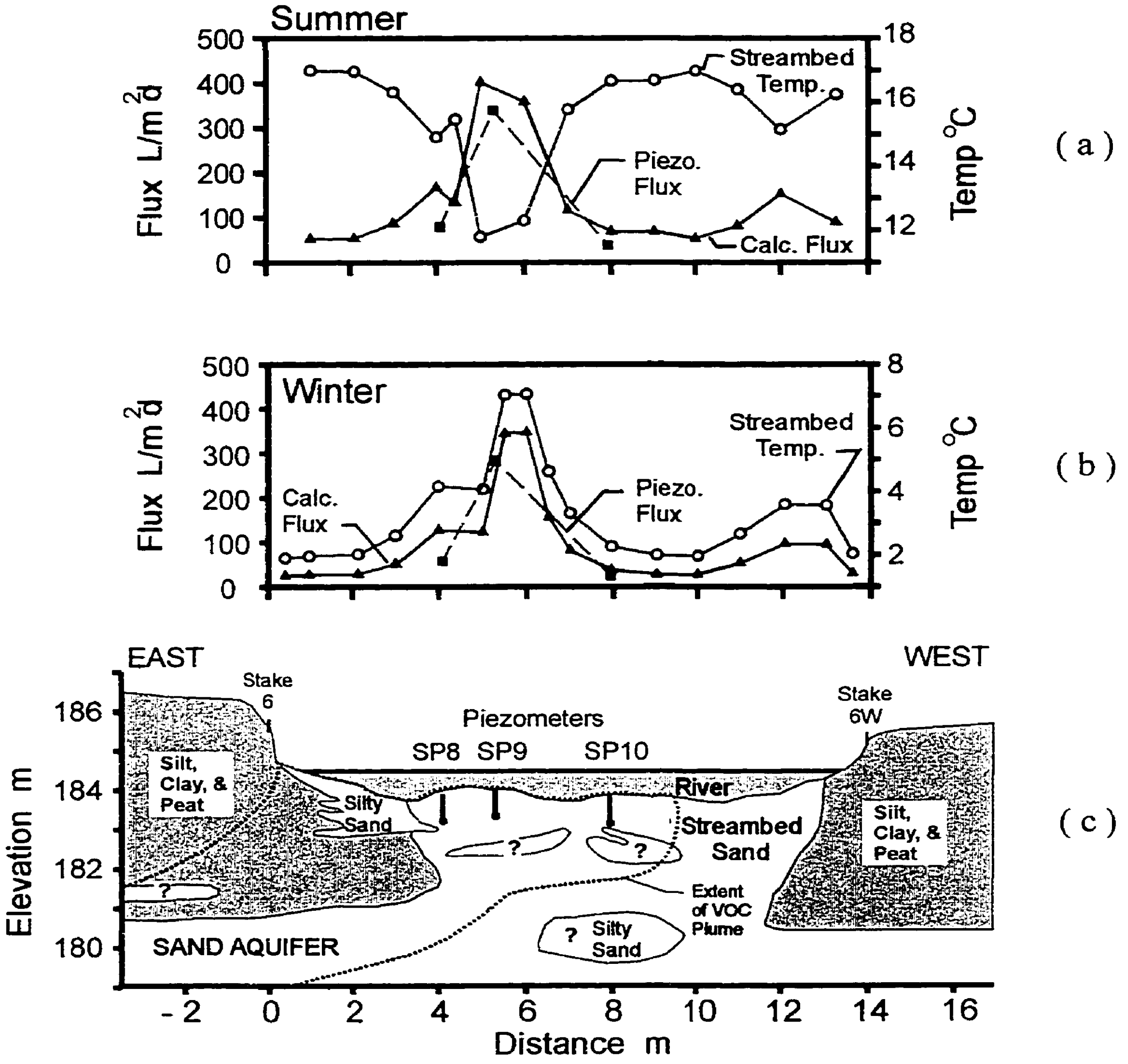


Figure 3-15. Graph of streambed temperature, flux obtained from piezometer data, and flux calculated from an empirical equation versus distance for transect 6-6W in (a) summer and (b) winter conditions. (c) Geological cross section along 6-6W showing location of streambed mini-piezometers that were tested and extent of the VOC plume in March 1999, (1 μg/L contour).

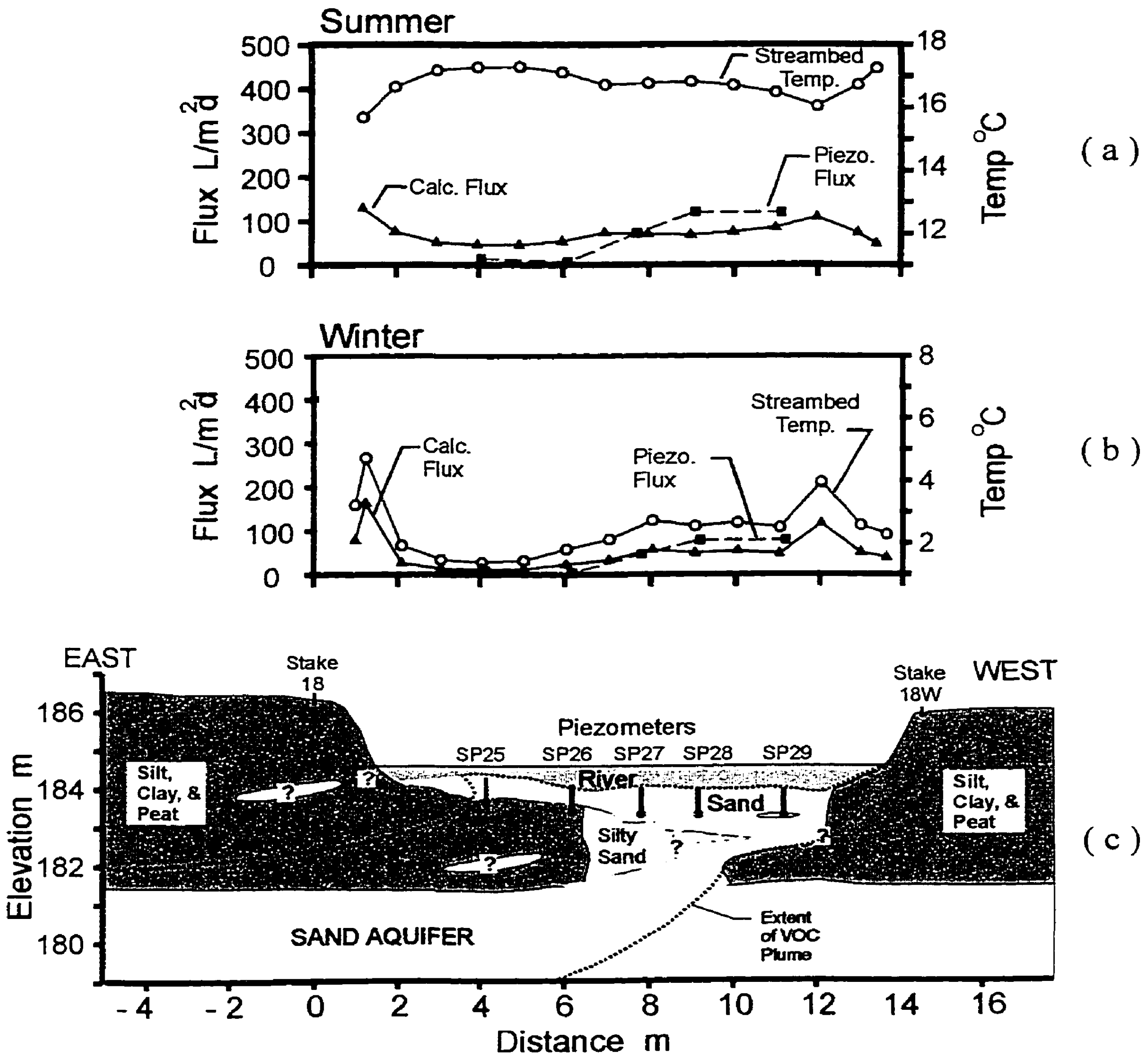


Figure 3-16. Graph of streambed temperature, flux obtained from piezometer data, and flux calculated from an empirical equation versus distance for transect 18-18W in (a) summer and (b) winter conditions. (c) Geological cross section along 18-18W showing location of streambed mini-piezometers that were tested and extent of the VOC plume in August 1997 (1 µg/L contour).

CHAPTER 4.

A PCE PLUME DISCHARGING THROUGH A RIVERBED: THE RELATIONSHIP BETWEEN WATER FLUX, GEOCHEMICAL CONDITIONS, BIODEGRADATION, AND MASS DISCHARGE

4.1 ABSTRACT

An exceptionally detailed investigation of a tetrachloroethene (PCE) groundwater plume discharging to a 60 m-long reach of a river showed a remarkably high degree of correlation between the extent of biodegradation, nature of redox conditions, and magnitude of the groundwater flux in the streambed. PCE biodegradation was quite spatially variable and virtually no evidence of PCE degradation was seen in high groundwater flux areas where water was typically anaerobic to nitrate reducing in the fine-sand streambed deposits. Complete transformation of PCE, primarily to cis-1,2-dichloroethene (cDCE) and vinyl chloride (VC) and to a lesser extent trichloroethene, 1,1-dichloroethene, trans-1,2-dichloroethene, ethene and ethane, occurred in nitrate reducing to methanogenic areas where groundwater fluxes were low. Active anaerobic biodegradation of PCE typically only occurred over very short vertical intervals (i.e. 0.45 to less than 0.15 m) either within or at interfaces with organic-rich silt and clay deposits in the upper most 2.5 m of the streambed. Because organic-rich deposits were typically low-hydraulic-conductivity deposits that caused low water flux, a conceptual model based on the direction and magnitude of water flux in the streambed was a useful framework for interpreting the complex pattern of interstitial-water quality and categorizing conditions into 5 different distinct types of behavior. Areas with the lowest fluxes (10 to 66 L/m^{2}d) were associated with the most reducing conditions (sulfate reducing to methanogenic) and the most dechlorination (ethane production). Overall, the mass of the PCE plume was significantly reduced as it traveled through the streambed; however, the PCE plume is undergoing only partial dechlorination in the streambed and not being significantly mineralized. About 41 to 46% of the total mass of contaminants (or about 26 to 29% of the moles) in the streambed was present as PCE, 40 to 44% as cDCE, 11 to 12% as VC, and only 2% as ethene and ethane. Despite nearly equal mass discharges for PCE and cDCE being diluted by river water, only PCE was occasionally detected in surface water and only at low concentrations ($\leq$ 23 μg/L), because PCE mass discharge to the river was focused in small areas of high groundwater flux (200 to 500 L/m^{2}d) while cDCE discharge was typically more diffuse. Direct evidence of cDCE or VC loss by aerobic degradation or oxidation was not observed at depths of 0.15 to 0.3 m, but may be occurring in the top few centimeters of the streambed.

4.2 INTRODUCTION

The fate of dissolved-phase groundwater contaminant plumes discharging into streams and rivers is not well understood, but these plumes have the potential to adversely affect benthic and hyporheic aquatic life in streambed sediments and the ecology of the surface water. There is now a renewed interest in understanding the processes controlling these discharges (USEPA, 2000). Groundwater plumes containing volatile organic compounds (VOCs), such as tetrachloroethene (PCE) and trichloroethene (TCE), account for a large number of all the contaminant plumes that have been discovered and many of these discharge, or have the potential to discharge, to streams and rivers (USEPA, 1989 and 1991). Some studies have examined VOC discharges to rivers using widely spaced seepage meters (Norman et al., 1986; Avery, 1994; Hess et al., 1989) or diffusion samplers (Vroblesky et al., 1991 and 1996; Savoie et al., 1999; Lyford et al., 1999). However, the published literature does not contain studies that evaluate the hydrogeology, geochemistry, and biodegradation in the near stream zone on a fine scale and its affect on the fate of an entire VOC plumes as it passes through this zone.

Recent investigations of a PCE plume discharging to the Pine River in Angus, Ontario, Canada, showed that the near-stream zone had a dramatic effect on the plume (see Chapter 2). Low hydraulic conductivity semi-confining deposits beneath the river altered flow paths and caused the size and shape of the plume to change while biodegradation reduced PCE concentrations and altered the composition of the plume by creating numerous degradation products. Biodegradation of the PCE plume was not uniform across the site with complete transformation of PCE to degradation products in many areas but virtually no PCE degradation in other areas. Many factors can potentially affect the rate and extent of biodegradation of PCE including redox conditions, the types of microbes present, nutrient supplies, temperature, and the residence time required for transformations to occur. Chapter 3 showed that subsurface conditions at the site resulted in groundwater discharge in the streambed that was quite variable, yet could be divided into 5 different types of discharge behavior based on the direction and magnitude of water fluxes in the streambed. It was hypothesized that the interstitial water within each of these 5 types of flow areas would have different geochemical and contaminant signatures and that the conceptual model would serve as a suitable framework for categorizing and interpreting the water quality. It was thought that the magnitude of the flux (which is directly proportional to groundwater velocities inversely proportional to residence time) could also directly affect the overall water quality in the streambed if residence times are too short to allow reactions to go to completion. It was further hypothesized that areas of low flux through high-organic-content low-hydraulic-conductivity materials would be more reducing and thus be favorable for biodegradation of PCE, whereas areas of high flux would be less reducing and PCE would undergo little or no biodegradation. Therefore, a very detailed field investigation was undertaken at the Pine River site to determine the relationship between the geochemistry of the interstitial water of the streambed, degree of biodegradation, and magnitude of groundwater flux through the streambed. An additional goal of this study was to quantify the total contaminant mass discharging through the streambed to the river and to determine the extent to which the final 2.5 m of flow through the streambed reduced the mass of the plume prior to discharging to surface water.

4.3 BACKGROUND

4.3.1 Geochemical Conditions in Streambeds

A wide range of biogeochemical and redox conditions can be encountered in the interstitial water of streambeds. Many factors play a role in determining these conditions including the origin of the interstitial water (e.g. groundwater or surface water), the degree of mixing of different types of water, the mineralogy of the aquifer solids, the organic content of the sediments, biologically mediated reactions, abiotic reactions, and water residence times. These factors may vary both spatially and temporally, which adds to the complexity of this environment. Of these factors, decomposition of organic matter in a streambed plays an important role in determining what geochemical processes occur and where. The amount of organic material buried in streambed sediments can vary in space, time, and composition (Metzler and Smock, 1990; Leichtfried, 1991). The sequence of redox reactions observed in a system with excess organic material or organic contamination typically occurs in an order of decreasing energy yield. In general, the reactions occur in this order: (1) oxygen (O_2) consumption (respiration), (2) denitrification of (NO_3) to nitrite (NO_2) and then to N_2, (3) nitrate reduction to ammonia (NH_3) (4) manganic manganese [Mn(IV)] reduction to soluble Mn(II), (5) reduction of organic matter by fermentation where CO_2 and various forms of dissolved organic carbon (DOC) are produced, (6) ferric iron [Fe(III)] reduction to soluble ferrous iron [Fe(II)], (7) sulfate (SO_4) reduction to produce sulfide species (H_2S, HS^-, and S^{2-}) and sulfide minerals, and (8) reduction of carbon dioxide (CO_2) to produce methane (CH_4) by methanogenesis. These reactions can result in accumulation of DOC if sufficient sediment material is being decomposed, or in depletion of the DOC if it is the only source of carbon being utilized. The redox condition can be inferred by the sequential depletion or accumulation of the electron acceptors and donors (Langmuir, 1997; Stumm and Morgan, 1996). This approach has some limitations since precipitation and dissolution of minerals can affect the amount of electron acceptors and donors in solution. Likewise, kinetic limitations to reactions may cause non-equilibrium conditions to occur in streambeds (Keating and Bahr, 1998). One method of overcoming these limitations is to measure hydrogen (H_2) concentrations in water because it is an intermediate product of microbiologically mediated processes and can be used to indicate specific redox conditions (Chapelle et al.,1995; Lovley et al., 1994). However, sampling for H_2 analyses requires pumping several liters of water, which precludes its use for depth specific sampling on a 0.15 m vertical spacing since the volumes of sampled aquifer would overlap (e.g. the spheres would exceed a radius of 0.075 m).

Numerous studies have characterized the microbiology and geochemistry of streambeds on meter to centimeter scales in an attempt to define and describe the hyporheic zone. The hyporheic zone, as defined by White (1993), is the "saturated interstitial areas beneath the streambed and into the stream banks that contain some portion of channel water or that have been altered by channel water infiltration (advection)". Several studies have characterized the geochemistry of the hyporheic zone in general (Dahm et al., 1998; Brunke and Gonser, 1997) or in the context of downwelling versus upwelling zones (Hendricks, 1993; Hendricks and White, 1991 and 1995; Jones et al., 1995; Valett et al., 1994; Baker et al., 1994) or in conjunction with assessing biological assemblages (Williams, 1989 and 1993; Plenet and Marmonier, 1995; Sterba et al., 1992). Others have focused specifically on nitrification and denitrification processes in the hyporheic zone (Triska et al., 1989, 1990, 1993a, and 1993b; Pfenning and McMahon, 1997; Wyer and Hill, 1984; Devito et al., 1999; Cey et al., 1999) and dissolved organic carbon (DOC) utilization or production (Rutherford and Hynes, 1987; Findlay et al., 1993; Vervier et. al., 1993; Schindler and Krabbenhoft, 1998). The production and presence of methane in streambeds have been the subject of a few studies (Dahm et al., 1991; Jones et al., 1994, and 1995; Baker et al., 1994). In one study, elevated interstitial methane concentrations were associated with riverbeds having lower hydraulic conductivity deposits and at groundwater upwelling zones rather than downwelling zones (Baker et al., 1994). Some studies have observed very local reducing zones or pockets within otherwise less reducing deposits (Boulton et al., 1998; Storey et al., 1999; Dahm et al., 1998). Additional insight regarding the range of geochemical behavior and development of sequential zones of reducing conditions in streambeds can be found in literature pertaining to surface water that infiltrates down through streambed deposits (Bourg and Bertin 1993; Jacobs et al., 1988; Doussan et al., 1997; Grischek et al., 1998) as is the case of induced infiltration near pumping wells.

4.3.2 Biodegradation of Chlorinated Ethenes

Biodegradation of the chlorinated ethenes PCE, TCE, 1,1-dichloroethene (11DCE), cis-1,2-dichloroethene (cDCE), trans-1,2-dichloroethene (tDCE), and vinyl chloride (VC) occur under a wide range of redox conditions in subsurface deposits. These degradation pathways have been recently summarized by Wiedemeier et al. (1999), the National Research Council (2000), and by Fetzner (1998). The geochemistry, oxidation-reduction potential, and the microbial community in the subsurface deposits all play an important role in determining which biodegradation reactions will occur and in what sequence. Microbial reductive dechlorination is sequential and usually goes from PCE to TCE, to the three isomers of DCE,.to VC, then to ethene and ethane which can be subsequently mineralized to CO_2, H_2O, and chloride. Although PCE and TCE can be biodegraded under a wide variety of reducing conditions (nitrate reducing to methanogenic), not all microbial communities are able to completely dechlorinate PCE to ethene and ethane and this may result in only partial dechlorination which stops at cDCE or VC. Complete reductive dechlorination of PCE to ethene or ethane and inorganic end products has been observed under methanogenic conditions with mixed cultures (Freedman and Gossett, 1989, and deBruin et al., 1992) and when microbes utilize the VOCs for energy and as a primary growth substrate (i.e. halorespiration) in a pure culture (Maymo-Gatell et al., 1997). In an anaerobic enriched culture, ethene has been produced in the absence of the methanogenesis (DiStephano et al., 1991). Partial dechlorination of PCE to TCE (Bouwer and McCarty, 1983) or to VC with partial mineralization to CO_2 (Vogel and McCarty, 1985) has also been observed under methanogenic conditions. PCE dechlorination to cDCE appears to be favored under sulfate reducing (Bagley and Gossett, 1990) and even under iron reducing and nitrate reducing conditions (Vogel et al., 1987). In fact, cDCE appears to be the end point for many different microorganisms that biodegrade PCE by dehalorespiration (Gossett and Zinder, 1996). In general, the anaerobic biodegradation of cDCE to VC and VC to ethene and ethane only occurs under sulfate reducing and methanogenic conditions and are relatively slow processes compared with the transformation of PCE to TCE and TCE to cDCE. However, VC may biodegrade relatively rapidly by direct oxidation under iron reducing to aerobic conditions where it is an electron donor and is mineralized directly to CO_2, H_2O, and chloride without producing ethene and ethane (Remediation Technologies Development Forum, 1997; and Wiedemeier, 1999). These differences in biodegradation rates can result in distinct patterns or distributions of degradation products within groundwater plumes (USEPA, 1998) and have been categorized into three types of behavior depending on the redox conditions and the source and amount of DOC available to drive reductive dechlorination.

4.3.3 Biodegradation in Streambeds

The geochemical conditions in streambeds can become quite reducing and can include all the conditions necessary for both anaerobic and aerobic biodegradation of chlorinated ethenes. The streambed is the interface between two rather distinct hydrogeologic and geochemical regimes and represents a unique and heterogeneous habitat that supports a diversity of microbial types (Storey et al., 1999; Pusch et al., 1998; Hendricks, 1996). The number and variety of microbes in the streambed is far greater than in aquifers, hence this environment likely has a higher potential to biodegrade contaminants than most sand aquifers. Laboratory microcosm studies have successfully biodegraded chlorinated ethenes in different types of streambed samples. PCE was biodegraded in hyporheic zone sediments (Noftsker and Watwood, 1997). TCE was biodegraded in muck samples (Barrio-Lage et al., 1987). TCE and VC were transformed to ethene, ethane and even methane in lake bed and streambed samples (Chapelle and Bradley, 1999). DCE and VC were aerobically mineralized in streambed samples (Chapelle and Bradley, 1998). Laboratory studies of cDCE biodegradation yielded a half life of about 50 days for streambed sediments which was about 10 times higher than that found for the adjacent aquifer deposits (Chapelle and Bradley, 1998). A compilation by Wiedemeier et al. (1999) of different first order biodegradation half lives for microcosm and field scale investigations (generally using aquifers materials) showed PCE to have values between 13 and 1019 days and TCE, cDCE, and VC to have values generally between 2 and 6930 days. Even if half lives are on the shorter end of this range, a discharging plume may or may not have sufficient residence time to be biodegraded as it passes though the streambed deposits.

4.3.4 Description of the Field Site

The site is located in Angus, Ontario, Canada, approximately 75 km north-northwest of Toronto and about 5.5 km north of the University of Waterloo Groundwater Research site on Canadian Forces Base Borden. An approximately 60 m wide dissolved-phase PCE groundwater plume emanates from source area beneath a dry cleaner facility and discharges to the Pine River approximately 195 m away (Figure 4-1). Where the plume discharges, the Pine River is about 11 to 14 m wide and during the summer has an average depth of about 0.5 m and flows of 1.39 to about 2.0 m^3/s. From its source at the dry cleaner, the plume travels toward the river through a confined aquifer of fine sand. At the river the plume discharges up through semi-confining deposits, consisting of up to 5 m of interbedded silts, clay, peat and very fine sands and then through the overlying fluvially deposited fine sands of the streambed. Both the semi-confining deposits and a sand filled former river channel that cuts down through them determines to a great extent where and how the groundwater plume discharges into the river. The semi-confining deposits beneath the river have low hydraulic conductivity values (4.44×10^{-6} to 9.34×10^{-4} cm/s) and high organic carbon content (foc of 1.69 to 7.18%). The streambed sands and silty-sands have higher hydraulic conductivities (1.73×10^{-3} to 3.89×10^{-2} cm/s) and lower organic contents with foc values ranging between 0.027 and 4.49% with a mean value of 0.15%. The underlying aquifer deposits near the river have hydraulic conductivities of 9.91×10^{-3} to 2.39×10^{-2} cm/s and have rather low foc values (0.007 to 0.039%). High upward vertical hydraulic gradients (i.e. up to 0.45) between the underlying aquifer and the river have been observed and vertical average-linear groundwater velocities range from a low of 6.4×10^{-5} m/d in the semi-confining deposits up to perhaps as much as 13.8 m/d in sandy streambed deposits (see Chapter 3).

Within 5 m of the river, the groundwater plume is about 45 m wide and 4 to 6 m thick, with many locations exceeding 1000 μg/L and having a maximum concentration of 8707 μg/L. The PCE plume in the aquifer upgradient of the river appears to have undergone virtually no biodegradation, however, beneath the river, the plume undergoes substantial anaerobic biodegradation as evidenced by the high concentrations of cDCE and VC. The size and composition of the plume changes dramatically over the last few meters of flow as it travels through the deposits beneath the river. The nature of the geological deposits, groundwater flow, and plume beneath and near the river are described in Chapter 2.

Areas of groundwater discharge were delineated and quantified in the streambed using an approach that combined streambed temperature measurements, hydraulic testing of mini-piezometers, and chloride concentration measurements in the interstitial water (see Chapter 3). Groundwater fluxes were calculated using an empirical relationship between streambed temperatures and Darcy fluxes obtained from slug testing of piezometers. This relationship allowed groundwater fluxes to be calculated and mapped on about a 1 to 2 m grid for both summer and winter conditions, and demonstrated the spatial variability of groundwater discharge at the site (Figures 4-2a and 4-2b). Three main groundwater discharge areas were identified (the eastern shore, south central, and west central discharge zones). Chloride concentrations were also used to indicate areas where surface water had penetrated into the streambed. This previous work resulted in the conceptual model for 5 different types of discharge at the river that is depicted schematically in cross-section in Figure 4-3. The plan-view distribution of these 5 types of discharge for this reach of river is shown in Figure 4-4. Type 1 behavior is the "short-circuit discharge", which are very localized high-discharge springs. Type 2 is the "high discharge" zone (fluxes greater than 200 L/m^2d), which represent groundwater upwelling zones and preferred groundwater flow paths through high hydraulic conductivity geological windows located within otherwise lower hydraulic conductivity deposits. Type 3 behavior is the "low to medium discharge" zone (fluxes of 0 to 200 L/m^2d), consisting of lower hydraulic conductivity deposits or low gradients or both, resulting in longer water residence times within the streambed. Type 4 behavior is the "no discharge" zone, where there is no discharge of groundwater although flow can be horizontal in this zone (e.g. the hyporheic zone). Type 5 behavior is the "recharge" zone (fluxes < 0 L/m^2d) where surface water flows down into the streambed deposits. Although the previous characterizations of the streambed showed distinct patterns in concentrations of PCE and its biodegradation products in the riverbed, it was not clear how these were related to the geochemical conditions within these deposits or the pattern of flux.

4.4 FIELD INVESTIGATIONS

Several different sampling devices and methods were used to characterize the geochemistry and contamination in the aquifer groundwater, interstitial water beneath the streambed, surface water, and water discharging from springs and seeps. Samples of aquifer groundwater were collected using the Waterloo Groundwater Profiler method (Pitkin 1994; Pitkin et al., 1999) and from permanently installed bundle multi-level (BML) samplers similar to those described by Mackay et al. (1986) and Bianchi-Mosquera and Mackay (1992). The Waterloo Groundwater Profiler, a newly developed mini-profiler, and two new types of driveable multi-level samplers (MLS) were used to collect water samples from the deposits beneath the river. The mini-profiler was modified from a soil vapor sampler described by Hughes et al. (1992). One type of the MLS samplers was constructed of stainless steel and was similar to those used by de Oliveira (1997) and Barbaro (1999) but were modified for driving into the ground. The second type of MLS were made of PVC and stainless steel and constructed as described in Chapter 2. Water samples were collected with a typical vertical spacing of 0.15 to 0.5 m using a sampling manifold, peristaltic pump, and flow-through cell. In order to make the samples as depth discrete as possible (i.e. minimize the volume of deposits from which the water was drawn) the total amount of water pumped including purged water was between 250 to 550 mL, depending on the types of analyses required. This volume of water is equivalent to a spherical zone of streambed deposits with a radius of about 0.05 to 0.07 m. Each device was constructed of teflon or stainless-steel sampling tubes with 0.00159 m inside diameter (ID), the purge volumes were sufficient to flush out stagnant water in the tubes since only about 75 to 190 mL of water were needed for a complete set of analyses. Most surface water samples were collected directly into glass vials by hand as grab samples, but on occasion the Waterloo Groundwater Profiler, mini-profiler, and MLS sample ports exposed just above the streambed were used to collect samples. Water from springs and seeps on shore were collected as grab samples except for Spring A, located in the streambed under the river, which was sampled by placing the mini-profiler down into the spring itself.

Analyses of water samples for VOCs were performed at the University of Waterloo. Water samples for PCE and TCE analysis were extracted using pentane and run using a Hewlett Packard (HP) 5890 Series II gas chromatograph equipped with an auto sampler, a Ni^{63} electron capture detector (ECD), a HP 6890 Series integrator, and a DB-624 megabore capillary column. Minimum detection limits for PCE and TCE were typically 0.7 and 0.9 µg/L. Analyses for cDCE, tDCE, 1,1-DCE, and VC were performed using a headspace method. The samples were analyzed using a HP 5890 Series II gas chromatograph equipped with a HNU photoionization detector (PID) with a fused silica capillary NSW-PLOT column. Samples prior to June 1998, were manually injected into the PID while those after that date were injected using an automated HP 7694 Headspace Sampler. The minimum detection limits for the manual and the automated methods were cDCE (7.8 and 1.0 µg/L), tDCE (1.9 and 1.4 µg/L), 1,1-DCE (3.2 and 1.4 µg/L) and VC (0.7 and 0.8 µg/L), respectively. Analyses of methane, ethene, and ethane were performed using a headspace method and samples were manually injected into a HP 5790A gas chromatograph equipped with a flame ionization detector (FID), a GS-Q megabore capillary column, and a HP 3396 Series II Integrator. The minimum detection limit for methane, ethene, and ethane was 0.5 µg/L. Some of the concentrations of methane greater than 1000 µg/L exceeded the calibration range of the equipment because they were not properly diluted prior to analyses and so these values should be considered approximate. Each set of samples analyzed usually included lab blanks, field and lab duplicates, trip blanks, and equipment blanks.

Laboratory analyses of water samples for inorganic parameters listed in Table 4-1 were performed by Philips Analytical Services [(previously known as MDS Environmental Services Limited) of Halifax, Nova Scotia]. These samples were filtered in the field using a plastic 60 cubic centimeter disposable syringe and Sartorius Minisart® 0.45 micron filter (Sartorius AG, Goettingen, Germany) and placed into two vials. One vial was 30 mL and the water was unpreserved and the second was a 12 mL vial for metals analyses and the sample was acidified with nitric acid (to pH <2). When total phosphorous analysis was required, a separate unfiltered and unpreserved sample was placed in a 50 mL plastic vial and submitted. Not all samples collected were analyzed for all parameters shown in Table 4-1. Note that analyses for Fe, Mn, and ammonia represent total values of all species in solution. Based on observed pH ranges, the Fe (total) values should closely reflect Fe (II) concentrations and Mn (total) should represent Mn (II) concentrations. Ammonia (total) represents both NH_3 and NH_4 concentrations which for pH less than 8.5 should be almost entirely NH_4. DOC likely represents total non-volatile carbon since the laboratory includes sparging the sample with N_2 gas to remove inorganic carbon.

Several parameters were measured in the field. Specific conductance, temperature, pH and Eh were measured by pumping water past probes placed in a small (less than 60 mL) flow-through cell. Specific conductance and temperature were measured using a Cole Parmer Model 19815-00 Basic Conductivity Meter and conductance readings were automatically temperature corrected to 25 °C. The pH and Eh measurement were made using either an Orion Model 290A or Markson Model 672 meter and an Orion AgCl internal reference pH probe and a Baxter platinium - Ag/Ag internal reference Eh probe. Eh probe readings in millivolts (mV) were to converted to Eh at 25 °C using the temperature dependent standard potential for the Ag/Ag electrode. Alkalinity was measured in the field by titrating a 25 mL water sample using a Hach Test Kit Model AL-DT. Two additional 25 ml samples were collected to determine concentrations of dissolved oxygen (DO) in the 0 to 10 mg/L range and total soluble sulfide in the 0 to 1.4 mg/L range. DO and sulfide were measured in the field photometrically using a CHEMetrics (Calverton, Virginia) VVR photometer and CHEMetrics Vacu-vials® self-filling ampoules. If sulfide concentrations exceeded the range of the photometer, sulfide concentrations were measured visually using a CHEMetrics CHEMets Kit Model K-9510 with self-filling ampoules. All equipment was calibrated in the field prior to use. In some winter sampling rounds, the cold temperatures adversely affected the equilibration time and accuracy of the pH probe, and resulted in many readings being discarded.

Sampling of water occurred at several times between 1996 and 1999 (see Chapter 2). The Waterloo Profiler was used to collect water samples at locations AP40 to AP52 in July and August 1996, PRP7 in November 1996, and AP53 to AP55 in November and December 1997. The mini-profiler was used to collect vertical profiles of water concentrations at PRP8R in August 1997 and at PRP14 and PRP15 in October 1997. The mini-profiler was also used in August 1998 to map the interstitial water concentrations at a depth of 0.3 m in the streambed in plan-view at 80 locations. All points at MLS17 and MLS18 were sampled in November 1998 along with selected points from 5 other MLS locations. All 10 BML and all 20 MLS installations were sampled in March 1999.

Figure 4-5 shows the location of various sampling locations and instrumentation, but does not include the 80 locations for the August 1998 plan-view mapping of the streambed with the mini-profiler which are shown on Figure 4-4. A Sokkia SET4E Total Station was used to survey the elevations and locations all land based instrumentation and sampling locations, the majority of riverbed installations, and the stakes that mark the end of transect lines across the river. Transect designations were used to identify sampling locations in the riverbed without the need for additional surveying. For example, location 6-6W 4.5 m indicates that the transect is approximately 6 m downstream (north) of the north edge of the King Street bridge (shown in Figures 4-1 and 4-5) and the point is 4.5 m west of stake 6 (on the east bank) toward stake 6W (on the west bank) as measured using a tape extending from one stake to the other. The locations of some transects are shown in Figure (4-2 and 4-5).

4.5 RESULTS AND DISCUSSION

4.5.1 Aquifer Groundwater Quality

The geochemistry of the groundwater in the aquifer was characterized in order to provide a baseline for determining the extent to which the geochemistry of the water changed as it traveled through the top 2.5 m of the streambed. Vertical profiles of groundwater quality were obtained for the confined aquifer at AP53 to AP55 located approximately 29 to 37 m east of the river (Levenick, 1998) and the aquifer beneath the semi-confining deposits at BML1, BML3, BML7, and BML11 which were located within 6.1 m of the river. Table 4-2 summarizes the median, average, minimum and maximum values of inorganic analyses and field measured parameters for these aquifer groundwater samples.

Vertical profiles of VOCs, redox sensitive parameters, and inorganic compounds are shown for BML1 in Figures 4-6a, 4-6b, and 4-6c, respectively. The corresponding results for BML3 are shown in Figures 4-7a, 4-7b, 4-7c. An examination of VOCs in Figures 4-6a and 4-7 clearly shows that the groundwater plume consists almost exclusively of PCE with very minor amounts of TCE (usually less than 10 μg/L). These VOC profiles are similar to the profiles observed at the other BML samplers east of the river. An examination of redox sensitive parameters in Figures 4-6b and 4-7b shows that the aquifer contains very little DO (< 0.85 mg/L), total Mn (< 0.15 mg/L), total Fe (< 0.55 mg/L), and sulfide (total) (< detection limit). NO_3 concentrations were as high as 18.1 mg/L (as N) and ammonia (total) was generally not detected except for small amounts (< 0.97 mg/L as N) generally occurring where NO_3 was depleted. SO_4 concentrations ranged between about 20 mg/L and 55 mg/L. At location BML3 methane ranged between 8.9 and 15.4 μg/L, but are between 60.3 and 192.3 μg/L at BML1 (note methane values in figures are multiplied by 100 or 1000 to plot on the graph). At BML1 and BML3, DOC ranged between 0.6 and 4.5 mg/L and Eh ranged between 255 and 494 mV.

Overall, the aquifer groundwater is anaerobic but is not particularly reducing with an average Eh of about 337 mV. This Eh value is favorable for nitrate reduction but care should be used when using values obtained from Eh probes since they can be slow to equilibrate, are not sensitive to all redox couples (e.g. those associated with sulfide and methane), and can represent mixed potentials (Stumm and Morgan, 1996, page 491). When interpreting redox conditions, more emphasis was placed on the presence or absence of redox couples in solution than the absolute value of Eh measurements, although trends in Eh were useful in identifying more aerobic versus anaerobic conditions. Because nitrate was present in the aquifer water but relatively little iron and manganese, the aquifer does not appear to be iron and manganese reducing but may be nitrate reducing. At some locations, iron is found in the very top of the aquifer where it contacts the organic rich semi-confining deposits or the peat of the aquitard and also in the very bottom portion of the aquifer. At AP53, AP54, and AP55 some sulfate reduction and methanogenesis may occur at the very top of the confined aquifer where it contacts the thin peat layer at the bottom of the aquitard (Levenick, 1998) suggesting iron reducing conditions. The very small amounts of cDCE (less than 14.5 μg/L) observed in the aquifer were found at the top of the aquifer where the plume contacted the semi-confining deposits. Most of the methane observed at BML1 and BML3 (Figures 6Fb and 4-7b) has likely been produced upgradient and transported to these locations. Methane was also analyzed in samples from all the other BML samplers east of the river in March 1999, and showed vertical concentration profiles of methane similar to BML3, except for 391 and 1516 µg/L at BML4-6 and BML4-7, respectively. The water quality on the west side of the river at BML11 and BML12 is generally more reducing than found to the east. For example, the bottom half of the sampling points at BML11 had high methane (618 to 1889 µg/L) and low sulfate (none detected to 9 mg/L) concentrations.

4.5.2 Spring Water Quality

Three springs, labeled A, B, and C, were identified and sampled during this study (Figure 4-4). The discharge from spring A at 30-30W 1.85 m was estimated to be greater than 1 liter per minute (L/min) and geochemical analyses of water from that spring was very similar to the median values for groundwater shown in Table 4-2. The spring water contained 666 to 778 µg/L of PCE and 1.2 to 3.8 µg/L of TCE but no other VOCs. In this location the water was groundwater which had not been geochemically altered. Spring C, located along the shore in a seep area about 2 m east of PRP1, had a considerably lower flow (less than 1 L/min) than Spring A. VOC analyses of this spring water contained 662 µg/L of PCE, 2.3 µg/L of TCE, and 110.1 µg/L cDCE, and thus 84.7% of the total moles of VOCs were PCE. Geochemical analyses were not done on this sample but iron staining of the sediments at the discharge point suggested the water likely contained dissolved iron and was reducing. Sampling of the very small spring B located in a seep (also less than 1 L/min) on the eastern shore near the bridge indicated 49.2 µg/L of PCE and no TCE in 1996 (no other VOCs were analyzed). Later sampling for all VOCs in August 1998 indicated only 2.9 µg/L of PCE and no other VOCs or methane. Iron staining at this spring suggested the water could be somewhat reducing.

4.5.3 Surface Water Quality

Table 4-3 summarizes the results of inorganic analyses of surface water measured between November 1996, and March 1999. Since the interstitial water of the streambed can, in some circumstances, originate as surface water, or can be a mixture of groundwater and surface water, it is useful to know the chemistry of the surface water. Surface water was typically quite aerobic with an average DO of 8.2 mg/L and an average Eh of 398.5 mV, both of which were significantly higher than the aquifer groundwater. Concentrations of many ions were lower in the surface water than in groundwater as would be expected based on the average specific conductance of 417 micro seimens per centimeter (µS/cm) which was about half the average value of the groundwater. Parameters showing the highest contrasts in average values were DO, K, Cl, Na, Ca, Mg, and specific conductance. The mean concentration of NO_3 as N was 1.31 mg/L, which was lower than the mean value of 1.65 mg/L as N in groundwater. On average, NO_3 concentrations were much higher in groundwater than in surface water. The average concentration of 20.4 mg/L for SO_4 was lower than the 34 mg/L value for groundwater, and observed surface water concentrations varied over a much smaller range. Low concentrations of chloride (less than the lowest groundwater concentration of 36.8 mg/L found to the east of the river) served as a relatively good indicator of the presence of surface water in streambed deposits since the average groundwater concentration was 130.1 mg/L. The high contrast and relatively constant concentration of chloride in surface water (average value of 14.6 mg/L) combined with its non-reactive nature made it a useful tracer for surface water (see Chapter 3). VOC sampling of surface water during the current study only detected PCE and/or TCE in 11 of 71 samples and at levels that were all less than 3.2 µg/L, except for 23.2 µg/L of PCE detected at one location downstream of Spring A (see Chapter 2). Overall, the values in Table 4-3 are consistent with the results of surface water sampling of the river performed by the Ontario Ministry of the Environment and Energy (MOEE) as part of the Provincial Water Quality Monitoring Network. Since 1966, the MOEE has monitored the surface water on almost a monthly basis at a location 213 m upstream of the site for numerous water quality parameters but not for VOCs.

4.5.4 Interstitial Water In The Streambed

4.5.4.1 Geochemistry and Redox Conditions in Plan View

The results of the August 1998, plan-view sampling of the interstitial water at a depth of 0.3 m below the streambed showed conditions ranged from aerobic to methanogenic. Overall, the streambed was anaerobic with a median DO concentration of 0.17 mg/L. DO concentrations greater than 0.8 mg/L were detected only at 8-8W 2.0 m (6.9 mg/L) and 36-36W 5.1 m (5.4 mg/L). These two locations were within Type 4 no discharge areas and had low chloride concentrations, indicating that the interstitial water was from the oxygen rich surface water. The distribution of NO_3, Fe (total), and CH_4 as shown in Figures 4-8a, 4-8b, and 4-8c tend to correlate with the 5 flow types. Some locations were quite reducing with high CH_4 concentrations (i.e. over 1000 μg/L) indicating methanogenic conditions in some areas of the streambed.

Concentrations of NO_3 that are higher than the mean surface water concentration of 1.3 mg/L as N were found in the streambed only in association with Type 2 high discharge areas (Figure 4-8a). Since high concentrations of NO_3 were only found in aquifer groundwater, these areas must be dominated by groundwater discharge that has not undergone appreciable nitrate reduction. Some of the other locations having detectable NO_3 concentrations that are less than 1.3 mg/L as N may also be discharging groundwater, but could also be from downwelling of surface water. Two of 8 Type 4 discharge area samples had NO_3 in this concentrations range and the NO_3 is likely from surface water. Concentrations of Fe(total) were low in both groundwater and surface water, but elevated concentrations were found in most of the streambed which indicates conditions favorable for iron reduction. Figure 4-8b shows that non-detectable and very low iron concentrations are associated with Type 2 and Type 4 discharge areas, and are likely from groundwater and surface water, respectively. Like iron, methane concentrations were relatively low in both groundwater and surface water and result in a plan-view pattern similar to that of iron, where low concentrations are associated with Type 2 areas (Figure 4-8c). In contrast to iron, concentrations of methane in the vicinity of Type 4 areas were either essentially non-detectable or quite high (i.e. ranged from 222 µg/L to over 1000 µg/L). Overall, concentrations of methane greater than 1000 µg/L were found at 22 of 80 locations in the streambed indicating substantial methanogenesis beneath the river. Loss of SO_4 (which was 10 mg/L or less at 32 locations) and the accumulation of total sulfide (0.1 mg/L or more at 16 locations) indicate that sulfate reduction is occurring in the streambed. Concentrations of SO_4 that are higher than the average surface water concentration (21 mg/L) are typically found at and near Type 2 areas and indicative of a groundwater source from the east. Most of the streambed is dominated by groundwater discharge from the east (see Chapter 2). In general, reducing reactions are occurring within the streambed, but in some parts of the streambed along the west bank of the river the high methane and low sulfate concentrations observed may be associated with groundwater discharge from depth in the area of BML11 to the west.

4.5.4.2 Geochemistry versus Groundwater Discharge Flux

To further understand the relationship between inorganic concentrations and flow through the streambed, the results of the August 1998, plan-view sampling for inorganics were compared to the July 1998, groundwater fluxes previously shown in Figure 4-2a. Figures 4-9a to 4-9h are scatter plots of NO_3 as N, ammonia (total) as N, Mn (total), Fe (total), SO_4, sulfide (total), CH_4, and DOC versus the flux determined for each of 76 sampling points. Each figure has a vertical line plotted at 200 L/m^2d to indicate where the division occurs between Type 2 high discharge and Type 3 low to medium discharge. Solid black circles were used to represent sample locations where VOCs were detected (i.e. locations within the discharging plume) and open circles indicate points where no contamination was detected. For sample points falling at fluxes between 200 and 500 L/m^2d, the geochemistry is very similar and consists of very low or non-detectable concentrations of Mn (total), Fe (total), sulfide (total), CH_4, ammonia (total), and DOC and relatively high concentrations of NO_3 and SO_4. The Type 2 water quality is essentially the same as unaltered groundwater in Table 4-2. At lower fluxes (within Type 3 discharge conditions), it appears that conditions are much more reducing, particularly when fluxes are lower than 100 L/m^{2}d. In that range, many locations show accumulations of Mn (total), Fe (total), sulfide (total), CH_4, ammonia (total), and DOC and depletion of NO_3 and SO_4. Conditions range from nitrate reducing to methanogenic in this zone. Several data points at fluxes less than 200 L/m^{2}d still show low concentrations of ammonia (total), Mn (total), Fe (total), sulfide (total), CH_4, and DOC which are similar to geochemically unmodified groundwater. The variability in geochemistry occurring at fluxes less than 200 L/m^{2}d suggests the redox conditions at some locations are not strictly a function of the flux. A few of these points with very low fluxes are Type 4 no discharge or Type 5 recharge locations that were not properly assigned zero or negative fluxes (see Chapter 3 for a discussion of accuracy of calculated fluxes) and are similar to surface water quality. An examination of sample locations inside the plume versus those outside did not show substantially different behaviors which suggests that the chemical composition of the contaminant plume does not influence the type of reducing conditions that develop. The similarity in conditions is likely because the plume does not contain elevated levels of labile dissolved organic carbon which could result in more reducing conditions, as is typically the case in petroleum hydrocarbon plumes.

4.5.4.3 Plan-View Distribution of VOCs

The results of the August 1998, plan-view sampling of the interstitial water at a depth of 0.3 m below the streambed shows that the PCE plume has been extensively biodegraded beneath the river. Figure 4-10a shows the plan-view concentrations of total VOCs expressed as PCE (i.e. moles of PCE, TCE, 11DCE, tDCE, cDCE, VC, ethene and ethane summed and expressed as equivalent PCE concentrations). This figure is intended to represent the entire extent of the contaminant plume in the streambed; however, the calculation equivalent PCE concentrations does not account for PCE that has been mineralized to CO_2, H_2O, and chloride, so the plume could be somewhat larger or have higher concentrations than those shown in Figure 4-10a. Figure 4-10b shows the plan-view concentration of PCE. Figure 4-10c shows the percent of total VOCs as equivalent PCE that still persists as PCE (on a molar basis) at each location that detected contamination. Figure 4-10c shows relative locations of the 5 types of flow zones from Figure 4-

4. A comparison of Figure 4-10a to Figure 4-10b clearly shows that much of the PCE plume has been completely transformed to degradation products. Figure 4-10c shows that at 29 of 53 sampling locations the contamination is present only as transformation products. This distribution is in stark contrast to the high concentration PCE plume in the confined aquifer beneath the east bank of the river which contained only trace amounts of TCE and rare detections of cDCE (see Chapter 2). The two highest concentrations of PCE detected in the streambed were 1433 µg/L at 12-12W 6.0 m and 817 µg/L at 24-24W 3.5 m which were much lower than the peak concentrations of 8707 and 6643 µg/L found in the aquifer beneath the east bank. Discharge of PCE occurs only in three isolated areas, two of which correlate with the Type 2 discharge zones.

The distributions of PCE, TCE, cDCE, VC and ethene concentrations shown in Figures 4-11a, 4-11b, 4-11c, 4-11d, and 4-11e, respectively, indicate that most of the plume has been transformed to cDCE and to a lesser extent VC. Peak concentrations of 4619 µg/L for cDCE and 849 µg/L for VC were found at the same location, 16-16W 7.0 m. In general, concentrations of TCE were low with only five locations in Figure 4-11b having concentrations higher than 7.8 µg/L. The maximum TCE value of 82 µg/L was detected at 6-6W 3.0 m. Detection of 11DCE was rare with only 2.7 µg/L found at 20-20W 6.0 m and 30 µg/L found at 16-16W 7.0 m. Likewise, tDCE was only detected in a small area of 4 adjacent sampling locations with the two peak concentrations found at 20-20W 6.0 m (46 µg/L) and at 16-16W 7.0 m (12 µg/L). Ethene was detected at 15 locations with a peak concentrations found at 20-20W 6.0 m (92.6 µg/L) and 10-10W 3.5 m (100.7 µg/L). Although not shown, ethane was detected at 8 locations, usually in conjunction with ethene but typically at lower concentrations. The two highest ethane concentrations were 11.6 µg/L found at 12-12W 4.0 m and 76.8 µg/L found at 20-20W 4.0 m. Chloride is also a degradation product but concentrations of chloride could not be used as a basis for indicating biodegradation because of high variations in background values of both chloride and excess chloride in the upgradient aquifer. Excess chloride was calculated to be the chloride that could not be accounted for by assuming all the sodium in solution was from dissolution of NaCl. Excess chloride values were as large as 66 mg/L in the streambed and 143 mg/L at the bottom of the upgradient aquifer at AP54. The high values could be a result of sodium depletion (e.g. by ion exchange) or additional chloride from dissolution of non-sodium salts. As is the case at other plumes undergoing anaerobic biodegradation, PCE has only been partially dechlorinated and there is a preferential accumulation of cDCE compared to 11DCE and tDCE (Wiedemeier et al., 1999). The presence of ethene and ethane indicate that some areas are quite reducing and capable of completely dechlorinating the PCE. These areas of more complete biodegradation occur in Type 3 low to medium discharge areas.

4.5.4.4 Geochemistry versus VOCs

Scatter plots of each VOC versus NO_3, Mn (total), Fe (total), SO_4, sulfide (total), CH_4, ammonia (total), and DOC were examined to determine if accumulations and depletion of redox couples in the water could be related to the appearance and disappearance of VOCs for the streambed samples collected August 1998. In general, as conditions became more reducing the contaminants progressively became more dechlorinated. An examination of PCE and TCE versus the redox sensitive parameters showed that they were usually detected where NO_3 and SO_4 were higher and Mn (total), Fe (total), sulfide (total), CH_4, ammonia (total), and DOC were all low or absent. This pattern indicates that PCE and TCE are present only when conditions are not particularly reducing (i.e. anaerobic to nitrate reducing). To characterize the geochemical behavior in this type of environment, vertical profiles of VOCs, redox sensitive parameters, and inorganic compounds were obtained at PRP15 (Figures 4-12a, 4-12b, and 4-12c) in October 1997 and at the MLS17 and MLS18 pair (Figure 4-13a, 4-13b, and 4-13c) in November 1998. Both locations are within Type 2 flow areas shown in Figure 4-4. The general stratigraphy at the location is indicated and the top most data point of each profile represents surface water quality at the time of sampling. At both locations, concentrations of PCE are high relative to the degradation products throughout most of the sampled interval. The redox conditions are not very reducing as evident by the presence of NO_3 and general absence of Fe (total) and Mn (total) in samples. However, within each profile there are very localized zones where PCE has been biodegraded to TCE and cDCE. No VC, ethene, or ethane were observed at PRP15 but small amounts were observed in the top 0.30 m of MLS17 where silty organic-rich deposits were observed near the streambed surface. These localized declines in PCE concentrations were associated with small drops in NO_3 and SO_4 concentrations and an increase in CH_4 in both profiles and increases in Fe (total), Mn (total), and DOC in those zones were also observed in the MLS17 and MLS18 pair.

The conditions associated with the presence of cDCE, tDCE,11DCE, and VC were all fairly similar, with little or no NO_3 or sulfide (total), low amounts of CH_4, and moderate to high amounts of Mn (total), Fe (total), SO_4, ammonia (total), and DOC. This pattern indicates cDCE, tDCE, 11DCE, and VC are primarily found when conditions are at least iron reducing and occasionally sulfate reducing and methanogenic. Ethene and ethane were typically associated with sulfate reducing and methanogenic conditions as indicated by lower levels of SO_4 and higher levels of CH_4. The higher ethene and ethane concentrations were also associated with higher ammonia (total) and DOC levels. The geochemical behavior in this type of environment is shown in vertical profiles of VOCs, redox sensitive parameters, and inorganic compounds obtained at PRP8R (Figures 4-14a, 4-14b, and 4-14c) in August 1997 and PRP14 (Figure 4-15a, 4-15b, and 4-15c) in October 1997. Both locations are within Type 3 flow areas shown in Figure 4-4. At the bottom of the PRP8R profile, 3639 µg/L of PCE appears to be transformed almost completely to cDCE over a vertical interval of only 0.15 m. This transformation is accompanied by a large increase in Fe (total) and a small increase in CH_4, and there are no appreciable amounts of DO or NO_3, which indicates at least iron reducing conditions. Further up in the profile, a sharp increase in VC to 1860.9 µg/L and ethane to 52.2 µg/L, corresponds to a sharp decline in SO_4 to 15 mg/L and an increases in methane to 313 µg/L, indicating methanogenic and sulfate reducing conditions. Above this elevation the conditions are not quite as reducing with Fe (total) declining as Mn (total) concentrations increase, and higher sulfate concentrations. Substantial biodegradation is also observed at PRP14 where, under relatively constant iron reducing conditions, PCE sequentially biodegrades to TCE, cDCE and VC as elevation increases. In both profiles the biodegradation occurs within the organic-rich lower-hydraulic-conductivity semi-confining deposits.

Determining the relationship between redox conditions and degree of biodegradation is problematic when VOCs are absent or depleted. Where sulfide (total) and CH_4 concentrations are high but VOCs are absent, the lack of VOCs could be a result of either (1) complete mineralization of the contaminants; (2) naturally reducing condition that exists outside of the plume; or (3) Type 4 or 5 conditions where the interstitial water is uncontaminated surface water that has become reduced. For example, VOCs were typically only detected at high concentrations when total sulfide was low or absent, but at the 17 locations where total sulfide exceeded 0.07 mg/L, the median value of VOCs was 0.5 μg/L and concentrations did not exceed 34 μg/L. The same observation can be made for CH_4 concentrations over 1200 μg/L where total VOCs were typically not detected and exceeded 4 μg/L at only 4 of 21 locations with the highest concentration of these being 84 μg/L. The low concentrations of total VOCs shows that most of these points exist at or near the detectable edge of the plume which suggests the actual edge of the discharging plume may be undetectable because it was mineralized. An example of the geochemical behavior in a Type 4 flow environment is shown in the vertical profiles of VOCs, redox sensitive parameters, and inorganic compounds for PRP7 (Figures 4-16a, 4-16b, and 4-16c) obtained in November 1996. The redox conditions in the streambed sands progressively go from aerobic at the top of the streambed to methanogenic at a depth 0.6 m as evidence in sequential depletion and accumulation of redox parameters (Figure 4-16b). Since VOCs are absent from this portion of the profile, one possible interpretation is that contaminants discharging very slowly out of the underlying semi-confining deposits are completely mineralized prior to entering the sand. Sampling of sediments from core RC1 collected at this location indicated the presence of PCE, TCE and cDCE in the underlying semi-confining deposits (see Chapter 2) where the profiler was unable to collect water samples. However, examination of chloride and other inorganic parameters (Figure 4-16c) show that the water in the top 0.45 m of the sand is nearly identical to surface water. The lack of contaminants in this portion of the profile reflects the fact that the water originated as uncontaminated surface water that is flowing horizontally through the subsurface at this location. The water at a depth of 0.6 m is groundwater or a mixture of groundwater and surface water and could be where VOCs have been completely mineralized. A second profile of the streambed sand at PRP7R performed in August 1997 at a location 0.2 m upstream of PRP7 also had chloride concentrations indicative surface water but also had 1.0 to 8.3 μg/L of TCE, 993 to 2046 μg/L of methane, and depleted SO_4 concentrations (between none and 11 mg/L). The absence of PCE makes sense but the presence of TCE is puzzling since it must have originated from groundwater and under these very reducing conditions should have been completely biodegraded. The most plausible explanation is that the sampling equipment was improperly decontaminated as indicated by detection of TCE in equipment blanks collected during this particular sampling event.

4.5.4.5 VOCs versus Water Flux

The relationship between the magnitude of groundwater flux and each of the VOCs for the August 1998 plan-view sampling of the streambed are shown in scatter plots (Figure 4-17a to 4-17h). The figures show the percent of VOCs on a molar basis for each of 53 samples detecting contamination versus the value of groundwater flux interpolated for each sample location using the July 1998 groundwater discharge map (Figure 4-2a). Different symbols are also used to indicate the type of flow zone associated with each point as determined from the composite map of flow types (Figure 4-4). Figure 4-17a shows the percent of total VOCs that remains as PCE (meaning the rest are biodegradation products) versus the flux. Three notable trends are found in Figure 4-17a. (1) For fluxes over 200 L/m^2d (Type 2, high discharge), the contamination is present almost exclusively as PCE with degradation products generally being 7.2% or less of the total moles of contamination. (2) Locations where PCE is absent and contamination is present only as 100 % degradation products generally occurs at fluxes less than 180 L/m^2d (within Type 3, low to medium discharge conditions) with all but one point occurring at less than

125 L/m^{2}d. (3) Intermediate degrees of PCE biodegradation (20 to 80%) were generally not detected with only 4 locations falling within this range, all of which had total VOC concentrations less than 100 µg/L. Although the degree of biodegradation appears to correlate well with flow type, scatter in Type 3 conditions (0 to 200 L/m^{2}d) is apparent with 7 of 42 points having high percentages of PCE (> 80%). An examination of these 7 points shows that they were either located adjacent to Type 2 areas and perhaps should be Type 2 locations or had concentrations of PCE that were 3.4 µg/L or less. Very low concentrations of VOCs might not provide accurate percentages of biodegradation if some VOCs were present but were not accounted for because they were below detection limits. At fluxes less than 60 L/m^{2}d, no Type 3 discharge locations contained more than 20% PCE. Thus, at high groundwater fluxes the contamination is almost all PCE (i.e. > 80%) and at very low fluxes it is almost all biodegraded (i.e. < 20% PCE). Since Type 4 and 5 flow conditions are no discharge or recharge conditions and typically contain surface water, there are very few of those types of points where contamination was detected and consequently can not be shown in Figure 4-17a. The 3 Type 4 locations where contamination contained either all PCE, half PCE and half biodegradation products, or no PCE. The only Type 5 location that was contaminated (44-44W 0.5 m) showed 41.8% degradation products consisting of 1.0 µg/L of PCE and 1.1 µg/L of TCE and these concentrations are near the reliable detection limit for these compounds.

The relationship between the magnitude of the flux and percentage of each of the 7 PCE biodegradation products (relative to total VOCs on a molar basis) are shown in Figures 4-17b to 4-17h. Figure 4-17b shows that only small percentages of TCE are found in points having fluxes over 200 L/m^{2}d. The minor concentrations of TCE detected here are similar to those found in the aquifer and are not indicative of biodegradation of PCE within the streambed but is rather the result of the TCE in the upgradient plume being transported through the streambed. Locations having higher percentages of TCE (up to 100%) generally occur at fluxes less than 200 L/m^{2}d. Although 11DCE and/or tDCE were detected at 4 locations, Figure 4-17c and 4-17d show that these amounts never exceed 1.5% of the total VOCs and were detected at fluxes between 41 and 74 L/m^{2}d. No cDCE, VC, ethene or ethane were found in locations where fluxes were over 200 L/m^{2}d. Locations with higher percentages of cDCE (up to 100%) and VC (up to 57.8%) occur where fluxes are less than 185 L/m^{2}d (Figure 4-17e). Higher percentages of ethene (up to 72.8%), ethane (up to 94.7%) are observed only where fluxes are less than 108 and 66 L/m^{2}d, respectively. Overall, progressively higher degrees of dechlorination are associated with progressively lower fluxes.

4.5.4.6 Contaminant Mass Discharge into the River

Estimates of the contaminant mass discharge to the river were made using the contoured plan-view VOC concentration distributions for August 1998 (e.g. those shown in Figures 4-10a and Figures 4-11a to 4-11e) and the calculated summer (July 1998) and winter (February 1999) groundwater flux contour maps shown in Figures 4-2a and 4-2b. The two types of contour maps were generated using Tecplot®(Amtec Engineering, Inc., 1998) and linearly interpolated onto a common grid where values were then multiplied together to obtain contour maps of mass discharge for each VOC. Figure 4-18a, 4-18b, 4-18c, 4-18d are contour maps of mass fluxes in mg/m^{2}d using the summer groundwater discharge for Total VOCs, PCE, cDCE, and VC, respectively. The discharge map for each VOC was then integrated using SURFER® (Golden Software, Inc., 1994) to obtain total contaminant mass discharges for the plume.

The total VOCs mass discharge map in Figure 4-18a shows mass loading rates to the river exceed 100 mg/m^{2}d in 4 areas that fall roughly along the same line. The peak mass flux value calculated was 424 mg/m^{2}d. Three of the 4 high discharge areas are associated with PCE and where PCE is absent along this line is where a high discharge area for cDCE occurs. Figure 4-18b shows that the highest PCE mass loading rates to the river (>100 mg/m^{2}d) occur in Type 2 groundwater discharge areas located in the eastern shore and south central discharge zones. Contaminant mass discharge within these 100 mg/m^{2}d areas area as high as 423 mg/m^{2}d and account for about 32% of the total mass of VOCs discharging even though they account for only about 14% of the overall area of plume discharge. The mass discharge for cDCE in Figure 4-18c shows that despite cDCE having much higher concentrations over a wider area than PCE, the areas having mass loading rates greater than 100 mg/m^{2}d are only about the same size as the combined PCE high flux areas. Overall, the total cDCE mass discharge is not much greater than that for PCE because the cDCE plume is limited to Type 3 lower groundwater discharge areas and has a lower peak value of mass flux 328 mg/m^{2}d. VC is present at lower concentrations than cDCE and discharges in Type 3 flow areas so VC mass discharges (Figure 4-18d) are even less than for cDCE, and has a peak value of only 61 mg/m^{2}d.

Table 4-4 shows the calculated contaminant mass discharges through the streambed for each VOC on a mass (mg/d) and molar basis (mM/d) for both the summer and winter groundwater flux conditions. The results show that the streambed has reduced the total mass of PCE discharging to the river, but the reduction is primarily a result of PCE transformation to degradation products and not the complete mineralization of the contaminants. The total mass of PCE discharging to the river determined from streambed measurements were 4.0 and 3.2 g/d for summer and winter, respectively. These values are well below the 19.7 to 7.7 g/d estimated for the PCE plume traveling toward the river aquifer beneath the east bank of the river in summer 1996, and winter 1999, respectively (see Chapter 2). The total mass of all VOCs discharging from the streambed measurements is 9.7 and 7.0 g/d for winter and summer, respectively. These VOC discharge values are below or near the low end of the 19.7 to 7.7 g/d range of PCE that discharges from the adjacent aquifer (note: the PCE discharge is equivalent to total VOC discharge because the aquifer contains a negligible amount of degradation products). The difference in these mass discharge values suggest some mass loss is caused by the streambed. If the total mass of VOCs discharging through the streambed is expressed as equivalent PCE (i.e. a molar basis), the estimated discharge is 15.4 g/d and 10.9 g/d using the summer and winter groundwater discharge conditions, respectively. These values of discharge are within the range obtained for the adjacent aquifer and thus suggest the streambed did not cause an appreciable reduction in the total moles of contaminant.

An examination of the streambed showed that only 41.2 to 45.5% (on a mass basis) and 25.8 to 29.3% (on a molar basis) remains as PCE with the rest discharging as degradation products. Most of the mass of the plume discharges to the river as a combination of cDCE (40.1 to 43.8%) and VC (11.1 to 11.6%) while the other VOCs each account for less than 1.6% of the total mass discharge. On a molar basis, about 6.4% of the contamination present in the streambed was rendered non-toxic as ethene and ethane. The percent difference in the mass discharge between the winter and summer condition is also shown for each contaminant. In each case, the contaminant discharge is less because the overall groundwater discharge is less in winter. The smallest decreases in mass discharge occur for PCE (-25%) and TCE (-28%) while larger decreases occur for the degradation products (ranging from -38 to -96%). This difference is consistent with the PCE and TCE discharge being associated with the Type 2 high discharge areas where groundwater fluxes remain fairly constant (see Chapter 3).

The method used to estimate the mass discharge through the streambed incorporates a high degree of spatial variability in water fluxes and in contaminant distribution and thus provides the best estimate of contaminant discharge to a river that is known to the author. However, some level of uncertainty will be associated with any estimate because of an inherent inability to determine the exact conditions at every location in the streambed. Several factors contribute to uncertainty in the estimates of mass discharge. Further biodegradation of contaminants may occur in the 0.3 m above where the streambed samples were collected (as was observed in Figure 4-15a for PRP14 and in Figure 4-13a for PRP15), which could result in lower mass discharges for individual VOCs and total VOCs. This type of biodegradation would explain why, despite the relatively high mass of cDCE and VC supposedly discharging to river, no cDCE or VC was ever detected in surface water samples. Diffusion of oxygen from the river into the top few centimeters of the streambed could make conditions amenable for aerobic oxidation of cDCE and VC (Bradley and Chappelle, 1998; Wiedemeier et al., 1999). The top of the streambed may be one of the few environments where oxygen and methane naturally mix to support biodegradation of TCE, cDCE, or VC (without creating ethene or ethane) by methane-oxidizing bacteria called methanotrophs (Wilson and

Wilson, 1985; Tsien et al., 1989; Semprini et al., 1990; Dolan and McCarty, 1995). It should be noted that PCE would likely not be degraded by methanotrophs (Oldenhius et al.,1989) and thus not be subject to this particular attenuation mechanism. Another uncertainty in flux calculations may be a result of the limitations in the empirical temperature method used to calculate groundwater fluxes, which may over-predict low fluxes and under predict very high fluxes (see Chapter 3). These limitations would result in over predicting the mass discharge of cDCE, VC, and other degradation products from Type 3 areas and underestimating PCE and TCE mass discharges from Type 2 areas. As for the winter mass discharge estimates, they may overestimate the mass of degradation products discharging because they were calculated using the summer concentration distribution because a second set of water quality samples could not be collected in winter. In winter it is anticipated that the composition of contaminants would be different because lower streambed temperatures would slow down reaction rates and thus less biodegradation products would be produced. Another minor source of error is that water flux data was not available between transects 44-44W and 56-56W for the summer, hence contaminant flux from this area is not included in Table 4-4. Since only low concentrations of TCE and cDCE were present in a small portion of this area and groundwater fluxes were also low, this omission has no appreciable affect on the over mass fluxes calculated.

4.5.5 Summary of Conditions in the 5 Different Flow Types

The flux, redox conditions, and degree of biodegradation associated with each of the 5 flow types are summarized in Table 4-5 and shown schematically in Figure 4-19.

4.5.5.1 Type 1: Short-Circuit Springs

This type of flow represents high discharge springs (>1 L/min) and conduits that allow groundwater to travel rapidly up through the streambed deposits, essentially short-circuiting the normal groundwater flow process. This type of flow results in water discharging to the river that is geochemically unaltered groundwater which, at this particular site, is anaerobic and possibly nitrate reducing. Contamination in the spring water remains primarily in the form of PCE with very small amounts of TCE and generally undergoes no biodegradation because of short residence times. The vertical groundwater flow velocities are likely tens of meters per day or more, resulting in very short residence times in streambed deposits, on the order of minutes to hours. If these springs have high concentrations of VOCs they can represent very significant points of mass loading to the surface water and result in locally detectable concentrations in surface water (see Chapter 2).

4.5.5.2 Type 2: High Discharge

In this study, the high discharge type of flow was defined by groundwater fluxes greater than 200 L/m^{2}d. The geochemistry of water discharging in this zone was also similar to unaltered groundwater. The conditions are anaerobic to nitrate reducing and the VOCs present consisted almost exclusively of PCE (Figure 4-17a) with minor amounts of TCE (Figure 4-17b). Based on flux rates in these areas, vertical groundwater velocities range from about 0.5 to 13.8 m/d (see Chapter 3) resulting in groundwater residence times in the streambed of about 5 hours to 6 days. These times are short when compared to the half lives for biodegradation of VOCs (Wiedemeier et al., 1999), hence allowing little opportunity for PCE or TCE to transform. However, the vertical profiles of water quality in these areas showed that very localized pockets of more reducing zones could occur, resulting in small amounts of cDCE at PRP15 (Figure 4-12a and 4-12b) and even VC, ethene and ethane at MLS17 and MLS18 (Figure 4-13a and 4-13b). These areas are believed to be associated with very localized organic-rich low-hydraulic-conductivity deposits within the otherwise high-hydraulic-conductivity deposits. Type 2 areas account for about 75% of all the mass of PCE that discharges into the river and about 32% of the total mass of VOCs discharging into the river.

4.5.5.3 Type 3: Low to Medium Discharge

In this study, the low to medium discharge type of flow was defined by groundwater fluxes between 0 and 200 L/m^{2}d. The geochemistry of this zone ranges from nitrate reducing to methanogenic conditions. In general, VOCs are typically present only as cDCE and VC, with some ethene and ethane and no PCE. PCE was not found at fluxes less than 60 L/m^{2}d. The concentrations of PCE that were detected were typically quite low except for two very high concentrations found at fluxes between 140 and 200 L/m^{2}d which had flow and geochemical characteristics similar to Type 2 flow locations. Based on flux rates at Type 3 areas, vertical groundwater velocities range from about 0.001 to 0.5 m/d (Chapter 3) resulting in groundwater residence times in the streambed of about 6 days to about 8 years, although most residence times would be on the order of weeks to months. Given these longer residence times, the rate of biodegradation reactions is sufficient to transform all the PCE to degradation products. Nearly all of the degradation products observed at the site occur in this type of flow regime. The Type 3 area is relatively large and the majority of all the VOCs mass discharging to the river occurs in this zone, including nearly 100% of the cDCE, tDCE, 11DCE, VC, ethene and ethane.

The geochemical conditions in Type 3 areas were not completely uniform and it is not clear why conditions varied as is indicated by the scatter of data points in Figures 4-9 and 4-17. Some Type 3 locations showed no biodegradation and not very reducing conditions suggesting that either the geochemical behavior was not solely a function of flux at these locations or that the calculated fluxes were not representative at those locations. Some Type 3 data points were just below the 200 L/m^{2}d cut off for Type 2 flow conditions and were geochemically similar to Type 2 data and perhaps were locations where calculated fluxes were too low or the cut off is too high and they really should have been categorized as Type 2 locations. For some low flux Type 3 locations, other factors such as a lack of appropriate microbes, or an insufficient source of labile carbon, or lack of appropriate nutrients may have prevented the biodegradation of PCE or the development of reducing conditions.

4.5.5.4 Type 4: No Discharge

Type 4 flow is defined as no groundwater discharge, which can be no vertical flow of groundwater or can be horizontal flow of groundwater or surface water (as hyporheic zone flow). This type of flow was small in area and tended to be quite localized and was typically identified by low chloride concentrations indicative of surface water, rather than by calculated groundwater fluxes. Relatively few sample points were located in this type of flow. Redox conditions ranged from aerobic to methanogenic as is evident from the vertical profile at PRP7 (Figure 4-16b). If water originates as surface water, then VOCs should be absent or at very low concentrations, which generally appeared to be the case. Low concentrations of PCE, TCE, and cDCE were detected in some locations and were absent in others. Methane was either absent or only present at quite high concentrations (220 μg/L to over 1000 μg/L). It is hard to equate these conditions to residence times in the streambed since the water is likely flowing horizontally for unknown distances, but some of the highest methane concentrations observed in the study were at Type 4 locations perhaps indicating relatively stagnant conditions. Type 4 locations do not contribute to the mass discharge to the river, although water moving horizontally from that zone may eventually discharge to the river at a later time.

4.5.5.5 Type 5: Recharge

Type 5 flow occurs where surface water flows downward into the streambed. Even though the area of Type 5 conditions in Figure 4-4 is relatively large, relatively few sampling points were located in this zone. Conditions in Type 5 locations are similar to Type 4 locations and can range from aerobic to methanogenic but the origin of the water is definitely surface water. If the depth below the streambed is small and the amount of time required to get there is short, any contamination that might be in the infiltrating water would have little or no time to biodegrade. One Type 5 and one Type 4 location were the only two samples in the plan-view mapping of streambed concentrations where the VOCs in the streambed were about 50 % PCE and 50% degradation products (Figure 4-17a). This partial biodegradation suggests the residence time may be too short to allow completion of these reactions. Downward flow means no VOCs discharge to the river at these locations.

4.5.6 Issues Concerning Data Interpretation and Monitoring

A strong correlation clearly exists between the magnitude of the flow, the redox conditions, and the amount of biodegradation of VOCs observed. However, at this site, the low hydraulic conductivity deposits that result in low fluxes are also generally quite organic-rich (i.e. the semi-confining deposits and organic-rich layers within the sandy streambed deposits). It was difficult to attribute the more reducing conditions solely to the longer residence times since these two factors generally were considered to be positively correlated. For example, Type 2 high discharge areas were associated with geological windows (see Chapter 3) where the low hydraulic conductivity semi-confining deposits were absent so residence times were short but the foc of deposits were low, and redox conditions were not very reducing. However, one exception to this pattern was at PRP12 in the eastern shore discharge area where both fluxes and the foc of the deposits were high. At PRP12, the surficial geology and shallow profiling indicated silt, peat, and silty-clay materials at depth but high concentrations of PCE and virtually no degradation products were observed in discharging water. Even though conditions may have been favorable for redox and biodegradation reactions to occur, the discharging water was likely moving too quickly to be affected by these kinetically limited reactions and so the water remained virtually unchanged.

Vertical water quality profiles typically showed that PCE was biodegrading over very short vertical distances (i.e. 0.45 to 0.15 m or less) where sharp changes in redox conditions occurred. These changes occurred either within the top of the semi-confining deposits where it interfaced with the overlying streambed sands at PRP7R, PRP14, and PRP8R or within thin organic rich layers and pockets within the streambed deposits as seen in profiles PRP15, the MLS17 and MLS18 pair, and PRP8R. Fermentation and other reactions within these organic-rich, low hydraulic conductivity deposits likely resulted in the production of DOC and solutes that are beneficial to the microbially mediated VOC degradation and redox reactions observed near or at these interfaces. An examination of aquifer/aquitard interfaces (McMahon, 2001) observed similar changes in redox conditions and biogeochemical conditions occurring at these interfaces. Finding the exact place where biodegradation of PCE is actively occurring within these transition zones can be difficult as evident by the fact that very few of the August 1998, samples documented this process when it was half way completed (e.g. samples containing about 50% PCE and 50% biodegradation products). The zones where PCE is actively converted to transformation products is shown schematically in Figure 4-19. The conditions in the streambed seemed to be all or nothing, meaning the conditions were either amenable for complete degradation of PCE to transformation products over relatively short distances or there was no degradation. Although researchers have shown a relationship between DOC and the degree of anaerobic biodegradation (USEPA, 1998), this study showed did not show a strong correlation between DOC concentrations and biodegradation of VOCs. The lack of correlation may be because the method used for DOC analyses did not accurately reflect the labile fraction of the DOC or because DOC in the subsurface was being consumed as rapidly as it was produced resulting in no measureable net gain. High DOC concentrations were associated with some highly dechlorinated samples, but the only clear trends observed with respect to DOC were that of increasing Mn (total) and ammonia (total) as DOC increased.

Fine scale variations in flow, geochemistry, and VOC concentrations make this environment a difficult one to fully characterize and monitor. Defining exact groundwater flow paths is also very difficult even using the fine scale of monitoring performed in this study. For example, the vertical water quality profile at PRP15 is in a Type 2 strong groundwater discharge area, but the flow does not appear to be exactly vertical based on conservation of mass considerations. Equivalent PCE concentrations are relatively constant in this profile, but PCE concentrations rise and fall along the profile, thus the profile can not be along a single flow path (i.e. flow can not be 1-dimensional). PCE can not be created in-situ and variation in the upgradient source of contamination is unlikely to result in such small scale pulses of contamination propagating through the system. The mini-profiler must have pierced a less conductive and more reducing layer or pocket of deposits that is in contact with the larger flow path and some contaminants move slowly through it and degrade while the rest goes vertically around it to the river (see Figure 4-19).

In the MLS17 and18 pair (Figure 4-13), the vertical distribution of VOCs suggests an oblique rather that a vertical flow path. At PRP8R (Figure 4-14), the equivalent PCE concentration varies considerably which also suggests an oblique flow path at this location. When one also considers the possibility of both horizontal and downward flow associated with Type 4 and Type 5 flow in streambeds, it is quite a challenge to design a "representative" monitoring program to define specific flow paths and, unless flow paths are defined, it will confound attempts to numerically model contaminant behavior. Contaminant sorption to high foc materials and retardation of their movement through the subsurface materials further complicates attempts to interpret contaminant transport in this environment especially if flow conditions change over time.

4.6 CONCLUSIONS

An exceptionally detailed investigation of a streambed where a PCE plume discharges to a river resulted in three major findings. 1) A very complex pattern of flow, redox conditions, biodegradation, and mass discharge occurs in the streambed. 2) The conceptual model of 5 different flow types at the site (Chapter 3) was a good framework for categorizing and interpreting the interstitial water quality of the streambed. 3) Anaerobic biodegradation in the streambed reduced the mass of PCE and total mass of chlorinated VOCs discharging to the river, but this reduction was achieved through transformation of PCE to degradation products and not by complete mineralization of the contaminants. The extent of anaerobic PCE biodegradation varied on a scale of 2 m laterally. Virtually no PCE degradation occurred in high flux anaerobic to nitrate reducing areas while complete conversion of PCE to transformation products (primarily cDCE and VC with lesser amounts of TCE, 11DCE, tDCE, ethene and ethane) occurred in low flux areas having nitrate reducing to methanogenic conditions. Vertical profiles showed that active transformation of PCE typically happened over very short vertical intervals (i.e. 0.45 to less than 0.15 m) usually where sharp changes to more reducing conditions occurred. The changes usually occurred at or within the top of the organic-rich semi-confining deposits or within localized pockets of organic-rich low-hydraulic-conductivity deposits within the streambed sands. No direct evidence of aerobic biodegradation or oxidation of cDCE or VC was found, probably because the streambed deposits were anaerobic and very little hyporheic mixing with oxygenated surface water was observed, but such oxidation may occur in the top few centimeters of the streambed which were not sampled. The magnitude of groundwater flux through the streambed was highly correlated with the redox conditions and extent of anaerobic dechlorination of the contaminants. Areas with the lowest groundwater fluxes were typically associated with sulfate reducing and methanogenic conditions and high amounts of degradation and dechlorination (down to ethene and ethane).

The key to being able to use the conceptual flow model (Chapter 3) to categorize and interpret the geochemical and contaminant distributions in the streambed was that the low rates of water flux were typically caused by and associated with organic-rich low-hydraulic-conductivity deposits. Relatively distinct biogeochemical conditions were associated with each type of flow. Low fluxes result in longer water residence times that can promote more reducing conditions and anaerobic biodegradation to occur by allowing sufficient time for reactions to go to completion. However, the effect of longer residence times versus exposure to organic-rich deposits could not be separated, so care should be taken when applying a flux based conceptual model to interpret biogeochemical conditions at other sites. The value of 200 L/m^2d separating high from low-to-medium discharge conditions is not meant to be a universal cut-off between these types of behaviors and the cut-off will likely be site specific and a function of residence times in the deposits.

The degree to which the mass of the plume was reduced in the streambed prior to discharging to the river was calculated using mass discharge maps created for each contaminant. Since the plume reaching the edge of the river was virtually all PCE, biodegradation of the plume in the streambed clearly reduced the mass of PCE and overall mass of VOCs discharging to the river. However, the PCE plume was only partially dechlorinated and did not undergo significant mineralization in the streambed (i.e. the total molar amount of contaminants discharging from the streambed were within the range estimated for the PCE plume traveling in the aquifer toward the river). In the streambed, an estimated 41 to 46% of the total mass of VOCs (or about 26 to 29% of the moles) was PCE, the remainder was primarily cDCE (40 to 44%) and VC (11 to 12%). Despite almost equal PCE and cDCE total mass discharge, only PCE was detected in surface water samples at low concentrations (≤ 23.2 μg/L), probably because PCE mass discharged in areas of the streambed having the highest fluxes and so were less rapidly diluted in surface water, whereas cDCE discharge was more spread out with lower fluxes. This study shows that the streambed is a mosaic of different biogeochemical conditions but, by performing detailed monitoring and viewing these pieces in the context of a conceptual flow model, a clear picture is developed of where, why, and how much the plume is transformed.

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Table 4-1. Water analyses methods and detection limits for inorganic and other parameters.

Parameter	**Analyses method**	**Procedure**	**Detection limit**	**Units**
Alkalinity as $CaCO_3$	USEPA Method 310.2	Colorimetric	1.0	mg/L
Alkalinity as $CaCO_3$ (field)	Hach Test Kit, Model AL-DT	Colormetric titration	10.0	mg/L
Ammonia as N (total)	USEPA Method 350.1	Colorimetric	0.05	mg/L
Calcium	USEPA Method 200.7	ICP-OES	0.1	mg/L
Chloride	USEPA Method 325.1	Colorimetric	1.0	mg/L
Color	Standard Methods, 16th Edition	Colorimeter	5.0	TCU
Copper	USEPA Method 200.7	ICP-OES	0.01	mg/L
Dissolved Organic Carbon (DOC)	Standard Methods, 19th Edition	UV Oxidation	0.5	mg/L
Dissolved Oxygen (DO)	CHEMetrics R-7503 / R-7513	Photometric	0.01	mg/L
Eh at 25 °C	Field Meter	Electrode	NA	mV
Iron (total)	USEPA Method 200.7	ICP-OES	0.02	mg/L
Magnesium	USEPA Method 200.7	ICP-OES	0.1	mg/L
Manganese (total)	USEPA Method 200.7	ICP-OES	0.01	mg/L
Methane	Gas Chromatography	FID	0.5	µg/L
Nitrate + Nitrate as N	USEPA Method 353.1	Colorimetric	0.05	mg/L
Nitrate as N	USEPA Method 353.1	Colorimetric	0.05	mg/L
Nitrite as N	USEPA Method 354.1	Colorimetric	0.01	mg/L
pH	USEPA Method 150.3	Electrometric	0.1	pH units
pH (field)	Field Meter	Electrode	NA	pH units
Phosphate (ortho)	USEPA Method 365.2	Colorimetric	0.01	mg/L
Phosphorous (total)	Standard Methods 4500P	Colorimetric	0.01	mg/L
Potassium	USEPA Method 200.7	ICP-OES	0.1	mg/L
Silica (reactive) as SiO_2	USEPA Method 370.1	Colorimetric	0.5	mg/L
Sodium	USEPA Method 200.7	ICP-OES	0.1	mg/L
Specific Conductance	Standard Methods, 19th Edition	Electrometric	1.0	µmhos/cm
Specific Conductance (field)	Field Meter	Electrode	1.0	µS/cm
Sulfate	USEPA Method 375.4	Turbidimetric	2.0	mg/L
Sulfide (total soluble)	CHEMetrics R-9503 / K9510	Photometric	0.01	mg/L
Turbidity	USEPA Method 180.1	Nephelometer	0.1	NTU
Zinc	USEPA Method 200.7	ICP-OES	0.01	mg/L

Notes:
FID = Flame ionization detector
ICP-OES = Inductively coupled plasma - optical emission spectroscopy
mg/L = milligrams per liter
mV = millivolts
NTU = Nephelometric turbidity units
TCU = total color units
µg/L = micrograms per liter
µmhos/cm = micromhos per centimeter (same as µS/cm)
µS/cm = microsiemens per centimeter

Table 4-2. Groundwater quality in the confined aquifer adjacent to and east of the river.

Parameter	Units	Median	Average	Minimum	Maximum	No. of Samples
Alkalinity as $CaCO_3$[A]	mg/L	248	250	130	402	44
Aluminum	mg/L	0	0	0	0	7
Ammonia (as N)	mg/L	0.00	0.18	0	1.94	44
Calcium	mg/L	114.0	115.7	93.1	146.0	7
Chloride	mg/L	127.5	130.1	36.8	207.0	44
Copper	mg/L	0	0	0	0	7
Dissolved Organic Carbon (DOC)	mg/L	3.50	3.14	0.0	5.7	44
Dissolved Oxygen (DO)	mg/L	0.17	0.28	0	0.87	44
Eh at 25 °C	mV	318.7	337.0	92.7	519.8	48
Iron (total)	mg/L	0.04	0.39	0	6.81	44
Magnesium	mg/L	9.2	10.8	7.6	19.2	14
Manganese (total)	mg/L	0.13	0.13	0.03	0.33	44
Methane	µg/L	8.7	52.4	0	644.8	46
Nitrate as N	mg/L	1.65	2.83	0	18.10	44
Nitrate + Nitrite as N	mg/L	1.74	2.89	0	18.28	44
Nitrite as N	mg/L	0.06	0.06	0	0.19	44
Phosphate (ortho)	mg/L	0	0.01	0	0.10	7
pH	pH units	7.8	7.8	7.3	8.1	44
pH (field)	pH units	7.18	7.14	5.64	7.58	48
Potassium	mg/L	9.7	9.7	5.9	11.7	7
Sodium	mg/L	58.2	66.0	14.5	124.0	44
Specific Conductance	µmhos/cm	973	985.3	753	1330	44
Specific Conductance (field)	µS/cm	827.5	788.3	471	1172	48
Sulfate	mg/L	34.0	33.5	4.0	66.0	44
Sulfide (total soluble)	mg/L	0	0.004	0	0.14	44
Zinc	mg/L	0	0	0	0	7

Notes:
Data from vertical water quality profiles at locations BML1, BML3, BML7, AP53, AP54, and AP55
[A] Alkalinity measured in laboratory
mg/L = milligrams per liter
mV = millivolts
µg/L = micrograms per liter
µmhos/cm = micromhos per centimeter (same as µS/cm)
µS/cm = microsiemens per centimeter

Table 4-3. Surface water quality in the Pine River.

Parameter	Units	Median	Average	Minimum	Maximum	No. of Samples
Alkalinity as $CaCO_3$	mg/L	201.6	195	181	245	19
Alkalinity as $CaCO_3$ (field)	mg/L	229.3	232	224	232	3
Ammonia (total) as N	mg/L	0.012	0	0	0.16	25
Calcium	mg/L	67.3	62.2	58.9	82	10
Chloride	mg/L	14.6	14.1	12.8	17.4	25
Color	mg/L	14.6	15	9	19	10
Copper	mg/L	0	0	0	0	10
Dissolved Organic Carbon (DOC)	mg/L	3.8	3.5	1.4	13.4	25
Dissolved Oxygen (DO)	mg/L	8.2	8.2	2.2	12.8	24
Eh at 25 °C	mV	392.5	398.5	290.1	508.6	19
Iron (total)	mg/L	0.032	0.03	0	0.08	25
Magnesium	mg/L	15.9	16.1	14.2	16.8	10
Manganese (total)	mg/L	0.02	0.01	0	0.12	25
Methane	µg/l	2.6	5.3	0.0	67.7	64
Nitrate + Nitrite as N	mg/L	1.25	1.15	0.89	2.06	25
Nitrate as N	mg/L	1.31	1.19	0.92	2.06	18
Nitrite as N	mg/L	0.008	0.01	0	0.02	18
pH	pH units	8.1	8.1	7.8	8.4	19
pH (field)	pH units	7.7	7.84	6.46	8.28	14
Phosphate (ortho)	mg/L	0	0	0	0	10
Phosphorous (total)	mg/L	0.030	0.028	0.022	0.041	3
Potassium	mg/L	1.4	1.4	0.9	2.8	10
Silica (reactive) as SiO_2	mg/L	9.3	9.3	8.8	10.6	10
Sodium	mg/L	8.3	8	6.6	15.4	25
Specific Conductance	µS/cm	505	509	450	550	19
Specific Conductance (field)	µmhos/ cm	419.9	417	340	463	19
Sulfate	mg/L	20.4	21	16	25	25
Sulfide (total soluble)	mg/L	0.01	0	0	0.05	24
Zinc	mg/L	0.001	0	0	0.01	10

Notes:
Samples collected from the Pine River between 1996 and 1999
mg/L = milligrams per liter
mV = millivolts
µg/L = micrograms per liter
µmhos/cm = micromhos per centimeter (same as µS/cm)
µS/cm = microsiemens per centimeter

Table 4-4. Contaminant mass discharge to the river for the plume based on the August 1998, streambed VOC concentrations distributions and the summer 1998 and winter 1999 groundwater discharge conditions

Parameter	Summer flux condition				Winter flux condition				Percent difference in mass discharge relative to winter
	Mass discharge		Molar discharge		Mass discharge		Molar discharge		
	mg/d	Percent of total VOCs	mM/d	Percent of total VOCs as PCE	mg/d	Percent of total VOCs	mM/d	Percent of total VOCs as PCE	
PCE	3989	41.2%	24.05	25.8%	3199	45.5%	19.29	29.3%	-25%
TCE	117	1.2%	0.89	1.0%	91	1.3%	0.69	1.1%	-28%
11DCE	14	0.1%	0.14	0.2%	10	0.1%	0.10	0.2%	-39%
tDCE	27	0.3%	0.28	0.3%	14	0.2%	0.14	0.2%	-96%
cDCE	4241	43.8%	43.75	46.9%	2820	40.1%	29.09	44.2%	-50%
VC	1127	11.6%	18.03	19.3%	782	11.1%	12.51	19.0%	-44%
Ethene	151	1.6%	5.40	5.8%	99	1.4%	3.53	5.4%	-53%
Ethane	25	0.3%	0.83	0.9%	13	0.2%	0.44	0.7%	-89%
Total VOCs	9691	100.0%	NA	NA	7027	100.0%	NA	NA	-38%
Total VOCs as equivalent PCE	15483	NA	93.37	100.0%	10909	NA	65.78	100.0%	-42%

Notes:
NA = not applicable
mg/d = milligrams per day
mM/d = millimoles per day

Table 4-5. Summary of flow conditions, redox conditions, and PCE biodegradation occurring for streambed water in each of the 5 different types of water discharge conditions

Flow Type	**Origin of water**	**Vertical flux range (L/m^2d)**	**Vertical velocity range (m/d)**	**Residence time of water in streambed**	**Redox conditions in streambed**	**PCE biodegradation occuring**
1) Short-Circuit Discharge	GW	> 1^D (L/min)	> 10	minutes to hours	Anaerobic, possibly nitrate reducing	None
2) High Discharge	GW	> 200	0.5 to 13.8	5 hours to 6 days	Anaerobic to nitrate reducing with some more reducing zones	None, except some in very localized zones
3) Low to Medium Discharge	GW	< 200 but > 0	0.0005 to 0.5	6 days to 8 years	Nitrate reducing to methanogenic	80 to 100% transformation, except for a few locations
4) No Discharge	GW, SW, or a mixture	0	0^A	Depends on length of flow path	Aerobic to methanogenic	NA^C
5) Recharge	SW	< 0	ND^B	Depends on length of flow path	Aerobic to methanogenic	NA^C

Notes:

[A] No vertical flow but there could still be horizontal flow

[B] Vertical velocities were not determined for this type of flow but are likely quite low.

[C] This type of flow condition is usually not contaminated

[D] Flow expressed as a total discharge not as a per-area flux

GW = groundwater
NA = not applicable
ND = not determined
SW = surface water

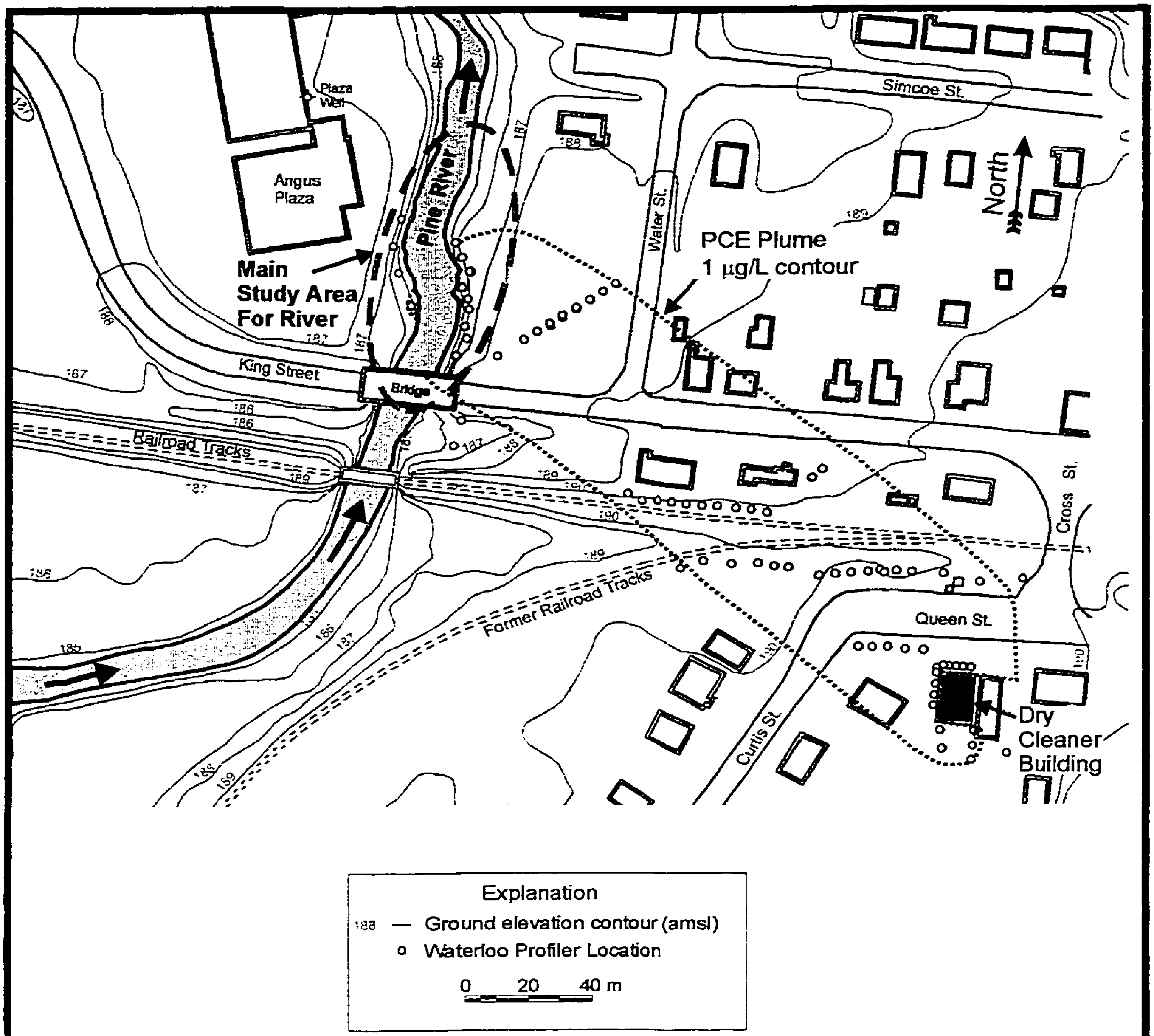


Figure 4-1. Map of dry cleaner site, Angus, Ontario, Canada, showing the location of the PCE plume (1 µg/L contour), land based Waterloo Profiler locations, ground elevation contours, and the main study area along the Pine River.

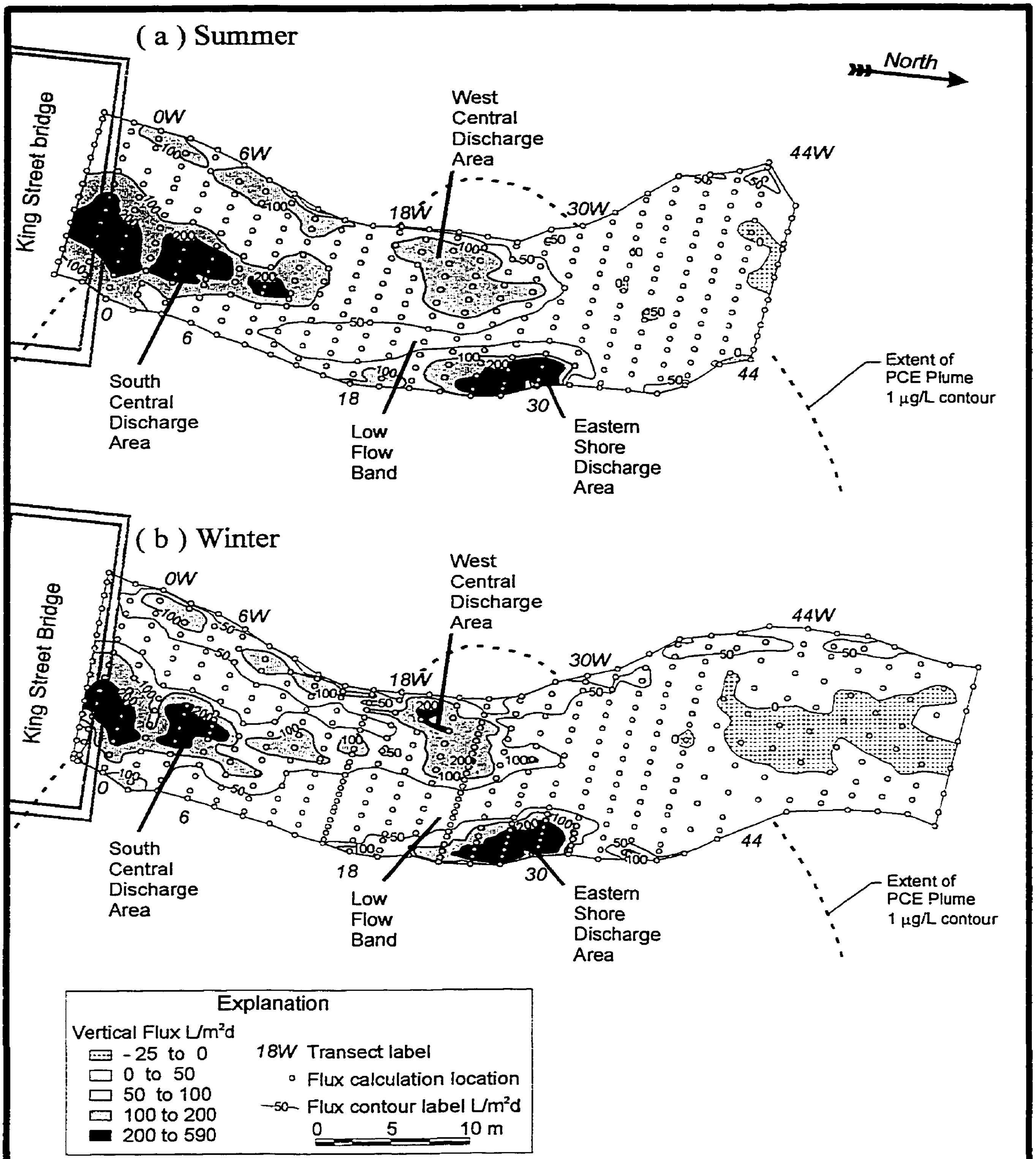


Figure 4-2. Plan-view contour maps of vertical water fluxes calculated using empirical relationships between streambed temperatures and Darcy flux for (a) summer 1998 and (b) winter 1999. Areas of high and low discharge and the position of the PCE plume are also shown.

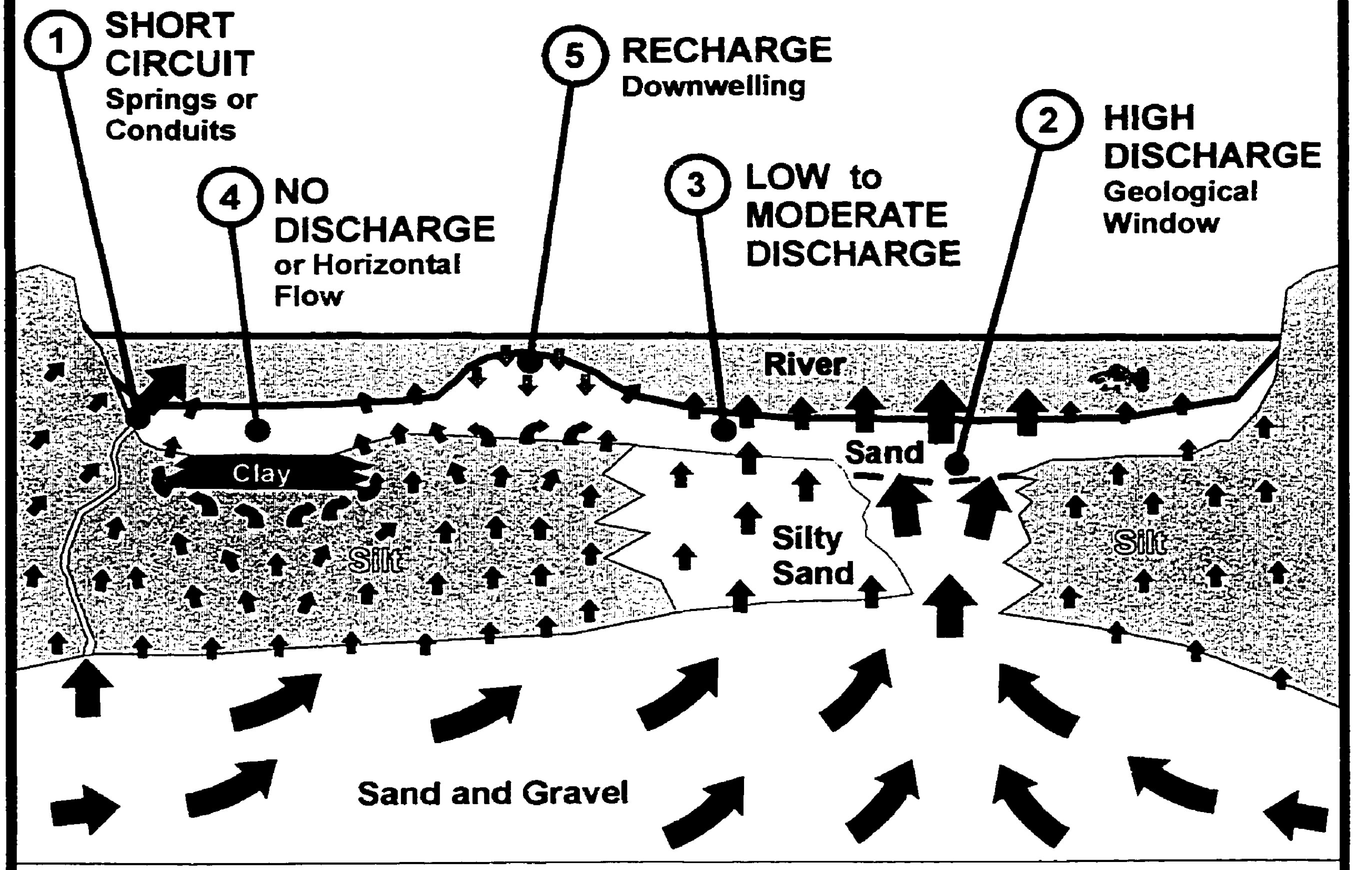


Figure 4-3. Conceptual model of 5 different types of flow beneath a river shown in cross section perpendicular to the direction of flow in the river. Arrows point in the direction of flow in the deposits and larger arrow sizes depict higher fluxes.

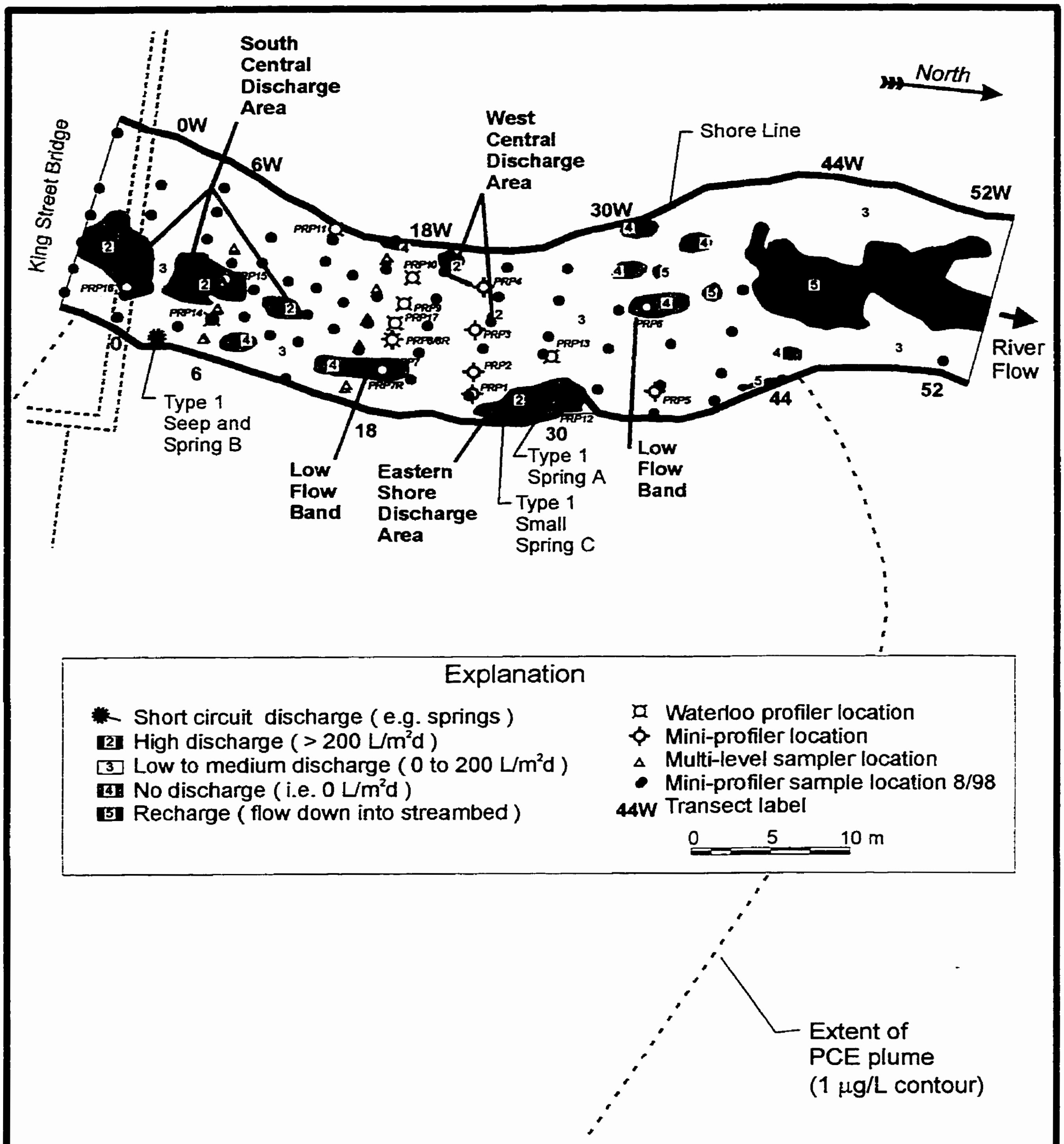


Figure 4-4. Plan-view of conceptual model for 5 different types of flow in streambed. The figure combines the behavior observed during the summer and winter mapping of fluxes and the geochemical data collected in summer. The maximum observed extent of Type 2 and Type 4 areas is shown hence the figure is a composite of conditions that have occurred over time. Type 4 areas may include Type 5 areas within them and vice versa but that were not delineated and are not shown.

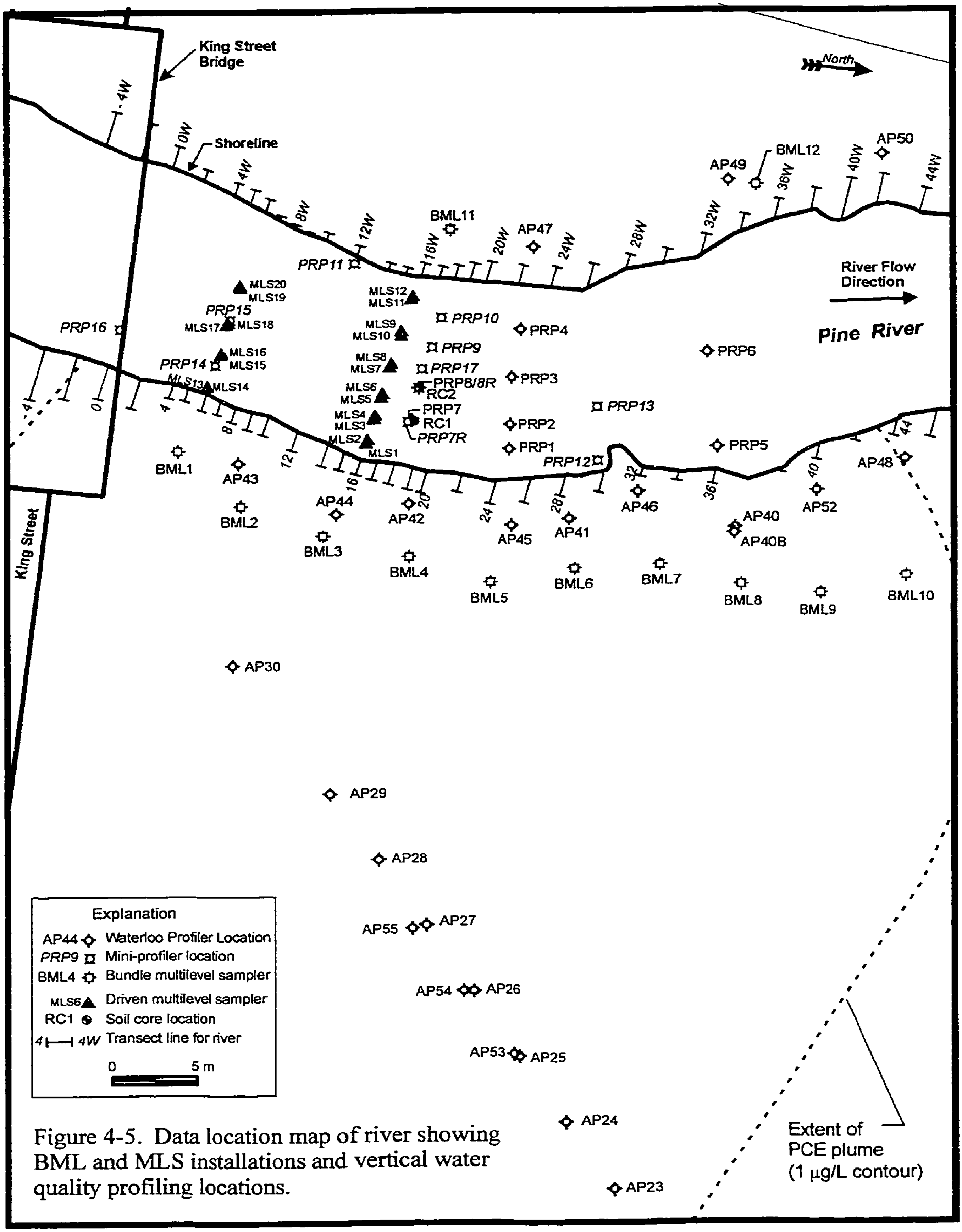


Figure 4-5. Data location map of river showing BML and MLS installations and vertical water quality profiling locations.

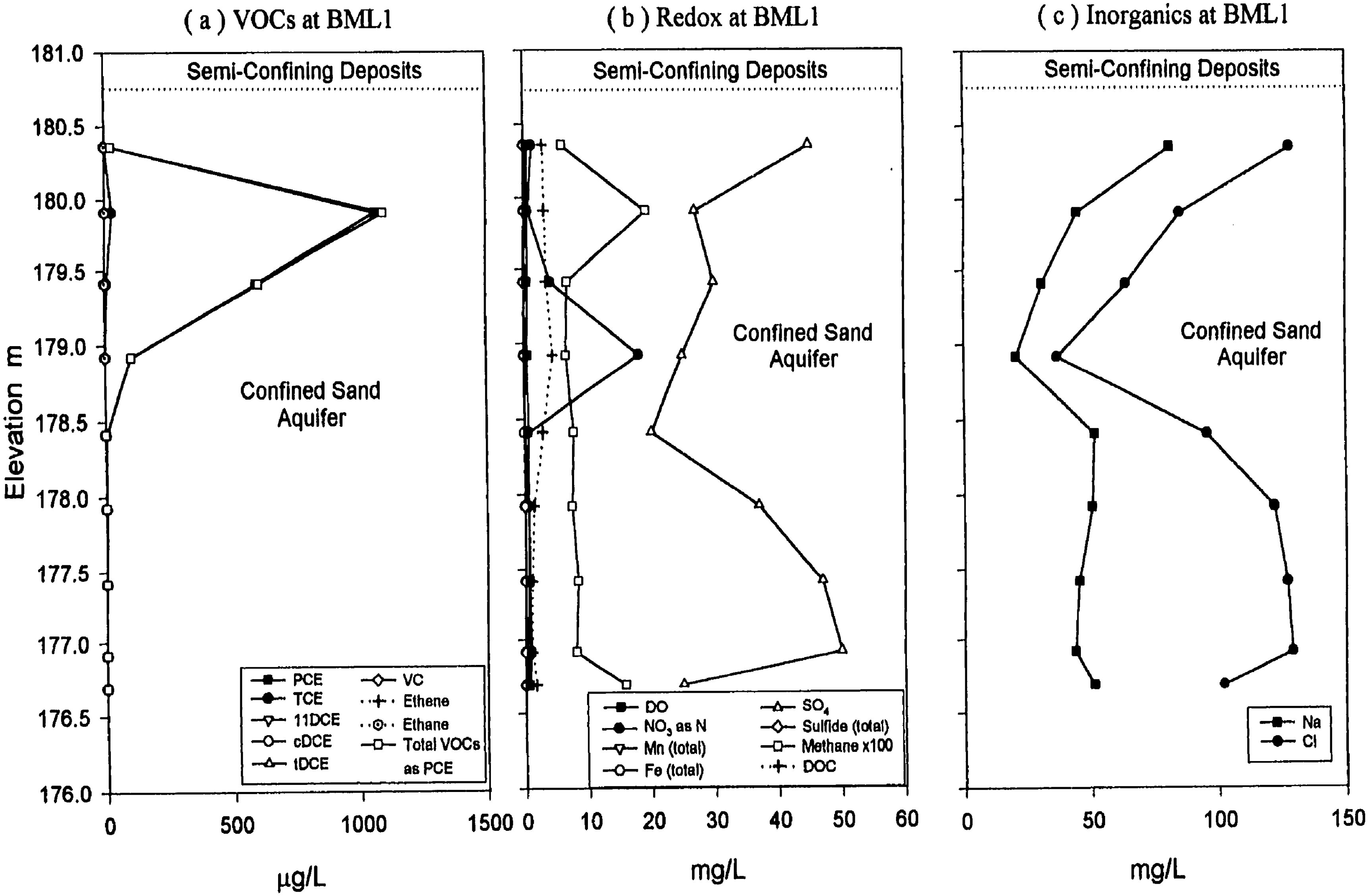


Figure 4-6. Vertical water quality profiles in the confined aquifer at bundle multilevel sampler location BML1. (a) VOC concentrations, (b) redox sensitive inorganic species and methane (c) chloride and sodium.

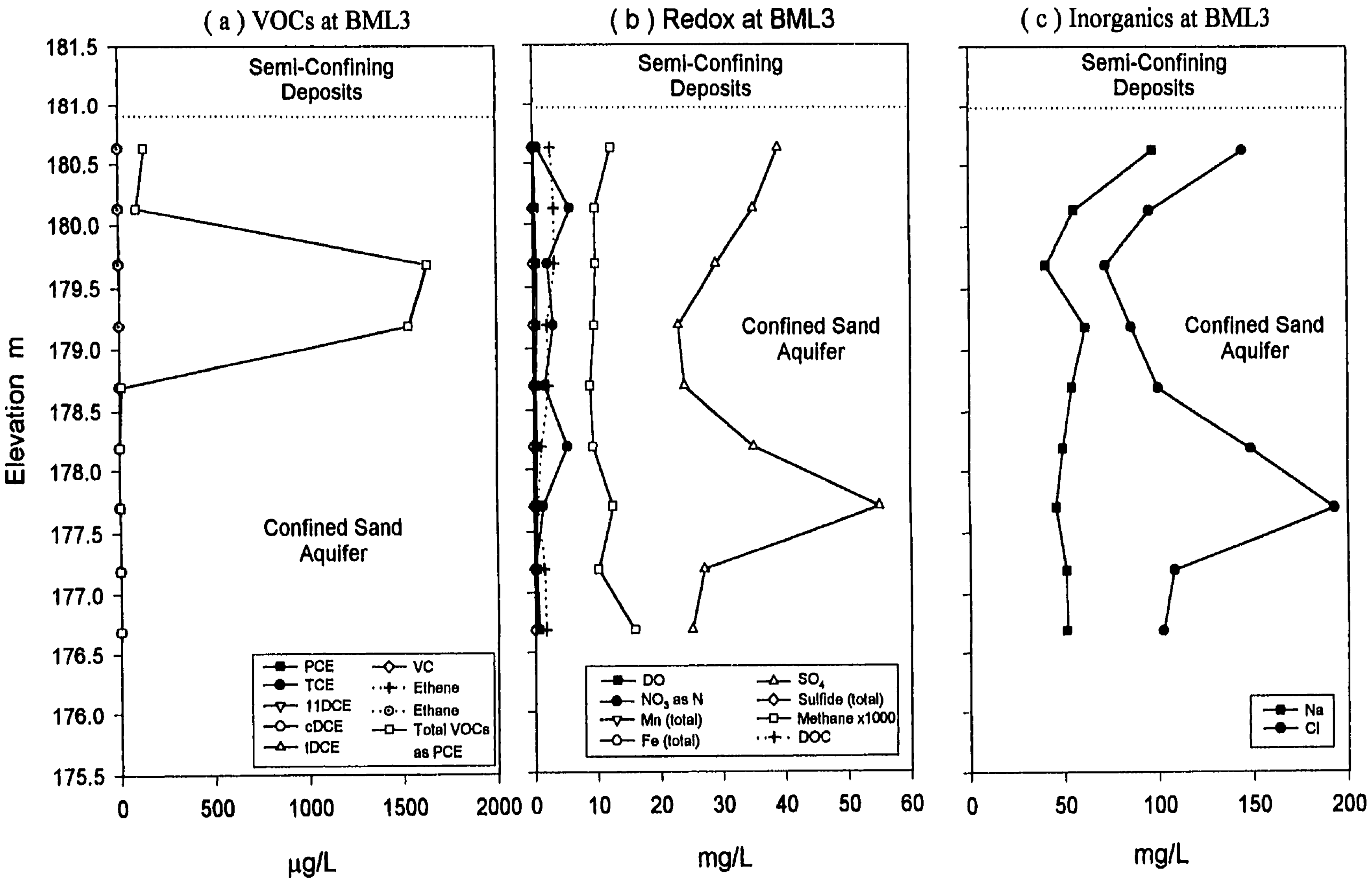


Figure 4-7. Vertical water quality profiles in the confined aquifer at bundle multilevel sampler location BML3. (a) VOC concentrations, (b) redox sensitive inorganic species and methane (c) chloride and sodium.

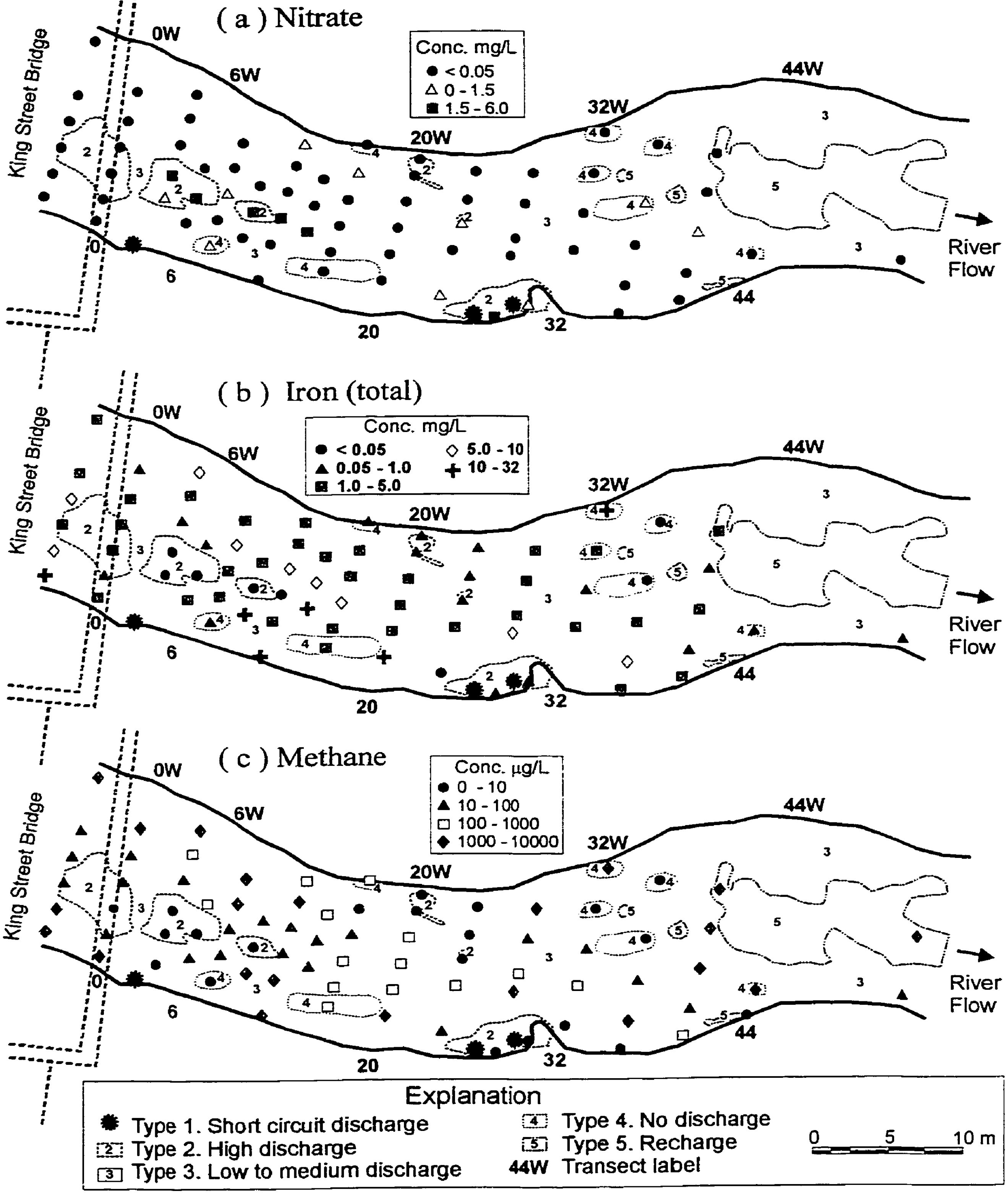


Figure 4-8. Plan-view of concentrations in the streambed at a depth of 0.3 m in August 1998, for (a) Nitrate, (b) Iron (total), and (c) Methane. Streambed is Type 3 discharge except where indicated otherwise.

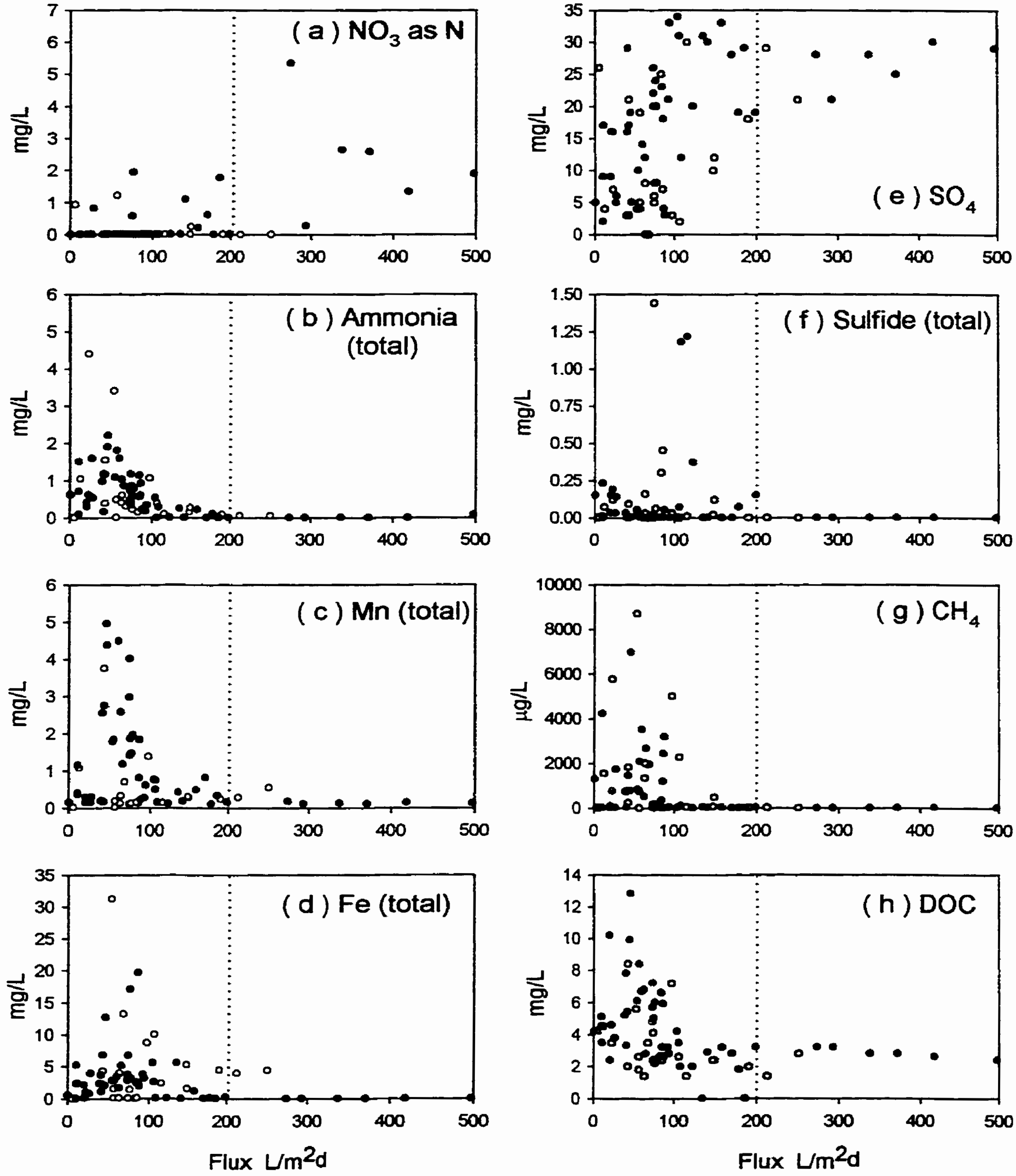


Figure 4-9. Streambed water concentrations (August 1998) versus water flux (July 1998) for (a) NO_3 as N, (b) Ammonia (total), (c) Mn (total), (d) Fe (total), (e) SO_4, (f) Sulfide (total), (g) CH_4, and (h) DOC at a depth of 0.3 m at 76 locations. Vertical dotted lines at 200 L/m^{2}d indicates the division between Type 2 and Type 3 flow. Closed circles indicate VOC contamination also detected at the location, open circles indicate no VOCs detected.

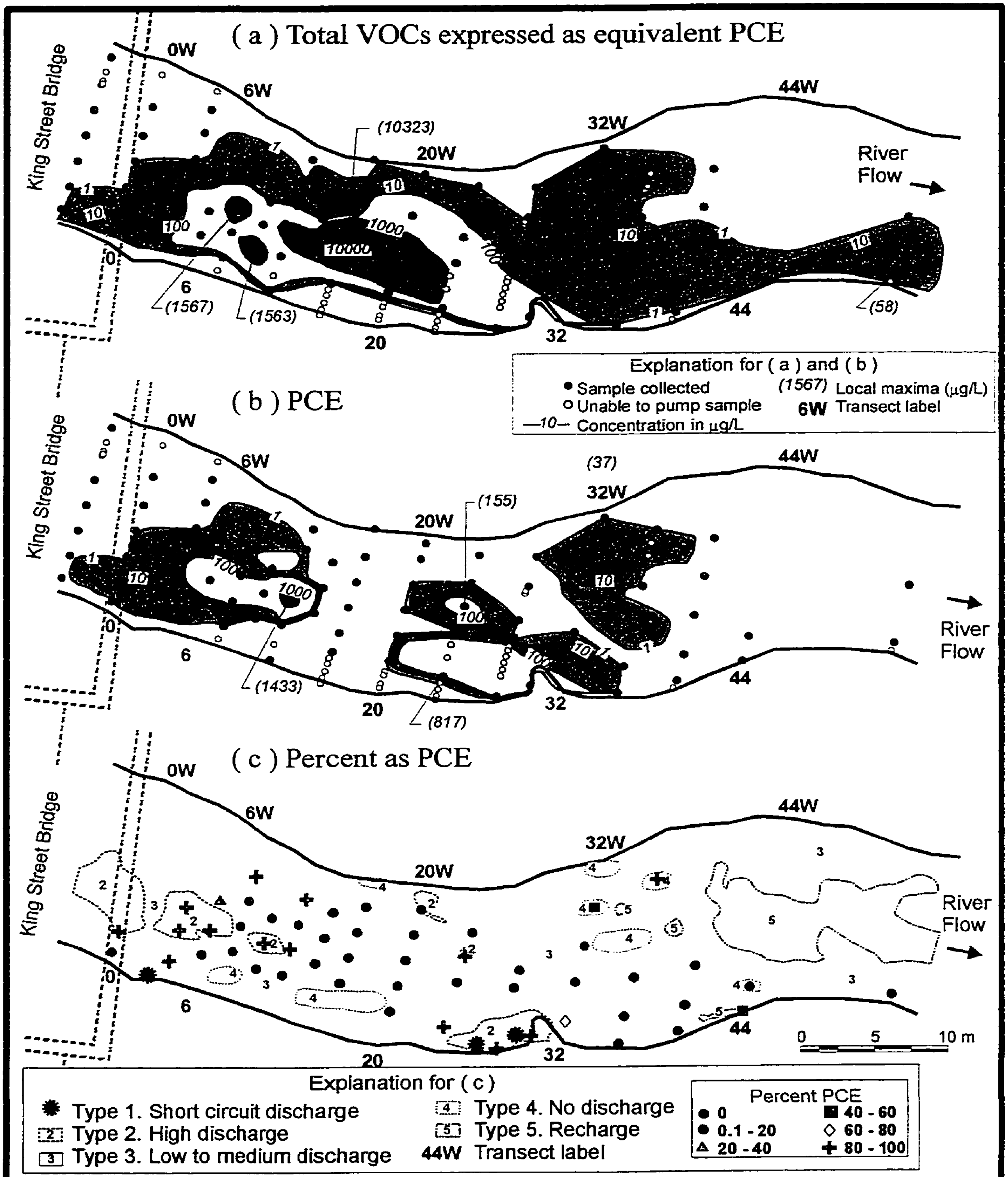


Figure 4-10. Plan-view of concentrations in the streambed at a depth of 0.3 m in August 1998, for (a) Total VOCs expressed as equivalent PCE, (b) PCE, (c) Percent as PCE for locations where VOCs were detected. Streambed discharge is type 3 discharge unless indicated otherwise on Figure (c).

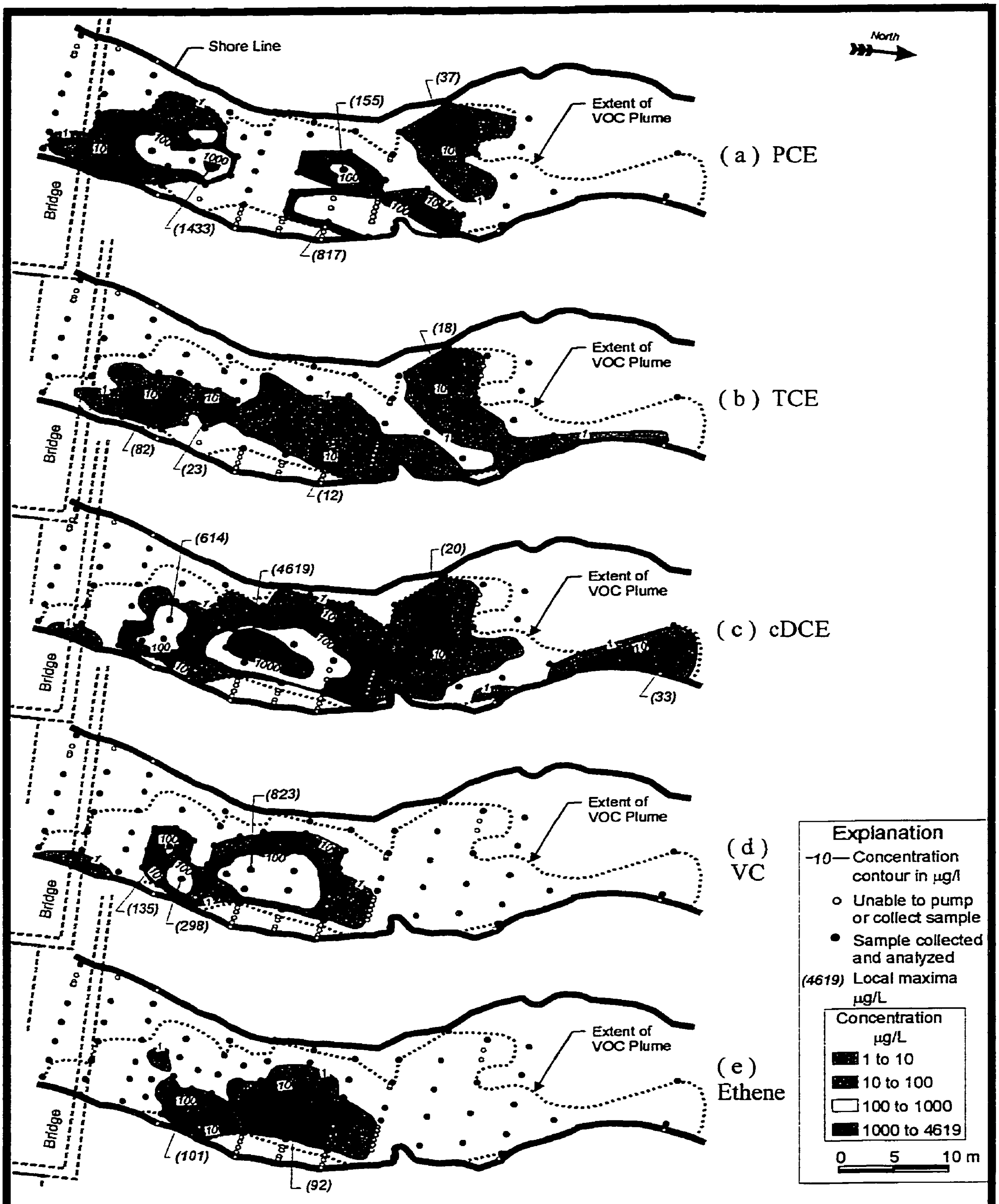


Figure 4-11. Plan-views of contaminant concentrations in the interstitial water of the streambed at a depth of 0.3 m in August 1998 for (a) PCE, (b) TCE, (c) cDCE, (d) VC, and (e) Ethene.

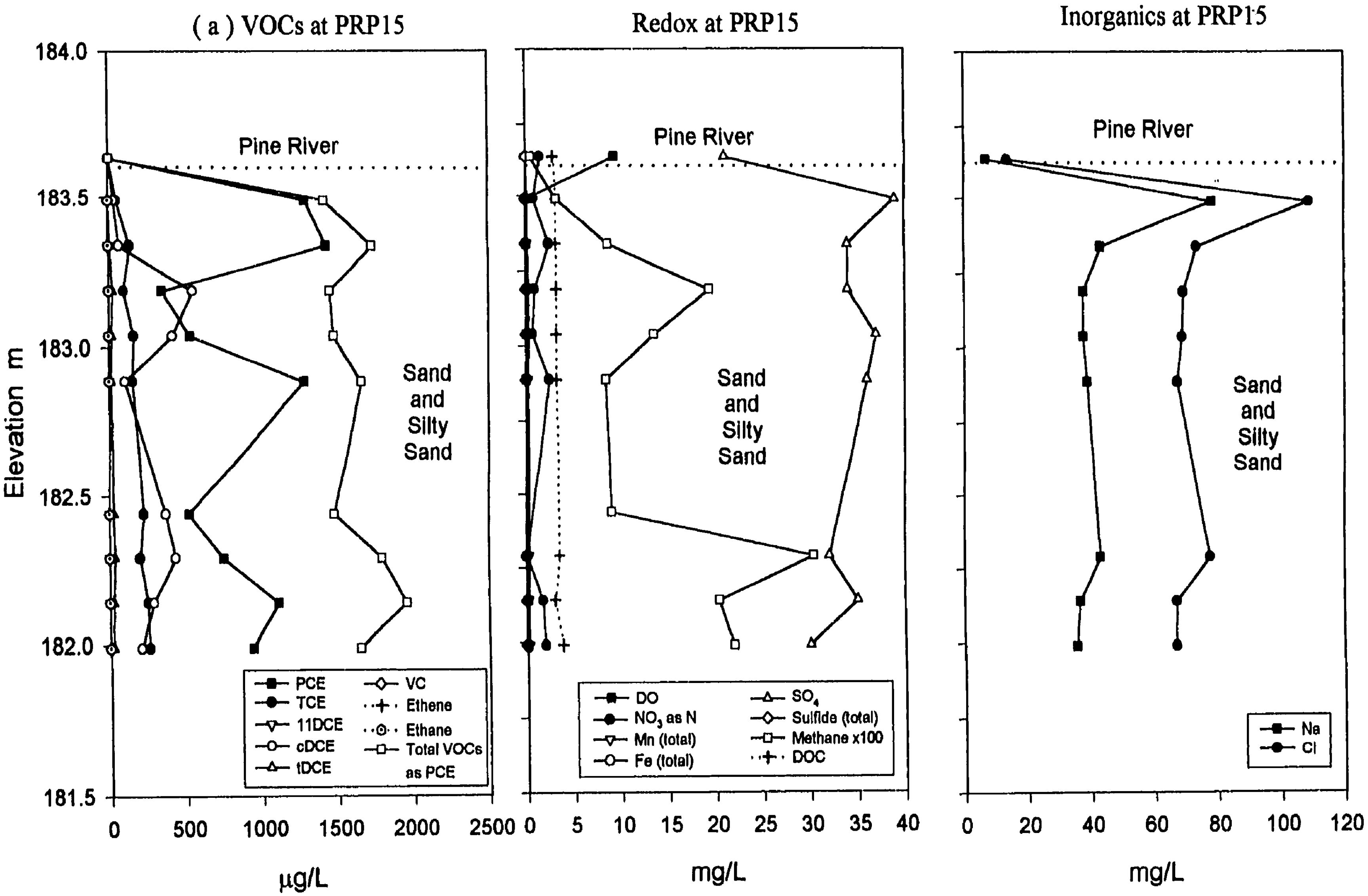


Figure 4-12. Vertical water quality profiles in Type 2 high discharge areas at mini-profiler location PRP15. (a) VOC concentrations, (b) redox sensitive inorganic species and methane (c) chloride and sodium.

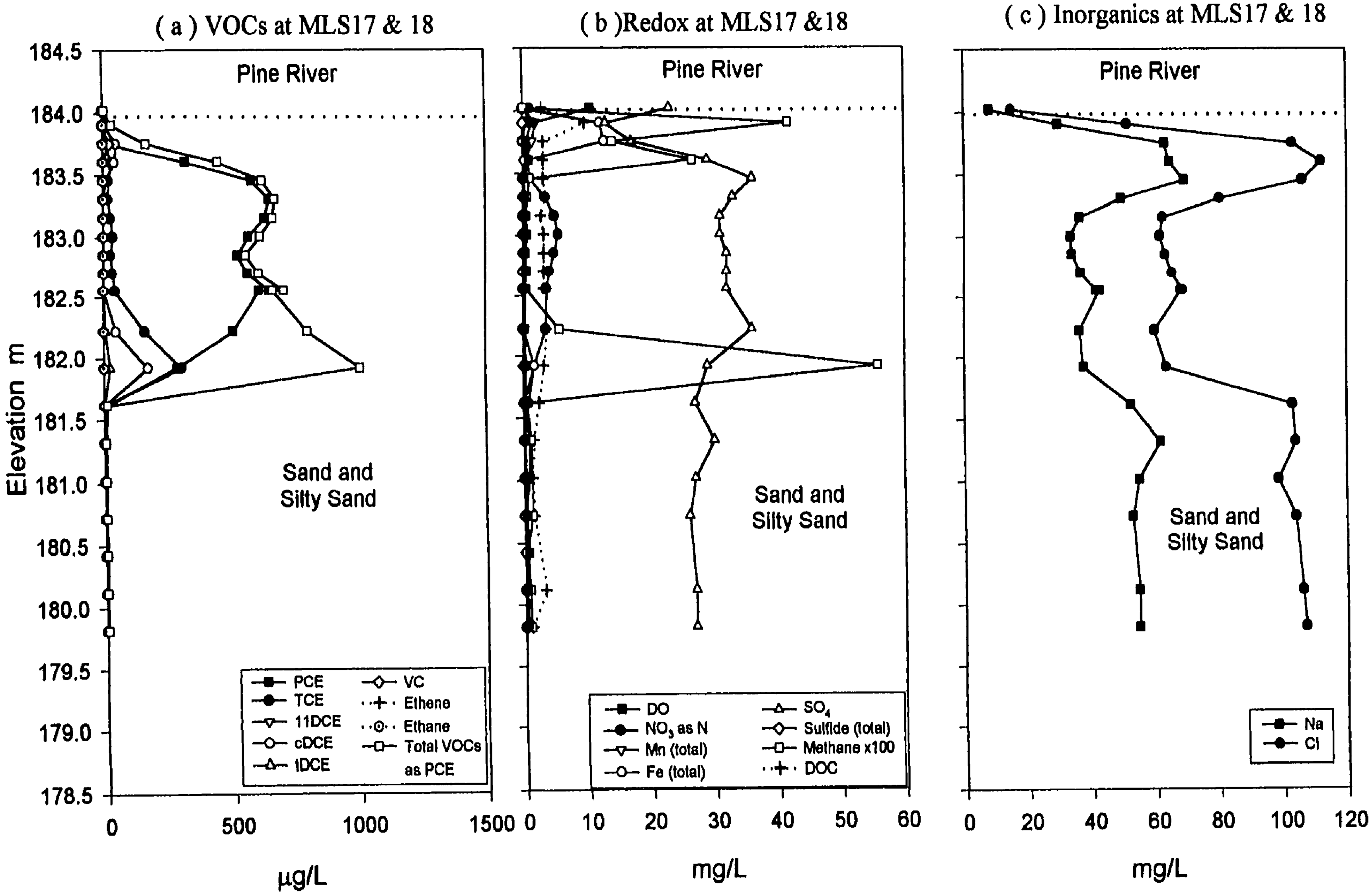


Figure 4-13. Vertical water quality profiles in Type 2 high discharge areas at multilevel sampler location MLS17 and MLS18. (a) VOC concentrations, (b) redox sensitive inorganic species and methane (c) chloride and sodium.

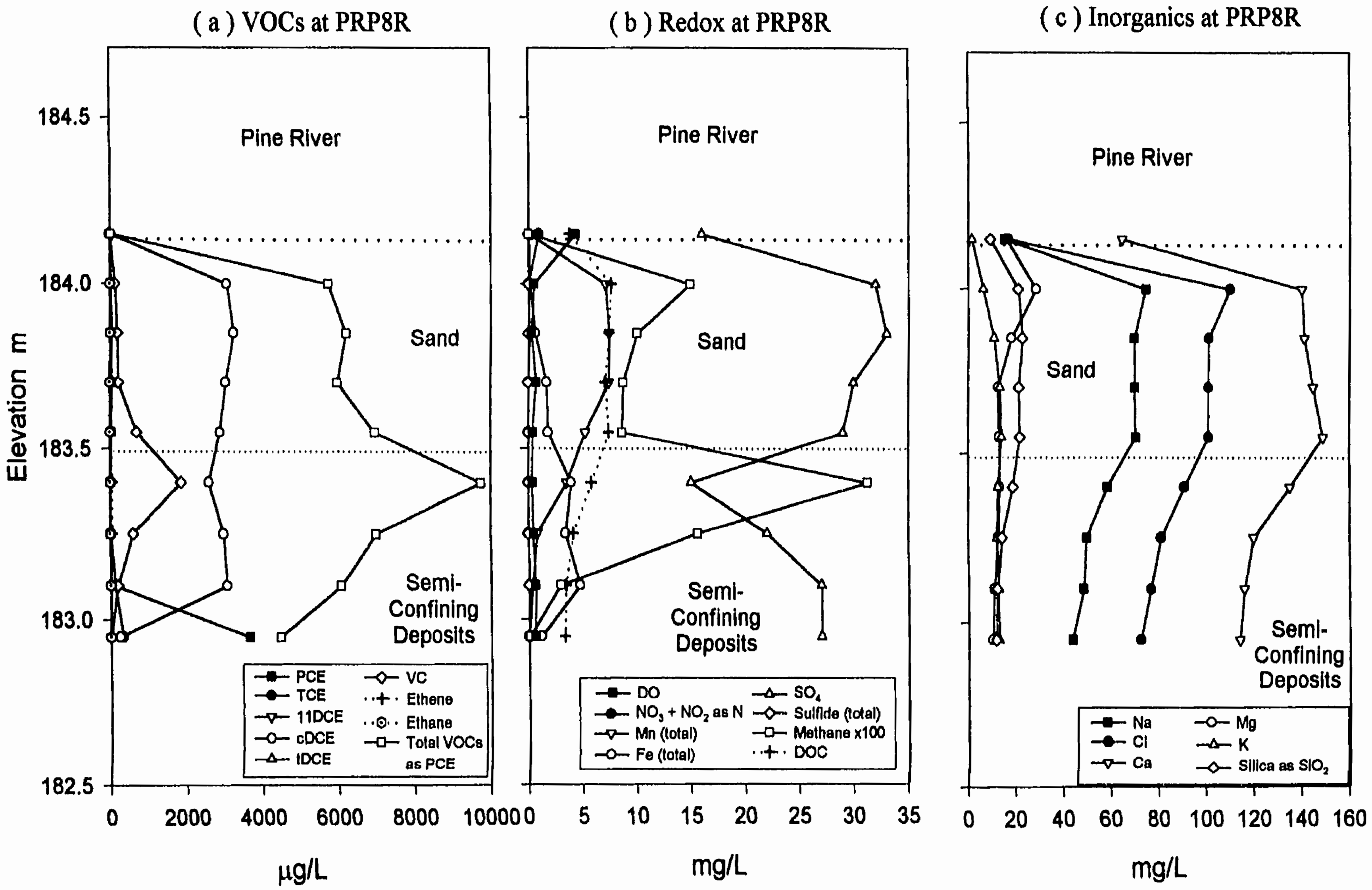


Figure 4-14. Vertical water quality profiles in Type 3 low to medium discharge areas at mini-profiler location PRP8R.
(a) VOC concentrations, (b) redox sensitive inorganic species and methane (c) other inorganics including chloride and sodium

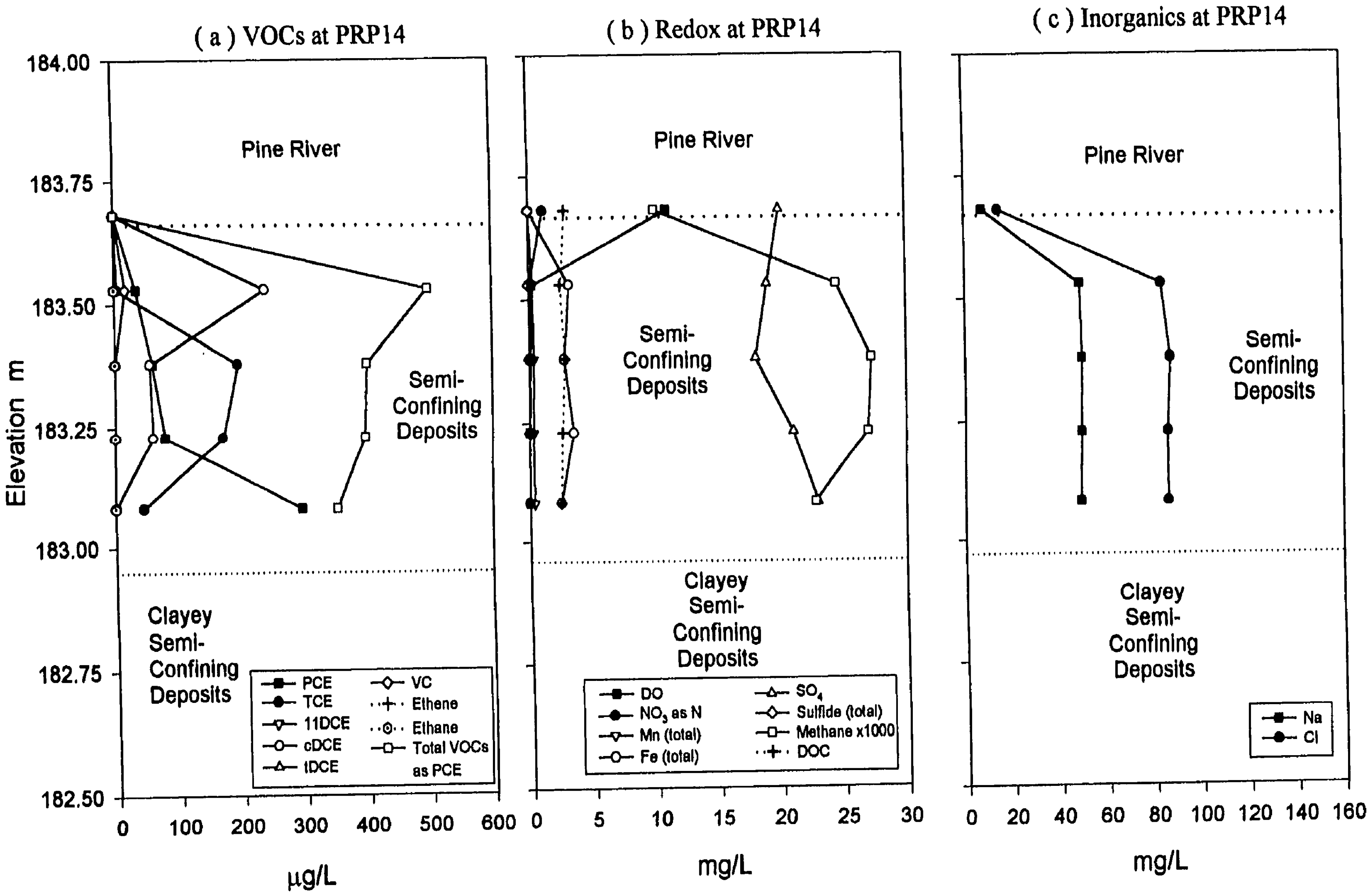


Figure 4-15. Vertical water quality profiles in Type 3 low to medium discharge areas at mini-profiler location PRP14. (a) VOC concentrations, (b) redox sensitive inorganic species and methane (c) chloride and sodium

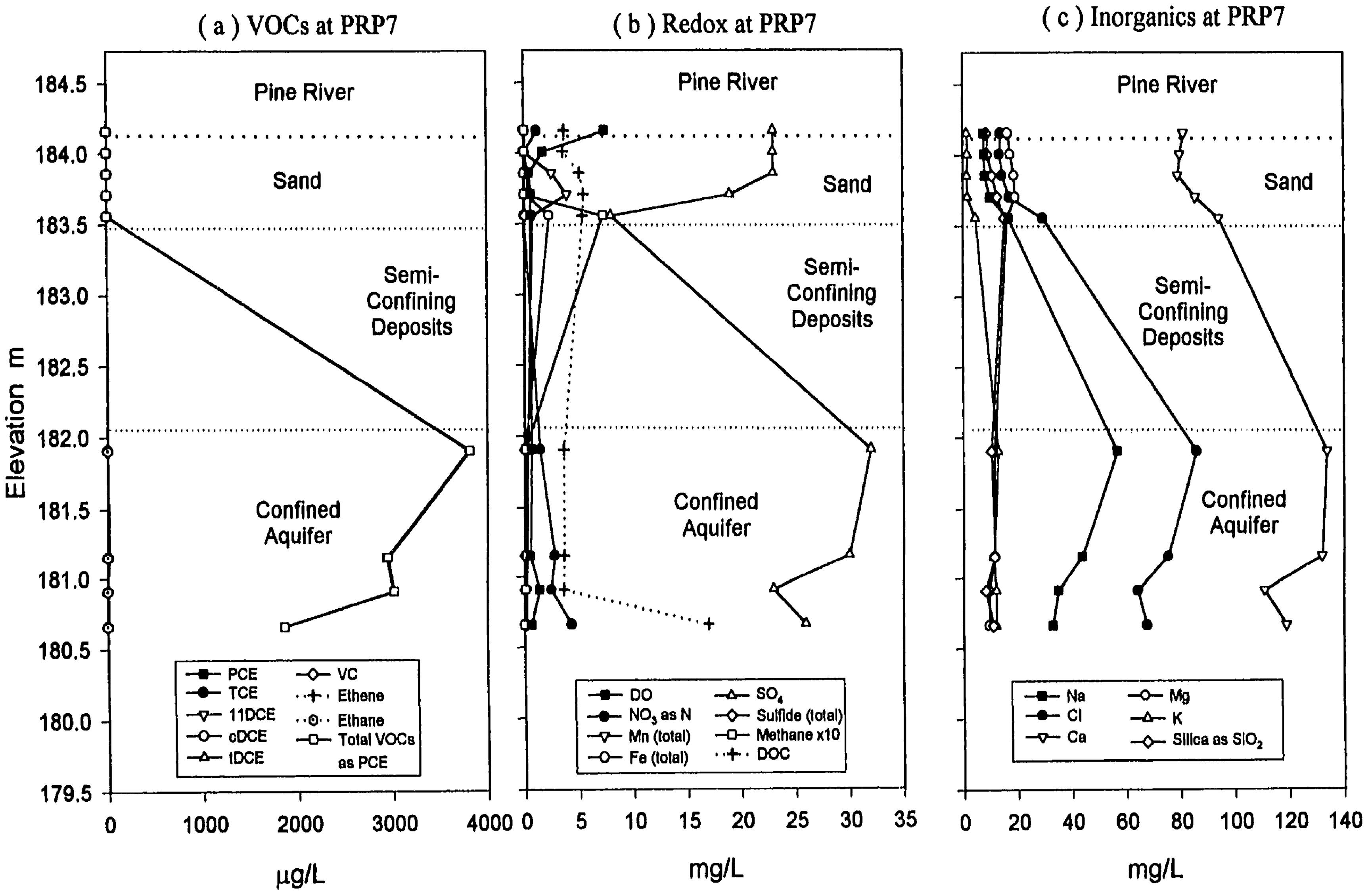


Figure 4-16. Vertical water quality profiles in Type 4 no flow areas at Waterloo Profiler location PRP7.
(a) VOC concentrations, (b) redox sensitive inorganic species and methane (c) other organics including chloride and sodium

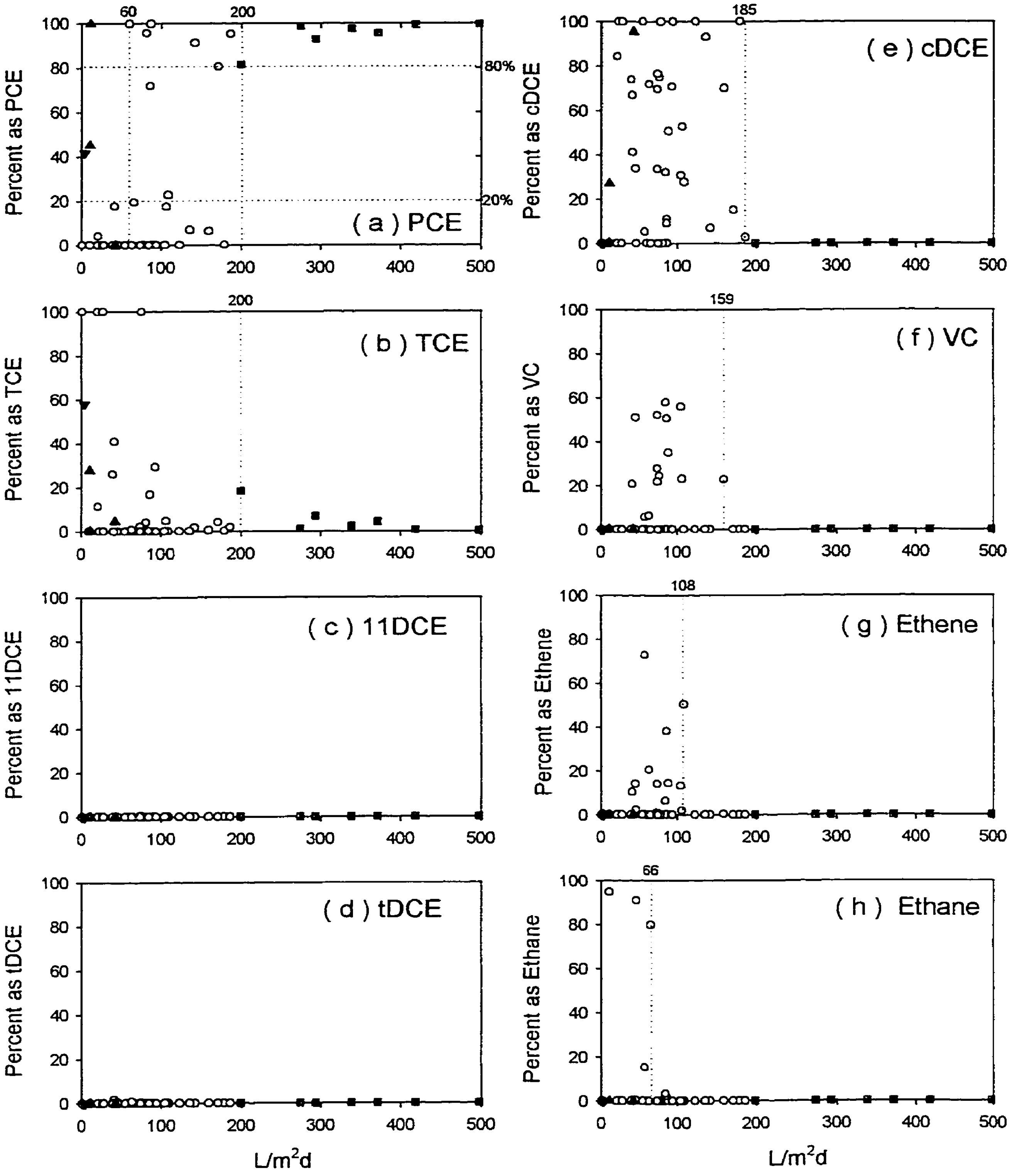


Figure 4-17. Percent of total moles of VOCs in the streambed water (August 1998) versus flux (July 1998) at a depth of 0.3 m at 53 locations. Red squares, yellow circles, blue triangles, and green upside down triangles represent Type 2, 3, 4,and 5 flow, respectively.

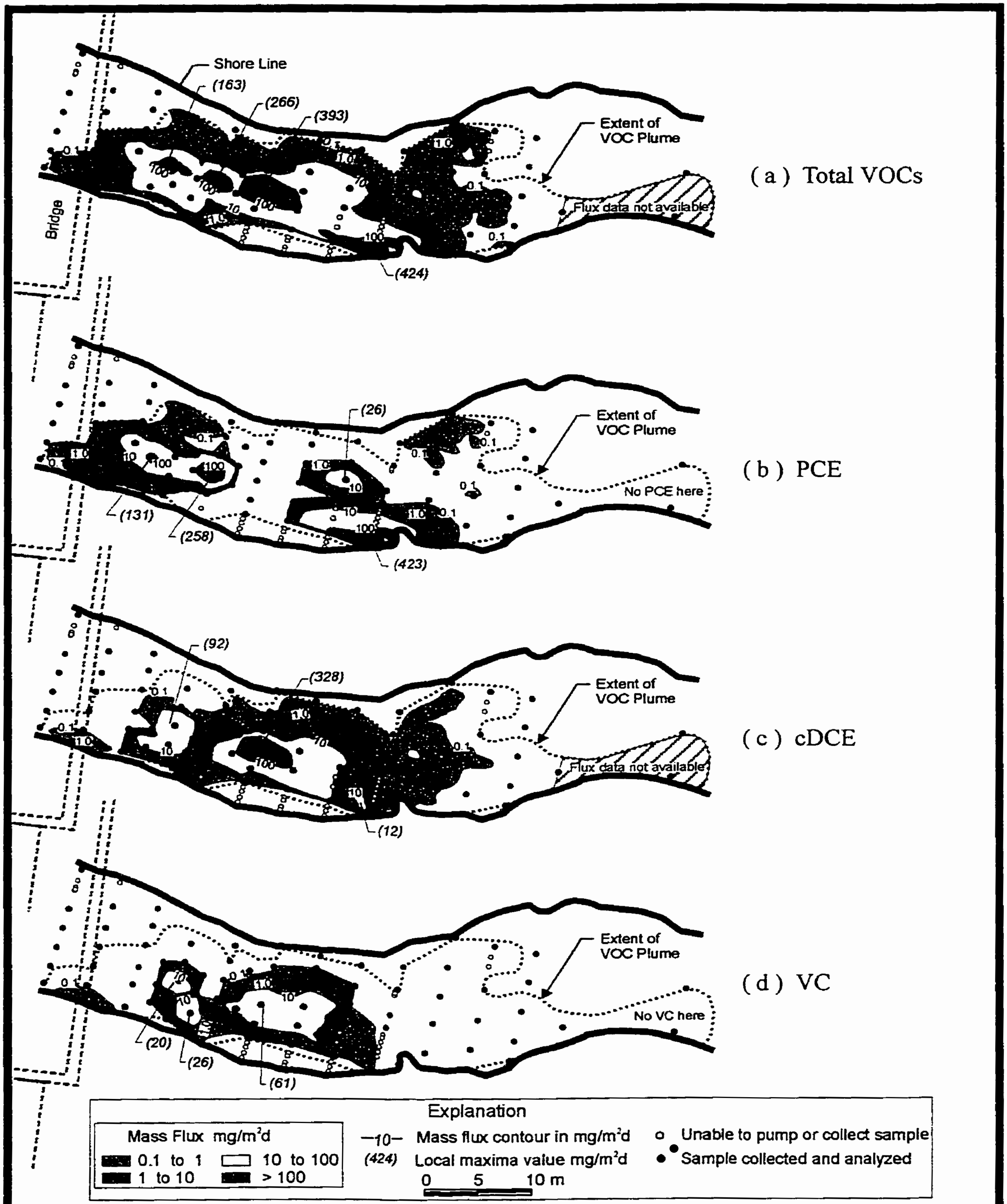


Figure 4-18. Plan-views of mass flux through the streambed based on August 1998, concentrations and July 1998, groundwater fluxes for (a) Total VOCs, (b) PCE, (d) cDCE, and (d) VC.

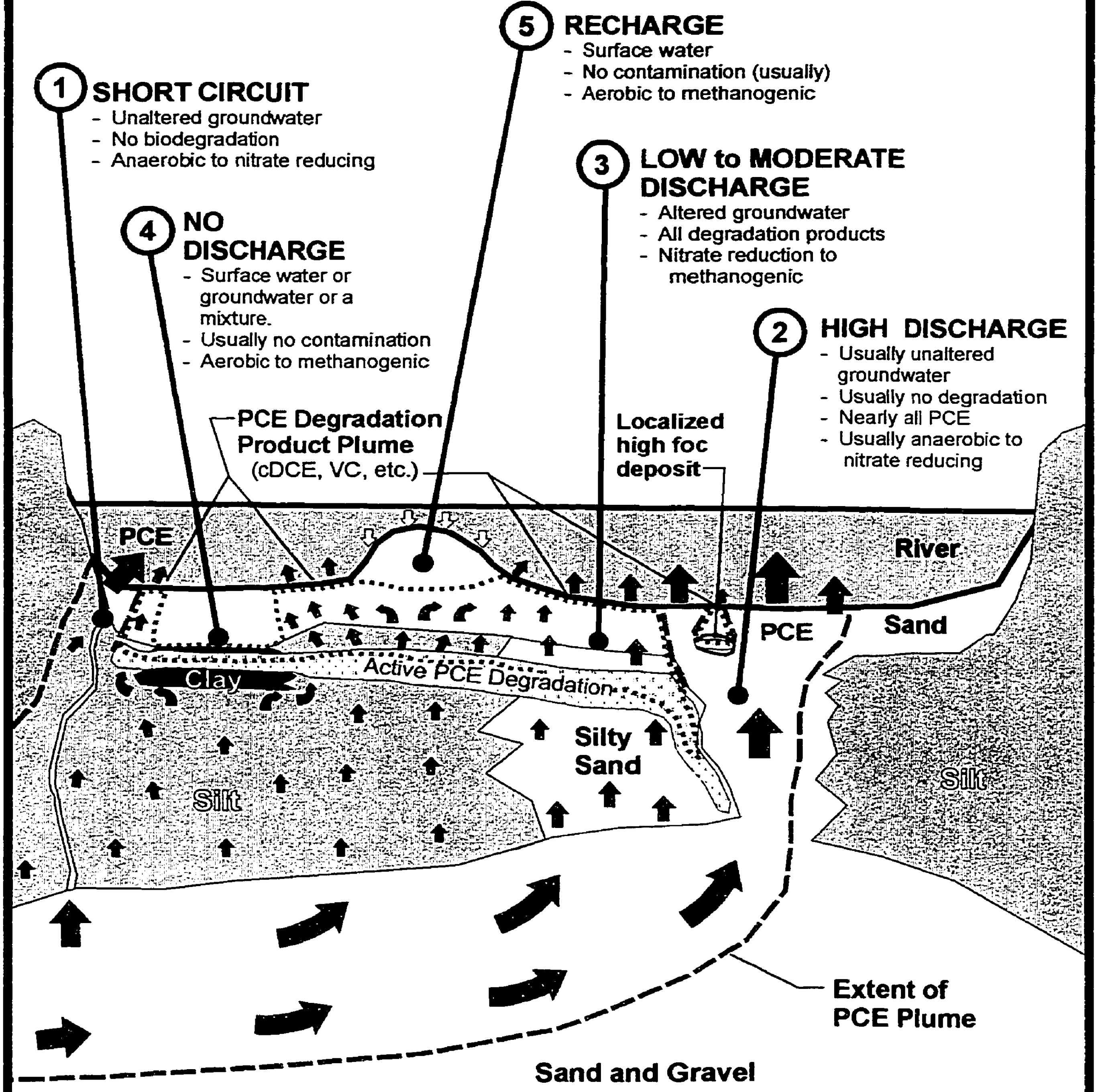


Figure 4-19. Conceptual schematic of geochemistry, biodegradation, and flow for 5 different types of flow conditions beneath a river (in cross section perpendicular to the direction of flow in the river). Areas of anaerobic biodegradation in the streamed convert the PCE plume (red arrows) to transformation products (green arrows) which are primarily cDCE and VC. Biodegradation of cDCE and VC by oxidation processes may also occur where contaminated waters contact surface water (e.g. the base of Type 4 and 5 zones or at the very top of streambed deposits). Arrows point in the direction of flow in the deposits and larger arrow sizes depict higher groundwater fluxes.

CHAPTER 5.

SUMMARY, CONCLUSIONS, AND IMPLICATIONS

The near-stream zone is a dynamic and unique environment that can potentially attenuate VOC groundwater plumes prior to their discharge into rivers or streams. Despite the relatively large number of plumes discharging to rivers and the potential for these plumes to cause adverse ecological effects, previous studies have not evaluated the fate and transport of VOC plumes in this zone in a comprehensive manner. The need for a detailed examination of these types of plumes was the main motivating factor for undertaking this study. By performing an exceptionally detailed investigation of a PCE plume discharging to a river, it was shown that the hydrogeology and biogeochemical conditions in the deposits beneath the river were quite complex and very different from those observed in the upgradient aquifer. The near stream zone modified not only the shape and size of the plume but also its concentration and composition. Several important observations were made regarding this zone:

1. Low-hydraulic conductivity silt, clay, and peat semi-confining deposits beneath the river caused flow in the streambed to be highly irregular. They caused the plume to spread out and to discharge over a large area of the streambed, extending over the full width of the river at some locations. Spatial variations in the geology caused groundwater fluxes to range from 0.03 to over 446 L/m^2d over lateral distances of 5.8 m or less.

2. Anaerobic biodegradation in the top 2.5 m of the streambed deposits dramatically changed the composition of the plume by transforming PCE primarily to cDCE and VC with the production of lesser amounts of TCE, tDCE, 11DCE, ethene, and ethane. The streambed was the only place along the approximately 200 m long flow path between the source at the dry cleaner facility and the river where significant biodegradation was observed. Biodegradation was spatially variable with no biodegradation in some areas and complete transformation of PCE to degradation products in other areas. Anaerobic biodegradation occurred in nitrate reducing to methanogenic areas of the streambed which were associated with organic-rich (up to 7.2% foc) low hydraulic conductivity deposits.

3. Biodegradation in the streambed reduced the total mass of PCE discharging to the river by 54 to 59%; however, the PCE plume only undergoes partial dechlorination (40 to 44% of the total mass still discharges as cDCE and 11 to 12% discharges as VC) and no significant amount of mineralization occurs (i.e. the total moles of contaminants traveling in the aquifer toward the river is essentially the same as the amount discharging from the streambed to the river). At a depth of 0.3 m in the streambed, approximately 54% of the plan-view area of the plume in the streambed does not contain any PCE, only degradation products.

4. High concentrations of PCE and its degradation products were found in the streambed deposits (up to 5529 μg/L as total VOCs or 10,323 μg/L expressed as equivalent PCE) and represent a potential hazard to hyporheic and benthic aquatic life. At several locations the concentrations are higher than Canadian and American ambient water quality criteria for fresh water aquatic life. The highest concentrations in the streambed are similar to the highest concentrations found in the upgradient aquifer. No measurable reduction in concentrations was caused by hyporheic mixing within the streambed, at least not at a depth of 0.3 m.

5. Contaminants were rarely detected in river water because of rapid dilution with clean surface water. Summer river flows were about 1.4 to 2 m^3/s and total contaminated groundwater discharge was about 2.9×10^{-4} to 3.3×10^{-4} m^3/s, which results in a dilution ratio of about 4200 to 6900. The PCE concentrations detected (by sampling at or near the river bottom of the river) were usually ≤ 3.1 μg/L, with one occurrence as high as 23.2 μg/L, but always within Canadian and American freshwater aquatic life guidelines. No cDCE or VC was detected in the surface water samples despite having relatively high total mass discharges. The detection of PCE but not cDCE in surface

water is most likely a consequence of PCE being associated with high groundwater discharge areas whereas cDCE was associated with low discharge areas.

6. Streambed temperatures proved to be a useful method to qualitatively map groundwater discharge zones. Furthermore, temperature can be converted to vertical fluxes by developing an empirical relationship between temperatures and Darcy fluxes calculated at piezometers. Maps of the flux and water quality in the streambed were used to develop a conceptual model for 5 different types of flow behavior based on the magnitude and direction of the flux. The 5 types of behavior included 1. short circuits and springs; 2. High discharge, 3. Low to moderate discharge; 4. No discharge or horizontal flow; and 5. Recharge. Such information is useful when trying to determine where the plume may be discharging to the river and may be helpful in identifing potential areas of high contaminant mass discharge.

7. Areas of high total VOC concentration in the streambed did not correspond to high groundwater discharge areas. The difference may be a result of high concentrations in the upgradient plume not being aligned with the high discharge areas of the streambed. The highest concentrations in the streambed were associated with low flux areas and may represent slow moving, sorbed or retarded remnants of the plume that are from higher concentrations that were present in the plume in the past. Overall, the plan-view pattern of contaminants in the streambed did not closely resemble the pattern found in vertical cross-section in the aquifer adjacent to the river.

8. The degree of biodegradation, redox conditions, and magnitude of the groundwater flux were highly correlated. The low-hydraulic-conductivity silt, clay, and peat deposits that caused the low fluxes at the site were typically organic-rich and, hence, quite reducing. The highest degrees of dechlorination (i.e. production of ethene and ethane) occurred where the fluxes were the lowest and

redox conditions were sulfate reducing to methanogenic. Virtually no dechlorination occurred in high flux anaerobic to nitrate reducing areas of the streambed and thus highest concentrations of PCE were found in these zones. The flux-based conceptual model for 5 types of flow in the streambed was a very useful framework for interpreting and categorizing the complex patterns of interstitial-water quality. Specific biogeochemical conditions were associated with each type of flow.

9. VOC concentrations in the streambed were spatially variable both vertically and horizontally and required a dense sampling array to accurately characterize the conditions in the streambed. Vertical profiles of the streambed showed that zones of active anaerobic PCE degradation occurred over very short vertical distances (less than 0.45 m) where sharp changes in redox conditions occurred. These changes were observed within the top of the semi-confining deposits or at the interface of streambed sands with other more organic-rich deposits. For example, at one location, 3639 µg/L of PCE was reduced to only 125.6 µg/L over a vertical distance of 0.15 m and resulted in the production of 3377 µg/L of degradation products consisting of about 90% cDCE. At another location the total VOCs were 5529 µg/L (or 10,323 µg/L if expressed as equivalent PCE) at a depth of 0.3 m but no VOCs were detected at the same depth 3.5 m away. The depth and location of monitoring points will affect how representative the samples are of the final composition and concentration of the plume that discharges into the surface water.

Several conclusions were drawn regarding the influence of the near-stream zone on the transport and fate of the PCE plume at this site. The main attenuation mechanism in the deposits beneath the river was anaerobic biodegradation and not hyporheic zone mixing. The low hydraulic conductivity organic-rich deposits beneath the river played a key role in these biodegradation processes and the upper portion of these deposits was the location of most biodegradation. In contrast, very little anaerobic degradation occurred in the overlying streambed sand deposits where the organic content of the deposits was usually low and where highly reducing conditions seldom occurred. Overall, the pattern of contaminant concentration found in the streambed was a result of 5 factors including: the initial concentrations in the aquifer traveling toward the stream, hydrology (i.e. groundwater flow and groundwater/surface-water interactions), geology (e.g. hydraulic conductivity and the organic content of the deposits), biogeochemical and other reactions (e.g. biodegradation, redox reactions, and adsorption) and time (e.g. temporal variations in upgradient plume concentrations reaching the river and the travel time required for the plume to flow through the streambed deposits). These 5 factors resulted in a mosaic of different conditions in the streambed. The newly developed method of combining streambed temperatures and Darcy fluxes to calculate discharge was a good method for resolving the variability in groundwater discharge at this site, but it relies on several underlying assumptions (e.g. flow is vertical in the streambed) which may not be valid at other sites. This method was not particularly good at detecting small areas of convective bed transport or hyporheic mixing, so it was necessary to use geochemical analyses of interstitial water to delineate these areas by determining if the water in the streambed was from surface water or not. High vertically upward hydraulic gradients along with geological heterogeneity beneath the river resulted in more spatial variability in discharge at this site than may be the case at other sites.

When examining the results of any field investigation, questions arise regarding how representative the site is relative to other sites and whether the study's conclusions and observations are applicable to other sites. The findings of this study will be most directly applicable to other river sites where the plume must discharge though organic-rich low hydraulic conductivity deposits in the near-stream zone. In this study, the organic-rich deposits at depth, and not the sandy surficial streambed deposits, played the main role in modifying the discharging plume. Even if other river sites appear to be similar to this section of the Pine River (e.g. has the same Rosgen river morphology classification), they may not have the same geological conditions at depth and hence may not display the same degree of variability or biodegradation. Although the semi-confining deposits may appear to make the Angus study results unique and less transferable, the exact opposite may be true and the findings may be applicable to a wide variety of other sites. The semi-confining deposits contributed to (and perhaps exaggerated) the variations in flow, geochemical conditions, and concentrations observed at the site, which meant a wide variety of conditions were all present at just one site. The conceptual models for flow, biogeochemical conditions and contaminant distributions developed for the site incorporated this variability and categorized the behaviors into 5 different types. Except in situations where conditions are similar to the Angus site, the full range of variability (i.e. all 5 types of flow conditions) will likely not be observed at other sites, but some of these 5 types will. For example, a river in a sand and gravel aquifer with no low hydraulic conductivity organic-rich deposits may be dominated by high discharge zones with lesser amounts of hyporheic flow and recharge (conceptual model Types 2, 4 and 5, respectively); therefore, extensive anaerobic biodegradation would not be anticipated and it would likely not be the main attenuation mechanism at that site (depending on the contaminant of concern). The conceptual flow model provided a good framework for intrepreting the redox conditions and biodegradation at the site but does rely on one key assumption which may limit its applicability to other sites. At Angus the low hydraulic conductivity deposit are generally associated with organic-rich and reducing deposits. If a site has low hydraulic conductivity deposits that are not organic-rich, the low flux areas may have less reducing and smaller ranges in redox conditions, and result in little or no anaerobic biodegradation.

The findings of this investigation have important implications for the design of monitoring programs for characterization of plumes discharging to other rivers and streams. One particularly relevant question worth addressing is how much data collection is necessary to properly characterize a site. The amount of data needed depends on the particular question being asked. If a complete and thorough understanding of the fate of the plume is needed, then the level of effort may be equal to or greater than performed in this study. However, the questions can be more narrow if they are related to certain ecological exposures or concerns such as: 1) determining the distribution of contaminants in the streambed (including maximum concentrations); 2) delineating and quantifying groundwater discharge; 3) determining the total contaminant mass flux to the river; and 4) quantifying contaminant mass losses in the streambed.

To determine concentrations in the interstitial water of the streambed it is clear that sampling of the streambed is necessary. Although characterizing the upgradient plume concentrations is useful for determining the degree of spatial and temporal variations in the plume, one can not predict the concentration distribution in the streambed using this information because the streambed modifies plume concentrations. Peak concentrations in the streambed were not necessarily associated with high groundwater discharge zones, so it is not necessary to delineate groundwater discharge to find them. However, the plume will discharge where groundwater discharges to the river, so delineating groundwater discharge zones can be very helpful when trying to determine the general area where the plume discharges to the river. The key is to monitor on a sufficiently small grid spacing that reflects the upgradient variations in plume concentrations so that any high concentration cores that are discharging will be detected. Inexpensive diffusion samplers may be sufficient to characterize the contaminant distribution and identify high concentration areas but the results are semi-quantitative and may have to be confirmed using the mini-profiler or other direct sampling methods. Since diffusion samplers are limited to shallow depths, characterization of deeper concentrations is best done with a mini-profiler or multilevel device. Since the biodegradation in the streambed can change the composition and toxicity of the plume, some profiling of deeper deposits may be necessary at targeted areas to characterize these changes. If the total area of the discharging plume is so large that fine scale monitoring of the plume is impractical, then samples may have to be collected on a larger spacing. Sparse monitoring networks may potentially result in misleading interpretations or conclusions because the full range of subsurface conditions is not encountered. In particular, small areas of high concentration and high mass flux can be easily missed, which is a potential problem since these are areas where aquatic life is most likely to be adversely affected. Measuring of streambed temperatures and using the conceptual model for biogeochemical behaviors may not necessarily locate the areas of highest concentration exposure, but may be useful for targeting locations that will be representative of the range in geochemical behaviors occurring at the site.

Groundwater discharges to rivers are primarily a function of the geology and hydrology at a site. To accurately delineate and quantify the discharges, the spatial scale of monitoring needs to reflect the scale of observed variations in the geology. In some circumstances, using streambed temperature measurements can be an effective and inexpensive way of delineating relatively high and low discharge zones on a small scale. Choosing an appropriate grid spacing can be somewhat problematic though because high discharge springs are very small in size yet may be responsible for a large portion of the total discharge. Mini-piezometers and seepage meters can be used to quantify the discharge and turn streambed temperature data into fluxes, but these methods do not determine the origin of the water. Geochemical analysis of water is needed to determine if the water is surface water, ground water or a mixture of the two, so that areas of convective bed transport, hyporheic mixing, or recharge can be delineated. When selecting a grid spacing, not only should the range of possible discharge behaviors be considered (i.e. the conceptual model for flow which includes springs, hyporheic flow, discharge, and recharge) but also the consequence of missing certain sized flow features. Timing of discharge measurements should also take into account the temporal variation in the hydraulic conditions (stream stage and groundwater levels).

Estimates of the total mass of contaminants discharging to the river may be a relevant question if surface water concentrations or total maximum daily loads (TMDLs) for the river are an issue. Direct sampling of the surface water may not provide useful information for TMDLs if concentrations are at or near detection limits, particularly if the mass loading of the river is spatially variable. For example, at the Angus site the surface water sampling gave no indication of the cDCE and VC that was discharging to the river. The key to accurately estimating the mass loading is to identify both the high concentration areas and high groundwater discharge areas (which don't necessarily occur in the same location). The sample spacing should be determined by the parameter that varies the most in magnitude and space. At the Angus site, both the flux and concentration varied by a factor of 1000 to 10000 over lateral distances of 3.5 m or less, so spatial characterization was equally important for both types of data. The results from the Angus site show that the majority of contaminant loading can be limited to a small percentage of the streambed, but the whole footprint of the plume needs to be investigated in order to identify them. In this case, the mini-profiler rather than diffusion samples should be used to obtain VOC concentrations to obtain more quantitative results.

Quantifying the total contaminant mass loss in the streambed and understanding the processes responsible for that loss may be needed for natural attenuation assessments. Both the total mass headed toward the river and that entering the surface water from the streambed need to be known so that the difference can be calculated. Loss of mass or mineralization of contaminants at isolated profile locations by examining concentration differences and isotopic enrichment of VOCs due to biodegradation and is useful for understanding attenuation processes. However, isolated profiles will not be sufficient to calculate the total mass. The level of characterization required to characterize the total mass loss is higher than the other scenarios previously described, particularly when potential attenuation mechanisms must be evaluated and redox conditions characterized. Water quality profiling of contaminant concentrations adjacent to the river accompanied by geological and hydrological investigations to determine groundwater fluxes are necessary to calculate the mass discharging toward the river. Ideally the mass discharge through aquifer should be measured along a transect (a surface) and then when that contaminated surface migrates and reaches the streambed the mass flux is measured again (this time in the streambed) and the difference is calculated to determine mass loss. The problem is that the travel time from the aquifer surface to the streambed can be quite different for different parts of the plume, so the mass discharge for the same "surface" can never be exactly measured. Hence, only large differences are likely to be detected using this method. This problem of delineating exact flow paths in the near-stream environment also makes it very difficult to reliably estimate rates of mass loss on smaller scales.

This detailed investigation of the discharging plume has provided a valuable example of the complexity that can be encountered when a plume discharges to a river. A better understanding of how plumes are modified by the near-stream zone has been reached and is summarized in the conceptual models for flow and biogeochemical conditions for the site. Armed with this new information, improved monitoring strategies for characterizing other discharging plumes can be developed.

APPENDIX A

SURVEY DATA

SURVEY DATA

Location	Ref. Point	Survey Date	East (m)	North (m)	Elev. (m)	Comments
RIVER TRANSECT STAKES						
-4 (stake)	STK	5/28/99				Destroyed before surveyed
-4 W (stake)	STK	11/5/98	928.301	994.838	185.206	Corrected, since raw reading -4W tilted 50cm E
-2 (stake)	STK	5/28/99				Destroyed before surveyed
-2 W (stake)	STK	11/5/98	929.023	996.952	185.780	
0 (stake)	STK	7/30/97	946.450	993.697	185.572	
0 W (stake)	STK	7/29/97	930.482	998.531	185.953	
2 (stake)	STK	7/29/97	947.058	995.626	185.566	
2 W (stake)	STK	7/29/97	931.967	1000.248	185.629	
4 (stake)	STK	7/29/97	946.421	997.854	185.542	
4 W (stake)	STK	7/29/97	932.805	1002.121	185.490	
5 (stake)	STK	11/5/98	946.611	998.775	185.553	
5 W (stake)	STK	11/5/98	933.235	1003.103	185.289	Corrected, since raw reading stake 5W was tilted 10cm W
6 (stake)	STK	7/29/97	947.230	999.798	185.610	
6 W (stake)	STK	7/29/97	933.828	1003.949	185.364	
7 (stake)	STK	11/5/98	947.470	1000.761	185.789	
7 W (stake)	STK	11/5/98	934.889	1004.627	185.540	
8 (stake)	STK	7/29/97	947.982	1001.607	185.680	
8 W (stake)	STK	7/29/97	935.457	1005.488	185.681	
9 (stake)	STK	11/5/98	948.455	1002.548	185.699	
9 W (stake)	STK	11/5/98	935.924	1006.344	185.616	
10 (stake)	STK	7/29/97	948.809	1003.469	185.886	
10 W (stake)	STK	7/29/97	935.965	1007.427	185.862	
12 (stake)	STK	7/29/97	949.773	1005.160	185.834	
12 W (stake)	STK	7/29/97	936.847	1009.187	185.759	
14 (stake)	STK	7/29/97	950.787	1006.904	185.932	
14 W (stake)	STK	7/29/97	937.941	1010.955	185.753	
15 (stake)	STK	11/5/98	951.042	1007.920	186.126	
15 W (stake)	STK	11/5/98	938.223	1011.946	185.499	
16 (stake)	STK	7/29/97	951.349	1008.877	186.045	
16 W (stake)	STK	7/29/97	937.972	1012.993	185.989	
17 (stake)	STK	11/5/98	951.679	1009.779	186.108	
17 W (stake)	STK	11/5/98	938.177	1014.004	185.967	
18 (stake)	STK	7/29/97	951.982	1010.737	186.289	
18 W (stake)	STK	7/29/97	938.095	1014.914	185.926	
19 (stake)	STK	11/5/98	952.306	1011.825	186.385	
19 W (stake)	STK	11/5/98	937.980	1015.861	185.973	Corrected, since raw reading stake 19 tilted 5 cm N
20 (stake)	STK	7/29/97	952.545	1012.638	186.449	Leaned rod to south, but no correction was applied+K66
20 W (stake)	STK	7/29/97	937.912	1016.851	186.045	
22 (stake)	STK	7/29/97	952.493	1014.749	186.183	
22 W (stake)	STK	7/29/97	938.110	1018.804	186.023	
24 (stake)	STK	7/29/97	953.264	1016.643	186.331	
24 (stake)	GRND	7/29/97	953.311	1016.625	186.191	ground surface next to stake
24 W (stake)	STK	7/29/97	938.212	1020.795	185.925	

Location	Ref. Point	Survey Date	East (m)	North (m)	Elev. (m)	Comments
26 (stake)	STK	7/29/97	953.165	1018.780	186.431	
26 W (stake)	STK	7/29/97	938.025	1022.954	185.707	
28 (stake)	STK	7/29/97	952.731	1020.921	186.354	
28 W (stake)	STK	7/29/97	937.444	1025.087	185.494	
30 (stake)	STK	7/29/97	952.503	1023.181	186.143	
30 W (stake)	STK	7/29/97	937.098	1027.186	185.644	
32 (stake)	STK	7/29/97	951.484	1025.651	185.937	
32 W (stake)	STK	7/29/97	936.187	1029.420	185.499	
34 (stake)	STK	7/29/97	951.792	1027.677	185.690	
34 W (stake)	STK	7/29/97	934.909	1031.654	185.511	
36 (stake)	GRND	7/29/97	952.006	1029.729	185.700	ground surface next to stake
36 W (stake)	STK	7/29/97	933.951	1033.672	185.813	
38 (stake)	STK	7/29/97	951.387	1031.928	185.713	
38 W (stake)	STK	7/30/97	933.256	1035.952	185.925	
40 (stake)	STK	7/29/97	951.228	1033.737	185.790	
40A (stake)	STK	11/5/98	951.640	1033.674	185.834	Stake 40 almost erroded away so new one put in
40 W (stake)	STK	7/30/97	932.654	1038.084	186.179	
42 (stake)	STK	7/30/97	950.428	1035.921	185.929	
42 W (stake)	STK	7/30/97	932.397	1039.986	186.573	
44 (stake)	STK	7/30/97	949.280	1038.235	185.911	Leaned rod to south, but no correction was applied
44A (stake)	STK	11/5/98	949.855	1038.093	186.094	Stake 44 almost erroded away so new one put in
44 W (stake)	STK	7/30/97	933.297	1042.447	186.360	
46 (stake)	STK	7/30/97	948.959	1040.489	185.810	
46 W (stake)	STK	7/30/97	933.585	1044.409	186.322	
48 (stake)	STK	7/30/97	949.050	1042.597	185.990	
48 (stake)	STK	7/30/97	949.043	1042.600	185.996	
48 W (stake)	STK	7/30/97	933.866	1046.471	186.455	
50 (stake)	STK	7/30/97	949.222	1044.535	186.078	
50 (stake)	STK	7/30/97	949.211	1044.576	186.087	Leaned survey rod to north but no correction was applied
50 W (stake)	STK	7/30/97	934.686	1048.298	186.551	
52 (stake)	STK	7/30/97	949.438	1046.516	186.061	
52 W (stake)	STK	7/30/97	935.411	1050.231	186.440	
54 (stake)	STK	7/30/97	949.406	1048.614	185.967	
54 W (stake)	STK	7/30/97	935.965	1052.151	186.350	
56 (stake)	STK	7/30/97	950.539	1050.368	186.053	
56 W (stake)	STK	7/30/97	936.411	1054.113	186.062	
58 (stake)	STK	7/30/97	950.650	1052.413	185.159	
58 W (stake)	STK	7/30/97	936.709	1056.015	186.108	
60 (stake)	STK	7/30/97	951.440	1054.243	185.144	
60 W (stake)	STK	7/30/97	935.969	1058.253	186.640	
62 (stake)	STK	7/30/97	952.612	1055.862	185.266	
62 W (stake)	STK	7/30/97	936.941	1060.119	186.816	
MONITORING WELLS						
AMW1	TOPVC	11/5/98	1087.998	900.593	190.522	Pitkin (1994) 2" PVC well near B1
AMW1	TOC	11/5/98	1087.979	900.611	190.596	protective casing, flush with ground

Location	Ref. Point	Survey Date	East (m)	North (m)	Elev. (m)	Comments
AMW2	TOPVC	11/5/98	1087.327	900.588	190.479	Pitkin (1994) 2" PVC well near B1
AMW2	TOC	11/5/98	1087.312	900.604	190.556	protective casing, flush with ground
AMW3	TOPVC	11/5/98	1076.132	926.763	190.221	Pitkin (1994) 2" PVC well, near AP5
AMW3	TOC	11/5/98	1076.152	926.748	190.284	protective casing, flush with ground
AMW3	TOC	11/17/99	1076.250	926.761	190.260	Must check, top of protective casing, driven over when installed ML1 and MCT1 ?
AMW4	TOPVC	11/5/98	1076.659	926.693	190.243	Pitkin (1994) 2" PVC well, near AP5
AMW4	TOC	11/5/98	1076.661	926.676	190.288	protective casing, flush with ground
AMW5	TOPVC	11/17/99	1066.188	925.706	190.148	Pitkin (1994) 2" PVC well, near B2, top of PVC
AMW5	TOC	11/17/99	1066.236	925.742	190.193	protective casing, flush with ground
WATERLOO PROFILER LOCATIONS						
AP6	STK	11/17/99	1081.408	926.616	190.273	Pitkin profiler location (1994), put in new stake
AP6	GRND	11/17/99	1081.436	926.630	190.267	
AP9	GRND	11/17/99	1052.448	928.975	189.146	Pitkin profiler location (1994)
AP10	STK	11/17/99	1050.241	947.529	189.741	Pitkin profiler location (1994), a new stake put loose in hole
AP10	GRND	11/17/99	1050.243	947.492	189.727	
AP11	STK	11/17/99	1045.150	948.571	189.732	Pitkin profiler location (1994)
AP11	GRND	11/17/99	1045.137	948.529	189.551	
AP12	STK	11/17/99	1040.295	949.181	189.806	Pitkin profiler location (1994)
AP12	GRND	11/17/99	1040.287	949.154	189.738	
AP18	STK	11/17/99	1047.232	929.898	189.381	Pitkin profiler location (1994)
AP18	GRND	11/17/99	1047.255	929.940	189.173	
AP20	GRND?	5/14/96	1004.985	954.023	189.298	Pitkin profiler location (1994)
AP36	GRND	11/17/99	1106.047	925.771	190.514	Approximate location of Writt profile (1996)
AP37	GRND	11/17/99	1125.844	863.449	190.812	Approximate location, Beneteau (unpublished data)
AP40	GRND	11/25/96	954.736	1031.038	186.264	
AP40-B	GRND	11/25/96	955.110	1030.981	186.241	
AP41	STK	11/5/98	954.484	1021.435	186.440	
AP42	GRND	11/25/96	953.177	1011.903	186.401	
AP43	GRND	11/25/96	950.591	1002.525	186.460	
AP44	GRND	11/25/96	953.865	1007.790	186.253	
AP45	STK	11/25/96	954.613	1017.971	186.303	
AP45	STK	11/25/96	954.624	1017.974	186.315	Resurvey stake from Station 5
AP46	GRND	11/25/96	952.448	1025.485	186.088	
AP47	STK	7/29/97	936.952	1019.352	186.108	
AP47	GRND	7/29/97	936.928	1019.362	186.061	
AP47	STK	7/7/98	936.949	1019.351	186.081	
AP47	STK	11/5/98	936.972	1019.345	186.089	
AP48	GRND	11/25/96	950.394	1041.155	186.157	
AP49	GRND	11/25/96	932.722	1030.691	185.983	
AP50	GRD?	11/25/96	931.097	1039.879	186.339	Corrected, raw data was 0.33 east of actual point (line of site problems)

Location	Ref. Point	Survey Date	East (m)	North (m)	Elev. (m)	Comments
AP51	GRND	11/25/96	933.680	1049.483	186.561	
AP52	GRND	11/25/96	952.422	1035.944	186.206	
AP53	STK	7/7/98	988.163	1018.102	188.176	Levenick (1998)
AP54	STK	7/7/98	984.157	1015.102	188.218	Levenick (1998)
AP55	STK	7/7/98	980.199	1012.122	188.179	Levenick (1998)
AP96-4	STK	11/17/99	1038.841	929.645	189.383	
AP96-4	GRND	11/17/99	1038.915	929.666	189.231	
AP96-5	STK	11/17/99	1116.976	922.848	190.577	
AP96-5	GRND	11/17/99	1116.976	922.859	190.564	
AP96-6	GRND	11/17/99	1064.264	959.534	189.793	No stake
AP96-7	GRND	11/17/99	1067.378	962.333	189.664	No stake
AP96-8	STK	11/17/99	1030.015	930.776	189.365	
AP96-8	GRND	11/17/99	1030.054	930.810	189.326	
AP96-9	STK	11/17/99	1022.590	928.233	189.507	
AP96-9	GRND	11/17/99	1022.632	928.272	189.361	
AP96-10	STK	11/17/99	1131.333	924.117	190.545	
AP96-10	GRND	11/17/99	1131.364	924.108	190.526	
AMA	GRND?	11/5/98	1104.746	864.740	190.812	Guilbeault (1999) profile location
AMB	GRND?	11/5/98	1104.201	871.265	190.877	Guilbeault (1999) profile location
AMC	GRND?	11/5/98	1102.325	883.376	190.866	Guilbeault (1999) profile location
AMD	GRND?	11/5/98	1102.708	887.309	190.804	Guilbeault (1999) profile location
AME	GRND?	11/5/98	1101.961	879.784	190.825	Guilbeault (1999) profile location
AMF	GRND?	11/5/98	1103.027	891.260	190.876	Guilbeault (1999) profile location
AMG	GRND?	11/5/98	1105.367	893.733	190.967	Guilbeault (1999) profile location
AMH	GRND?	11/5/98	1109.257	893.350	190.979	Guilbeault (1999) profile location
AMI	GRND?	11/5/98	1114.048	893.018	190.957	Guilbeault (1999) profile location
AMJ	GRND?	11/5/98	1106.874	893.560	190.970	Guilbeault (1999) profile location
AMK	GRND?	11/5/98	1103.204	892.837	190.881	Guilbeault (1999) profile location
AMM	GRND?	11/5/98	1111.542	893.169	190.965	Guilbeault (1999) profile location (no AML location)
BUNDLE MULTILEVEL SAMPLERS						
BML1	TOC	5/28/99	949.797	998.241	186.541	
BML1	GRND	5/28/99	949.779	998.239	186.517	
BML1	TOP	5/28/99	949.825	998.348	186.423	
BML2	TOC	5/28/99	953.289	1002.038	186.319	
BML2	GRND	5/28/99	953.287	1002.034	186.277	
BML2	TOP	5/28/99	953.319	1002.166	185.929	
BML3	TOC	5/28/99	955.193	1006.962	186.244	
BML3	GRND	5/28/99	955.181	1006.948	186.225	
BML3	TOP	5/28/99	955.237	1007.033	186.199	
BML4	TOC	5/28/99	956.588	1011.846	186.198	
BML4	GRND	5/28/99	956.559	1011.835	186.157	
BML4	TOP	5/28/99	956.598	1011.961	186.032	
BML4	TOP no cap	5/28/99	956.603	1011.960	186.003	Top of PVC pipe, without the PVC cap on it
BML5	TOC	5/28/99	957.348	1016.905	186.266	

Location	Ref. Point	Survey Date	East (m)	North (m)	Elev. (m)	Comments
BML5	GRND	5/28/99	957.336	1016.887	186.234	
BML5	TOP	5/28/99	957.335	1016.984	186.103	
BML6	TOC	5/28/99	956.275	1021.741	186.365	
BML6	GRND	5/28/99	956.266	1021.717	186.343	
BML6	TOP	5/28/99	956.297	1021.817	186.099	
BML7	TOC	5/28/99	957.079	1026.599	186.360	
BML7	GRND	5/28/99	957.082	1026.586	186.352	
BML7	TOP	5/28/99	957.126	1026.697	186.088	
BML8	TOC	5/28/99	958.358	1031.334	186.260	
BML8	GRND	5/28/99	958.344	1031.309	186.253	
BML8	TOP	5/28/99	958.390	1031.397	186.046	
BML9	TOC	5/28/99	959.010	1036.113	186.187	
BML9	GRND	5/28/99	959.019	1036.108	186.147	
BML9	TOP	5/28/99	958.967	1036.145	185.950	
BML10	TOC	5/28/99	957.806	1041.147	186.120	
BML10	GRND	5/28/99	957.799	1041.130	186.104	
BML10	TOP	5/28/99	957.847	1041.202	185.888	
BML11	TOC	5/28/99	935.806	1014.322	186.358	
BML11	GRND	5/28/99	935.801	1014.305	186.352	
BML11	TOP	5/28/99	935.835	1014.410	186.187	
BML12	TOC	5/28/99	933.024	1032.190	185.917	
BML12	GRND	5/28/99	933.018	1032.167	185.893	
BML12	TOP	5/28/99	933.018	1032.272	185.747	
Bundle multilevel	P-cover	11/17/99	1088.177	900.006	190.568	Pitkin (1994) Bundle multilevel near B1
Bundle multilevel	TOP/CS	11/17/99	1065.473	925.538	190.160	Pitkin (1994) Bundle 1/8-inch tubes multilevel near B2, no protective casing
DRIVEPOINT WELLS						
AW-1	TOC	7/7/98	955.286	1018.358	187.256	Drive point well (1.25-in ID) for aquifer level logger
AW-1	GRND	7/7/98	955.220	1018.352	186.312	
DP1	GRND	5/14/96	949.700	1041.376	186.044	ground surface between DP1 set
DP1-1	TOC	5/14/96	949.576	1041.369	186.196	
DP1-1	TOC	11/25/96	949.620	1041.407	186.194	
DP1-1	TOC	5/28/99	949.627	1041.431	186.199	
DP1-1	GRND	11/25/96	949.638	1041.394	186.046	
DP1-2	TOC	5/14/96	949.725	1041.271	186.323	
DP1-2	TOC	11/25/96	949.743	1041.308	186.329	
DP1-2	TOC	5/28/99	949.771	1041.366	186.334	
DP1-2	GRND	11/25/96	949.782	1041.294	186.074	
DP1-3	TOC	5/14/96	949.757	1041.446	186.172	
DP1-3	TOC	11/25/96	949.768	1041.479	186.178	
DP1-3	TOC	5/28/99	949.791	1041.531	186.186	
DP1-3	GRND	11/25/96	949.805	1041.487	186.077	
DP2	GRND	5/14/96	956.285	1056.781	185.609	ground surface between DP2 set
DP2-1	TOC	5/14/96	956.200	1056.768	185.810	
DP2-1	TOC	6/18/96	956.222	1056.728	185.823	

Location	Ref. Point	Survey Date	East (m)	North (m)	Elev. (m)	Comments
DP2-1	TOC	11/25/96	956.199	1056.777	185.817	
DP2-1	GRND	11/25/96	956.195	1056.790	185.636	
DP2-2	TOC	5/14/96	956.318	1056.660	185.698	
DP2-2	TOC	11/25/96	956.306	1056.690	185.709	
DP2-2	GRND	11/25/96	956.297	1056.700	185.633	
DP2-3	TOC	5/14/96	956.333	1056.834	185.926	
DP2-3	TOC	11/25/96	956.336	1056.832	185.935	
DP2-3	GRND	11/25/96	956.334	1056.817	185.643	
DP3	GRND	5/14/96	962.619	1045.922	185.883	ground surface between DP3 set
DP3-1	TOC	5/14/96	962.498	1045.925	186.093	
DP3-1	TOC	6/18/96	962.498	1045.925	186.093	
DP3-1	TOC	11/25/96	962.493	1045.924	186.088	
DP3-1	TOC	5/28/99	962.543	1045.957	186.120	
DP3-2	TOC	5/14/96	962.649	1045.814	186.189	
DP3-2	TOC	11/25/96	962.662	1045.802	186.185	
DP3-2	TOC	5/28/99	962.707	1045.830	186.215	
DP3-3	TOC	5/14/96	962.704	1045.994	186.231	
DP3-3	TOC	11/25/96	962.730	1045.991	186.225	
DP3-3	TOC	5/28/99	962.758	1046.017	186.254	
DP4-1	TOC	6/18/96	941.844	1075.798	186.367	
DP4-1	TOC	5/28/99	941.887	1075.839	186.364	
DP4-2	TOC	6/18/96	941.743	1076.033	186.974	
DP4-2	TOC	5/28/99	941.875	1076.056	186.987	
DP4-2	GRND	6/18/96	941.732	1075.878	186.245	
DP4-3	TOC	6/18/96	941.655	1075.768	186.598	
DP4-3	TOC	5/28/99	941.718	1075.736	186.597	
DP5-1	TOC	6/18/96	936.274	1058.964	186.821	
DP5-2	TOC	6/18/96	936.162	1059.145	186.962	
DP5-3	TOC	6/18/96	936.092	1058.832	186.766	
DP5-3	GRND	6/18/96	936.171	1058.983	186.534	
DP6-1	TOC	6/18/96	933.766	1067.544	186.999	
DP6-1	TOC	6/18/96	933.902	1067.669	187.015	
DP6-1	TOC	7/7/98	933.903	1067.661	187.007	
DP6-1	GRND	6/18/96	933.833	1067.553	186.795	
DP6-1	GRND	7/7/98	933.899	1067.643	186.836	
DP6-2	TOC	6/18/96	933.580	1067.533	187.078	
DP6-2	TOC	7/7/98	933.708	1067.641	187.087	
DP6-2	GRND	6/18/96	933.623	1067.536	186.917	
DP6-2	GRND	7/7/98	933.709	1067.628	186.929	
DP6-3	TOC	6/18/96	933.459	1067.528	187.132	
DP6-3	TOC	7/7/98	933.565	1067.647	187.141	Was damaged and so new coupling put on and resurvey
DP6-3	GRND	6/18/96	933.468	1067.529	186.957	
DP6-3	GRND	7/7/98	933.559	1067.626	186.979	
DP6-3	TOC	11/5/98	933.570	1067.606	187.138	
DP7-1	TOC	11/25/96	954.774	1030.180	186.596	
DP7-1	GRND	11/25/96	954.734	1030.172	186.293	
DP7-2	TOC	11/25/96	954.913	1030.023	186.568	
DP7-2	GRND	11/25/96	954.896	1030.015	186.316	

Location	Ref. Point	Survey Date	East (m)	North (m)	Elev. (m)	Comments
DP7-3	TOC	11/25/96	954.953	1030.219	186.716	
DP7-3	GRND	11/25/96	954.939	1030.229	186.323	
DP8-1	TOC	11/25/96	954.760	1017.019	186.551	
DP8-1	GRND	11/25/96	954.740	1017.024	186.231	
DP8-2	TOC	11/25/96	954.991	1016.880	186.473	
DP8-2	GRND	11/25/96	954.973	1016.887	186.228	
DP8-3	TOC	11/25/96	954.989	1017.154	186.677	
DP8-3	GRND	11/25/96	954.964	1017.160	186.260	
DP9-1	TOC	11/25/96	937.719	1019.669	186.104	
DP9-1	TOC	5/28/99	937.766	1019.719	186.121	
DP9-1	GRND	11/25/96	937.690	1019.691	185.938	
DP9-2	TOC	11/25/96	937.480	1019.840	186.255	
DP9-2	TOC	5/28/99	937.554	1019.879	186.271	
DP9-2	GRND	11/25/96	937.474	1019.856	185.974	
DP9-3	TOC?	11/25/96	937.268	1019.878	186.164	
DP9-3	TOC	11/25/96	937.263	1019.878	186.147	
DP9-3	TOC	5/28/99	937.305	1019.893	186.167	
DP9-3	GRND	11/25/96	937.237	1019.871	185.994	
DP10-S	TOC	7/7/98	949.090	996.758	186.806	
DP10-S	GRND	7/7/98	949.098	996.783	186.610	
DP10-D	TOC	7/7/98	949.322	996.673	186.798	
DP10-D	GRND	7/7/98	949.296	996.699	186.637	
DP11	TOC	7/7/98	974.656	1000.314	188.181	
DP11	TOC	11/5/98	974.689	1000.337	188.189	
DP11	GRND	7/7/98	974.669	1000.325	188.233	
DP12	TOC	7/7/98	980.188	1021.905	188.087	
DP12	GRND	7/7/98	980.186	1021.918	188.115	
DP13	TOC	7/7/98	1003.536	1040.836	187.968	
DP13	GRND	7/7/98	1003.544	1040.835	188.013	
DP13	TOC	11/17/99	1003.537	1040.862	187.965	check of location
DP14-S	TOC	7/7/98	928.563	999.912	186.839	
DP14-S	GRND	7/7/98	928.567	999.966	186.627	
DP14-D	TOC	7/7/98	928.423	1000.062	186.973	
DP14-D	GRND	7/7/98	928.426	1000.108	186.631	
DP15	TOC	7/7/98	970.858	974.634	186.837	
DP15	GRND	7/7/98	970.863	974.617	186.795	
DP16	TOC	7/7/98	999.318	953.773	189.743	
DP16	GRND	7/7/98	999.282	953.776	189.477	
DP17-S	TOC	7/7/98	934.126	967.734	186.037	
DP17-S	GRND	7/7/98	934.116	967.746	185.935	
DP17-D	TOC	7/7/98	934.281	967.680	186.262	
DP17-D	GRND	7/7/98	934.289	967.702	185.954	
DP18	TOC	7/7/98	890.962	1015.906	186.364	
DP18	GRND	7/7/98	890.957	1015.920	186.378	
DP19	TOC	7/7/98	878.617	984.847	186.833	
DP19	GRND	7/7/98	878.572	984.867	186.248	
DP20	TOC	7/7/98	920.385	976.326	186.294	
DP20	GRND	7/7/98	920.350	976.331	185.973	

Location	Ref. Point	Survey Date	East (m)	North (m)	Elev. (m)	Comments
P1	TOC	5/14/96	1002.569	1002.439	188.108	Beneteau (1996), destroyed in summer 1999 by sidewalk construction
P1	TOC	7/7/98	1002.576	1002.416	188.124	Beneteau (1996), 0.016 elev. difference - previous survey
P1	TOC	5/28/99	1002.583	1002.451	188.132	Beneteau (1996), check of location
P2	TOC	5/14/96	994.826	991.644	188.540	Beneteau (1996)
P2	TOC	11/25/96	994.825	991.644	188.540	Beneteau (1996)
APZ1	TOC	11/5/98	1114.031	863.685	190.916	Guilbeault (1999) drivepoint well
APZ2	TOC	11/5/98	1099.250	865.520	190.916	Guilbeault (1999) drivepoint well
APZ3	TOC	11/5/98	1102.112	888.956	190.759	Guilbeault (1999) drivepoint well
B1-A	TOC	11/17/99	1088.763	899.691	190.604	Pitkin (1994) near B1, top of drive point casing cut off w/ hacksaw
B1-B	TOC	11/17/99	1088.442	899.754	190.609	Pitkin (1994) near B1, top of drive point casing cut off w/ hacksaw
B1-C	TOC	11/17/99	1088.100	899.749	190.590	Pitkin (1994) near B1, top of drive point casing cut off w/ hacksaw
B1-D	TOC	11/17/99	1087.812	899.795	190.606	Pitkin (1994) near B1, top of drive point casing cut off w/ hacksaw
B1-E	TOC	11/17/99	1087.520	899.802	190.586	Pitkin (1994) near B1, top of drive point casing cut off w/ hacksaw
B1-F	TOC	11/17/99	1087.227	899.806	190.580	Pitkin (1994) near B1, top of drive point casing cut off w/ hacksaw
DRIVEABLE MULTILEVEL SAMPLERS IN RIVER						
MLS prototype	TOP	11/5/98	944.655	1012.763	184.076	Failed attempt/removed, PVC pipe put in, same location as PRP17
MLS prototype	SB	6/24/98			184.049	Calculated streambed elevation at time *of installation*
MLS1	TOP	11/5/98	949.419	1009.458	184.207	
MLS2	TOC	11/5/98	949.173	1009.552	184.241	
MLS3	TOP	11/5/98	947.888	1009.917	184.360	
MLS4	TOC	11/5/98	947.668	1009.997	184.329	
MLS5	TOP	11/5/98	946.516	1010.342	184.214	
MLS6	TOC	11/5/98	946.282	1010.418	184.225	
MLS7	TOP	11/5/98	944.616	1010.835	184.019	
MLS8	TOC	11/5/98	944.383	1010.941	184.193	
MLS9	TOP	11/5/98	942.302	1011.534	184.038	
MLS10	TOP	11/5/98	942.613	1011.518	184.048	Failed attempt, PVC pipe put in place
MLS10A	TOP	11/5/98	942.096	1011.612	184.012	Failed attempt, PVC pipe put in place
MLS10B	TOC	11/5/98	941.890	1011.668	183.997	Final location MLS10
MLS11	TOP	11/5/98	940.300	1012.125	183.873	
MLS12	TOC	11/5/98	940.099	1012.219	184.046	
MLS13	TOP	11/5/98	945.859	1000.091	184.298	
MLS14	TOC	11/5/98	945.765	1000.180	184.347	
MLS15	TOP	11/5/98	943.771	1000.995	183.975	
MLS16	TOC	11/5/98	943.676	1001.045	183.983	

Location	Ref. Point	Survey Date	East (m)	North (m)	Elev. (m)	Comments
MLS17	TOP	11/5/98	941.859	1001.345	184.060	
MLS18	TOC	11/5/98	941.739	1001.411	184.025	
MLS19	TOP	11/5/98	939.489	1002.155	184.018	
MLS20	TOC	11/5/98	939.363	1002.143	184.097	
PINE RIVER PROFILER LOCATIONS						
PRP1	SB	8/7/96			183.933	Calculated streambed elevation at time of sampling
PRP1	TOP	7/29/97	949.783	1017.905	184.481	Top of PVC Casing
PRP1	SB	11/25/96	949.743	1017.881	183.859	streambed elevation
PRP1	SB	7/29/97	949.699	1017.963	183.911	streambed
PRP2	SB	8/8/96			184.002	Calculated streambed elevation at time of sampling
PRP2	TOP	7/29/97	948.185	1017.951	184.532	Top of PVC Casing
PRP2	SB	11/25/96	948.198	1017.931	183.827	streambed elevation
PRP2	SB	7/29/97	948.172	1018.027	184.101	streambed
PRP3	SB	8/9/96			183.912	Calculated streambed elevation at time of sampling
PRP3	TOP	7/29/97	945.151	1018.066	184.044	Top of PVC Casing
PRP3	SB	11/25/96	945.168	1018.032	183.803	streambed elevation
PRP3	SB	7/29/97	945.088	1018.082	183.985	streambed
PRP4	SB	8/28/96			183.957	Calculated streambed elevation at time of sampling
PRP4	TOP	7/29/97	942.132	1018.651	184.122	Top of PVC Casing
PRP4	SB	11/25/96	942.132	1018.617	184.042	streambed elevation
PRP4	SB	7/29/97	942.108	1018.582	184.048	streambed
PRP5	SB	10/7/96			184.121	Calculated streambed elevation at time of sampling
PRP5	TOP	7/29/97	949.589	1030.037	184.231	Top of PVC cap
PRP5	SB	11/25/96	949.624	1030.028	184.113	streambed elevation
PRP5	SB	7/29/97	949.544	1030.009	184.188	streambed
PRP6	SB	10/9/96			183.927	Calculated streambed elevation at time of sampling
PRP6	TOP	7/29/97	943.563	1029.443	184.036	Top of PVC Casing
PRP6	SB	11/25/96	943.601	1029.460	183.872	streambed elevation
PRP6	SB	7/29/97	943.535	1029.418	183.926	streambed
PRP7	SB	11/7/96			184.159	Approx. calc. streambed elev. at time of sampling, may be 20 cm too high
PRP7	SB	11/25/96	947.933	1012.053	183.732	streambed elevation
PRP7	TOP	7/29/97	947.956	1012.110	184.448	Top of PVC Casing
PRP7	SB	7/29/97	947.912	1012.136	184.127	streambed
PRP7	TOP	11/5/98	947.968	1012.111	184.437	
PRP7R	SB	8/12/97			184.246	Approximate calculated streambed elev. at time of sampling (+/- 5 cm)
PRP7R			948.01	1011.93		Not surveyed, calculated from stakes
PRP8	SB	11/11/97			183.893	Approximate calculated streambed elev. at time of sampling (+/- 10cm)
PRP8			942.756	1012.110		Not surveyed, very approx. location, measured as 2.2 m west of PRP7

Location	Ref. Point	Survey Date	East (m)	North (m)	Elev. (m)	Comments
PRP8R	SB	8/13/97			184.154	Calculated streambed elevation at time of sampling
PRP8R			945.85	1012.58		Not surveyed, calculated from stakes
PRP9	SB	8/13/97			183.959	Calculated streambed elevation at time of sampling
PRP9			943.27	1013.36		Not surveyed, calculated from stakes
PRP10	SB	8/14/97			183.862	Calculated streambed elevation at time of sampling
PRP10	Steel pipe	11/5/98	941.422	1013.902	184.024	Finally found it
PRP11	SB	8/14/97			183.692	Calculated streambed elevation at time of sampling
PRP11			937.93	1008.85		Not surveyed, calculated from stakes
PRP12	SB	8/15/97			183.857	Calculated streambed elevation at time of sampling
PRP12			950.5	1023.15		Not surveyed, calculated from stakes
PRP13	SB	8/15/97			184.011	Calculated streambed elevation at time of sampling
PRP13	TOP	5/28/99	947.067	1023.138	184.149	
PRP14	SB	10/29/97			183.684	Calculated streambed elevation at time of sampling
PRP14			944.36	1000.69		Not surveyed, calculated from stakes
PRP15	SB	10/30/97			183.637	Calculated streambed elevation at time of sampling
PRP15			941.5	1001.57		Not surveyed, calculated from stakes
PRP16	SB	10/31/97			184.030	Calculated streambed elevation at time of sampling
PRP16			942.05	995.03		Not surveyed, calculated from stakes
PRP17	SB	6/24/98			184.057	Calculated streambed elevation at time of sampling
PRP17	TOP	11/5/98	944.655	1012.763	184.076	Same location as MLS prototype, top of PVC pipe
SOIL CORE LOCATIONS						
RC1	SB	3/16/98			183.843	Calculated streambed elevation at time of coring
RC1	TOP	11/5/98	948.121	1012.415	184.276	
RC2	SB	3/17/98			183.827	Calculated streambed elevation at time of coring
RC2	TOP	11/5/98	944.649	1012.751	184.075	
RC3	SB	3/17/98			183.957	Calculated streambed elevation at time of coring
RC3	TOP	11/5/98	941.488	1001.688	184.217	
RC4	SB	3/17/98			184.007	Calculated streambed elevation at time of coring

Location	Ref. Point	Survey Date	East (m)	North (m)	Elev. (m)	Comments
RC4	TOP	11/5/98	941.800	1001.497	184.127	
RC5	SB	10/16/98			183.896	Calculated streambed elevation at time of coring
RC5	TOP	11/5/98	939.757	1002.070	183.946	
RC6	SB	10/16/98			183.722	Calculated streambed elevation at time of coring
RC6	TOP	11/5/98	940.875	1003.741	183.782	
RC7	SB	10/16/98			183.845	Calculated streambed elevation at time of coring
RC7	TOP	11/5/98	944.861	1004.580	183.910	
RC8	SB	10/16/98			183.844	Calculated streambed elevation at time of coring
RC8	TOP	11/5/98	941.822	1007.520	183.914	
RC9	SB	10/16/98			184.319	Calculated streambed elevation at time of coring
RC9	TOP	5/28/99	946.928	1008.132	184.139	
RC10	SB	10/16/98			183.890	Calculated streambed elevation at time of coring
RC10	TOP	11/5/98	944.166	1008.993	183.940	
RC11	SB	10/16/98			183.909	Calculated streambed elevation at time of coring
RC11	TOP	11/5/98	945.524	1010.546	183.949	
RC12	SB	10/16/98			183.898	Calculated streambed elevation at time of coring
RC12	TOP	5/28/99	946.432	1017.545	183.904	
SC7	STK	5/14/96	949.419	1041.496	186.044	stake elev. no longer valid
SC8	STK	5/14/96	956.113	1056.321	185.628	stake elev. no longer valid
SC9	STK	5/14/96	962.761	1046.180	185.908	stake elev. no longer valid
SC10-A	STK?	6/18/96	943.725	1075.286	185.932	
SC10-B-E	STK?	6/18/96	942.518	1075.590	186.085	
SC11	GRND	5/28/99	936.701	1017.641	185.909	Elev. Approx., at least 0.1 m low
SC12	STK	7/29/97	953.927	1014.960	186.385	
SC12	GRND	7/29/97	953.936	1014.979	186.365	
SC13	GRND		985.487	1013.593	188.201	Estimated location and elevation, 0.55 m from Simulprobe SP-1 location
B2	GRND	11/17/99	1066.349	925.338	190.224	Pitkin (1994) Soil core location B2, hole still open
STAFF GAGE LOCATIONS						
SG-1	TSG	5/14/96	947.285	1002.126	185.607	
SG-1	TSG	11/25/96	947.343	1002.169	185.608	
SG-1	TSG	5/28/99	947.347	1002.267	185.598	
SG-1A	TSG	11/5/98	950.556	1012.939	185.821	
SG-1A	TSG	11/5/98	950.540	1012.929	185.826	Check the location again after setup
SG-1A	TSG	5/28/99	950.552	1012.986	185.832	
SG-1A	TSG	5/28/99	950.537	1012.988	185.837	
SG-2	TSG	5/14/96	948.661	1036.481	185.560	
SG-2	TSG	11/25/96	948.683	1036.507	185.564	

Location	Ref. Point	Survey Date	East (m)	North (m)	Elev. (m)	Comments
SG-2	TSG	7/29/97	948.672	1036.489	185.137	staff gage has shifted
SG-2	TSG	5/28/99	948.736	1036.583	185.015	staff gage has shifted
SG-3	TSG	5/14/96	956.867	1073.759	185.771	
SG-3	TSG	6/18/96	956.874	1073.780	185.783	
SG-4	TSG	7/30/97	947.605	1048.111	185.053	
SG-4	TSG	5/28/99	947.631	1048.156	185.056	
SG-5	TSG	7/30/97	946.659	1059.744	184.494	
SG-6	TSG	7/30/97	955.427	1065.230	185.118	
SG-6	TSG	5/28/99	955.509	1065.271	185.072	
STREAM PIEZOMETERS						
SP Prototype	TOP	11/5/98	941.705	1001.523	183.819	
SP1	TSG	6/18/96	947.583	1048.067	185.099	Same as SG-4, datum for both -S and -D
SP1	TSG	11/25/96	947.592	1048.131	185.109	SP-1 top of staff gauge (vandalized), same as SG-4
SP2	TSG	6/18/96	946.665	1059.581	184.848	Same as SG-5, datum for both -S and -D
SP3	TSG	6/18/96	955.458	1065.229	185.066	Same as SG-6, datum for both -S and -D
SP4	TOP	11/5/98	942.052	997.281	184.348	Corrected, since raw reading SP4 tilted 4cm E
SP5	TOP	11/5/98	942.547	999.182	184.234	
SP6	TOP	11/5/98	941.549	999.406	184.260	
SP7	TOP	11/5/98	940.728	999.582	184.084	
SP8	TOP	11/5/98	943.362	1001.147	183.944	
SP9	TOP	11/5/98	942.167	1001.323	184.069	
SP10	TOP	11/5/98	939.673	1002.204	183.878	
SP11	TOP	11/5/98	940.741	1003.775	183.760	
SP12	TOP	11/5/98	944.772	1004.650	183.984	
SP13	TOP	11/5/98	944.442	1006.727	184.134	
SP14	TOP	11/5/98	941.687	1007.546	183.905	
SP15	TOP	11/5/98	948.868	1007.522	184.280	
SP16	TOP	11/5/98	946.848	1008.218	184.283	
SP17	TOP	11/5/98	945.464	1008.649	184.222	
SP18	TOP	11/5/98	944.051	1009.046	183.976	
SP19	TOP	11/5/98	943.109	1009.283	183.930	
SP20	TOP	11/5/98	949.885	1009.294	184.414	
SP21	TOP	11/5/98	947.231	1010.115	184.328	
SP22	TOP	11/5/98	945.378	1010.601	183.962	
SP23	TOP	11/5/98	943.561	1011.161	184.051	
SP24	TOP	11/5/98	941.175	1011.838	183.885	
SP25	TOP	11/5/98	948.116	1012.069	184.256	
SP26	TOP	11/5/98	946.130	1012.563	184.042	
SP27	TOP	11/5/98	944.513	1012.769	183.962	
SP28	TOP	11/5/98	943.246	1013.319	183.944	
SP29	TOP	11/5/98	941.314	1013.932	183.941	
SP30	TOP	5/28/99	947.980	1018.005	183.941	
SP31	TOP	5/28/99	946.287	1017.809	183.988	

Location	Ref. Point	Survey Date	East (m)	North (m)	Elev. (m)	Comments
SP32	TOP	5/28/99	944.953	1018.107	183.987	
SP33	TOP	5/28/99	942.042	1018.590	184.063	
SP34	TOP	5/28/99	950.788	1021.497	184.144	
SP35	TOP	5/28/99	947.224	1023.109	183.884	
SP36	TOP	5/28/99	949.494	1030.093	184.240	
SP37	TOP	5/28/99	943.420	1029.435	183.972	
AMP-2	SB	7/29/97	948.614	1007.420	184.114	Pitkin (1994), Dave Lee mini-piezometer
AMP-3	SB	7/29/97	950.794	1022.799	183.908	Pitkin (1994), Dave Lee mini-piezometer
MISCELLANEOUS						
Level Logger PR	TOP	11/5/98	949.774	1017.964	184.449	Top of PVC pipe attached to PRP1 that holds the river level logger
Simulprobe (SP-1)	STK	7/7/98	985.183	1014.058	188.201	Simulprobe core/water sampling location, Levenick (1998)
Seep at Bridge	GRND	5/28/99	946.745	995.103	185.095	Middle of seep area
Plaza Well	TOC	5/28/99	903.577	1091.648	187.807	Top of unopened cap
Plaza Well	GRND	5/28/99	903.688	1091.618	186.830	Pavement
MCT1	TOC	11/17/99	1075.631	926.911	190.223	Multi-Channel Tubing by Einarson (1999)
MCT1	TOP/CS	11/17/99	1075.571	926.906	190.222	top of the multi-channel tubing
SURVEY STATIONS AND CONTROL POINTS						
Hydrant Outlet	Outlet	11/25/96	1014.437	989.792	189.270	Hydrant - top of south outlet edge nearest to the plug, but not on the screw cap
Station "T"	T in cement	11/25/96	953.319	993.225	188.606	Station 11 "T" in word Tim in sidewalk cement next to NE corner of bridge
Station 1	Gate Valve	5/14/96	1000.000	1000.000	188.180	Set up over water shut off valve
Station 2	STK	5/14/96	969.058	1043.120	187.646	Stake at edge of field
Station 3	STK	5/14/96	933.330	1054.394	186.758	Station 3
Station 4	STK	5/14/96	942.178	1082.061	186.597	Station 4, corrected elevation
Station 5	Steel pipe	11/25/96	937.107	1017.603	186.005	Station 5 on west side of river south of DP9
Station 6	STK	7/29/97	954.174	996.012	188.220	Station 6 from 1 (near bridge north of "Tim")
Station 7	STK	7/30/97	933.067	1047.468	186.629	Station 7 from Station 5 (near stake 48 W)
Station 8	STK	7/7/98	914.239	988.131	188.043	This is new Station 8
Station 9	Steel pipe	5/28/99	931.180	1077.504	187.298	
CP1	STK	11/5/98	1058.602	981.670	189.620	Control point CP1 along side walk
CP2	Nail in road	11/5/98	1102.799	899.214	190.811	
CP3	?	11/5/98	1117.085	899.136	190.833	

Location	Ref. Point	Survey Date	East (m)	North (m)	Elev. (m)	Comments
CP4	?	11/5/98	1116.479	890.859	190.961	
CP5	?	11/5/98	1097.238	864.173	190.905	
CP6	?	11/5/98	1102.517	927.523	190.483	
CP7	STK	11/17/99	1086.191	928.824	190.231	Turning/check point
CP8	Tent Stake	11/17/99	1050.127	940.764	189.981	CP8
CP9	Nail in road	11/17/99	1128.927	891.664	190.853	Nail in asphalt at edge of driveway
Benchmark / Curtis-Jonas St	Nail in HP	11/17/99	1017.619	815.299	190.656	Elevation bench mark, nail in west side of hydro pole at SE corner of Curtis and Jonas street, elevation should be 190.664 m ASL
Benckmark/ Queen-Curtis St	Nail in HP	11/17/99	1076.522	904.026	190.387	Elevation bench mark, nail in west side of hydro pole at SE corner of Queen and Curtis street, elevation should be 190.387 m ASL

Notes:

Ref Point - is the reference point at the location that was surveyed

If the data if have multiple survey values, use the first value shown for the location

Gate valve - center of brass bolt on water shutoff gate valve, this was bent over and repaired so elevation can no longer be used

GRND - ground surface

Outlet - is the southern most, top edge of the outlet on the hydrant (not the screw cap)

SB - streambed surface

STK - top of wooden stake

Steel pipe - top of a 0.5-inch steel pipe (Survey Station locations have a caps on them)

"T" in cement - The place where lines cross in the letter T in the word Tim, drawn in the sidewalk cement (NE corner of bridge)

TOC - Top of metal casing or pipe for drivepoints, or the larger diameter protective casing for multilevels

TOP - Top of polyethylene tube or PVC pipe

TSG - Top of staff gage (top of a 0.5-inch metal pipe)

TOP/CS - Top of center stalk (PVC)

TOPVC - top of the 2-inch PVC well casing

p-Cover - Top of 4-inch diameter PVC protective cap

M-cap - has the metal cap still on the 1/2 or 3/4-inch pipe when surveyed the drive point

Tent Stake - a yellow plastic tent stake 6-inches long flush with ground

APPENDIX B

WELL CONSTRUCTION DATA

List of Tables and Figures

DRIVEPOINT WELL CONSTRUCTION DETAILS

Location	Elev. top of casing (m)	Stickup of casing above GND (m)	Approx. total length of pipe (m)	Approx. DBG of bot. of screen (m)	Approx. Elev. of bot. screen amls (m)	Screen length (m)	Screen Type	Geologic material at screen
DP1-1	186.196	0.145	3.02	2.88	183.17	0.19	DP/SS	Silt, Sand & Peat
DP1-2	186.323	0.262	5.46	5.20	180.84	0.19	DP/SS	Sand Aquifer
DP1-3	186.172	0.110	7.60	7.49	178.56	0.19	DP/SS	Sand aquifer
DP2-1	185.810	0.180	3.02	2.84	182.77	0.19	DP/SS	Silt, Sand & Peat
DP2-2	185.698	0.070	5.46	5.39	180.22	0.19	DP/SS	Sand Aquifer
DP2-3	185.926	0.290	7.90	7.61	178.00	0.19	DP/SS	Sand aquifer
DP3-1	186.093	0.202	4.19	3.99	181.89	0.15	DP/Nitex	Sand Aquifer
DP3-2	186.189	0.269	5.77	5.50	180.39	0.19	DP/SS	Sand Aquifer
DP3-3	186.231	0.320	7.60	7.28	178.61	0.19	DP/SS	Sand aquifer
DP4-1	186.367	0.130	2.63	2.50	183.74	0.19	DP/Nitex	Silt & Peat
DP4-2	186.974	0.705	6.67	5.97	180.28	0.19	DP/SS	Sand Aquifer
DP4-3	186.598	0.340	8.09	7.75	178.49	0.19	DP/Nitex	Sand aquifer
DP5-1	186.821	0.290	3.32	3.03	183.51	0.19	DP/SS	Silt, Sand & Peat
DP5-2	186.962	0.395	5.76	5.36	181.17	0.19	DP/SS	Silt & Peat
DP5-3	186.766	0.260	8.19	7.93	178.60	0.19	DP/SS	Sand aquifer
DP6-1	186.999	0.170	3.62	3.45	183.34	0.19	DP/SS	Silt & Sand
DP6-2	187.078	0.160	5.76	5.60	181.32	0.19	DP/SS	Sand aquifer
DP6-3	187.132	0.150	8.19	8.04	178.91	0.19	DP/SS	Sand aquifer
DP7-1	186.596	0.292	3.26	2.91	183.38	0.19	DP/SS	Silt & Sand
DP7-2	186.568	0.228	5.79	5.51	180.81	0.19	DP/SS	Sand aquifer
DP7-3	186.716	0.390	7.91	7.46	178.86	0.19	DP/SS	Sand aquifer
DP8-1	186.551	0.282	3.38	3.04	183.19	0.19	DP/SS	Silt & peat
DP8-2	186.473	0.215	5.77	5.50	180.73	0.19	DP/SS	Sand aquifer
DP8-3	186.677	0.375	7.93	7.50	178.76	0.19	DP/SS	Sand aquifer
DP9-1	186.104	0.150	2.70	2.49	183.45	0.19	DP/SS	Silt and Sand
DP9-2	186.255	0.242	5.77	5.47	180.50	0.19	DP/SS	Sand aquifer
DP9-3	186.147	0.122	7.60	7.42	178.57	0.19	DP/SS	Sand aquifer
DP10-S	186.806	0.185	3.99	3.80	182.81	0.16	DP/SS	Silt and Clay
DP10-D	186.798	0.140	6.86	6.72	179.92	0.16	DP/SS	Sand Aquifer
DP11	188.181	-0.055	7.02	7.07	181.16	0.16	DP/SS	Silt
DP12	188.087	-0.050	7.11	7.16	180.95	0.16	DP/SS	Sand aquifer
DP13	187.968	-0.045	7.04	7.08	180.93	0.16	DP/SS	Sand aquifer
DP14-S	186.839	0.200	3.40	3.20	183.43	0.16	DP/SS	Silt & peat
DP14-D	186.973	0.350	7.42	7.07	179.56	0.16	DP/SS	Sand aquifer
DP15	186.837	0.026	6.83	6.81	179.99	0.16	DP/SS	Silt & Sand
DP16	189.743	0.270	7.73	7.46	182.01	0.16	DP/SS	Sand aquifer
DP17-S	186.037	0.090	3.46	3.37	182.57	0.16	DP/SS	Silt & peat

DRIVEPOINT WELL CONSTRUCTION DETAILS

Location	Elev. top of casing (m)	Stickup of casing above GND (m)	Approx. total length of pipe (m)	Approx. DBG of bot. of screen (m)	Approx. Elev. of bot. screen amls (m)	Screen length (m)	Screen Type	Geologic material at screen
DP17-D	186.262	0.295	6.86	6.56	179.39	0.16	DP/SS	Sand aquifer
DP18	186.364	-0.015	7.73	7.74	178.63	0.16	DP/SS	Silt and Sand
DP19	186.833	0.580	8.33	7.75	178.50	0.16	DP/SS	Sand aquifer
DP20	186.294	0.315	6.84	6.52	179.45	0.16	DP/SS	Sand aquifer
AW1	187.256	0.944	7.25	6.30	180.01	0.56	SP/SS	Sand Aquifer

Notes:

- Elevations are relative to mean sea level

DBG = Depth below ground surface
GND = Ground surface
bot. = bottom
poly. tube = Polyethylene tubing (3/8-inch inside diameter (ID))
DP/SS = Drivepoint with an inner stainless steel mesh screen
DP/Nitex = Drivepoint with an inner Nitex mesh screen

- Drivepoint tips for DP1 to DP9 sets are 0.28 m long with screen opening between 0.026 to 0.216 m below top of drivepoint (except DP3-1)
- Drivepoint tip for DP3-1 is 25.5 cm long with openings between 0.04 and 0.192 m below top of drivepoint
- Drivepoint tips for DP10 to DP20 sets are 0.26 m long with screen opening between 0.0235 to 0.20 m below top of drivepoint

SP/SS = 1.25-inch I.D. "red" sand point perforated and wrapped with 80-mesh screen
Casing = Steel protective pipe (1/2-inch ID for DP1 to DP9 and 3/4-inch ID for DP10 to DP20)

STREAMBED PIEZOMETER CONSTRUCTION DETAILS

Location	Elev. top of casing (m)	Stickup above stream-bed (m)	Approx. total length of piezo (m)	Approx. DBS of bot. of screen (m)	Approx. Elev. of of bot. screen (m)	Screen length (m)	Screen Type	Geologic material at screen
SP1-S	185.099	0.933	2.28	0.45	95.54	0.10	P/Nitex	Streambed
SP1-D	185.099	0.933	3.13	1.19	94.79	0.10	P/Nitex	Streambed
SP2-S	185.066	0.860	1.77	0.71	95.32	0.10	P/Nitex	Streambed
SP2-D	185.066	0.860	2.39	1.23	94.80	0.10	P/Nitex	Streambed
SP3-S	184.848	0.820	2.35	0.63	95.22	0.10	P/Nitex	Streambed
SP3-D	184.848	0.820	3.10	1.28	94.57	0.10	P/Nitex	Streambed
SP4	184.348	0.110	0.74	0.63	95.43	0.10	PVC/SS	Streambed
SP5	184.234	0.120	0.74	0.62	95.32	0.10	PVC/SS	Streambed
SP6	184.260	0.075	0.74	0.66	95.35	0.10	PVC/SS	Streambed
SP7	184.084	0.074	0.74	0.66	95.17	0.10	PVC/SS	Streambed
SP8	183.944	0.040	0.74	0.70	95.03	0.10	PVC/SS	Streambed
SP9	184.069	0.060	0.74	0.68	95.15	0.10	PVC/SS	Streambed
SP10	183.878	0.035	0.74	0.70	94.96	0.10	PVC/SS	Streambed
SP11	183.760	0.020	0.74	0.72	94.85	0.10	PVC/SS	Streambed
SP12	183.984	0.030	0.74	0.71	95.07	0.10	PVC/SS	Streambed
SP13	184.134	0.070	0.74	0.67	95.22	0.10	PVC/SS	Streambed
SP14	183.905	0.080	0.74	0.66	94.99	0.10	PVC/SS	Streambed
SP15	184.280	0.040	0.74	0.70	95.37	0.10	PVC/SS	Streambed
SP16	184.283	0.020	0.74	0.72	95.37	0.10	PVC/SS	Streambed
SP17	184.222	0.010	0.74	0.73	95.31	0.10	PVC/SS	Streambed
SP18	183.976	0.060	0.74	0.68	95.06	0.10	PVC/SS	Streambed
SP19	183.930	-0.010	0.74	0.75	95.02	0.10	PVC/SS	Streambed
SP20	184.414	0.050	0.74	0.69	95.50	0.10	PVC/SS	Streambed
SP21	184.328	-0.020	0.74	0.76	95.41	0.10	PVC/SS	Streambed
SP22	183.962	0.050	0.74	0.69	95.05	0.10	PVC/SS	Streambed
SP23	184.051	0.190	0.74	0.55	95.14	0.10	PVC/SS	Streambed
SP24	183.885	0.095	0.74	0.64	94.97	0.10	PVC/SS	Streambed
SP25	184.256	0.030	0.74	0.71	95.34	0.10	PVC/SS	Streambed
SP26	184.042	0.090	0.74	0.65	95.13	0.10	PVC/SS	Streambed
SP27	183.962	0.090	0.74	0.65	95.05	0.10	PVC/SS	Streambed
SP28	183.944	0.090	0.74	0.65	95.03	0.10	PVC/SS	Streambed
SP29	183.941	0.060	0.74	0.68	95.03	0.10	PVC/SS	Streambed
SP30	183.941	0.050	0.74	0.69	95.03	0.10	PVC/SS	Streambed
SP31	183.988	0.055	0.74	0.68	95.07	0.10	PVC/SS	Streambed
SP32	183.987	0.075	0.74	0.66	95.07	0.10	PVC/SS	Streambed
SP33	184.063	0.060	0.74	0.68	95.15	0.10	PVC/SS	Streambed
SP34	184.144	0.105	0.74	0.63	95.23	0.10	PVC/SS	Streambed
SP35	183.884	0.040	0.74	0.70	94.97	0.10	PVC/SS	Streambed
SP36	184.240	0.060	0.74	0.68	95.33	0.10	PVC/SS	Streambed
SP37	183.972	0.050	0.74	0.69	95.06	0.10	PVC/SS	Streambed
SP Prototype	183.819	-0.040	0.64	0.68	95.00	0.10	PVC/SS	Streambed

Notes on the next page

STREAMBED PIEZOMETER CONSTRUCTION DETAILS

Notes:

- Elevations are in m above mean sea level
- SP1 through SP3 installed using the method of Lee and Cherry (1978), the rest were driven in

*Total length of piezo = total length of polyethylene tubing and the screen (together) for SP1 to SP3 and from top of flat part of PVC elbow connector to bottom of screen for SP4 to SP37

** = For SP1,SP2,and SP3 stickup above streambed refers distance of top of 0.5-inch I.D. steel support pipe above streambed surface and for SP4 to SP37 it means the stickup from streambed to the top of the PVC elbow connecter

DBS = Depth below streambed surface

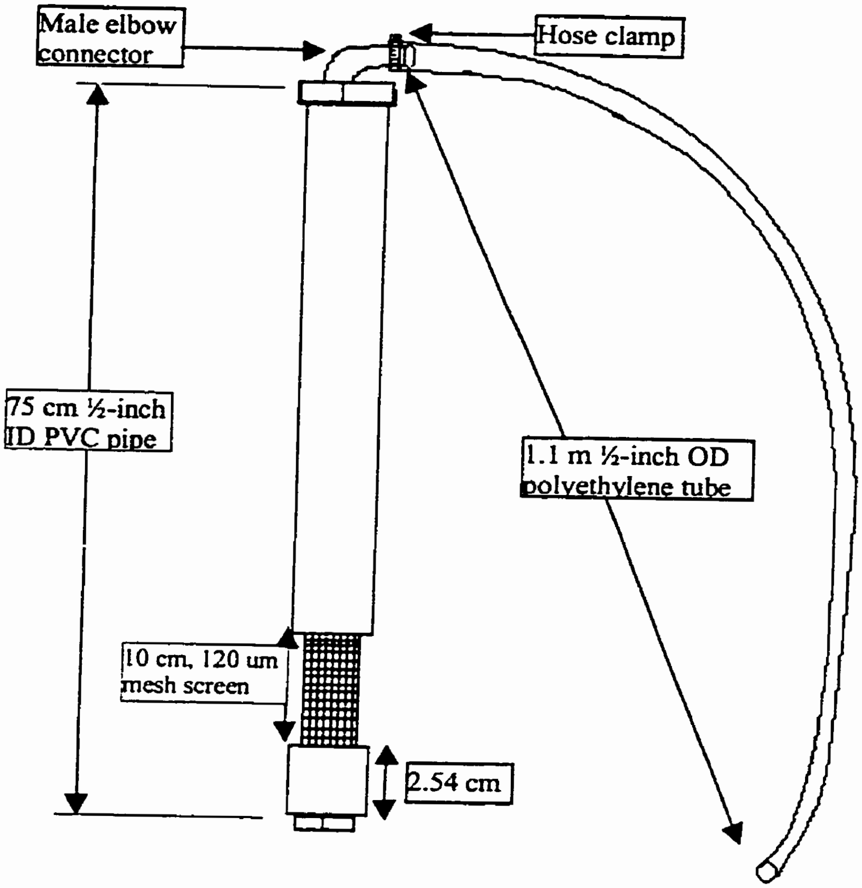
bot. = bottom

NM = not measured

PVC/SS = Perforated PVC pipe wrapped with stainless steel mesh

P/Nitex = The screen is a perforated polyethylene tube wrapped in Nitex mesh

SCHEMATIC OF STREAMBED PIEZOMETER



Drawing not to scale

(Figure created by Titia Praamsma, 1999)

BUNDLE MULTILEVEL (BML) CONSTRUCTION DETAILS

Location	Elev. top of center stalk[1] (m)	Elev. of Ground (m)	Total length of center stalk[2] (m)	Number of sample points	Depth of Grout BGS[3] (m)	Depth to bottom most point[4] (m)	Depth to top most point[4] (m)	Comments
BML1	186.407	186.517	9.93	8	5.50	9.49	6.05	
BML2	185.913	186.277	9.93	8	5.35	9.49	6.05	Point at 7.99 m BTCS is broken
BML3	186.181	186.225	9.93	9	4.57	9.49	5.55	
BML4	186.014	186.157	9.93	9	4.57	9.49	5.55	
BML5	186.085	186.234	9.93	9	4.57	9.49	5.55	
BML6	186.081	186.343	9.93	9	4.57	9.49	5.55	Center stalk broke during installation, points at 6.49 and 6.99 m BTCS were broken
BML7	186.070	186.352	9.93	11	3.96	9.49	4.55	Point at 6.05 m BTCS is broken
BML8	186.028	186.253	9.93	9	4.57	9.49	5.55	
BML9	185.932	186.147	9.93	10	4.27	9.49	5.05	
BML10	185.870	186.104	9.93	10	4.27	9.49	5.05	
BML11	186.169	186.352	9.93	10	4.42	9.49	5.05	
BML12	185.731	185.893	9.93	8	5.49	9.49	6.05	

Notes:

[1] Elevation is without the caps on (about 0.016 to 0.018 lower than TOP elevations in survey table)

[2] Length includes the bottom cap but not the top cap

[3] Grout tremmied into borehole from ground surface down to this depth below ground surface (BGS)

[4] Vertical spacing between points is 0.5 m except between a depth of 6.05 and 6.49 where it is 0.44 m

Sample points are numbered sequentially starting at the highest elevation and going down (e.g. at BML1 the top point is BML1-1 and the bottom point is BML1-8)

BTCS means below top of center stalk (with no cap on)

Elevations are in m above mean sea level

Center stalk is made of Timco schedule 40 1/2-inch ID PVC flush threaded pipe

Sample tubes are teflon 1/8-inch OD by 1/16-inch ID

Sample points at ends of the tube were covered with Nitex Nylon screen held in place with stainless-steel wire

Locking steel road boxes were cemented in place, flush to the ground, at each BML to protect the installation

DRIVEABLE MULTILEVEL SAMPLERS (MLS) CONSTRUCTION DETAILS

Location	Elev. top of MLS[1] (m)	Stickup above Stream-bed[2] (m)	Total length of MLS[3] (m)	Number of sample points	Type of MLS[4] (m)	Depth to top most point[5] (m)	Depth to bottom most point[5] (m)	Comments
MLS1	184.207	0.05	3.03	7	PVC	0.15	1.05	
MLS2	184.241	0.07	5.06	9	SS	2.56	4.96	
MLS3	184.360	0.05	3.03	7	PVC	0.15	1.05	
MLS4	184.329	-0.01	4.56	9	SS	2.06	4.46	
MLS5	184.214	0.01	3.03	10	PVC	0.15	1.50	
MLS6	184.225	0.11	4.56	9	SS	2.06	4.46	
MLS7	184.019	0.14	3.03	10	PVC	0.15	1.50	
MLS8	184.193	0.31	4.56	9	SS	2.06	4.46	
MLS9	184.038	0.17	3.03	10	PVC	0.15	1.50	
MLS10	183.997	0.21	4.30	9	SS	1.80	4.20	
MLS11	183.873	0.18	3.03	10	PVC	0.15	1.50	
MLS12	184.046	0.38	4.56	9	SS	2.06	4.46	Point MLS12-5 at 3.26 m below the top of the MLS is broken
MLS13	184.298	0.00	3.03	10	PVC	0.15	1.50	
MLS14	184.347	0.04	5.56	9	SS	3.02	5.43	
MLS15	183.975	0.24	3.03	10	PVC	0.15	1.50	
MLS16	183.983	0.20	4.80	9	SS	2.30	4.70	
MLS17	184.060	0.06	3.03	10	PVC	0.15	1.50	
MLS18	184.025	0.07	4.30	9	SS	1.80	4.20	
MLS19	184.018	0.09	3.03	10	PVC	0.15	1.50	
MLS20	184.097	0.19	4.30	9	SS	1.80	4.20	

Notes:

[1] The top of the MLS is the top of the stainless-steel pipe (TOC) or top of the PVC pipe (TOP) and elevations are in m above mean sea level

[2] Stickup to top of MLS above streambed at time of the installation (these values change over time)

[3] Length is from the top of the MLS to the bottom of the drive tip

[4] The MLS type is either the stainless-steel (SS) pipe kind or the PVC pipe kind.

[5] The depth is from the top of the MLS pipe to the center of the sampling points

Sample points are numbered sequentially starting at the highest elevation and going down (e.g. at MLS5 the top point is MLS5-1 and the bottom point is MLS5-10)

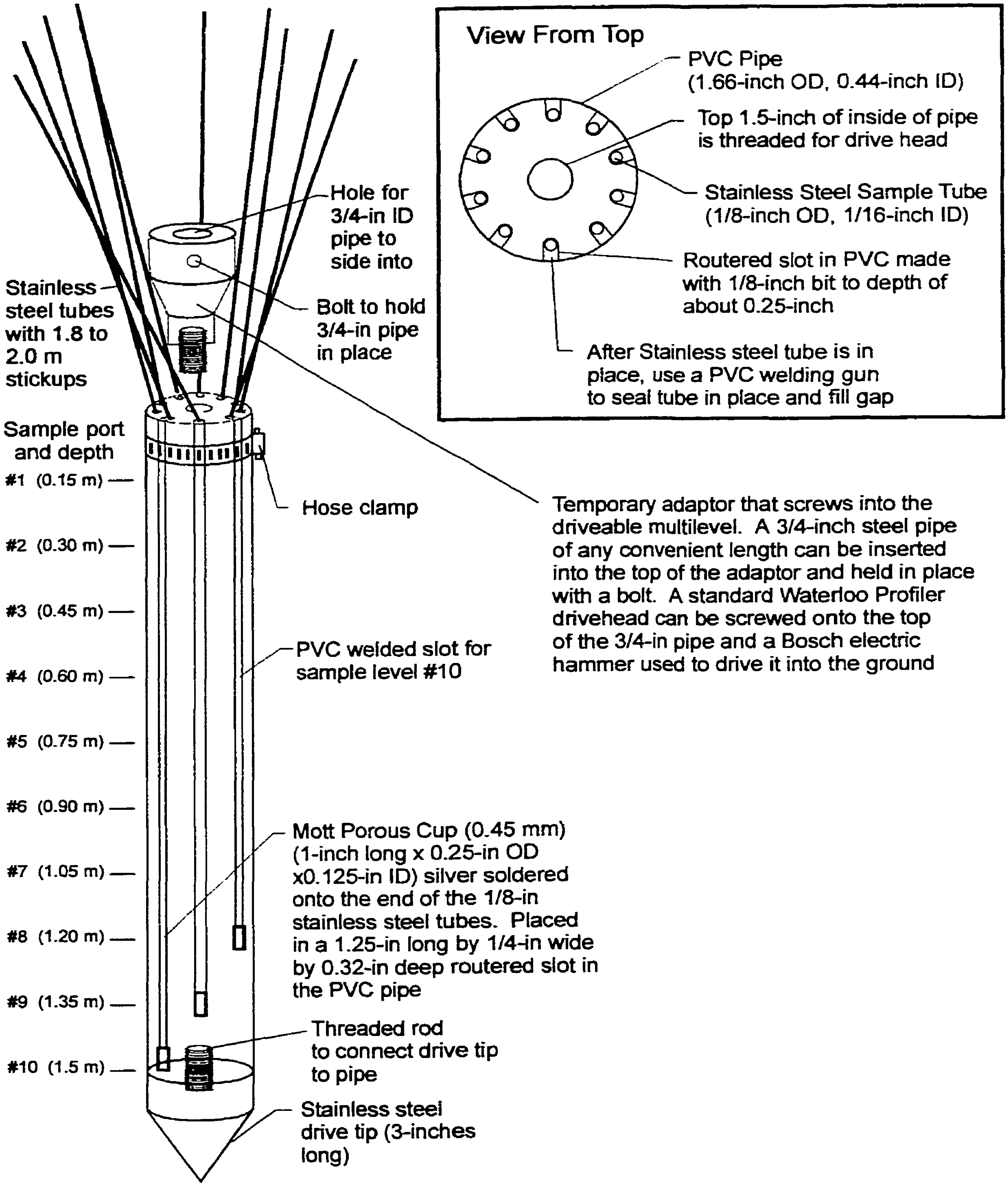
SS type MLS are made of 0.0335 m OD stainless-steel pipe, and stainless-steel tubes

PVC type MLS are made with 0.42 m OD PVC pipe, and stainless-steel tubes

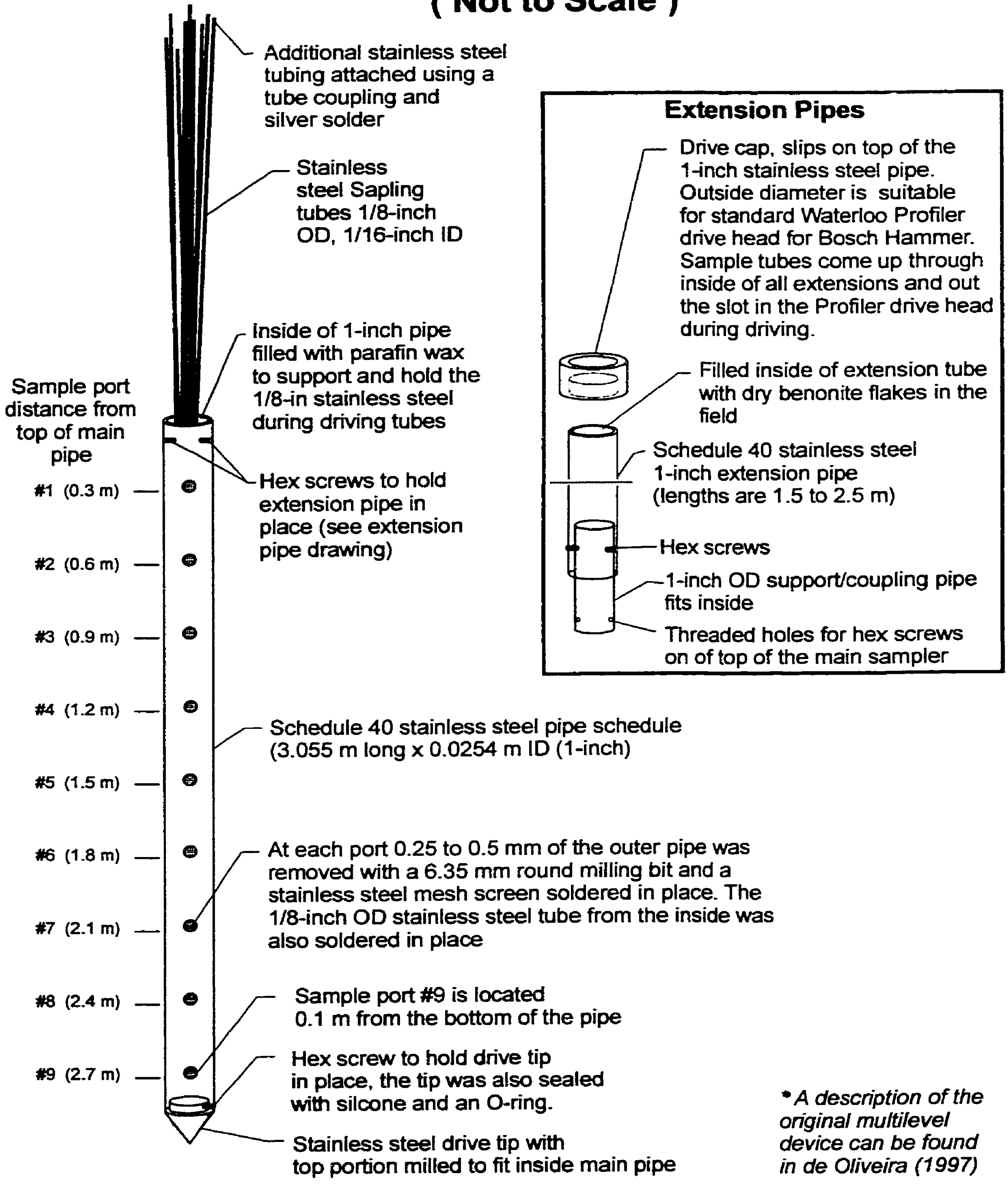
Sample tubes are all made of 1/8-inch OD, 020-thousand-wall thickness, stainless-steel seamless tubes

Sample points consisted of stainless-steel mesh for SS multilevels and 1-inch long 0.45 micron opening porous cup for the PVC types

SCHEMATIC OF DRIVEABLE PVC MULTILEVEL SAMPLER
(Not to Scale)



SCHEMATIC OF DRIVEABLE STAINLESS-STEEL MULTILEVEL SAMPLER*
(Not to Scale)



Additional stainless steel tubing attached using a tube coupling and silver solder

Stainless steel Sapling tubes 1/8-inch OD, 1/16-inch ID

Inside of 1-inch pipe filled with parafin wax to support and hold the 1/8-in stainless steel during driving tubes

Hex screws to hold extension pipe in place (see extension pipe drawing)

Schedule 40 stainless steel pipe schedule (3.055 m long x 0.0254 m ID (1-inch)

At each port 0.25 to 0.5 mm of the outer pipe was removed with a 6.35 mm round milling bit and a stainless steel mesh screen soldered in place. The 1/8-inch OD stainless steel tube from the inside was also soldered in place

Sample port #9 is located 0.1 m from the bottom of the pipe

Hex screw to hold drive tip in place, the tip was also sealed with silcone and an O-ring.

Stainless steel drive tip with top portion milled to fit inside main pipe

Extension Pipes

Drive cap, slips on top of the 1-inch stainless steel pipe. Outside diameter is suitable for standard Waterloo Profiler drive head for Bosch Hammer. Sample tubes come up through inside of all extensions and out the slot in the Profiler drive head during driving.

Filled inside of extension tube with dry benonite flakes in the field

Schedule 40 stainless steel 1-inch extension pipe (lengths are 1.5 to 2.5 m)

1-inch OD support/coupling pipe fits inside

Threaded holes for hex screws on of top of the main sampler

**A description of the original multilevel device can be found in de Oliveira (1997)*

APPENDIX C

WATER LEVEL DATA

Manual Water Level Measurements at piezometers & staff gauges

- Summary of Water Levels May 1996- August 1997
- Water levels 6/10/98
- Water levels 7/17/98
- Water levels 8/12/98
- Water levels 9/16/98
- Water levels 10/15/98
- Water levels 11/5/98
- Water levels 12/10/98
- Water levels 2/9/99
- Water levels 4/5/99
- Water levels 5/5/99
- Water levels 6/10/99
- Water levels 7/19/99
- Water levels 8/16/99

Data Logger Level Measurements

- AW1 water levels from 7/9/98 to 6/11/99

SUMMARY OF WATER LEVELS MAY 1996 - AUGUST 97

Location	Water Level in m measured on these dates							
	5/15/96	6/18/96	6/25/96	7/25/96	8/15/96	9/29/96	11/9/96	8/4/97
DP1-1	96.678	96.405	96.541	97.355^C	96.255	96.596	96.968	96.217
DP1-2	98.194	97.963	98.054	98.304	97.706	97.897	98.102	97.660
DP1-3	98.305	98.080	98.149	98.104	97.814	97.982	98.178	97.747
DP2-1	96.702	96.434	96.568	96.504	96.263	96.627	96.988^E	96.199
DP2-2	98.376	98.154	98.211	98.130	97.935	98.091	98.267	97.846
DP2-3	98.371	98.157	98.214	98.127	97.931	98.083	98.252	97.852
DP3-1	98.317	98.177	98.203	96.363^C	97.810	97.998^D	98.193^E	97.832
DP3-2	98.414	98.186	98.214	98.094	97.960	98.120	98.312	97.875
DP3-3	98.413	98.183	98.244	98.105	97.956	98.107	98.301	97.865
DP4-1	NA	96.452	96.642	96.481	96.279	96.614	97.000	96.239^B
DP4-2	NA	98.183	98.120^B	97.947^B	97.782^B	97.954^B	98.195^B	NA^B
DP4-3	NA	98.140	98.254^B	98.106^B	97.924^B	98.078^B	98.306^B	97.857^B
DP5-1	NA	96.386	96.598	96.421	96.246	96.581	96.973	96.217
DP5-2	NA	95.927	98.108	97.978	97.876	98.024	98.234	97.902
DP5-3	NA	98.078	98.232	98.082	97.860	97.962	98.240	97.711
DP6-1	NA	96.414	96.622	96.454	96.262	96.602	96.980	96.223
DP6-2	NA	97.987	98.141	97.967	97.789	97.918	98.167	97.742
DP6-3	NA	97.992	98.137	97.974	97.790	97.918	98.171	97.742
DP7-1	NA	NA	NA	NA	NA	NA	97.256	96.545
DP7-2	NA	NA	NA	NA	NA	NA	98.146	97.692
DP7-3	NA	NA	NA	NA	NA	NA	98.147	97.687
DP8-1	NA	NA	NA	NA	NA	NA	97.285^D	96.938
DP8-2	NA	NA	NA	NA	NA	NA	98.092	97.623
DP8-3	NA	NA	NA	NA	NA	NA	98.091	97.614
DP9-1	NA	NA	NA	NA	NA	NA	96.993	96.271
DP9-2	NA	NA	NA	NA	NA	NA	98.017	97.523
DP9-3	NA	NA	NA	NA	NA	NA	98.019	97.541
DP10-S	NA	NA	NA	NA	NA	NA	NA	NA
DP10-D	NA	NA	NA	NA	NA	NA	NA	NA
DP11	NA	NA	NA	NA	NA	NA	NA	NA
DP12	NA	NA	NA	NA	NA	NA	NA	NA
DP13	NA	NA	NA	NA	NA	NA	NA	NA
DP14-S	NA	NA	NA	NA	NA	NA	NA	NA
DP14-D	NA	NA	NA	NA	NA	NA	NA	NA
DP15	NA	NA	NA	NA	NA	NA	NA	NA
DP16	NA	NA	NA	NA	NA	NA	NA	NA
DP17-S	NA	NA	NA	NA	NA	NA	NA	NA
DP17-D	NA	NA	NA	NA	NA	NA	NA	NA

Location	Water Level in m measured on these dates							
	5/15/96	**6/18/96**	**6/25/96**	**7/25/96**	**8/15/96**	**9/29/96**	**11/9/96**	**8/4/97**
DP18	NA	NA	NA	NA	NA	NA	NA	NA
DP19	NA	NA	NA	NA	NA	NA	NA	NA
DP20	NA	NA	NA	NA	NA	NA	NA	NA
SP1-S	NA	96.359	96.538	96.381	96.228	96.563	96.933	NA
SP1-D	NA	96.360	96.537	96.385	96.229	96.563	96.933	NA
SP2-S	NA	96.369	96.541	96.385	96.238	96.575	NA	NA
SP2-D	NA	96.372	96.539	96.393	96.239	96.578	NA	NA
SP3-S	NA	96.375	96.545	96.405	96.240	96.583	96.955	NA
SP3-D	NA	96.376	96.546	96.409	96.242	96.584	96.951	NA
SG-1	96.654	96.420	NA	96.432	96.302	96.606	96.958	96.283
SG-2	96.626	96.386	96.518	96.403	96.260	96.577	96.944	96.254
SG-3	96.591	96.348	NA	96.364	96.212	DES	DES	DES
SG-4	NA	96.359A	96.538	96.378	96.227	96.558	96.928	96.286
SG-5	NA	96.367	96.546[A]	96.394[A]	96.239	96.577	NA	96.223
SG-6	NA	96.370	96.538	96.385	96.234	96.572	96.945	NA
P1	98.763	98.533	NA	98.519	98.347	98.482	98.646	98.227
P2	98.753	98.520	NA	98.512	98.343	98.475	98.642	98.218

Notes:

NA means not measured, in some cases the location was not yet in existence

DES means location was destroyed, can not measure

Elevations are relative to an arbitrary datum, add 88.18 m to values to get elevation in m above mean sea level.

[A] Possible survey error?

[B] Location vandalized may not be representative

[C] bad reading, had not equilbrated after sampling

[D] Not equilibrated, water level still rising

[E] Water level difficult to read accurately

ANGUS WATER LEVELS JUNE 10, 1998

Location	Top of Casing Elev (m)	Plastic stickup (m)	Elev. meas. point (m)	Meas. point	Depth to water (m)	Elev. of water (m)	AMSL Elevation (m)	Comments
DP1-1	98.016	0.285	98.301	TOP	1.937	96.364	184.54	
DP1-2	98.143	0.286	98.429	TOP	0.635	97.794	185.97	
DP1-3	97.992	0.585	98.577	TOP	0.699	97.878	186.06	
DP2-1	97.630	0.284	97.914	TOP	1.550	96.364	184.54	
DP2-2	97.518		97.518	TOC	-0.434	97.952	186.13	Artesian (DTW was positive in raw notes)
DP2-3	97.746		97.746	TOC	-0.224	97.970	186.15	Artesian (DTW was positive in raw notes)
DP3-1	97.913		97.913	TOC	-0.075	97.988	186.17	Artesian (DTW was positive in raw notes)
DP3-2	98.009	0.585	98.594	TOP	0.601	97.993	186.17	Artesian
DP3-3	98.051	0.330	98.381	TOP	0.412	97.969	186.15	Artesian
DP4-1	98.187	0.292	98.479	NM	NM	NM	NM	Casing bent - vandalized
DP4-2	98.794	0.291	99.085	NM	NM	NM	NM	Casing bent - vandalized
DP4-3	98.418	0.315	98.733	NM	NM	NM	NM	Casing bent - vandalized
DP5-1	98.641	0.270	98.911	TOP	2.561	96.350	184.53	
DP5-2	98.782	0.460	99.242	TOP	1.378	97.864	186.04	seems a bit low when graphed
DP5-3	98.586	0.570	99.156	TOP	1.205	97.951	186.13	seems a bit high when graphed
DP6-1	98.819	0.285	99.104	NM	NM	NM	NM	Too dark to read
DP6-2	98.898		98.898	NM	NM	NM	NM	Too dark to read
DP6-3	98.952	0.620	99.572	NM	NM	NM	NM	Too dark to read
DP7-1	98.416	0.174	98.590	TOP	1.854	96.736	184.92	
DP7-2	98.388	0.423	98.811	TOP	0.986	97.825	186.01	
DP7-3	98.536	0.292	98.828	TOP	1.009	97.819	186.00	
DP8-1	98.371	0.428	98.799	TOP	1.751	97.048	185.23	
DP8-2	98.293	0.426	98.719	TOP	0.952	97.767	185.95	
DP8-3	98.497	0.309	98.806	TOP	1.050	97.756	185.94	
DP9-1	97.924	0.405	98.329	TOP	1.935	96.394	184.57	
DP9-2	98.075	0.446	98.521	TOP	0.851	97.670	185.85	
DP9-3	97.967	0.435	98.402	TOP	0.720	97.682	185.86	

Location	Top of Casing Elev (m)	Plastic stickup (m)	Elev. meas. point (m)	Meas. point	Depth to water (m)	Elev. of water (m)	AMSL Elevation (m)	Comments
SP1-S	96.929		96.929	NM	NM	NM	NM	
SP1-D	96.929		96.929	NM	NM	NM	NM	
SP2-S	96.314		96.314	NM	NM	NM	NM	
SP2-D	96.314		96.314	NM	NM	NM	NM	
SP3-S	96.938		96.938	NM	NM	NM	NM	
SP3-D	96.938		96.938	NM	NM	NM	NM	
SG-1	97.427		97.427	TSG	1.027	96.400	184.58	Pine River
SG-1A	97.641		97.641	TSG	1.238	96.403	184.58	Pine River
SG-2	96.957		96.957	TSG	0.478	96.479	184.66	Pine River
SG-3	97.591		97.591	NM	NM	NM	NM	Destroyed - unable to measure
SG-4	96.929		96.929	TSG	0.516	96.413	184.59	Pine River (SP1 loc.)
SG-5	96.314		96.314	NM	NM	NM	NM	Pine River (SP2 loc.) water level is near TSG
SG-6	96.938		96.938	TSG	0.585	96.353	184.53	Pine River (SP3 loc.)
P1	99.928	0.005	99.933	TOP	1.578	98.355	186.54	
P2	100.360		100.360	TOC	2.015	98.345	186.53	

Notes:

NM = Water levels not measured at this location
TOC = top of steel pipe coupling (steel casing P1 and P2)
TOP = top of plastic polyethylene tubing
TSG = top of staff gauge (steel pipe)
AP20/ Pitken elev = 189.84m, Conant elev = 101.118, difference is 88.722 to convert to MSL
Revised elevation for SP1 and elevations for SG-2,5,6 from July 1997 survey
Stickups measured today except for DP4 and DP6 sets

.ANGUS WATER LEVELS JULY 17, 1998

Location	Top of Casing Elev (m)	Plastic stickup (m)	Elev. meas. point (m)	Meas. point	Depth to water (m)	Elev. of water (m)	AMSL Elevation (m)	Comments
DP1-1	98.016	0.285	98.301	TOP	2.045	96.256	184.44	
DP1-2	98.143	0.286	98.429	TOP	0.726	97.703	185.88	
DP1-3	97.992	0.585	98.577	TOP	0.791	97.786	185.97	
DP2-1	97.630	0.284	97.914	TOP	1.678	96.236	184.42	
DP2-2	97.518		97.518	TOC	-0.344	97.862	186.04	Artesian
DP2-3	97.746		97.746	TOC	-0.126	97.872	186.05	Artesian
DP3-1	97.913	0.305	98.218	TOP	0.395	97.823	186.00	Artesian
DP3-2	98.009	0.585	98.594	TOP	0.691	97.903	186.08	Artesian
DP3-3	98.051	0.330	98.381	TOP	0.482	97.899	186.08	Artesian
DP4-1	98.187	0.292	98.479	TOP	2.209	96.270	184.45	Casing bent - vandalized
DP4-2	98.794	0.291	99.085	TOP	1.402	97.683	185.86	Casing bent - vandalized
DP4-3	98.418	0.315	98.733	TOP	0.900	97.833	186.01	Casing bent - vandalized
DP5-1	98.641	0.270	98.911	TOP	2.669	96.242	184.42	
DP5-2	98.782	0.460	99.242	TOP	1.492	97.750	185.93	
DP5-3	98.586	0.570	99.156	TOP	1.411	97.745	185.93	
DP6-1	98.819	0.285	99.104	TOP	2.846	96.258	184.44	
DP6-2	98.898		98.898	TOC	1.231	97.667	185.85	
DP6-3	98.952	0.620	99.572	TOP	1.893	97.679	185.86	
DP7-1	98.416	0.174	98.590	TOP	2.002	96.588	184.77	
DP7-2	98.388	0.423	98.811	TOP	1.076	97.735	185.92	
DP7-3	98.536	0.292	98.828	TOP	1.098	97.730	185.91	
DP8-1	98.371	0.428	98.799	TOP	1.797	97.002	185.18	
DP8-2	98.293	0.426	98.719	TOP	1.043	97.676	185.86	
DP8-3	98.497	0.309	98.806	TOP	1.134	97.672	185.85	
DP9-1	97.924	0.405	98.329	TOP	2.030	96.299	184.48	
DP9-2	98.075	0.446	98.521	TOP	0.993	97.528	185.71	
DP9-3	97.967	0.435	98.402	TOP	0.862	97.540	185.72	Stickup dif. than before
DP10-S	98.626		98.626	TOC	3.672	94.954	183.13	Not correct, hasn't recovered, very low water level

Location	Top of Casing Elev (m)	Plastic stickup (m)	Elev. meas. point (m)	Meas. point	Depth to water (m)	Elev. of water (m)	AMSL Elevation (m)	Comments
DP10-D	98.618	0.460	99.078	TOP	1.320	97.758	185.94	
DP11	100.001		100.001	TOC	1.896	98.105	186.29	Slow responder, may not have equilibrated
DP12	99.907		99.907	TOC	1.800	98.107	186.29	
DP13	99.788		99.788	TOC	1.615	98.173	186.35	
DP14-S	98.659	0.069	98.728	TOP	2.319	96.409	184.59	
DP14-D	98.793	0.252	99.045	TOP	1.368	97.677	185.86	
DP15	98.657	0.594	99.251	TOP	1.341	97.910	186.09	Still recovering, may not have equilibrated
DP16	101.563	0.062	101.625	TOP	3.194	98.431	186.61	
DP17-S	97.857	0.293	98.150	TOP	1.362	96.788	184.97	Slow recovery, may not have equilibrated
DP17-D	98.082	0.566	98.648	TOP	0.720	97.928	186.11	
DP18	98.184	0.010	98.194	TOP	0.345	97.849	186.03	
DP19	98.653	0.054	98.707	TOP	0.798	97.909	186.09	
DP20	98.114	0.558	98.672	TOP	0.849	97.823	186.00	Artesian
SP1-S	96.929		96.929	NM	NM	NM	NM	
SP1-D	96.929		96.929	NM	NM	NM	NM	
SP2-S	96.314		96.314	NM	NM	NM	NM	
SP2-D	96.314		96.314	NM	NM	NM	NM	
SP3-S	96.938		96.938	NM	NM	NM	NM	
SP3-D	96.938		96.938	NM	NM	NM	NM	
SG-1	97.427		97.427	TSG	1.116	96.311	184.49	Pine River
SG-1A	97.641		97.641	TSG	1.332	96.309	184.49	Pine River
SG-2	96.957		96.957	TSG	0.578	96.379	184.56	Pine River
SG-3	97.591		97.591	NM	NM	NM	NM	Destroyed - unable to measure
SG-4	96.929		96.929	TSG	0.619	96.310	184.49	Pine River (SP1 loc.)
SG-5	96.314		96.314	TSG	0.059	96.255	184.44	Pine River (SP2 loc.) , pipe is badly bent
SG-6	96.938		96.938	NM	DRY	NM	NM	Pine River (SP3 loc.)

Location	Top of Casing Elev (m)	Plastic stickup (m)	Elev. meas. point (m)	Meas. point	Depth to water (m)	Elev. of water (m)	AMSL Elevation (m)	Comments
P1	99.928	0.005	99.933	TOP	1.676	98.257	186.44	
P2	100.360		100.360	TOC	2.107	98.253	186.43	
AW1	99.076		99.076	TOC	1.408	97.668	185.85	

Notes:

NM = Water levels not measured at this location
TOC = top of steel pipe coupling (steel casing P1 and P2)
TOP = top of plastic polyethylene tubing
TSG = top of staff gauge (steel pipe)
To convert Conant elevations to meters above mean sea level, add 88.18 m to Conant values
Revised elevation for SP1 and elevations for SG-2,5,6 from July 1997 survey
Stickups for DP1 to DP9 from June 10, and DP10-20 from July 10, 1998 measurements
Stickups for DP3-1, DP4 set, and DP6 set are from much older measurement

ANGUS WATER LEVELS AUGUST 12, 1998

Location	Top of Casing Elev (m)	Plastic stickup (m)	Elev. meas. point (m)	Meas. point	Depth to water (m)	Elev. of water (m)	AMSL Elevation (m)	Comments
DP1-1	98.016	0.288	98.304	TOP	2.002	96.302	184.48	
DP1-2	98.143	0.284	98.427	TOP	0.750	97.677	185.86	almost artesian - but below ground
DP1-3	97.992	0.587	98.579	TOP	0.820	97.759	185.94	almost artesian - but below ground
DP2-1	97.630	0.284	97.914	TOP	1.632	96.282	184.46	
DP2-2	97.518		97.518	TOC	-0.332	97.850	186.03	Artesian, measure up from coupling
DP2-3	97.746		97.746	TOC	-0.102	97.848	186.03	Artesian, measure up from coupling
DP3-1	97.913	0.305	98.218	TOP	0.414	97.804	185.98	Artesian
DP3-2	98.009	0.584	98.593	TOP	0.695	97.898	186.08	Artesian
DP3-3	98.051	0.333	98.384	TOP	0.490	97.894	186.07	Artesian
DP4-1	98.187	0.295	98.482	TOP	2.164	96.318	184.50	Casing bent, vandalized
DP4-2	98.794	0.280	99.074	TOP	1.342	97.732	185.91	Casing bent, vandalized
DP4-3	98.418	0.310	98.728	TOP	0.855	97.873	186.05	Casing bent, vandalized
DP5-1	98.641	0.273	98.914	TOP	2.620	96.294	184.47	
DP5-2	98.782	0.465	99.247	TOP	1.454	97.793	185.97	
DP5-3	98.586	0.576	99.162	TOP	1.319	97.843	186.02	
DP6-1	98.819	0.292	99.111	TOP	2.798	96.313	184.49	
DP6-2	98.898		98.898	TOC	1.153	97.745	185.93	
DP6-3	98.952	0.623	99.575	TOP	1.825	97.750	185.93	
DP7-1	98.416	0.176	98.592	TOP	1.945	96.647	184.83	
DP7-2	98.388	0.423	98.811	TOP	1.092	97.719	185.90	
DP7-3	98.536	0.295	98.831	TOP	1.114	97.717	185.90	
DP8-1	98.371	0.432	98.803	TOP	1.832	96.971	185.15	
DP8-2	98.293	0.428	98.721	TOP	1.062	97.659	185.84	Water level below ground
DP8-3	98.497	0.312	98.809	TOP	1.157	97.652	185.83	
DP9-1	97.924	0.409	98.333	TOP	1.992	96.341	184.52	
DP9-2	98.075	0.449	98.524	TOP	0.932	97.592	185.77	
DP9-3	97.967	0.438	98.405	TOP	0.805	97.600	185.78	
DP10-S	98.626		98.626	TOC	1.392	97.234	185.41	This well was dry last time

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Location	Top of Casing Elev (m)	Plastic stickup (m)	Elev. meas. point (m)	Meas. point	Depth to water (m)	Elev. of water (m)	AMSL Elevation (m)	Comments
DP10-D	98.618	0.461	99.079	TOP	1.317	97.762	185.94	
DP11	100.001		100.001	TOC	1.415	98.586	186.77	Slow recoverer, did not equilibrate, water level is high
DP12	99.907		99.907	TOC	1.810	98.097	186.28	
DP13	99.788		99.788	TOC	1.612	98.176	186.36	
DP14-S	98.659	0.066	98.725	TOP	2.292	96.433	184.61	
DP14-D	98.793	0.253	99.046	TOP	1.300	97.746	185.93	
DP15	98.657	0.591	99.248	TOP	1.040	98.208	186.39	Slow recoverer, measured later
DP16	101.563	0.063	101.626	TOP	3.185	98.441	186.62	
DP17-S	97.857	0.294	98.151	TOP	1.172	96.979	185.16	
DP17-D	98.082	0.568	98.650	TOP	0.707	97.943	186.12	Artesian but can't see in pipe
DP18	98.184	0.010	98.194	TOP	0.249	97.945	186.13	
DP19	98.653	0.054	98.707	TOP	0.727	97.980	186.16	
DP20	98.114	0.554	98.668	TOP	0.802	97.866	186.05	Barely artesian
SP1-S	96.929		96.929	NM	NM	NM	NM	
SP1-D	96.929		96.929	NM	NM	NM	NM	
SP2-S	96.314		96.314	NM	NM	NM	NM	
SP2-D	96.314		96.314	NM	NM	NM	NM	
SP3-S	96.938		96.938	NM	NM	NM	NM	
SP3-D	96.938		96.938	NM	NM	NM	NM	
SG-1	97.427		97.427	TSG	1.098	96.329	184.51	Pine River
SG-1A	97.641		97.641	TSG	1.309	96.332	184.51	Pine River
SG-2	96.957		96.957	TSG	0.545	96.412	184.59	Pine River
SG-3	97.591		97.591	NM	NM	NM	NM	Destroyed - unable to measure
SG-4	96.929		96.929	NM	NM	NM	NM	Pine River (SP1 loc.)
SG-5	96.314		96.314	NM	NM	NM	NM	Pine River (SP2 loc.) , pipe is badly bent
SG-6	96.938		96.938	NM	NM	NM	NM	Pine River (SP3 loc.)

Location	Top of Casing Elev (m)	Plastic stickup (m)	Elev. meas. point (m)	Meas. point	Depth to water (m)	Elev. of water (m)	AMSL Elevation (m)	Comments
P1	99.928	0.009	99.937	TOP	1.677	98.260	186.44	
P2	100.360	0.002	100.362	TOP	2.102	98.260	186.44	2 mm TOP stick up - steel pipe loose
AW1	99.076		99.076	TOC	1.360	97.716	185.90	

Notes:

NM = Water levels not measured at this location
TOC = top of steel pipe coupling (steel casing P1 and P2)
TOP = top of plastic polyethylene tubing
TSG = top of staff gauge (steel pipe)
To convert Conant elevations to meters above mean sea level, add 88.18 m to Conant values
Used stickups measured on this day.
Revised elevation datums for SP-1 and SG-2, SG-5, SG-6

ANGUS WATER LEVELS SEPTEMBER 16, 1998

Location	Top of Casing Elev (m)	Plastic stickup (m)	Elev. meas. point (m)	Meas. point	Depth to water (m)	Elev. of water (m)	AMSL Elevation (m)	Comments
DP1-1	98.016	0.287	98.303	TOP	1.865	96.438	184.62	
DP1-2	98.143	0.286	98.429	TOP	0.672	97.757	185.94	forgot to unplug - came back later
DP1-3	97.992	0.586	98.578	TOP	0.739	97.839	186.02	Almost artesian
DP2-1	97.630	0.283	97.913	TOP	1.487	96.426	184.61	
DP2-2	97.518		97.518	TOC	-0.388	97.906	186.09	Artesian above TOC - add DTW to top of tube
DP2-3	97.746		97.746	TOC	-0.160	97.906	186.09	Artesian above TOC
DP3-1	97.913	0.307	98.220	TOP	0.349	97.871	186.05	Artesian
DP3-2	98.009	0.587	98.596	TOP	0.638	97.958	186.14	Artesian
DP3-3	98.051	0.333	98.384	TOP	0.432	97.952	186.13	Artesian
DP4-1	98.187	0.295	98.482	TOP	2.047	96.435	184.62	Bent pipe
DP4-2	98.794	0.280	99.074	TOP	1.320	97.754	185.93	Severely bent (flat to ground- bend back)
DP4-3	98.418	0.312	98.730	TOP	0.827	97.903	186.08	Bent
DP5-1	98.641	0.274	98.915	TOP	2.494	96.421	184.60	
DP5-2	98.782	0.468	99.250	TOP	1.382	97.868	186.05	
DP5-3	98.586	0.579	99.165	TOP	1.324	97.841	186.02	
DP6-1	98.819	0.295	99.114	TOP	2.675	96.439	184.62	
DP6-2	98.898		98.898	TOC	1.140	97.758	185.94	
DP6-3	98.952	0.626	99.578	TOP	1.826	97.752	185.93	
DP7-1	98.416	0.177	98.593	TOP	1.839	96.754	184.93	
DP7-2	98.388	0.425	98.813	TOP	1.002	97.811	185.99	
DP7-3	98.536	0.295	98.831	TOP	1.023	97.808	185.99	
DP8-1	98.371	0.432	98.803	TOP	1.801	97.002	185.18	
DP8-2	98.293	0.427	98.720	TOP	0.960	97.760	185.94	
DP8-3	98.497	0.312	98.809	TOP	1.052	97.757	185.94	
DP9-1	97.924	0.410	98.334	TOP	1.869	96.465	184.65	
DP9-2	98.075	0.450	98.525	TOP	0.881	97.644	185.82	
DP9-3	97.967	0.437	98.404	TOP	0.751	97.653	185.83	
DP10-S	98.626		98.626	TOC	1.364	97.262	185.44	TOC and TOP same - this well responds slowly

Location	Top of Casing Elev (m)	Plastic stickup (m)	Elev. meas. point (m)	Meas. point	Depth to water (m)	Elev. of water (m)	AMSL Elevation (m)	Comments
DP10-D	98.618	0.461	99.079	TOP	1.222	97.857	186.04	
DP11	100.001		100.001	TOC	1.608	98.393	186.57	Slow recoverer, may not have equilibrated
DP12	99.907		99.907	TOC	1.730	98.177	186.36	
DP13	99.788		99.788	TOC	1.534	98.254	186.43	
DP14-S	98.659	0.067	98.726	TOP	2.151	96.575	184.76	
DP14-D	98.793	0.253	99.046	TOP	1.252	97.794	185.97	
DP15	98.657	0.592	99.249	TOP	0.975	98.274	186.45	Slow recoverer, measured well later
DP16	101.563	0.063	101.626	TOP	3.125	98.501	186.68	
DP17-S	97.857	0.293	98.150	TOP	1.057	97.093	185.27	
DP17-D	98.082	0.566	98.648	TOP	0.628	98.020	186.20	Artesian
DP18	98.184	0.010	98.194	TOP	0.221	97.973	186.15	
DP19	98.653	0.056	98.709	TOP	0.679	98.030	186.21	
DP20	98.114	0.555	98.669	TOP	0.745	97.924	186.10	
SP1-S	96.929		96.929	NM	NM	NM	NM	
SP1-D	96.929		96.929	NM	NM	NM	NM	
SP2-S	96.314		96.314	NM	NM	NM	NM	
SP2-D	96.314		96.314	NM	NM	NM	NM	
SP3-S	96.938		96.938	NM	NM	NM	NM	
SP3-D	96.938		96.938	NM	NM	NM	NM	
SG-1	97.427		97.427	TSG	0.971	96.456	184.64	Pine River
SG-1A	97.641		97.641	TSG	1.189	96.452	184.63	Pine River
SG-2	96.957		96.957	TSG	0.419	96.538	184.72	Pine River
SG-3	97.591		97.591	NM	NM	NM	NM	Destroyed - unable to measure
SG-4	96.929		96.929	TSG	0.456	96.473	184.65	Pine River (SP1 loc.)
SG-5	96.314		96.314	TSG	-0.110	96.424	184.60	Pine River (SP2 loc.) above staff gauge
SG-6	96.938		96.938	TSG	0.513	96.425	184.61	Pine River (SP3 loc.)

Location	Top of Casing Elev (m)	Plastic stickup (m)	Elev. meas. point (m)	Meas. point	Depth to water (m)	Elev. of water (m)	AMSL Elevation (m)	Comments
P1	99.928	0.009	99.937	TOP	1.609	98.328	186.51	
P2	100.360	0.003	100.363	TOP	2.036	98.327	186.51	
AW1	99.076		99.076	TOC	1.352	97.724	185.90	

Notes:

NM = Water levels not measured at this location
TOC = top of steel pipe coupling (steel casing P1 and P2)
TOP = top of plastic polyethylene tubing
TSG = top of staff gauge (steel pipe)
To convert Conant elevations to meters above mean sea level, add 88.18 m to Conant values
Revised elevation datums for SP-1 and SG-2, SG-5, SG-6
Used stickups measured on this day

ANGUS WATER LEVELS OCTOBER 15, 1998

Location	Top of Casing Elev (m)	Plastic stickup (m)	Elev. meas. point (m)	Meas. point	Depth to water (m)	Elev. of water (m)	AMSL Elevation (m)	Comments
DP1-1	98.016	0.287	98.303	TOP	1.954	96.349	184.53	
DP1-2	98.143	0.286	98.429	TOP	0.690	97.739	185.92	
DP1-3	97.992	0.586	98.578	TOP	0.752	97.826	186.01	
DP2-1	97.630	0.283	97.913	TOP	1.528	96.385	184.57	
DP2-2	97.518		97.518	TOC	-0.382	97.900	186.08	Artesian
DP2-3	97.746	0.320	98.066	TOP	0.162	97.904	186.08	Artesian
DP3-1	97.913	0.307	98.220	TOP	0.355	97.865	186.05	
DP3-2	98.009	0.587	98.596	TOP	0.654	97.942	186.12	
DP3-3	98.051	0.333	98.384	TOP	0.448	97.936	186.12	
DP4-1	98.187	0.295	98.482	TOP	NM	NM	NM	could not open - vandalized
DP4-2	98.794	0.280	99.074	TOP	NM	NM	NM	could not open - vandalized
DP4-3	98.418	0.312	98.730	TOP	NM	NM	NM	could not open - vandalized
DP5-1	98.641	0.274	98.915	TOP	2.585	96.330	184.51	
DP5-2	98.782	0.468	99.250	TOP	1.276	97.974	186.15	
DP5-3	98.586	0.579	99.165	TOP	1.294	97.871	186.05	
DP6-1	98.819	0.295	99.114	TOP	2.759	96.355	184.54	
DP6-2	98.898		98.898	TOC	1.126	97.772	185.95	
DP6-3	98.952	0.626	99.578	TOP	1.806	97.772	185.95	steel pipe snapped off, need to replace and survey
DP7-1	98.416	0.177	98.593	TOP	1.811	96.782	184.96	
DP7-2	98.388	0.425	98.813	TOP	1.031	97.782	185.96	
DP7-3	98.536	0.295	98.831	TOP	1.052	97.779	185.96	
DP8-1	98.371	0.432	98.803	TOP	1.842	96.961	185.14	
DP8-2	98.293	0.427	98.720	TOP	0.997	97.723	185.90	
DP8-3	98.497	0.312	98.809	TOP	1.088	97.721	185.90	
DP9-1	97.924	0.410	98.334	TOP	1.959	96.375	184.56	
DP9-2	98.075	0.450	98.525	TOP	0.908	97.617	185.80	
DP9-3	97.967	0.437	98.404	TOP	0.776	97.628	185.81	
DP10-S	98.626		98.626	TOC	1.357	97.269	185.45	

Location	Top of Casing Elev (m)	Plastic stickup (m)	Elev. meas. point (m)	Meas. point	Depth to water (m)	Elev. of water (m)	AMSL Elevation (m)	Comments
DP10-D	98.618	0.461	99.079	TOP	1.256	97.823	186.00	
DP11	100.001		100.001	TOC	1.846	98.155	186.34	slow recoverer, was measured later, looks stable
DP12	99.907		99.907	TOC	1.772	98.135	186.32	
DP13	99.788		99.788	TOC	1.588	98.200	186.38	
DP14-S	98.659	0.067	98.726	TOP	2.231	96.495	184.68	
DP14-D	98.793	0.253	99.046	TOP	1.262	97.784	185.96	
DP15	98.657	0.592	99.249	TOP	1.086	98.163	186.34	slow recoverer, was measured later
DP16	101.563	0.063	101.626	TOP	3.171	98.455	186.64	
DP17-S	97.857	0.293	98.150	TOP	1.065	97.085	185.27	
DP17-D	98.082	0.566	98.648	TOP	0.672	97.976	186.16	
DP18	98.184	0.010	98.194	TOP	0.205	97.989	186.17	
DP19	98.653	0.056	98.709	TOP	0.680	98.029	186.21	
DP20	98.114	0.555	98.669	TOP	0.756	97.913	186.09	
SP1-S	96.929		96.929	NM	NM	NM	NM	
SP1-D	96.929		96.929	NM	NM	NM	NM	
SP2-S	96.314		96.314	NM	NM	NM	NM	
SP2-D	96.314		96.314	NM	NM	NM	NM	
SP3-S	96.938		96.938	NM	NM	NM	NM	
SP3-D	96.938		96.938	NM	NM	NM	NM	
SG-1	97.427		97.427	TSG	1.081	96.346	184.53	Pine River
SG-1A	97.641		97.641	TSG	1.290	96.351	184.53	Pine River
SG-2	96.957		96.957	TSG	0.528	96.429	184.61	Pine River
SG-3	97.591		97.591	NM	NM	NM	NM	Destroyed - unable to measure
SG-4	96.929		96.929	TSG	0.561	96.368	184.55	Pine River (SP1 loc.)
SG-5	96.314		96.314	NM	NM	NM	NM	Pine River (SP2 loc.) pipe is badly bent
SG-6	96.938		96.938	TSG	0.631	96.307	184.49	Pine River (SP3 loc.)

Location	Top of Casing Elev (m)	Plastic stickup (m)	Elev. meas. point (m)	Meas. point	Depth to water (m)	Elev. of water (m)	AMSL Elevation (m)	Comments
P1	99.928		99.928	TOC	1.654	98.274	186.45	
P2	100.360		100.360	TOC	2.082	98.278	186.46	
AW1	99.076		99.076	TOC	1.353	97.723	185.90	opened after all of the east side and before did west

Notes:

NM = Water levels not measured at this location
TOC = top of steel pipe coupling (steel casing P1 and P2)
TOP = top of plastic polyethylene tubing
TSG = top of staff gauge (steel pipe)
To convert Conant elevations to meters above mean sea level, add 88.18 m to Conant values
Revised elevation datums for SP-1 and SG-2, SG-5, SG-6
Use stickups measured in September

ANGUS WATER LEVELS NOVEMBER 5, 1998

Location	Top of Casing Elev (m)	Plastic stickup (m)	Elev. of meas. point (m)	Meas. point	Depth to water (m)	Elev. of water (m)	AMSL Elevation (m)	Comments
DP1-1	98.016	0.287	98.303	TOP	1.967	96.336	184.52	
DP1-2	98.143	0.286	98.429	TOP	0.722	97.707	185.89	
DP1-3	97.992	0.586	98.578	TOP	0.794	97.784	185.96	
DP2-1	97.630	0.283	97.913	TOP	1.542	96.371	184.55	
DP2-2	97.518	0.286	97.804	TOP	-0.065	97.869	186.05	Artesian
DP2-3	97.746	0.320	98.066	TOP	0.208	97.858	186.04	Artesian
DP3-1	97.913	0.307	98.220	TOP	0.366	97.854	186.03	Artesian
DP3-2	98.009	0.587	98.596	TOP	0.695	97.901	186.08	Artesian (weak signal)
DP3-3	98.051	0.333	98.384	TOP	0.535	97.849	186.03	Artesian
DP4-1	98.187	0.295	98.482	TOP	2.142	96.340	184.52	
DP4-2	98.794	0.280	99.074	TOP	1.319	97.755	185.94	
DP4-3	98.418	0.312	98.730	TOP	1.838	96.892	185.07	Water level is very low, could it be 0.838?
DP5-1	98.641	0.274	98.915	TOP	2.618	96.297	184.48	
DP5-2	98.782	0.468	99.250	TOP	1.281	97.969	186.15	
DP5-3	98.586	0.579	99.165	TOP	1.308	97.857	186.04	
DP6-1	98.819	0.295	99.114	TOP	2.798	96.316	184.50	
DP6-2	98.898		98.898	TOC	1.140	97.758	185.94	
DP6-3	98.952	0.060	99.012	TOP	1.241	97.771	185.95	new steel pipe and a new stickup
DP7-1	98.416	0.177	98.593	TOP	1.803	96.790	184.97	
DP7-2	98.388	0.425	98.813	TOP	1.059	97.754	185.93	
DP7-3	98.536	0.295	98.831	TOP	1.080	97.751	185.93	
DP8-1	98.371	0.432	98.803	TOP	1.826	96.977	185.16	
DP8-2	98.293	0.427	98.720	TOP	1.026	97.694	185.87	
DP8-3	98.497	0.312	98.809	TOP	1.118	97.691	185.87	
DP9-1	97.924	0.410	98.334	TOP	1.966	96.368	184.55	
DP9-2	98.075	0.450	98.525	TOP	0.934	97.591	185.77	
DP9-3	97.967	0.437	98.404	TOP	0.809	97.595	185.78	
DP10-S	98.626		98.626	TOC	1.394	97.232	185.41	

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Location	Top of Casing Elev (m)	Plastic stickup (m)	Elev. of meas. point (m)	Meas. point	Depth to water (m)	Elev. of water (m)	AMSL Elevation (m)	Comments
DP10-D	98.618	0.461	99.079	TOP	1.296	97.783	185.96	
DP11	100.001		100.001	TOC	1.843	98.158	186.34	Slow responder, measured later
DP12	99.907		99.907	TOC	1.784	98.123	186.30	
DP13	99.788		99.788	TOC	1.603	98.185	186.37	
DP14-S	98.659	0.067	98.726	TOP	2.249	96.477	184.66	
DP14-D	98.793	0.253	99.046	TOP	1.292	97.754	185.93	
DP15	98.657	0.592	99.249	TOP	1.126	98.123	186.30	Slow responder, measured later
DP16	101.563	0.063	101.626	TOP	3.185	98.441	186.62	
DP17-S	97.857	0.293	98.150	TOP	1.064	97.086	185.27	
DP17-D	98.082	0.566	98.648	TOP	0.690	97.958	186.14	Artesian
DP18	98.184	0.010	98.194	TOP	0.237	97.957	186.14	
DP19	98.653	0.056	98.709	TOP	0.718	97.991	186.17	
DP20	98.114	0.555	98.669	TOP	0.792	97.877	186.06	Artesian
SP1-S	96.929		96.929	NM	NM	NM	NM	
SP1-D	96.929		96.929	NM	NM	NM	NM	
SP2-S	96.314		96.314	NM	NM	NM	NM	
SP2-D	96.314		96.314	NM	NM	NM	NM	
SP3-S	96.938		96.938	NM	NM	NM	NM	
SP3-D	96.938		96.938	NM	NM	NM	NM	
SG-1	97.427		97.427	TSG	1.091	96.336	184.52	Pine River
SG-1A	97.641		97.641	TSG	1.303	96.338	184.52	Pine River
SG-2	96.957		96.957	TSG	0.547	96.410	184.59	Pine River
SG-3	97.591		97.591	NM	NM	NM	NM	Destroyed - unable to measure
SG-4	96.929		96.929	TSG	0.570	96.359	184.54	Pine River (SP1 loc.)
SG-5	96.314		96.314	TSG	0.013	96.301	184.48	Pine River (SP2 loc.), difficult to read, ±.01
SG-6	96.938		96.938	TSG	0.639	96.299	184.48	Pine River (SP3 loc.)

Location	Top of Casing Elev (m)	Plastic stickup (m)	Elev. of meas. point (m)	Meas. point	Depth to water (m)	Elev. of water (m)	AMSL Elevation (m)	Comments
P1	99.928		99.928	TOC	1.676	98.252	186.43	
P2	100.360		100.360	TOC	2.111	98.249	186.43	
AW1	99.076		99.076	TOC	1.386	97.690	185.87	did not air out, data loggers inside
AMW1	102.342		102.342	TOPVC	3.060	99.282	187.46	Measured by Guilbeault
AMW2	102.299		102.299	TOPVC	3.060	99.239	187.42	Measured by Guilbeault
AMW3	102.041		102.041	TOPVC	3.012	99.029	187.21	Measured by Guilbeault
AMW4	102.063		102.063	TOPVC	2.950	99.113	187.29	Measured by Guilbeault
APZ1	102.736		102.736	TOC	3.170	99.566	187.75	Measured by Guilbeault
APZ2	102.736		102.736	TOC	3.240	99.496	187.68	Measured by Guilbeault (TOP?)
APZ3	102.579		102.579	TOC	3.165	99.414	187.59	Measured by Guilbeault

Notes:

NM = Water levels not measured at this location
TOC = top of steel pipe coupling (steel casing P1 and P2)
TOP = top of plastic polyethylene tubing
TSG = top of staff gauge (steel pipe)
To convert Conant elevations to meters above mean sea level, add 88.18 m to Conant values
Revised elevation datums for SP-1 and SG-2, SG-5, SG-6
Use stickups measured in September, except for DP2-2 and DP2-3, and DP6-3 which is new

ANGUS WATER LEVELS DECEMBER 10, 1998

Location	Top of Casing Elev (m)	Plastic stickup (m)	Elev. meas. point (m)	Meas. point	Depth to water (m)	Elev. of water (m)	AMSL Elevation (m)	Comments
DP1-1	98.016	0.287	98.303	TOP	1.815	96.488	184.67	
DP1-2	98.143	0.286	98.429	TOP	0.552	97.877	186.06	Artesian
DP1-3	97.992	0.586	98.578	TOP	0.611	97.967	186.15	Artesian
DP2-1	97.630	0.283	97.913	TOP	1.371	96.542	184.72	
DP2-2	97.518	0.286	97.804	TOP	-0.282	98.086	186.27	Artesian
DP2-3	97.746	0.320	98.066	TOP	-0.026	98.092	186.27	Artesian
DP3-1	97.913	0.307	98.220	TOP	0.199	98.021	186.20	Artesian
DP3-2	98.009		98.009	TOC	-0.109	98.118	186.30	Artesian
DP3-3	98.051		98.051	TOC	-0.057	98.108	186.29	Artesian
DP4-1	98.187	0.295	98.482	TOP	1.980	96.502	184.68	
DP4-2	98.794	0.295	99.089	NM	NM	NM	NM	Vandalized completely bent over
DP4-3	98.418	0.312	98.730	TOP	0.692	98.038	186.22	
DP5-1	98.641	0.274	98.915	TOP	2.466	96.449	184.63	
DP5-2	98.782	0.468	99.250	TOP	1.176	98.074	186.25	
DP5-3	98.586	0.579	99.165	TOP	1.178	97.987	186.17	
DP6-1	98.819	0.295	99.114	TOP	2.641	96.473	184.65	
DP6-2	98.898		98.898	TOC	0.999	97.899	186.08	
DP6-3	98.952	0.060	99.012	TOP	1.107	97.905	186.09	
DP7-1	98.416	0.177	98.593	TOP	1.688	96.905	185.09	
DP7-2	98.388	0.425	98.813	TOP	0.874	97.939	186.12	
DP7-3	98.536	0.295	98.831	TOP	0.896	97.935	186.12	
DP8-1	98.371	0.432	98.803	TOP	1.699	97.104	185.28	
DP8-2	98.293	0.427	98.720	TOP	0.853	97.867	186.05	
DP8-3	98.497	0.312	98.809	TOP	0.940	97.869	186.05	
DP9-1	97.924	0.410	98.334	TOP	1.824	96.510	184.69	
DP9-2	98.075	0.450	98.525	TOP	0.782	97.743	185.92	
DP9-3	97.967	0.437	98.404	TOP	0.652	97.752	185.93	
DP10-S	98.626		98.626	TOC	1.100	97.526	185.71	

Location	Top of Casing Elev (m)	Plastic stickup (m)	Elev. meas. point (m)	Meas. point	Depth to water (m)	Elev. of water (m)	AMSL Elevation (m)	Comments
DP10-D	98.618	0.461	99.079	TOP	1.130	97.949	186.13	
DP11	100.001		100.001	TOC	1.682	98.319	186.50	Slow responder, measured later
DP12	99.907		99.907	TOC	1.592	98.315	186.50	
DP13	99.788		99.788	TOC	1.414	98.374	186.55	
DP14-S	98.659	0.067	98.726	TOP	2.111	96.615	184.80	
DP14-D	98.793	0.253	99.046	TOP	1.136	97.910	186.09	
DP15	98.657	0.592	99.249	TOP	1.046	98.203	186.38	Slow responder, measured later
DP16	101.563	0.063	101.626	TOP	3.011	98.615	186.80	
DP17-S	97.857	0.293	98.150	TOP	0.981	97.169	185.35	
DP17-D	98.082	0.566	98.648	TOP	0.509	98.139	186.32	Artesian
DP18	98.184	0.010	98.194	TOP	0.070	98.124	186.30	
DP19	98.653	0.056	98.709	TOP	0.531	98.178	186.36	Artesian
DP20	98.114	0.555	98.669	TOP	0.616	98.053	186.23	Artesian
SP1-S	96.929		96.929	NM	NM	NM	NM	
SP1-D	96.929		96.929	NM	NM	NM	NM	
SP2-S	96.314		96.314	NM	NM	NM	NM	
SP2-D	96.314		96.314	NM	NM	NM	NM	
SP3-S	96.938		96.938	NM	NM	NM	NM	
SP3-D	96.938		96.938	NM	NM	NM	NM	
SG-1	97.427		97.427	TSG	0.972	96.455	184.64	Pine River
SG-1A	97.641		97.641	TSG	1.193	96.448	184.63	Pine River
SG-2	96.957		96.957	TSG	0.425	96.532	184.71	Pine River
SG-3	97.591		97.591	NM	NM	NM	NM	Destroyed - unable to measure
SG-4	96.929		96.929	TSG	0.451	96.478	184.66	Pine River (SP1 loc.)
SG-5	96.314		96.314	NM	NM	NM	NM	Pine River (SP2 loc)
SG-6	96.938		96.938	TSG	0.513	96.425	184.61	Pine River (SP3 loc.)

Location	Top of Casing Elev (m)	Plastic stickup (m)	Elev. meas. point (m)	Meas. point	Depth to water (m)	Elev. of water (m)	AMSL Elevation (m)	Comments
P1	99.928		99.928	TOC	1.491	98.437	186.62	
P2	100.360		100.360	TOC	1.914	98.446	186.63	
AW1	99.076		99.076	TOC	1.213	97.863	186.04	
AMW1	102.342		102.342	TOPVC	2.906	99.436	187.62	
AMW2	102.299		102.299	TOPVC	2.892	99.407	187.59	
AMW3	102.041		102.041	TOPVC	2.835	99.206	187.39	
AMW4	102.063		102.063	TOPVC	2.851	99.212	187.39	
APZ1	102.736	0.000	102.736	TOP	2.994	99.742	187.92	
APZ2	102.736	0.026	102.762	TOP	2.980	99.782	187.96	
APZ3	102.579		102.579	NM	NM	NM	NM	

Notes:

NM = Water levels not measured at this location
TOC = top of steel pipe coupling (steel casing P1 and P2)
TOP = top of plastic polyethylene tubing
TSG = top of staff gauge (steel pipe)
To convert Conant elevations to meters above mean sea level, add 88.18 m to Conant values
Revised elevation datums for SP-1 and SG-2, SG-5,SG-6
Use stickups measured in September, except for DP2-2 and DP2-3, and DP6-3 which is new

ANGUS WATER LEVELS FEBRUARY 9, 1999

Location	Top of Casing Elev (m)	Plastic stickup (m)	Elev. meas. point (m)	Meas. point	Depth to water (m)	Elev of water (m)	AMSL Elevation (m)	Comments
DP1-1	98.016	0.287	98.303	TOP	1.833	96.470	184.65	
DP1-2	98.143	0.286	98.429	TOP	NM	NM	NM	ice at 58 cm
DP1-3	97.992	0.586	98.578	TOP	0.562	98.016	186.20	ice at 76 cm melted with torch
DP2-1	97.630	0.283	97.913	TOP	1.382	96.531	184.71	
DP2-2	97.518		97.518	TOC	-0.570	98.088	186.27	Artesian (raw reading was reversed with DP2-3)
DP2-3	97.746		97.746	TOC	-0.353	98.099	186.28	Artesian (raw reading was reversed with DP2-2)
DP3-1	97.913		97.913	TOC	-0.152	98.065	186.25	Artesian
DP3-2	98.009		98.009	TOC	-0.131	98.140	186.32	Artesian, ice in well
DP3-3	98.051		98.051	TOC	-0.074	98.125	186.31	Artesian
DP4-1	98.187	0.295	98.482	TOP	2.000	96.482	184.66	Vandalized, very bent casing
DP4-2	98.794	0.295	99.089	NM	NM	NM	NM	Vandalized completely bent over
DP4-3	98.418	0.312	98.730	NM	NM	NM	NM	Can't get probe past bend in pipe
DP5-1	98.641	0.274	98.915	TOP	2.493	96.422	184.60	
DP5-2	98.782	0.468	99.250	NM	NM	NM	NM	Ice, can't push or melt
DP5-3	98.586	0.579	99.165	TOP	1.115	98.050	186.23	Ice in well
DP6-1	98.819	0.295	99.114	TOP	2.665	96.449	184.63	
DP6-2	98.898		98.898	TOC	0.971	97.927	186.11	
DP6-3	98.952	0.060	99.012	TOP	1.107	97.905	186.09	
DP7-1	98.416	0.177	98.593	TOP	1.667	96.926	185.11	
DP7-2	98.388	0.425	98.813	TOP	0.839	97.974	186.15	
DP7-3	98.536	0.295	98.831	TOP	0.856	97.975	186.16	Ice in well
DP8-1	98.371	0.432	98.803	TOP	1.730	97.073	185.25	
DP8-2	98.293	0.427	98.720	TOP	0.835	97.885	186.07	Ice in well, water level seems too low
DP8-3	98.497	0.312	98.809	TOP	0.895	97.914	186.09	
DP9-1	97.924	0.410	98.334	TOP	1.858	96.476	184.66	
DP9-2	98.075	0.450	98.525	TOP	0.729	97.796	185.98	Ice in well
DP9-3	97.967	0.437	98.404	TOP	0.608	97.796	185.98	
DP10-S	98.626		98.626	TOC	0.902	97.724	185.90	Seems higher than river stage

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Location	Top of Casing Elev (m)	Plastic stickup (m)	Elev. meas. point (m)	Meas. point	Depth to water (m)	Elev of water (m)	AMSL Elevation (m)	Comments
DP10-D	98.618	0.461	99.079	TOP	1.085	97.994	186.17	
DP11	100.001		100.001	TOC	1.539	98.462	186.64	Slow responder, didn't equilibrate! Elevation is lower
DP12	99.907		99.907	TOC	1.590	98.317	186.50	Ponded water around top of piezometer
DP13	99.788		99.788	TOC	1.409	98.379	186.56	
DP14-S	98.659	0.067	98.726	TOP	2.141	96.585	184.77	Seems a bit deep
DP14-D	98.793	0.253	99.046	TOP	1.112	97.934	186.11	
DP15	98.657	0.592	99.249	TOP	1.057	98.192	186.37	Slow responder, measured later
DP16	101.563	0.063	101.626	TOP	2.987	98.639	186.82	
DP17-S	97.857	0.293	98.150	TOP	0.974	97.176	185.36	
DP17-D	98.082		98.082	TOC	-0.059	98.141	186.32	Artesian
DP18	98.184	0.010	98.194	TOP	0.055	98.139	186.32	
DP19	98.653	0.056	98.709	TOP	0.522	98.187	186.37	Artesian
DP20	98.114	0.555	98.669	TOP	0.603	98.066	186.25	Artesian
SP1-S	96.929		96.929	NM	NM	NM	NM	
SP1-D	96.929		96.929	NM	NM	NM	NM	
SP2-S	96.314		96.314	NM	NM	NM	NM	
SP2-D	96.314		96.314	NM	NM	NM	NM	
SP3-S	96.938		96.938	NM	NM	NM	NM	
SP3-D	96.938		96.938	NM	NM	NM	NM	
SG-1	97.427		97.427	TSG	0.987	96.440	184.62	Pine River
SG-1A	97.641		97.641	TSG	1.202	96.439	184.62	Pine River, hard to read
SG-2	96.957		96.957	NM	NM	NM	NM	Pine River
SG-3	97.591		97.591	NM	NM	NM	NM	Destroyed - unable to measure
SG-4	96.929		96.929	NM	NM	NM	NM	Pine River (SP1 loc.)
SG-5	96.314		96.314	NM	NM	NM	NM	Pine River (SP2 loc.)
SG-6	96.938		96.938	NM	NM	NM	NM	Pine River (SP3 loc.)
P1	99.928	0.002	99.930	TOP	1.475	98.455	186.64	Ponded water around top of piezometer
P2	100.360		100.360	TOC	1.901	98.459	186.64	
AW1	99.076		99.076	TOC	1.177	97.899	186.08	

Location	Top of Casing Elev (m)	Plastic stickup (m)	Elev. meas. point (m)	Meas. point	Depth to water (m)	Elev of water (m)	AMSL Elevation (m)	Comments
AMW1	102.342		102.342	NM	NM	NM	NM	
AMW2	102.299		102.299	NM	NM	NM	NM	
AMW3	102.041		102.041	NM	NM	NM	NM	
AMW4	102.063		102.063	NM	NM	NM	NM	
APZ1	102.736	0.000	102.736	NM	NM	NM	NM	
APZ2	102.736	0.026	102.762	NM	NM	NM	NM	
APZ3	102.579		102.579	NM	NM	NM	NM	

Notes:

NM = Water levels not measured at this location
TOC = top of steel pipe coupling (steel casing P1 and P2)
TOP = top of plastic polyethylene tubing
TSG = top of staff gauge (steel pipe)
To convert Conant elevations to meters above mean sea level, add 88.18 m to Conant values
Revised elevation datums for SP-1 and SG-2, SG-5, SG-6
Use stickups measured in September, except for DP6-3 which is new

ANGUS WATER LEVELS APRIL 5, 1999

Location	Top of Casing Elev (m)	Plastic stickup (m)	Elev. meas. point (m)	Meas. point	Depth to water (m)	Elev. of water (m)	AMSL Elevation (m)	Comments
DP1-1	98.016	0.281	98.297	TOP	1.621	96.676	184.86	
DP1-2	98.143	0.280	98.423	TOP	0.419	98.004	186.18	Artesian? Hard to read
DP1-3	97.992		97.992	TOC	-0.081	98.073	186.25	Artesian. Hard to read
DP2-1	97.630	0.277	97.907	TOP	1.181	96.726	184.91	
DP2-2	97.518		97.518	TOC	-0.627	98.145	186.33	Artesian
DP2-3	97.746		97.746	TOC	-0.392	98.138	186.32	Artesian
DP3-1	97.913		97.913	TOC	-0.226	98.139	186.32	Artesian
DP3-2	98.009		98.009	TOC	-0.185	98.194	186.37	Artesian
DP3-3	98.051		98.051	TOC	-0.135	98.186	186.37	Artesian
DP4-1	98.187	0.293	98.480	TOP	1.816	96.664	184.84	Bent casing
DP4-2	98.794	0.273	99.067	TOP	1.072	97.995	186.18	Bent casing
DP4-3	98.418	0.312	98.730	TOP	0.617	98.113	186.29	Almost artesian
DP5-1	98.641	0.265	98.906	TOP	2.291	96.615	184.80	
DP5-2	98.782	0.455	99.237	TOP	0.984	98.253	186.43	hard to read
DP5-3	98.586	0.566	99.152	TOP	1.059	98.093	186.27	
DP6-1	98.819	0.284	99.103	TOP	2.462	96.641	184.82	
DP6-2	98.898		98.898	TOC	0.885	98.013	186.19	
DP6-3	98.952	0.060	99.012	TOP	0.988	98.024	186.20	
DP7-1	98.416	0.169	98.585	TOP	1.560	97.025	185.21	
DP7-2	98.388	0.419	98.807	TOP	0.758	98.049	186.23	
DP7-3	98.536	0.290	98.826	TOP	0.781	98.045	186.23	
DP8-1	98.371	0.425	98.796	TOP	1.647	97.149	185.33	
DP8-2	98.293	0.425	98.718	TOP	0.721	97.997	186.18	hard to read
DP8-3	98.497	0.307	98.804	TOP	0.810	97.994	186.17	
DP9-1	97.924	0.403	98.327	TOP	1.666	96.661	184.84	
DP9-2	98.075	0.444	98.519	TOP	0.619	97.900	186.08	
DP9-3	97.967	0.430	98.397	TOP	0.486	97.911	186.09	
DP10-S	98.626		98.626	TOC	0.665	97.961	186.14	

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Location	Top of Casing Elev (m)	Plastic stickup (m)	Elev. meas. point (m)	Meas. point	Depth to water (m)	Elev. of water (m)	AMSL Elevation (m)	Comments
DP10-D	98.618	0.453	99.071	TOP	0.987	98.084	186.26	
DP11	100.001		100.001	TOC	1.498	98.503	186.68	Slow responder, measured later, (could be 10 cm off)
DP12	99.907		99.907	TOC	1.495	98.412	186.59	
DP13	99.788		99.788	TOC	1.323	98.465	186.65	
DP14-S	98.659	0.060	98.719	TOP	1.960	96.759	184.94	
DP14-D	98.793	0.245	99.038	TOP	1.000	98.038	186.22	
DP15	98.657	0.585	99.242	TOP	0.875	98.367	186.55	Slow responder, measured later
DP16	101.563	0.056	101.619	TOP	2.884	98.735	186.92	
DP17-S	97.857	0.287	98.144	TOP	0.850	97.294	185.47	
DP17-D	98.082		98.082	TOC	-0.170	98.252	186.43	Artesian
DP18	98.184		98.184	TOC	-0.067	98.251	186.43	Artesian
DP19	98.653	0.053	98.706	TOP	0.413	98.293	186.47	Artesian, hard to read
DP20	98.114		98.114	TOC	-0.042	98.156	186.34	Artesian, hard to read
SP1-S	96.929		96.929	NM	NM	NM	NM	
SP1-D	96.929		96.929	NM	NM	NM	NM	
SP2-S	96.314		96.314	NM	NM	NM	NM	
SP2-D	96.314		96.314	NM	NM	NM	NM	
SP3-S	96.938		96.938	NM	NM	NM	NM	
SP3-D	96.938		96.938	NM	NM	NM	NM	
SG-1	97.427		97.427	TSG	0.782	96.645	184.83	Pine River
SG-1A	97.641		97.641	NM	NM	NM	NM	Pine River
SG-2	96.957		96.957	NM	NM	NM	NM	Pine River
SG-3	97.591		97.591	NM	NM	NM	NM	Destroyed - unable to measure
SG-4	96.929		96.929	NM	NM	NM	NM	Pine River (SP1 loc.)
SG-5	96.314		96.314	NM	NM	NM	NM	Pine River (SP2 loc.)
SG-6	96.938		96.938	NM	NM	NM	NM	Pine River (SP3 loc.)

Location	Top of Casing Elev (m)	Plastic stickup (m)	Elev. meas. point (m)	Meas. point	Depth to water (m)	Elev. of water (m)	AMSL Elevation (m)	Comments
P1	99.928		99.928	TOC	1.383	98.545	186.73	
P2	100.360		100.360	TOC	1.810	98.550	186.73	hard to read
AW1	99.076		99.076	TOC	1.056	98.020	186.20	
AMW1	102.342		102.342	TOPVC	2.825	99.517	187.70	
AMW2	102.299		102.299	TOPVC	2.823	99.476	187.66	
AMW3	102.041		102.041	TOPVC	2.732	99.309	187.49	
AMW4	102.063		102.063	TOPVC	2.753	99.310	187.49	
APZ1	102.736		102.736	TOC	2.939	99.797	187.98	
APZ2	102.736	0.025	102.761	TOP	3.000	99.761	187.94	hard to read
APZ3	102.579		102.579	TOC	2.914	99.665	187.85	

Notes:

NM = Water levels not measured at this location
TOC = top of steel pipe coupling (steel casing P1 and P2)
TOP = top of plastic polyethylene tubing
TSG = top of staff gauge (steel pipe)
To convert Conant elevations to meters above mean sea level, add 88.18 m to Conant values
Revised elevation datums for SP-1 and SG-2, SG-5, SG-6
Use stickups measured on this day
*** Water level meter had frayed wire making all wells hard to read ***

ANGUS WATER LEVELS MAY 5, 1999

Location	Top of Casing Elev (m)	Plastic stickup (m)	Elev. meas. point (m)	Meas. point	Depth to water (m)	Elev. of water (m)	AMSL Elevation (m)	Comments
DP1-1	98.016	0.285	98.301	TOP	1.959	96.342	184.52	
DP1-2	98.143	0.284	98.427	TOP	0.601	97.826	186.01	Barely artesian
DP1-3	97.992	0.586	98.578	TOP	0.657	97.921	186.10	Artesian
DP2-1	97.630	0.280	97.910	TOP	1.511	96.399	184.58	
DP2-2	97.518		97.518	TOC	-0.474	97.992	186.17	Artesian
DP2-3	97.746		97.746	TOC	-0.255	98.001	186.18	Artesian
DP3-1	97.913		97.913	TOC	-0.042	97.955	186.14	Artesian
DP3-2	98.009		98.009	TOC	-0.028	98.037	186.22	Artesian
DP3-3	98.051	0.332	98.383	TOP	0.354	98.029	186.21	Artesian
DP4-1	98.187	0.051	98.238	TOP	1.880	96.358	184.54	Bent casing
DP4-2	98.794	0.050	98.844	TOP	0.985	97.859	186.04	Bent casing, bent back up
DP4-3	98.418	0.052	98.470	TOP	0.462	98.008	186.19	Bent casing
DP5-1	98.641	0.272	98.913	TOP	2.615	96.298	184.48	
DP5-2	98.782	0.463	99.245	TOP	1.085	98.160	186.34	
DP5-3	98.586	0.575	99.161	TOP	1.195	97.966	186.15	
DP6-1	98.819	0.285	99.104	TOP	2.781	96.323	184.50	
DP6-2	98.898		98.898	TOC	1.020	97.878	186.06	
DP6-3	98.952	0.064	99.016	TOP	1.102	97.914	186.09	
DP7-1	98.416	0.173	98.589	TOP	1.741	96.848	185.03	
DP7-2	98.388	0.422	98.810	TOP	0.944	97.866	186.05	
DP7-3	98.536	0.293	98.829	TOP	0.962	97.867	186.05	
DP8-1	98.371	0.429	98.800	TOP	1.776	97.024	185.20	
DP8-2	98.293	0.429	98.722	TOP	0.918	97.804	185.98	
DP8-3	98.497	0.310	98.807	TOP	1.003	97.804	185.98	
DP9-1	97.924	0.405	98.329	TOP	1.977	96.352	184.53	
DP9-2	98.075	0.446	98.521	TOP	0.825	97.696	185.88	
DP9-3	97.967	0.433	98.400	TOP	0.700	97.700	185.88	
DP10-S	98.626		98.626	TOC	0.887	97.739	185.92	

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Location	Top of Casing Elev (m)	Plastic stickup (m)	Elev. meas. point (m)	Meas. point	Depth to water (m)	Elev. of water (m)	AMSL Elevation (m)	Comments
DP10-D	98.618	0.459	99.077	TOP	1.185	97.892	186.07	
DP11	100.001		100.001	TOC	1.670	98.331	186.51	Slow responder, measured later
DP12	99.907		99.907	TOC	1.667	98.240	186.42	
DP13	99.788		99.788	TOC	1.496	98.292	186.47	
DP14-S	98.659	0.062	98.721	TOP	2.270	96.451	184.63	
DP14-D	98.793	0.250	99.043	TOP	1.180	97.863	186.04	
DP15	98.657	0.585	99.242	TOP	0.985	98.257	186.44	Slow responder, measured later
DP16	101.563	0.059	101.622	TOP	3.050	98.572	186.75	
DP17-S	97.857	0.289	98.146	TOP	0.917	97.229	185.41	
DP17-D	98.082	0.564	98.646	TOP	0.584	98.062	186.24	
DP18	98.184	0.002	98.186	TOP	0.083	98.103	186.28	
DP19	98.653	0.055	98.708	TOP	0.575	98.133	186.31	
DP20	98.114	0.550	98.664	TOP	0.667	97.997	186.18	Barely artesian
SP1-S	96.929		96.929	NM	NM	NM	NM	
SP1-D	96.929		96.929	NM	NM	NM	NM	
SP2-S	96.314		96.314	NM	NM	NM	NM	
SP2-D	96.314		96.314	NM	NM	NM	NM	
SP3-S	96.892		96.892	NM	NM	NM	NM	
SP3-D	96.892		96.892	NM	NM	NM	NM	
SG-1	97.427		97.427	TSG	1.096	96.331	184.51	Pine River
SG-1A	97.641		97.641	TSG	1.307	96.334	184.51	Pine River
SG-2	96.835		96.835	TSG	0.522	96.313	184.49	Pine River
SG-3	97.591		97.591	NM	NM	NM	NM	Destroyed - unable to measure
SG-4	96.876		96.876	TSG	0.582	96.294	184.47	Pine River (SP1 loc.)
SG-5	96.314		96.314	TSG	-0.040	96.354	184.53	Pine River (SP2 loc.)
SG-6	96.892		96.892	TSG	0.597	96.295	184.48	Pine River (SP3 loc.)

Location	Top of Casing Elev (m)	Plastic stickup (m)	Elev. meas. point (m)	Meas. point	Depth to water (m)	Elev. of water (m)	AMSL Elevation (m)	Comments
P1	99.928	0.003	99.931	TOP	1.552	98.379	186.56	
P2	100.360		100.360	TOC	1.978	98.382	186.56	
AW1	99.076		99.076	TOC	1.269	97.807	185.99	
AMW1	102.342		102.342	TOPVC	2.940	99.402	187.58	
AMW2	102.299		102.299	TOPVC	2.930	99.369	187.55	
AMW3	102.041		102.041	TOPVC	2.870	99.171	187.35	
AMW4	102.063		102.063	TOPVC	2.885	99.178	187.36	
APZ1	102.736		102.736	TOC	3.052	99.684	187.86	
APZ2	102.736	0.027	102.763	TOP	3.142	99.621	187.80	
APZ3	102.579	0.007	102.586	TOP	3.032	99.554	187.73	

Notes:

NM = Water levels not measured at this location
TOC = top of steel pipe coupling (steel casing P1 and P2)
TOP = top of plastic polyethylene tubing
TSG = top of staff gauge (steel pipe)
To convert Conant elevations to meters above mean sea level, add 88.18 m to Conant values
Revised elevation datums for SP-1 and May 1998 survey data for SG-2,4,5 and 6
Use stickups measured on this day

ANGUS WATER LEVELS JUNE 10, 1999

Location	Top of Casing Elev (m)	Plastic stickup (m)	Elev. of meas. point (m)	Meas. point	Depth to water (m)	Elev. of water (m)	AMSL Elevation (m)	Comments
DP1-1	98.016	0.286	98.302	TOP	2.016	96.286	184.47	
DP1-2	98.143	0.285	98.428	TOP	0.665	97.763	185.94	
DP1-3	97.992	0.588	98.580	TOP	0.734	97.846	186.03	Artesian
DP2-1	97.630	0.282	97.912	TOP	1.610	96.302	184.48	
DP2-2	97.518		97.518	TOC	-0.440	97.958	186.14	Artesian
DP2-3	97.746		97.746	TOC	-0.181	97.927	186.11	Artesian
DP3-1	97.913	0.304	98.217	TOP	0.335	97.882	186.06	
DP3-2	98.009	0.589	98.598	TOP	0.633	97.965	186.15	
DP3-3	98.051	0.334	98.385	TOP	0.422	97.963	186.14	
DP4-1	98.184	0.052	98.236	TOP	1.922	96.314	184.49	Not bent or vandalized since May survey
DP4-2	98.807	0.050	98.857	TOP	1.075	97.782	185.96	Not bent or vandalized since May survey
DP4-3	98.417	0.054	98.471	TOP	0.548	97.923	186.10	Not bent or vandalized since May survey
DP5-1	98.641	0.275	98.916	TOP	2.635	96.281	184.46	
DP5-2	98.782	0.466	99.248	TOP	1.142	98.106	186.29	
DP5-3	98.586	0.579	99.165	TOP	1.289	97.876	186.06	
DP6-1	98.819	0.292	99.111	TOP	2.810	96.301	184.48	
DP6-2	98.898		98.898	TOC	1.120	97.778	185.96	
DP6-3	98.952	0.068	99.020	TOP	1.217	97.803	185.98	
DP7-1	98.416	0.173	98.589	TOP	1.898	96.691	184.87	
DP7-2	98.388	0.422	98.810	TOP	1.007	97.803	185.98	
DP7-3	98.536	0.293	98.829	TOP	1.028	97.801	185.98	
DP8-1	98.371	0.432	98.803	TOP	1.951	96.852	185.03	
DP8-2	98.293	0.428	98.721	TOP	0.972	97.749	185.93	
DP8-3	98.497	0.312	98.809	TOP	1.062	97.747	185.93	
DP9-1	97.924	0.409	98.333	TOP	2.005	96.328	184.51	
DP9-2	98.075	0.449	98.524	TOP	0.895	97.629	185.81	
DP9-3	97.967	0.436	98.403	TOP	0.768	97.635	185.82	
DP10-S	98.626		98.626	TOC	0.915	97.711	185.89	Seems high relative to river

Location	Top of Casing Elev (m)	Plastic stickup (m)	Elev. of meas. point (m)	Meas. point	Depth to water (m)	Elev. of water (m)	AMSL Elevation (m)	Comments
DP10-D	98.618	0.460	99.078	TOP	1.248	97.830	186.01	
DP11	100.001		100.001	TOC	1.655	98.346	186.53	Slow responder, measured later
DP12	99.907		99.907	TOC	1.726	98.181	186.36	
DP13	99.788		99.788	TOC	1.558	98.230	186.41	
DP14-S	98.659	0.066	98.725	TOP	2.300	96.425	184.61	
DP14-D	98.793	0.252	99.045	TOP	1.262	97.783	185.96	
DP15	98.657	0.585	99.242	TOP	0.951	98.291	186.47	Slow responder, measured later
DP16	101.563	0.063	101.626	TOP	3.116	98.510	186.69	
DP17-S	97.857	0.291	98.148	TOP	0.915	97.233	185.41	Seems high
DP17-D	98.082	0.568	98.650	TOP	0.646	98.004	186.18	Artesian
DP18	98.184	0.005	98.189	TOP	0.201	97.988	186.17	
DP19	98.653	0.057	98.710	TOP	0.671	98.039	186.22	
DP20	98.114	0.556	98.670	TOP	0.743	97.927	186.11	
SP1-S	96.929		96.929	NM	NM	NM	NM	
SP1-D	96.929		96.929	NM	NM	NM	NM	
SP2-S	96.314		96.314	NM	NM	NM	NM	
SP2-D	96.314		96.314	NM	NM	NM	NM	
SP3-S	96.892		96.892	NM	NM	NM	NM	
SP3-D	96.892		96.892	NM	NM	NM	NM	
SG-1	97.427		97.427	TSG	1.112	96.315	184.50	Pine River
SG-1A	97.641		97.641	TSG	1.323	96.318	184.50	Pine River
SG-2	96.835		96.835	TSG	0.532	96.303	184.48	Pine River
SG-3	97.591		97.591	NM	NM	NM	NM	Destroyed - unable to measure
SG-4	96.876		96.876	TSG	0.593	96.283	184.46	Pine River (SP1 loc.)
SG-5	96.314		96.314	TSG	-0.027	96.341	184.52	Pine River (SP2 loc.)
SG-6	96.892		96.892	TSG	0.603	96.289	184.47	Pine River (SP3 loc.)
P1	99.928	0.006	99.934	TOP	1.609	98.325	186.51	
P2	100.360	0.003	100.363	TOP	2.033	98.330	186.51	
AW1	99.076		99.076	TOC	1.317	97.759	185.94	

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Location	Top of Casing Elev (m)	Plastic stickup (m)	Elev. of meas. point (m)	Meas. point	Depth to water (m)	Elev. of water (m)	AMSL Elevation (m)	Comments
AMW1	102.342		102.342	TOPVC	2.975	99.367	187.55	
AMW2	102.299		102.299	TOPVC	2.971	99.328	187.51	
AMW3	102.041		102.041	TOPVC	2.901	99.140	187.32	
AMW4	102.063		102.063	TOPVC	2.928	99.135	187.32	
AMW5	101.968		101.968	TOPVC	2.886	99.082	187.26	New well 10 m west of AMW1
APZ1	102.736		102.736	TOC	3.085	99.651	187.83	
APZ2	102.736	0.026	102.762	TOP	3.146	99.616	187.80	
APZ3	102.579	0.011	102.590	TOP	3.045	99.545	187.73	

Notes:

NM = Water levels not measured at this location
TOC = top of steel pipe coupling (steel casing P1 and P2)
TOP = top of plastic polyethylene tubing
TSG = top of staff gauge (steel pipe)
To convert Conant elevations to meters above mean sea level, add 88.18 m to Conant values
Revised elevation datums for SP-1 and May 1998 survey of SG-2,4,5 and 6, and May 1999 for DP4 set
Use stickups measured on this day except for DP7 set and DP15 which used May measurements

ANGUS WATER LEVELS JULY 19, 1999

Location	Top of Casing Elev (m)	Plastic stickup (m)	Elev. meas. point (m)	Meas. point	Depth to water (m)	Elev. of water (m)	AMSL Elevation (m)	Comments
DP1-1	98.016	0.287	98.303	TOP	2.088	96.215	184.40	
DP1-2	98.143	0.287	98.430	TOP	0.734	97.696	185.88	
DP1-3	97.992	0.587	98.579	TOP	0.793	97.786	185.97	
DP2-1	97.630	0.282	97.912	TOP	1.680	96.232	184.41	
DP2-2	97.518		97.518	TOC	-0.349	97.867	186.05	Artesian
DP2-3	97.746		97.746	TOC	-0.123	97.869	186.05	Artesian
DP3-1	97.913	0.303	98.216	TOP	0.350	97.866	186.05	
DP3-2	98.009	0.589	98.598	TOP	0.680	97.918	186.10	
DP3-3	98.051	0.334	98.385	TOP	0.463	97.922	186.10	
DP4-1	98.184	0.054	98.238	TOP	2.019	96.219	184.40	Not bent or vandalized since May survey
DP4-2	98.807	0.050	98.857	TOP	1.130	97.727	185.91	Not bent or vandalized since May survey
DP4-3	98.417	0.055	98.472	TOP	0.596	97.876	186.06	Not bent or vandalized since May survey
DP5-1	98.641	0.275	98.916	TOP	2.720	96.196	184.38	
DP5-2	98.782	0.466	99.248	TOP	1.413	97.835	186.02	
DP5-3	98.586	0.578	99.164	TOP	1.336	97.828	186.01	
DP6-1	98.819	0.291	99.110	TOP	2.896	96.214	184.39	
DP6-2	98.898		98.898	TOC	1.162	97.736	185.92	
DP6-3	98.952	0.070	99.022	TOP	1.274	97.748	185.93	
DP7-1	98.416	0.175	98.591	TOP	1.953	96.638	184.82	
DP7-2	98.388	0.427	98.815	TOP	1.062	97.753	185.93	
DP7-3	98.536	0.295	98.831	TOP	1.082	97.749	185.93	
DP8-1	98.371	0.432	98.803	TOP	1.903	96.900	185.08	
DP8-2	98.293	0.428	98.721	TOP	1.017	97.704	185.88	
DP8-3	98.497	0.312	98.809	TOP	1.111	97.698	185.88	
DP9-1	97.924	0.408	98.332	TOP	2.073	96.259	184.44	
DP9-2	98.075	0.448	98.523	TOP	0.924	97.599	185.78	
DP9-3	97.967	0.437	98.404	TOP	0.795	97.609	185.79	
DP10-S	98.626		98.626	TOC	1.068	97.558	185.74	

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Location	Top of Casing Elev (m)	Plastic stickup (m)	Elev. meas. point (m)	Meas. point	Depth to water (m)	Elev. of water (m)	AMSL Elevation (m)	Comments
DP10-D	98.618	0.460	99.078	TOP	1.297	97.781	185.96	
DP11	100.001		100.001	TOC	1.532	98.469	186.65	Slow responder, measured later
DP12	99.907		99.907	TOC	1.754	98.153	186.33	
DP13	99.788		99.788	TOC	1.574	98.214	186.39	
DP14-S	98.659	0.065	98.724	TOP	2.371	96.353	184.53	
DP14-D	98.793	0.252	99.045	TOP	1.291	97.754	185.93	
DP15	98.657	0.595	99.252	TOP	0.898	98.354	186.53	Slow responder, measured later
DP16	101.563	0.062	101.625	TOP	3.122	98.503	186.68	
DP17-S	97.857	0.291	98.148	TOP	1.166	96.982	185.16	
DP17-D	98.082	0.567	98.649	TOP	0.681	97.968	186.15	Artesian
DP18	98.184	0.007	98.191	TOP	0.225	97.966	186.15	
DP19	98.653	0.055	98.708	TOP	0.708	98.000	186.18	
DP20	98.114	0.557	98.671	TOP	0.786	97.885	186.07	
SP1-S	96.929		96.929	NM	NM	NM	NM	
SP1-D	96.929		96.929	NM	NM	NM	NM	
SP2-S	96.314		96.314	NM	NM	NM	NM	
SP2-D	96.314		96.314	NM	NM	NM	NM	
SP3-S	96.892		96.892	NM	NM	NM	NM	
SP3-D	96.892		96.892	NM	NM	NM	NM	
SG-1	97.427		97.427	TSG	1.186	96.241	184.42	Pine River
SG-1A	97.641		97.641	TSG	1.396	96.245	184.43	Pine River
SG-2	96.835		96.835	TSG	0.610	96.225	184.41	Pine River
SG-3	97.591		97.591	NM	NM	NM	NM	Destroyed - unable to measure
SG-4	96.876		96.876	TSG	0.678	96.198	184.38	Pine River (SP1 loc.)
SG-5	96.314		96.314	TSG	0.058	96.256	184.44	Pine River (SP2 loc.) (5.1 cm upstream/ 6.5 down)
SG-6	96.892		96.892	TSG	0.694	96.198	184.38	Pine River (SP3 loc.)
P1	99.928	0.009	99.937	TOP	1.637	98.300	186.48	
P2	100.360	0.005	100.365	TOP	2.062	98.303	186.48	
AW1	99.076		99.076	TOC	1.382	97.694	185.87	

WL 7/19/99
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Location	Top of Casing Elev (m)	Plastic stickup (m)	Elev. meas. point (m)	Meas. point	Depth to water (m)	Elev. of water (m)	AMSL Elevation (m)	Comments
AMW1	102.342		102.342	TOPVC	2.971	99.371	187.55	
AMW2	102.299		102.299	TOPVC	2.961	99.338	187.52	
AMW3	102.041		102.041	TOPVC	2.905	99.136	187.32	
AMW4	102.063		102.063	TOPVC	2.923	99.140	187.32	
AMW5	101.968		101.968	TOPVC	2.879	99.089	187.27	New well 10 m west of AMW1
APZ1	102.736		102.736	TOC	3.065	99.671	187.85	
APZ2	102.736	0.027	102.763	TOP	3.163	99.600	187.78	
APZ3	102.579	0.011	102.590	TOP	3.048	99.542	187.72	

Notes:

NM = Water levels not measured at this location
TOC = top of steel pipe coupling (steel casing P1 and P2)
TOP = top of plastic polyethylene tubing
TSG = top of staff gauge (steel pipe)
To convert Conant elevations to meters above mean sea level, add 88.18 m to Conant values
Revised elevation datums for SP-1 and May 1998 survey of SG-2,4,5 and 6, and May 1999 for DP4 set
Use stickups measured on this day except for DP7 set and DP15 which used May measurements

ANGUS WATER LEVELS AUGUST 16, 1999

Location	Top of Casing Elev (m)	Plastic stickup (m)	Elev. meas. point (m)	Meas. point	Depth to water (m)	Elev. of water (m)	AMSL Elevation (m)	Comments
DP1-1	98.016	0.286	98.302	TOP	2.079	96.223	184.40	
DP1-2	98.143	0.288	98.431	TOP	0.722	97.709	185.89	
DP1-3	97.992	0.588	98.580	TOP	0.782	97.798	185.98	
DP2-1	97.630	0.282	97.912	TOP	1.693	96.219	184.40	
DP2-2	97.518		97.518	TOC	-0.350	97.868	186.05	Artesian
DP2-3	97.746		97.746	TOC	-0.138	97.884	186.06	Artesian
DP3-1	97.913	0.304	98.217	TOP	0.387	97.830	186.01	
DP3-2	98.009	0.589	98.598	TOP	0.682	97.916	186.10	
DP3-3	98.051	0.335	98.386	TOP	0.478	97.908	186.09	
DP4-1	98.184	0.054	98.238	TOP	2.004	96.234	184.41	Not bent or vandalized since May survey
DP4-2	98.807	0.051	98.858	TOP	1.116	97.742	185.92	Not bent or vandalized since May survey
DP4-3	98.417	0.055	98.472	TOP	0.595	97.877	186.06	Not bent or vandalized since May survey
DP5-1	98.641	0.275	98.916	TOP	2.702	96.214	184.39	
DP5-2	98.782	0.466	99.248	TOP	1.464	97.784	185.96	?
DP5-3	98.586	0.579	99.165	TOP	1.319	97.846	186.03	?
DP6-1	98.819	0.293	99.112	TOP	2.873	96.239	184.42	
DP6-2	98.898		98.898	TOC	1.147	97.751	185.93	
DP6-3	98.952	0.071	99.023	TOP	1.254	97.769	185.95	
DP7-1	98.416	0.175	98.591	TOP	1.995	96.596	184.78	
DP7-2	98.388	0.426	98.814	TOP	1.063	97.751	185.93	
DP7-3	98.536	0.296	98.832	TOP	1.078	97.754	185.93	
DP8-1	98.371	0.431	98.802	TOP	2.016	96.786	184.97	
DP8-2	98.293	0.428	98.721	TOP	1.023	97.698	185.88	
DP8-3	98.497	0.312	98.809	TOP	1.115	97.694	185.87	
DP9-1	97.924	0.408	98.332	TOP	2.061	96.271	184.45	
DP9-2	98.075	0.449	98.524	TOP	0.932	97.592	185.77	
DP9-3	97.967	0.435	98.402	TOP	0.806	97.596	185.78	
DP10-S	98.626		98.626	TOC	1.064	97.562	185.74	

Location	Top of Casing Elev (m)	Plastic stickup (m)	Elev. meas. point (m)	Meas. point	Depth to water (m)	Elev. of water (m)	AMSL Elevation (m)	Comments
DP10-D	98.618	0.461	99.079	TOP	1.302	97.777	185.96	
DP11	100.001		100.001	TOC	1.474	98.527	186.71	Slow responder, measured later
DP12	99.907		99.907	TOC	1.785	98.122	186.30	
DP13	99.788		99.788	TOC	1.615	98.173	186.35	
DP14-S	98.659	0.065	98.724	TOP	2.355	96.369	184.55	
DP14-D	98.793	0.254	99.047	TOP	1.307	97.740	185.92	
DP15	98.657		98.657	TOC	-0.016	98.673	186.85	Artesian! Slow responder, measured later
DP16	101.563	0.062	101.625	TOP	3.182	98.443	186.62	
DP17-S	97.857	0.292	98.149	TOP	1.115	97.034	185.21	Seems high
DP17-D	98.082	0.569	98.651	TOP	0.711	97.940	186.12	Artesian
DP18	98.184	0.007	98.191	TOP	0.243	97.948	186.13	
DP19	98.653	0.055	98.708	TOP	0.736	97.972	186.15	
DP20	98.114	0.554	98.668	TOP	0.801	97.867	186.05	
SP1-S	96.929		96.929	NM	NM	NM	NM	
SP1-D	96.929		96.929	NM	NM	NM	NM	
SP2-S	96.314		96.314	NM	NM	NM	NM	
SP2-D	96.314		96.314	NM	NM	NM	NM	
SP3-S	96.892		96.892	NM	NM	NM	NM	
SP3-D	96.892		96.892	NM	NM	NM	NM	
SG-1	97.427		97.427	TSG	1.176	96.251	184.43	Pine River
SG-1A	97.641		97.641	TSG	1.386	96.255	184.44	Pine River
SG-2	96.835		96.835	TSG	1.603	95.232	183.41	Pine River
SG-3	97.591		97.591	NM	NM	NM	NM	Destroyed - unable to measure
SG-4	96.876		96.876	TSG	0.667	96.209	184.39	Pine River (SP1 loc.)
SG-5	96.314		96.314	TSG	0.051	96.264	184.44	Pine River (SP2 loc.) (4.5 cm upstream/5.6 down)
SG-6	96.892		96.892	TSG	0.679	96.213	184.39	Pine River (SP3 loc.)
P1	99.928	0.010	99.938	TOP	1.671	98.267	186.45	
P2	100.360	0.006	100.366	TOP	2.097	98.269	186.45	
AW1	99.076		99.076	TOC	1.377	97.699	185.88	

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Location	Top of Casing Elev (m)	Plastic stickup (m)	Elev. meas. point (m)	Meas. point	Depth to water (m)	Elev. of water (m)	AMSL Elevation (m)	Comments
AMW1	102.342		102.342	TOPVC	3.032	99.310	187.49	
AMW2	102.299		102.299	TOPVC	3.026	99.273	187.45	
AMW3	102.041		102.041	TOPVC	2.963	99.078	187.26	
AMW4	102.063		102.063	TOPVC	2.993	99.070	187.25	
AMW5	101.968		101.968	TOPVC	2.951	99.017	187.20	New well 10 m west of AMW1
APZ1	102.736		102.736	TOC	3.145	99.591	187.77	
APZ2	102.736	0.026	102.762	TOP	3.237	99.525	187.71	
APZ3	102.579	0.012	102.591	TOP	3.126	99.465	187.65	
MCT1-1	102.042		102.042	TCT	2.524	99.518	187.70	Murray's **M**ulti **C**hannel **T**ubing, "-1" is marked red
MCT1-2	102.042		102.042	TCT	2.535	99.507	187.69	"-2" is numbered clockwise from red "-1"
MCT1-3	102.042		102.042	TCT	3.009	99.033	187.21	
MCT1-4	102.042		102.042	TCT	3.000	99.042	187.22	
MCT1-5	102.042		102.042	TCT	2.998	99.044	187.22	
MCT1-6	102.042		102.042	TCT	3.001	99.041	187.22	
MCT1-7	102.042		102.042	TCT	3.010	99.032	187.21	
ML1-1	102.101	-0.037	102.064	TOP	3.009	99.055	187.24	**M**ulti-**L**evel Piezometer/sampler
ML1-2	102.101	-0.015	102.086	TOP	3.025	99.061	187.24	
ML1-3	102.101	0.004	102.105	TOP	3.054	99.051	187.23	
ML1-4	102.101	0.026	102.127	TOP	3.070	99.057	187.24	
ML1-5	102.101	0.060	102.161	TOP	3.100	99.061	187.24	Tubing badly kinked
ML1-6	102.101	0.091	102.192	TOP	3.133	99.059	187.24	Tubing badly kinked
ML1-7	102.101	0.113	102.214	TOP	3.156	99.058	187.24	Tubing badly kinked
ML1-8	102.101	0.139	102.240	TOP	2.722	99.518	187.70	Why same as level 9? Tubing badly kinked
ML1-9	102.101	0.174	102.275	TOP	2.722	99.553	187.73	Remeasured and was 2.721, Tubing badly kinked
ML1-ST	102.101		102.101	TOP	3.035	99.066	187.25	Center stalk

Notes:

NM = Water levels not measured at this location

TOC = top of steel pipe coupling (steel casing P1 and P2)

TOP = top of plastic polyethylene tubing

TOPVC = top of the 2-inch PVC pipe

TCT = top of channel tubing

TSG = top of staff gauge (steel pipe)

To convert Conant elevations to meters above mean sea level, add 88.18 m to Conant values

Revised elevation datums for SP-1 and May 1998 survey of SG-2,4,5 and 6, and May 1999 for DP4 set

Use stickups measured on this day except for DP7 set and DP15 which used May measurements

WL 8/16/99
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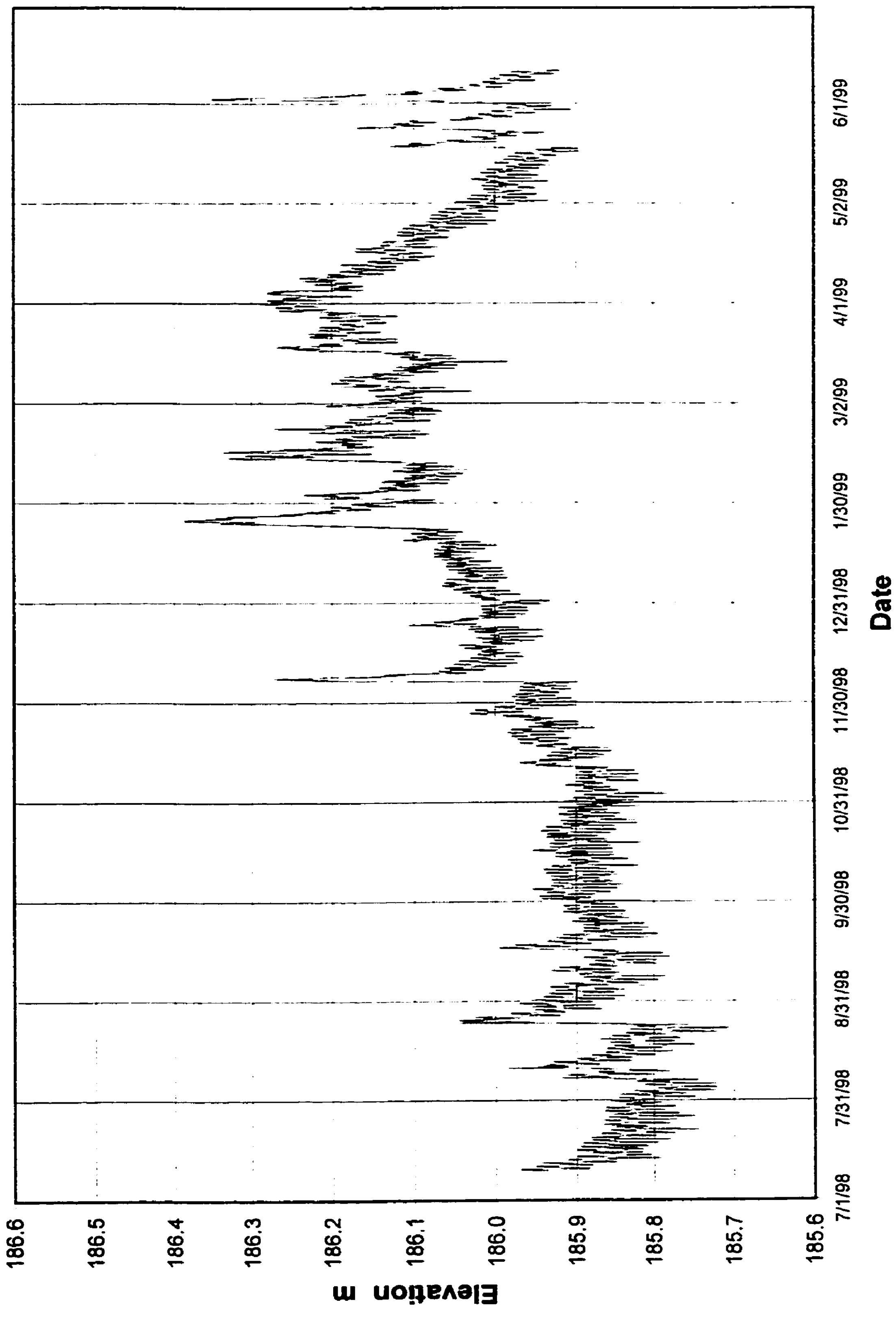


Water Levels at AW1:
Levelogger Measurements

APPENDIX D

RIVER STAGE AND FLOW MEASUREMENTS

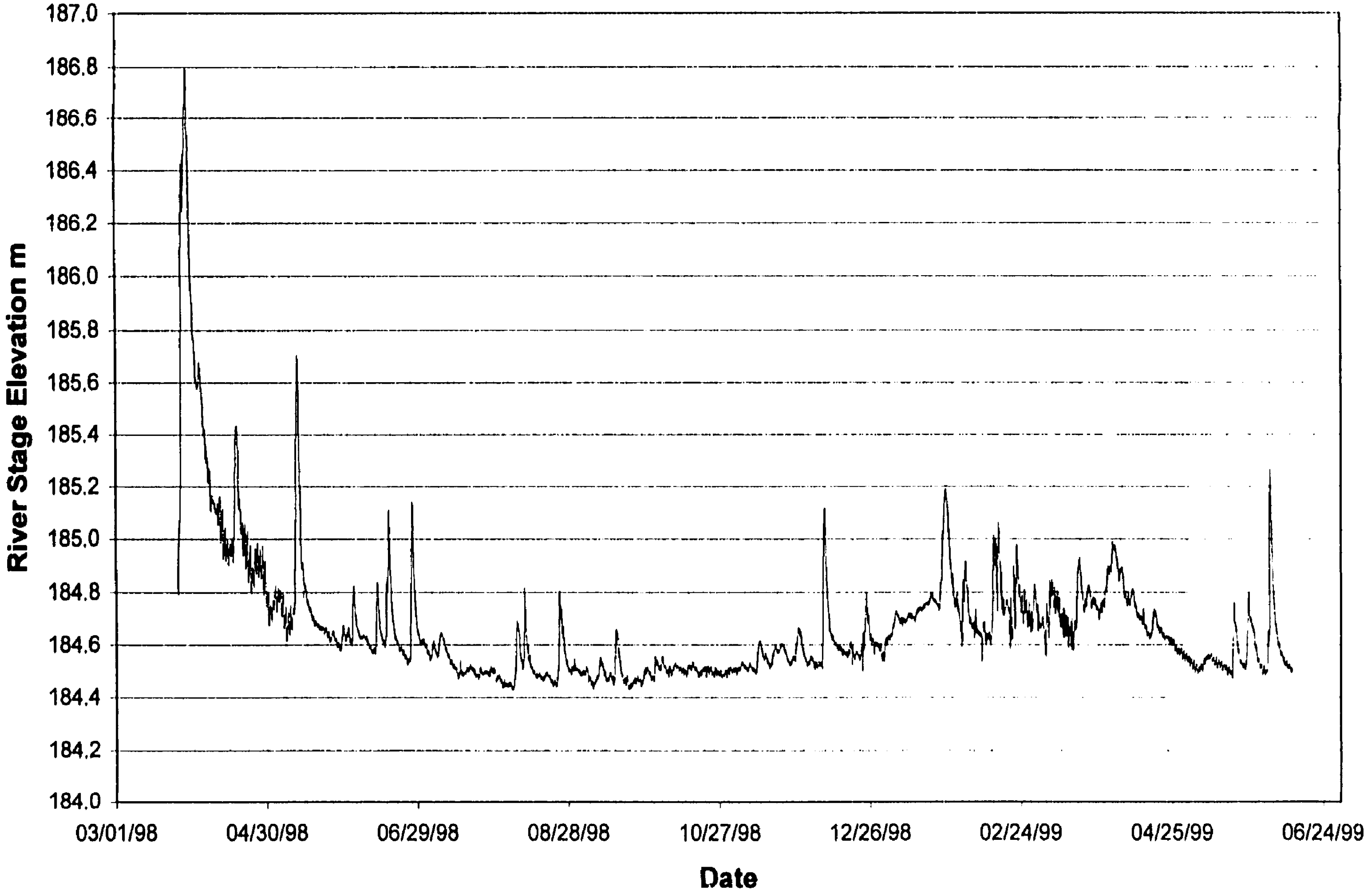
Levelogger Measurements of River stage

- Graph 3/25/98 to 6/11/99 (all data together)
- Graph 3/25/98 to 5/14/98
- Graph 5/14/98 to 6/25/98
- Graph 6/25/98 to 7/29/98
- Graph 7/29/98 to 8/12/98
- Graph 8/12/98 to 9/4/98
- Graph 9/4/98 to 10/29/98
- Graph 10/29/98 to 12/10/98
- Graph 12/10/98 to 2/9/99
- Graph 2/9/99 to 2/20/99
- Graph 2/20/99 to 4/5/99
- Graph 4/5/99 to 5/5/99
- Graph 5/5/99 to 6/11/99

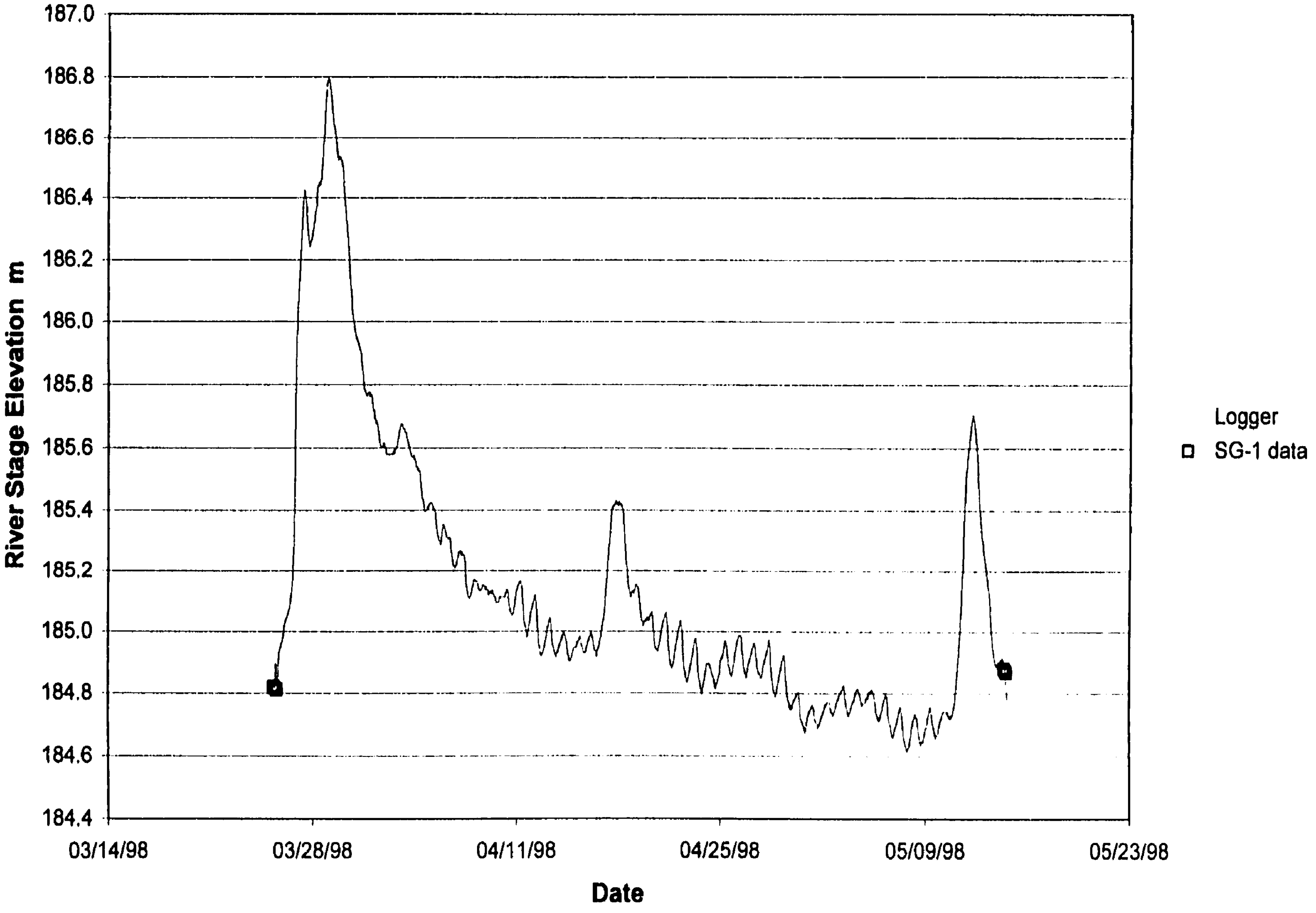
Discharge Measurements For Pine River

- March 16, 1998
- March 17, 1998
- March 25, 1998
- May 14,1998
- June 25, 1998 (0-0W)
- June 25, 1998 (18-18W)
- September 4, 1998

Stage Discharge Relationship for Pine River

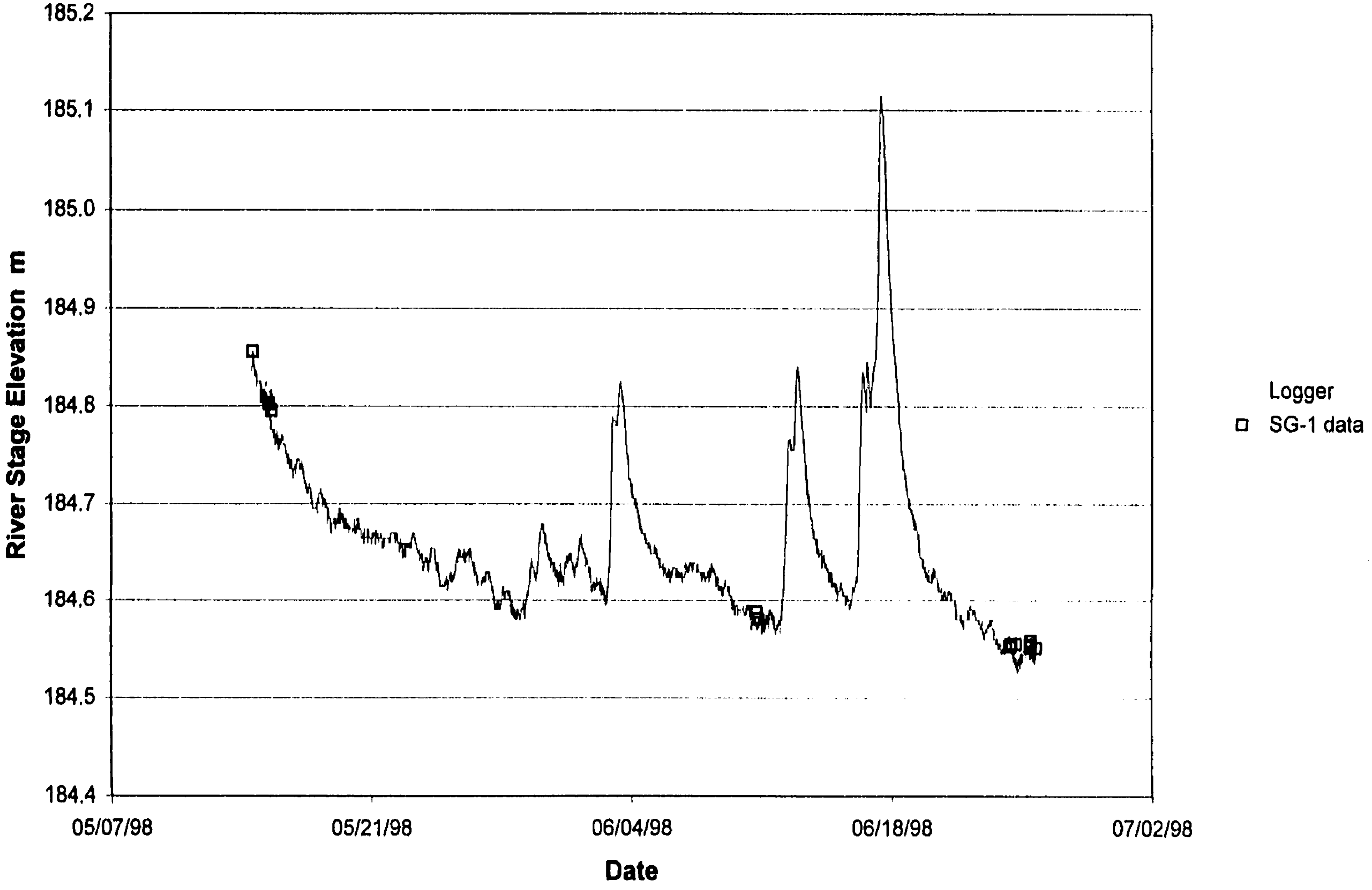


Pine River
Levelogger Measurements (3/25/98 to 6/11/99)

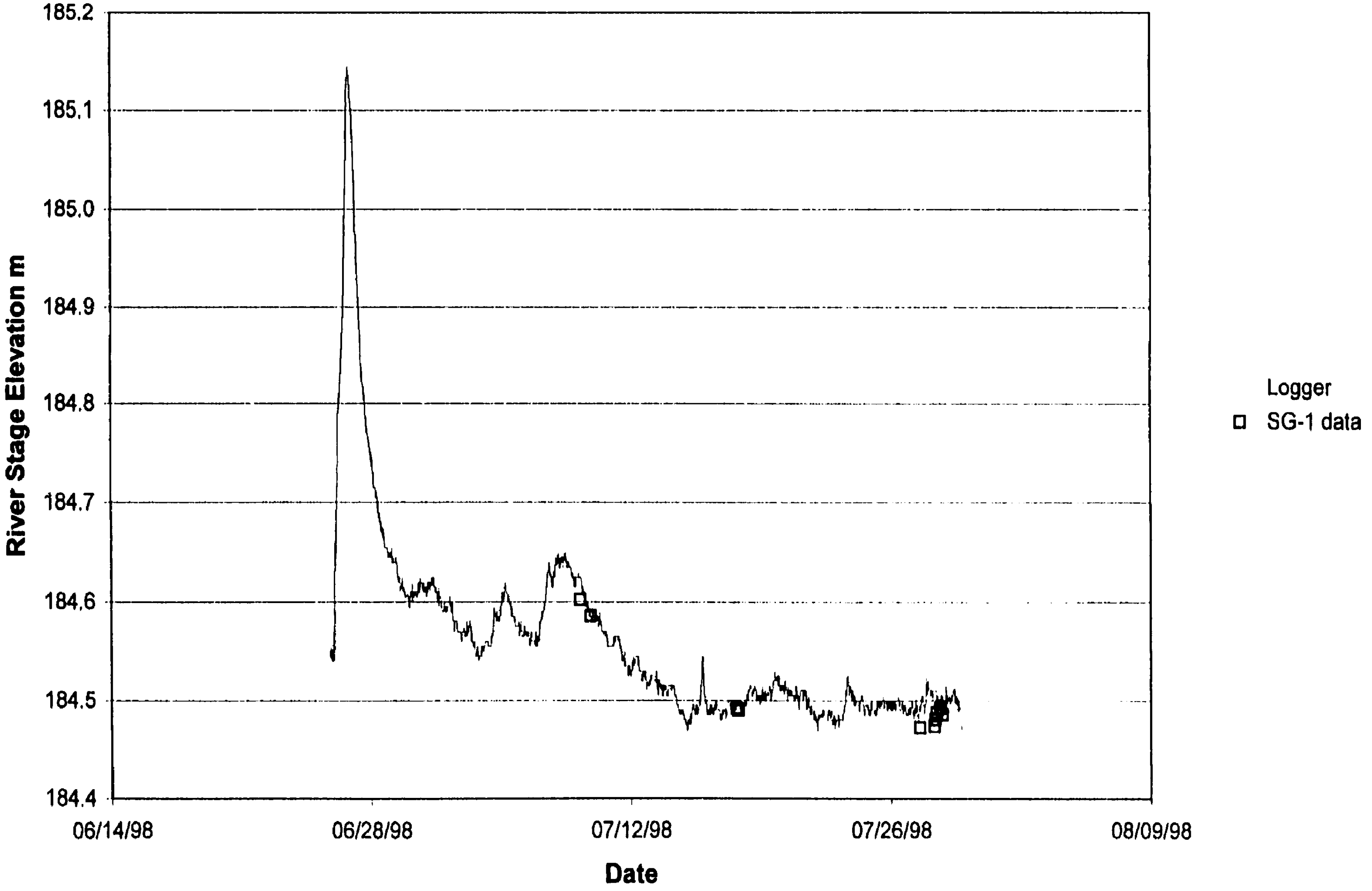


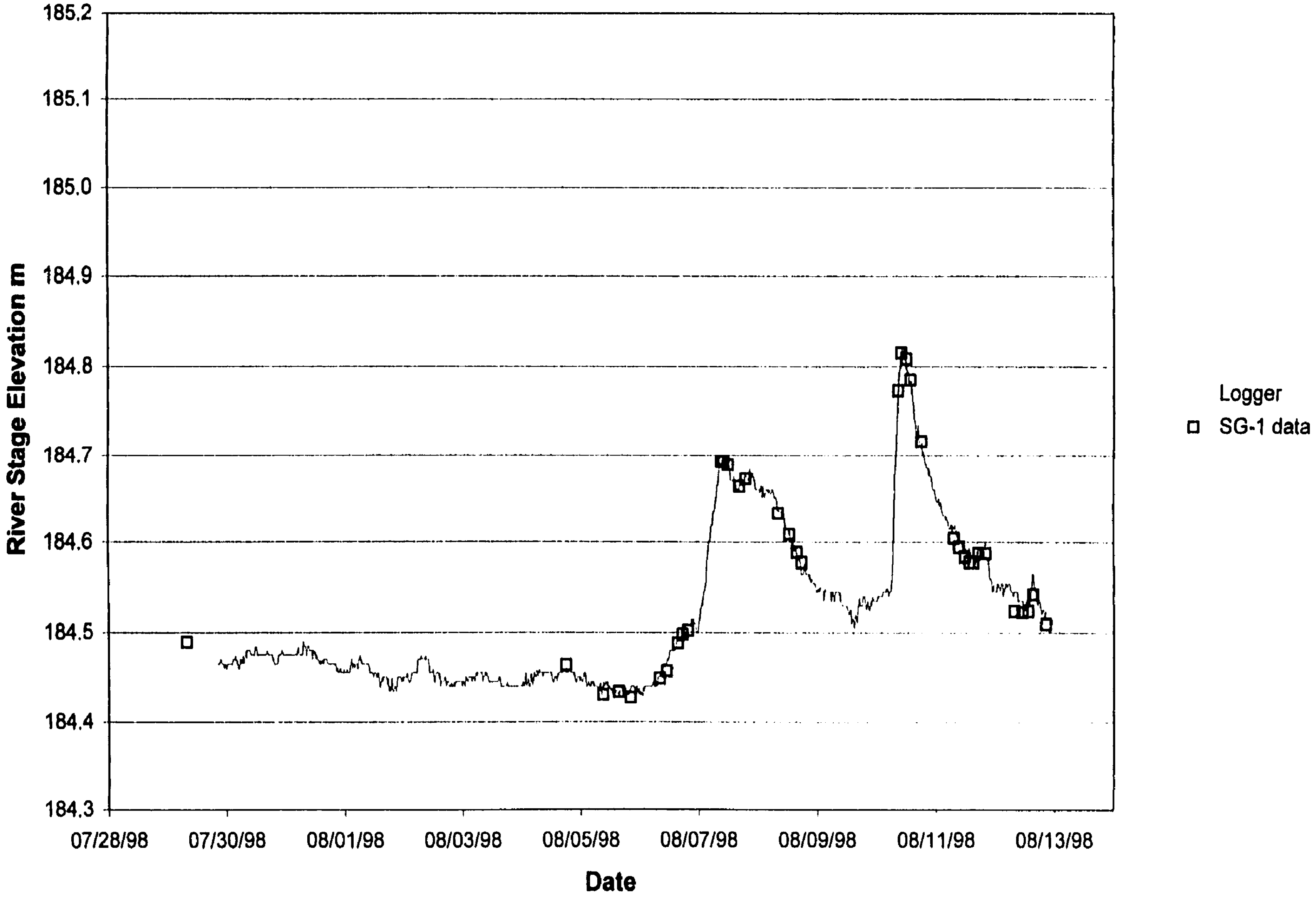
Pine River
Levelogger Measurements 3/25/98 to 5/14/98 (File LL2_PR2)

Pine River
Levelogger Measurements 5/14/98 to 6/25/98 (File LL2_PR3)

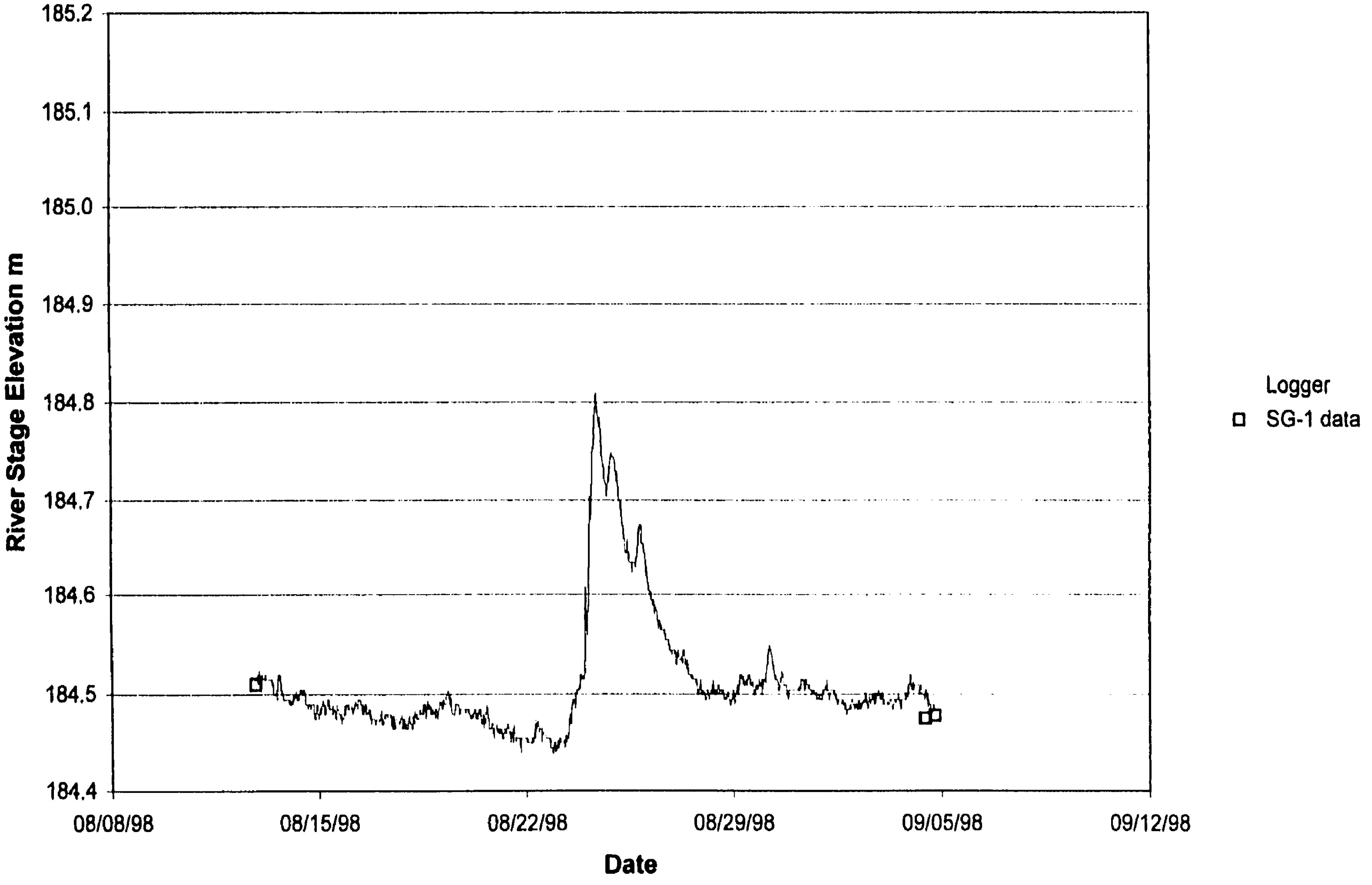


Pine River
Levelogger Measurements 6/25/98 to 7/29/98 (File LL2_PR5)

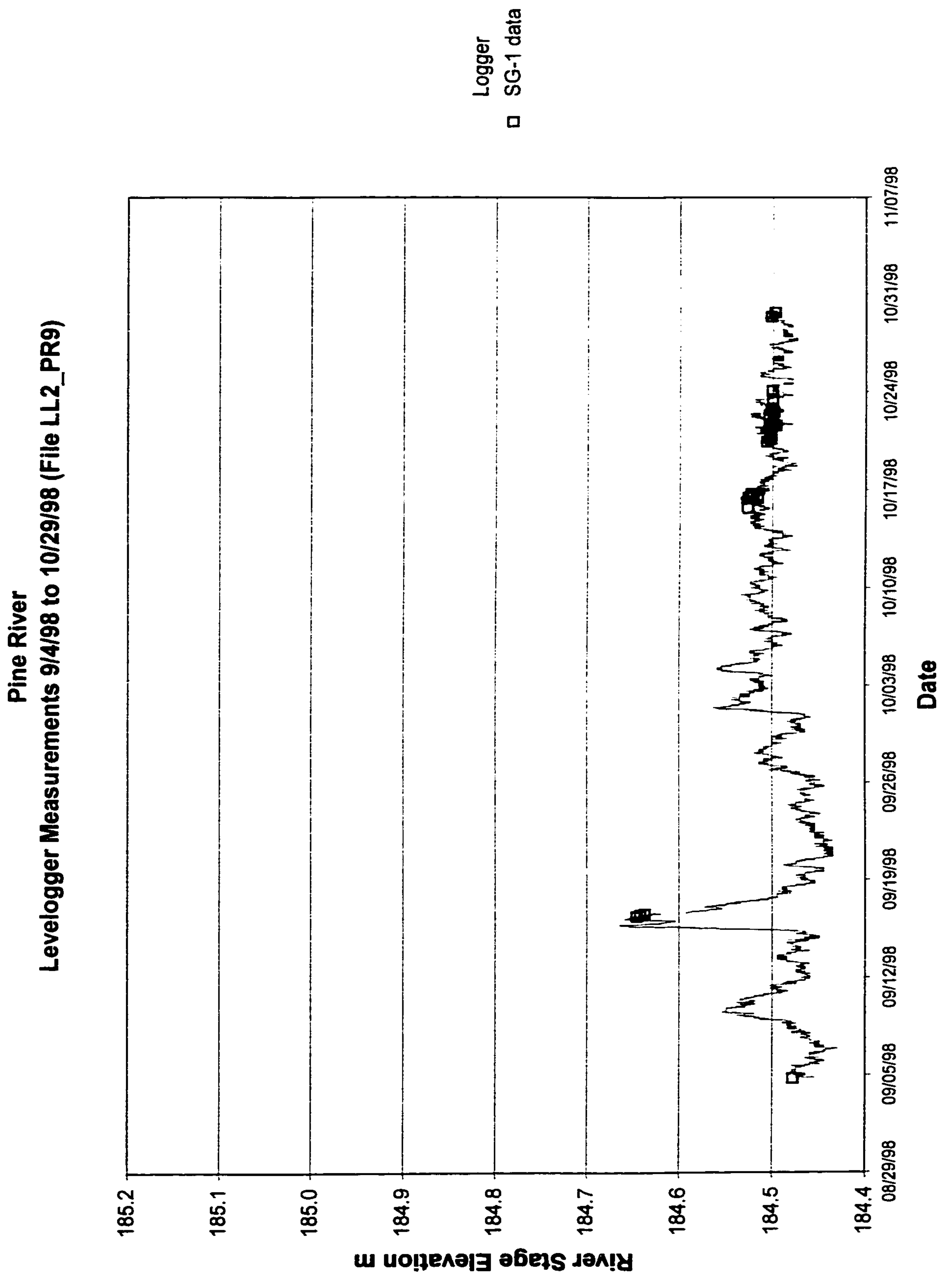




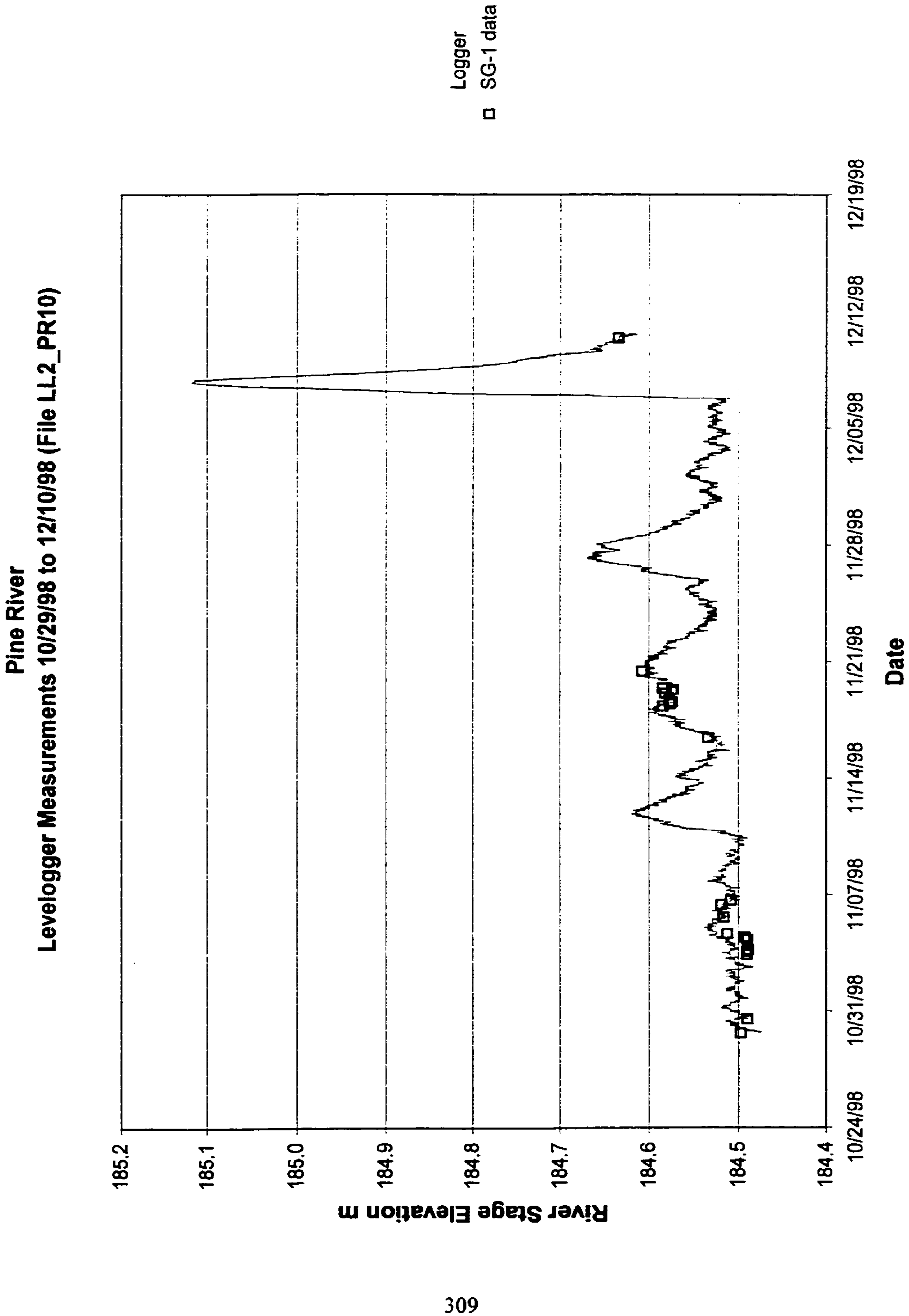
Pine River
Levelogger Measurements 7/29/98 to 8/12/98 (File LL2_PR6)

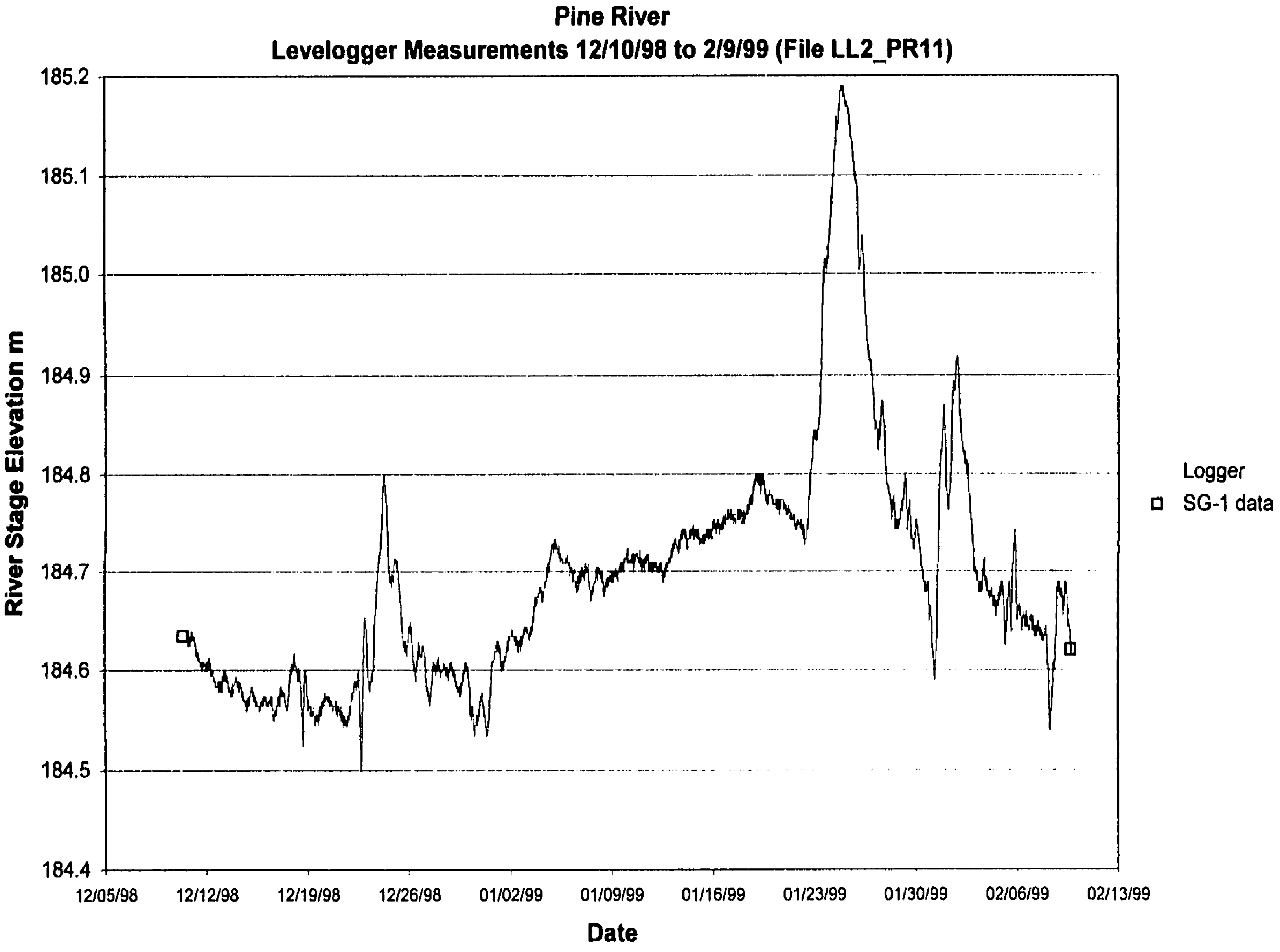


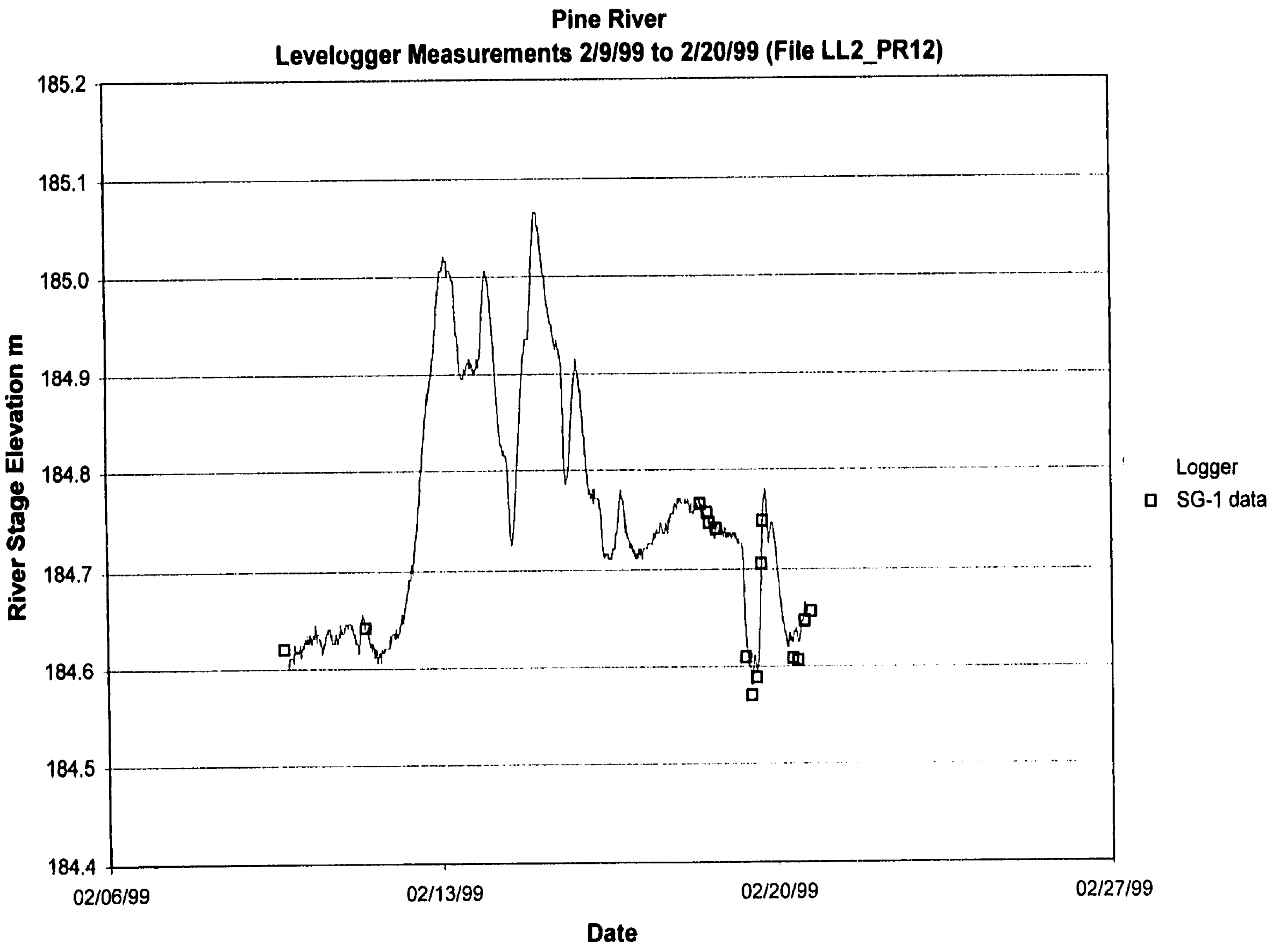
Pine River
Levelogger Measurements 8/12/98 to 9/4/98 (File LL2_PR6)



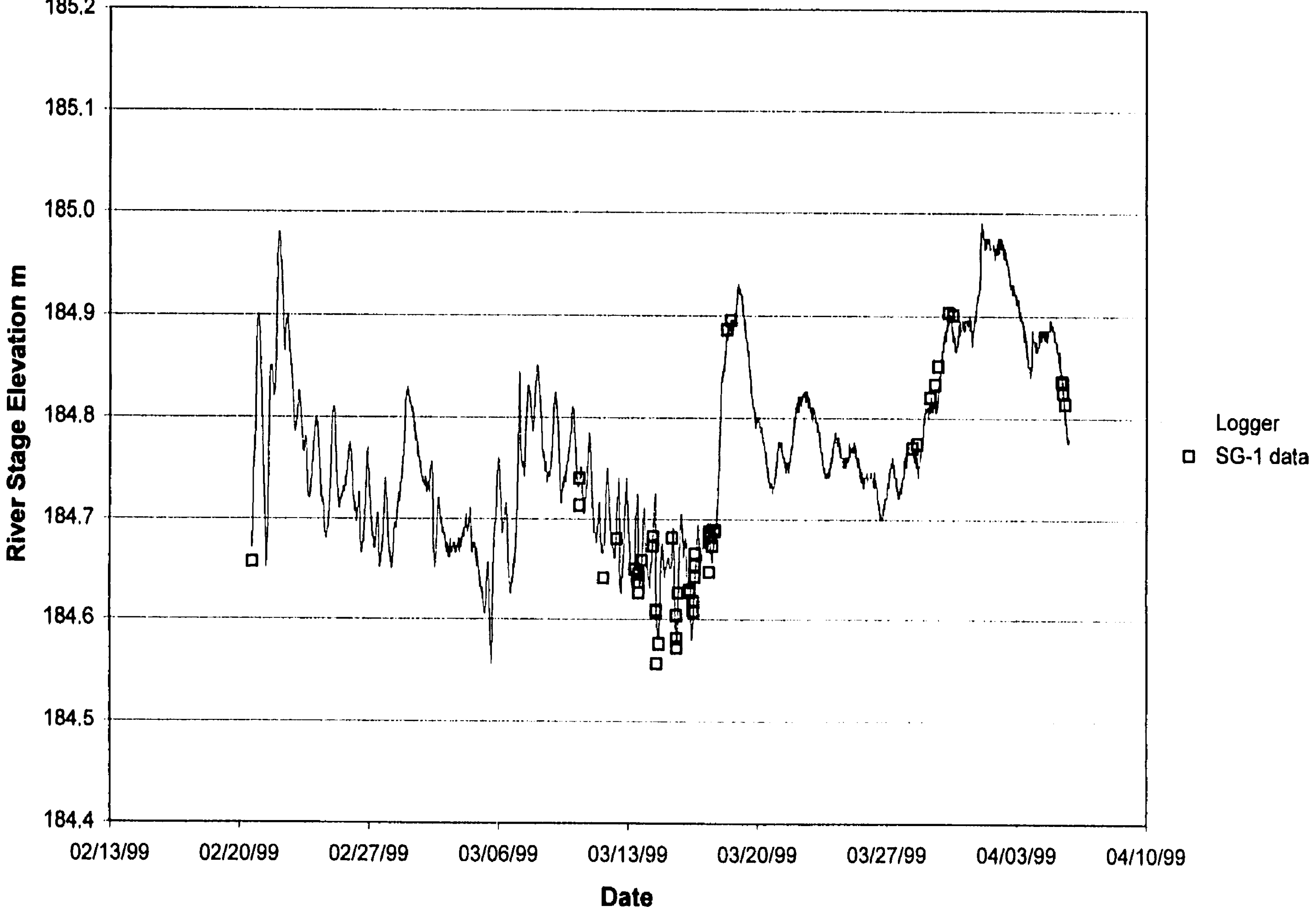
Pine River
Levelogger Measurements 9/4/98 to 10/29/98 (File LL2_PR9)


Pine River
Levelogger Measurements 10/29/98 to 12/10/98 (File LL2_PR10)
River Stage Elevation m
185.2
185.1
185.0
184.9
184.8
184.7
184.6
184.5
184.4
10/24/98
10/31/98
11/07/98
11/14/98
11/21/98
11/28/98
12/05/98
12/12/98
12/19/98
Date
Logger
□ SG-1 data

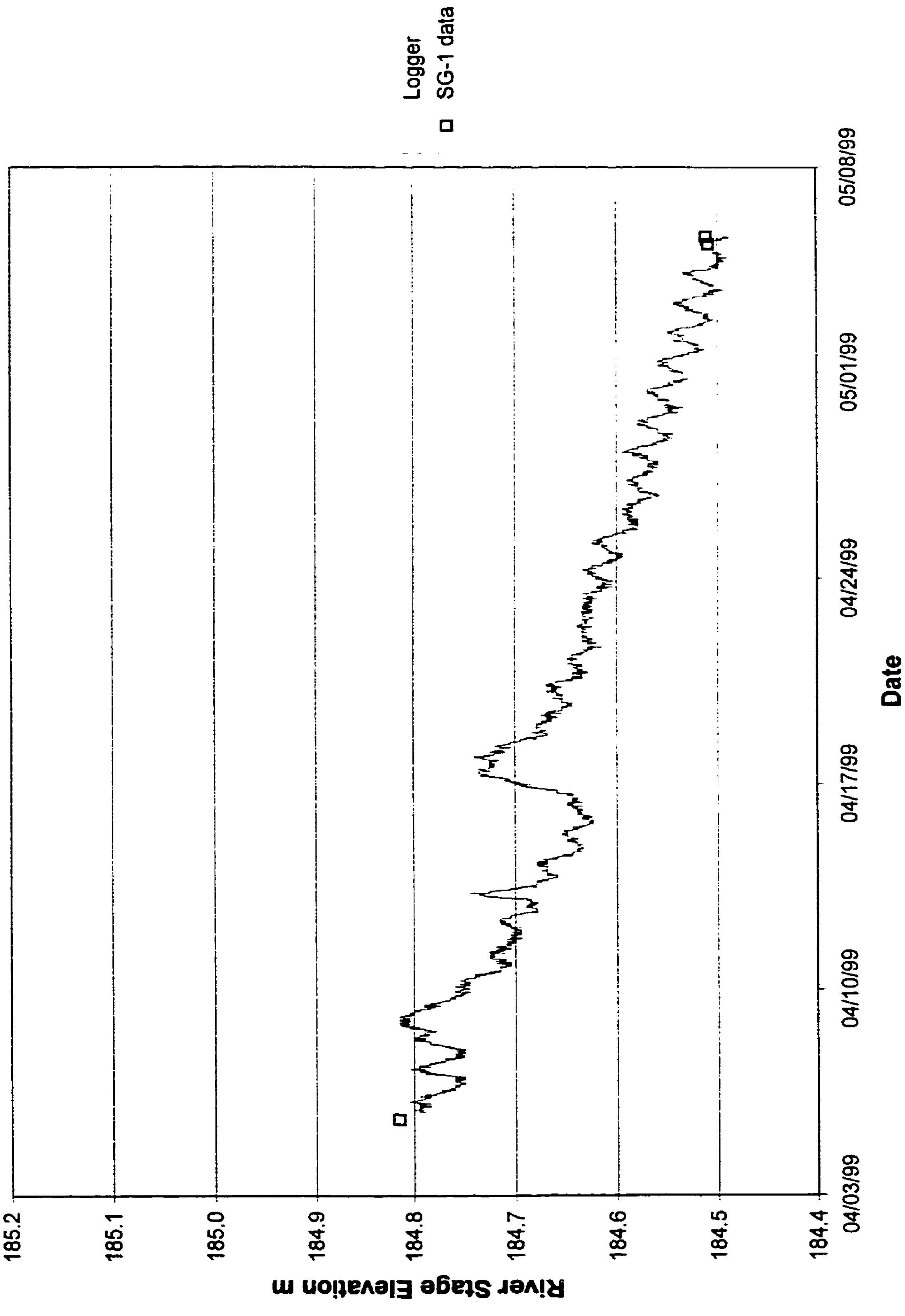

Pine River
Levelogger Measurements 12/10/98 to 2/9/99 (File LL2_PR11)
River Stage Elevation m
185.2
185.1
185.0
184.9
184.8
184.7
184.6
184.5
184.4
12/05/98
12/12/98
12/19/98
12/26/98
01/02/99
01/09/99
01/16/99
01/23/99
01/30/99
02/06/99
02/13/99
Date
Logger
SG-1 data

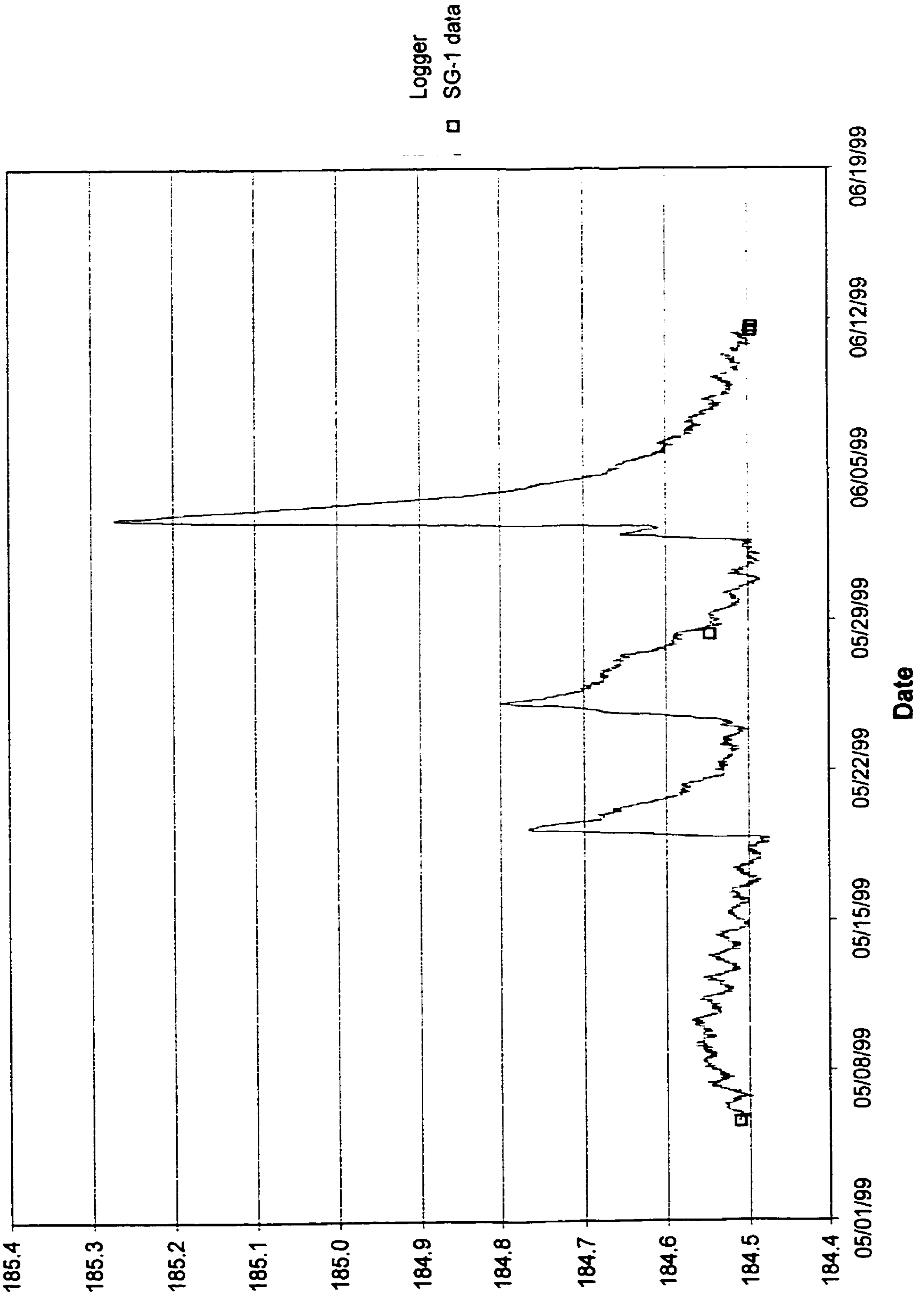

Pine River
Levelogger Measurements 2/9/99 to 2/20/99 (File LL2_PR12)
River Stage Elevation m
185.2
185.1
185.0
184.9
184.8
184.7
184.6
184.5
184.4
02/06/99
02/13/99
02/20/99
02/27/99
Date
Logger
□ SG-1 data

Pine River
Levelogger Measurements 2/20/99 to 4/5/99 (File LL2_PR13)



Pine River
Levelogger Measurements 4/5/99 to 5/5/99 (File LL2_PR14)





Pine River
Levelogger Measurements 5/5/99 to 6/11/99 (File LL2_PR15)

STREAM/RIVER LOCATION: Pine River along 18 - 18w
STREAM STAGE/CONDITION (start): NA
STREAM STAGE/CONDITION (end): SG-1 TSG 0.794 m , SG-1A TSG 1.023 m at 1:33 pm
VELOCITY METER USED: Swoffer Model 2100 - STDX and LX WAND USED: Model 2100 Sensor
DATE: Mar. 16, 1998 WEATHER: Partly Cloudy STREAM TEMP. 0.13 C at 1:37 pm from data logger
OPERATORS: Brewster Conant and Dave Thomson

Dist. from initial point (m)	Depth of water at Location (m)	Depth of Measure (m)	Meter position	Velocity				Width (m)	Area (m^2)	Discharge			Comments
				at point (m/s)	(assigned) Mean in vertical (m/s)	Min. (m/s)	Max. (m/s)			Assigned (m^3/s)	Min (m^3/s)	Max (m^3/s)	
East Bank													
1.10	0.00	0.000											
1.50	0.19	0.110	0.6	-0.06	-0.06	NA	NA	0.65	0.124	-0.007	-0.007	-0.007	Reverse flow
2.00	0.51	0.306	0.6	0.00	0.00	NA	NA	0.5	0.255	0.000	0.000	0.000	
2.50	0.55	0.330	0.6	0.06	0.06	0.02		0.5	0.275	0.017	0.006	0.000	
3.00	0.71	0.430	0.6	0.18	0.18	NA	NA	0.5	0.355	0.064	0.064	0.064	Second reading
3.50	0.78	0.470	0.6	0.30	0.30	NA	NA	0.5	0.390	0.117	0.117	0.117	
4.00	0.84	0.500	0.6	0.30	0.30	0.25	0.34	0.5	0.420	0.126	0.105	0.143	
4.50	0.845	0.510	0.6	0.30	0.30	0.33	0.28	0.5	0.423	0.127	0.139	0.118	
5.00	0.845	0.510	0.6	0.28	0.30	0.26	0.30	0.5	0.423	0.127	0.110	0.127	
5.50	0.87	0.520	0.6	0.30	0.30	0.26	0.30	0.5	0.435	0.131	0.113	0.131	
6.00	0.87	0.520	0.6	0.33	0.33	0.28	0.33	0.5	0.435	0.144	0.122	0.144	
6.50	0.83	0.500	0.6	0.31	0.31	0.28	0.40	0.5	0.415	0.129	0.116	0.166	
7.00	0.78	0.470	0.6	0.41	0.41	NA	NA	0.5	0.390	0.160	0.160	0.160	Checked again later get 0.42, 0.35/0.42 m/s
7.50	0.74	0.440	0.6	0.32	0.32	0.28	0.38	0.5	0.370	0.118	0.104	0.141	Checked again later get 0.37, 0.37/0.44 m/s
8.00	0.67	0.400	0.6	0.37	0.37	0.32	0.37	0.5	0.335	0.124	0.107	0.124	
8.50	0.645	0.390	0.6	0.37	0.37	0.32	0.38	0.5	0.323	0.119	0.103	0.123	
9.00	0.645	0.390	0.6	0.40	0.40	0.35	0.41	0.5	0.323	0.129	0.113	0.132	
9.50	0.63	0.380	0.6	0.40	0.40	0.37	0.41	0.5	0.315	0.126	0.117	0.129	
10.00	0.605	0.360	0.6	0.34	0.34	0.32	0.40	0.5	0.303	0.103	0.097	0.121	
10.50	0.59	0.350	0.6	0.38	0.38	0.30	0.38	0.5	0.295	0.112	0.089	0.112	
11.00	0.58	0.350	0.6	0.28	0.28	0.26	0.32	0.5	0.290	0.081	0.075	0.093	

Dist. from initial point	Depth of water at Location	Depth of Measure	Meter position	Velocity				Width	Area	Discharge			Comments
				at point	(assigned) Mean in vertical	Min.	Max.			Assigned	Min	Max	
(m)	(m)	(m)		(m/s)	(m/s)	(m/s)	(m/s)	(m)	(m^2)	(m^3/s)	(m^3/s)	(m^3/s)	
11.50	0.585	0.350	0.6	0.32	0.32	0.25	0.32	0.5	0.293	0.094	0.073	0.094	
12.00	0.58	0.350	0.6	0.24	0.24	0.24	0.27	0.5	0.290	0.070	0.070	0.078	
12.50	0.49	0.290	0.6	0.11	0.11	0.09	0.13	0.5	0.245	0.027	0.022	0.032	
13.00	0.38	0.230	0.6	0.06	0.06	0.04	0.08	0.5	0.190	0.011	0.008	0.015	Thin sheet of ice
13.50	0.14	0.080	0.6	0.00	0.00	NA	NA	0.41	0.057	0.000	0.000	0.000	
13.66	0.00												
West Bank								Sum	7.966	**2.246**	2.021	2.355	

STREAM/RIVER LOCATION: Pine River along 18 - 18w
STREAM STAGE/CONDITION (start): NA
STREAM STAGE/CONDITION (end): SG-1 TSG 0.680 m at 6:43 pm, SG-1A TSG 0.894 m at 6:44 pm
VELOCITY METER USED: Swoffer Model 2100 - STDX and LX WAND USED: Model 2100 Sensor
DATE: Mar. 17, 1998 WEATHER: Sunny STREAM TEMP. 0.29 C at 6:39 pm from data logger
OPERATORS: Brewster Conant and Dave Thomson

Dist. from initial point (m)	Depth of water at Location (m)	Depth of Measure (m)	Meter position	Velocity				Width (m)	Area (m^2)	Discharge			Comments
				at point (m/s)	(assigned) Mean in vertical (m/s)	Min. (m/s)	Max. (m/s)			Assigned (m3/s)	Min (m3/s)	Max (m3/s)	
East Bank													
1.10	0.00	0.00											Starting distance is approximate
1.50	0.48	0.29	0.6	0.00	0.00	0.00	0.01	0.65	0.312	0.000	0.000	0.003	
2.00	0.80	0.48	0.6	0.04	0.04	0.04	0.23	0.5	0.400	0.016	0.016	0.092	
2.50	0.91	0.55	0.6	0.25	0.25	0.18	0.31	0.5	0.455	0.114	0.082	0.141	
3.00	0.98	0.59	0.6	0.31	0.31	0.20	0.33	0.5	0.490	0.152	0.098	0.162	
3.50	1.06	0.21	0.2	0.35	0.33	0.20	0.41	0.5	0.530	0.175	0.114	0.191	
3.50	1.06	0.82	0.8	0.31		0.23	0.31						
4.00	1.14	0.23	0.2	0.40	0.36	0.26	0.46	0.5	0.570	0.205	0.162	0.265	
4.00	1.14	0.73	0.8	0.32		0.31	0.47						
4.50	1.14	0.23	0.2	0.48	0.45	0.37	0.50	0.5	0.570	0.254	0.208	0.282	
4.50	1.14	0.73	0.8	0.41		0.36	0.49						
5.00	1.14	0.23	0.2	0.44	0.43	0.34	0.44	0.5	0.570	0.242	0.191	0.245	
5.00	1.14	0.73	0.8	0.41		0.33	0.42						
5.50	1.18	0.24	0.2	0.42	0.38	0.31	0.44	0.5	0.590	0.224	0.174	0.230	
5.50	1.18	0.94	0.8	0.34		0.28	0.34						
6.00	1.18	0.24	0.2	0.49	0.43	0.44	0.62	0.5	0.590	0.254	0.204	0.316	
6.00	1.18	0.94	0.8	0.37		0.25	0.45						
6.50	1.15	0.23	0.2	0.58	0.54	0.52	0.64	0.5	0.575	0.311	0.259	0.328	
6.50	1.15	0.92	0.8	0.50		0.38	0.50						
7.00	1.12	0.22	0.2	0.37	0.41	0.37	0.60	0.5	0.560	0.227	0.204	0.302	
7.00	1.12	0.90	0.8	0.44		0.36	0.48						
7.50	1.07	0.21	0.2	0.56	0.53	0.47	0.60	0.5	0.535	0.281	0.238	0.292	
7.50	1.07	0.86	0.8	0.49		0.42	0.49						

Dist. from initial point (m)	Depth of water at Location (m)	Depth of Measure (m)	Meter position	Velocity				Width (m)	Area (m^2)	Discharge			Comments
				at point (m/s)	(assigned) Mean in vertical (m/s)	Min. (m/s)	Max. (m/s)			Assigned (m3/s)	Min (m3/s)	Max (m3/s)	
8.00	0.98	0.59	0.6	0.53	0.53	0.42	0.53	0.5	0.490	0.260	0.206	0.260	
8.50	0.96	0.58	0.6	0.48	0.48	0.45	0.57	0.5	0.480	0.230	0.216	0.274	
9.00	0.94	0.56	0.6	0.52	0.52	0.50	0.58	0.5	0.470	0.244	0.235	0.273	
9.50	0.95	0.57	0.6	0.58	0.58	0.54	0.66	0.5	0.475	0.276	0.257	0.314	
10.00	0.89	0.53	0.6	0.56	0.56	0.49	0.60	0.5	0.445	0.249	0.218	0.267	
10.50	0.87	0.52	0.6	0.52	0.52	0.46	0.52	0.5	0.435	0.226	0.200	0.226	
11.00	0.82	0.49	0.6	0.43	0.43	0.25	0.43	0.5	0.410	0.176	0.103	0.176	
11.50	0.81	0.49	0.6	0.38	0.38	0.35	0.42	0.5	0.405	0.154	0.142	0.170	
12.00	0.81	0.49	0.6	0.42	0.42	0.37	0.44	0.5	0.405	0.170	0.150	0.178	
12.50	0.66	0.40	0.6	0.23	0.23	0.19	0.23	0.5	0.330	0.076	0.063	0.076	
13.00	0.56	0.34	0.6	0.17	0.17	0.06	0.17	0.5	0.280	0.048	0.017	0.048	
13.50	0.39	0.23	0.6	0.00	0.00	0.00	0.00	0.55	0.215	0.000	0.000	0.000	
13.80	0.00												
West Bank								Sum	11.587	**4.563**	3.755	5.109	

STREAM/RIVER LOCATION: Pine River along 18 - 18w
STREAM STAGE/CONDITION (start): NA
STREAM STAGE/CONDITION (end): SG-1 TSG 0.793 m at 11:42 am.
VELOCITY METER USED: Swoffer Model 2100 - STDX and LX WAND USED: Model 2100 Sensor
DATE: Mar. 25, 1998 WEATHER: Clear and cold STREAM TEMP. 1.73 C at 11:27am from data logger
OPERATORS: Brewster Conant and Dave Thomson

Dist. from initial point (m)	Depth of water at Location (m)	Depth of Measure (m)	Meter position	Velocity				Width (m)	Area (m^2)	Discharge			Comments
				at point (m/s)	(assigned) Mean in vertical (m/s)	Min. (m/s)	Max. (m/s)			Assigned (m^3/s)	Min (m^3/s)	Max (m^3/s)	
East Bank													
0.95	0.00	0.000											
1.00	0.10	0.060	0.6	0.00	0.00	0.00	0.00	0.55	0.055	0.000	0.000	0.000	
1.50	0.38	0.230	0.6	0.00	0.00	0.00	0.00	0.525	0.200	0.000	0.000	0.000	
2.00	0.65	0.390	0.6	0.22	0.22	0.16	0.22	0.75	0.488	0.107	0.078	0.107	
2.50	0.77	0.460	0.6	0.34	0.34	0.21	0.37	0.5	0.385	0.131	0.081	0.142	
3.00	0.92	0.550	0.6	0.27	0.27	0.24	0.29	0.5	0.460	0.124	0.110	0.133	
3.50	1.03	0.210	0.2	0.42	0.39	0.37	0.42	0.5	0.515	0.201	0.180	0.216	
3.50	1.03	0.820	0.8	0.36		0.33	0.42						
4.00	1.02	0.200	0.2	0.47	0.44	0.43	0.47	0.5	0.510	0.224	0.191	0.227	
4.00	1.02	0.820	0.8	0.41		0.32	0.42						
4.50	0.97	0.580	0.6	0.41	0.41	0.38	0.45	0.5	0.485	0.199	0.184	0.218	
5.00	0.91	0.550	0.6	0.40	0.40	0.39	0.44	0.5	0.455	0.182	0.177	0.200	
5.50	0.86	0.520	0.6	0.52	0.52	0.44	0.52	0.5	0.430	0.224	0.189	0.224	
6.00	0.82	0.480	0.6	0.49	0.49	0.46	0.52	0.5	0.410	0.201	0.189	0.213	
6.50	0.76	0.460	0.6	0.62	0.62	0.53	0.63	0.5	0.380	0.236	0.201	0.239	
7.00	0.74	0.440	0.6	0.51	0.51	0.41	0.57	0.5	0.370	0.189	0.152	0.211	
7.50	0.72	0.430	0.6	0.59	0.59	0.44	0.59	0.5	0.360	0.212	0.158	0.212	
8.00	0.72	0.430	0.6	0.44	0.44	0.37	0.48	0.5	0.360	0.158	0.133	0.173	
8.50	0.75	0.450	0.6	0.46	0.46	0.45	0.54	0.5	0.375	0.173	0.169	0.203	
9.00	0.85	0.520	0.6	0.56	0.56	0.46	0.58	0.5	0.425	0.238	0.196	0.247	
9.50	0.86	0.520	0.6	0.55	0.55	0.52	0.56	0.5	0.430	0.237	0.224	0.241	
10.00	0.80	0.480	0.6	0.45	0.45	0.43	0.53	0.5	0.400	0.180	0.172	0.212	
10.50	0.75	0.450	0.6	0.48	0.48	0.37	0.53	0.5	0.375	0.180	0.139	0.199	

Dist. from initial point (m)	Depth of water at Location (m)	Depth of Measure (m)	Meter position	Velocity				Width (m)	Area (m^2)	Discharge			Comments
				at point (m/s)	(assigned) Mean in vertical (m/s)	Min. (m/s)	Max. (m/s)			Assigned (m^3/s)	Min (m^3/s)	Max (m^3/s)	
11.00	0.72	0.430	0.6	0.43	0.43	0.35	0.46	0.5	0.360	0.155	0.126	0.166	
11.50	0.76	0.460	0.6	0.48	0.48	0.38	0.54	0.5	0.380	0.182	0.144	0.205	
12.00	0.73	0.440	0.6	0.45	0.45	0.45	0.49	0.5	0.365	0.164	0.164	0.179	
12.50	0.65	0.390	0.6	0.26	0.26	0.20	0.26	0.5	0.325	0.085	0.065	0.085	
13.00	0.43	0.260	0.6	0.07	0.07	0.07	0.07	0.5	0.215	0.015	0.015	0.015	
13.50	0.32	0.190	0.6	0.11	0.11	0.08	0.13	0.48	0.154	0.017	0.012	0.020	
13.73	0.00												
West Bank								Sum	9.666	**4.013**	3.451	4.287	

STREAM/RIVER LOCATION: Pine River along 18 - 18w
STREAM STAGE/CONDITION (start): SG-1 TSG 0.734 at 10:55 am, SG-2 TSG 0.181m at 10:57 am, SG-1A TSG 0.948 at 10:59 am
STREAM STAGE/CONDITION (end): SG-1 TSG 0.736 at 11:42 am, SG-2 0.185 +- 0.001 at 11:44 am, SG-1A TSG 0.951 at 11:42 am
VELOCITY METER USED: Swoffer Model 2100 - STDX and LX WAND USED: Model 2100 Sensor
DATE: May 14, 1998 WEATHER: Sunny and clear STREAM TEMP. 14.61 C
OPERATORS: Brewster Conant and Trevor Baine

Dist. from initial point (m)	Depth of water at Location (m)	Depth of Measure (m)	Meter position	Velocity				Width (m)	Area (m^2)	Discharge			Comments
				at point (m/s)	(assigned) Mean in vertical (m/s)	Min. (m/s)	Max. (m/s)			Assigned (m^3/s)	Min (m^3/s)	Max (m^3/s)	
East Bank													
1.02	0.00	0.000											
1.50	0.35	0.210	0.6	0	0	0	0	0.73	0.256	0.000	0.000	0.000	
2.00	0.66	0.396	0.6	0.15	0.15	0.15	0.18	0.5	0.330	0.050	0.050	0.059	
2.50	0.82	0.492	0.6	0.18	0.18	0.12	0.12	0.5	0.410	0.074	0.049	0.049	Maximum is assumed
3.00	0.99	0.594	0.6	0.16	0.16	0.15	0.18	0.5	0.495	0.079	0.074	0.089	
3.50	0.96	0.576	0.6	0.30	0.30	0.29	0.40	0.5	0.480	0.144	0.139	0.192	
4.00	0.99	0.594	0.6	0.39	0.39	0.29	0.39	0.5	0.495	0.193	0.144	0.193	
4.50	0.98	0.588	0.6	0.39	0.39	0.37	0.45	0.5	0.490	0.191	0.181	0.221	
5.00	0.97	0.582	0.6	0.37	0.37	0.35	0.39	0.5	0.485	0.179	0.170	0.189	
5.50	0.97	0.582	0.6	0.35	0.35	0.34	0.39	0.5	0.485	0.170	0.165	0.189	
6.00	1.01	0.202	0.2	0.55	0.42	0.46	0.56	0.5	0.505	0.212	0.157	0.215	
6.00	1.01	0.808	0.8	0.29		0.16	0.29						
6.50	1.06	0.212	0.2	0.61	0.47	0.59	0.62	0.5	0.530	0.246	0.217	0.284	
6.50	1.06	0.848	0.8	0.32		0.23	0.45						
7.00	1.06	0.212	0.2	0.56	0.46	0.48	0.60	0.5	0.530	0.241	0.207	0.260	
7.00	1.06	0.848	0.8	0.35		0.30	0.38						
7.50	1.05	0.210	0.2	0.55	0.46	0.50	0.55	0.5	0.525	0.242	0.210	0.257	
7.50	1.05	0.840	0.8	0.37		0.30	0.43						
8.00	1.03	0.206	0.2	0.50	0.39	0.44	0.50	0.5	0.515	0.198	0.157	0.221	
8.00	1.03	0.824	0.8	0.27		0.17	0.36						
8.50	1.00	0.200	0.2	0.40	0.32	0.40	0.46	0.5	0.500	0.160	0.153	0.175	
8.50	1.00	0.800	0.8	0.24		0.21	0.24						
9.00	1.03	0.206	0.2	0.49	0.41	0.43	0.49	0.5	0.515	0.209	0.173	0.214	

Dist. from initial point (m)	Depth of water at Location (m)	Depth of Measure (m)	Meter position	Velocity				Width (m)	Area (m²)	Discharge			Comments
				at point (m/s)	(assigned) Mean in vertical (m/s)	Min. (m/s)	Max. (m/s)			Assigned (m^3/s)	Min (m^3/s)	Max (m^3/s)	
9.00	1.03	0.824	0.8	0.32		0.24	0.34						
9.50	0.95	0.570	0.6	0.51	0.51	0.43	0.53	0.5	0.475	0.242	0.204	0.252	
10.00	0.91	0.546	0.6	0.44	0.44	0.44	0.47	0.5	0.455	0.200	0.200	0.214	
10.50	0.89	0.534	0.6	0.42	0.42	0.37	0.44	0.5	0.445	0.187	0.165	0.196	
11.00	0.84	0.504	0.6	0.32	0.32	0.30	0.38	0.5	0.420	0.134	0.126	0.160	
11.50	0.80	0.480	0.6	0.43	0.43	0.35	0.43	0.5	0.400	0.172	0.140	0.172	
12.00	0.73	0.438	0.6	0.41	0.41	0.37	0.41	0.5	0.365	0.150	0.135	0.150	
12.50	0.63	0.378	0.6	0.20	0.20	0.20	0.26	0.5	0.315	0.063	0.063	0.082	behind unknown obstruction
13.00	0.45	0.270	0.6	0.13	0.13	0.09	0.13	0.5	0.225	0.029	0.020	0.029	
13.50	0.24	0.144	0.6	0.05	0.05	0.03	0.07	0.37	0.089	0.004	0.003	0.006	
13.74	0.15	0.090	0.6	0.00	0.00	0.00	0.00	0.13	0.020	0.000	0.000	0.000	Max and min velocity assumed
13.75	0.00	0.000											

West Bank

Sum 10.754 **3.770** 3.300 4.067

STREAM/RIVER LOCATION: Pine River along 0 - 0w
STREAM STAGE/CONDITION (start): SG-1 TSG 1.054 at 11:55 am
STREAM STAGE/CONDITION (end): SG-1 TSG 1.050 at 12:27 pm
VELOCITY METER USED: Swoffer Model 2100 - STDX and LX WAND USED: Model 2100 Sensor
DATE: June 25, 1998 WEATHER: Hot, hazy, sunny and muggy STREAM TEMP. 21.22 C at 12:40 pm
OPERATORS: Brewster Conant and Matt Bogart

Dist. from initial point (m)	Depth of water at Location (m)	Depth of Measure (m)	Meter position	Velocity				Width (m)	Area (m^2)	Discharge			Comments
				at point (m/s)	(assigned) Mean in vertical (m/s)	Min. (m/s)	Max. (m/s)			Assigned (m^3/s)	Min (m^3/s)	Max (m^3/s)	
East Bank													
1.87	0.00	0											
2.50	0.19	0.114	0.6	0.12	0.12	0.10	0.12	0.88	0.167	0.020	0.017	0.020	
3.00	0.21	0.124	0.6	0.12	0.12	0.10	0.14	0.5	0.104	0.012	0.010	0.014	
3.50	0.40	0.241	0.6	0.11	0.11	0.11	0.13	0.5	0.201	0.022	0.022	0.026	
4.00	0.46	0.276	0.6	0.25	0.25	0.23	0.25	0.5	0.230	0.058	0.053	0.058	
4.50	0.49	0.294	0.6	0.02	0.02	0.02	0.12	0.5	0.245	0.005	0.005	0.029	where baby carriage was: right behind pylon
5.00	0.48	0.288	0.6	0.35	0.35	0.33	0.37	0.5	0.240	0.084	0.079	0.089	
5.50	0.45	0.270	0.6	0.34	0.34	0.34	0.37	0.5	0.225	0.077	0.077	0.083	
6.00	0.46	0.276	0.6	0.45	0.45	0.39	0.52	0.5	0.230	0.104	0.090	0.120	do over
6.50	0.49	0.294	0.6	0.43	0.43	0.43	0.45	0.5	0.245	0.105	0.105	0.110	
7.00	0.51	0.306	0.6	0.44	0.44	0.33	0.47	0.5	0.255	0.112	0.084	0.120	
7.50	0.55	0.330	0.6	0.35	0.35	0.32	0.40	0.5	0.275	0.096	0.088	0.110	
8.00	0.56	0.336	0.6	0.44	0.44	0.33	0.44	0.5	0.280	0.123	0.092	0.123	
8.50	0.58	0.348	0.6	0.45	0.45	0.38	0.45	0.5	0.290	0.131	0.110	0.131	
9.00	0.62	0.372	0.6	0.45	0.45	0.45	0.53	0.5	0.310	0.140	0.140	0.164	
9.50	0.62	0.372	0.6	0.38	0.38	0.38	0.49	0.5	0.310	0.118	0.118	0.152	
10.00	0.59	0.354	0.6	0.47	0.47	0.42	0.47	0.5	0.295	0.139	0.124	0.139	
10.50	0.59	0.354	0.6	0.41	0.41	0.40	0.42	0.5	0.295	0.121	0.118	0.124	
11.00	0.57	0.342	0.6	0.54	0.54	0.43	0.54	0.5	0.285	0.154	0.123	0.154	
11.50	0.56	0.336	0.6	0.50	0.50	0.46	0.50	0.5	0.280	0.140	0.129	0.140	
12.00	0.54	0.324	0.6	0.47	0.47	0.41	0.47	0.5	0.270	0.127	0.111	0.127	
12.50	0.49	0.294	0.6	0.38	0.38	0.37	0.39	0.5	0.245	0.093	0.091	0.096	

Dist. from initial point (m)	Depth of water at Location (m)	Depth of Measure (m)	Meter position	Velocity				Width (m)	Area (m^2)	Discharge			Comments
				at point (m/s)	(assigned) Mean in vertical (m/s)	Min. (m/s)	Max. (m/s)			Assigned (m^3/s)	Min (m^3/s)	Max (m^3/s)	
13.00	0.43	0.258	0.6	0.34	0.34	0.28	0.34	0.5	0.215	0.073	0.060	0.073	
13.50	0.40	0.240	0.6	0.37	0.37	0.35	0.40	0.5	0.200	0.074	0.070	0.080	
14.00	0.46	0.200	0.6	0.35	0.35	0.33	0.36	0.5	0.230	0.081	0.076	0.083	obstruction upstream, do at 20 cm depth
14.50	0.42	0.252	0.6	0.10	0.10	0.10	0.17	0.5	0.210	0.021	0.021	0.036	
15.00	0.12	0.072	0.6	0.08	0.08	0.08	0.13	0.61	0.073	0.006	0.006	0.010	
15.36	0.00												
West Bank								Sum	6.204	**2.234**	2.017	2.409	

STREAM/RIVER LOCATION: Pine River along 18 - 18w
STREAM STAGE/CONDITION (start): SG-1 TSG 1.055 at 10:44 am, SG-1A TSG 1.271 at 10:43 am, SG-2 at 0.505m at 10:45 am
STREAM STAGE/CONDITION (end): SG-1 TSG 1.054 at 11:25 am, SG-1A TSG 1.269 at 11:24 am, SG-2 TSG at 0.505 at 11:26
VELOCITY METER USED: Swoffer Model 2100 - STDX and CX WAND USED: Model 2100 Sensor
DATE: June 25, 1998 WEATHER: Overcast, hot and muggy STREAM TEMP. 20.82 C at 10:38 am
OPERATORS: Brewster Conant and Matt Bogart

Dist. from initial point (m)	Depth of water at Location (m)	Depth of Measure (m)	Meter position	Velocity				Width	Area	Discharge			Comments
				at point (m/s)	(assigned) Mean in vertical (m/s)	Min. (m/s)	Max. (m/s)	(m)	(m^2)	Assigned (m^3/s)	Min (m^3/s)	Max (m^3/s)	
East Bank													
1.06	0.00	0.000											
1.50	0.13	0.078	0.6	0.28	0.28	0.24	0.33	0.69	0.090	0.025	0.022	0.030	
2.00	0.43	0.258	0.6	0.32	0.32	0.32	0.37	0.5	0.215	0.069	0.069	0.080	
2.50	0.45	0.270	0.6	0.38	0.38	0.30	0.40	0.5	0.225	0.086	0.068	0.090	
3.00	0.39	0.234	0.6	0.33	0.33	0.31	0.36	0.5	0.195	0.064	0.060	0.070	
3.50	0.37	0.222	0.6	0.36	0.36	0.30	0.36	0.5	0.185	0.067	0.056	0.067	
4.00	0.37	0.222	0.6	0.34	0.34	0.34	0.35	0.5	0.185	0.063	0.063	0.065	Something wrong with meter - do over
4.50	0.40	0.240	0.6	0.33	0.33	0.29	0.33	0.5	0.200	0.066	0.058	0.066	
5.00	0.46	0.276	0.6	0.32	0.32	0.28	0.33	0.5	0.230	0.074	0.064	0.076	
5.50	0.50	0.300	0.6	0.35	0.35	0.35	0.40	0.5	0.250	0.088	0.088	0.100	
6.00	0.52	0.312	0.6	0.39	0.39	0.38	0.42	0.5	0.260	0.101	0.099	0.109	
6.50	0.50	0.300	0.6	0.50	0.50	0.46	0.50	0.5	0.250	0.125	0.115	0.125	
7.00	0.52	0.312	0.6	0.43	0.43	0.43	0.49	0.5	0.260	0.112	0.112	0.127	
7.50	0.54	0.324	0.6	0.44	0.44	0.44	0.51	0.5	0.270	0.119	0.119	0.138	
8.00	0.57	0.342	0.6	0.36	0.36	0.34	0.41	0.5	0.285	0.103	0.097	0.117	
8.50	0.60	0.360	0.6	0.40	0.40	0.39	0.42	0.5	0.300	0.120	0.117	0.126	
9.00	0.61	0.366	0.6	0.44	0.44	0.44	0.52	0.5	0.305	0.134	0.134	0.159	
9.50	0.57	0.342	0.6	0.58	0.58	0.43	0.58	0.5	0.285	0.165	0.123	0.165	
10.00	0.58	0.348	0.6	0.54	0.54	0.50	0.58	0.5	0.290	0.157	0.145	0.168	
10.50	0.46	0.276	0.6	0.49	0.49	0.49	0.58	0.5	0.230	0.113	0.113	0.133	
11.00	0.47	0.282	0.6	0.47	0.47	0.43	0.49	0.5	0.235	0.110	0.101	0.115	
11.50	0.49	0.294	0.6	0.51	0.51	0.44	0.52	0.5	0.245	0.125	0.108	0.127	

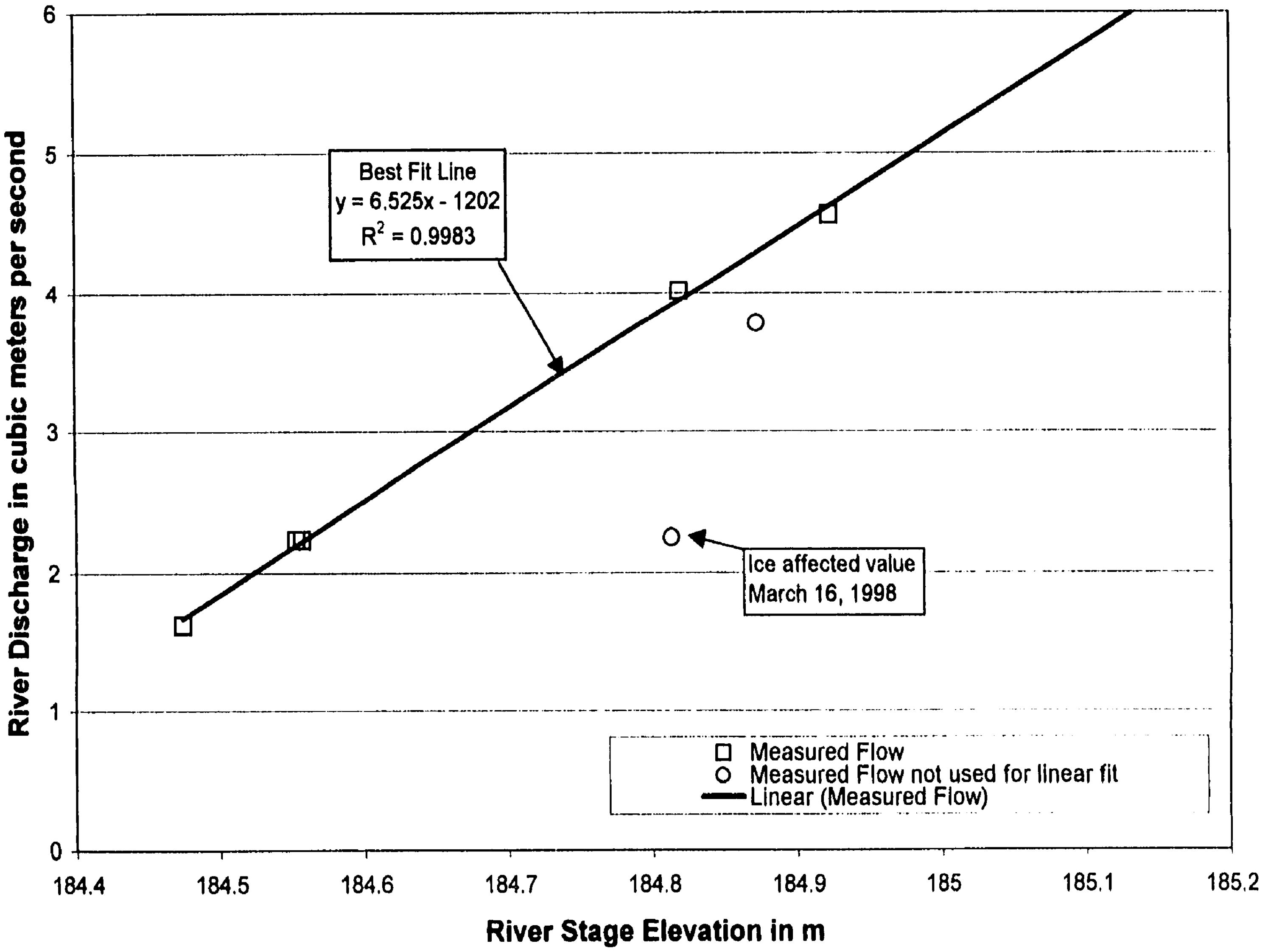
Dist. from initial point (m)	Depth of water at Location (m)	Depth of Measure (m)	Meter position	Velocity				Width (m)	Area (m^2)	Discharge			Comments
				at point (m/s)	(assigned) Mean in vertical (m/s)	Min. (m/s)	Max. (m/s)			Assigned (m^3/s)	Min (m^3/s)	Max (m^3/s)	
12.00	0.46	0.276	0.6	0.39	0.39	0.36	0.41	0.5	0.230	0.090	0.083	0.094	
12.50	0.33	0.198	0.6	0.26	0.26	0.24	0.27	0.5	0.165	0.043	0.040	0.045	
13.00	0.20	0.120	0.6	0.11	0.11	0.09	0.12	0.74	0.148	0.016	0.013	0.018	
13.49	0.00												
West Bank								Sum	5.533	**2.233**	2.064	2.409	

STREAM/RIVER LOCATION: Pine River along 18 - 18w
STREAM STAGE/CONDITION (start): SG-1 TSG 1.133 at 10:34 am, SG-1A TSG 1.343 at 10:35 am
STREAM STAGE/CONDITION (end): SG-1 TSG 1.133 at 11:28 am, SG-1A TSG 1.343 at 11:29 am
VELOCITY METER USED: Swoffer Model 2100 - STDX and CX WAND USED: Model 2100 Sensor
DATE: Sept. 4, 1998 WEATHER: Sunny and warm STREAM TEMP. 14.13 C at 10:39 am
OPERATORS: Brewster Conant and Titia Praamsma

Dist. from initial point (m)	Depth of water at Location (m)	Depth of Measure (m)	Meter position	Velocity				Width (m)	Area (m^2)	Discharge			Comments
				at point (m/s)	(assigned) Mean in vertical (m/s)	Min. (m/s)	Max. (m/s)			Assigned (m^3/s)	Min (m^3/s)	Max (m^3/s)	
East Bank													
1.09	0	0											
1.50	0.16	0.10	0.6	0	0	0	0	0.66	0.106	0.000	0.000	0.000	slight reverse flow
2.00	0.38	0.23	0.6	0.25	0.25	0.20	0.25	0.5	0.190	0.048	0.038	0.048	
2.50	0.45	0.27	0.6	0.20	0.20	0.17	0.20	0.5	0.225	0.045	0.038	0.045	
3.00	0.43	0.26	0.6	0.11		0.11	0.16						30 cm downstream from sandbar face, *split
3.00	0.43	0.09	0.2	0.29	0.18	0.27	0.29	0.5	0.215	0.038	0.034	0.039	split
3.00	0.43	0.34	0.8	0.06		0.05	0.07						split
3.50	0.40	0.24	0.6	0.03		0.03	0.07						30 cm downstream from sandbar face, *split
3.50	0.40	0.08	0.2	0.25	0.13	0.22	0.28	0.5	0.200	0.025	0.022	0.028	split
3.50	0.40	0.32	0.8	0.00		0.00	0.00						split
4.00	0.39	0.23	0.6	0.00		0.00	0.00						30 cm downstream from sandbar face, *split
4.00	0.39	0.08	0.2	0.26	0.13	0.22	0.31	0.5	0.195	0.025	0.021	0.030	split
4.00	0.39	0.31	0.8	0.00		0.00	0.00						split
4.50	0.36	0.22	0.6	0.28	0.28	0.22	0.28	0.5	0.180	0.050	0.040	0.050	
5.00	0.38	0.23	0.6	0.23	0.23	0.22	0.26	0.5	0.190	0.044	0.042	0.049	
5.50	0.46	0.28	0.6	0.22	0.22	0.20	0.24	0.5	0.230	0.051	0.046	0.055	
6.00	0.54	0.32	0.6	0.24	0.24	0.24	0.31	0.5	0.270	0.065	0.065	0.084	
6.50	0.59	0.35	0.6	0.23	0.23	0.23	0.35						propellor wobble
6.50	0.59	0.35	0.6	0.26	0.26	0.23	0.34	0.5	0.295	0.077	0.068	0.100	redo
7.00	0.61	0.37	0.6	0.29	0.29	0.28	0.33	0.5	0.305	0.088	0.085	0.101	

Dist. from initial point (m)	Depth of water at Location (m)	Depth of Measure (m)	Meter position	Velocity				Width (m)	Area (m^2)	Discharge			Comments
				at point (m/s)	(assigned) Mean in vertical (m/s)	Min. (m/s)	Max. (m/s)			Assigned (m^3/s)	Min (m^3/s)	Max (m^3/s)	
7.50	0.61	0.37	0.6	0.33	0.33	0.33	0.39	0.5	0.305	0.101	0.101	0.119	
8.00	0.59	0.35	0.6	0.36	0.36	0.32	0.36	0.5	0.295	0.106	0.094	0.106	
8.50	0.545	0.33	0.6	0.44	0.44	0.42	0.46	0.5	0.273	0.120	0.114	0.125	
9.00	0.52	0.31	0.6	0.48	0.48	0.43	0.51	0.5	0.260	0.125	0.112	0.133	
9.50	0.52	0.31	0.6	0.45	0.45	0.41	0.46	0.5	0.260	0.117	0.107	0.120	
10.00	0.54	0.32	0.6	0.34	0.34	0.28	0.40	0.5	0.270	0.092	0.076	0.108	
10.50	0.54	0.32	0.6	0.43	0.43	0.37	0.43	0.5	0.270	0.116	0.100	0.116	
11.00	0.55	0.33	0.6	0.40	0.40	0.30	0.40	0.5	0.275	0.110	0.083	0.110	
11.50	0.58	0.35	0.6	0.25	0.25	0.16	0.34	0.5	0.290	0.073	0.046	0.099	buried log 5' upstream
12.00	0.69	0.41	0.6	0.25	0.25	0.23	0.28	0.5	0.345	0.086	0.079	0.097	
12.50	0.535	0.32	0.6	0.11	0.11	0.07	0.15	0.5	0.268	0.029	0.019	0.040	next to log sticking up in water
13.00	0.195	0.12	0.6	0	0	0	0	0.67	0.131	0.000	0.000	0.000	
13.42	0.00	0.00	0.6										
West Bank								Sum	5.841	**1.630**	1.430	1.801	

Stage Discharge Relationship For Pine River



APPENDIX E

CORING AND TESTING OF UNCONSOLIDATED DEPOSITS

GEOLOGICAL LOGS OF CORES

- Cores RC1 to RC12: Geological Descriptions
- Core Summary for SC7 to SC10
- Core SC11: Geological Description
- Core SC12: Geological Description
- Core SC13: Geological Description

FALLING HEAD PERMEAMETER TESTS ON CORE SAMPLES

- Falling head permeameter Tests on Core Samples (Table)
- Hydraulic Conductivity vs. Elevation at RC1 and RC2 (Graph)
- Hydraulic Conductivity vs. Elevation at RC3 and RC4 (Graph)
- Hydraulic Conductivity vs. Elevation at RC5 and RC6 (Graph)
- Hydraulic Conductivity vs. Elevation at RC7 and RC8 (Graph)
- Hydraulic Conductivity vs. Elevation at RC9 and RC10 (Graph)
- Hydraulic Conductivity vs. Elevation at RC11 and RC12 (Graph)
- Hydraulic Conductivity vs. Elevation at SC12 15-20 ft (Graph)

FOC ANALYSES OF CORE SAMPLES

CORES RC1 to RC12: Geological Descriptions

Core RC-1
18 - 18W 4.20 m (0.34 cm down stream of PRP7)
Elevation of top of core 95.663 m
Driven Depth 1.00 m
Measured Recovery 0.89 m
Percent Recovery 89%

Depth Interval[1]		Geologic Description
Top (m)	Bottom (m)	
0.00	0.09	Tan brown fine to medium **SAND** (clean)
0.09	0.15	Grey brown very fine **SAND**, sharp angled contact with clay
0.15	1.00	Grey brown silty **CLAY**

Core RC-2
18 - 18W 6.40 m (15 cm down stream of PRP8)
Elevation of top of core 95.647 m
Driven Depth 1.40 m
Measured Recovery 1.29 m
Percent Recovery 92%

Depth Interval[1]		Geologic Description
Top (m)	Bottom (m)	
0.00	0.35	Tan fine to medium **SAND**, (clean), with coarser layer at 4.5 cm and 17.5 cm (with darker layer). Sharp, sloped contact 35 cm to 38.
0.35	0.74	Green grey silty **CLAY**, with shells. Some dark black mottling
0.74	1.13	Lighter green-grey, brown silty **CLAY**, with shells. Fibrous peat zone at 84 to 91 cm as a pocket in the center of the core.
1.13	1.40	Darker brown **SILT** and **PEAT**. Organic rich layer at about 120-128 cm.

Core RC-3
6 - 6W 6.00 m
Elevation of top of core 95.777 m
Driven Depth 0.70 m (but sample only collected in top 50 cm)
Measured Recovery 0.40 m
Percent Recovery 57% (or 78% for top 50 cm)

Depth Interval[1]		Geologic Description
Top (m)	Bottom (m)	
0.00	0.16	Tan brown fine to very fine **SAND**, clean
0.16	0.19	Tan brown fine to medium **SAND**, clean
0.19	0.50	Tan brown fine to very fine **SAND**, clean. Hit a stone at this point, no more recovery, tube is blocked

Core RC-4
6 - 6W 5.65 m
Elevation of top of core 95.827 m
Driven Depth 1.40 m
Measured Recovery 1.00 m
Percent Recovery 71%

Depth Interval[1]		Geologic Description
Top (m)	Bottom (m)	
0.00	0.42	Tan fine **SAND**, clean
0.42	0.50	Tan fine **SAND**, with pebble and rusted chrome pipe
0.50	0.69	Grey brown fine to very fine **SAND**
0.69	0.76	Black brown, organic rich fine to medium **SAND** with bark and shells
0.76	0.99	Grey brown fine to very fine **SAND**, with shells
0.99	1.05	Large rounded stone along with part of core catcher
1.05	1.40	Grey-brown blackish, silty very fine **SAND**, with lots of shells

Core RC-5
6 - 6W 7.05m
Elevation of top of core 95.716 m
Driven Depth 1.40 m
Measured Recovery 1.00 m
Percent Recovery 71%

Depth Interval[1]		Geologic Description
Top (m)	Bottom (m)	
0.00	0.20	Grey fine to very fine **SAND**, with 0.5 cm pockets of organic material
0.20	0.22	Grey medium SAND, clean (water washed) and is the coarsest layer in the core
0.22	0.57	Grey fine to medium **SAND**, has 0.5 cm more shell rich layers. A chunk of 3 cm glass found with stick at 0.26 to 0.31 cm
0.57	0.76	Grey fine to medium **SAND**, little silt, sticks and organic chips. At top of layer is a 1 cm clayey silt layer
0.76	0.90	Grey fine **SAND**, some shells.
0.90	0.92	Grey **SAND**, darker silt with sticks and trace peat
0.92	1.01	Grey fine **SAND**, no shells, trace silt, pretty uniform, like 76 to 90 cm zone.
1.01	1.40	Grey fine to medium **SAND**, silty, with medium shell fragments and some brown peaty material

Core RC-6
8 - 8W 7.40m
Elevation of top of core 95.542 m
Driven Depth 1.30 m
Measured Recovery 0.96 m
Percent Recovery 74%

Depth Interval[1]		**Geologic Description**
Top (m)	**Bottom (m)**	
0.00	0.36	Light tan grey fine to very fine **SAND**, horizontal layering, no traces of organic rich layers. Clean sand, recently deposited material
0.36	0.51	Grey very fine **SAND**, little organic material, trace silt. Transition zone, top is a brown black organic 1 cm thick curved layer. Zone is generally finer as go down.
0.51	0.62	Grey fine **SAND**, some silt, trace clay with woody debris. Wood is still light brown in color with chunks up to 1.5 cm in size
0.62	0.83	Grey fine **SAND**, little very fine sand, trace speckled with medium sized shell fragments
0.83	1.00	Dark brown **WOODY DEBRIS**, in a mucky peaty matrix. Wood pieces up to 2 to 3 cm in length. No sand.
1.00	1.30	Grey **SILT** and very fine to fine sand, little shell fragments. Shells are medium sized with some whole shells.

Core RC-7
10 - 10W 4.10 m
Elevation of top of core 95.665 m
Driven Depth 1.40 m
Measured Recovery 1.06 m
Percent Recovery 76%

Depth Interval[1]		**Geologic Description**
Top (m)	**Bottom (m)**	
0.00	0.54	Tan-grey fine **SAND**, becoming very fine sand at times. Relatively clean, few shells except in thin (<1cm) layers. No organics except occasionally with shells. Horizontal layering. Finer sand zones were at depths of 19-25, 31-39, and 46-50 cm. Shell layers were at depths of 7, 8, 40, and 42 cm
0.54	0.59	Grey-tan fine to medium **SAND** with shells. Organic silt layers 0.5 cm thick are at the top and bottom of this layer.
0.59	0.76	Grey-tan very fine to fine SAND. Generally clean. Organic chunks with light brown stick at 64-65 cm. Finer zone at 73-76 cm.
0.76	0.77	Grey silty very fine SAND. Erosional contact with sticks and chunk of bark (1-2 cm in size).
0.77	0.83	Grey-tan fine **SAND**, trace shells. Clean. Like 59-76 cm zone.
0.83	0.91	Grey fine to coarse SAND and fine gravel, chunks of wood and 2cm diameter ball of clay. Triangular, 4 cm long, piece of a 33-rpm record found at 83 cm.
0.91	1.15	Grey fine to very fine **SAND**. Still clean. Iron stained zone at 15-20 degree angle at a depth of 105-108 cm

RC7 Continued

Depth Interval[1]		Geologic Description
Top (m)	Bottom (m)	
1.15	1.25	Grey fine **SAND,** fair amount of shells relative to above layer. Transition zone to next layer.
1.25	1.40	Grey to darker grey **SILT**, little clay. Top 1 cm has dark brown bark and organics. Rest has scattered light brown woody material up to 10% of core. Trace shells. Low hydraulic conductivity layer

Core RC-8
12 -12W 8.30 m
Elevation of top of core 95.664 m
Driven Depth 1.40 m
Measured Recovery 1.015 m
Percent Recovery 73%

Depth Interval[1]		Geologic Description
Top (m)	Bottom (m)	
0.00	0.10	Tan fine to very fine **SAND**. Clean, trace of shells, orange tint.
0.10	0.28	Grey very fine **SAND**. Clean, no organics, no shells.
0.28	0.38	Grey fine **SAND**, little medium shells, trace organics. Clean.
0.38	0.42	Grey fine **SAND**. Uniform and clean
0.42	0.57	Grey fine to medium **SAND**. Clean, shell zone at 49-50 cm.
0.57	0.68	Grey fine **SAND**. Clean, with horizontal layering.
0.68	0.90	Grey fine to medium **SAND**. Clean, trace of organics, and fair amount of shells at 71-83 cm.
0.90	0.99	Grey very fine **SAND**. Uniform and clean
0.99	1.40	Dark grey very fine **SAND**, trace silt. Organic rich in zones, little shells, no chunks of wood.
		Note: On vertical edge of core there was a orange tan colored 1-2 cm wide column in the sand extending from 0 to 18 cm depth. This might possibly be and old temperature probe hole or profiler probe hole.

Core RC-9
14 - 14W 4.00m
Elevation of top of core 96.139 m (approximate)
Driven Depth 1.80 m
Measured Recovery 1.260 m
Percent Recovery 70%

Depth Interval[1]		Geologic Description
Top (m)	Bottom (m)	
0.00	0.17	Tan fine **SAND**. Clean and uniform, horizontal layering, no organics
0.17	0.19	Grey tan very fine **SAND**, with chunk of stick
0.19	0.30	Tan fine **SAND**. Clean and uniform, bottom 29-30 cm is shelly and organic rich

RC9 Continued

Depth Interval[1]		Geologic Description
Top (m)	Bottom (m)	
0.30	0.40	Grey tan very fine **SAND**. Uniform, horizontal layer. Like 17-19 cm layer. Light brown wood chunk at 35 cm and carbonized dark brown wood chunk at 38 cm.
0.40	0.54	Tan fine to medium **SAND**. Clean, no organics. Sloped contact with clay from 54 to 55 cm. Very fine sand layer 0.5 cm thick, lies directly on contact.
0.54	0.72	Grey to olive grey **CLAY**. Mushy, "fat" clay, no organics. Top 1.5 cm of clay has an iron stained weathering tint. A subvertical 2-3 mm wide sand filled fracture/crack extends down from 54 to 64 cm.
0.72	0.74	Black grey very fine **SAND** layer, little to trace silt. Pretty clean. This horizontal 1.5 cm thick sand stringer is the only one found in the clay.
0.74	1.23	Grey to olive grey **CLAY**. Like the above clay, but looks more mushy.
1.23	1.73	Grey to lighter grey brown **CLAY**. Alternating horizontal bands (2-3 cm thick) of grey and light brown clay. Trace shells here and there.
1.73	1.80	Dark brown silty **CLAY**. More organic rich than above clays.

Core RC-10
14 - 14W 7.00m
Elevation of top of core 95.710 m
Driven Depth 1.50 m
Measured Recovery 1.12 m
Percent Recovery 75%

Depth Interval[1]		Geologic Description
Top (m)	Bottom (m)	
0.00	0.24	Grey tan very fine to fine **SAND**. Clean, no organics, trace shells. Sand is medium and has more shells at 22-24 cm.
0.24	0.34	Grey very fine **SAND**, trace silt, trace dark brown black organics.
0.34	0.66	Grey tan fine to medium **SAND**. Pretty clean, gets finer with depth. Some shells in 0.5 cm layers. Coarser than 0-24 cm layer.
0.66	0.77	Grey to grey-tan very fine **SAND**, trace shells. Clean, no organics.
0.77	1.14	Grey-tan fine to medium **SAND** alternating with 1 cm thick more shelly, coarser zones and finer greyer zones.
1.14	1.34	Dark grey silty fine **SAND**. More organic rich pockets at 124 and 127 cm. Decayed shell or calcareous pebble at 120 cm.
1.34	1.50	Dark brown-grey fine **SAND**, little silt. Pockets of organics and fair amount of shells. Like above layer but more shells and a bit coarser.

Core RC-11
16 - 16W 6.10m
Elevation of top of core 95.729 m
Driven Depth 1.50 m
Measured Recovery 1.10 m
Percent Recovery 73%

Depth Interval[1]		**Geologic Description**
Top (m)	**Bottom (m)**	
0.00	0.10	Grey very fine **SAND**. Uniform and clean. Some sticks and twigs at about 0 to 5 cm.
0.10	0.25	Grey tan fine to medium **SAND** with alternating 0.5 cm thick shelly layers every 2 cm or so. Clean, no organics.
0.25	0.32	Grey very fine **SAND** with trace organic material. Uniform, clean, no silt.
0.32	1.03	Grey tan fine **SAND**, little medium sand. Horizontal layers, occasional coarser zone with shells at 55-56 cm and at 96 cm. This layer has a sharp slanted contact with the clay 103-107 cm.
1.03	1.19	Tan-brown silty **CLAY**. No sticks, slimey to touch.
1.19	1.28	Darker tan-brown silty **CLAY**. Rotting stick at 128 cm.
1.28	1.36	Grey darker tan-brown silty **CLAY**, trace sand. Still slimey.
1.36	1.50	Dark black brown silty **CLAY** to clayey **SILT**, little fibrous peat in the bottom 2 cm. Some iron stained pockets.

Core RC-12
24 - 22W 7.00m (approximate)
Elevation of top of core 95.718 m (approximate)
Driven Depth 1.40 m
Measured Recovery 1.165 m
Percent Recovery 83%

Depth Interval[1]		**Geologic Description**
Top (m)	**Bottom (m)**	
0.00	0.12	Grey-tan very fine to fine **SAND**. Orange tint to material. There is one organic rich, 1 cm thick layer at a 30 degree angle.
0.12	0.27	Grey very fine to fine **SAND**. Shelly. Very fine sand lies at bottom of layer at contact with clay.
0.27	0.65	Grey-olive-grey **CLAY**. No shells or organic pockets. Similar to clay found in RC9
0.65	0.83	Browner olive-grey **CLAY**. Same as above clay, just a color transition to the browner clay below
0.83	1.21	Tan grey-brown silty **CLAY**. No shells or organics. Becomes dark brown at depth. Spongy to touch.
1.21	1.40	Dark brown silty **CLAY**. Fibrous with woody chips - peaty.

Notes:

[1] Depth interval top and bottom have been corrected for partial core recovery using measurements of recovery collected every 10 cm as the core was being driven in

Elevations can be converted to mean sea level by adding 88.18 m to them

CORE SUMMARY FOR SC7 to SC10

Core	Cored interval DBG (ft)	Cored interval DBG (m)	Total recovery in core (m)	Percent recovery	Dominant geological material for interval
SC7-A	0.0 - 5.0	0.0 - 1.52	0.94	62	Silt and peat
SC7-B	5.0 - 10.0	1.52 - 3.05	1.16	76	Silt and peat little sand
SC7-C	10.0 - 15.0	3.05 - 4.57	0.00	0	?
SC7-D	15.0 - 20.0	4.57 - 6.10	1.44	94	Sand
SC7-E	20.0 - 25.0	6.10 - 7.62	1.32	87	Sand
SC8-A	0.0 - 4.7	0.0 - 1.42	0.89	63	Silt and peat
SC8-A Repeat	0.0 - 5.0	0.0 - 1.52	1.04	68	Silt and peat
SC8-B	5.0 - 10.0	1.52 - 3.05	1.23	81	Peat and silty sand
SC8-C	10.0 - 15.0	3.05 - 4.57	1.27	83	Peat and silt and clay
SC8-D	15.0 - 20.0	4.57 - 6.10	1.52	100	Sand
SC8-E	20.0 - 25.0	6.10 - 7.62	1.52	100	Sand
SC9-A	0.0 - 4.0	0.0 - 1.22	0.88	72	Silt and peat
SC9-A Repeat	0.0 - 5.0	0.0 - 1.52	0.68	45	Silt and peat
SC9-B	5.0 - 10.0	1.52 - 3.05	1.26	83	Silt and peat
SC9-C	10.0 - 15.0	3.05 - 4.57	1.45	95	Silt and clay/over sand
SC9-D	15.0 - 20.0	4.57 - 6.10	1.52	100	Sand
SC9-E	20.0 - 25.0	6.10 - 7.62	1.50	98	Sand
SC10-A	0 - 4.91	0 - 1.50	0.95	63	Silt and Peat
SC10-B	6.17 - 10.0	1.88 - 3.05	0.84	72	Silt and Sand
SC10-C	10.0 - 15.0	3.05 - 4.57	1.50	98	Silt and Sand
SC10-D	15.0 - 20.0	4.57 - 6.10	1.50	98	Sand, Silt and Clay
SC10-E	20.0 - 25.0	6.10 - 7.62	1.50	98	Sand, Silt and Clay

Note:

DBG = Depth below ground surface
Core SC7 collected May 8, 1996
Core SC8 collected May 9, 1996
Core SC9 collected May 9-10, 1996
Core SC10 collected at 2 locations 3.5 ft apart on June 17, 1996
Holes SC7-SC9 grouted May 15, 1996 to depth of 14-15 feet

Core SC11: Geologic Description

Core	Cored interval DBG (m)	Total rec. (m)[1]	Rec. %[2]	Dist. Down core top[3] (cm)	Dist. Down core bot.[4] (cm)	Total Depth top[5] (m)	Total Depth bot[6] (m)	Geologic Description of Materials[7]
SC11-A	0 - 1.52	0.972	64%	0	10	0.00	0.16	Dark brown organic **SILT**
				10	21	0.16	0.33	Tan very fine **SAND**
				21	29	0.33	0.45	Dark brown **SILT** grades down into fine **SAND**
				29	33	0.45	0.52	Tan fine **SAND** and **SILT** (mixed)
				33	46	0.52	0.72	Dark brown **SILT**
				46	63	0.72	0.99	Light brown to brown very fine **SAND** and silt. Chunk of asphalt at 56 to 59 cm. Wetter at 56 cm.
				63	83	0.99	1.30	Light medium brown very fine **SAND** and silt. Wet, with twigs and sticks at 76 cm. Grades down into lower grey material
				83	97	1.30	1.52	Grey **SILT**, trace fine sand, with chunks of wood
								NOTE: hard spot at 3 ft depth and end of tube bent when retrieved
SC11-B	1.52 - 3.05	1.26	83%	0	13	1.52	1.68	Grey very fine **SAND** and silt, trace twigs. Clay layer at 7 cm.
				13	33	1.68	1.92	Grey fine **SAND**, trace medium, lots of sticks and twigs
				33	34	1.92	1.93	Tin foil that was put in to separate partial recovery from attempt 2 (above) from the good recovery (below) for attempt 3 (this core)
				34	86	1.93	2.56	Brown grey very fine **SAND** and silt. Soupy appearance and lots of fibrous sticks and twigs up to 0.5 cm in size
				86	95	2.56	2.67	Grey very fine **SAND**, uniform and cleaner than above, trace twigs.
				95	102	2.67	2.75	Dark brown organic **SILT**, peaty layer.
				102	106	2.75	2.80	Grey very fine to fine **SAND**, like above 86 to 95 cm layer
				106	110.5	2.80	2.85	Grey to tan grey silty **CLAY**, loose.
				110.5	116.5	2.85	2.93	Grey very fine **SAND** grading down into a silty **CLAY** with shell fragments
				116.5	126	2.93	3.05	Dark grey **CLAY**. Tough, with trace shells.

Core	Cored interval DBG (m)	Total rec. (m)[1]	Rec. %[2]	Dist. Down core top[3] (cm)	Dist. Down core bot.[4] (cm)	Total Depth top[5] (m)	Total Depth bot[6] (m)	Geologic Description of Materials[7]
								NOTE: First attempt got only about 1 ft, retrieved grey medium sand with brownish silt. Second attempt, move over 1 ft, have lots of problems at 6'10" depth (1'10" of recovery is still in barrel as move to next spot). So, place tin foil in base of partially filled core barrel, move to new spot, and hand auger and proceed from 6'10" depth.
SC11-C	3.05 - 4.57	1.47	97%	0	15	3.05	3.21	Brown grey **SILT** and **SAND**, interbedded. Silt is clayey
				15	48	3.21	3.55	Olive brown silty **CLAY** with shell fragments.
				48	50	3.55	3.57	Very fine grey **SAND** lense, with fibrous brown to red brown stick.
				50	69	3.57	3.76	Olive brown **SILT**, like above with shells.
				69	98	3.76	4.06	Grey brown very fine **SAND** and **SILT** zones alternating. Trace shells and organic material.
				98	124	4.06	4.33	Grey brown very fine to fine **SAND**, some silt at layers and still some shells.
				124	137	4.33	4.47	Brown **SILT**, muddy with a little sand
				137	147	4.47	4.57	Grey brown very fine to fine **SAND**, trace silt and shells, cleaner
SC11-D	4.57 - 6.10	1.40	92%	0	7	4.57	4.64	Grey brown very fine **SAND**
				7	10.5	4.64	4.68	Grey brown silty very fine **SAND**
				10.5	69	4.68	5.26	Grey brown very fine **SAND**, with occasional silt and shelly layers and trace wood bits. Shells at 12, 59, and 66 cm.
				69	100	5.26	5.57	Grey very fine **SAND**, trace shells, no sticks
				100	109	5.57	5.66	Grey very fine **SAND** with lots of shells, white pebbly looking like concretions 1 to 4 mm diameter
				109	125	5.66	5.82	Grey very fine **SAND**, trace shells. Uniform and fairly clean
				125	127	5.82	5.84	Grey fine to coarse **SAND** with rounded pebbles
				127	140	5.84	5.97	Grey very fine **SAND**, uniform and pretty clean. Massive but may have run in core
				140	152	5.97	6.10	Empty - no sample, fell out of bottom of core
SC11-E	6.10 - 7.62	1.505	99%	0	46	6.10	6.56	Grey very fine **SAND**, uniform, looks clean, no shells or organics
				46	56	6.56	6.67	Grey very fine **SAND** (almost silt), uniform
				56	150.5	6.67	7.62	Grey very fine **SAND**, uniform

Core	Cored interval DBG (m)	Total rec. (m)[1]	Rec. %[2]	Dist. Down core top[3] (cm)	Dist. Down core bot.[4] (cm)	Total Depth top[5] (m)	Total Depth bot[6] (m)	Geologic Description of Materials[7]
SC11-F	7.62 - 9.14	1.52	100%	0	63	7.62	8.25	Grey very fine **SAND**. Uniform, no shells or twigs or other size material. A 0.5 cm clay layer at 38 cm and at 63 cm. Layer at 30-40 degree angle at 63 cm
				63	152	8.25	9.14	Grey fine **SAND**, uniform and massive.

Notes:

[1] Total Rec. = total length of soil recovered in core

[2] Percent recovery, the length of the recovered core divided by the distance the core was advanced

[3] Distance down from the top of the core to the top of the geological layer

[4] Distance down from the top of the core to the bottom of the geological layer

[5] Total depth below ground of the top of the geological layer (corrected for partial core recovery)

[6] Total depth below ground of the bottom of the geological layer (corrected for partial core recovery)

[7] The distances referred to in the geological descriptions (e.g. 56 cm) are distances along the particular core segment and are not corrected depths

Core SC12: Geologic Description

Core	Cored interval DBG (m)	Total rec. (m)[1]	Rec. %[2]	Dist. Down core top[3] (cm)	Dist. Down core bot.[4] (cm)	Total Depth top[5] (m)	Total Depth bot[6] (m)	Geologic Description of Materials[7]
SC12-A	0 - 1.52	1.09	72%	0	3	0.00	0.04	Light brown very fine **SAND**, clean
				3	8.5	0.04	0.12	Brown **SILT**, grass roots, little fine sand
				8.5	27	0.12	0.38	Light brown **SAND**, trace silt, clean
				27	48	0.38	0.67	Interlayered brown **SILT** with fine to very fine **SAND**
				48	84	0.67	1.17	Brown **SILT**, trace roots. At bottom a 2mm iron stained sand bed
				84	109	1.17	1.52	Blacker brown, clayey mucky looking **SILT**, not quite peaty, but has wood chunks at 106-109 cm
SC12-B	1.52 - 3.05	1.045	69%	0	7	1.52	1.62	Black organic **SILT** with trace wood bits
				7	46	1.62	2.19	Black to grey black **SILT**, some grey clayey zones and circular 4 ring root at 27cm
				46	49	2.19	2.23	Grey very fine **SAND**, uniform and clean
				49	53	2.23	2.29	Black brown **SILT**, like above
				53	56	2.29	2.33	Grey very fine **SAND**, uniform and clean, like above
				56	58	2.33	2.36	Black brown **SILT**
				58	60	2.36	2.39	Grey very fine **SAND**
				60	65.5	2.39	2.47	Black brown **SILT**, like above
				65.5	67	2.47	2.49	Grey brown fine **SAND**, clean, lies on top of clay
				67	73	2.49	2.58	Greenish grey clayey **SILT**, slimey, with shells
				73	104.5	2.58	3.04	Darker greenish grey **SILT** grades into browner slimey **SILT**
SC12-C	3.35 - 4.11	0.7	92%	*				NOTE: Core barrel dropped to 11 ft through 1 ft of soft material. Refusal at 13 ft, only expect 2.5 ft of core.
				0	13	3.35	3.49	Chocolate brown, loose **SILT** with wood chunks ("loon shit")
				13	52	3.49	3.92	Same **SILT** as above, but is soft and slimey
				52	57	3.92	3.97	Layer has lots of **WOOD**
				57	70	3.97	4.11	Same **SILT** as 13 - 52 interval, some 2-3 cm gaps in core because core slipped in tube
								NOTE: No core is collected between 13.5 and 15 ft
SC12-D	4.57 - 6.10	1.35	89%	0	6.5	4.57	4.64	Olive-grey **CLAY**, slimey but tough, with little chunks of wood
				6.5	11	4.64	4.68	Brown-black **PEAT**, wood chunks
				11	46	4.68	5.03	Brown to tan-brown clayey **SILT**, coarsens downward, small back chunks in sample

Core	Cored interval DBG (m)	Total rec. (m)[1]	Rec. %[2]	Dist. Down core top[3] (cm)	Dist. Down core bot.[4] (cm)	Total Depth top[5] (m)	Total Depth bot[6] (m)	Geologic Description of Materials[7]
				46	60	5.03	5.17	Brown - tan, very fine **SAND**, coarsens downward
				60	135	5.17	5.92	Tan fine to medium **SAND**, trace coarse sand, clean
				135	152	5.92	6.10	NOTE: Bottom of core empty, probably fell out
SC12-E	6.10 - 7.62	1.51	99%	0	13	6.10	6.23	Tan brown fine **SAND**, clean
				13	28	6.23	6.38	Tan brown medium **SAND**, little fine sand, clean
				28	34.5	6.38	6.45	Tan fine **SAND**, clean (no fines)
				38	41	6.48	6.51	Tan to a tinted orange, very fine to fine **SAND**. A dark subhorizontal layer at 40.5 cm
				41	47	6.51	6.57	Brown fine **SAND** and rounded 1/2-inch gravel
				47	52	6.57	6.62	Brown fine **SAND**, with orange iron stain
				52	151	6.62	7.62	Tan brown to grey white fine **SAND**, very uniform, massive

Notes:

[1] Total Rec. = total length of soil recovered in core

[2] Percent recovery, the length of the recovered core divided by the distance the core was advanced

[3] Distance down from the top of the core to the top of the geological layer

[4] Distance down from the top of the core to the bottom of the geological layer

[5] Total depth below ground of the top of the geological layer (corrected for partial core recovery)

[6] Total depth below ground of the bottom of the geological layer (corrected for partial core recovery)

[7] The distances referred to in the geological descriptions (e.g. 56 cm) are distances along the particular core segment and are not corrected depths

Core SC13: Geologic Description

Core	Cored interval DBG (m)	Total rec. (m)[1]	Rec. %[2]	Dist. Down core top[3] (cm)	Dist. Down core bot.[4] (cm)	Total Depth top[5] (m)	Total Depth bot[6] (m)	Geologic Description of Materials[7]
SC13-A	4.57 - 6.10	1.47	97%	0	3	4.57	4.60	Grey **CLAY** with fibrous peat and woody material
				3	11	4.60	4.68	Dark brown-black **PEAT** and organic silt. Chunks of wood, some are browner and newer looking than others (Writt's marker bed)
				11	46	4.69	5.05	Tan very fine **SAND**. Clean, no silt, trace pockets of organic material
				46	84	5.05	5.44	Tan very fine to fine **SAND**, trace silt, trace coarse sand and fine gravel, trace shells. Some organic pockets 1-2 cm long. Coarser near the top. Gravel is rounded. Layer is more organic rich than layers above and below.
				84	113.5	5.44	5.74	Tan fine **SAND**, litle medium to coarse sand. Clean and water washed, layer is coarser with depth.
				113.5	121.5	5.75	5.83	Yellow tan **SILT** and fine to coarse sand, trace fine gravel, trace clay. Clay possibly present as eroded balls or chunks. Fine in overal appearance and has a sharp flat contact with underlying sand.
				121.5	147	5.83	6.09	Tan to grey tan, very fine **SAND**, almost silt sized. Uniform in grain size, has a bit of horizontal layering of dark bands (bands 2-3 mm thick with a 1-2 cm spacing)
SC13-B	6.10 - 7.62	1.40	92%	0	4			Empty - no sample
				4	41.5	6.14	6.51	Tan very fine **SAND**, almost silt sized. Relatively clean and uniform. Some layering on a 0.5 to 1 cm interval with dark bands 2-3 mm thick. The bands are angled 30 degrees above 25 cm depth but then almost horizontal below. Thin broken clay layer (2-3 mm thick) at 21.5 to 23.5 cm depth

				41.5	60	6.51	6.70	Tan very fine **SAND**, almost silt sized. Like above but more frequent clay layers. Clay layers are angled and some are off set (faulted). Clay found at 41.5-43 (4 mm thick), 46-49 (2 mm thick), about 4 (1 mm thick) ones to 57 cm. Silt and clay from 57 to 60 cm with a 0.5 cm thick clay band.
				60	144	6.70	7.54	Tan very fine **SAND**, almost silt sized. Clean and uniform, no clay layers. Dark banding from 60 -70 cm (horizontal) and from 70-106 cm (angled). A root or organic string 2 mm wide in center of core, and runs 5 cm vertically from 64 to 69 cm depth
				144	152			Empty - no sample in lower 3-4 inches, it fell out of bottom of core
SC13-C	7.62 - 9.14	1.408	93%	0	8			Empty - no sample
				8	73	7.63	8.33	Greyish tan very fine **SAND**, clean and uniform. Similar to bottom of last core. Horizontal to concave down layering (2-3 mm thick) dark banding on a 1- 2 cm interval, but a bit less as goes down.
				73	148.8	8.33	9.15	Tan very fine to fine **SAND**, clean and uniform (less dark than above). No strong layering, massive.
SC13-D	9.14 - 10.67	1.45	95%	0	5			Empty - no sample
				5	19	9.15	9.29	Tan very fine to fine **SAND**, clean and uniform. Sharp contact with finer layer below
				19	82	9.29	9.95	Tan very fine **SAND** and Silt. Uniform and has hints of clayey zones at 25 cm, 28 cm, 69 cm (a 4 mm thick yellow clay layer), 75.5 cm and 81.5 cm. Dark bands at 45 degree angle at 40 cm and horizontal below it.
				82	150	9.95	10.67	Tan very fine **SAND**, a bit of banding at the top but massive at bottom (105 to 150 cm). The top 3 cm looks more iron yellow than tan grey.
SC13-E	10.67-12.19	1.451	95%	0	5			Empty - no sample
				5	25	10.67	10.88	Tan very fine **SAND**, massive, no bedding. Like bottom of previous core.
				25	50	10.88	11.14	Tan to grey tan, very fine **SAND** and silt. Finer as go down. Has horizontal to subhorizontal dark bands. Top part (25 -38 cm) is a bit tanner in color.

				50	150.1	11.14	12.19	Grey tan very fine **SAND**, is almost silt sized. Like above layer. Dark banding at 45 degree angle from 54 to 70 cm, but horizontal the rest of the way down. The bottom 30 cm is more massive and much harder to cut with knife as open core. The bottom 45 cm of the core driving was also hard.

Notes:

[1]Total Rec. = total length of soil recovered in core

[2] Percent recovery, the length of the recovered core divided by the distance the core was advanced

[3] Distance down from the top of the core to the top of the geological layer

[4] Distance down from the top of the core to the bottom of the geological layer

[5] Total depth below ground of the top of the geological layer (corrected for partial core recovery)

[6] Total depth below ground of the bottom of the geological layer (corrected for partial core recovery)

[7] The distances referred to in the geological descriptions (e.g. 56 cm) are distances along the particular core segment and are not corrected depths

FALLING HEAD PERMEAMETER TESTS ON CORE SAMPLES

Core	Sampled Interval Depth Start (m)[1]	Sampled Interval Depth End (m)[1]	Sampled Interval Elevation Start (m)	Sampled Interval Elevation End (m)	K in cm/s at 10 °C[2]	Porosity
RC1	0.00	0.04	183.84	183.80	2.26E-02	34%
RC1	0.04	0.09	183.80	183.75	2.42E-02	36%
RC1	0.09	0.16	183.75	183.69	5.70E-03	32%
RC1	0.16	0.26	183.69	183.59	4.48E-05	57%
RC1	0.26	0.31	183.59	183.53	2.36E-05	64%
RC2	0.00	0.05	183.83	183.78	2.05E-02	36%
RC2	0.05	0.10	183.78	183.73	1.82E-02	38%
RC2	0.10	0.16	183.73	183.67	1.40E-02	36%
RC2	0.16	0.21	183.67	183.61	1.30E-02	38%
RC2	0.21	0.28	183.61	183.55	1.77E-02	36%
RC2	0.28	0.36	183.55	183.46	2.86E-02	36%
RC2	0.36	0.42	183.46	183.41	7.48E-05	63%
RC3	0.00	0.06	183.96	183.89	1.79E-02	33%
RC3	0.06	0.13	183.89	183.83	2.12E-02	35%
RC3	0.13	0.19	183.83	183.77	2.69E-02	41%
RC3	0.19	0.25	183.77	183.71	1.80E-02	46%
RC3	0.25	0.31	183.71	183.64	1.70E-02	40%
RC3	0.31	0.39	183.64	183.57	1.78E-02	37%
RC3	0.39	0.46	183.57	183.50	1.52E-02	37%
RC3	0.46	0.50	183.50	183.46	1.60E-02	36%
RC4	0.00	0.07	184.01	183.94	1.93E-02	34%
RC4	0.07	0.13	183.94	183.87	1.90E-02	35%
RC4	0.13	0.20	183.87	183.81	2.02E-02	36%
RC4	0.20	0.30	183.81	183.71	2.32E-02	37%
RC4	0.30	0.36	183.71	183.65	1.84E-02	37%
RC4	0.36	0.42	183.65	183.59	1.90E-02	35%
RC4	0.42	0.52	183.59	183.49	1.23E-02	43%
RC4	0.52	0.61	183.49	183.39	2.57E-02	38%
RC4	0.61	0.69	183.39	183.32	2.14E-02	37%
RC4	0.69	0.76	183.32	183.24	2.57E-02	59%
RC4	0.76	0.83	183.24	183.18	1.34E-02	45%
RC4	0.83	0.90	183.18	183.11	2.13E-02	39%
RC4	0.90	0.98	183.11	183.03	2.39E-02	43%
RC4	0.98	1.05	183.03	182.96	1.73E-02	39%
RC4	1.05	1.12	182.96	182.89	1.43E-02	51%
RC4	1.12	1.18	182.89	182.83	1.41E-02	51%
RC4	1.18	1.24	182.83	182.77	7.56E-03	49%
RC4	1.24	1.30	182.77	182.71	8.81E-03	53%
RC4	1.30	1.40	182.71	182.61	7.24E-03	54%
RC5	0.00	0.04	183.90	183.86	6.02E-03	38%
RC5	0.04	0.08	183.86	183.82	8.90E-03	41%
RC5	0.08	0.13	183.82	183.77	9.21E-03	36%
RC5	0.13	0.19	183.77	183.70	1.02E-02	37%
RC5	0.19	0.26	183.70	183.63	1.78E-02	35%
RC5	0.26	0.34	183.63	183.55	1.12E-02	43%

Core	Sampled Interval Depth Start (m)[1]	Sampled Interval Depth End (m)[1]	Sampled Interval Elevation Start (m)	Sampled Interval Elevation End (m)	K in cm/s at 10 °C[2]	Porosity
RC5	0.34	0.43	183.55	183.47	1.81E-02	40%
RC5	0.43	0.49	183.47	183.40	1.95E-02	36%
RC5	0.49	0.56	183.40	183.34	1.64E-02	38%
RC5	0.56	0.62	183.34	183.28	1.80E-03	57%
RC5	0.62	0.68	183.28	183.21	4.31E-03	44%
RC5	0.68	0.74	183.21	183.16	1.10E-02	48%
RC5	0.74	0.81	183.16	183.09	1.33E-02	40%
RC5	0.81	0.88	183.09	183.01	2.11E-02	41%
RC5	0.88	0.96	183.01	182.93	2.01E-02	41%
RC5	0.96	1.05	182.93	182.84	2.31E-02	37%
RC5	1.05	1.15	182.84	182.75	2.20E-02	41%
RC5	1.15	1.24	182.75	182.66	1.77E-02	54%
RC5	1.24	1.33	182.66	182.56	1.12E-02	56%
RC5	1.33	1.40	182.56	182.50	8.57E-03	64%
RC6	0.00	0.08	183.72	183.65	1.82E-02	32%
RC6	0.08	0.13	183.65	183.59	2.00E-02	35%
RC6	0.13	0.18	183.59	183.54	2.39E-02	38%
RC6	0.18	0.24	183.54	183.48	1.93E-02	36%
RC6	0.24	0.30	183.48	183.42	9.29E-03	33%
RC6	0.30	0.38	183.42	183.34	1.13E-02	36%
RC6	0.38	0.45	183.34	183.28	8.92E-03	39%
RC6	0.45	0.51	183.28	183.21	4.79E-03	46%
RC6	0.51	0.57	183.21	183.15	1.73E-03	56%
RC6	0.57	0.63	183.15	183.09	1.98E-03	46%
RC6	0.63	0.69	183.09	183.03	1.46E-02	39%
RC6	0.69	0.76	183.03	182.96	1.67E-02	34%
RC6	0.76	0.84	182.96	182.89	1.86E-02	54%
RC6	0.84	0.91	182.89	182.81	2.03E-02	80%
RC6	0.91	1.00	182.81	182.73	9.43E-03	77%
RC6	1.00	1.08	182.73	182.64	2.38E-02	53%
RC6	1.08	1.17	182.64	182.56	2.08E-02	55%
RC6	1.17	1.25	182.56	182.47	1.52E-02	56%
RC6	1.25	1.30	182.47	182.42	8.43E-03	51%
RC7	0.00	0.05	183.85	183.80	1.26E-02	33%
RC7	0.05	0.09	183.80	183.75	1.55E-02	41%
RC7	0.09	0.15	183.75	183.70	1.86E-02	34%
RC7	0.15	0.20	183.70	183.64	1.22E-02	37%
RC7	0.20	0.26	183.64	183.59	1.12E-02	31%
RC7	0.26	0.32	183.59	183.52	1.44E-02	36%
RC7	0.32	0.40	183.52	183.44	1.03E-02	41%
RC7	0.40	0.46	183.44	183.39	1.15E-02	37%
RC7	0.46	0.50	183.39	183.34	5.25E-03	35%
RC7	0.50	0.57	183.34	183.27	1.70E-02	39%
RC7	0.57	0.63	183.27	183.21	1.96E-02	38%
RC7	0.63	0.70	183.21	183.14	1.89E-02	34%
RC7	0.70	0.77	183.14	183.07	9.40E-03	36%
RC7	0.77	0.85	183.07	183.00	1.67E-02	34%
RC7	0.85	0.92	183.00	182.92	8.99E-03	38%

Core	Sampled Interval Depth Start (m)^1	Sampled Interval Depth End (m)^1	Sampled Interval Elevation Start (m)	Sampled Interval Elevation End (m)	K in cm/s at 10 °C^2	Porosity
RC7	0.92	1.00	182.92	182.85	1.73E-02	33%
RC7	1.00	1.08	182.85	182.77	2.13E-02	36%
RC7	1.08	1.15	182.77	182.69	1.44E-02	33%
RC7	1.15	1.23	182.69	182.61	1.39E-02	39%
RC7	1.23	1.32	182.61	182.53	4.29E-04	52%
RC7	1.32	1.40	182.53	182.45	2.81E-04	61%
RC8	0.00	0.04	183.84	183.80	2.39E-02	35%
RC8	0.04	0.08	183.80	183.76	2.60E-02	37%
RC8	0.08	0.14	183.76	183.71	1.64E-02	34%
RC8	0.14	0.18	183.71	183.66	2.18E-02	36%
RC8	0.18	0.23	183.66	183.62	1.79E-02	35%
RC8	0.23	0.28	183.62	183.56	1.55E-02	38%
RC8	0.28	0.34	183.56	183.51	2.49E-02	45%
RC8	0.34	0.38	183.51	183.46	1.77E-02	42%
RC8	0.38	0.43	183.46	183.41	1.03E-02	34%
RC8	0.43	0.49	183.41	183.35	2.68E-02	37%
RC8	0.49	0.56	183.35	183.29	2.68E-02	39%
RC8	0.56	0.62	183.29	183.22	2.12E-02	36%
RC8	0.62	0.70	183.22	183.15	1.74E-02	35%
RC8	0.70	0.77	183.15	183.08	2.10E-02	40%
RC8	0.77	0.83	183.08	183.01	2.52E-02	43%
RC8	0.83	0.90	183.01	182.95	1.87E-02	35%
RC8	0.90	0.97	182.95	182.87	1.14E-02	31%
RC8	0.97	1.05	182.87	182.79	1.52E-02	37%
RC8	1.05	1.14	182.79	182.70	1.54E-02	40%
RC8	1.14	1.24	182.70	182.61	2.09E-02	37%
RC8	1.24	1.40	182.61	182.44	2.16E-02	37%
RC9	0.00	0.05	183.32	183.27	1.83E-02	33%
RC9	0.05	0.10	183.27	183.22	1.84E-02	34%
RC9	0.10	0.17	183.22	183.15	2.11E-02	35%
RC9	0.17	0.23	183.15	183.09	1.59E-02	37%
RC9	0.23	0.29	183.09	183.03	2.10E-02	37%
RC9	0.29	0.34	183.03	182.98	1.14E-02	40%
RC9	0.34	0.40	182.98	182.92	8.36E-03	36%
RC9	0.40	0.47	182.92	182.85	2.30E-02	42%
RC9	0.47	0.54	182.85	182.78	2.19E-02	35%
RC9	0.54	0.61	182.78	182.71	TLTM	58%
RC10	0.00	0.05	183.89	183.84	1.02E-02	35%
RC10	0.05	0.12	183.84	183.77	1.04E-02	33%
RC10	0.12	0.18	183.77	183.71	1.80E-02	36%
RC10	0.18	0.24	183.71	183.65	2.29E-02	37%
RC10	0.24	0.31	183.65	183.58	1.01E-02	36%
RC10	0.31	0.36	183.58	183.53	1.88E-02	37%
RC10	0.36	0.40	183.53	183.49	3.38E-02	37%
RC10	0.40	0.45	183.49	183.44	3.89E-02	37%
RC10	0.45	0.51	183.44	183.38	2.49E-02	36%
RC10	0.51	0.57	183.38	183.32	2.17E-02	36%
RC10	0.57	0.64	183.32	183.25	1.65E-02	38%

Core	Sampled Interval Depth Start (m)[1]	Sampled Interval Depth End (m)[1]	Sampled Interval Elevation Start (m)	Sampled Interval Elevation End (m)	K in cm/s at 10 °C[2]	Porosity
RC10	0.64	0.70	183.25	183.19	2.04E-02	34%
RC10	0.70	0.77	183.19	183.12	1.70E-02	36%
RC10	0.77	0.85	183.12	183.04	2.28E-02	37%
RC10	0.85	0.93	183.04	182.96	2.61E-02	40%
RC10	0.93	1.03	182.96	182.86	2.30E-02	38%
RC10	1.03	1.14	182.86	182.75	2.67E-02	42%
RC10	1.14	1.21	182.75	182.68	4.38E-03	46%
RC10	1.21	1.27	182.68	182.62	1.07E-02	46%
RC10	1.27	1.33	182.62	182.56	9.08E-03	44%
RC10	1.33	1.41	182.56	182.48	1.12E-02	48%
RC10	1.41	1.50	182.48	182.39	1.80E-02	45%
RC11	0.00	0.05	183.91	183.86	8.55E-03	37%
RC11	0.05	0.11	183.86	183.80	9.65E-03	34%
RC11	0.11	0.17	183.80	183.74	1.78E-02	31%
RC11	0.17	0.23	183.74	183.68	2.01E-02	37%
RC11	0.23	0.29	183.68	183.62	9.92E-03	37%
RC11	0.29	0.33	183.62	183.58	9.94E-03	34%
RC11	0.33	0.39	183.58	183.52	1.81E-02	35%
RC11	0.39	0.45	183.52	183.46	1.83E-02	31%
RC11	0.45	0.52	183.46	183.39	2.36E-02	36%
RC11	0.52	0.59	183.39	183.32	2.32E-02	36%
RC11	0.59	0.68	183.32	183.23	2.19E-02	33%
RC11	0.68	0.76	183.23	183.15	1.82E-02	34%
RC11	0.76	0.84	183.15	183.07	1.66E-02	32%
RC11	0.84	0.92	183.07	182.99	1.95E-02	35%
RC11	0.92	0.97	182.99	182.94	1.98E-02	35%
RC11	0.97	1.07	182.94	182.84	2.29E-02	37%
RC11	1.07	1.14	182.84	182.77	1.38E-04	67%
RC11	1.14	1.22	182.77	182.69	3.95E-04	68%
RC11	1.22	1.28	182.69	182.62	2.44E-04	69%
RC12	0.00	0.05	183.90	183.85	1.32E-02	34%
RC12	0.05	0.10	183.85	183.80	2.01E-02	44%
RC12	0.10	0.16	183.80	183.74	2.18E-02	41%
RC12	0.16	0.21	183.74	183.69	1.60E-02	43%
RC12	0.21	0.27	183.69	183.63	1.39E-02	38%
RC12	0.27	0.33	183.63	183.57	5.11E-05	61%
RC12	0.33	0.39	183.57	183.51	4.97E-05	65%
SC12 D 15-20	4.92	4.97	181.45	181.40	2.66E-05	48%
SC12 D 15-20	4.97	5.02	181.40	181.35	1.45E-04	44%
SC12 D 15-20	5.02	5.07	181.35	181.30	2.21E-04	41%
SC12 D 15-20	5.07	5.12	181.30	181.25	3.87E-03	40%
SC12 D 15-20	5.12	5.17	181.25	181.20	4.36E-03	35%
SC12 D 15-20	5.17	5.22	181.20	181.15	1.40E-02	30%
SC12 D 15-20	5.22	5.27	181.15	181.10	1.61E-02	30%
SC12 D 15-20	5.27	5.32	181.10	181.05	2.10E-02	39%
SC12 D 15-20	5.32	5.355	181.05	181.01	1.30E-02	31%
SC12 D 15-20	5.355	5.42	181.01	180.95	1.40E-02	31%
SC12 D 15-20	5.42	5.47	180.95	180.90	2.39E-02	35%

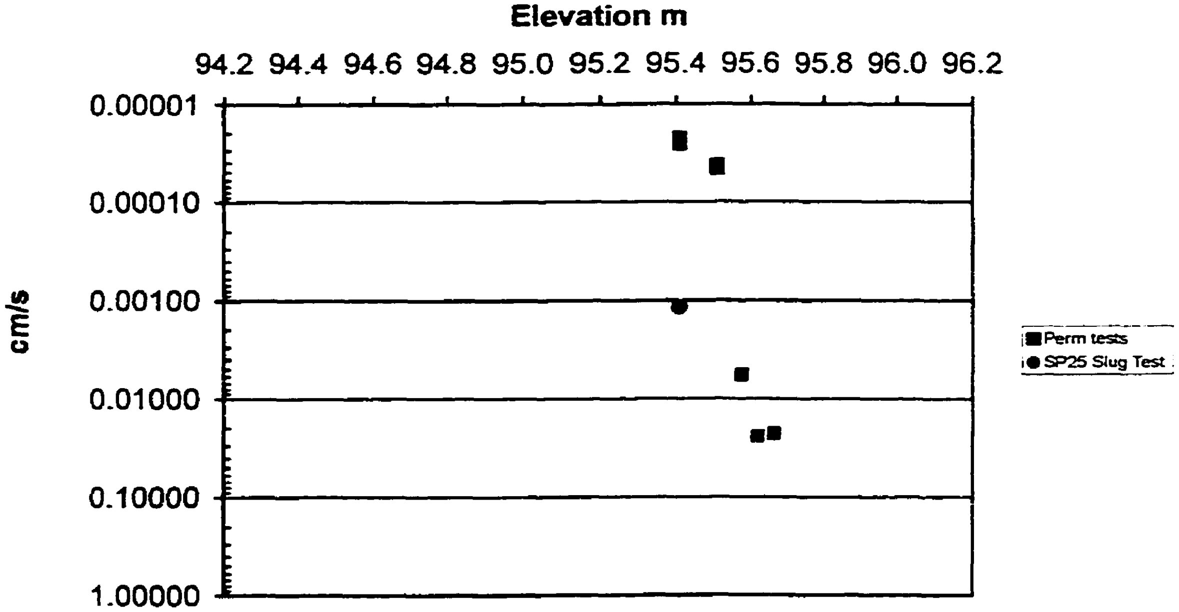
Core	Sampled Interval Depth Start (m)[1]	Sampled Interval Depth End (m)[1]	Sampled Interval Elevation Start (m)	Sampled Interval Elevation End (m)	K in cm/s at 10 °C[2]	Porosity
SC12 D 15-20	5.47	5.52	180.90	180.85	1.00E-02	31%
SC12 D 15-20	5.52	5.57	180.85	180.80	1.19E-02	30%
SC12 D 15-20	5.57	5.62	180.80	180.75	1.02E-02	40%
SC12 D 15-20	5.62	5.67	180.75	180.70	1.43E-02	30%
SC12 D 15-20	5.67	5.72	180.70	180.65	1.62E-02	31%
SC12 D 15-20	5.72	5.77	180.65	180.60	1.45E-02	29%
SC12 D 15-20	5.77	5.82	180.60	180.55	1.65E-02	31%
SC12 D 15-20	5.82	5.87	180.55	180.50	2.08E-02	33%
SC12 D 15-20	5.87	5.92	180.50	180.45	1.50E-02	30%
SC12 E 20-25	6.10	6.17	180.27	180.19	1.03E-02	31%
SC12 E 20-25	6.17	6.23	180.19	180.13	1.01E-02	31%
SC12 E 20-25	6.23	6.30	180.13	180.06	1.60E-02	33%
SC12 E 20-25	6.30	6.35	180.06	180.01	1.89E-02	33%
SC12 E 20-25	6.35	6.40	180.01	179.96	1.46E-02	35%
SC12 E 20-25	6.40	6.44	179.96	179.92	1.38E-02	36%
SC12 E 20-25	6.44	6.50	179.92	179.86	2.07E-02	39%
SC12 E 20-25	6.50	6.57	179.86	179.79	9.69E-03	33%
SC12 E 20-25	6.57	6.63	179.79	179.73	1.01E-02	34%
SC12 E 20-25	6.63	6.70	179.73	179.66	1.21E-02	33%
SC12 E 20-25	6.70	6.75	179.66	179.61	1.27E-02	32%
SC12 E 20-25	6.75	6.80	179.61	179.56	1.35E-02	34%
SC12 E 20-25	6.80	6.85	179.56	179.51	1.17E-02	30%
SC12 E 20-25	6.85	6.91	179.51	179.46	1.06E-02	29%
SC12 E 20-25	6.91	6.96	179.46	179.41	2.07E-02	32%
SC12 E 20-25	6.96	7.01	179.41	179.36	1.21E-02	31%
SC12 E 20-25	7.01	7.06	179.36	179.31	1.23E-02	31%
SC12 E 20-25	7.06	7.11	179.31	179.26	1.16E-02	31%
SC12 E 20-25	7.11	7.16	179.26	179.21	1.24E-02	31%
SC12 E 20-25	7.16	7.21	179.21	179.16	1.23E-02	31%
SC12 E 20-25	7.21	7.26	179.16	179.11	1.30E-02	32%
SC12 E 20-25	7.26	7.31	179.11	179.06	9.91E-03	30%
SC12 E 20-25	7.31	7.36	179.06	179.01	1.25E-02	30%
SC12 E 20-25	7.36	7.41	179.01	178.96	1.30E-02	31%
SC12 E 20-25	7.41	7.46	178.96	178.91	1.30E-02	31%
SC12 E 20-25	7.46	7.51	178.91	178.86	1.34E-02	28%
SC12 E 20-25	7.51	7.56	178.86	178.81	1.21E-02	30%
SC12 E 20-25	7.56	7.63	178.81	178.74	1.08E-02	29%

Notes:

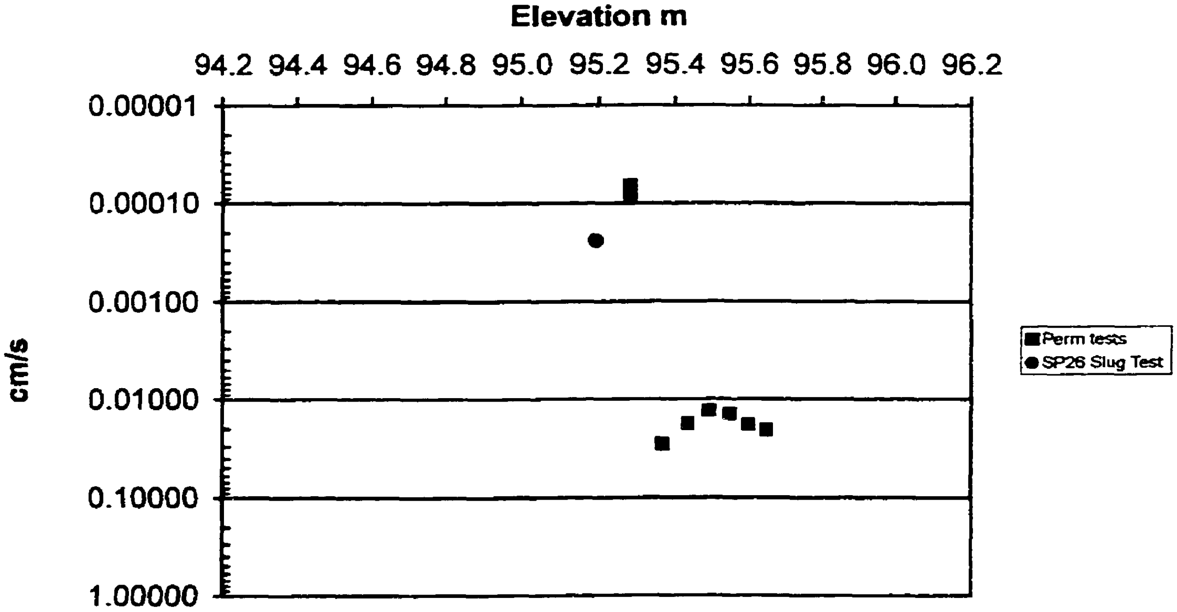
[1] Depths have been corrected for partial core recovery

[2] Hydraulic conductivity value is an average of 3 tests on each sample, which were corrected from laboratory temperature to 10°C

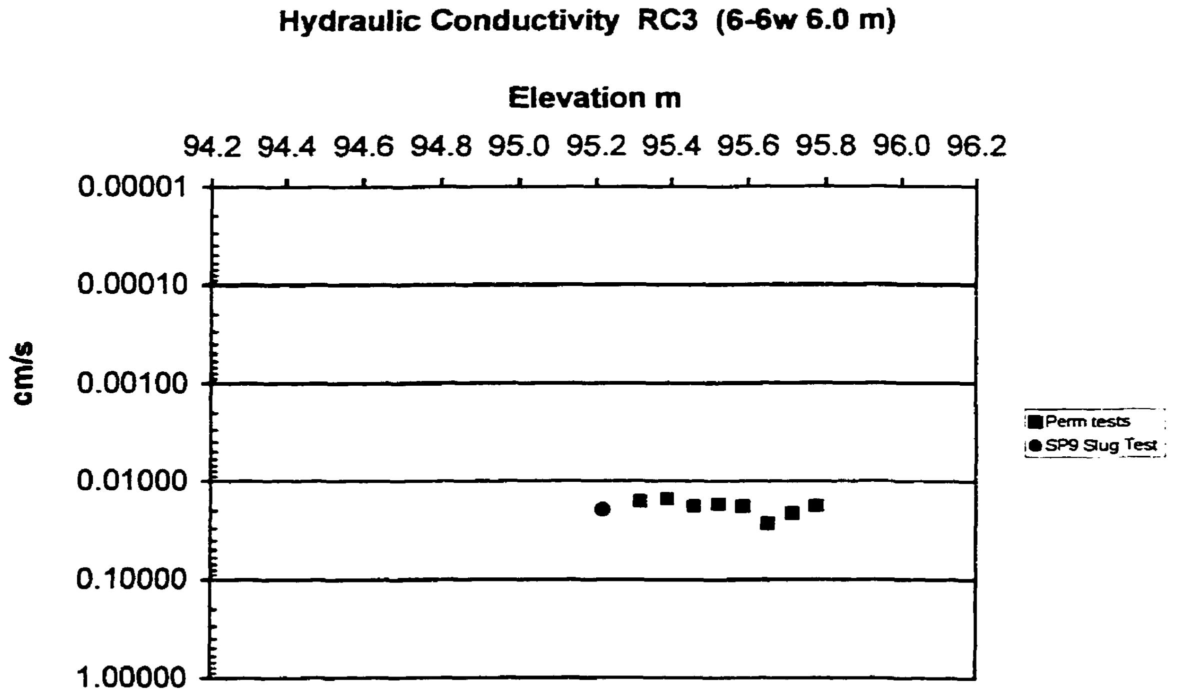
TLTM = To low to measure, probably orders of magnitude lower than 1x10^{-6} cm/s

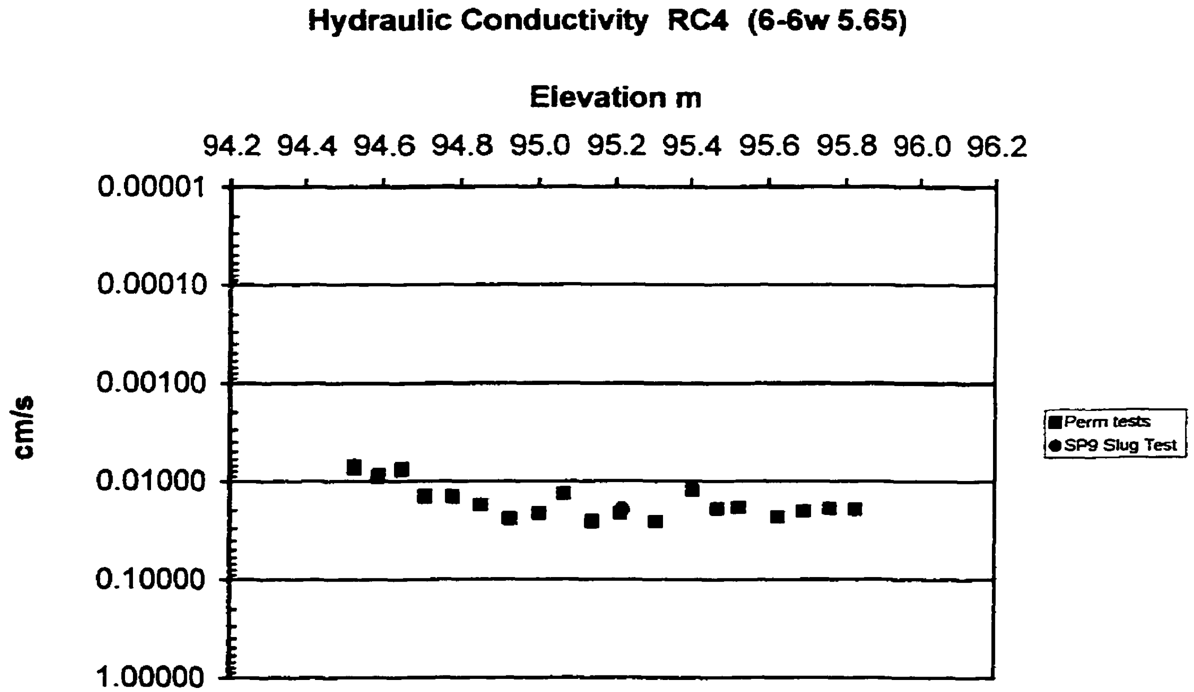


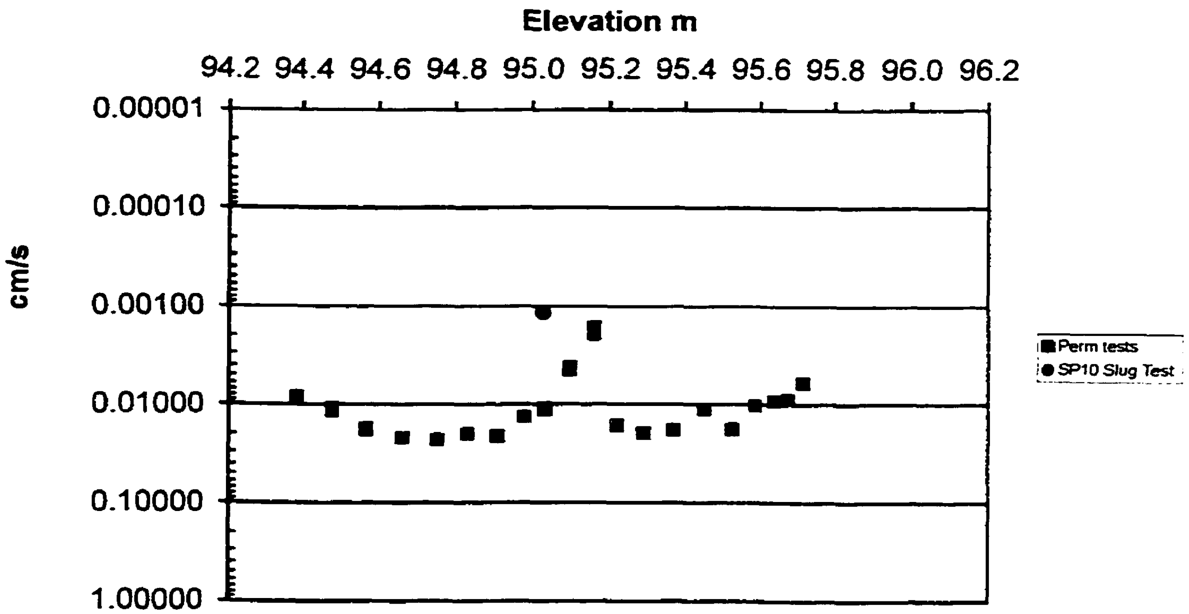
Hydraulic Conductivity RC1 (18-18w 4.20 m)



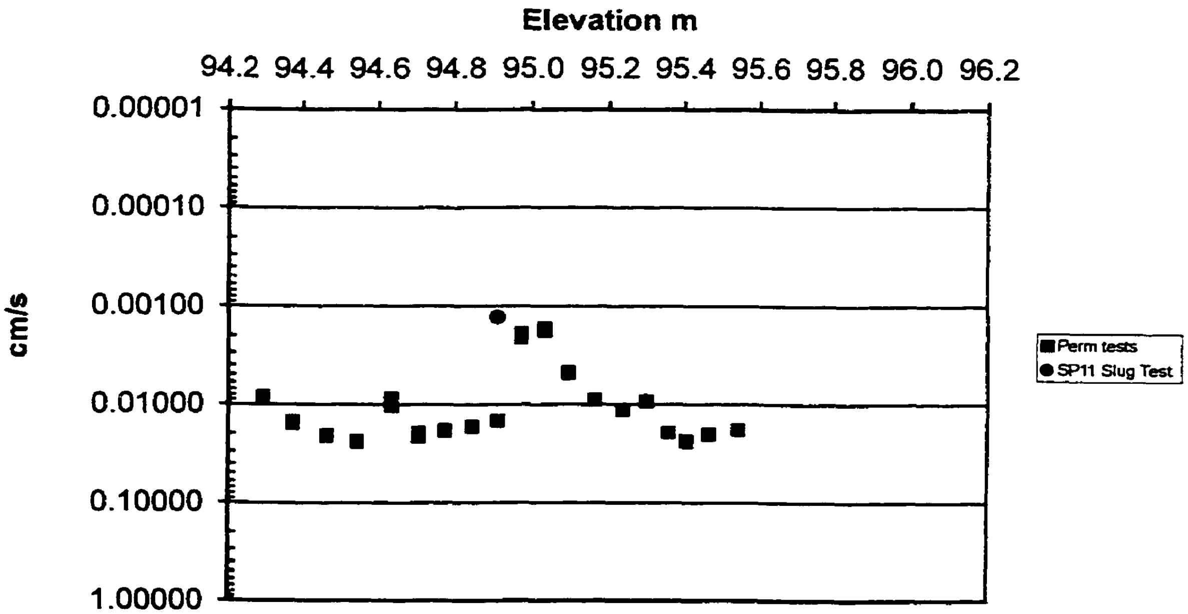
Hydraulic Conductivity RC2 (18-18w 6.4 m)


Hydraulic Conductivity RC3 (6-6w 6.0 m)
Elevation m
94.2 94.4 94.6 94.8 95.0 95.2 95.4 95.6 95.8 96.0 96.2
cm/s
0.00001
0.00010
0.00100
0.01000
0.10000
1.00000
■ Perm tests
● SP9 Slug Test

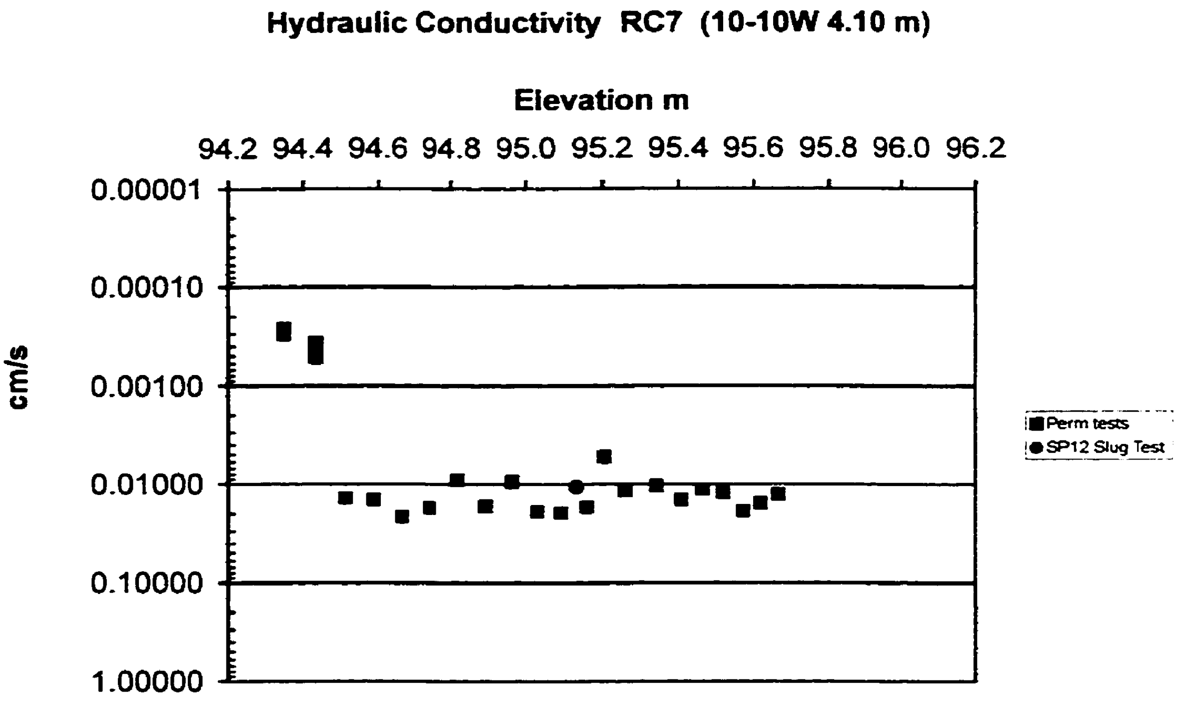

Hydraulic Conductivity RC4 (6-6w 5.65)
Elevation m
94.2 94.4 94.6 94.8 95.0 95.2 95.4 95.6 95.8 96.0 96.2
cm/s
0.00001
0.00010
0.00100
0.01000
0.10000
1.00000
■ Perm tests
● SP9 Slug Test

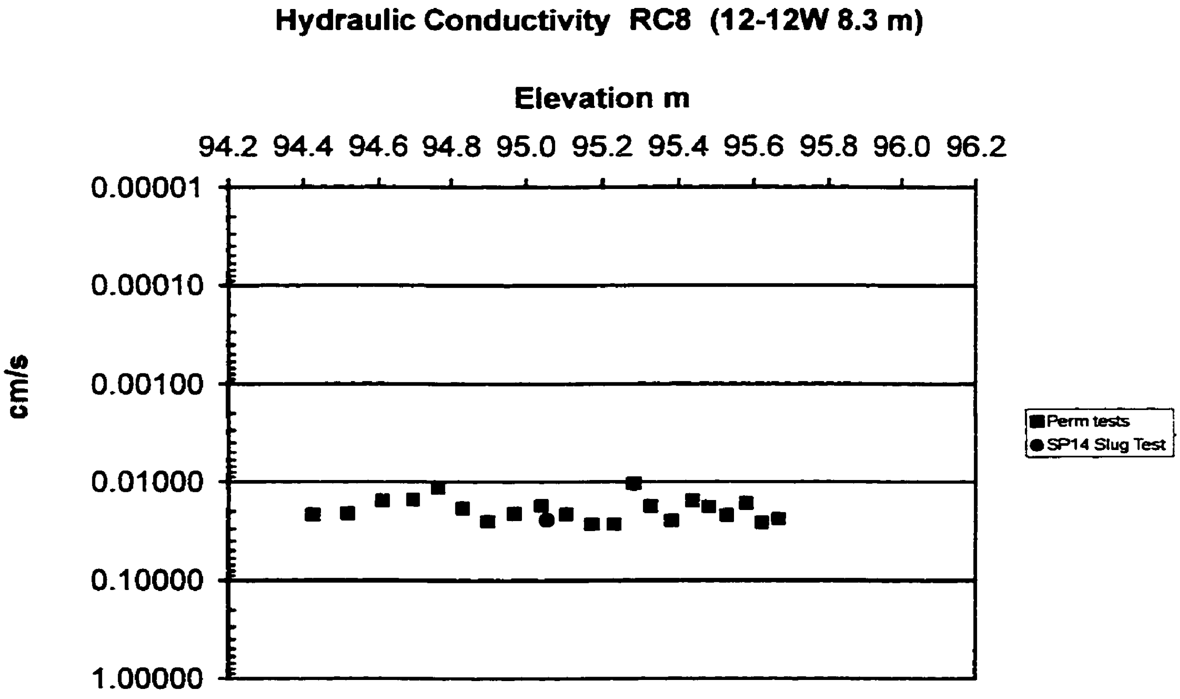


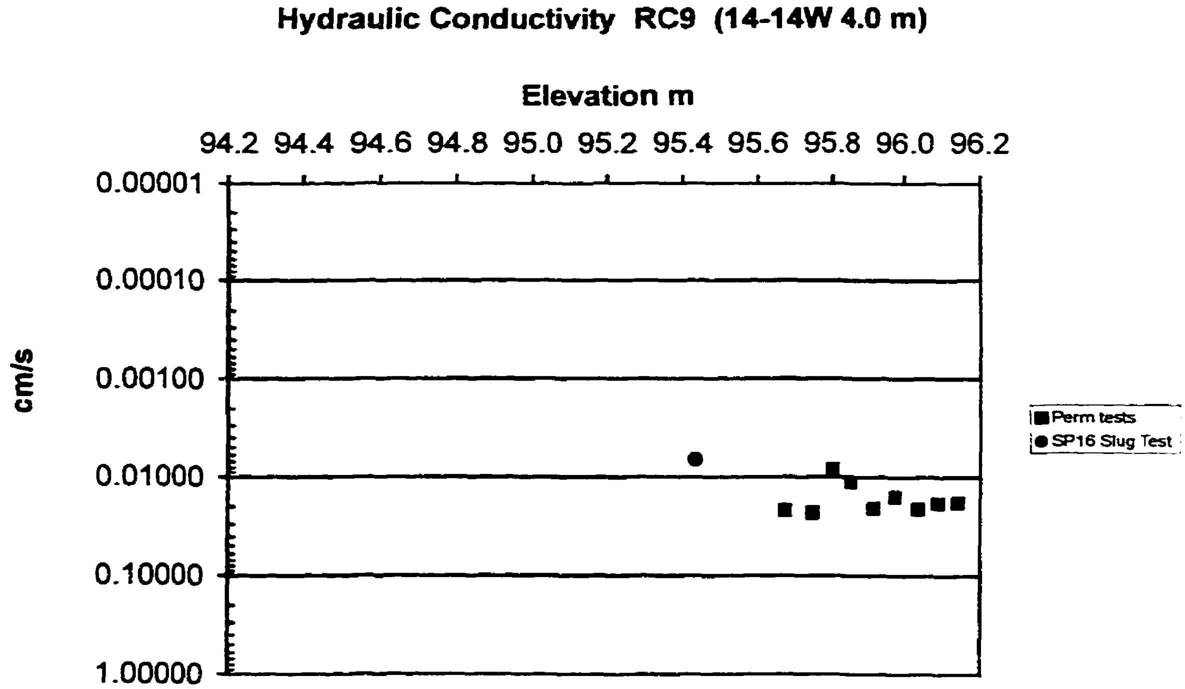
Hydraulic Conductivity RC5 (6-6W 7.05 m)

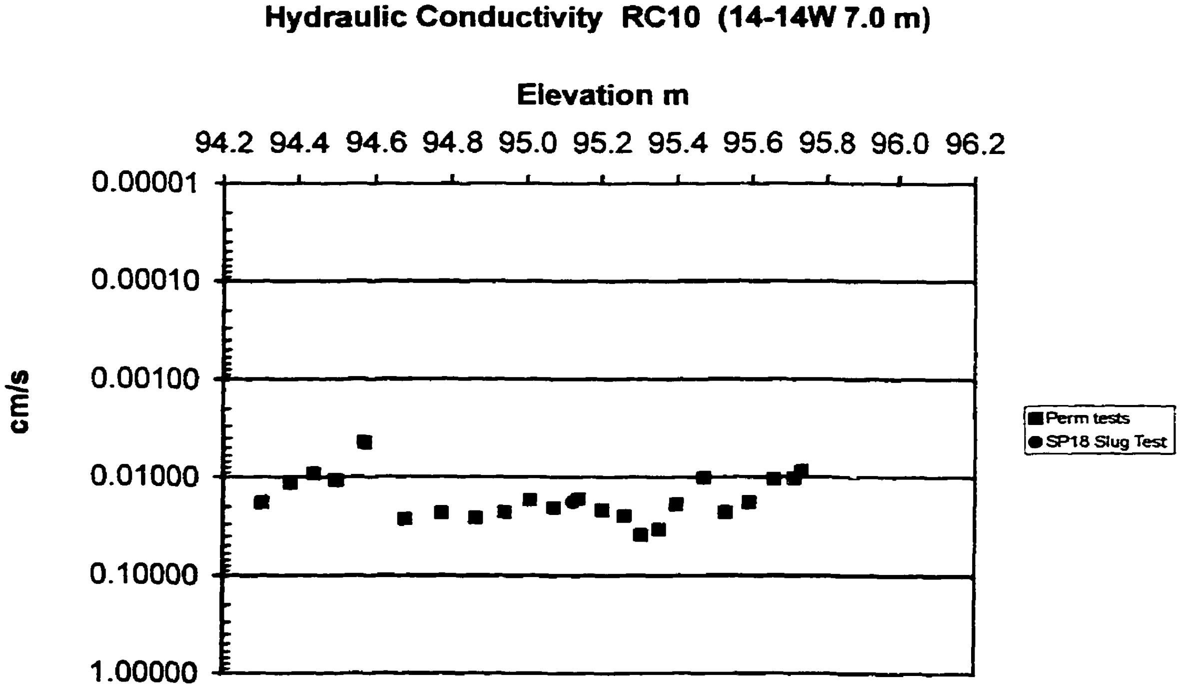


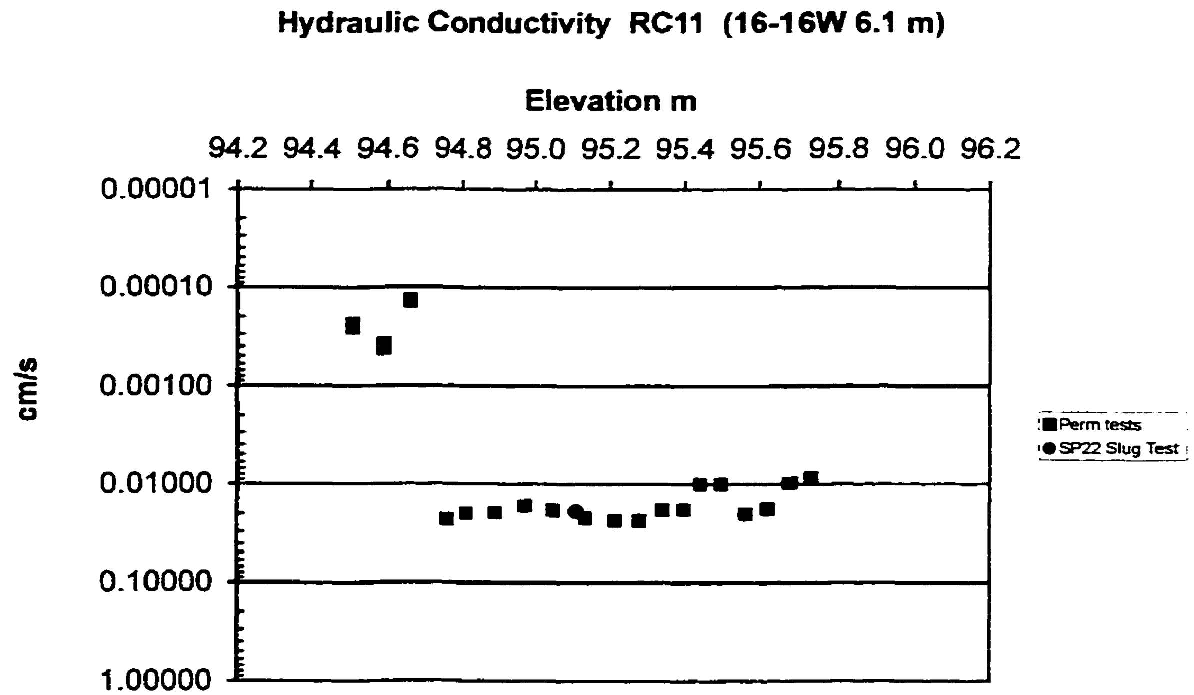
Hydraulic Conductivity RC6 (8-8W 7.40 m)

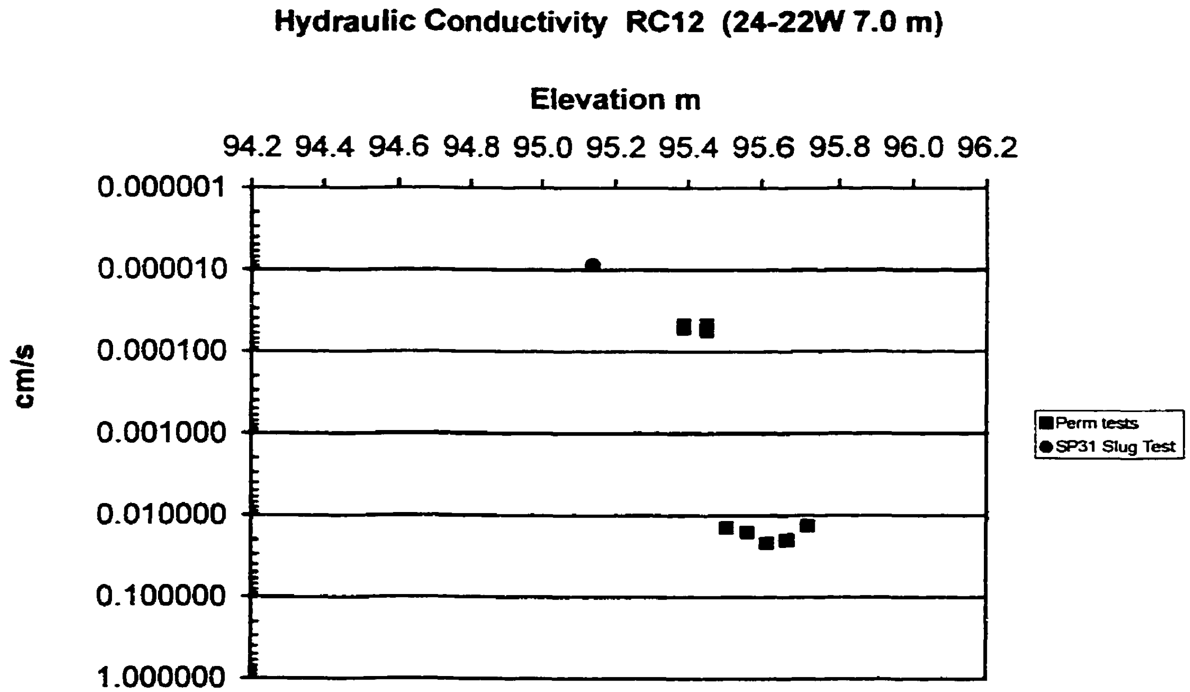

Hydraulic Conductivity RC7 (10-10W 4.10 m)
Elevation m
94.2 94.4 94.6 94.8 95.0 95.2 95.4 95.6 95.8 96.0 96.2
cm/s
0.00001
0.00010
0.00100
0.01000
0.10000
1.00000
■ Perm tests
● SP12 Slug Test

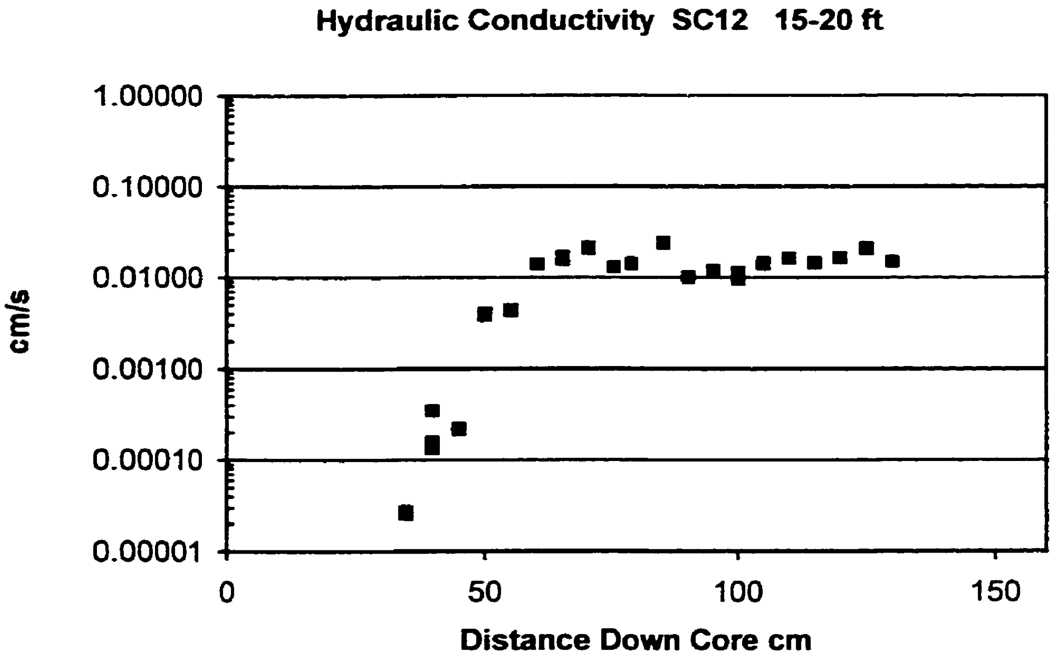

Hydraulic Conductivity RC8 (12-12W 8.3 m)
Elevation m
94.2 94.4 94.6 94.8 95.0 95.2 95.4 95.6 95.8 96.0 96.2
cm/s
0.00001
0.00010
0.00100
0.01000
0.10000
1.00000
■ Perm tests
● SP14 Slug Test

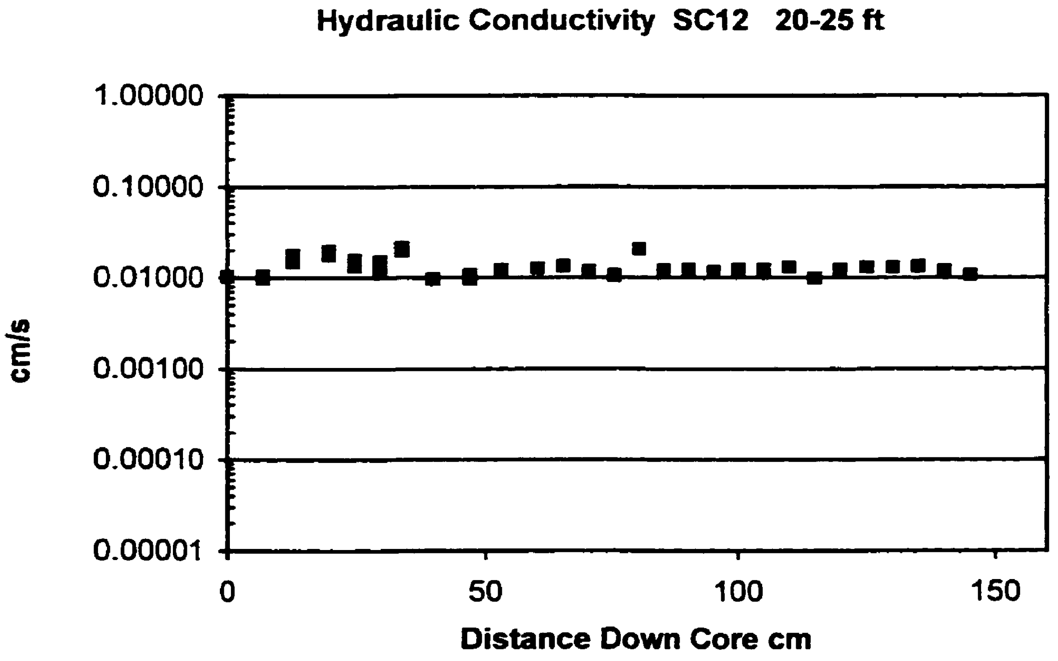

Hydraulic Conductivity RC9 (14-14W 4.0 m)
Elevation m
94.2
94.4
94.6
94.8
95.0
95.2
95.4
95.6
95.8
96.0
96.2
cm/s
0.00001
0.00010
0.00100
0.01000
0.10000
1.00000
■ Perm tests
● SP16 Slug Test


Hydraulic Conductivity RC10 (14-14W 7.0 m)
Elevation m
94.2
94.4
94.6
94.8
95.0
95.2
95.4
95.6
95.8
96.0
96.2
cm/s
0.00001
0.00010
0.00100
0.01000
0.10000
1.00000
■ Perm tests
● SP18 Slug Test


Hydraulic Conductivity RC11 (16-16W 6.1 m)


Hydraulic Conductivity RC12 (24-22W 7.0 m)


Hydraulic Conductivity SC12 15-20 ft
cm/s
1.00000
0.10000
0.01000
0.00100
0.00010
0.00001
0
50
100
150
Distance Down Core cm


Hydraulic Conductivity SC12 20-25 ft
cm/s
1.00000
0.10000
0.01000
0.00100
0.00010
0.00001
0
50
100
150
Distance Down Core cm

FOC ANALYSES OF CORE SAMPLES

Core location and sample no.	Depth m[1]	Geological layer[2]	Description of materials	Foc[4] %	Lab[3]	Comments
RC1 79.5 cm #1	0.21	SCD	Silty Clay	5.93	G	
RC1 69.5 cm #2	0.43	SCD	Silty Clay	6.30	G	
RC1 59 cm #3	0.66	SCD	Silty Clay	7.18	G	
RC1 39 cm #4	0.77	SCD	Silty Clay	4.40	G	
RC1 18.5 cm #5	0.88	SCD	Silty Clay	2.74	G	
RC2 15 cm #6	0.16	SBS	Sand	0.119	UW	
RC2 30 cm #7	0.34	SBS	Sand	0.036	UW	
RC2 45 cm #8	0.51	SCD	Silty Clay	5.71	G	
RC2 60 cm #9	0.67	SCD	Silty Clay	3.98	G	
RC2 75 cm #10	0.83	SCD	Silty Clay	2.30	G	
RC2 90 cm #11	0.98	SCD	Silty Clay	5.09	G	
QA Dup-2 (#11)	0.98	SCD	Silty Clay	5.53	G	Blind duplicate of RC2 90 cm #11
RC2 105 cm #12	1.14	SCD	Silt and Peat	5.72	G	
RC2 120 cm #13	1.30	SCD	Silt and Peat	4.68	G	
RC4 10 cm #14	0.13	SBS	Sand	0.033	UW	
RC4 20 cm #15	0.30	SBS	Sand	0.057	UW	
RC4 30 cm #16	0.42	SBS	Sand	0.335	UW	
RC4 30 cm #16	0.42	SBS	Sand	0.39	G	
RC4 40 cm #17	0.60	SBS	Sand	0.091	UW	
RC4 50 cm #18	0.73	SBS	Sand with woody pieces	4.49	G	
QA Dup-1 (#18)	0.73	SBS	Sand with woody pieces	4.57	G	Blind duplicate of RC4 50 cm #18
RC4 60 cm #19	0.85	SBS	Sand	0.216	UW	
RC4 70 cm #20	0.98	SBS	Sand	0.946	UW	
RC4 70 cm #20	0.98	SBS	Sand	0.97	G	
RC4 80 cm #21	1.12	SBS	Sand	1.113	UW	
RC4 80 cm #21	1.12	SBS	Sand	1.02	G	
RC4 90 cm #22	1.24	SBS	Sand	1.834	UW	
RC4 90 cm #22	1.24	SBS	Sand	1.58	G	
RC11 5 cm	0.05	SBS	Sand	0.08	UW	
RC11 15 cm	0.17	SBS	Sand	0.112	UW	
RC11 25 cm	0.28	SBS	Sand	0.296	UW	
RC11 25 cm	0.28	SBS	Sand	0.25	G	Mislabeled vial as RC4 25 cm when submitted
RC11 35 cm	0.39	SBS	Sand	0.640	UW	
RC11 35 cm	0.39	SBS	Sand	0.58	G	
RC11 45 cm	0.52	SBS	Sand	0.151	UW	
RC11 55 cm	0.68	SBS	Sand	0.027	UW	
RC11 65 cm	0.92	SBS	Sand	0.065	UW	
RC11 75 cm	0.99	SBS	Sand	0.175	UW	
RC11 85 cm	1.16	SCD	Silty Clay	3.08	G	
RC11 95 cm	1.3	SCD	Silty Clay	1.69	G	
RC11 105 cm	1.45	SCD	Silty Clay	5.64	G	

Core location and sample no.	Depth m[1]	Geological layer[2]	Description of materials	Foc[4] %	Lab[3]	Comments
SC12 15-20 #33	4.62	SCD	Clay	4.54	G	
SC12 15-20 #34	4.72	SCD	Silt	5.88	G	
SC12 15-20 #35	4.88	SCD	Silt	2.11	G	
SC12 15-20 #36	5.02	SCD	Silt	0.30	G	
SC12 15-20 #36	5.02	SCD	Silt	0.379	UW	
SC12 15-20 # 37	5.13	Layer 2	Sand	0.033	UW	
SC12 15-20 # 38	5.37	Layer 2	Sand	0.039	UW	
SC12E 20-25 #39	6.29	Layer 1	Sand	0.029	UW	
SC12E 20-25 #40	6.61	Layer 1	Sand	0.021	UW	
SC12E 20-25 #41	6.86	Layer 1	Sand	0.021	UW	
SC12E 20-25 #42	7.41	Layer 1	Sand	0.019	UW	
SC13 24 ft	7.31	Layer 2	Sand	0.020	UW	
SC13 26 ft	7.92	Layer 2	Sand	0.024	UW	
SC13 28 ft	8.53	Layer 1	Sand	0.019	UW	
SC13 30 ft	9.14	Layer 1	Sand	0.018	UW	
SC13 32 ft	9.75	Layer 1	Sand and silt	0.021	UW	
SC13 34 ft	10.36	Layer 1	Sand	0.010	UW	Less than LOQ
SC13 36 ft	10.97	Layer 1	Sand and silt	0.007	UW	Less than MDL
SC13 38 ft	11.58	Layer 1	Sand	0.019	UW	
SC13 40 ft	12.19	Layer 1	Sand	0.011	UW	Less than LOQ
Ottawa Sand QA #1	NA	NA	Ottawa sand blank	0.000	UW	Quality control sample. Less than MDL
Ottawa Sand #40	NA	NA	Ottawa sand blank	0.008	UW	Quality control sample
QA OS-1	NA	NA	Ottawa sand blank	<0.05%	G	Quality control sample
QA OS #40	NA	NA	Ottawa sand blank	<0.05%	G	Quality control sample

Notes:

[1] Depths are measured from the top of the core and have been corrected for partial core recovery

[2] Geological layers 1 and 2 in confined aquifer as defined by Writt (1996) or
SCD = semi-confining deposits
SBS = streambed sands

[3] Laboratory that performed the analyses
G= Guelph Soil and Nutrient Laboratory
UW = University of Waterloo Laboratory

[4] Fraction of organic carbon in percent as determined by UW or Guelph laboratory

NA = Not applicable
MDL = method detection limit for UW laboratory analysis
LOQ = Limit of quantification for UW laboratory analysis

APPENDIX F

SLUG TESTING RESULTS

Hydraulic conductivity and vertical flux for streambed piezometers at 10 °C, winter and summer temperatures

Properties of water from Marsily and Temperature Correction Factors for K

Hydraulic conductivity and vertical flux for streambed piezometer at 10 °C, winter, and summer temperatures

Name	Location [1]	Material at Screen [2]	Temp at time of test °C [7]	Grad. at time of test (-)[8]	At 10 °C			Winter Temperature Conditions			Summer Temperature Conditions		
					K_h [3] cm/s at 10 °C	K_v [3] cm/s at 10 °C	Vertical flux q_v at temp [6] L/m^{2}d	Temp °C [4]	K_v [3] at temp cm/s	Vertical flux q_v at temp [6] L/m^{2}d	Temp °C [5]	K_v [3] at temp cm/s	Vertical flux q_v at temp [6] L/m^{2}d
SP4	2-2W 5.23m	Sand	5.33	0.047	7.66E-03	5.86E-03	239.9	4.46	4.96E-03	203.0	14.69	6.68E-03	273.3
SP5	4-4W 4.09m	Sand	5.18	0.034	1.14E-02	8.76E-03	256.8	6.09	7.80E-03	228.5	12.98	9.53E-03	279.3
SP6	4-4W 5.11m	Sand	5.33	0.033	1.20E-02	9.22E-03	263.3	6.32	8.26E-03	235.9	12.73	9.96E-03	284.4
SP7	4-4W 5.95m	Sand	5.33	0.031	2.15E-02	1.65E-02	445.7	7.73	1.54E-02	416.8	11.91	1.74E-02	470.5
SP8	6-6W 4.09m	Sand	5.18	0.016	6.70E-03	5.12E-03	69.2	4.16	4.29E-03	58.0	15.03	5.89E-03	79.5
SP9	6-6W 5.29m (RC4, PRP15, MLS17)	Sand	5.18	0.024	2.01E-02	1.54E-02	321.6	5.79	1.36E-02	283.6	11.96	1.63E-02	340.0
SP10	6-6W 7.93m (RC5, MLS19)	Sand and Silt	5.02	0.039	1.22E-03	9.30E-04	31.2	2.29	7.34E-04	24.6	16.61	1.11E-03	37.3
SP11	8-8W 7.55m (RC6)	Sand and Silt	4.87	0.041	1.33E-03	1.02E-03	36.0	2.32	8.06E-04	28.5	16.77	1.23E-03	43.3
SP12	10-10W 4.20m	Sand	4.71	0.005	1.11E-02	8.46E-03	33.7	3.58	6.96E-03	27.7	15.97	9.96E-03	39.7
SP13	12-12W 5.55m	Sand	3.77	0.007	6.55E-03	5.01E-03	28.4	3.00	4.05E-03	22.9	14.75	5.72E-03	32.4
SP14[10	12-12W 8.43m	Sand	4.71	0.013	*2.52E-02*	*1.93E-02*	*221.8*	3.75	*1.59E-02*	*183.5*	15.61	*2.25E-02*	*258.9*
SP15	14-14W 2.01m	Sand and Silt	4.40	0.036	1.33E-03	1.02E-03	31.6	1.92	7.95E-04	24.7	17.02	1.23E-03	38.3
SP16	14-14W 4.15m	Sand and Silt	4.56	0.006	6.92E-03	5.29E-03	27.7	1.68	4.10E-03	21.4	17.25	6.44E-03	33.7
SP17	14-14W 5.60m	Sand	3.93	0.003	1.87E-02	1.43E-02	37.0	1.96	1.12E-02	28.9	16.74	1.72E-02	44.4
SP18	14-14W 7.07m (RC10)	Sand	4.40	0.010	1.84E-02	1.41E-02	117.8	3.80	1.17E-02	97.6	16.26	1.67E-02	139.8
SP19[9]	14-14W 8.04m	Sand	3.93	0.010	2.02E-02	1.54E-02	135.3	3.10	1.25E-02	109.6	15.98	1.82E-02	159.4
SP20	16-16W 1.52m (MLS1)	Silt and Clay	4.24	0.079	7.85E-06	6.01E-06	0.41	2.21	4.73E-06	0.32	16.68	7.21E-06	0.49
SP21	16-16W 4.30m (MLS4)	Sand	4.24	0.009	1.83E-02	1.40E-02	103.9	1.48	1.08E-02	79.9	17.25	1.71E-02	126.5

Name	Location [(1)]	Material at Screen [(2)]	Temp at time of test °C [(7)]	Grad. at time of test (-)[(8)]	At 10 °C			Winter Temperature Conditions			Summer Temperature Conditions		
					K_h [(3)] cm/s at 10 °C	K_v [(3)] cm/s at 10 °C	Vertical flux q_v at temp [(6)] L/m²d	Temp °C [(4)]	K_v [(3)] at temp cm/s	Vertical flux q_v at temp [(6)] L/m²d	Temp °C [(5)]	K_v [(3)] at temp cm/s	Vertical flux q_v at temp [(6)] L/m²d
SP22[(9)]	16-16W 6.21m (RC11)	Sand	4.40	0.003	1.96E-02	1.50E-02	41.2	2.28	1.19E-02	32.5	16.77	1.81E-02	49.5
SP23	16-16W 8.12m	Sand	4.09	0.010	8.92E-03	6.83E-03	60.2	3.73	5.64E-03	49.8	16.59	8.17E-03	72.1
SP24	16-16W 10.60m	Sand and Silt	3.93	0.044	2.48E-04	1.90E-04	7.3	2.23	1.49E-04	5.7	16.60	2.27E-04	8.7
SP25	18-18W 4.09m (RC1, PRP7)	Silt and Clay	4.40	0.011	1.22E-03	9.34E-04	8.7	1.38	7.16E-04	6.7	17.23	1.14E-03	10.6
SP26	18-18W 6.13m (RC2, PRP8)	Silt and Clay	4.40	0.012	2.48E-04	1.90E-04	1.95	1.83	1.48E-04	1.51	17.02	2.30E-04	2.4
SP27	18-18W 7.74m (PRP17)	Sand	4.40	0.007	1.26E-02	9.64E-03	56.5	2.55	7.67E-03	45.0	16.71	1.16E-02	67.8
SP28	18-18W 9.11m (PRP9)	Sand	4.40	0.007	2.15E-02	1.64E-02	96.3	2.54	1.31E-02	76.7	16.76	1.98E-02	115.8
SP29	18-18W 11.14m (PRP10)	Sand and Silt	4.40	0.069	2.10E-03	1.61E-03	96.2	2.68	1.28E-03	76.9	16.37	1.91E-03	114.5
SP30	24-22W 5.50m (PRP2)	Silt and Clay	5.02	0.108	5.80E-06	4.44E-06	0.41	1.62	3.43E-06	0.320	17.10	5.39E-06	0.50
SP31	24-22W 7.07m (RC12)	Silt and Clay	5.02	0.005	9.02E-06	6.90E-06	0.029	2.15	5.42E-06	0.022	16.69	8.28E-06	0.034
SP32[(10)]	24-22W 8.44m (PRP3)	Sand	4.87	0.020	*2.51E-02*	*1.92E-02*	*329.1*	4.37	*1.62E-02*	*277.6*	15.18	*2.22E-02*	*379.8*
SP33	24-22W 11.39m (PRP4)	Sand and Silt	4.87	0.031	4.88E-03	3.73E-03	98.8	4.00	3.11E-03	82.4	15.29	4.32E-03	114.4
SP34[(10]	28-28W 2.02m	Sand	2.83	0.405	*2.63E-02*	*2.02E-02*	*7059.8*	8.86	*1.95E-02*	6829.7	10.32	*2.04E-02*	*7126.6*
SP35	28-28W 5.92m (PRP13)	Sand and Silt	2.83	0.084	4.99E-04	3.82E-04	27.8	1.68	2.95E-04	21.5	17.22	4.64E-04	33.8
SP36	36-36W 2.53m (PRP5)	Sand	5.02	0.010	1.23E-02	9.42E-03	78.8	1.77	7.31E-03	61.2	17.87	1.16E-02	97.4

Name	Location [1]	Material at Screen [2]	Temp at time of test °C [7]	Grad. at time of test (-)[8]	At 10 °C			Winter Temperature Conditions			Summer Temperature Conditions		
					K_h [3] cm/s at 10 °C	K_v [3] cm/s at 10 °C	Vertical flux q_v at temp [6] L/m²d	Temp °C [4]	K_v [3] at temp cm/s	Vertical flux q_v at temp [6] L/m²d	Temp °C [5]	K_v [3] at temp cm/s	Vertical flux q_v at temp [6] L/m²d
SP37	34-34W 8.55m (PRP6)	Sand and Silt	5.02	0.016	7.10E-04	5.43E-04	7.5	1.21	4.14E-04	5.7	18.31	6.79E-04	9.3

Notes:

[1] Transect location and distance with name of adjacent soil cores or water sampling locations listed in parentheses

[2] Materials at well screen determined from coring or inferred from surficial geology and GPR data

[3] Kh and Kv calculated using Hvorslev (1951) variable-head equation, an anisotropic ratio of K_h/K_v = 1.248, and corrected to the temperatures indicated

[4] Temperatures used for K_v and q_v calculation. Interpolated values at piezometers from streambed mapping during February 18-20,1999, survey

[5] Temperatures used for K_v and q_v calculation. Interpolated values at piezometers from streambed mapping during July 28-29,1998, surveys

[6] Vertical fluxes calculated using K_v and the gradients measured at the time of piezometer testing, and Darcy's law

[7] Temperature at time of test used to then convert K values to10 °C. The river surface water temperature was used to represent the temperature of the test water because the water passed through and presumably equilibrated with a considerable tubing lying underwater in the river

[8] Gradients based on head difference measured on Nov 3 to 6, 1998, except for SP34 and SP35 measured on Dec 10, 1998.

[9] Variable-head calculations at SP19 and SP22 analyzed using only very early time data

[10] *Italic values* = Hydraulic conductivity values that were above the reliable limit for slug testing equipment, actual values of K_h, K_v and q_v could be higher

Properties of water from Marsily (1986) page 416

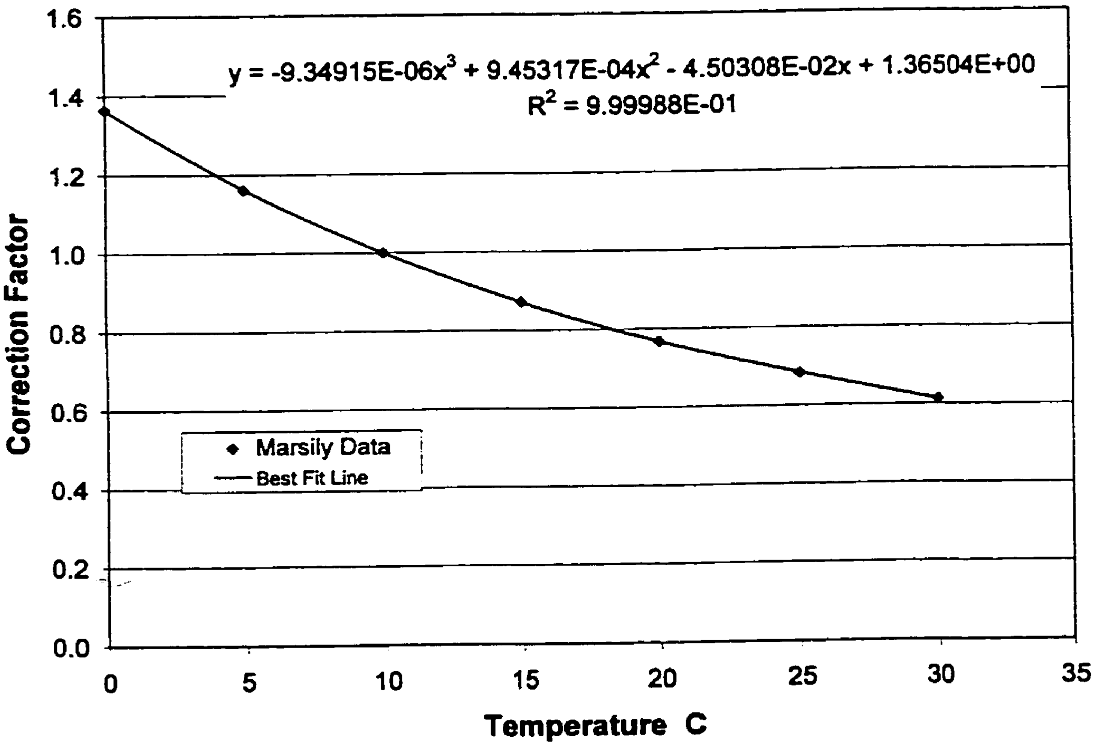
Temp °C	Mass per unit volum ρ kg/m^3	Dynamic Viscosity μ 10^3 / Pa S	Dynamic Viscosity Pa S	Ratio ρ/μ	Ratio of ρ/μ relative to ρ/μ at 10 °C
0	999.8	1.781	1785	1.785	1.366
5	1000	1.518	1518	1.518	1.161
10	999.7	1.307	1307	1.307	1.000
15	999.1	1.139	1139	1.140	0.872
20	998.2	1.002	1002	1.004	0.768
25	997	0.89	890	0.893	0.683
30	995.7	0.798	798	0.801	0.613

Equation for hydraulic conductivity

$$K = k\rho g/\mu$$

K = hydraulic conductivity
k = intrinsic permeability
ρ = density
g = gravitational constant
μ = dynamic viscosity

Pa = pascals
S = seconds
kg = kilograms
m = meters



APPENDIX G

GEOPHYSICS: GPR and TDR

GPR Survey In Pine River May 15, 1998

- Pine River GPR survey May 15, 1998: Descriptions of transects (Table)
- GPR Transect 4-4W (200 MHz Figure)
- GPR Transect 6-6W (200 MHz Figure)
- GPR Transect 8-8W (200 MHz Figure)
- GPR Transect 16-16W (200 MHz Figure)
- GPR Transect 18-18W (200 MHz Figure)
- GPR Transect 20-20W (200 MHz Figure)

GPR Survey In Pine River October 15, 1998

- GPR survey in the Pine River October 15, 1998: Descriptions of transects (Table)
- GPR Transect 4-4W (Figure)
- GPR Transect 5-5W (Figure)
- GPR Transect 6-6W (Figure)
- GPR Transect 7-7W (Figure)
- GPR Transect 8-8W (Figure)
- GPR Transect 9-9W (Figure)
- GPR Transect 10-10W (Figure)
- GPR Transect 10-12W (Figure)
- GPR Transect 14-14W (Figure)
- GPR Transect 15-15W (Figure)
- GPR Transect 16-16W (Figure)
- GPR Transect 17-17W (Figure)
- GPR Transect 18-18W (Figure)
- GPR Transect 19-19W (Figure)
- GPR Transect 20-20W (Figure)
- GPR Transect 24-22W (Figure)

TDR Results: Water Content of Streambed Materials (December 10, 1998)

Pine River GPR Survey

May, 1998

MEMO FROM
DAVE REDMAN
TO B. CONANT

Introduction:

GPR surveys were performed in the Pine River, in Angus Ontario to map the stratigraphy below the bottom of the river. The area surveyed covers a section of the Pine River where a PCE plume exists east of the river and enters into the river through the bottom.

Surveys were performed by placing the antennas, that were mounted on a plywood sheet, in the bottom of a rubber dinghy and moving the raft along a set of survey lines across the river. The inflatable ribs in the bottom of the raft were not inflated providing better coupling between the antennas and the water.

All positions along the lines (with the exception of Piner2 file) are with respect the associated stake at the east end of the line. Centre of antenna was located 0.2 m north (upstream) of the indicated line. The end of the transmitter handle was used for positioning resulting in this small offset. The transmitter was located to the west and the receiver to the east during surveying.

Water temperature in river at time of the survey was 15 C giving relative dielectric permittivity of 82 and velocity of 0.0331 m/ns.

GPR surveys were initially performed at 100 and 200 MHz.

File	Line	Start (m)	End (m)	Freq (MHz)	Station Spacing (m)	Antenna Separation (m)	Comment
PINER1	20	0.5	18.3	100	0.2	1.0	Lines runs from stake 20 to east
PINER2	18-18W	2.0	12.8	100	0.1	0.62	
PINER3	20-20W	3.0	13.3	100	0.1	0.62	
PINER4	16-16W	2.2	12.2	100	0.1	0.62	
PINER5	18-18W	1.9	12.9	200	0.1	0.46	
PINER6	20-20W	2.9	13.1	200	0.1	0.46	
PINER7	16-16W	2.2	12.2	200	0.1	0.46	
PINER8	6-6W	1.2	12.3	200	0.1	0.46	
PINER9	4-4W	0.9	13.3	200	0.1	0.46	
PINER10	8-8W	1.5	11.8	200	0.1	0.46	
PINER11	4-4W	1.0	13.4	100	0.1	0.62	
PINER12	6-6W	1.1	12.5	100	0.1	0.62	
PINER13	8-8W	1.5	11.9	100	0.1	0.62	

GPR Line On Riverbank- Stake 20 to East (PINER1):

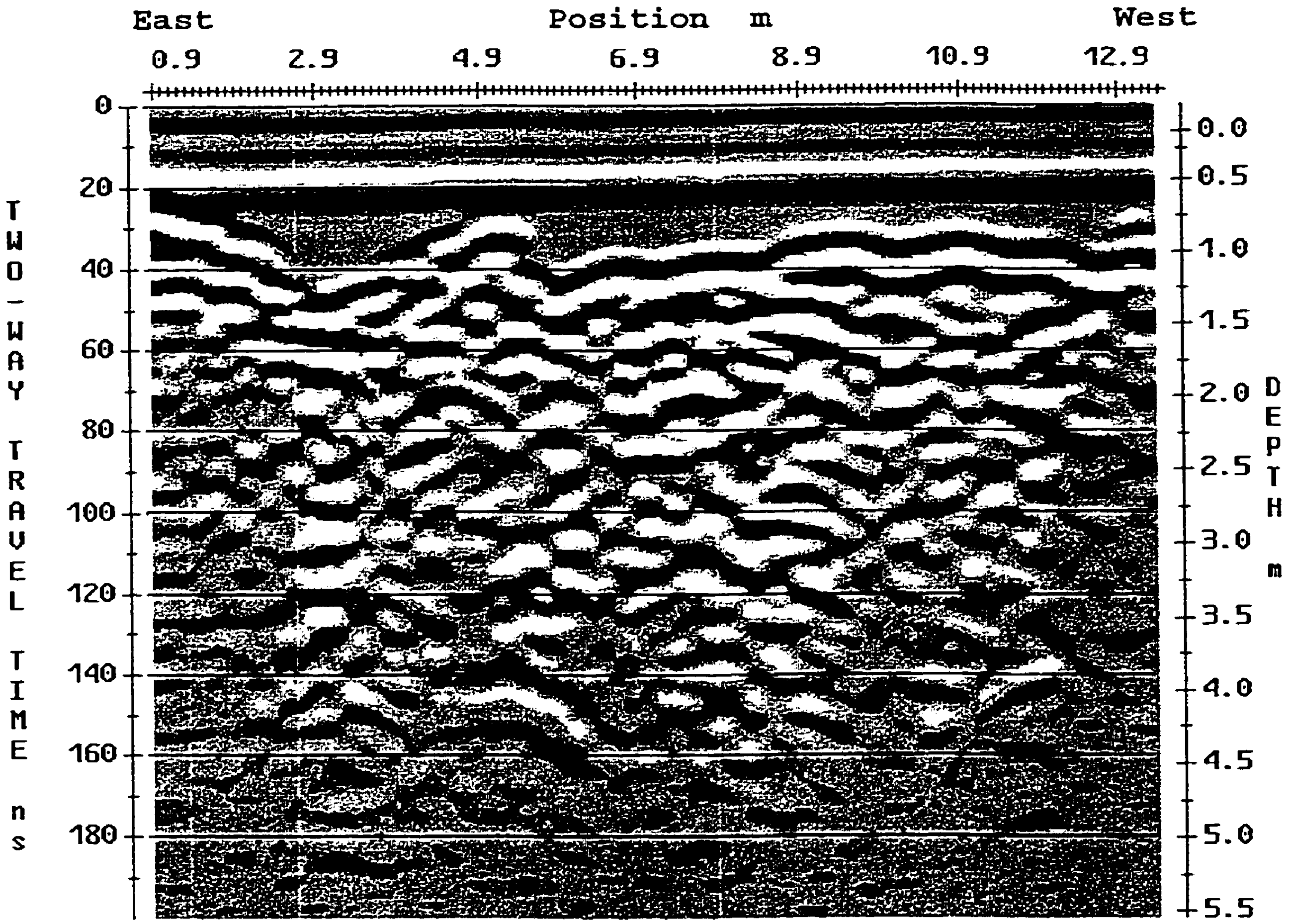
Clear evidence for fill on surface from 4-5 m to 13-14 m. At the eastern end of the line an events at 90 ns and 125 ns may be the top and bottom of the aquitard. Further work needs to be performed at 200 MHz and 50 MHz (if greater depths of interest) extending the existing line to the east and performing some CMP surveys as well. It is unclear if the event at 250 ns is an air wave (would have to be structure at 37 m) or some significant feature at depth within the aquifer.

GPR Lines in River:

Multiples from the river bottom are a problem for interpretation. The arrival time for the multiple does depend somewhat on the antenna separation (see spreadsheet file) but for two way travel times greater than about 30 ns the first multiple arrival time is about twice the first arrival. The 200 MHz data are more useful because they provide more detail between the multiple arrivals.

GPR Transect 4 - 4W

May 15, 1998



GPR Survey Settings
Number of Points per Trace = 500
Total Time Window = 400 ns
Step Size Used = 0.1 m
Nominal Frequency = 200 Mhz
Antenna Separation = 0.46 m
Pulser Voltage = 400
Number of Stacks 64
Survey Mode = Reflection

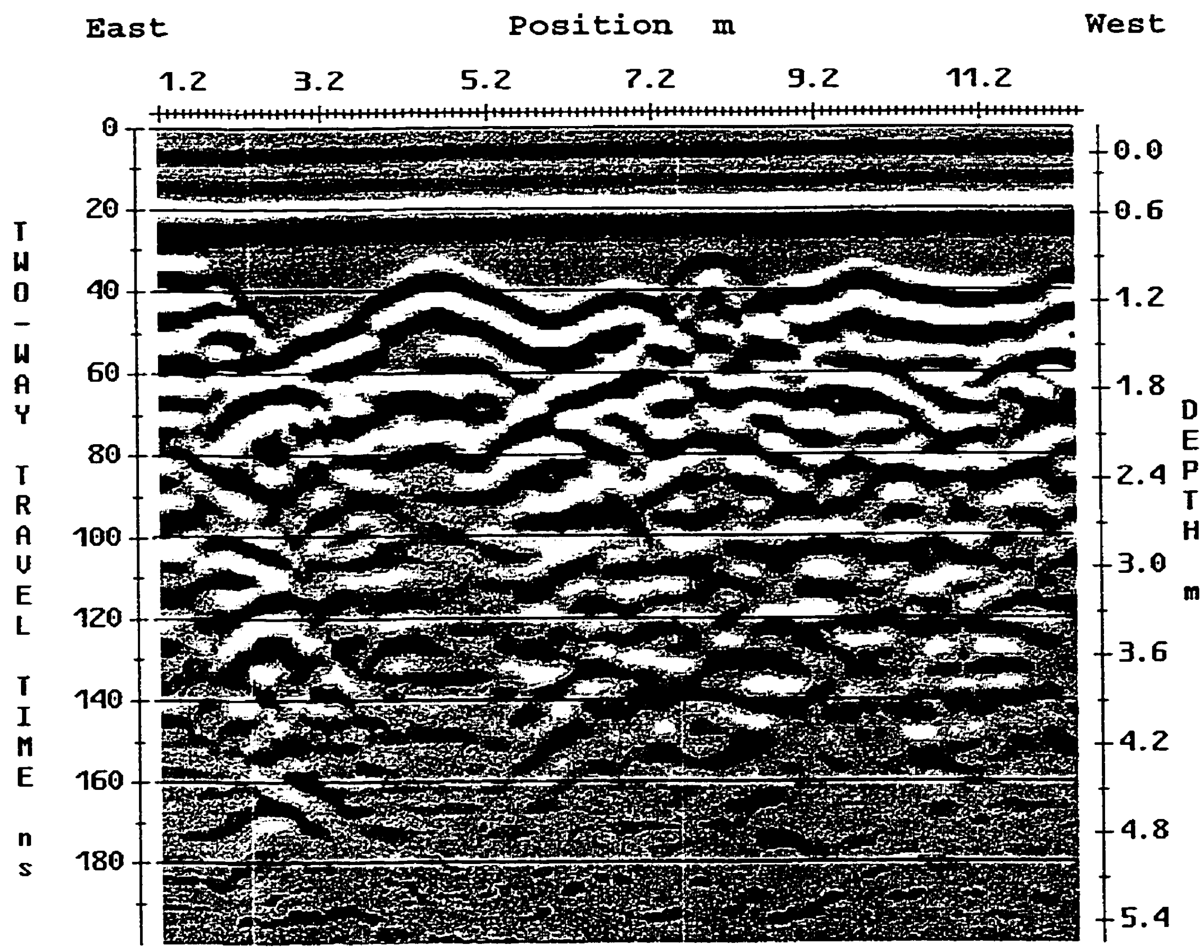
Plot Settings : File PINER9
Filter
- Trace to Trace Average = 4
- Down the Trace Average = 5
- Different Traces = Off
- Trace Correction = DEWOW

Gain SEC
- Gain = 1000
- Attenuation = 2.0
- Start Value = 1.0

Layout for Traces
- Traces per inch = 17
- Width Spacing Ratio = 1.6

Options - Color Options = On
Selection - Start / End Time = 0 / 200 ns
Velocity for Depth Axis = 0.055 m/ns

GPR Transect 6 - 6W
May 15, 1998



GPR Survey Settings
Number of Points per Trace = 500
Total Time Window = 400 ns
Step Size Used = 0.1 m
Nominal Frequency = 200 Mhz
Antenna Separation = 0.46 m
Pulser Voltage = 400
Number of Stacks 64
Survey Mode = Reflection

Plot Settings : File PINER8
Filter
- Trace to Trace Average = 4
- Down the Trace Average = 5
- Different Traces = Off
- Trace Correction = DEWOW

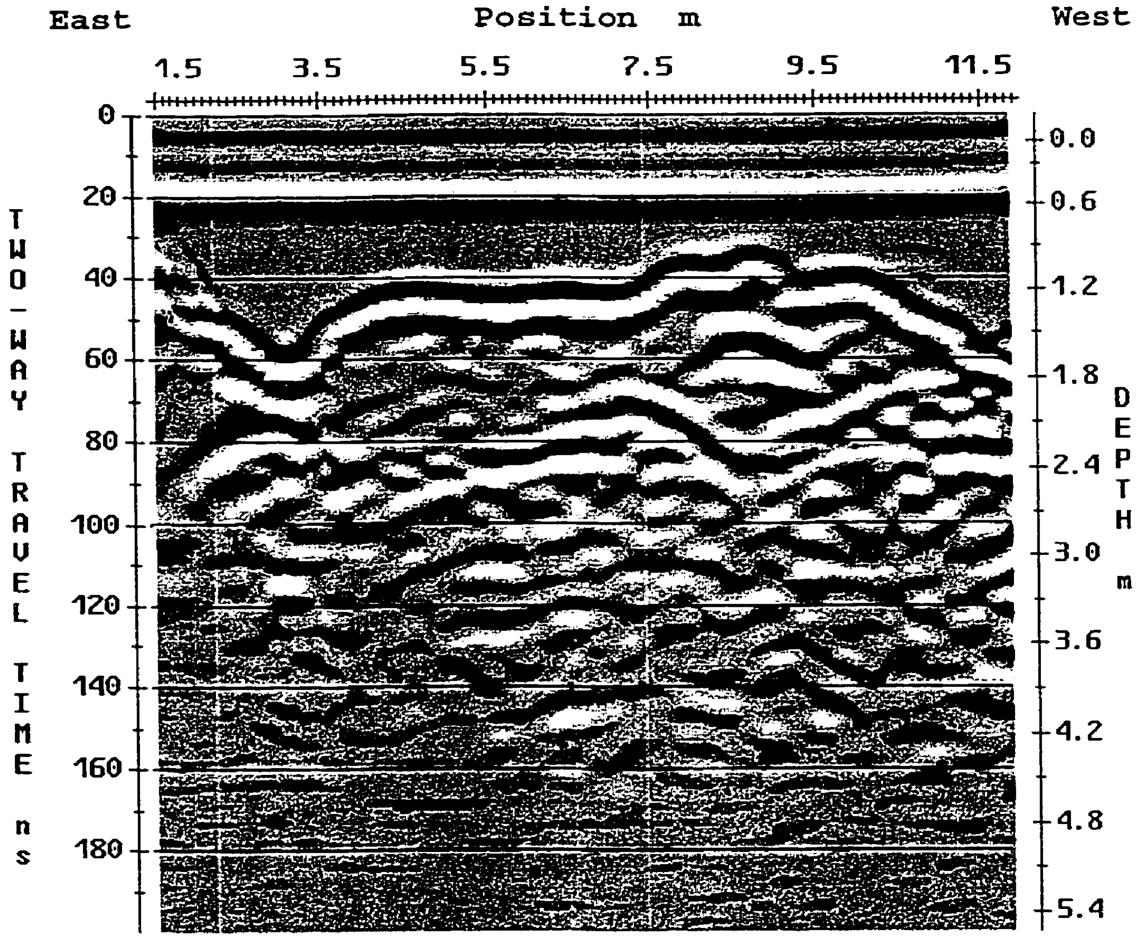
Gain SEC
- Gain = 1000
- Attenuation = 2.0
- Start Value = 1.0

Layout for Traces
- Traces per inch = 17
- Width Spacing Ratio = 1.6

Options - Color Options = On
Selection - Start / End Time = 0 / 200 ns
Velocity for Depth Axis = 0.055 m/ns

GPR Transect 8 - 8W

May 15, 1998



GPR Survey Settings
Number of Points per Trace = 500
Total Time Window = 400 ns
Step Size Used = 0.1 m
Nominal Frequency = 200 Mhz
Antenna Separation = 0.46 m
Pulser Voltage = 400
Number of Stacks 64
Survey Mode = Reflection

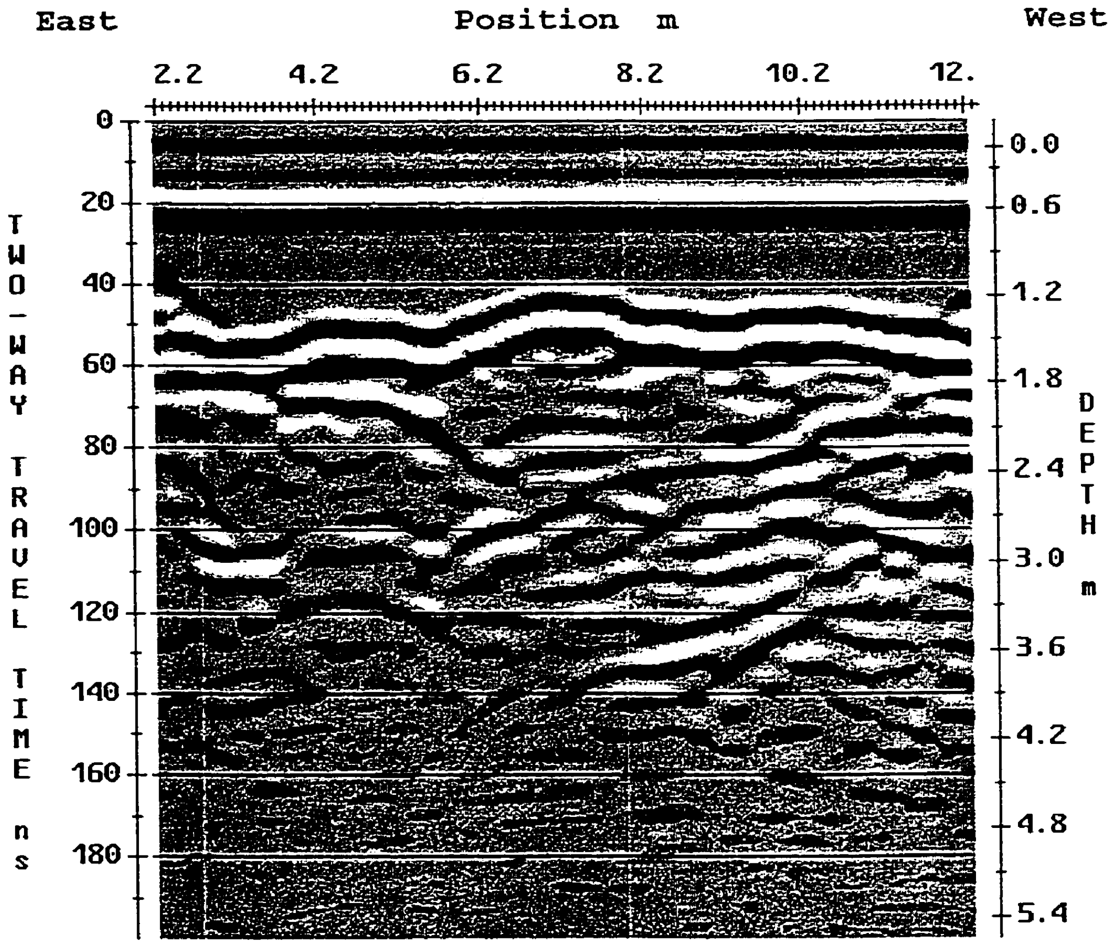
Plot Settings : File PINER10
Filter
- Trace to Trace Average = 4
- Down the Trace Average = 5
- Different Traces = Off
- Trace Correction = DEWOW

Gain SEC
- Gain = 1000
- Attenuation = 2.0
- Start Value = 1.0

Layout for Traces
- Traces per inch = 17
- Width Spacing Ratio = 1.6

Options - Color Options = On
Selection - Start / End Time = 0 / 200 ns
Velocity for Depth Axis = 0.055 m/ns

GPR Transect 16 - 16W
May 15, 1998



GPR Survey Settings
Number of Points per Trace = 500
Total Time Window = 400 ns
Step Size Used = 0.1 m
Nominal Frequency = 200 Mhz
Antenna Separation = 0.46 m
Pulser Voltage = 400
Number of Stacks 64
Survey Mode = Reflection

Plot Settings : File PINER7
Filter
- Trace to Trace Average = 4
- Down the Trace Average = 5
- Different Traces = Off
- Trace Correction = DEWOW

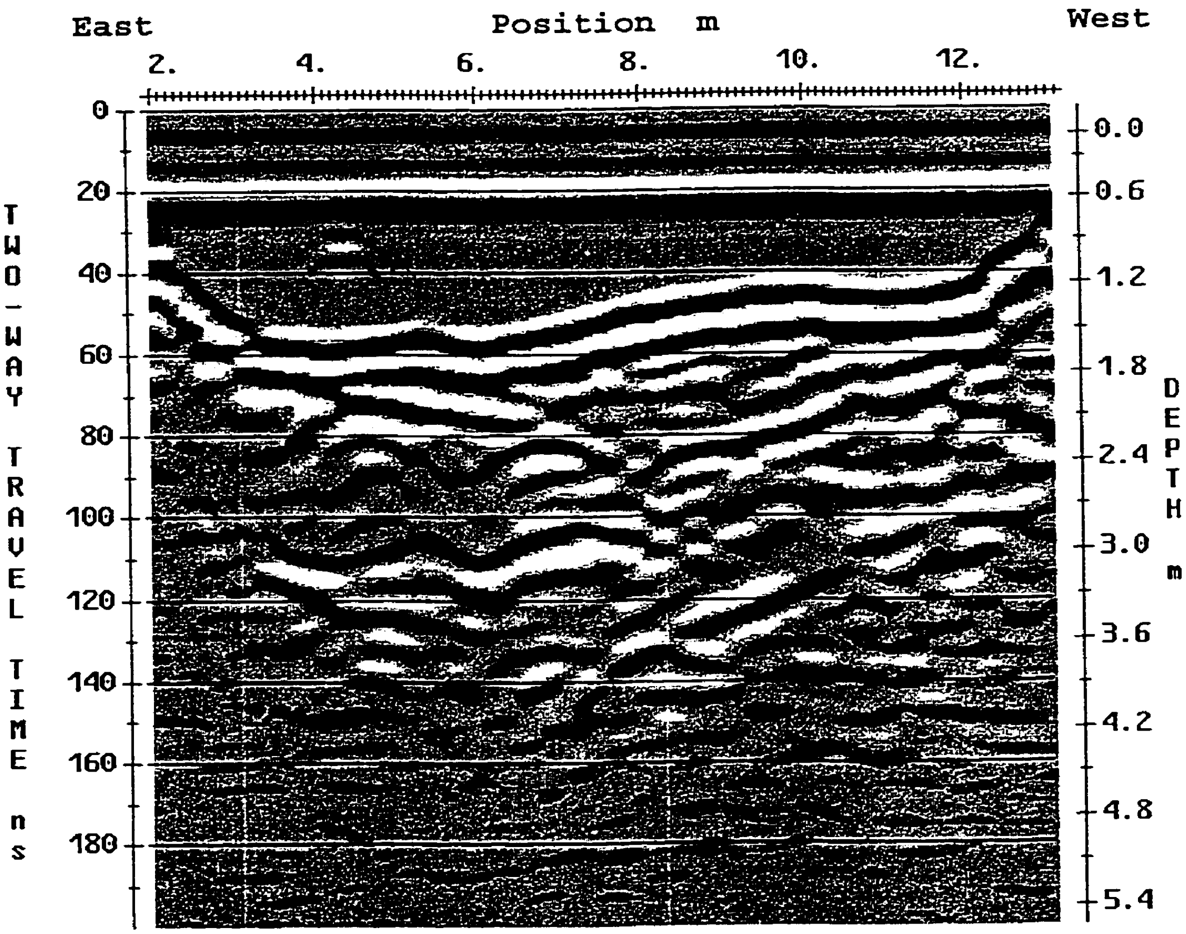
Gain SEC
- Gain = 1000
- Attenuation = 2.0
- Start Value = 1.0

Layout for Traces
- Traces per inch = 17
- Width Spacing Ratio = 1.6

Options - Color Options = On
Selection - Start / End Time = 0 / 200 ns
Velocity for Depth Axis = 0.055 m/ns

GPR Transect 18 - 18W

May 15, 1998



GPR Survey Settings
Number of Points per Trace = 500
Total Time Window = 400 ns
Step Size Used = 0.1 m
Nominal Frequency = 200 Mhz
Antenna Separation = 0.46 m
Pulser Voltage = 400
Number of Stacks 64
Survey Mode = Reflection

Plot Settings : File PINER5
Filter
- Trace to Trace Average = 4
- Down the Trace Average = 5
- Different Traces = Off
- Trace Correction = DEWOW

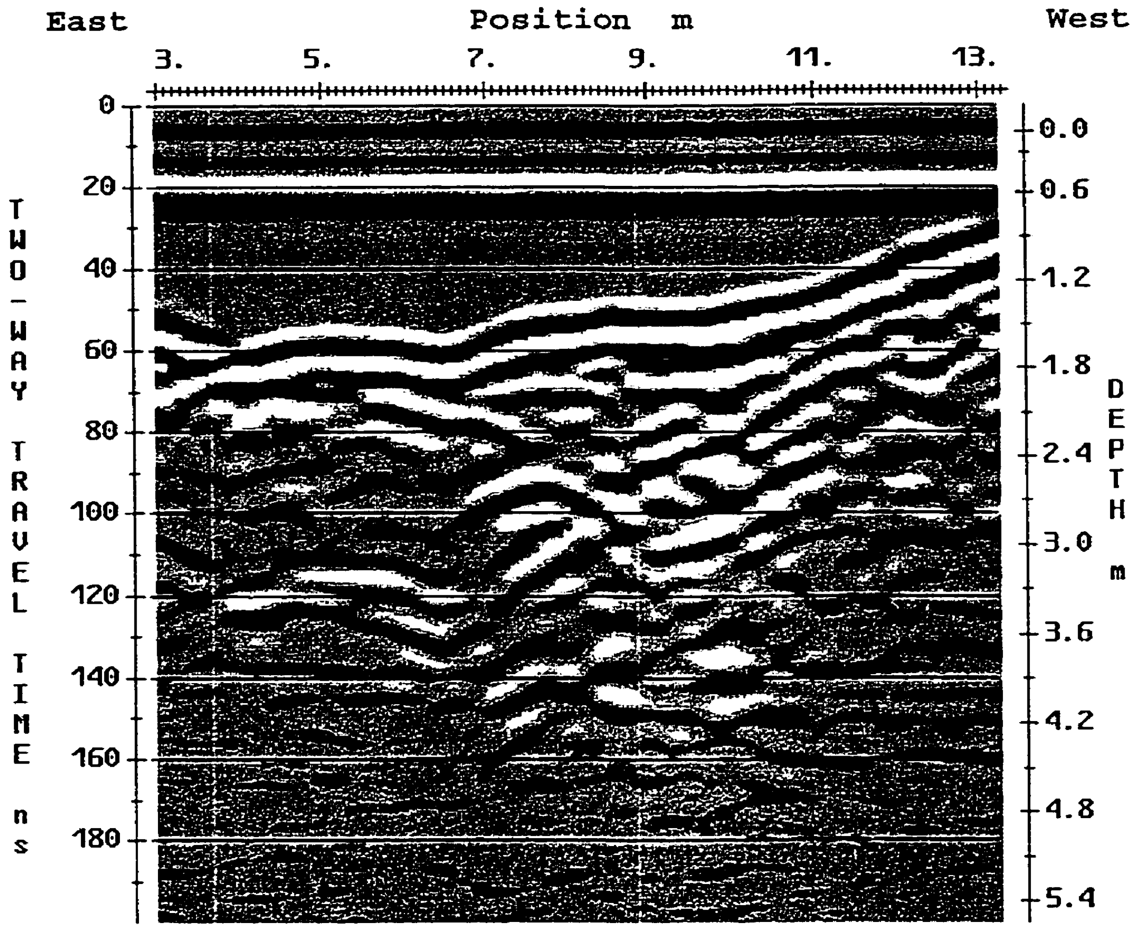
Gain SEC
- Gain = 1000
- Attenuation = 2.0
- Start Value = 1.0

Layout for Traces
- Traces per inch = 17
- Width Spacing Ratio = 1.6

Options - Color Options = On
Selection - Start / End Time = 0 / 200 ns
Velocity for Depth Axis = 0.055 m/ns

GPR Transect 20 - 20W

May 15, 1998



GPR Survey Settings
Number of Points per Trace = 500
Total Time Window = 400 ns
Step Size Used = 0.1 m
Nominal Frequency = 200 Mhz
Antenna Separation = 0.46 m
Pulser Voltage = 400
Number of Stacks 64
Survey Mode = Reflection

Plot Settings : File PINER6
Filter
- Trace to Trace Average = 4
- Down the Trace Average = 5
- Different Traces = Off
- Trace Correction = DEWOW

Gain SEC
- Gain = 1000
- Attenuation = 2.0
- Start Value = 1.0

Layout for Traces
- Traces per inch = 17
- Width Spacing Ratio = 1.6

Options - Color Options = On
Selection - Start / End Time = 0 / 200 ns
Velocity for Depth Axis = 0.055 m/ns

GPR Survey in the Pine River October 15, 1998: Description of Transects

File Name	Transect	Start Dist. m	End Dist. m	No. of Traces	Shore line Dist. m	Shore line Dist. m	Comments
PINEB2	4-4W	1.10	12.60	116	?	13.70	At 3.7 m metal grates and garbage can - nw until 6.5 - 7.0 m lots of debris and rocks. At 4.8 to 5.2 m is a shopping cart. At 8.9 m is a cinder block. At 10.1 m are sticks and cinder block. The 4.8 m measurement may be a bit off laterally.
PINEB3	5-5W	0.90	12.60	118	?	13.45	Shore to 2.9 m is gravel and cobbles with boulders at 1.8 and 2.3 m. Shopping cart upstream of line at 4.5 to 5.3 m. At 6.1 m is a 6-inch diameter log. At 7.5 m metal frame (of lawn chair?). At 10.5 m (up stream of line) is a large metal truck muffler. At 11.8 m a log. Can not reach far shore because of log jam.
PINEB4	6-6W	1.20	12.60	115	0.80		Shore to 3.2 m is gravel and cobbles. At 5.65 m and 6.0 m are PVC pipes full of bentonite (RC4 and RC3 respectively). At 11.4 and 12.1 are (1.9?-diam) logs. The 10 m measurement was taken too early. *Confirmation soil core RC5 collected at 7.82 m.*
PINEB6	7-7W	1.40	12.10	108	0.75	13.00	At 9.5 m and about 50 cm downstream is a buried shopping cart (not directly under antennae). Sandy bottom. At 11.0 and 11.3 are logs
PINEB7	8-8W	1.40	12.00	107	0.90	13.05	The steel staff gauge SG-1 is near shore. Shore line to 3.1 m is gravelly and cobbles. At 2.0 to 3.1 m it is slippery and silty peat. Sandy. Shopping cart at 8.4 m. Large log at 10.8 m. *Confirmation soil core RC6 collected at 7.40 m*
PINEB8	9-9W	1.50	12.10	107	1.05	12.80	Over hanging trees from shore to 8.7 m. Rest is sandy.
PINEB10	10-10W	1.50	12.00	106	1.05	12.85	Sandy. Small log at 11.7 m. *Confirmation soil core RC7 collected at 4.10 m.*
PINEB16	12-12W	1.80	12.10	104	1.30		Deeper at 4.30 m then shallower at 5 m. From 10.0 to 12.75 m is a suspended log in the water (not resting on the streambed, in the antennae parallel to it but 20 cm down stream. Lawn mower at 11.7 to 12.1 m. *Confirmation soil core RC8 collected at 8.3 m.*

File Name	Transect	Start Dist. m	End Dist. m	No. of Traces	Shore line Dist. m	Shore line Dist. m	Comments
PINEB18	14-14W	1.90	12.30	105	1.55	12.90	All Sand. *Confirmation soil cores RC9 and RC10 collected at 4.0 m and 7.0 m, respectively.*
PINEB19	15-15W	2.00	12.10	102	1.45	12.90	A 1 foot diameter, large log extends from far shore back to 11.9 m.
PINEB20	16-16W	1.70	12.00	104	1.30	12.95	Very shallow at 4.7 m. Stopped early because of log. Large log at 10 to 12 m that is perpendicular to water flow and about 40 cm down stream. *Confirmation soil core RC11 collected at 6.1 m.*
PINEB21	17-17W	1.80	12.70	110	1.35	13.35	Log at 12.3 m
PINEB22	18-18W	1.80	13.00	113	1.35	13.00	Antennae pass directly over PVC pipes filled with bentonite and having metal clamps at 4.1 to 4.2 m (RC1 and PRP7), and also at 6.4 m (RC2) and 7.5 m (PRP17). Small log at 12 m.
PINEB23	19-19W	2.40	13.30	110	1.50	13.80	Log at 11.9 m.
PINEB24	20-20W	3.20	13.30	102	1.80	13.90	Large log/stump 2-3 ft out from shore
PINEB25	24-22W	2.30	5.80	36	1.90		At 4.9-5.1 m bottom of raft on PRP2 bentonite filled PVC pipe, at 5.8 m raft all way over PRP2. Shift 4.9 to 5.8 back by 10 cm (?missed reading?). Transect continued below.
PINEB26	24-22W	4.90	13.00	82	2.30	14.15	Resume transect line to opposite shore. At 3.65 pass over the benotonite filled, PVC pipe of PRP1 and the PVC pipe with the stainless steel Levelogger and Tidbit logger in it. The PRP1 pipe is only 6 cm below the water surface. At 5.15 is the PRP2 bentonite filled PVC pipe near the water surface, and the raft gets stuck on it. At 8.14 m is the PRP3 pipe sticking 6 cm above the streambed. At 11.2 m is the PRP4 pipe sticking 6 cm above the streambed. From 11.0 to 12.3 m is a buried log. *Confirmation soil core RC12 collected at approximately 7.0 m.*

Notes:

Dist. = Distance along transect from east to west

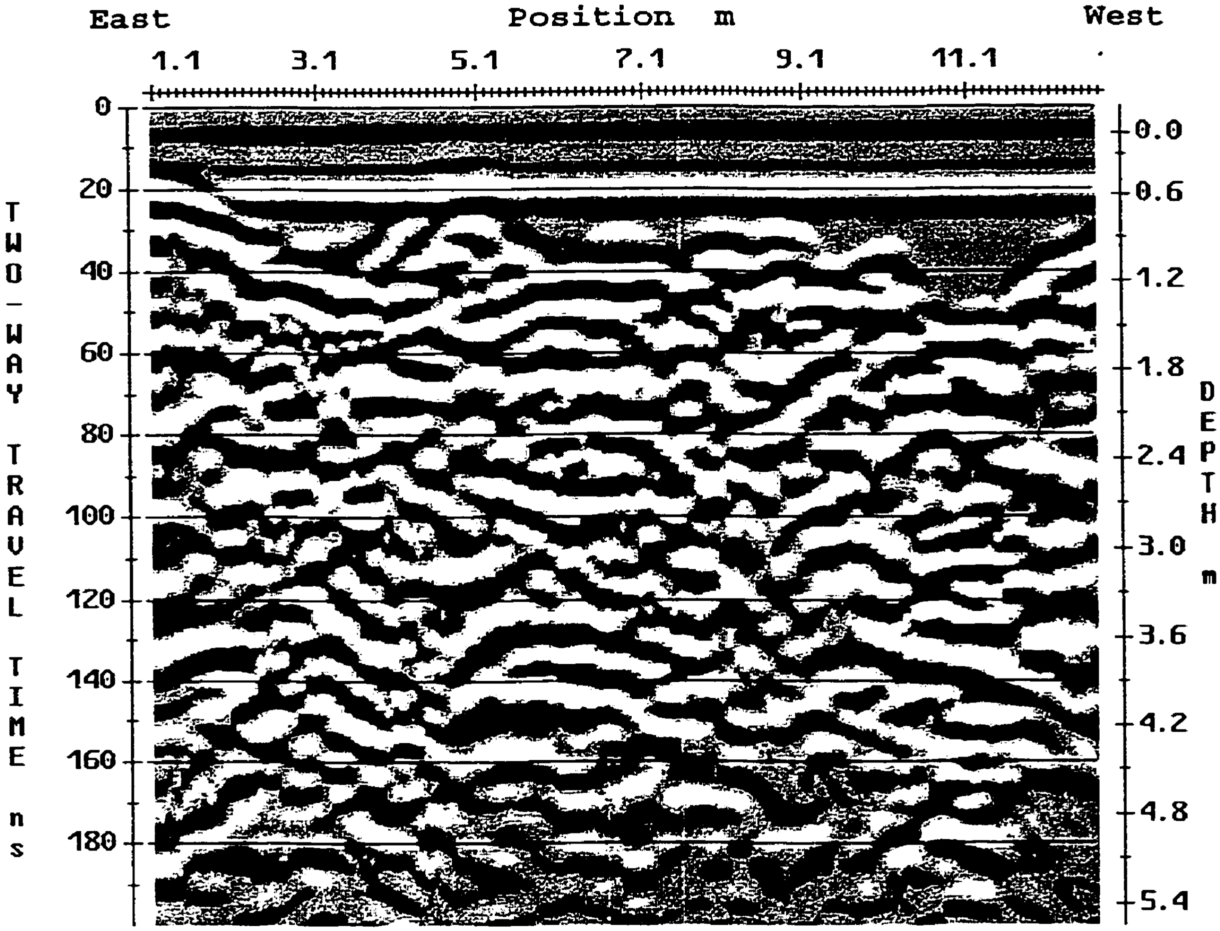
SG1 river water level was 1.068 m at 11:37 am (elevation is 184.54 m amsl)

GPR Survey Settings:

Number of points per trace = 312	Antenna Separation 0.46 m
Total time Window = 250 ns	Pulser Voltage = 400
Step size used = 0.1 m	Number of Stacks 128
Nominal Frequency 200 MHz	Survey Mode = Reflection

Survey performed by Brewster Conant, Scott Piggot, and Breda Savoldelli

GPR Transect 4 - 4W
October 15, 1998



GPR Survey Settings
Number of Points per Trace =312
Total Time Window = 250 ns
Step Size Used = 0.1 m
Nominal Frequency = 200 Mhz
Antenna Separation = 0.46 m
Pulser Voltage = 400
Number of Stacks 128
Survey Mode = Reflection

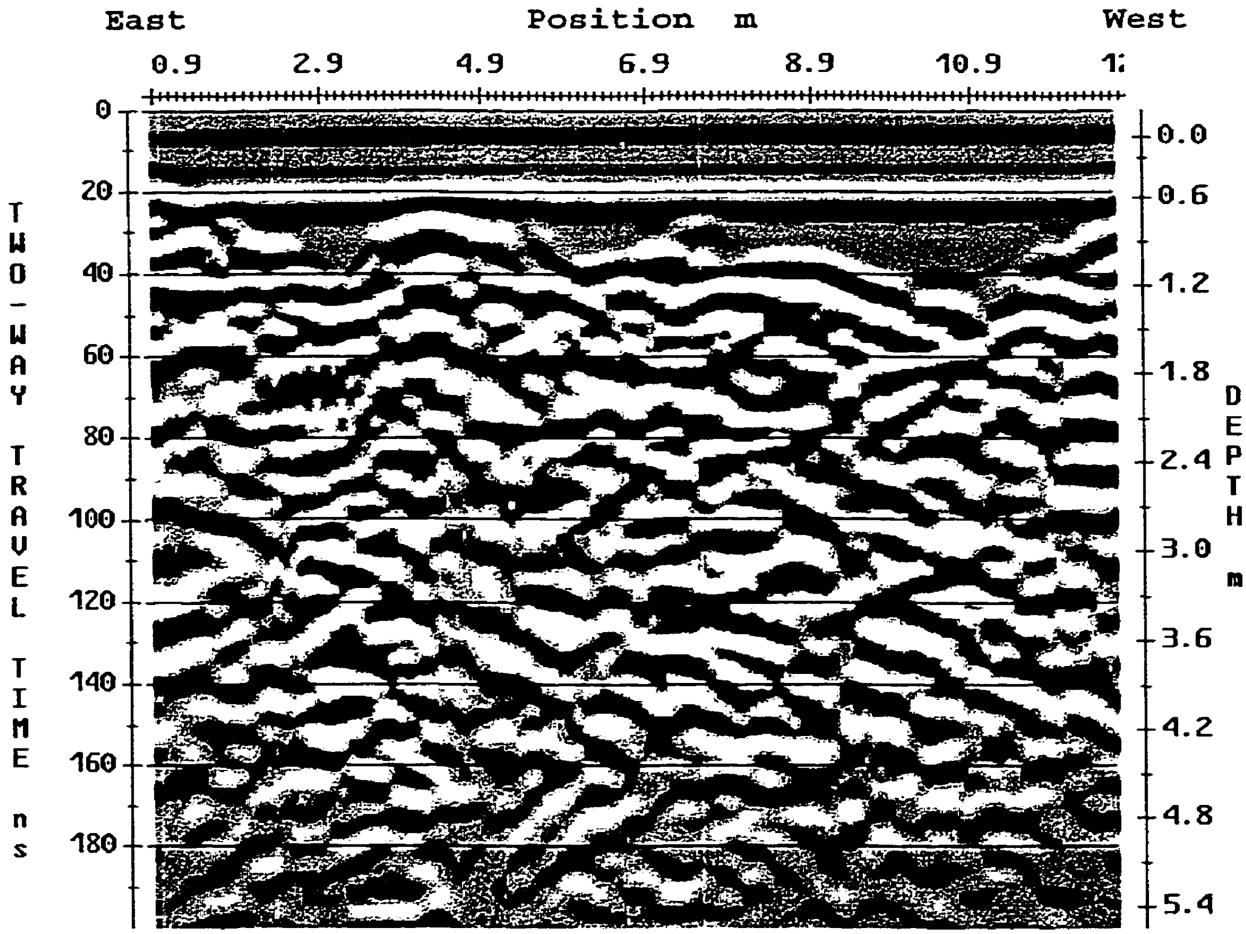
Plot Settings : File PINEB2
Filter
- Trace to Trace Average = 4
- Down the Trace Average = 5
- Different Traces = Off
- Trace Correction = DEWOW

Gain SEC
- Gain = 1000
- Attenuation = 2.0
- Start Value = 1.0

Layout for Traces
- Traces per inch = 17
- Width Spacing Ratio = 1.6

Options - Color Options = On
Selection - Start / End Time = 0 / 200 ns
Velocity for Depth Axis = 0.055 m/ns

GPR Transect 5 - 5W
October 15, 1998



GPR Survey Settings
Number of Points per Trace =312
Total Time Window = 250 ns
Step Size Used = 0.1 m
Nominal Frequency = 200 Mhz
Antenna Separation = 0.46 m
Pulser Voltage = 400
Number of Stacks 128
Survey Mode = Reflection

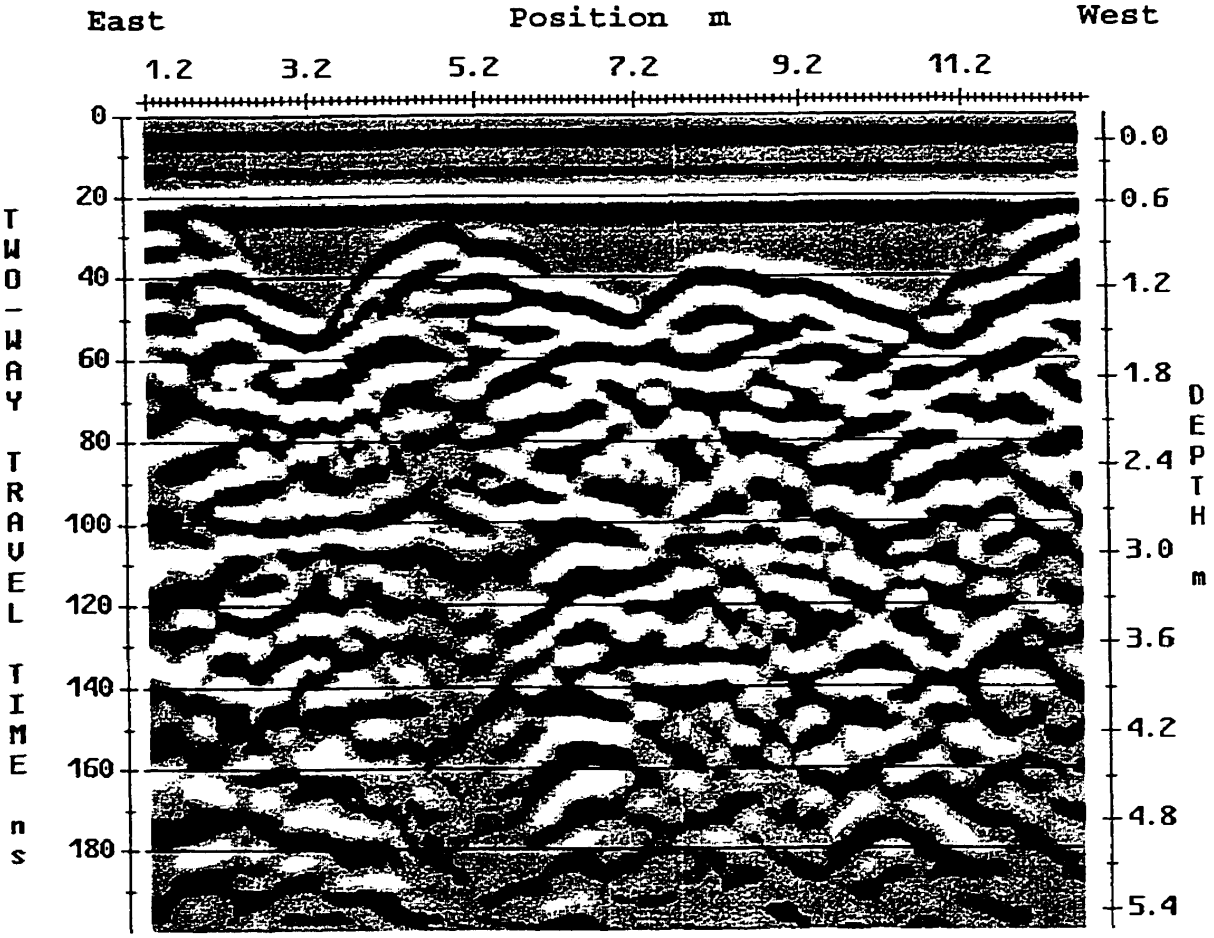
Plot Settings : File PINEB3
Filter
- Trace to Trace Average = 4
- Down the Trace Average = 5
- Different Traces = Off
- Trace Correction = DEWOW

Gain SEC
- Gain = 1000
- Attenuation = 2.0
- Start Value = 1.0

Layout for Traces
- Traces per inch = 17
- Width Spacing Ratio = 1.6

Options - Color Options = On
Selection - Start / End Time = 0 / 200 ns
Velocity for Depth Axis = 0.055 m/ns

GPR Transect 6 - 6W
October 15, 1998



GPR Survey Settings
Number of Points per Trace =312
Total Time Window = 250 ns
Step Size Used = 0.1 m
Nominal Frequency = 200 Mhz
Antenna Separation = 0.46 m
Pulser Voltage = 400
Number of Stacks 128
Survey Mode = Reflection

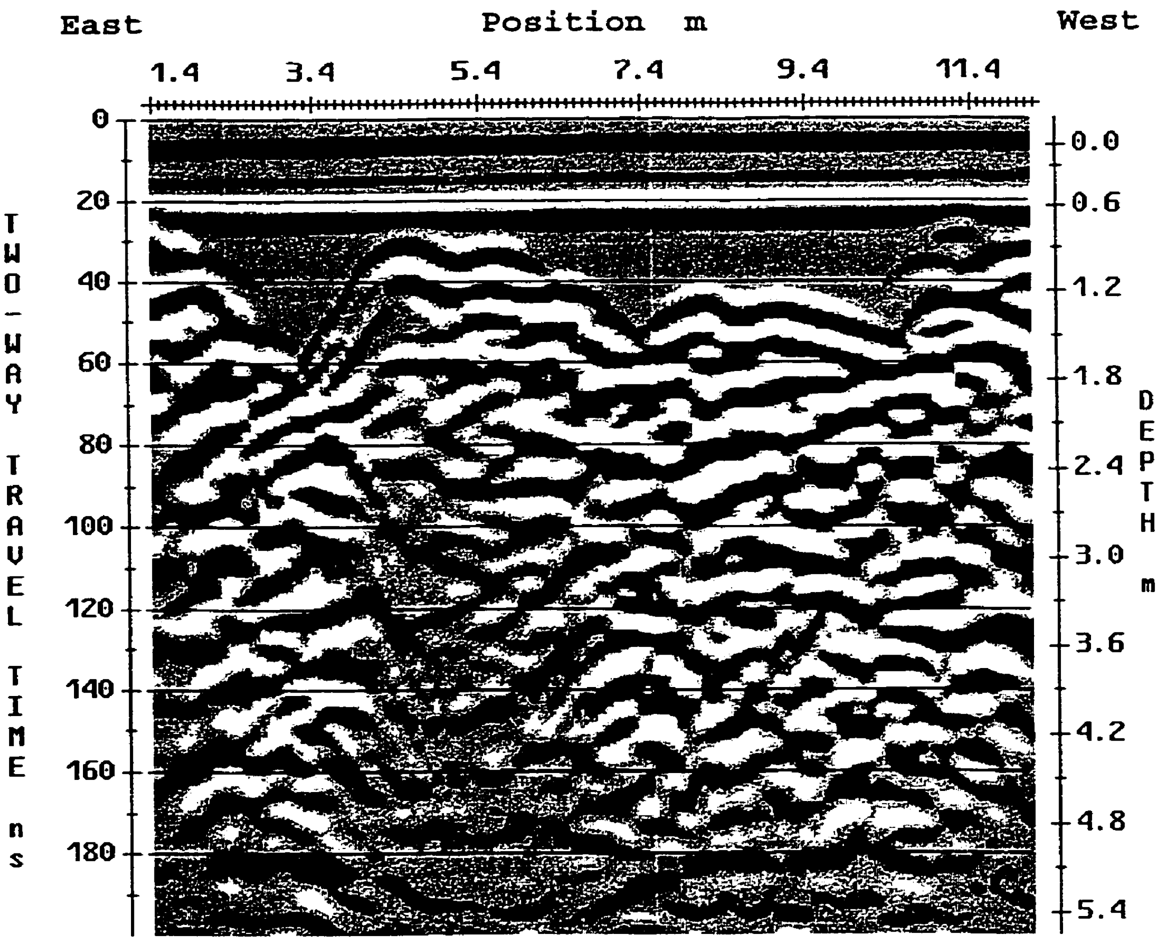
Plot Settings : File PINEB4
Filter
- Trace to Trace Average = 4
- Down the Trace Average = 5
- Different Traces = Off
- Trace Correction = DEWOW

Gain SEC
- Gain = 1000
- Attenuation = 2.0
- Start Value = 1.0

Layout for Traces
- Traces per inch = 17
- Width Spacing Ratio = 1.6

Options - Color Options = On
Selection - Start / End Time = 0 / 200 ns
Velocity for Depth Axis = 0.055 m/ns

GPR Transect 7 - 7W
October 15, 1998



GPR Survey Settings
Number of Points per Trace =312
Total Time Window = 250 ns
Step Size Used = 0.1 m
Nominal Frequency = 200 Mhz
Antenna Separation = 0.46 m
Pulser Voltage = 400
Number of Stacks 128
Survey Mode = Reflection

Plot Settings : File PINEB6
Filter
- Trace to Trace Average = 4
- Down the Trace Average = 5
- Different Traces = Off
- Trace Correction = DEWOW

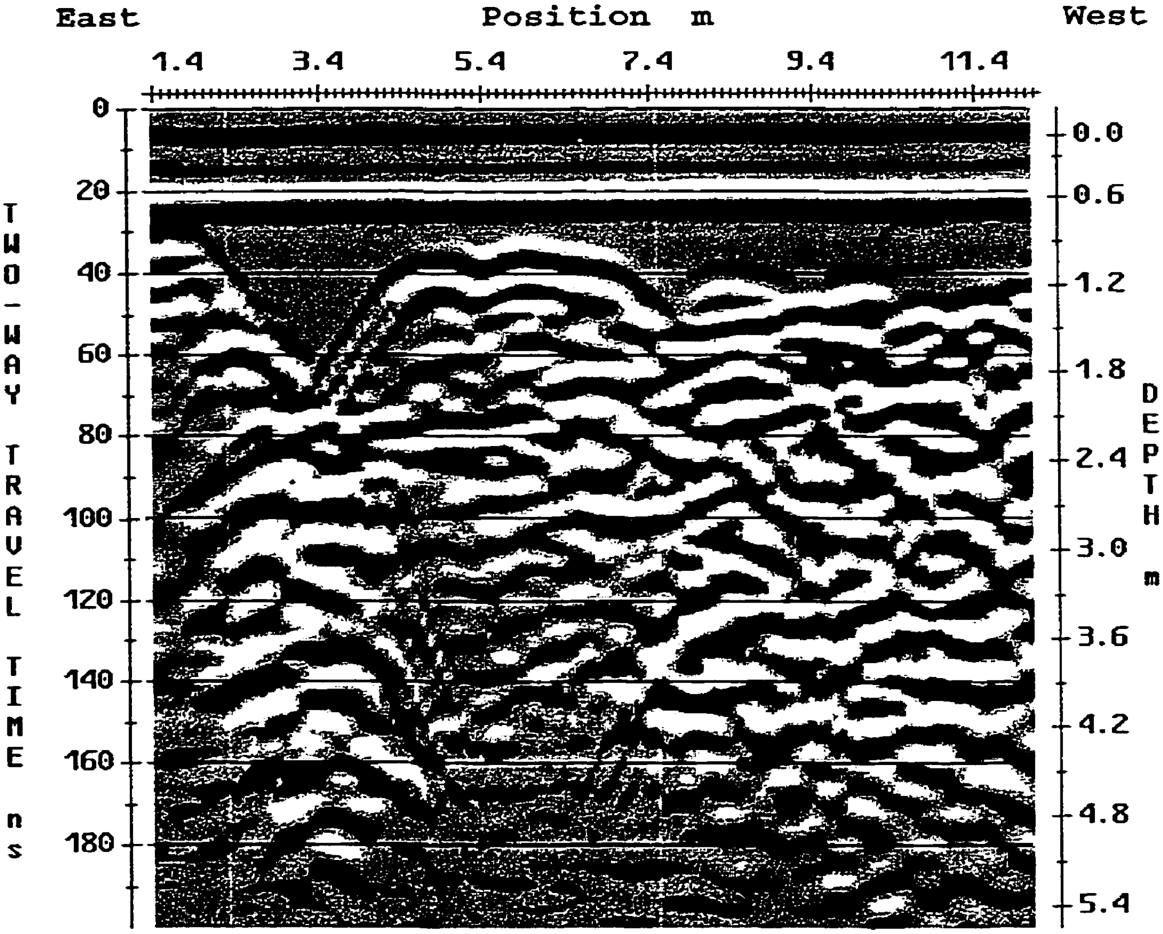
Gain SEC
- Gain = 1000
- Attenuation = 2.0
- Start Value = 1.0

Layout for Traces
- Traces per inch = 17
- Width Spacing Ratio = 1.6

Options - Color Options = On
Selection - Start / End Time = 0 / 200 ns
Velocity for Depth Axis = 0.055 m/ns

GPR Transect 8 - 8W

October 15, 1998



GPR Survey Settings
Number of Points per Trace =312
Total Time Window = 250 ns
Step Size Used = 0.1 m
Nominal Frequency = 200 Mhz
Antenna Separation = 0.46 m
Pulser Voltage = 400
Number of Stacks 128
Survey Mode = Reflection

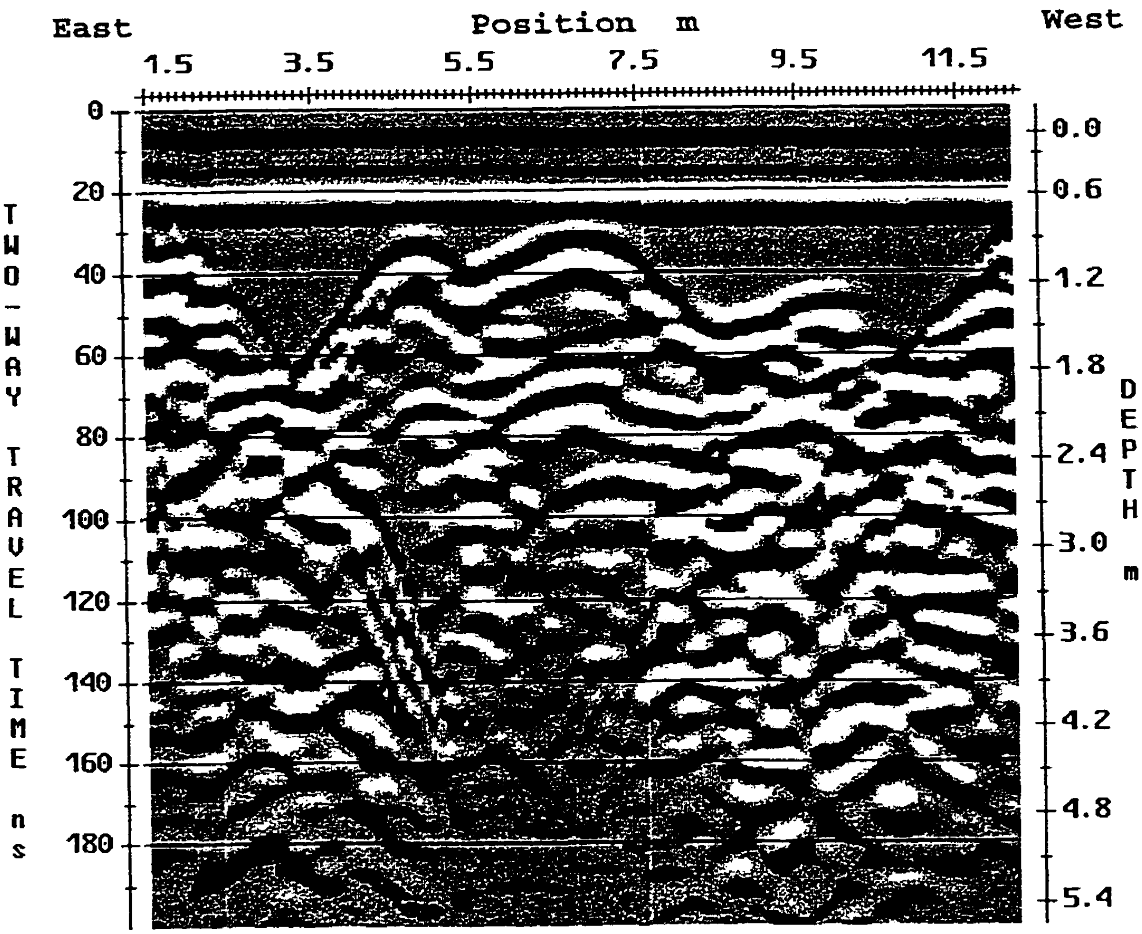
Plot Settings : File PINEB7
Filter
- Trace to Trace Average = 4
- Down the Trace Average = 5
- Different Traces = Off
- Trace Correction = DEWOW

Gain SEC
- Gain = 1000
- Attenuation = 2.0
- Start Value = 1.0

Layout for Traces
- Traces per inch = 17
- Width Spacing Ratio = 1.6

Options - Color Options = On
Selection - Start / End Time = 0 / 200 ns
Velocity for Depth Axis = 0.055 m/ns

GPR Transect 9 - 9W
October 15, 1998



GPR Survey Settings
Number of Points per Trace =312
Total Time Window = 250 ns
Step Size Used = 0.1 m
Nominal Frequency = 200 Mhz
Antenna Separation = 0.46 m
Pulser Voltage = 400
Number of Stacks 128
Survey Mode = Reflection

Plot Settings : File PINEB8
Filter
- Trace to Trace Average = 4
- Down the Trace Average = 5
- Different Traces = Off
- Trace Correction = DEWOW

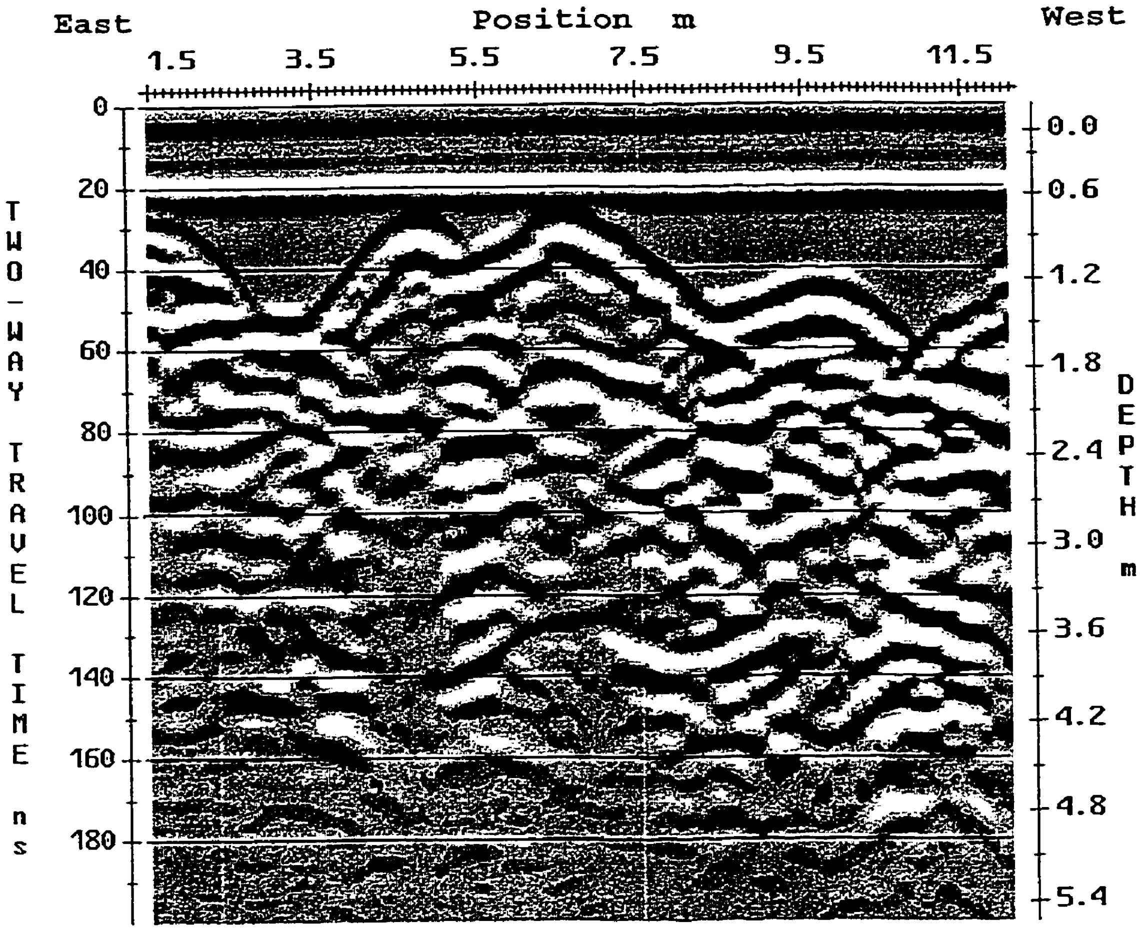
Gain SEC
- Gain = 1000
- Attenuation = 2.0
- Start Value = 1.0

Layout for Traces
- Traces per inch = 17
- Width Spacing Ratio = 1.6

Options - Color Options = On
Selection - Start / End Time = 0 / 200 ns
Velocity for Depth Axis = 0.055 m/ns

GPR Transect 10 - 10W

October 15, 1998



GPR Survey Settings
Number of Points per Trace =312
Total Time Window = 250 ns
Step Size Used = 0.1 m
Nominal Frequency = 200 Mhz
Antenna Separation = 0.46 m
Pulser Voltage = 400
Number of Stacks 128
Survey Mode = Reflection

Plot Settings : File PINEB10
Filter
- Trace to Trace Average = 4
- Down the Trace Average = 5
- Different Traces = Off
- Trace Correction = DEWOW

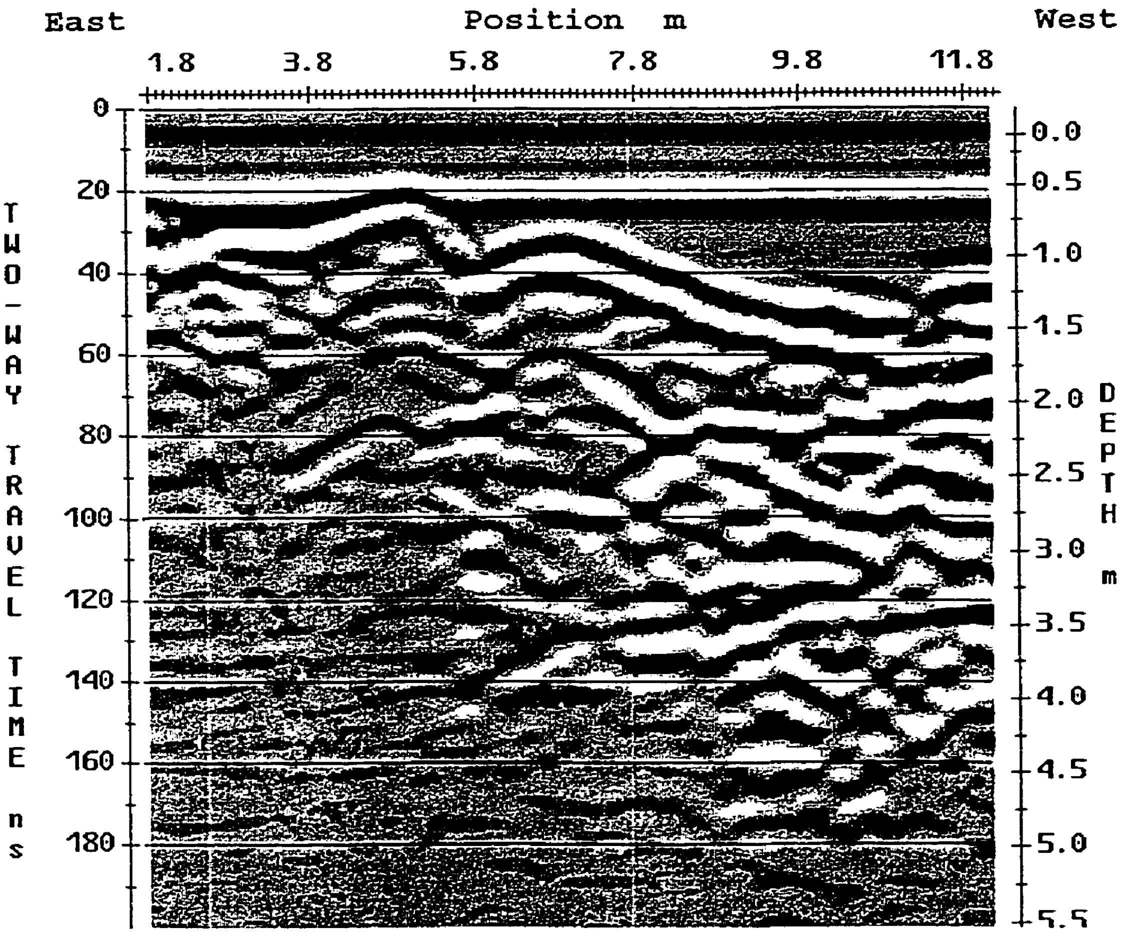
Gain SEC
- Gain = 1000
- Attenuation = 2.0
- Start Value = 1.0

Layout for Traces
- Traces per inch = 17
- Width Spacing Ratio = 1.6

Options - Color Options = On
Selection - Start / End Time = 0 / 200 ns
Velocity for Depth Axis = 0.055 m/ns

GPR Transect 12 - 12W

October 15, 1998



GPR Survey Settings
Number of Points per Trace =312
Total Time Window = 250 ns
Step Size Used = 0.1 m
Nominal Frequency = 200 Mhz
Antenna Separation = 0.46 m
Pulser Voltage = 400
Number of Stacks 128
Survey Mode = Reflection

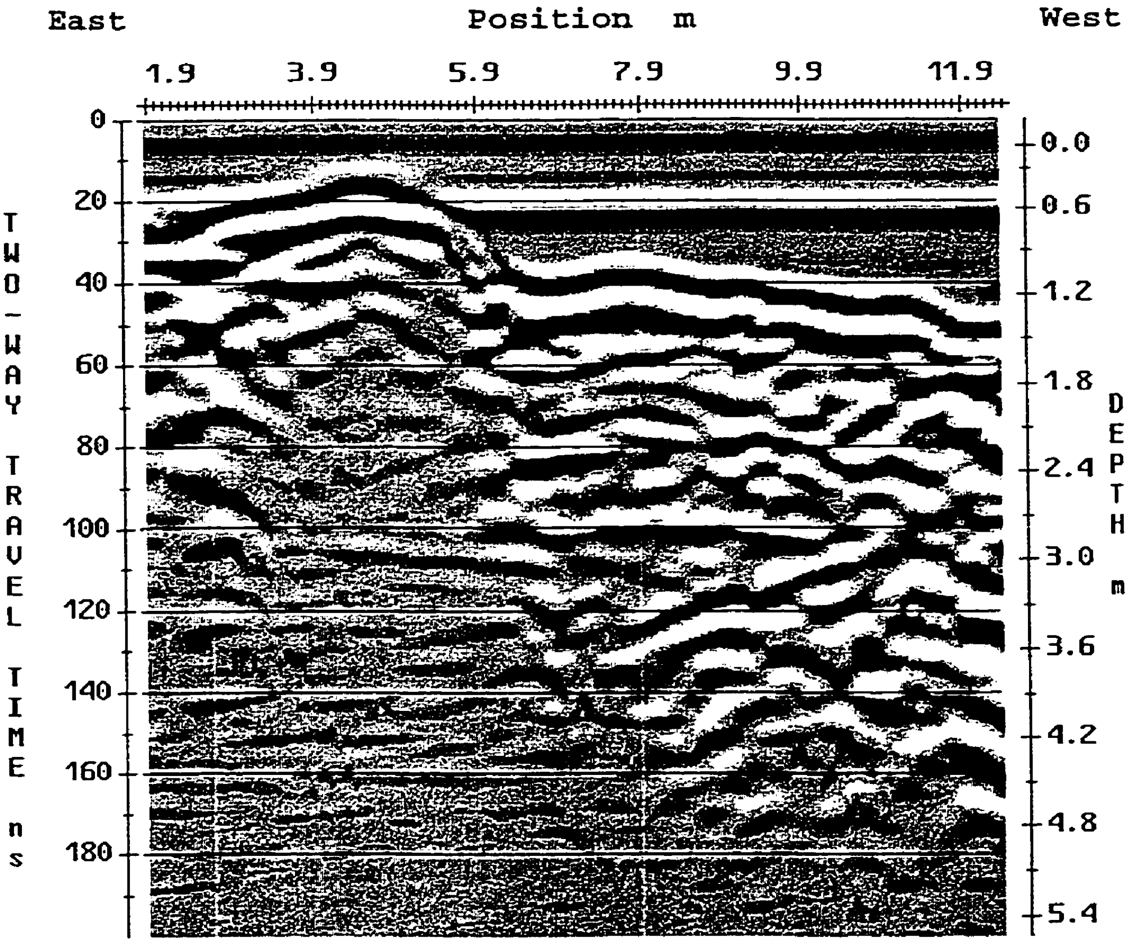
Plot Settings : File PINEB16
Filter
- Trace to Trace Average = 4
- Down the Trace Average = 5
- Different Traces = Off
- Trace Correction = DEWOW

Gain SEC
- Gain = 1000
- Attenuation = 2.0
- Start Value = 1.0

Layout for Traces
- Traces per inch = 17
- Width Spacing Ratio = 1.6

Options - Color Options = On
Selection - Start / End Time = 0 / 200 ns
Velocity for Depth Axis = 0.055 m/ns

GPR Transect 14 - 14W
October 15, 1998



GPR Survey Settings
Number of Points per Trace =312
Total Time Window = 250 ns
Step Size Used = 0.1 m
Nominal Frequency = 200 Mhz
Antenna Separation = 0.46 m
Pulser Voltage = 400
Number of Stacks 128
Survey Mode = Reflection

Plot Settings : File PINEB18
Filter
- Trace to Trace Average = 4
- Down the Trace Average = 5
- Different Traces = Off
- Trace Correction = DEWOW

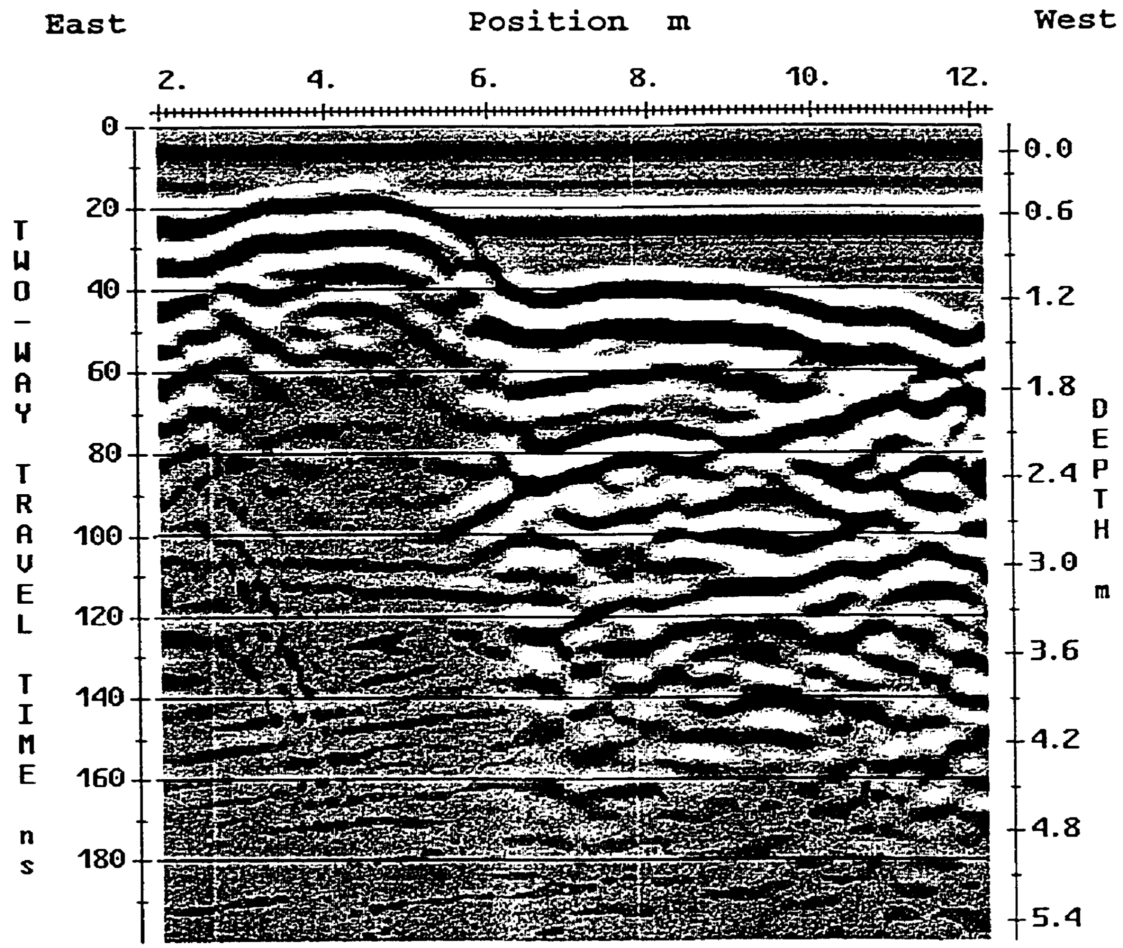
Gain SEC
- Gain = 1000
- Attenuation = 2.0
- Start Value = 1.0

Layout for Traces
- Traces per inch = 17
- Width Spacing Ratio = 1.6

Options - Color Options = On
Selection - Start / End Time = 0 / 200 ns
Velocity for Depth Axis = 0.055 m/ns

GPR Transect 15 - 15W

October 15, 1998



GPR Survey Settings
Number of Points per Trace =312
Total Time Window = 250 ns
Step Size Used = 0.1 m
Nominal Frequency = 200 Mhz
Antenna Separation = 0.46 m
Pulser Voltage = 400
Number of Stacks 128
Survey Mode = Reflection

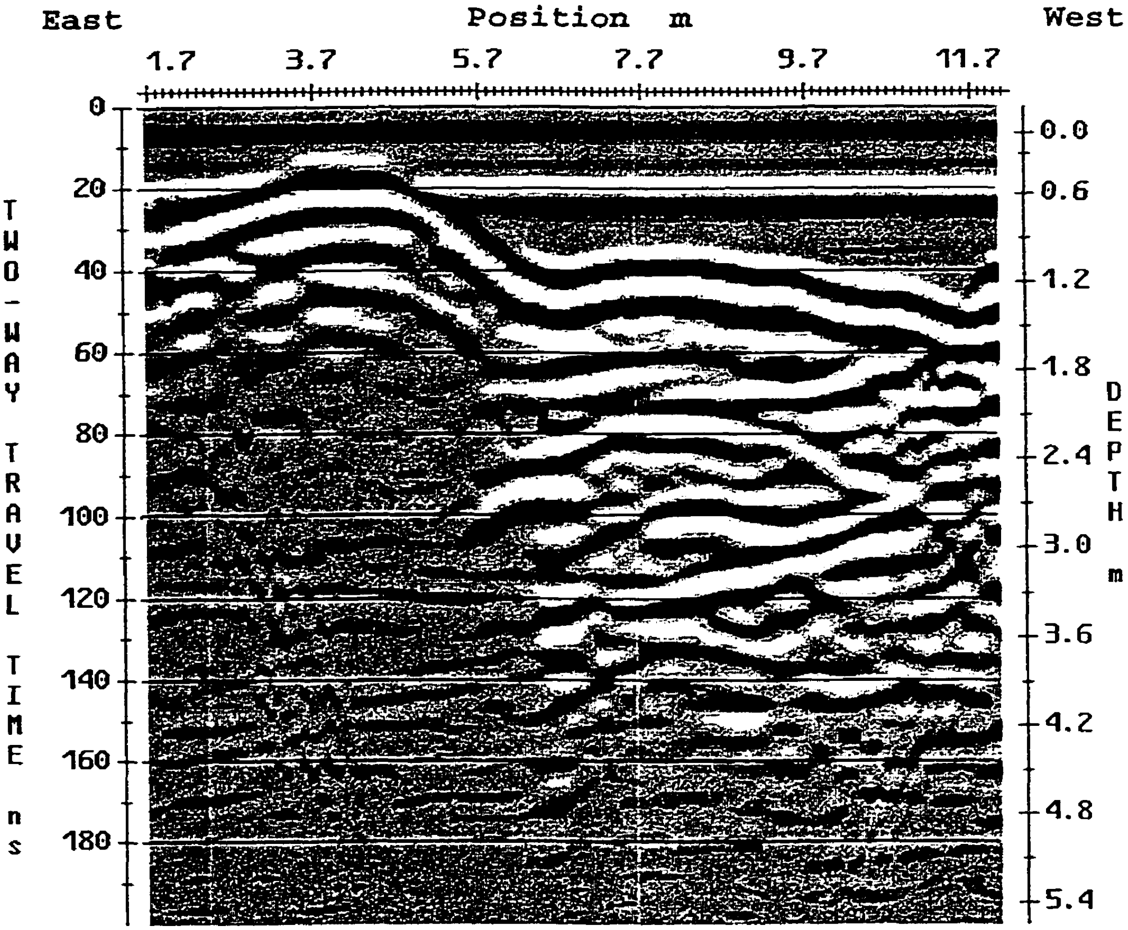
Plot Settings : File PINEB19
Filter
- Trace to Trace Average = 4
- Down the Trace Average = 5
- Different Traces = Off
- Trace Correction = DEWOW

Gain SEC
- Gain = 1000
- Attenuation = 2.0
- Start Value = 1.0

Layout for Traces
- Traces per inch = 17
- Width Spacing Ratio = 1.6

Options - Color Options = On
Selection - Start / End Time = 0 / 200 ns
Velocity for Depth Axis = 0.055 m/ns

GPR Transect 16 - 16W
October 15, 1998



GPR Survey Settings
Number of Points per Trace =312
Total Time Window = 250 ns
Step Size Used = 0.1 m
Nominal Frequency = 200 Mhz
Antenna Separation = 0.46 m
Pulser Voltage = 400
Number of Stacks 128
Survey Mode = Reflection

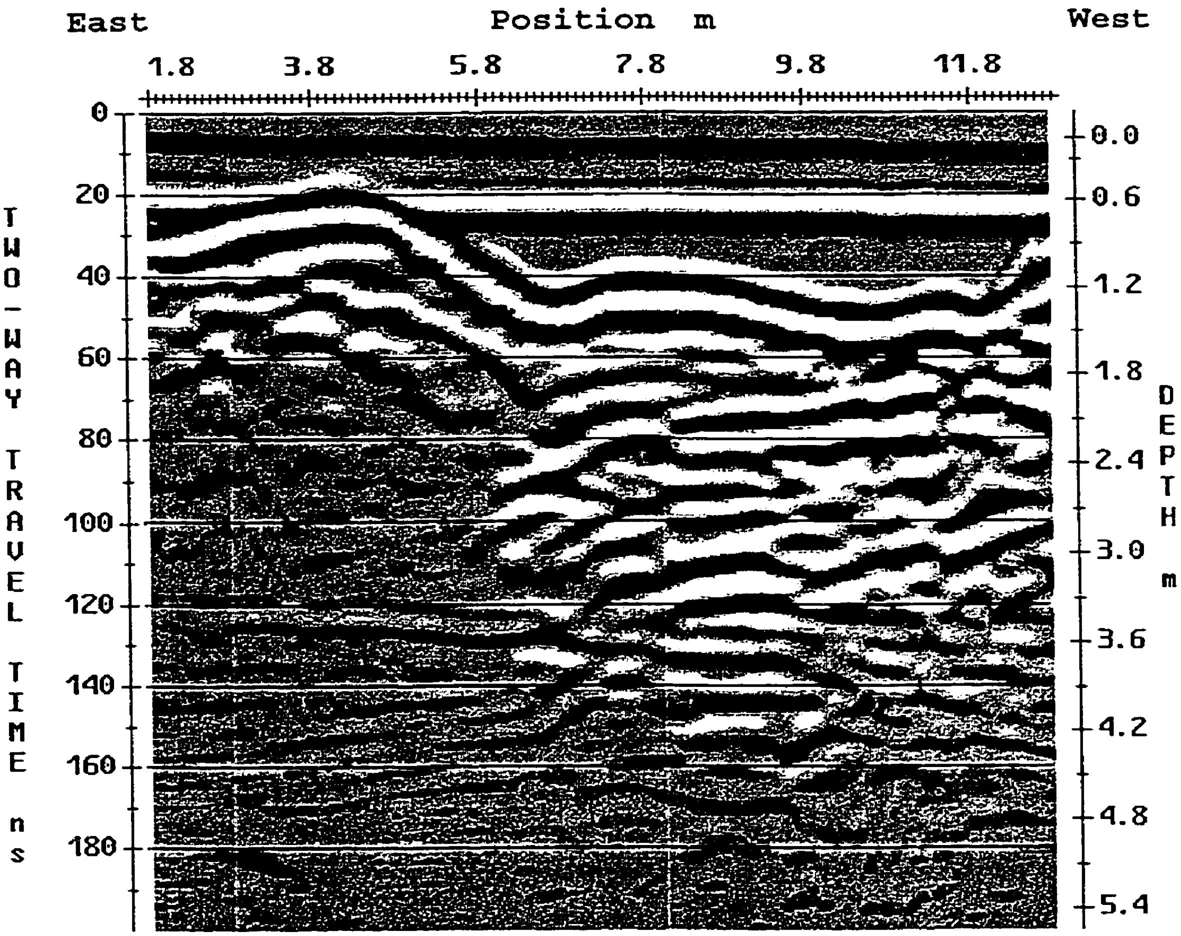
Plot Settings : File PINEB20
Filter
- Trace to Trace Average = 4
- Down the Trace Average = 5
- Different Traces = Off
- Trace Correction = DEWOW

Gain SEC
- Gain = 1000
- Attenuation = 2.0
- Start Value = 1.0

Layout for Traces
- Traces per inch = 17
- Width Spacing Ratio = 1.6

Options - Color Options = On
Selection - Start / End Time = 0 / 200 ns
Velocity for Depth Axis = 0.055 m/ns

GPR Transect 17 - 17W
October 15, 1998



GPR Survey Settings
Number of Points per Trace =312
Total Time Window = 250 ns
Step Size Used = 0.1 m
Nominal Frequency = 200 Mhz
Antenna Separation = 0.46 m
Pulser Voltage = 400
Number of Stacks 128
Survey Mode = Reflection

Plot Settings : File PINEB21
Filter
- Trace to Trace Average = 4
- Down the Trace Average = 5
- Different Traces = Off
- Trace Correction = DEWOW

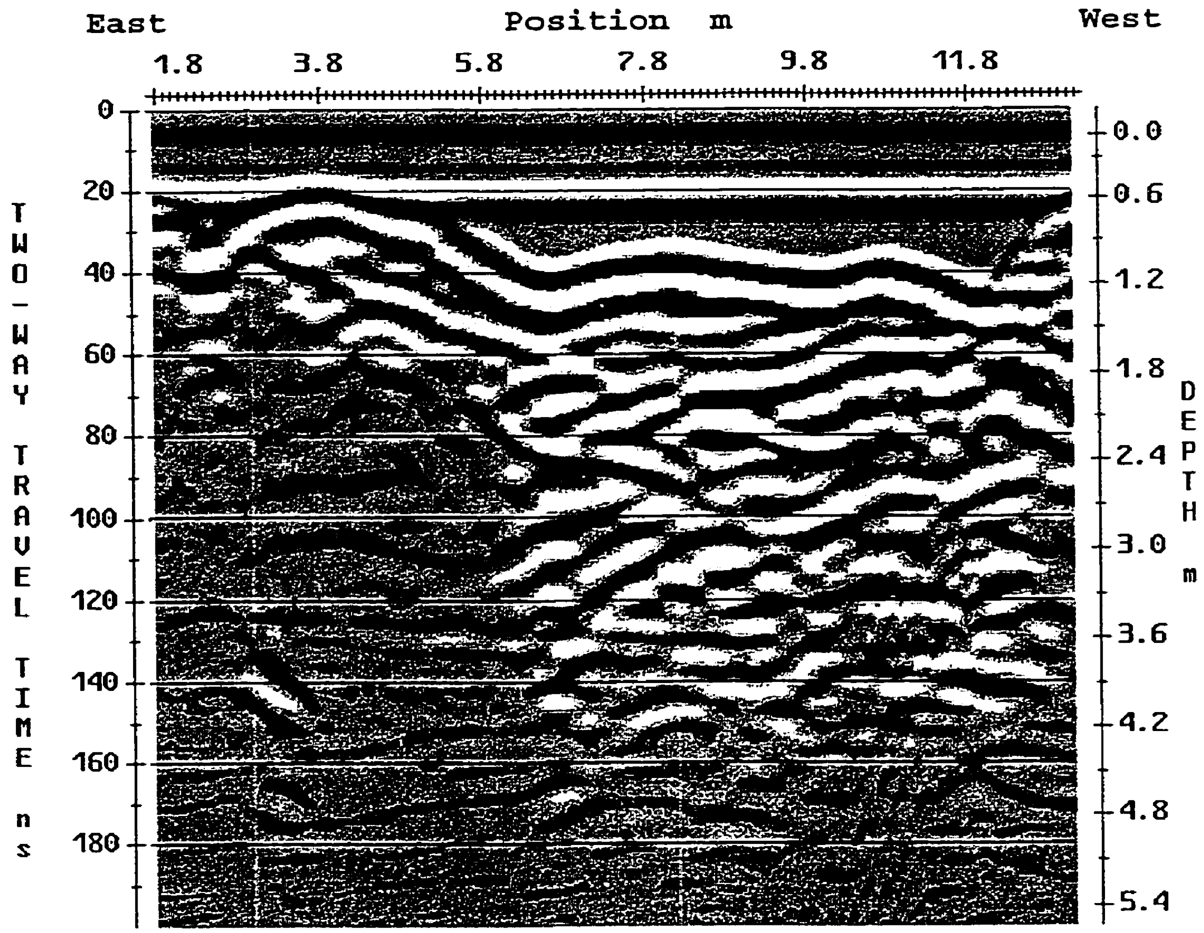
Gain SEC
- Gain = 1000
- Attenuation = 2.0
- Start Value = 1.0

Layout for Traces
- Traces per inch = 17
- Width Spacing Ratio = 1.6

Options - Color Options = On
Selection - Start / End Time = 0 / 200 ns
Velocity for Depth Axis = 0.055 m/ns

GPR Transect 18 - 18W

October 15, 1998



GPR Survey Settings
Number of Points per Trace =312
Total Time Window = 250 ns
Step Size Used = 0.1 m
Nominal Frequency = 200 Mhz
Antenna Separation = 0.46 m
Pulser Voltage = 400
Number of Stacks 128
Survey Mode = Reflection

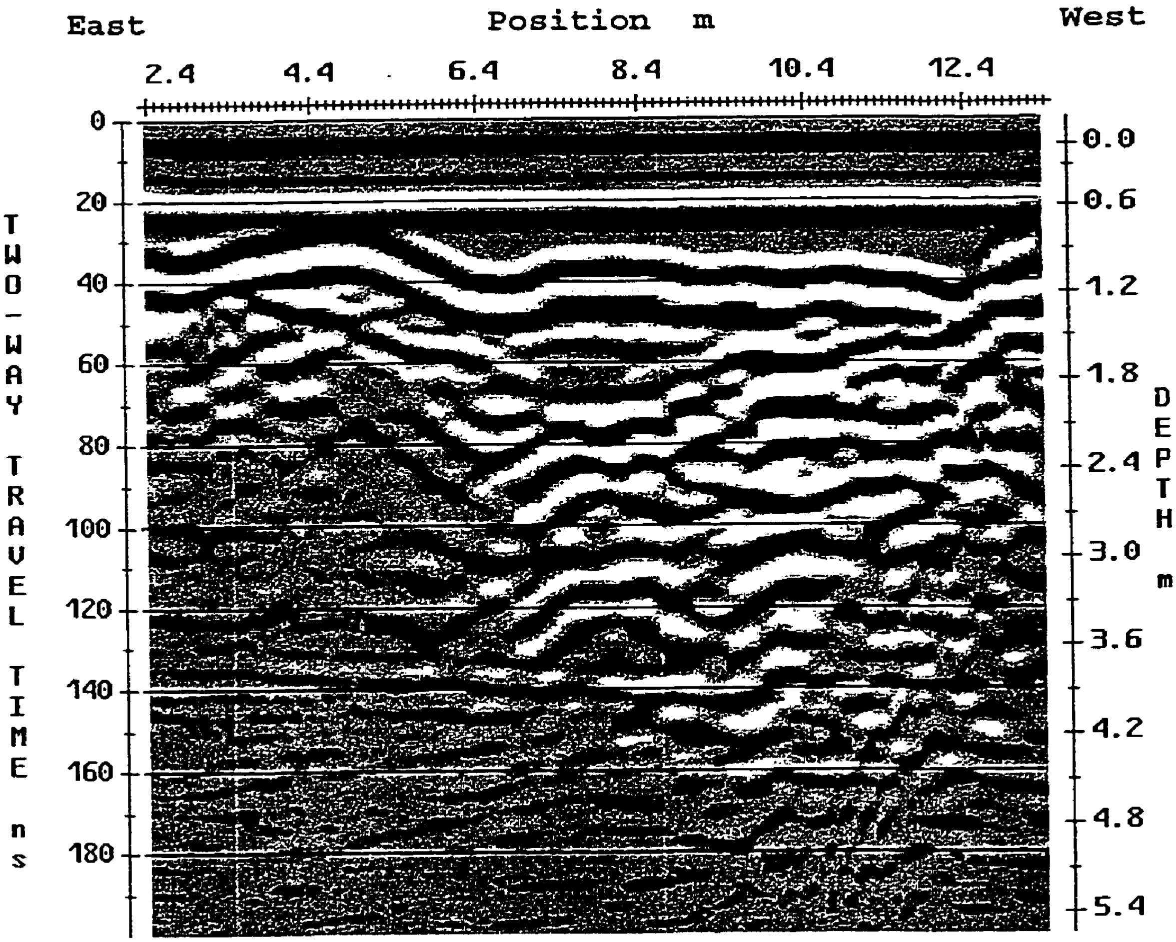
Plot Settings : File PINEB22
Filter
- Trace to Trace Average = 4
- Down the Trace Average = 5
- Different Traces = Off
- Trace Correction = DEWOW

Gain SEC
- Gain = 1000
- Attenuation = 2.0
- Start Value = 1.0

Layout for Traces
- Traces per inch = 17
- Width Spacing Ratio = 1.6

Options - Color Options = On
Selection - Start / End Time = 0 / 200 ns
Velocity for Depth Axis = 0.055 m/ns

GPR Transect 19 - 19W
October 15, 1998



GPR Survey Settings
Number of Points per Trace =312
Total Time Window = 250 ns
Step Size Used = 0.1 m
Nominal Frequency = 200 Mhz
Antenna Separation = 0.46 m
Pulser Voltage = 400
Number of Stacks 128
Survey Mode = Reflection

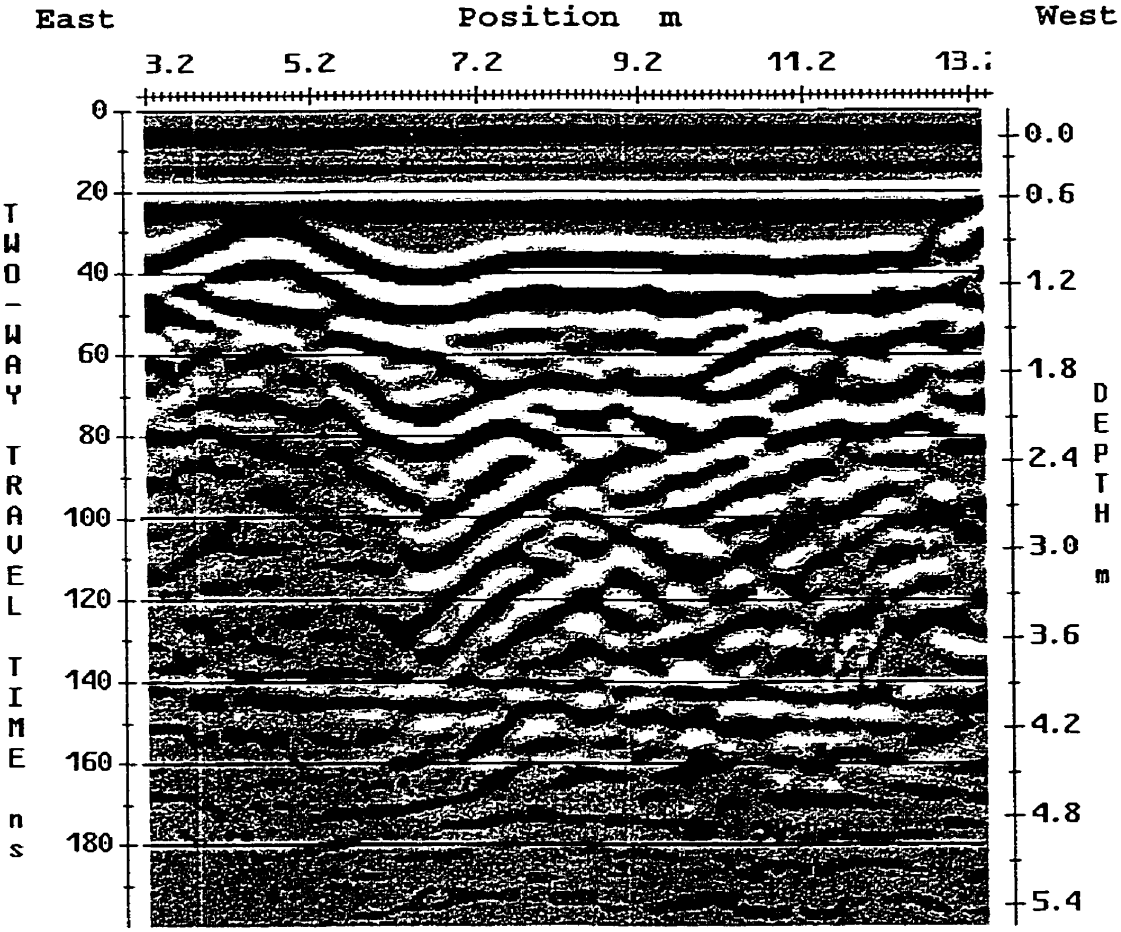
Plot Settings : File PINEB23
Filter
- Trace to Trace Average = 4
- Down the Trace Average = 5
- Different Traces = Off
- Trace Correction = DEWOW

Gain SEC
- Gain = 1000
- Attenuation = 2.0
- Start Value = 1.0

Layout for Traces
- Traces per inch = 17
- Width Spacing Ratio = 1.6

Options - Color Options = On
Selection - Start / End Time = 0 / 200 ns
Velocity for Depth Axis = 0.055 m/ns

GPR Transect 20 - 20W
October 15, 1998



GPR Survey Settings
Number of Points per Trace =312
Total Time Window = 250 ns
Step Size Used = 0.1 m
Nominal Frequency = 200 Mhz
Antenna Separation = 0.46 m
Pulser Voltage = 400
Number of Stacks 128
Survey Mode = Reflection

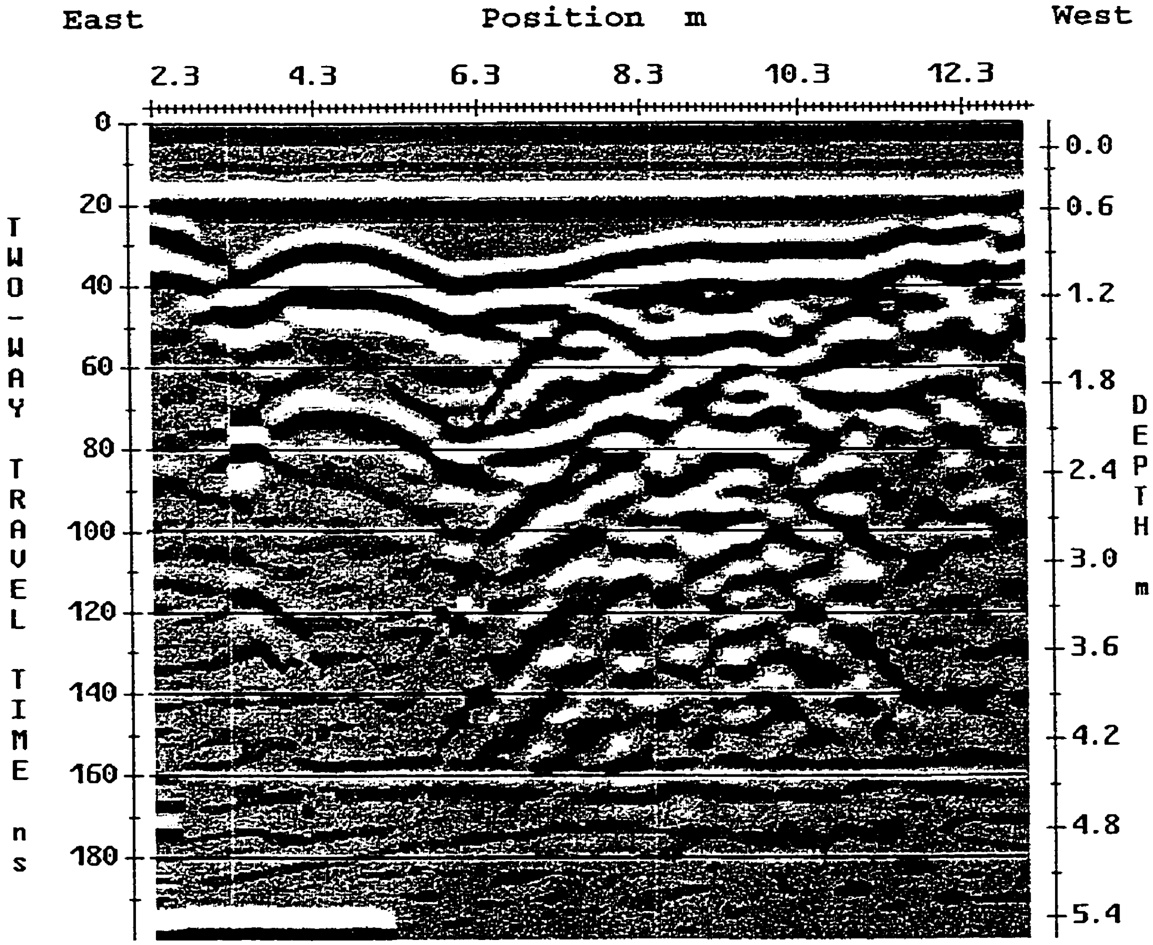
Plot Settings : File PINEB24
Filter
- Trace to Trace Average = 4
- Down the Trace Average = 5
- Different Traces = Off
- Trace Correction = DEWOW

Gain SEC
- Gain = 1000
- Attenuation = 2.0
- Start Value = 1.0

Layout for Traces
- Traces per inch = 17
- Width Spacing Ratio = 1.6

Options - Color Options = On
Selection - Start / End Time = 0 / 200 ns
Velocity for Depth Axis = 0.055 m/ns

GPR Transect 24 - 22W
October 15, 1998



GPR Survey Settings
Number of Points per Trace =312
Total Time Window = 250 ns
Step Size Used = 0.1 m
Nominal Frequency = 200 Mhz
Antenna Separation = 0.46 m
Pulser Voltage = 400
Number of Stacks 128
Survey Mode = Reflection

Plot Settings : File PI2526PS
Filter
- Trace to Trace Average = 4
- Down the Trace Average = 5
- Different Traces = Off
- Trace Correction = DEWOW

Gain SEC
- Gain = 1000
- Attenuation = 2.0
- Start Value = 1.0

Layout for Traces
- Traces per inch = 17
- Width Spacing Ratio = 1.6

Options - Color Options = On
Selection - Start / End Time = 0 / 200 ns
Velocity for Depth Axis = 0.055 m/ns

TDR RESULTS: WATER CONTENT OF STREAMBED MATERIALS

Transect or location	Distance along Transect m [1]	Stream-bed piezo or nearby equipt.	T_1 [2]	T_2 [3]	K_r [4]	Water content %	Geological description
4-4W	4.20	SP5	115.35	118.48	27.18	42.1	sand
4-4W	5.20	SP6	115.36	118.69	30.71	45.0	sand
6-6W	0.60		115.34	118.60	29.59	44.1	silty clay with gravel
6-6W	1.25	MLS13	115.35	118.60	29.19	43.8	silty sand with gravel
6-6W	4.10	SP8	115.36	118.63	29.59	44.1	sand
6-6W	4.80		115.38	118.72	31.08	45.2	sand, top of sand bar
6-6W	5.20	SP9	115.37	119.26	42.07	52.2	silty sand with leaves
6-6W	7.70	SP10	115.39	118.70	30.53	44.8	sand
8-8W	7.50	SP11	115.32	118.63	30.40	44.7	Sand (new)
10-10W	4.30	SP12	115.35	118.86	34.17	47.4	Sand loose
12-12W	East shore		115.27	118.94	37.27	49.4	clayey silt loose
12-12W	8.40	SP14	115.35	118.53	28.13	42.9	Sand
12-12W	5.60	SP13	115.32	118.73	32.19	46.1	Sand
14-14W	1.10		115.57	118.85	29.99	44.4	clayey silt
14-14W	2.15	SP15	115.55	118.81	29.36	43.9	Silty sand, loose
14-14W	4.30	SP16	115.56	118.69	27.18	42.1	Sand
14-14W	5.70	SP17	115.57	118.75	28.09	42.9	Sand
14-14W	7.20	SP18	115.41	118.60	28.22	43.0	Sand
14-14W	8.10	SP19	115.31	118.59	29.81	44.3	Sand
14-14W	12.10		115.33	119.19	41.28	51.8	Silty sand, peat with roots
16-16w	1.00		114.98	118.81	40.80	51.5	clayey silt,slippery
16-16w	1.60	SP20	114.95	118.78	40.59	51.4	clayey silt, loose
16-16w	2.30	MLS2	114.94	118.18	29.05	43.7	Thin sand layer, with silt underneath
16-16w	3.30	MLS3	114.91	118.67	39.09	50.5	Sand
16-16w	3.40	SP21	114.94	118.28	31.08	45.2	Sand
16-16w	5.40	MLS6	114.94	118.28	31.13	45.3	Sand, loose
16-16w	6.30	SP22	114.95	118.20	29.37	43.9	Sand, loose
16-16w	7.40	MLS8	114.94	118.26	30.62	44.9	Sand
16-16w	8.20	SP23	114.95	118.16	28.61	43.3	Sand
16-16w	10.00	MLS10A	114.98	118.20	28.75	43.4	Sand
16-16w	10.60	SP24	114.97	118.28	30.44	44.8	Sand
16-16w	11.30	MLS11	114.98	118.22	29.14	43.7	Sand
16-16w	13.10		114.99	118.97	44.07	53.4	Silty clayey peat with roots
18-18W	1.10		115.34	120.04	61.10	65.9	clayey silt, peat, roots
18-18W	4.00	SP25	115.37	118.92	34.95	47.9	sand
18-18W	6.20	SP26	115.38	118.65	29.72	44.2	sand
18-18W	7.80	SP27	115.37	118.70	30.85	45.1	sand
18-18W	9.20	SP28	115.37	118.67	30.26	44.6	sand
18-18W	11.20	SP29	115.38	118.54	27.74	42.6	sand
18-18W	13.10		115.37	118.87	34.13	47.4	silty sand loose, possible peat
18-18W	13.60		115.37	119.51	47.40	55.3	clayey silt peat with roots
20-20W	1.20		115.40	119.76	52.62	58.7	silty clay peat, stiff

Transect or location	Distance along Transect m (1)	Stream-bed piezo or nearby equipt.	T_1 (2)	T_2 (3)	K_r (4)	Water content %	Geological description
22-22W	1.70		115.41	119.77	52.80	58.8	silty clay peat, stiff
PRP1		PRP1	115.42	119.74	51.91	58.2	clayey silt, stiff
24-22W	5.70	SP30	115.42	119.14	38.43	50.1	silt
24-22W	7.20	SP31	115.40	118.72	30.58	44.9	sand
24-22W	8.50	SP32	115.39	118.68	29.95	44.4	sand
24-22W	11.10	SP33	115.41	118.61	28.26	43.0	sand, sticks
22W-24	1.05		115.39	118.86	33.27	46.8	silty sand
28-28W	2.40	SP34	115.39	119.19	40.18	51.1	silt loose
30-30W	1.80		115.36	119.56	48.88	56.2	silty clayey peat, very stiff
30-30W	2.20		115.40	119.29	42.07	52.2	clayey peat, loose
PRP13		SP35	115.42	118.72	30.22	44.6	sand gravel silt
PRP5		SP36	115.41	118.67	29.36	43.9	silty sand with sticks
34-34W	0.70	SP37	115.42	120.30	66.20	71.7	clayey peat

Notes:

(1) Distance along transect from east to west
(2) Begining of automatic analysis window
(3) End of automatic analysis method
(4) Relative dielectric permittivity
Couldn't reach locations SP4 or SP7 to take measurements, cable not long enough

APPENDIX H

TEMPERATURE DATA

SURFACE WATER TEMPERATURES

- Pine River 1997
- Pine River 1998
- Pine River 1999

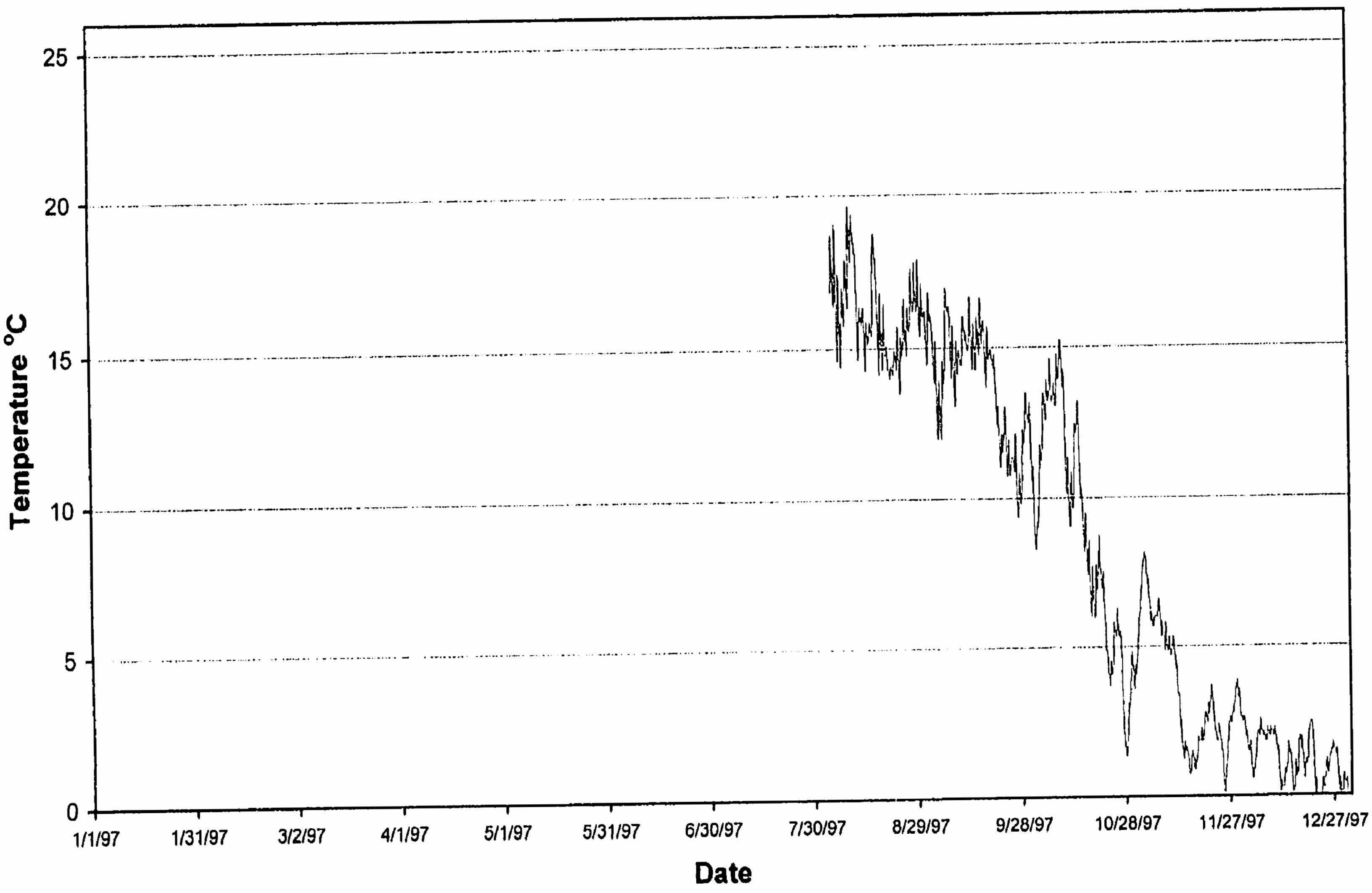
GROUNDWATER TEMPERATURES

- AW1 July 9, 1998, to November 17, 1999

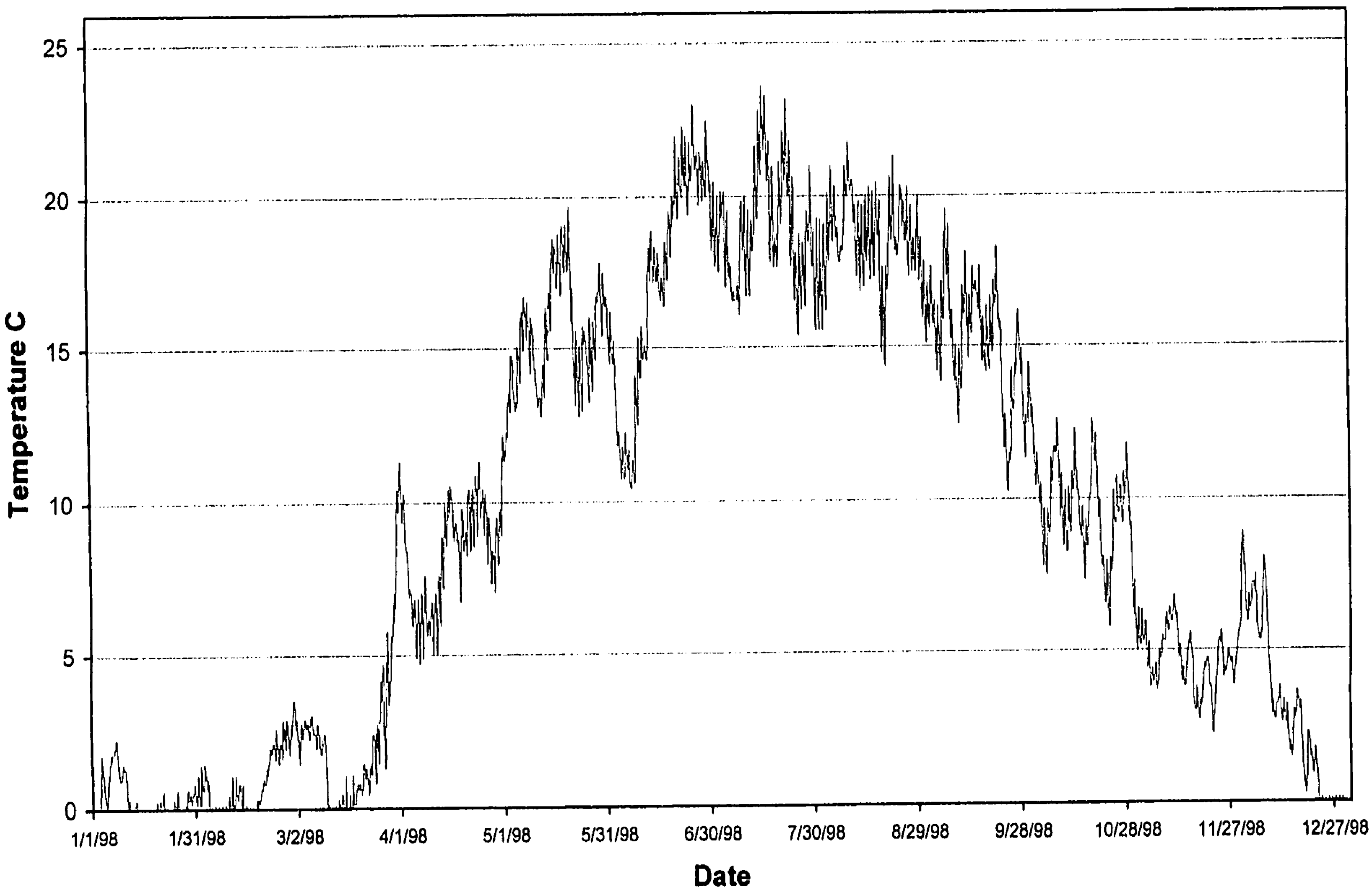
STREAMBED TEMPERATURES

- Streambed temperature mapping of Pine River July 28-29, 1998
- Streambed temperature mapping of Pine River February 18-20, 1999

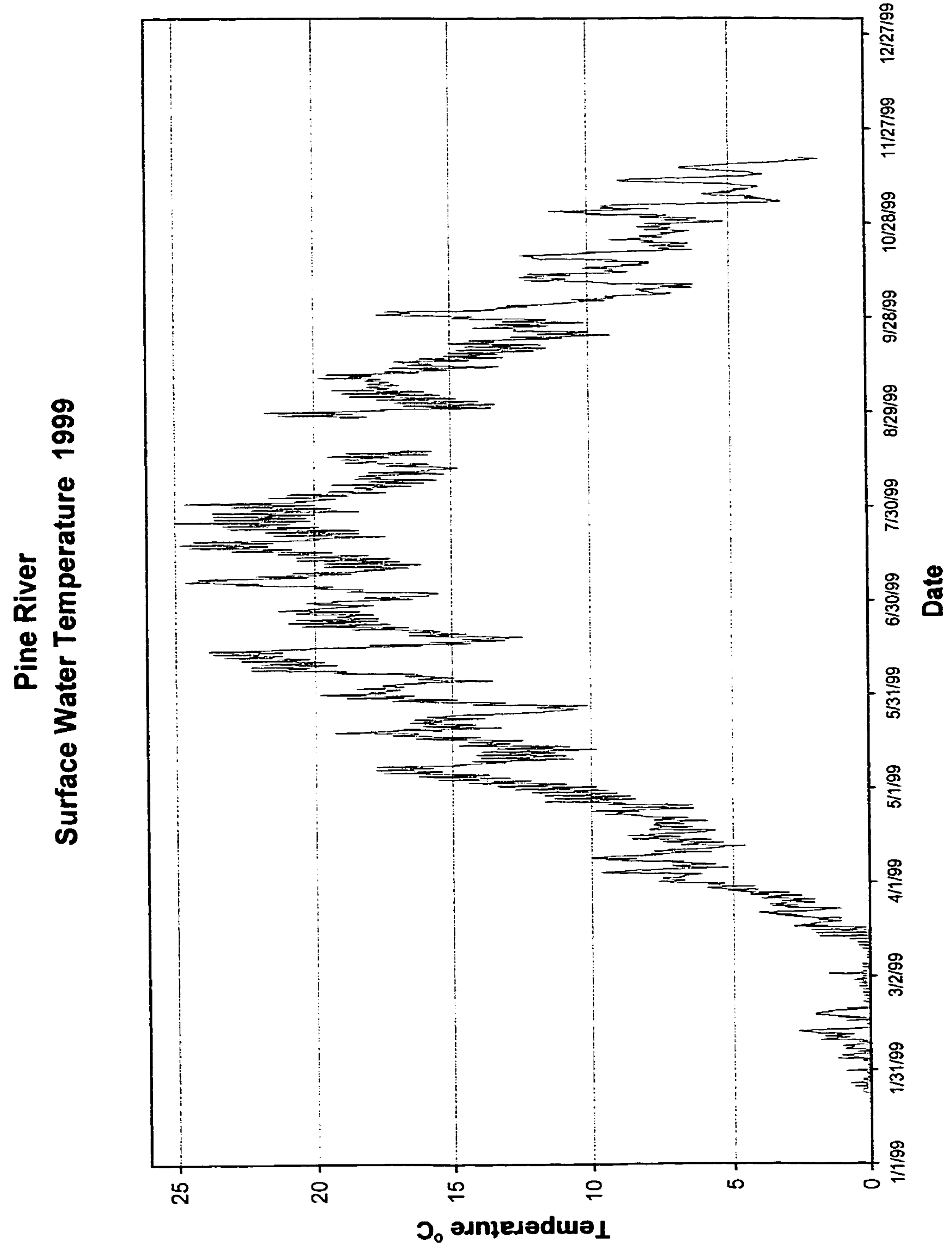
Pine River
Surface Water Temperature 1997



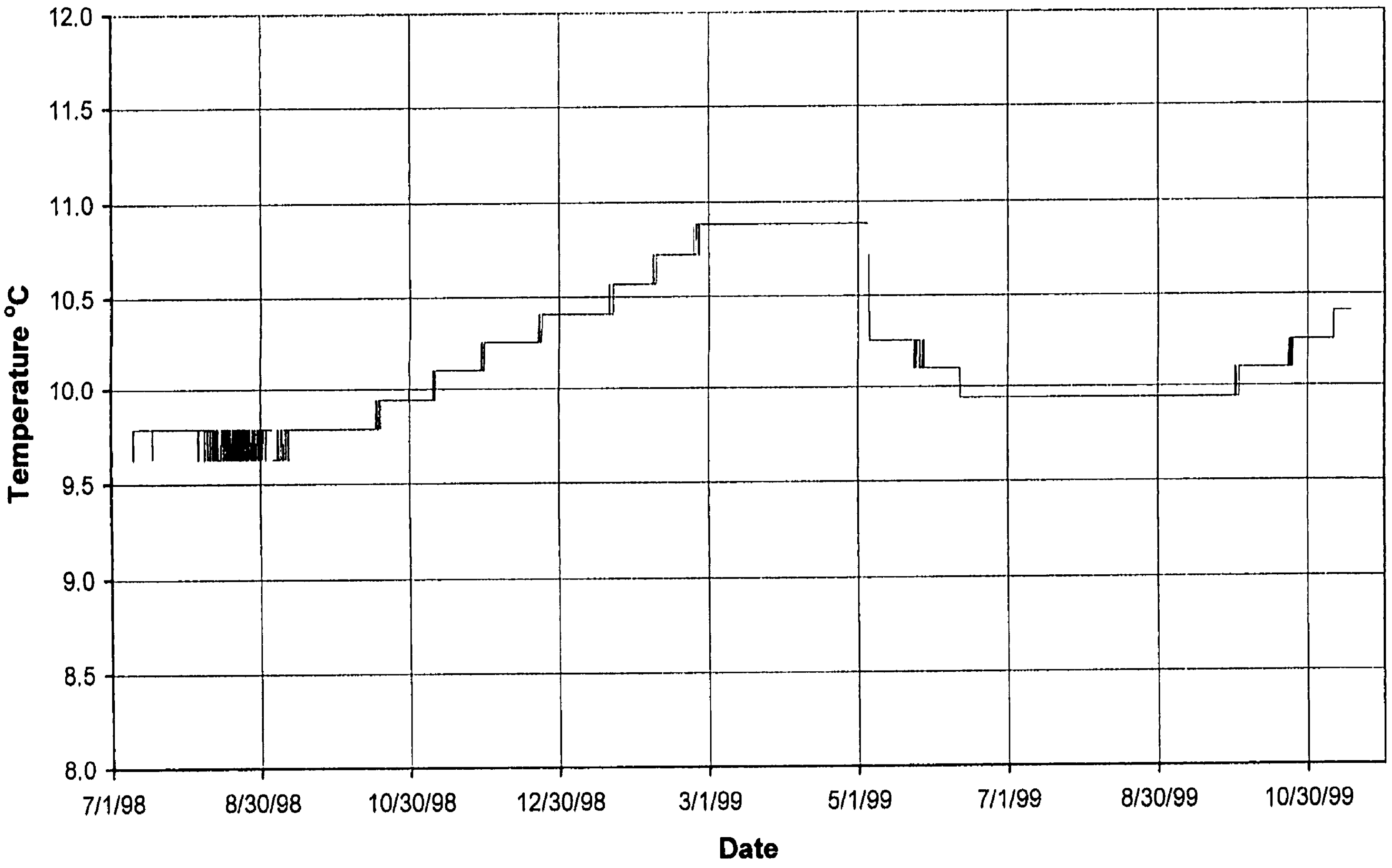
Pine River
Surface Water Temperature 1998



Pine River
Surface Water Temperature 1999



Groundwater Temperatures at AW1
July 9, 1998 to November 17,1999



Streambed Temperature Mapping of Pine River - July 28-29, 1998

Transect Location	Meas. No.	Dist. (m)(1)	Coordinates (2)		Water depth (cm)	Time of meas.	Temp °C	Geological description of streambed deposits(3)								Comments(4)
			East X (m)	North Y (m)				Bo	Co	Gr	Sa	Si	Cl	Pe	Other	
-4 - -4 W	1	4.02	942.58	990.79	0.0	9:52 AM	16.61				x	x				Water line, in shade
	2	5.00	941.64	991.06	33.0	9:53 AM	16.40				x	x				very soft bottomed, 30cm north west of pylon, in shade
	3	6.00	940.68	991.33	37.3	9:54 AM	15.73				x	x				very soft, in shade
	4	7.00	939.71	991.60	43.0	9:55 AM	14.47				x					in shade
	5	8.00	938.75	991.88	62.5	9:57 AM	13.93				x					in shade
	6	9.00	937.79	992.15	62.5	9:58 AM	14.47				x					in shade
	7	10.00	936.83	992.42	55.8	9:59 AM	14.86				x					in shade
	8	11.00	935.87	992.69	67.5	10:00 AM	15.34				x					in shade
	9	12.00	934.90	992.97	70.2	10:01 AM	16.39				x					in shade
	10	13.00	933.94	993.24	72.3	10:02 AM	16.83				x					in shade
	11	14.00	932.98	993.51	78.0	10:03 AM	16.87				x					in shade
	12	15.00	932.02	993.79	39.9	10:03 AM	16.87				x	x				very soft, in shade
	13	16.00	931.06	994.06	18.4	10:04 AM	16.71				x	x				very soft, in shade
	14	16.48	930.59	994.19	0.0	10:05 AM	16.50				x	x				Water line: soft, in shade
	15	10.00	936.83	992.42	SW	10:07 AM	16.51									Surface water, in shade
-2 - -2 W	16	3.45	943.15	992.69	0.0	10:10 AM	16.11				x	x				wedge: very soft (Water line), in shade
	17	4.00	942.62	992.85	17.0	10:11 AM	16.14				x	x				lots of bubbles, very soft, in shade
	18	5.00	941.66	993.14	39.0	10:13 AM	15.26				x	x				30 cm upstream of pylon, very soft, in shade
	19	6.00	940.71	993.43	36.5	10:15 AM	14.36				x					in shade
	20	7.00	939.75	993.72	49.0	10:16 AM	13.41				x					in shade
	21	8.00	938.79	994.01	54.0	10:18 AM	13.71				x					in shade
	22	9.00	937.83	994.30	58.5	10:19 AM	13.93				x					in shade
	23	10.00	936.88	994.58	61.0	10:20 AM	14.12				x					in shade
	24	11.00	935.92	994.87	61.5	10:22 AM	15.24				x					in shade
	25	12.00	934.96	995.16	65.0	10:23 AM	16.15				x					in shade
	26	13.00	934.00	995.45	61.5	10:25 AM	16.59				x					28 cm east of pylon, in shade

Transect Location	Meas. No.	Dist. (m)(1)	Coordinates (2)		Water depth (cm)	Time of meas.	Temp °C	Geological description of streambed deposits(3)								Comments(4)
			East X (m)	North Y (m)				Bo	Co	Gr	Sa	Si	Cl	Pe	Other	
	27	14.00	933.05	995.74	55.5	10:27 AM	16.67				x					difficult to insert, buried wood; temp was 17.5°C when first inserted; in shade
	28	15.07	932.02	996.05	27.5	10:30 AM	16.38			x	x	x				difficult to insert, buried wood, in shade
	29	15.77	931.35	996.25	0.0	10:32 AM	16.56			x	x	x				Water line, difficult to insert, wood debris, in shade
	30	10.00	936.88	994.58	SW	10:33 AM	16.63									Surface water, midstream, in shade
0 - 0 W	31	2.12	944.42	994.31	0.0	10:37 AM	15.33				x	x				Water line, soft, in shade
	32	3.00	943.58	994.57	22.7	10:39 AM	15.08				x	x			sticks	bubbles, in shade, brown algae covered sand ripples
	33	4.00	942.62	994.86	35.2	10:41 AM	14.31				x					in shade, difficult to insert, buried sticks, lots of bubbles
	34	5.00	941.66	995.15	37.0	10:42 AM	13.76				x					in shade
	35	6.00	940.71	995.44	40.0	10:44 AM	13.61				x					in shade
	36	7.00	939.75	995.73	48.0	10:45 AM	13.78				x					in shade
	37	8.00	938.79	996.01	52.0	10:46 AM	14.13				x					in shade
	38	9.00	937.84	996.30	54.0	10:47 AM	15.27				x					in shade
	39	10.00	936.88	996.59	54.5	10:49 AM	15.78				x					in shade
	40	11.00	935.92	996.88	58.5	10:50 AM	16.38				x					in shade
	41	12.00	934.96	997.17	55.5	10:52 AM	16.81			x	x					difficult to insert, in shade, temperature starts @ 17.5°C
	42	13.00	934.01	997.46	NA	10:54 AM	NA									stone and buried log, unable to insert
	43	13.78	933.26	997.69	34.5	10:56 AM	16.57			x	x					difficult to insert, in shade, buried log, bubbles
	44	14.50	932.57	997.90	36.0	10:58 AM	15.32		x	x	x	x			sticks & logs	difficult to insert, in shade
	45	15.14	931.96	998.08	0.0	11:00 AM	15.18				x	x			sticks & logs	Water line, partial sun
	46	8.50	938.31	996.16	SW	11:01 AM	16.78									Surface water, midstream, in shade

Transect Location	Meas. No.	Dist. (m)(1)	Coordinates (2)		Water depth (cm)	Time of meas.	Temp °C	Geological description of streambed deposits(3)								Comments(4)
			East X (m)	North Y (m)				Bo	Co	Gr	Sa	Si	Cl	Pe	Other	
Seep on Shore	47	NA			NA	11:08 AM	10.19			x	x	x				seep next to bridge: head of seep near bridge above it, in shade, difficult to insert
2 - 2 W	48	1.88	945.26	996.18	0.0	11:10 AM	15.39	x	x	x	x	x				Water line, in shade
	49	3.10	944.09	996.53	33.0	11:15 AM	16.22	x		x	x				sticks	difficult to insert, probe depth 10 cm
	50	3.96	943.27	996.79	39.0	11:19 AM	16.19		x	x	x				sticks	difficult to insert, probe depth 15 cm, partial sun
	51	4.94	942.33	997.07	36.0	11:20 AM	14.57	x		x	x				sticks	difficult to insert, 10 cm upstream of cinder block
	52	5.92	941.40	997.36	24.5	11:23 AM	14.99	x	x	x	x				sticks	difficult to insert, inside 2' x 2' steel frame
	53	7.07	940.30	997.70	21.5	11:25 AM	15.23	x	x	x	x					difficult to insert, 30 cm downstream of transect line, in sun
	54	8.25	939.17	998.04	41.0	11:28 AM	15.76	x	x	x	x					in sun
	55	9.25	938.21	998.33	43.0	11:31 AM	16.46	x	x	x	x					difficult to insert, in sun, probe depth 18 cm
	56	10.28	937.23	998.64	44.0	11:34 AM	16.71	x	x	x	x					difficult to insert, in sun, bubbles
	57	11.33	936.22	998.94	48.2	11:37 AM	16.91		x	x	x					difficult to insert, in sun
	58	12.04	935.55	999.15	47.0	11:38 AM	16.94			x	x					difficult to insert, in sun
	59	13.00	934.63	999.43	49.0	11:41 AM	16.41				x					in sun
	60	14.02	933.65	999.73	37.5	11:42 AM	15.79		x	x	x				sticks	difficult to insert, in sun
	61	15.18	932.54	1000.07	0.0	11:44 AM	16.29				x	x		x	roots & logs	Water line, in sun
	62	8.50	938.93	998.12	SW	11:45 AM	17.11									Surface water, midstream, in sun
4 - 4 W	63	0.92	945.54	998.13	0.0	11:50 AM	16.71		x	x	x	x				Water line, in shade, difficult to insert
	64	1.80	944.70	998.39	20.0	11:52 AM	16.38	x	x	x	x					difficult to insert, boulder @ 2m, in sun
	65	3.35	943.22	998.86	55.5	11:55 AM	14.84		x	x	x					difficult to insert, near bottom of channel, in sun
	66	4.00	942.60	999.05	33.0	11:57 AM	12.99				x					in sun, downstream of trash can, side of sand bar, bubbles

Transect Location	Meas. No.	Dist. (m)[1]	Coordinates [2] East X (m)	North Y (m)	Water depth (cm)	Time of meas.	Temp °C	Geological description of streambed deposits[3] Bo	Co	Gr	Sa	Si	Cl	Pe	Other	Comments[4]
	67	5.00	941.65	999.35	21.0	12:00 PM	12.86				x					in sun, upstream of shopping cart, lots of bubbles, near top of sand bar
	68	5.90	940.79	999.62	49.0	12:02 PM	11.79	x	x		x				sticks	difficult to insert, bubbles, probe depth 18 cm, in sun
	69	6.90	939.84	999.92	45.5	12:05 PM	14.09	x	x	x	x				sticks	difficult to insert, bubbles, in sun
	70	8.04	938.75	1000.26	45.0	12:07 PM	16.30				x					pushed through cloth bag, in sun
	71	8.98	937.85	1000.54	55.5	12:09 PM	16.72			x	x				sticks	difficult to insert, in sun, 15 cm upstream of cinder block
	72	10.18	936.71	1000.90	66.0	12:11 PM	16.94			x	x					difficult to insert, in sun, downstream of new shopping cart, next to buried shopping cart.
	73	10.95	935.97	1001.13	78.0	12:13 PM	16.78			x	x				sticks	difficult to insert, in sun, near bottom of channel
	74	12.00	934.97	1001.44	44.0	12:15 PM	16.11			x	x				sticks	in sun, 5 cm downstream of kitchen sink
	75	13.06	933.96	1001.76	23.0	12:16 PM	16.27		x		x	x			sticks & logs	in sun, difficult to insert
	76	13.64	933.41	1001.93	0.0	12:20 PM	16.64				x	x			logs	Water line, difficult to insert, buried log, in sun
	77	7.25	939.50	1000.02	SW	12:23 PM	17.56									Surface water, midstream, in sun
6 - 6 W	78	1.06	946.22	1000.11	0.0	12:26 PM	17.00				x	x				Water line, in shade
	79	2.09	945.23	1000.42	51.0	12:28 PM	16.97	x		x	x	x				difficult to insert, in shade, next to boulder
	80	3.00	944.36	1000.69	83.0	12:30 PM	16.32	x	x	x	x					bottom of channel, partial sun, difficult to insert
	81	4.00	943.41	1000.98	58.7	12:32 PM	14.92				x					east side of sand bar, in sun, very soft
	82	4.44	942.99	1001.11	41.0	12:34 PM	15.48				x					top of sand bar, in sun, very soft
	83	5.00	942.45	1001.28	66.7	12:35 PM	11.81				x					very soft, bubbles, west side of sand bar, in sun
	84	6.00	941.50	1001.57	81.0	12:37 PM	12.31				x					soft, bubbles, in sun, 10 cm upstream of RC-3
	85	7.00	940.54	1001.87	67.0	12:38 PM	15.78				x					in sun

Transect Location	Meas. No.	Dist. (m)[1]	Coordinates [2]		Water depth (cm)	Time of meas.	Temp °C	Geological description of streambed deposits[3]								Comments[4]
			East X (m)	North Y (m)				Bo	Co	Gr	Sa	Si	Cl	Pe	Other	
	86	8.00	939.59	1002.16	48.0	12:40 PM	16.67				x					top of sand bar, in sun
	87	9.00	938.63	1002.46	64.0	12:41 PM	16.69				x				sticks	soft, in sun
	88	10.00	937.68	1002.76	64.5	12:42 PM	16.99				x					soft, in sun
	89	11.00	936.72	1003.05	66.0	12:44 PM	16.41				x				logs	in sun
	90	12.00	935.77	1003.35	59.5	12:47 PM	15.16				x				sticks	between two large logs, in sun, bubbles
	91	13.27	934.55	1003.72	0.0	12:49 PM	16.26				x	x			sticks, logs & roots	Water line, in sun
	92	7.00	940.54	1001.87	SW	12:50 PM	17.84									Surface water, midstream, in sun
8 - 8 W	93	0.90	947.12	1001.87	0.0	12:55 PM	16.72				x	x				Water line, in shade, 37 cm upstream of SG-1, soft
	94	2.00	946.07	1002.20	52.5	12:57 PM	16.99				x	x				soft, in shade
	95	3.00	945.12	1002.49	107.0	12:59 PM	16.27		x		x	x			logs	near bottom of channel, slippery clay to east, in shade
	96	4.00	944.16	1002.79	80.5	1:00 PM	16.07				x					soft, east side of sand bar
	97	5.00	943.21	1003.09	72.5	1:02 PM	15.68				x					soft, bubbles, in sun, west side of sand bar
	98	6.00	942.25	1003.38	99.0	1:03 PM	15.59				x				sticks	soft, in sun, lots of bubbles
	99	7.00	941.30	1003.68	78.0	1:04 PM	16.71				x					soft, in sun
	100	8.00	940.34	1003.97	64.0	1:06 PM	16.82				x					soft, in sun, east of buried shopping cart
	101	9.00	939.39	1004.27	69.0	1:07 PM	16.74				x					west side of buried shopping cart, in sun
	102	10.00	938.43	1004.57	56.0	1:09 PM	16.88				x					next to buried wood, partial sun
	103	11.09	937.39	1004.89	69.0	1:10 PM	15.82				x				sticks & logs	downstream of 15' log, in shade
	104	12.00	936.52	1005.16	62.0	1:12 PM	14.83				x	x			sticks & roots	in sun
	105	12.90	935.66	1005.43	0.0	1:14 PM	15.42				x	x			roots, sticks & logs	Water line, difficult to insert, in sun, buried log
	106	7.00	941.30	1003.68	SW	1:15 PM	17.96									Surface water, midstream, in sun
10 - 10 W	107	0.98	947.87	1003.76	0.0	2:00 PM	16.65				x	x	x		roots	Water line, in shade
	108	2.00	946.90	1004.06	51.0	2:01 PM	17.04				x	x	x		sticks	in shade
	109	3.00	945.94	1004.35	98.4	2:03 PM	16.11				x					in shade

Transect Location	Meas. No.	Dist. (m)[1]	Coordinates [2]		Water depth (cm)	Time of meas.	Temp °C	Geological description of streambed deposits[3]								Comments[4]
			East X (m)	North Y (m)				Bo	Co	Gr	Sa	Si	Cl	Pe	Other	
	110	4.00	944.99	1004.65	55.6	2:04 PM	16.47				x					soft, top of sand bar, in sun
	111	5.00	944.03	1004.94	91.0	2:06 PM	13.95				x					soft, bubbles, in sun
	112	5.50	943.55	1005.09	105.0	2:08 PM	12.95				x					bottom of channel, soft, bubbles, in sun
	113	6.00	943.08	1005.24	94.4	2:09 PM	13.93				x					east edge of sand bar, in sun
	114	7.00	942.12	1005.53	71.8	2:11 PM	16.14				x					soft, in sun
	115	8.00	941.16	1005.82	69.6	2:12 PM	16.31				x					soft, partial sun
	116	9.00	940.21	1006.12	67.0	2:13 PM	16.47				x					soft, partial sun
	117	10.00	939.25	1006.41	64.5	2:14 PM	16.72				x					soft, partial sun
	118	11.00	938.30	1006.71	58.0	2:15 PM	16.82				x					soft, partial sun
	119	11.99	937.35	1007.00	74.5	2:17 PM	15.32				x	x		x	sticks & logs	partial sun
	120	12.72	936.65	1007.21	0.0	2:18 PM	17.04				x	x		x	roots	Water line, in shade
	121	7.00	942.12	1005.53	SW	2:19 PM	18.50									Surface water, midstream, in sun
12 - 12 W	122	1.21	948.62	1005.52	0.0	2:24 PM	16.76				x	x	x		sticks	Water line, in shade
	123	2.00	947.86	1005.75	45.0	2:25 PM	17.01				x	x	x		sticks	in shade
	124	3.00	946.91	1006.05	44.0	2:26 PM	17.15				x					in shade
	125	4.00	945.95	1006.35	38.0	2:27 PM	16.97				x					soft, top of sand bar, partial sun
	126	5.00	945.00	1006.65	77.7	2:29 PM	16.11				x					soft, partial sun
	127	5.55	944.47	1006.81	102.0	2:31 PM	14.75				x					soft, in sun, bottom of channel, bubbles
	128	6.00	944.04	1006.94	92.0	2:32 PM	14.64				x					in sun, soft
	129	7.00	943.09	1007.24	63.0	2:34 PM	15.12				x					in sun, soft
	130	8.00	942.14	1007.54	65.0	2:35 PM	15.33				x					in sun
	131	9.00	941.18	1007.84	64.0	2:36 PM	15.97				x					partial sun
	132	10.00	940.23	1008.13	60.0	2:37 PM	16.39				x					partial sun
	133	11.00	939.27	1008.43	52.0	2:39 PM	15.59				x					partial sun
	134	11.80	938.51	1008.67	75.4	2:41 PM	14.79				x	x			logs	difficult to insert, in shade, upstream of lawn mower
	135	12.54	937.80	1008.89	0.0	2:43 PM	18.73					x	x	x	roots	Water line, difficult to insert, in shade
	136	6.75	943.33	1007.17	SW	2:44 PM	18.76									Surface water, midstream, in sun
14 - 14 W	137	1.48	949.38	1007.35	0.0	2:49 PM	16.71				x	x	x			Water line, soft and slippery, in shade

Transect Location	Meas. No.	Dist. (m)[1]	Coordinates [2]		Water depth (cm)	Time of meas.	Temp °C	Geological description of streambed deposits[3]								Comments[4]
			East X (m)	North Y (m)				Bo	Co	Gr	Sa	Si	Cl	Pe	Other	
	138	2.00	948.88	1007.51	26.3	2:50 PM	17.02				x	x	x			next to buried log, in shade, small bubbles, near Dave Lee mini piezo
	139	3.00	947.93	1007.81	35.0	2:52 PM	17.31				x					soft, in shade, downstream face of sand bar
	140	4.00	946.97	1008.11	30.0	2:53 PM	17.29				x					soft, in shade, downstream face of sand bar
	141	5.00	946.02	1008.41	56.0	2:55 PM	17.01				x					in shade
	142	6.00	945.06	1008.71	73.0	2:56 PM	16.56				x					in sun
	143	7.00	944.11	1009.01	64.0	2:57 PM	16.28				x					in sun
	144	8.00	943.16	1009.31	58.0	2:59 PM	15.98				x					in sun
	145	9.00	942.20	1009.61	56.0	3:00 PM	16.07				x					in sun
	146	10.00	941.25	1009.91	53.0	3:01 PM	16.51				x					in sun
	147	11.00	940.30	1010.21	57.0	3:02 PM	16.62				x					partial sun
	148	12.00	939.34	1010.51	63.0	3:04 PM	16.25				x					partial sun
	149	12.78	938.60	1010.75	0.0	3:05 PM	15.85				x	x		x	roots	Water line, difficult to insert, in shade
	150	7.25	943.87	1009.08	SW	3:06 PM	18.83									Surface water, midstream
16 - 16 W	151	1.25	950.15	1009.24	0.0	3:10 PM	16.53				x	x	x		sticks	Water line, slippery, in shade
	152	2.00	949.44	1009.47	39.0	3:11 PM	16.95				x	x				soft, in shade
	153	3.00	948.48	1009.76	52.0	3:12 PM	17.18				x					in shade
	154	4.00	947.53	1010.05	47.0	3:13 PM	17.27				x					in shade
	155	5.00	946.57	1010.35	45.3	3:15 PM	17.19				x					partial sun
	156	6.00	945.61	1010.64	52.0	3:16 PM	16.83				x					soft, in sun
	157	7.00	944.66	1010.94	60.0	3:17 PM	16.56				x					soft, in sun
	158	8.00	943.70	1011.23	55.0	3:18 PM	16.59				x					soft, in sun
	159	9.00	942.75	1011.52	48.0	3:19 PM	16.57				x					soft, in sun
	160	10.00	941.79	1011.82	54.3	3:20 PM	16.62				x					soft
	161	11.00	940.84	1012.11	57.0	3:22 PM	16.58				x					partial sun
	162	12.00	939.88	1012.41	58.0	3:23 PM	16.52		x		x				sticks	downstream of fallen log, in shade
	163	12.88	939.04	1012.66	0.0	3:25 PM	17.02				x	x		x	roots	Water line, difficult to insert, in shade
	164	7.00	944.66	1010.94	SW	3:26 PM	18.93									Surface water, midstream

Transect Location	Meas. No.	Dist. (m)[1]	Coordinates [2]		Water depth (cm)	Time of meas.	Temp °C	Geological description of streambed deposits[3]								Comments[4]
			East X (m)	North Y (m)				Bo	Co	Gr	Sa	Si	Cl	Pe	Other	
18 - 18 W	165	1.24	950.79	1011.09	0.0	3:32 PM	15.64				x	x	x		roots	Water line, slippery, in shade
	166	2.00	950.07	1011.31	43.0	3:33 PM	16.61				x	x	x		sticks	in shade
	167	3.00	949.11	1011.60	35.4	3:35 PM	17.13				x					underlain by silt, partial sun
	168	4.00	948.15	1011.89	46.0	3:37 PM	17.23				x					25 cm south east of PRP-7, partial sun
	169	5.00	947.19	1012.18	41.0	3:38 PM	17.25				x					in sun
	170	6.00	946.24	1012.47	44.5	3:40 PM	17.07				x					in sun
	171	7.00	945.28	1012.75	58.0	3:42 PM	16.67				x					in sun, 45 cm east of PRP17 and MLS prototype attempt
	172	8.00	944.32	1013.04	54.0	3:44 PM	16.72				x					partial sun
	173	9.00	943.36	1013.33	49.0	3:45 PM	16.77				x					partial sun
	174	10.00	942.41	1013.62	48.0	3:47 PM	16.65				x					partial sun
	175	11.00	941.45	1013.91	53.0	3:49 PM	16.43				x					in shade, 10 cm west of PRP-10
	176	12.00	940.49	1014.19	57.0	3:52 PM	15.99		x		x				buried wood	in shade
	177	13.00	939.53	1014.48	12.0	3:54 PM	16.67				x	x				in shade, bubbles, very soft
	178	13.44	939.11	1014.61	0.0	3:55 PM	17.20				x	x				Water line, in shade
	179	7.00	945.28	1012.75	SW	3:56 PM	19.13									Surface water, midstream, in sun
20 - 20 W	180	1.60	951.01	1013.08	0.0	4:00 PM	15.72				x	x			roots	Water line, partial sun, under base of trunk of dead elm
	181	2.24	950.39	1013.26	46.0	4:06 PM	14.69				x	x			sticks	difficult to insert, in sun, in sticks next to stump, lots of bubbles
	182	3.00	949.66	1013.47	53.0	4:07 PM	16.71		x		x	x			sticks	in sun, difficult to insert, stiff
	183	4.00	948.70	1013.74	50.0	4:09 PM	17.24				x					in sun
	184	5.00	947.74	1014.02	41.0	4:10 PM	17.37				x					in sun
	185	6.00	946.78	1014.30	44.0	4:11 PM	17.33				x					in sun
	186	7.00	945.82	1014.57	55.0	4:12 PM	16.86				x					partial sun
	187	8.00	944.86	1014.85	53.0	4:13 PM	16.57				x					partial sun
	188	9.00	943.90	1015.13	56.0	4:14 PM	16.51				x					partial sun
	189	10.00	942.94	1015.40	48.0	4:15 PM	16.43				x					partial sun
	190	11.00	941.97	1015.68	48.0	4:17 PM	16.17				x					in shade
	191	12.00	941.01	1015.96	49.0	4:18 PM	14.59		x		x					in shade
	192	13.00	940.05	1016.23	31.0	4:20 PM	15.90				x	x			sticks	in shade, bubbles
	193	13.77	939.31	1016.45	0.0	4:22 PM	17.40				x	x			roots	Water line

Transect Location	Meas. No.	Dist. (m)[1]	Coordinates [2]		Water depth (cm)	Time of meas.	Temp °C	Geological description of streambed deposits[3]								Comments[4]
			East X (m)	North Y (m)				Bo	Co	Gr	Sa	Si	Cl	Pe	Other	
	194	8.00	944.86	1014.85	SW	4:23 PM	19.25									Surface water, midstream, in sun
22 - 22 W	195	1.42	951.13	1015.13	0.0	4:28 PM	16.46				x	x	x			Water line, slippery/stiff, in sun
	196	2.00	950.57	1015.29	29.8	4:29 PM	16.61				x	x				soft/stiff, in sun
	197	3.00	949.61	1015.56	59.5	4:31 PM	16.46	x	x		x	x			sticks	stiff, in sun
	198	4.00	948.64	1015.83	46.0	4:32 PM	16.92				x					in sun
	199	5.00	947.68	1016.11	41.0	4:34 PM	17.28				x					in sun
	200	6.00	946.72	1016.38	53.0	4:35 PM	17.07				x					partial sun
	201	7.00	945.76	1016.65	53.0	4:37 PM	16.48				x					partial sun
	202	8.00	944.79	1016.92	51.0	4:38 PM	15.65				x					1.3 m upstream of PRP-3, partial sun
	203	9.00	943.83	1017.19	52.0	4:40 PM	15.67				x					partial sun
	204	10.00	942.87	1017.46	54.0	4:42 PM	15.12				x					partial sun
	205	11.00	941.91	1017.73	45.0	4:45 PM	14.67				x					95 cm upstream of PRP-4, partial sun
	206	12.00	940.94	1018.01	33.0	4:48 PM	15.60				x				sticks	downstream of small log, partial sun
	207	13.00	939.98	1018.28	14.0	4:50 PM	16.58				x				sticks & logs	difficult to insert, partial sun, bubbles
	208	13.47	939.53	1018.40	0.0	4:51 PM	17.57				x	x			sticks	Water line, partial sun
	209	7.50	945.27	1016.78	SW	4:52 PM	19.39									Surface water, midstream, partial sun
24 - 24 W	210	1.92	951.41	1017.15	0.0	4:58 PM	16.62				x	x	x			Water line, stiff, in shade, next to 1/2" OD bubbling hole
	211	3.00	950.37	1017.44	63.0	4:59 PM	15.26		x		x	x	x			partial sun, stiff, 72 cm SE of PRP-1, bubbles
	212	4.00	949.41	1017.71	59.0	5:01 PM	15.42				x	x	x			stiff, partial sun, 47 cm SW of PRP-1
	213	5.00	948.44	1017.97	48.0	5:03 PM	16.99				x					22 cm east of PRP-2
	214	6.00	947.48	1018.24	51.0	5:04 PM	17.20				x					partial sun
	215	7.00	946.52	1018.50	55.0	5:05 PM	16.77				x					partial sun
	216	8.00	945.55	1018.77	55.0	5:06 PM	15.58				x					partial sun, 70 cm downstream of PRP-3
	217	9.00	944.59	1019.04	54.0	5:10 PM	14.68				x					partial sun

Transect Location	Meas. No.	Dist. (m)[1]	Coordinates [2]		Water depth (cm)	Time of meas.	Temp °C	Geological description of streambed deposits[3]								Comments[4]
			East X (m)	North Y (m)				Bo	Co	Gr	Sa	Si	Cl	Pe	Other	
	218	10.00	943.62	1019.30	51.0	5:12 PM	14.94				x					partial sun
	219	10.80	942.85	1019.51	40.0	5:15 PM	15.89				x				sticks	partial sun, buried log at 11 m, difficult to insert
	220	12.00	941.70	1019.83	52.0	5:16 PM	14.67				x				sticks	buried stick, partial sun
	221	13.00	940.73	1020.10	20.5	5:18 PM	16.54				x	x			sticks	partial sun
	222	13.85	939.91	1020.33	0.0	5:19 PM	17.93				x	x			sticks	Water line, next to fallen log, partial sun
	223	8.00	945.55	1018.77	SW	5:20 PM	19.37									Surface water, midstream, partial sun
26 - 26 W	224	1.48	951.74	1019.17	0.0	5:24 PM	15.56				x	x	x	x		Water line, bubbles, stiff, in shade
	225	2.00	951.24	1019.31	31.0	5:26 PM	13.11				x	x		x		soft & stiff, in shade
	226	3.00	950.27	1019.58	63.0	5:27 PM	14.51				x	x	x			stiff, in shade, bubbles
	227	4.00	949.31	1019.84	55.0	5:29 PM	15.17				x	x			buried sticks	stiff, in shade, bubbles
	228	5.00	948.34	1020.11	53.0	5:30 PM	16.99				x					partial sun
	229	6.00	947.38	1020.37	54.0	5:32 PM	17.26				x					partial sun
	230	7.00	946.42	1020.64	54.0	5:34 PM	17.01				x					partial sun
	231	8.00	945.45	1020.91	49.0	5:35 PM	16.36				x					partial sun
	232	9.00	944.49	1021.17	49.0	5:37 PM	15.67				x					partial sun
	233	10.00	943.52	1021.44	46.0	5:39 PM	15.91				x					partial sun
	234	11.00	942.56	1021.70	44.0	5:40 PM	16.95				x					partial sun
	235	12.00	941.60	1021.97	12.1	5:42 PM	17.08		x		x	x			sticks & logs	difficult to insert, partial sun
	236	13.00	940.63	1022.24	9.5	5:44 PM	17.21				x	x			sticks	
	237	13.30	940.34	1022.31	0.0	5:45 PM	17.77				x	x			sticks	Water line, partial sun
	238	7.50	945.93	1020.77	SW	5:46 PM	19.36									Surface water, midstream, partial sun
28 - 28 W	239	1.03	951.74	1021.19	0.0	5:53 PM	10.00				x	x	x	x		Water line, in shade, stiff, lots of bubbles, near dime sized spring
	240	2.00	950.80	1021.45	45.0	5:55 PM	10.27				x	x		x		in shade, lots of bubbles, stiff
	241	1.60	951.19	1021.34	21.0	5:57 PM	9.97				x	x		x		bubbling spring in footprint, in shade
	242	3.00	949.84	1021.71	49.0	5:59 PM	12.96				x	x		x		stiff, in shade
	243	4.00	948.87	1021.97	50.0	6:01 PM	16.06				x					stiff, in shade
	244	5.00	947.91	1022.24	56.0	6:02 PM	17.02				x				buried sticks	bubbles, in shade

Transect Location	Meas. No.	Dist. (m)[1]	Coordinates [2]		Water depth (cm)	Time of meas.	Temp °C	Geological description of streambed deposits[3]								Comments[4]
			East X (m)	North Y (m)				Bo	Co	Gr	Sa	Si	Cl	Pe	Other	
	245	6.00	946.94	1022.50	56.0	6:03 PM	17.24				x				buried sticks	in shade, 52 cm upstream of PRP-13
	246	7.00	945.98	1022.76	52.0	6:06 PM	17.21				x					in shade
	247	8.00	945.01	1023.02	49.0	6:10 PM	16.56				x					partial sun
	248	9.00	944.05	1023.29	49.0	6:11 PM	15.35				x					partial sun
	249	10.00	943.08	1023.55	44.0	6:13 PM	16.47				x					partial sun
	250	11.00	942.12	1023.81	48.0	6:15 PM	16.84				x				sticks	partial sun
	251	12.00	941.15	1024.08	12.7	6:17 PM	17.17				x	x			sticks & logs	downstream of small log/stick jam
	252	13.00	940.19	1024.34	10.0	6:18 PM	17.01				x	x			sticks	partial sun
	253	13.77	939.45	1024.54	0.0	6:20 PM	17.47				x	x			sticks & logs	Water line, partial sun
	254	7.50	945.49	1022.89	SW	6:21 PM	19.32									Surface water, midstream, partial sun
-4 - -4 W	255	4.00	942.60	990.79	0.0	6:31 PM	16.63									Water line, repeat
REDO	256	4.90	941.74	991.03	NA	NA	16.56									repeat
	257	5.90	940.77	991.31	NA	NA	15.93									repeat
	258	6.90	939.81	991.58	NA	NA	14.87									repeat
	259	7.90	938.85	991.85	NA	NA	14.16									repeat
	260	8.90	937.89	992.12	NA	NA	14.96									repeat
	261	10.00	936.83	992.42	NA	NA	15.39									repeat
	262	11.00	935.87	992.69	NA	NA	15.64									repeat
	263	12.00	934.90	992.97	NA	NA	16.71									repeat
	264	13.00	933.94	993.24	NA	NA	17.04									repeat
	265	14.00	932.98	993.51	NA	NA	17.14									repeat
	266	15.00	932.02	993.79	NA	NA	17.03									repeat
	267	16.00	931.06	994.06	NA	NA	16.87									repeat
	268	16.53	930.55	994.20	0.0	6:50 PM	16.84									Water line, repeat
	269	10.00	936.83	992.42	SW	7:01 PM	19.30									Surface water, repeat
10 - 10 W	270	1.00	947.85	1003.76	0.0	7:11 PM	17.06									Water line, repeat
REDO	271	2.00	946.90	1004.06	NA	NA	17.32									repeat
	272	3.00	945.94	1004.35	NA	NA	16.71									repeat
	273	4.00	944.99	1004.65	NA	NA	16.54									repeat
	274	5.00	944.03	1004.94	NA	NA	14.28									repeat
	275	5.50	943.55	1005.09	NA	NA	13.02									repeat

Transect Location	Meas. No.	Dist. (m)[1]	Coordinates [2]		Water depth (cm)	Time of meas.	Temp °C	Geological description of streambed deposits[3]								Comments[4]
			East X (m)	North Y (m)				Bo	Co	Gr	Sa	Si	Cl	Pe	Other	
	276	6.00	943.08	1005.24	NA	NA	13.54									repeat
	277	7.00	942.12	1005.53	NA	NA	16.49									repeat
	278	8.00	941.16	1005.82	NA	NA	16.52									repeat
	279	9.00	940.21	1006.12	NA	NA	16.82									repeat
	280	10.00	939.25	1006.41	NA	NA	16.96									repeat
	290	11.00	938.30	1006.71	NA	NA	17.11									repeat
	291	12.00	937.34	1007.00	NA	NA	15.29									repeat
	292	12.72	936.65	1007.21	0.0	NA	17.02									Water line, repeat, distance is approximate
	293	7.00	942.12	1005.53	NA	7:32 PM	19.27									Surface water, repeat
July 29																
28 - 28 W	1	1.07	951.70	1021.20	0.0	7:59 AM	10.07				x	x		x	roots	Water line, stiff, bubbles, in shade
	2	2.00	950.80	1021.45	45.5	8:01 AM	10.62				x	x	x			soft, stiff, in shade
	3	3.00	949.84	1021.71	49.4	8:03 AM	14.61				x	x				stiff, sandy at surface, in shade
	4	4.00	948.87	1021.97	52.0	8:05 AM	16.47				x					in shade
	5	5.00	947.91	1022.24	56.0	8:07 AM	17.57				x					in shade
	6	6.00	946.94	1022.50	56.5	8:08 AM	17.78				x					60 cm upstream of PRP-13, in shade
	7	7.00	945.98	1022.76	55.5	8:10 AM	17.53				x					in shade
	8	8.00	945.01	1023.02	51.0	8:11 AM	16.89				x					in shade
	9	9.00	944.05	1023.29	49.5	8:14 AM	15.37				x					in shade, bubbles, buried stone
	10	10.00	943.08	1023.55	43.0	8:16 AM	17.03				x					in shade
	11	11.00	942.12	1023.81	47.0	8:18 AM	17.48			x	x				sticks	in shade
	12	12.00	941.15	1024.08	16.5	8:20 AM	17.64				x	x			sticks & logs	in shade, downstream of stick jam
	13	13.00	940.19	1024.34	9.5	8:22 AM	17.38				x	x			sticks	in shade
	14	13.84	939.38	1024.56	0.0	8:25 AM	17.49				x	x			sticks & logs	Water line, in shade
	15	7.50	945.49	1022.89	SW	8:26 AM	18.32									Surface water, midstream, in shade
30 - 30 W	16	1.50	951.05	1023.56	0.0	8:30 AM	17.85					x	x	x		Water line, in shade, insert probe horizontally into bank, very stiff
	17	1.60	950.95	1023.58	34.0	8:32 AM	18.03					x	x	x		very stiff, in shade

Transect Location	Meas. No.	Dist. (m)[1]	Coordinates [2] East X (m)	Coordinates [2] North Y (m)	Water depth (cm)	Time of meas.	Temp °C	Geological description of streambed deposits[3] Bo	Co	Gr	Sa	Si	Cl	Pe	Other	Comments[4]
	18	2.00	950.57	1023.68	77.0	8:36 AM	9.96				x	x				very soft, in shade, eroded pothole under knob
	19	3.00	949.60	1023.94	76.0	8:38 AM	11.45				x	x				stiff, in shade, in eroded pothole
	20	4.00	948.63	1024.19	62.0	8:40 AM	16.41				x					soft, in shade
	21	5.00	947.66	1024.44	63.0	8:42 AM	17.12				x					soft, in shade
	22	6.03	946.67	1024.70	61.0	8:45 AM	17.68		x		x					in shade, difficult to insert
	23	6.80	945.92	1024.89	54.0	8:48 AM	17.72		x		x					difficult to insert, in shade, probe was bent here
	24	7.97	944.79	1025.19	42.0	8:50 AM	17.93			x	x					next to buried log (upstream of), in shade
	25	9.05	943.74	1025.46	53.0	8:52 AM	17.14		x	x	x					difficult to insert, in shade, depth of water is approximate
	26	10.03	942.80	1025.70	52.0	8:56 AM	17.72			x	x					difficult to insert, in shade
	27	11.11	941.75	1025.98	43.0	8:58 AM	17.93			x	x					difficult to insert, in shade
	28	12.00	940.89	1026.20	34.0	9:01 AM	17.69				x				sticks	in shade
	29	13.00	939.92	1026.45	36.0	9:03 AM	17.42				x	x			logs	soft, in shade
	30	13.81	939.14	1026.66	0.0	9:06 AM	17.63				x	x			sticks	Water line, bubbles, in shade
	31	7.75	945.00	1025.13	SW	9:07 AM	18.63									Surface water, midstream, in shade
32 - 32 W	32	0.55	950.95	1025.78	0.0	9:14 AM	18.53					x	x	x	roots	Water line, very stiff, in shade
	33	2.00	949.54	1026.13	74.0	9:16 AM	16.28				x	x			logs & sticks	soft & stiff, in shade, in pothole, bubbles
	34	3.00	948.57	1026.37	70.0	9:19 AM	16.76				x	x			logs & sticks	difficult to insert because of logs, stiff, in shade
	35	3.97	947.63	1026.60	73.0	9:20 AM	17.56		x		x				logs & sticks	difficult to insert, in shade, depth of water is approximate
	36	5.00	946.63	1026.85	71.0	9:24 AM	17.68		x		x	x	x		sticks	stiff, in shade
	37	6.04	945.62	1027.10	61.0	9:25 AM	17.92		x	x	x				logs	difficult to insert, in shade
	38	7.00	944.69	1027.33	46.0	9:28 AM	17.86		x	x	x					difficult to insert, in shade, downstream of edge of cobble bar
	39	8.03	943.69	1027.57	50.0	9:31 AM	17.71		x	x	x					downstream of cobble bar, in shade
	40	9.05	942.70	1027.82	52.0	9:34 AM	17.96			x	x					difficult to insert, in shade

Transect Location	Meas. No.	Dist. (m)[1]	Coordinates [2]		Water depth (cm)	Time of meas.	Temp °C	Geological description of streambed deposits[3]								Comments[4]
			East X (m)	North Y (m)				Bo	Co	Gr	Sa	Si	Cl	Pe	Other	
	41	10.00	941.77	1028.04	30.0	9:35 AM	18.19				x					in shade
	42	11.00	940.80	1028.28	33.0	9:37 AM	18.01			x	x					in shade, on something hard, but probe is at full depth
	43	12.00	939.83	1028.52	35.0	9:40 AM	17.66				x					in shade, on something hard
	44	13.00	938.86	1028.76	22.0	9:42 AM	17.17				x					in shade, bubbles
	45	13.75	938.13	1028.94	0.0	9:44 AM	17.31				x					Water line, in shade
	46	7.00	944.69	1027.33	SW	9:45 AM	18.57									Surface water, midstream, in shade
34 - 34 W	47	0.63	951.18	1027.82	0.0	10:16 AM	17.39					x		x	sticks	Water line, stiff, in shade
	48	1.00	950.82	1027.91	19.0	10:17 AM	17.34				x	x			logs & sticks	in shade
	49	2.00	949.85	1028.14	31.0	10:19 AM	17.66				x	x			sticks	in shade
	50	3.00	948.87	1028.36	57.0	10:21 AM	17.64				x	x			sticks	in shade, upstream of large log
	51	3.95	947.95	1028.58	67.0	10:23 AM	17.18			x	x				sticks & logs	in shade, downstream of large log, difficult to insert
	52	4.98	946.94	1028.82	75.0	10:24 AM	17.18				x				sticks & logs	difficult to insert, in shade
	53	6.00	945.95	1029.05	74.0	10:26 AM	17.19		x	x	x	x				stiff, in shade
	54	6.93	945.05	1029.27	58.0	10:29 AM	17.92		x		x	x				very stiff, difficult to insert, in shade, on buried log?
	55	8.10	943.91	1029.53	61.0	10:32 AM	18.35		x	x	x					probe depth = 15 cm, difficult to insert, on something hard
	56	9.00	943.03	1029.74	55.0	10:34 AM	18.26		x	x	x					in shade
	57	10.00	942.06	1029.97	54.0	10:36 AM	18.13			x	x					in shade
	58	11.00	941.09	1030.20	42.0	10:39 AM	18.32			x	x					in shade
	59	12.10	940.01	1030.45	25.0	10:40 AM	18.16			x	x					on something hard, difficult to insert
	60	13.05	939.09	1030.67	34.0	10:42 AM	17.71			x	x					easy insert, partial sun
	61	14.00	938.16	1030.89	34.0	10:45 AM	17.48				x					in sun
	62	15.00	937.19	1031.12	24.5	10:46 AM	17.42				x	x			sticks	lots of bubbles, difficult to insert, in sun
	63	15.51	936.70	1031.23	0.0	10:48 AM	17.19				x	x				Water line, in sun
	64	8.00	944.01	1029.51	SW	10:49 AM	18.98									Surface water, midstream, in shade
36 - 36 W	65	0.70	951.32	1029.88	0.0	10:55 AM	17.53					x		x	sticks & logs	Water line, in shade

Transect Location	Meas. No.	Dist. (m)[1]	Coordinates [2]		Water depth (cm)	Time of meas.	Temp °C	Geological description of streambed deposits[3]								Comments[4]
			East X (m)	North Y (m)				Bo	Co	Gr	Sa	Si	Cl	Pe	Other	
	66	1.93	950.12	1030.14	35.0	10:58 AM	17.53			x	x	x			sticks & logs	in shade, 57 cm NE of PRP-5, difficult to insert
	67	2.97	949.10	1030.36	33.0	10:59 AM	18.12				x					in shade, small sand bar
	68	4.00	948.10	1030.58	51.0	11:01 AM	17.87				x					in shade
	69	5.12	947.00	1030.82	54.0	11:03 AM	18.07				x				logs	in shade, next to buried log
	70	6.06	946.09	1031.02	79.0	11:07 AM	17.08				x				logs	in shade, difficult to insert, next to buried log, upstream of large logs
		6.90	945.26	1031.20							x				buried log	30 cm upstream of large logs, logs moved to insert - unfinished due to short in probe,
																** replaced probe ** and will do *midstream test and redo* 7m
	71	7.00	945.17	1031.22	SW	11:58 AM	18.97									Surface water, in shade
	72	6.65	945.51	1031.15	71.0	12:00 PM	16.94				x				log	difficult to insert, lots of buried logs, upstream of large log jam, in shade
	73	8.15	944.04	1031.47	51.0	12:02 PM	17.79		x	x	x					west end of log jam, probe depth 17 cm, partial sun, difficult to insert
	74	9.17	943.05	1031.69	45.0	12:05 PM	18.24		x	x	x					difficult to insert, partial sun
	75	9.97	942.27	1031.86	56.0	12:07 PM	17.84		x	x	x				log	immediately upstream of buried log, partial sun
	76	11.00	941.26	1032.08	49.0	12:08 PM	17.59		x	x	x				log	partial sun
	77	12.08	940.20	1032.31	20.0	12:10 PM	18.06		x	x	x					partial sun, difficult to insert, downstream of buried log
	78	13.05	939.26	1032.51	28.0	12:12 PM	17.94			x	x					partial sun
	79	13.84	938.48	1032.68	34.0	12:14 PM	18.07		x	x	x					difficult to insert, in sun
	80	14.95	937.40	1032.92	31.0	12:17 PM	17.97	x	x	x	x					probe depth = 17 cm, downstream side of boulders
	81	16.00	936.37	1033.14	25.0	12:19 PM	17.57		x	x	x					broken bricks, difficult to insert, probe depth = 19 cm, in sun, bubbles
	82	16.99	935.41	1033.35	0.0	12:21 PM	17.11		x		x	x				Water line, on a stone

Transect Location	Meas. No.	Dist. (m)(1)	Coordinates (2)		Water depth (cm)	Time of meas.	Temp °C	Geological description of streambed deposits(3)								Comments(4)
			East X (m)	North Y (m)				Bo	Co	Gr	Sa	Si	Cl	Pe	Other	
	83	8.75	943.46	1031.60	SW	12:22 PM	19.03									Surface water, midstream, partial sun
38 - 38 W	84	-0.20	951.58	1031.88	0.0	12:27 PM	16.71				x	x		x	logs	Water line, undercut bank, stiff, under a tree trunk
	85	0.95	950.46	1032.13	43.0	12:28 PM	17.33				x	x			sticks & logs	in shade, easy/soft
	86	2.00	949.43	1032.36	48.0	12:30 PM	17.57				x	x			sticks & logs	in shade
	87	3.15	948.31	1032.61	75.0	12:32 PM	17.08				x				sticks & logs	under large floating log, in shade
	88	4.00	947.48	1032.79	77.0	12:34 PM	17.29		x	x	x				sticks & logs	in shade, under above floating log, difficult to insert
	89	5.00	946.51	1033.01	72.0	12:35 PM	17.23			x	x				sticks & logs	in shade, 50 cm downstream of floating log
	90	5.90	945.63	1033.21	58.0	12:37 PM	17.53			x	x				log & sticks	difficult to insert, in shade, buried log
	91	7.00	944.55	1033.44	54.0	12:39 PM	17.11		x	x	x					difficult to insert, in shade
	92	8.00	943.58	1033.66	52.0	12:40 PM	17.47		x	x	x					difficult to insert, partial sun
	93	9.00	942.60	1033.88	43.0	12:43 PM	17.81			x	x					difficult to insert, downstream of cobble bar
	94	10.05	941.58	1034.11	47.0	12:45 PM	17.94		x	x	x					difficult to insert, in sun
	95	11.05	940.60	1034.32	42.0	12:47 PM	17.84			x	x					difficult to insert, in sun, 25 cm downstream of 2' concrete cylinders
	96	12.00	939.67	1034.53	24.0	12:49 PM	17.78				x					east side of sand bar, in sun
	97	13.00	938.70	1034.74	14.0	12:50 PM	17.96				x					top of sand bar, in sun
	98	14.00	937.72	1034.96	35.0	12:52 PM	17.80			x	x					west side of sand bar, partial sun
	99	15.02	936.72	1035.18	26.0	12:54 PM	17.75			x	x					50 cm downstream of tire
	100	15.90	935.86	1035.37	27.0	12:57 PM	17.59			x	x	x				difficult to insert, in sun, probe depth = 18 cm, on something hard, next to culvert pipe
	101	16.47	935.31	1035.50	0.0	12:59 PM	16.92				x	x			sticks	Water line, stiff, 15 cm of water
	101	8.25	943.33	1033.72	SW	1:00 PM	19.17									Surface water, midstream, in sun
40 - 40 W	102	0.28	950.96	1033.80	0.0	1:42 PM	16.89				x	x		x	roots, sticks & logs	Water line, in shade, stiff
	103	1.00	950.25	1033.96	25.0	1:44 PM	17.26				x	x			sticks & logs	soft, in shade, bubbles

Transect Location	Meas. No.	Dist. (m)[1]	Coordinates [2] East X (m)	Coordinates [2] North Y (m)	Water depth (cm)	Time of meas.	Temp °C	Bo	Co	Gr	Sa	Si	Cl	Pe	Other	Comments[4]
								Geological description of streambed deposits[3]								
	104	2.00	949.28	1034.19	26.0	1:45 PM	17.79				x				sticks & logs	in shade
	105	3.05	948.26	1034.43	39.0	1:47 PM	17.51				x				sticks	next to buried stone, partial sun
	106	4.00	947.33	1034.65	38.0	1:48 PM	17.86				x				sticks & logs	partial sun
	107	5.00	946.36	1034.88	42.0	1:49 PM	17.68				x				logs	next to buried log, partial sun
	108	6.00	945.39	1035.10	61.0	1:50 PM	17.56				x					in sun
	109	7.00	944.41	1035.33	68.0	1:53 PM	17.77			x	x				sticks	difficult to insert, partial sun
	110	8.22	943.22	1035.61	81.0	1:55 PM	17.37			x	x				logs	west of buried log in hole, stiff, difficult to insert, in sun
	111	9.00	942.46	1035.79	81.0	1:56 PM	17.62			x	x					in sun, near buried log
	112	10.04	941.45	1036.02	66.0	1:58 PM	17.79		x	x	x					difficult to insert, in sun
	113	11.00	940.52	1036.24	61.0	2:00 PM	17.77			x	x					in sun
	114	12.00	939.54	1036.47	35.0	2:01 PM	17.93				x					in sun
	115	13.00	938.57	1036.70	19.0	2:02 PM	17.89				x					top of sand bar, in sun, near mop handle
	116	14.00	937.60	1036.93	24.0	2:04 PM	17.73				x					in sun
	117	15.00	936.62	1037.16	34.0	2:05 PM	17.54				x					in sun, on something hard
	118	15.90	935.75	1037.36	28.0	2:07 PM	17.16			x	x	x				in sun, difficult to insert, lots of bubbles, east of wire mesh
	119	16.61	935.06	1037.52	0.0	2:09 PM	17.61				x	x			sticks	Water line, in sun, through wire mesh and plastic bag
	120	8.25	943.20	1035.62	SW	2:10 PM	19.62									Surface water, midstream, in sun
42 - 42 W	121	1.03	949.42	1036.15	0.0	2:21 PM	18.42				x	x		x	roots	Water line, in shade, stiff
	122	2.00	948.48	1036.36	50.0	2:23 PM	17.32				x	x			sticks & logs	partial sun, 23 cm west of SG-2
	123	3.00	947.50	1036.58	46.0	2:25 PM	17.52				x					soft, in sun
	124	4.00	946.53	1036.80	40.0	2:26 PM	17.79				x					soft, bubbles, in sun
	125	5.00	945.55	1037.02	47.0	2:27 PM	17.74				x					soft, in sun
	126	6.02	944.56	1037.24	55.0	2:29 PM	17.94			x	x				sticks	in sun, difficult to insert
	127	6.95	943.65	1037.45	57.0	2:30 PM	18.17			x	x					in sun, difficult to insert
	128	8.16	942.47	1037.72	64.0	2:33 PM	18.17		x	x	x					difficult to insert, 3' upstream of log and cobble bar, in sun
	129	9.00	941.65	1037.90	65.0	2:35 PM	17.95		x	x	x					partial sun
	130	9.90	940.77	1038.10	65.0	2:36 PM	17.90		x	x	x					30 cm upstream of debris dam (tire rim and wire table frames)

Transect Location	Meas. No.	Dist. (m)[1]	Coordinates [2]		Water depth (cm)	Time of meas.	Temp °C	Geological description of streambed deposits[3]								Comments[4]
			East X (m)	North Y (m)				Bo	Co	Gr	Sa	Si	Cl	Pe	Other	
	131	11.10	939.60	1038.36	52.0	2:38 PM	18.62			x	x					on a stone, probe depth 17 cm
	132	12.00	938.72	1038.56	60.0	2:42 PM	18.27		x	x	x				sticks	difficult to insert, partial sun
	133	13.20	937.55	1038.82	52.0	2:44 PM	18.10		x	x	x				logs	difficult to insert, next to buried log
	134	14.00	936.77	1039.00	27.0	2:46 PM	17.99				x					soft, on top of sandbar, downstream of debris dam
	135	15.13	935.67	1039.25	32.0	2:48 PM	16.56				x				sticks & logs	difficult to insert, in sun, west of buried log, when take out get bubbles
	136	16.00	934.82	1039.44	27.0	2:50 PM	17.19		x	x	x	x			sticks	difficult to insert, bubbles, in sun
	137	16.40	934.43	1039.53	0.0	2:52 PM	17.28		x		x	x		x	roots	Water line, difficult to insert, stiff, in sun
	138	8.75	941.89	1037.85	SW	2:53 PM	20.01									Surface water, midstream, in sun
44 - 44 W	139	0.25	949.04	1038.30	0.0	2:59 PM	18.97				x	x		x	roots	Water line, base of upturned tree roots
	140	1.00	948.31	1038.49	52.0	3:01 PM	17.07				x				roots	base of roots of upturned tree, difficult to insert, in shade
	141	2.05	947.30	1038.76	75.0	3:02 PM	17.51			x	x				roots	in hole beneath fallen tree, in shade
	142	2.90	946.48	1038.97	68.0	3:04 PM	18.05			x	x					difficult to insert, 15 cm downstream of submerged log
	143	4.03	945.38	1039.26	54.0	3:06 PM	17.87		x	x	x					40 cm downstream of submerged log, partial sun
	144	4.80	944.64	1039.46	47.0	3:10 PM	18.16		x	x	x					very difficult to insert, partial sun, 60 cm downstream of submerged log
	145	6.55	942.95	1039.90	41.0	3:15 PM	18.57		x	x	x					very difficult to insert, probe depth 15 cm, on something hard
	146	7.55	941.98	1040.16	36.0	3:18 PM	18.49		x	x	x					very difficult to insert, probe depth 17 cm, on cobble bar
	147	8.72	940.85	1040.46	35.0	3:22 PM	18.36		x	x	x					very difficult to insert, on cobble bar, in sun
	148	9.13	940.45	1040.56	38.0	3:25 PM	18.05		x	x	x					difficult to insert, in sun

Transect Location	Meas. No.	Dist. (m)[1]	Coordinates [2]		Water depth (cm)	Time of meas.	Temp °C	Geological description of streambed deposits[3]								Comments[4]
			East X (m)	North Y (m)				Bo	Co	Gr	Sa	Si	Cl	Pe	Other	
	149	10.04	939.57	1040.79	57.0	3:27 PM	17.77		x	x	x					difficult to insert, in sun
	150	11.08	938.57	1041.06	55.0	3:29 PM	17.56		x	x	x				sticks	difficult to insert, in sun
	151	12.00	937.68	1041.29	27.0	3:30 PM	17.60				x					in sun, 1m downstream of buried shopping cart
																At this location 2nd probe malfunctioned, transect incomplete, survey stopped

Notes:

Measurements made with Barnant Thermometer and YSI 418 probe at depth of 20 cm in the streambed by Brewster Conant and Matt Bogaart

[1] Distance is along the transect line measured from the east stake toward the west stake

[2] Coordinates are relative to an arbitrary datum with 1000, 1000 m located at gate valve near the NW corner of King and Water St.

[3] Geological description has following abbreviations and "x" in the column means it is present in deposits

Bo = Boulders
Co = Cobbles
Gr = Gravel
Sa = Sand
Si = Silt
Cl = Clay
Pe = Peat
Other = other items observed such as sticks, logs, and roots

[4] Several comments include whether the location was sunny or shaded

Streambed Temperature Mapping of Pine River - February 18-20, 1999

Transect Location	Meas. No.	Dist. (m)(1)	Coordinates (2)		Water depth (cm)	Time of meas.	Temp °C	Geological description of streambed deposits(3)								Comments(4)
			East X (m)	North Y (m)				Bo	Co	Gr	Sa	Si	Cl	Pe	Other	
-2 - -4 W	1	2.62	943.87	992.14	0.0	11:14 AM	1.88				x	x				Water line, soft
	2	3.00	943.49	992.21	16.0	11:17 AM	2.39				x	x				Soft
	3	4.00	942.51	992.38	42.5	11:19 AM	2.36				x					Soft
	4	5.00	941.52	992.55	53.5	11:20 AM	2.24				x					Soft
	5	6.00	940.54	992.72	87.5	11:21 AM	4.36				x					Harder
	6	7.00	939.55	992.89	99.0	11:22 AM	6.41				x					Hard
	7	8.00	938.57	993.06	84.0	11:25 AM	5.19				x					Hard
	8	9.00	937.58	993.23	86.0	11:27 AM	4.64				x					Hard
	9	10.00	936.60	993.40	90.0	11:28 AM	4.53				x					Hard
	10	11.00	935.61	993.57	89.0	11:29 AM	3.27				x					Hard
	11	12.00	934.63	993.74	86.5	11:30 AM	2.16				x					Hard
	12	12.90	933.74	993.90	105.0	11:33 AM	2.13				x					Eroded hole, 20 cm from pylon
	13	14.00	932.66	994.08	91.0	11:35 AM	2.14				x					Hard
	14	15.00	931.67	994.25	62.0	11:36 AM	2.11				x					Little bit softer
	15	16.00	930.68	994.43	34.5	11:37 AM	2.11				x	x				Soft
	16	16.72	929.97	994.55	6.0	11:40 AM	0.81				x	x				Soft
	17	16.90	929.80	994.58	0.0	11:42 AM	NA				x	x				Water line, difficult to insert, frozen very hard, unable to take reading
	18	9.75	936.84	993.36	SW	11:43 AM	1.44									Surface water, midstream
-2 - -2 W	19	2.53	944.03	992.43	0.0	11:50 AM	2.46				x	x				Water line, hard and frozen
	20	3.00	943.58	992.56	19.0	11:53 AM	2.78				x	x				Soft
	21	4.00	942.62	992.85	44.5	11:56 AM	2.52				x	x				Soft
	22	5.00	941.66	993.14	62.5	11:55 AM	2.62				x					25 cm upstream of pylon
	23	6.00	940.71	993.43	86.0	11:57 AM	5.17				x					Slightly harder
	24	7.00	939.75	993.72	90.0	11:59 AM	5.98				x					Hard
	25	8.00	938.79	994.01	86.0	12:00 PM	6.05				x					
	26	9.00	937.83	994.30	89.0	12:02 PM	5.22				x					
	27	10.00	936.88	994.58	91.0	12:03 PM	5.02				x					
	28	11.00	935.92	994.87	88.0	12:05 PM	3.65				x					
	29	12.00	934.96	995.16	86.0	12:06 PM	2.43				x					

Transect Location	Meas. No.	Dist. (m)[1]	Coordinates [2] East X (m)	North Y (m)	Water depth (cm)	Time of meas.	Temp °C	Geological description of streambed deposits[3] Bo	Co	Gr	Sa	Si	Cl	Pe	Other	Comments[4]
	30	13.00	934.00	995.45	80.0	12:07 PM	2.16				x					30 cm east of pylon
	31	14.00	933.05	995.74	75.0	12:08 PM	2.72				x	x				Soft
	32	15.00	932.09	996.03	49.0	12:10 PM	3.07				x	x				Soft, temp as high as 3.4 C then drops
	33	16.30	930.84	996.40	0.0	12:12 PM	1.84				x	x			sticks	Water line
	34	9.00	937.83	994.30	SW	12:15 PM	1.48									Surface water, midstream
0 - 0 W	35	1.60	944.92	994.16	0.0	1:45 PM	3.59				x	x				Water line, soft, in vicinity of seeps
	36	2.00	944.54	994.28	15.0	1:46 PM	3.29				x	x				Soft
	37	3.00	943.58	994.57	42.0	1:47 PM	3.86				x	x				Soft, 30 cm downstream and west of pylon
	38	4.06	942.56	994.87	67.0	1:49 PM	5.68				x	x			sticks	Difficult to insert
	39	5.00	941.66	995.15	80.0	1:50 PM	6.31				x					Harder
	40	6.00	940.71	995.44	84.0	1:51 PM	6.25				x					
	41	6.97	939.78	995.72	84.5	1:52 PM	5.76				x					
	42	8.00	938.79	996.01	82.0	1:54 PM	4.67				x					
	43	8.97	937.86	996.30	81.0	1:55 PM	3.62				x					
	44	10.00	936.88	996.59	80.0	1:56 PM	3.02				x					Possibly on something hard, wood?
	45	11.00	935.92	996.88	78.0	1:58 PM	2.39				x					
	46	12.00	934.96	997.17	69.0	1:59 PM	1.93				x					
	47	13.06	933.95	997.48	56.0	2:00 PM	1.96				x				sticks	Difficult to insert, sticks
	48	14.00	933.05	997.75	55.0	2:01 PM	3.00				x	x				Soft
	49	15.00	932.09	998.04	38.0	2:03 PM	4.90				x	x			sticks & log	Upstream of buried log
	50	15.84	931.29	998.29	0.0	2:04 PM	2.64				x	x			roots	Water line, possible peat too
	51	8.75	938.08	996.23	SW	2:05 PM	1.53									Surface water, midstream
2 - 2 W	52	0.88	946.22	995.88	0.0	2:12 PM	5.02			x	x	x			roots	Water line, north edge of seep area
	53	1.50	945.62	996.07	23.0	2:13 PM	4.54			x	x	x				Difficult to insert, stiff, clay?
	54	2.20	944.95	996.27	35.0	2:16 PM	3.37	x			x	x				Difficult to insert
	55	2.85	944.33	996.46	45.0	2:20 PM	3.37		x	x	x	x				Difficult to insert, poked through blanket, same reading as at 2.20 m

Transect Location	Meas. No.	Dist. (m)[1]	Coordinates [2] East X (m)	North Y (m)	Water depth (cm)	Time of meas.	Temp °C	Geological description of streambed deposits[3] Bo	Co	Gr	Sa	Si	Cl	Pe	Other	Comments[4]
	56	3.88	943.35	996.76	62.0	2:22 PM	3.33	x	x	x	x					Difficult to insert
	57	4.95	942.33	997.08	64.0	2:25 PM	4.94	x	x	x	x					Difficult to insert, probe depth is 16 cm
	58	5.96	941.36	997.37	28.0	2:29 PM	3.21	x	x	x	x					Cinder block at 6 m, probe inside 2 foot square box, 20 cm down stream of line, probe depth 13 cm, on something hard
	59	7.05	940.32	997.69	49.0	2:32 PM	3.09	x	x	x	x					Difficult to insert, probe depth is 15 cm
	60	8.00	939.41	997.97	61.0	2:34 PM	3.38	x	x	x	x					Difficult to insert, probe depth is 15 cm (again)
	61	9.06	938.40	998.28	62.0	2:37 PM	2.34	x	x	x	x					Difficult to insert, probe depth is 12 cm
	62	10.00	937.50	998.55	69.0	2:39 PM	2.07	x	x	x	x					Difficult to insert
	63	11.13	936.42	998.89	71.0	2:41 PM	1.93	x	x	x	x					Difficult to insert
	64	11.97	935.61	999.13	69.0	2:44 PM	1.91			x	x					Difficult to insert
	65	13.00	934.63	999.43	79.0	2:45 PM	3.06				x	x			sticks	Soft
	66	13.94	933.73	999.71	64.0	2:47 PM	4.14			x	x	x			sticks	Difficult to insert
	67	15.03	932.69	1000.03	35.0	2:48 PM	4.31				x	x			sticks, log	Difficult to insert, stiff
	68	15.44	932.29	1000.15	0.0	2:51 PM	1.98				x	x			roots	Water line
	69	8.25	939.17	998.04	SW	2:52 PM	1.55									Surface water, midstream
4 - 4 W	70	0.14	946.29	997.90	0.0	3:07 PM	2.36			x	x	x			roots	Water line, difficult to insert
	71	1.00	945.47	998.15	28.5	3:11 PM	2.67		x	x	x	x				Difficult to insert, temp as high as 3.4 C then drops, probe depth 15 cm
	72	2.22	944.30	998.52	63.0	3:14 PM	2.77	x	x	x	x	x				Difficult to insert, temp as high as 3.28 C then drops
	73	3.00	943.56	998.75	77.0	3:15 PM	3.61	x	x	x	x					Difficult to insert
	74	4.00	942.60	999.05	71.0	3:17 PM	6.08		x	x	x					Difficult to insert, near SP
	75	5.03	941.62	999.36	58.0	3:18 PM	6.19				x					On something hard, up stream of shopping cart
	76	6.12	940.58	999.68	69.0	3:20 PM	8.01		x	x	x					Difficult to insert
	77	6.77	939.96	999.88	72.0	3:23 PM	5.73			x	x				sticks	Difficult to insert

Transect Location	Meas. No.	Dist. (m)[1]	Coordinates [2] East X (m)	North Y (m)	Water depth (cm)	Time of meas.	Temp °C	Geological description of streambed deposits[3] Bo	Co	Gr	Sa	Si	Cl	Pe	Other	Comments[4]
	78	8.00	938.79	1000.25	77.0	3:25 PM	2.57			x	x					Difficult to insert
	79	9.00	937.83	1000.55	78.0	3:26 PM	2.31	x		x	x					Difficult to insert, stiff
	80	10.00	936.88	1000.84	66.0	3:27 PM	1.87				x					
	81	11.00	935.92	1001.14	80.0	3:28 PM	2.10				x					
	82	12.00	934.97	1001.44	78.0	3:30 PM	3.34			x	x	x			log	Difficult to insert
	83	13.00	934.02	1001.74	51.0	3:31 PM	3.26				x	x			sticks, log	Difficult to insert
	84	13.95	933.11	1002.03	0.0	3:33 PM	1.72				x	x			roots, sticks	Water line, easy to insert
	85	7.00	939.74	999.95	SW	3:34 PM	1.59									Surface water, midstream
Seep	86				Seep	3:48 PM	8.59									Seep on shore, 1.5 from stake 0 toward stake 2
6 - 6 W	87	0.40	946.85	999.92	0.0	3:50 PM	1.91			x	x	x			roots	Water line
	88	0.98	946.29	1000.09	30.0	3:52 PM	1.97			x	x	x				Stiff
	89	2.13	945.20	1000.43	66.0	3:54 PM	2.03	x	x	x	x	x				Difficult to insert, stiff
	90	3.00	944.36	1000.69	103.0	3:55 PM	2.62			x	x	x				Deep part of channel
	91	4.00	943.41	1000.98	96.0	3:57 PM	4.17				x					East side of sand bar
	92	5.00	942.45	1001.28	67.0	3:58 PM	4.07				x					Bubbles, top of sand bar
	93	5.50	941.98	1001.43	95.0	4:02 PM	7.04				x					Soft, next to MLS17 and 18
	94	6.00	941.50	1001.57	99.0	3:59 PM	7.07				x					Base of channel
	95	6.50	941.02	1001.72	92.0	4:04 PM	4.63				x					
	96	7.00	940.54	1001.87	83.0	4:00 PM	3.31				x					
	97	7.95	939.64	1002.15	75.0	4:05 PM	2.27				x					Next to MLS19 and 20
	98	9.00	938.63	1002.46	70.0	4:06 PM	2.00				x					
	99	10.00	937.68	1002.76	72.0	4:07 PM	1.97				x					
	100	11.00	936.72	1003.05	91.0	4:08 PM	2.67				x					
	101	12.04	935.73	1003.36	75.0	4:10 PM	3.60				x				sticks, log	Difficult to insert, upstream of buried logs
	102	13.00	934.81	1003.64	40.0	4:11 PM	3.57				x	x			sticks, log	Difficult to insert, stiff
	103	13.58	934.26	1003.82	0.0	4:12 PM	2.05				x	x			roots	Water line, peat?
	104	7.00	940.54	1001.87	SW	4:15 PM	1.57									Surface water, midstream
8 - 8 W	105	0.50	947.50	1001.75	0.0	4:42 PM	1.91				x	x			roots	Water line, stiff
	106	1.00	947.03	1001.90	33.5	4:43 PM	2.03			x	x	x				Difficult to insert
	107	2.00	946.07	1002.20	86.0	4:44 PM	2.33				x	x	x			soft, clay
	108	3.00	945.12	1002.49	132.0	4:46 PM	3.63				x	x	x			Stiff, clay at bottom of channel

Transect Location	Meas. No.	Dist. (m)[1]	Coordinates [2]		Water depth (cm)	Time of meas.	Temp °C	Geological description of streambed deposits[3]								Comments[4]
			East X (m)	North Y (m)				Bo	Co	Gr	Sa	Si	Cl	Pe	Other	
	109	4.00	944.16	1002.79	111.0	4:48 PM	4.10				x					East edge of sand bar
	110	5.00	943.21	1003.09	56.0	4:50 PM	2.53				x					Top of sand bar
	111	6.00	942.25	1003.38	87.0	4:51 PM	3.54				x					
	112	7.00	941.30	1003.68	83.0	4:52 PM	2.57				x					
	113	8.00	940.34	1003.97	78.0	4:53 PM	2.11				x					
	114	9.00	939.39	1004.27	74.0	4:54 PM	2.01				x					
	115	10.00	938.43	1004.57	82.0	4:55 PM	2.35				x					
	116	11.10	937.38	1004.89	93.0	4:57 PM	3.81			x	x				sticks & log	Difficult to insert, downstream of suspended log
	117	12.00	936.52	1005.16	81.0	4:59 PM	4.72				x	x			sticks & log	Difficult to insert
	118	13.03	935.54	1005.46	0.0	5:01 PM	2.88				x	x		x	roots	Water line, under cut bank, stiff
	119	6.50	941.77	1003.53	SW	5:03 PM	1.54									Surface water, midstream
10 - 10 W	120	0.63	948.21	1003.65	0.0	5:14 PM	2.61				x	x	x		roots	Water line, slippery, stiff
	121	1.00	947.85	1003.76	33.0	5:15 PM	2.55				x	x	x			Slippery, stiff
	122	2.00	946.90	1004.06	77.0	5:16 PM	2.17				x	x	x			Slippery, stiff
	123	3.00	945.94	1004.35	119.0	5:18 PM	3.26				x	x	x			Stiff, bottom of channel
	124	4.00	944.99	1004.65	103.0	5:20 PM	3.80				x					Next to RC7 and SP12, edge of channel, one foot of SP exposed
	125	5.00	944.03	1004.94	64.0	5:22 PM	2.72				x					
	126	6.00	943.08	1005.24	86.0	5:23 PM	4.36				x					
	127	7.00	942.12	1005.53	85.0	5:24 PM	3.31				x					
	128	8.00	941.16	1005.82	82.0	5:25 PM	2.61				x					
	129	9.00	940.21	1006.12	82.0	5:26 PM	2.46				x					
	130	10.00	939.25	1006.41	84.0	5:27 PM	2.26				x					
	131	11.00	938.30	1006.71	109.0	5:29 PM	2.96				x					Soft
	132	11.90	937.44	1006.97	94.0	5:30 PM	3.71				x				log	Difficult to insert, upstream of buried log
	133	12.95	936.43	1007.28	0.0	5:31 PM	2.40				x	x		x	roots	Water line, stiff
	134	6.25	942.84	1005.31	SW	5:32 PM	1.52									Surface water, midstream
12 - 12 W	135	0.80	949.01	1005.40	0.0	5:46 PM	2.53				x	x	x		roots	Water line, stiff
	136	1.02	948.80	1005.46	11.0	5:47 PM	2.44				x	x	x		roots & sticks	Stiff
	137	2.00	947.86	1005.75	60.0	5:48 PM	2.07				x	x	x			Soft and stiff

Transect Location	Meas. No.	Dist. (m)[1]	Coordinates [2]		Water depth	Time of meas.	Temp °C	Geological description of streambed deposits[3]								Comments[4]
			East X (m)	North Y (m)	(cm)			Bo	Co	Gr	Sa	Si	Cl	Pe	Other	
	138	3.00	946.91	1006.05	88.0	5:49 PM	2.20				x	x	x			Stiff
	139	4.00	945.95	1006.35	87.0	5:50 PM	3.16				x					Clay? Stiff
	140	5.00	945.00	1006.65	68.0	5:54 PM					x					** Probe may be broken *** temp was 9.58 C
Feb 18																
Feb 19																
10 - 10 W	141	0.86	947.99	1003.72	0.0	8:39 AM	2.37				x	x	x	x		Water line, slippery, stiff *** New Probe ****
Redo	142	1.00	947.85	1003.76	13.0	8:40 AM	2.28				x	x	x	x		Stiff
	143	2.02	946.88	1004.06	67.0	8:41 AM	2.04				x	x	x			Slippery, stiff
	144	3.00	945.94	1004.35	107.0	8:43 AM	3.05				x	x				Clay? stiff, bottom of channel
	145	4.00	944.99	1004.65	94.0	8:45 AM	3.49				x					Next to RC7 and SP12
	146	5.00	944.03	1004.94	54.5	8:46 AM	2.68				x					
	147	6.00	943.08	1005.24	72.0	8:47 AM	4.16				x					
	148	7.00	942.12	1005.53	69.0	8:48 AM	3.04				x					
	149	8.00	941.16	1005.82	65.0	8:49 AM	2.34				x					
	150	9.00	940.21	1006.12	61.0	8:50 AM	1.94				x					
	151	10.00	939.25	1006.41	68.0	8:51 AM	1.94				x					
	152	11.00	938.30	1006.71	87.0	8:52 AM	2.51				x				sticks	
	153	11.96	937.38	1006.99	80.0	8:53 AM	3.01				x				sticks & log	
	154	12.82	936.56	1007.24	0.0	8:54 AM	2.10				x	x		x	sticks	Water line
	155	6.25	942.84	1005.31	SW	8:56 AM	0.01									Surface water, midstream
12 - 12 W	156	1.05	948.77	1005.47	0.0	9:00 AM	2.12				x	x	x			Water line, soft and stiff
	157	2.00	947.86	1005.75	49.5	9:01 AM	1.87				x	x	x			Soft and stiff
	158	3.00	946.91	1006.05	72.0	9:02 AM	1.96				x	x	x			Stiff
	159	4.00	945.95	1006.35	74.0	9:03 AM	2.52				x	x				Stiff
	160	5.00	945.00	1006.65	54.0	9:04 AM	2.54				x					
	161	6.00	944.04	1006.94	74.0	9:05 AM	3.38				x					Silt? Stiff
	162	7.00	943.09	1007.24	75.0	9:06 AM	4.61				x					
	163	8.00	942.14	1007.54	73.0	9:07 AM	4.18				x					
	164	9.00	941.18	1007.84	70.0	9:08 AM	3.17				x					
	165	10.00	940.23	1008.13	71.0	9:09 AM	2.36				x					
	166	11.00	939.27	1008.43	73.0	9:10 AM	3.19				x					

Transect Location	Meas. No.	Dist. (m)(1)	Coordinates (2) East X (m)	North Y (m)	Water depth (cm)	Time of meas.	Temp °C	Geological description of streambed deposits(3) Bo	Co	Gr	Sa	Si	Cl	Pe	Other	Comments(4)
	167	11.82	938.49	1008.68	94.0	9:13 AM	4.64				x				sticks	Upstream edge of lawn mower
	168	12.40	937.93	1008.85	77.0	9:14 AM	5.28				x	x			sticks	Stiff
	169	12.72	937.63	1008.94	0.0	9:16 AM	0.58				x	x		x	sticks, roots, log	Water line
	170	6.80	943.28	1007.18	SW	9:17 AM	0.01									Surface water
14 - 14 W	171	1.25	949.59	1007.28	0.0	9:30 AM	2.09				x	x	x			Water line, soft and stiff
	172	2.05	948.83	1007.52	40.0	9:31 AM	1.91				x	x	x			Stiff, next to SP15
	173	3.00	947.93	1007.81	41.0	9:32 AM	1.52				x					Stiff, overlying silt and clay
	174	4.00	946.97	1008.11	52.0	9:33 AM	1.66				x					Next to SP16
	175	5.00	946.02	1008.41	44.0	9:34 AM	1.78				x					
	176	6.00	945.06	1008.71	59.0	9:35 AM	2.08				x					
	177	7.00	944.11	1009.01	88.0	9:36 AM	3.74				x					Next to RC10 and SP18
	178	7.20	943.92	1009.07	87.0	9:37 AM	3.92				x					
	179	8.00	943.16	1009.31	75.0	9:38 AM	3.10				x					Next to SP19
	180	9.00	942.20	1009.61	70.0	9:39 AM	3.01				x					
	181	10.00	941.25	1009.91	68.0	9:40 AM	2.37				x					
	182	11.00	940.30	1010.21	70.0	9:41 AM	2.03				x					
	183	12.00	939.34	1010.51	84.0	9:43 AM	2.86				x				sticks	
	184	12.45	938.91	1010.65	78.0	9:44 AM	4.13				x	x		x		Stiff
	185	12.92	938.47	1010.79	0.0	9:45 AM	2.25				x	x		x	roots	Water line
	186	7.50	943.63	1009.16	SW	9:46 AM	0.02									Surface water, midstream
16 - 16 W	187	1.21	950.19	1009.23	0.0	9:55 AM	2.32				x	x	x			Water line, soft and stiff
	188	1.50	949.92	1009.32	27.0	9:57 AM	2.23				x	x	x			Soft, stiff, next to SP20
	189	2.00	949.44	1009.47	38.0	9:59 AM	1.77					x	x			Stiff, next to MLS1 and 2
	190	2.50	948.96	1009.61	35.0	10:00 AM	1.46				x					Stiff, overlying silt and clay
	191	3.00	948.48	1009.76	36.0	10:01 AM	1.63				x					Stiff at bottom
	192	3.65	947.86	1009.95	35.0	10:02 AM	1.75				x					Between MLS3 and 4
	193	4.00	947.53	1010.05	32.0	10:03 AM	1.49				x					10 cm east of SP21
	194	4.50	947.05	1010.20	30.0	10:04 AM	1.38				x					
	195	5.00	946.57	1010.35	33.0	10:05 AM	1.56				x					
	196	5.50	946.09	1010.49	43.0	10:06 AM	1.83				x					Near MLS5
	197	6.00	945.61	1010.64	60.0	10:07 AM	2.11				x					Near RC11 and SP22
	198	6.50	945.14	1010.79	79.0	10:08 AM	2.51				x					

Transect Location	Meas. No.	Dist. (m)[1]	Coordinates[2]		Water depth (cm)	Time of meas.	Temp °C	Geological description of streambed deposits[3]								Comments[4]
			East X (m)	North Y (m)				Bo	Co	Gr	Sa	Si	Cl	Pe	Other	
	199	7.10	944.56	1010.97	88.0	10:10 AM	2.74				x					Between MLS7 and 8
	200	7.50	944.18	1011.08	85.0	10:11 AM	2.87				x					
	201	8.10	943.61	1011.26	82.0	10:12 AM	3.69				x					Next to SP23
	202	8.50	943.22	1011.38	79.0	10:13 AM	4.43				x					
	203	9.12	942.63	1011.56	76.0	10:15 AM	4.33				x					Between MLS9 and 10
	204	9.50	942.27	1011.67	74.0	10:17 AM	3.50				x					Next to failed MLS
	205	10.00	941.79	1011.82	72.0	10:18 AM	2.76				x					Soft
	206	10.50	941.31	1011.96	70.0	10:19 AM	2.25				x					
	207	11.00	940.84	1012.11	73.0	10:20 AM	2.17				x					
	208	11.58	940.28	1012.28	86.0	10:22 AM	3.81				x					Between MLS11 and 12
	209	12.13	939.76	1012.44	68.0	10:23 AM	2.37				x	x			sticks	Difficult to insert
	210	12.80	939.12	1012.64	43.0	10:25 AM	4.01				x	x		x	roots	Stiff
	211	13.13	938.80	1012.74	0.0	10:26 AM	2.48					x	x	x	roots	Water line
	212	7.00	944.66	1010.94	SW	10:28 AM	0.04									Surface water, midstream
18 - 18 W	213	0.95	951.07	1011.01	0.0	10:45 AM	3.21				x	x	x	x	roots	Water line, stiff
	214	1.20	950.83	1011.08	45.0	10:46 AM	4.72				x	x		x		Stiff
	215	2.05	950.02	1011.33	62.0	10:48 AM	1.92				x					Stiff at bottom
	216	3.00	949.11	1011.60	36.0	10:49 AM	1.46				x					
	217	4.00	948.15	1011.89	27.0	10:50 AM	1.37				x					
	218	5.00	947.19	1012.18	29.0	10:51 AM	1.43				x					
	219	6.00	946.24	1012.47	54.0	10:52 AM	1.79				x					
	220	7.00	945.28	1012.75	75.0	10:53 AM	2.10				x					
	221	8.00	944.32	1013.04	85.0	10:54 AM	2.71				x					40 cm west of failed MLS prototype (PRP17) and SP27
	222	9.00	943.36	1013.33	79.0	10:55 AM	2.53				x					Next to SP28
	223	10.00	942.41	1013.62	70.0	10:56 AM	2.64				x					
	224	11.00	941.45	1013.91	67.0	10:58 AM	2.48				x					
	225	12.00	940.49	1014.19	72.0	10:59 AM	3.93				x				log	
	226	12.97	939.56	1014.47	39.0	11:00 AM	2.56				x	x				Stiff
	227	13.58	938.98	1014.65	0.0	11:01 AM	2.26				x	x		x	roots	Water line
	228	7.25	945.04	1012.83	SW	11:02 AM	0.06									Surface water, midstream

Transect Location	Meas. No.	Dist. (m)[1]	Coordinates [2]		Water depth (cm)	Time of meas.	Temp °C	Geological description of streambed deposits[3]								Comments[4]
			East X (m)	North Y (m)				Bo	Co	Gr	Sa	Si	Cl	Pe	Other	
20 - 20 W	229	1.35	951.25	1013.01	0.0	11:19 AM	3.39				x	x			roots	Water line, stiff, under base of tree trunk, distance is approximate
	230	1.85	950.77	1013.15	22.0	11:20 AM	3.34				x		x		roots	Stiff, next to SG1A
	231	2.62	950.03	1013.36	58.0	11:21 AM	3.60				x	x			sticks	Next to stump in water
	232	3.13	949.54	1013.50	56.0	11:27 AM	1.76				x	x			sticks & logs	Difficult to insert
	233	4.00	948.70	1013.74	37.0	11:24 AM	1.50				x					
	234	5.00	947.74	1014.02	41.0	11:25 AM	1.62				x					
	235	6.00	946.78	1014.30	54.0	11:26 AM	1.51				x					
	236	7.00	945.82	1014.57	73.0	11:27 AM	2.02				x					
	237	8.00	944.86	1014.85	78.0	11:28 AM	2.79				x					
	238	9.00	943.90	1015.13	77.0	11:29 AM	2.75				x					
	239	10.00	942.94	1015.40	77.0	11:30 AM	3.02				x					
	240	11.00	941.97	1015.68	65.0	11:31 AM	3.04				x					
	241	12.00	941.01	1015.96	59.0	11:33 AM	5.27				x					Stiff, silt?
	242	13.08	939.98	1016.26	54.0	11:34 AM	6.57				x	x			logs	Difficult to insert, stiff, bubbles
	243	13.94	939.15	1016.49	0.0	11:35 AM	2.57				x	x	x		roots	Water line, difficult to insert, stiff
	244	7.50	945.34	1014.71	SW	11:37 AM	0.12									Surface water, midstream
22 - 22 W	245	1.42	951.13	1015.13	0.0	11:48 AM	3.18				x	x				Water line, stiff, soft, clay?
	246	2.00	950.57	1015.29	48.0	11:49 AM	3.67				x	x				Stiff, clay?
	247	3.12	949.49	1015.60	65.0	11:50 AM	2.41				x	x			sticks & log	Difficult to insert, stiff
	248	4.00	948.64	1015.83	51.0	11:51 AM	1.94				x					Stiff at depth
	249	5.00	947.68	1016.11	58.0	11:52 AM	1.66				x					
	250	6.00	946.72	1016.38	73.0	11:53 AM	1.74				x					
	251	7.00	945.76	1016.65	77.0	11:54 AM	2.77				x					
	252	8.00	944.79	1016.92	73.0	11:55 AM	4.32				x					
	253	9.00	943.83	1017.19	74.0	11:56 AM	4.29				x					
	254	10.00	942.87	1017.46	68.0	11:58 AM	4.67				x					Little bit stiff
	255	11.00	941.91	1017.73	58.0	11:59 AM	5.33				x					
	256	12.00	940.94	1018.01	39.0	12:01 PM	3.82				x	x			log	Difficult to insert, on a piece of wood
	257	12.97	940.01	1018.27	31.0	12:02 PM	3.66				x	x			sticks & log	Difficult to insert, next to buried log

Transect Location	Meas. No.	Dist. (m)$^{(1)}$	Coordinates $^{(2)}$		Water depth (cm)	Time of meas.	Temp °C	Geological description of streambed deposits$^{(3)}$								Comments$^{(4)}$
			East X (m)	North Y (m)				Bo	Co	Gr	Sa	Si	Cl	Pe	Other	
	258	13.59	939.41	1018.44	0.0	12:03 PM	2.48				x	x			sticks & log	Water line, difficult to insert
	259	7.00	945.76	1016.65	SW	12:05 PM	0.16									Surface water, midstream
24 - 24 W	260	1.66	951.66	1017.08	0.0	12:15 PM	3.63				x	x	x			Water line, soft and stiff
	261	2.00	951.34	1017.17	27.0	12:17 PM	4.83				x	x	x			Soft and stiff
	262	2.50	950.85	1017.31	47.0	12:19 PM	4.83				x	x	x		log	Soft and stiff, same temperature as before
	263	3.00	950.37	1017.44	63.0	12:20 PM	3.09				x	x	x			Stiff
	264	3.60	949.79	1017.60	67.0	12:21 PM	3.03				x	x				Stiff, 30 cm upstream of PRP1
	265	4.00	949.41	1017.71	61.0	12:22 PM	2.81				x	x				Sand overlying silt
	266	4.50	948.93	1017.84	54.0	12:23 PM	2.12				x	x				Stiff and soft
	267	5.05	948.40	1017.99	63.0	12:24 PM	1.87				x	x				Soft 10 cm east of PRP2
	268	5.50	947.96	1018.11	67.0	12:25 PM	1.62				x					Sand overlying silt
	269	6.00	947.48	1018.24	71.0	12:26 PM	1.46				x					
	270	6.50	947.00	1018.37	79.0	12:27 PM	1.69				x					
	271	7.00	946.52	1018.50	81.0	12:28 PM	2.01				x					Near SP31 (?)
	272	7.50	946.03	1018.64	79.0	12:29 PM	3.04				x					
	273	8.00	945.55	1018.77	74.0	12:30 PM	3.44				x					
	274	8.50	945.07	1018.90	73.0	12:32 PM	4.50				x					Downstream of SP32
	275	9.00	944.59	1019.04	72.0	12:32 PM	5.23				x					
	276	9.50	944.11	1019.17	72.0	12:34 PM	5.32				x					
	277	10.00	943.62	1019.30	64.0	12:36 PM	4.43				x					
	278	10.50	943.14	1019.44	54.0	12:37 PM	4.04				x					
	279	11.00	942.66	1019.57	54.0	12:38 PM	4.51				x				log	Next to buried log
	280	11.50	942.18	1019.70	54.0	12:39 PM	3.85					x			sticks & log	
	281	12.00	941.70	1019.83	64.0	12:40 PM	5.15			x	x				sticks	Difficult to insert
	282	12.41	941.30	1019.94	64.0	12:41 PM	4.63			x	x				sticks & log	Difficult to insert
	283	13.00	940.73	1020.10	43.0	12:42 PM	2.68				x	x			sticks	Difficult to insert
	284	13.66	940.10	1020.28	15.0	12:45 PM	2.13				x	x			sticks & log	Difficult to insert, next to log
	285	14.26	939.52	1020.43	0.0	12:46 PM	1.96				x	x				Water line, stiff
	286	8.00	945.55	1018.77	SW	12:48 PM	0.23									Surface water, midstream
26 - 26 W	287	1.38	951.83	1019.15	0.0	12:55 PM	2.85				x	x	x			Water line, stiff
	288	1.95	951.29	1019.30	45.0	12:56 PM	6.44				x	x	x			Stiff, bubbles

Transect Location	Meas. No.	Dist. (m)[1]	Coordinates[2] East X (m)	North Y (m)	Water depth (cm)	Time of meas.	Temp °C	Geological description of streambed deposits[3] Bo	Co	Gr	Sa	Si	Cl	Pe	Other	Comments[4]
	289	2.50	950.75	1019.44	54.0	12:57 PM	6.37				x	x	x			Soft and stiff, stuck standing in mud
	290	3.00	950.27	1019.58	46.0	12:58 PM	4.11				x					
	291	3.50	949.79	1019.71	50.0	12:59 PM	4.27				x					
	292	4.15	949.16	1019.88	53.0	1:00 PM	4.05		x	x	x					Difficult to insert
	293	5.00	948.34	1020.11	67.0	1:02 PM	1.93			x	x					
	294	6.00	947.38	1020.37	78.0	1:03 PM	1.67				x					
	295	7.00	946.42	1020.64	81.0	1:04 PM	1.76				x					
	296	8.00	945.45	1020.91	77.0	1:05 PM	2.76				x					
	297	9.00	944.49	1021.17	67.0	1:06 PM	3.25				x					
	298	10.00	943.52	1021.44	60.6	1:07 PM	2.96				x					
	299	11.00	942.56	1021.70	56.0	1:08 PM	2.01			x	x					
	300	11.85	941.74	1021.93	52.0	1:09 PM	2.20			x	x				log	
	301	12.96	940.67	1022.22	38.0	1:10 PM	2.71			x	x				sticks & log	
	302	14.00	939.67	1022.50	23.0	1:11 PM	3.59				x				log	bubbles
	303	14.34	939.34	1022.59	0.0	1:12 PM	2.54				x				sticks & log	Water line
	304	8.00	945.45	1020.91	SW	1:13 PM	0.63									Surface water, midstream
28 - 28 W	305	0.90	951.86	1021.16	0.0	2:19 PM	4.49				x	x	x		roots	Water line, very stiff
	306	1.50	951.28	1021.32	37.0	2:20 PM	9.34				x	x	x			Loose and stiff
	307	2.00	950.80	1021.45	55.0	2:21 PM	8.91				x	x	x			Soft and stiff
	308	2.50	950.32	1021.58	57.0	2:23 PM	7.73				x	x				Soft and stiff, clay?
	309	3.00	949.84	1021.71	54.0	2:24 PM	5.88				x	x				
	310	3.50	949.35	1021.84	50.0	2:25 PM	5.43				x					
	311	4.00	948.87	1021.97	62.0	2:26 PM	4.12				x					
	312	4.50	948.39	1022.10	67.0	2:27 PM	2.39				x					
	313	5.53	947.40	1022.38	82.0	2:29 PM	1.71				x				log	log obstructions from 5 to 5.40 m
	314	6.25	946.70	1022.56	82.0	2:30 PM	1.66		x		x				log	
	315	6.96	946.02	1022.75	80.0	2:31 PM	1.69			x	x					On a stone
	316	8.00	945.01	1023.02	73.0	2:32 PM	2.04				x					
	317	9.00	944.05	1023.29	62.0	2:33 PM	3.85			x	x					On a stone
	318	10.00	943.08	1023.55	58.0	2:34 PM	2.72				x					
	319	11.00	942.12	1023.81	57.0	2:35 PM	2.01			x	x				sticks	Difficult to insert

Transect Location	Meas. No.	Dist. (m)[1]	Coordinates [2]		Water depth (cm)	Time of meas.	Temp °C	Geological description of streambed deposits[3]								Comments[4]
			East X (m)	North Y (m)				Bo	Co	Gr	Sa	Si	Cl	Pe	Other	
	320	12.32	940.84	1024.16	33.0	2:36 PM	2.06			x	x				sticks & log	Difficult to insert, in sticks and log jam
	321	13.05	940.14	1024.35	41.0	2:37 PM	3.46			x	x				sticks & log	Difficult to insert
	322	14.05	939.18	1024.62	26.0	2:38 PM	3.42			x	x	x			sticks & log	Stiff
	323	14.98	938.28	1024.86	0.0	2:39 PM	2.77				x	x			sticks & roots	Water line
	324	8.00	945.01	1023.02	SW	2:41 PM	0.67									Surface water, midstream
30 - 30 W	325	1.38	951.17	1023.53	0.0	2:55 PM	0.92				x	x		x	roots	Water line, side of steep bank
	326	1.60	950.95	1023.58	47.0	2:56 PM	6.19					x	x	x		Stiff
	327	2.00	950.57	1023.68	68.0	2:59 PM	8.31					x	x			Very soft, in eroded pothole, undercut bank, stiff
	328	2.50	950.08	1023.81	77.0	3:00 PM	8.47					x	x			Very soft, stiff
	329	3.00	949.60	1023.94	84.0	3:01 PM	9.09					x	x			Soft and stiff
	330	3.50	949.12	1024.06	83.0	3:02 PM	7.55				x	x	x		sticks	Difficult to insert, next to buried log
	331	4.00	948.63	1024.19	86.0	3:04 PM	5.32				x	x			sticks	Stiff
	332	4.50	948.15	1024.31	89.0	3:05 PM	3.87				x	x				Clay?
	333	5.00	947.66	1024.44	88.0	3:06 PM	2.69				x	x			sticks	Stiff
	334	6.00	946.70	1024.69	81.0	3:07 PM	1.16				x	x			sticks	Boulder at 5.5 m
	335	6.85	945.87	1024.90	64.0	3:10 PM	1.18		x	x	x					Difficult to insert
	336	8.24	944.53	1025.25	60.0	3:12 PM	2.37		x	x	x				log	Difficult to insert, buried log at 8 m
	337	9.00	943.79	1025.45	65.0	3:14 PM	2.43		x	x	x				sticks	Difficult to insert, probe depth is 14 cm
	338	10.15	942.68	1025.73	64.0	3:15 PM	1.74			x	x					Difficult to insert
	339	11.00	941.86	1025.95	55.0	3:16 PM	1.37		x	x	x					Difficult to insert
	340	12.00	940.89	1026.20	42.0	3:17 PM	1.67				x					Easy push
	341	13.00	939.92	1026.45	39.0	3:18 PM	2.06				x				sticks	Downstream of buried log
	342	14.00	938.95	1026.70	40.0	3:19 PM	2.62				x					Downstream of buried log
	343	14.70	938.28	1026.88	37.0	3:21 PM	2.66				x	x				Stiff
	344	15.17	937.82	1027.00	0.0	3:22 PM	2.12				x	x			roots	Water line, stiff
	345	8.00	944.76	1025.19	SW	3:24 PM	0.87									Surface water, midstream

Transect Location	Meas. No.	Dist. (m)[1]	Coordinates [2] East X (m)	North Y (m)	Water depth (cm)	Time of meas.	Temp °C	Geological description of streambed deposits[3] Bo	Co	Gr	Sa	Si	Cl	Pe	Other	Comments[4]
32 - 32 W	346	0.35	951.14	1025.73	0.0	3:45 PM	2.41					x	x	x	roots & log	Water line, stiff, distance is approximate
	347	0.65	950.85	1025.81	32.0	3:47 PM	1.42					x	x	x	sticks	Stiff
	348	1.00	950.51	1025.89	44.0	3:49 PM	2.46					x	x	x		Stiff
	349	1.50	950.03	1026.01	62.0	3:50 PM	2.91				x	x	x		sticks & log	Stiff
	350	1.95	949.59	1026.12	82.0	3:51 PM	3.11				x	x			sticks & log	Stiff, downstream of branch in water
	351	2.50	949.06	1026.25	89.0	3:53 PM	3.73				x	x			sticks	Difficult to insert, stiff, lots of debris
	352	3.12	948.45	1026.40	89.0	3:54 PM	2.92			x	x	x			sticks & log	Difficult to insert
	353	3.96	947.64	1026.60	90.0	3:56 PM	1.79		x	x	x	x			sticks	Difficult to insert, stiff
	354	5.10	946.53	1026.87	98.0	3:57 PM	2.29			x	x	x	x		sticks	Difficult to insert, stiff, clay on probe
	355	6.03	945.63	1027.09	79.0	3:58 PM	1.37		x	x	x	x				Difficult to insert, stiff
	356	6.96	944.73	1027.32	63.0	4:00 PM	1.28		x	x	x					Difficult to insert
	357	8.00	943.72	1027.56	69.0	4:01 PM	1.45		x	x	x					Difficult to insert
	358	9.00	942.75	1027.80	70.0	4:03 PM	1.81			x	x					Easier push
	359	10.00	941.77	1028.04	55.0	4:04 PM	1.40			x	x					
	360	11.00	940.80	1028.28	53.0	4:05 PM	1.76			x	x					
	361	12.00	939.83	1028.52	39.0	4:06 PM	1.79				x					
	362	13.00	938.86	1028.76	36.0	4:07 PM	2.60				x					Soft
	363	14.00	937.89	1029.00	26.0	4:08 PM	2.62			x	x					Soft
	364	14.60	937.31	1029.14	0.0	4:09 PM	2.37			x	x					Water line, soft
	365	7.50	944.20	1027.45	SW	4:10 PM	0.86									Surface water, midstream
34 - 34 W	366	0.27	951.53	1027.74	0.0	4:32 PM	1.68				x	x	x		roots & log	Water line, stiff
	367	1.00	950.82	1027.91	38.0	4:33 PM	2.23					x	x		sticks	Stiff and soft
	368	1.90	949.94	1028.11	50.0	4:34 PM	1.08				x	x			sticks	Stiff, clay?
	369	2.95	948.92	1028.35	57.0	4:35 PM	2.12				x	x			sticks	Stiff
	370	4.00	947.90	1028.59	75.0	4:36 PM	2.03				x	x				
	371	5.00	946.93	1028.82	101.0	4:37 PM	2.51				x				sticks & logs	
	372	6.00	945.95	1029.05	96.0	4:39 PM	2.35		x		x				sticks	Stiff
	373	6.90	945.08	1029.26	82.0	4:40 PM	1.68		x	x	x				sticks	Difficult to insert
	374	8.00	944.01	1029.51	82.0	4:42 PM	1.18		x	x	x					Difficult to insert

Transect Location	Meas. No.	Dist. (m)[1]	Coordinates [2]		Water depth (cm)	Time of meas.	Temp °C	Geological description of streambed deposits[3]								Comments[4]
			East X (m)	North Y (m)				Bo	Co	Gr	Sa	Si	Cl	Pe	Other	
	375	9.00	943.03	1029.74	80.0	4:43 PM	1.23		x	x	x					Difficult to insert
	376	10.00	942.06	1029.97	73.0	4:45 PM	1.36			x	x					
	377	11.00	941.09	1030.20	60.0	4:46 PM	1.38				x					Easy
	378	11.95	940.16	1030.42	56.0	4:47 PM	1.47			x	x					Difficult to insert
	379	13.00	939.14	1030.66	49.0	4:48 PM	2.29				x					Easy
	380	14.00	938.16	1030.89	46.0	4:49 PM	2.83			x	x					Soft
	381	15.00	937.19	1031.12	33.0	4:50 PM	2.70			x	x					Soft
	382	16.07	936.15	1031.36	0.0	4:52 PM	2.25			x	x				roots	Water line, stiff
	383	8.25	943.76	1029.57	SW	4:54 PM	0.53									*Surface water, midstream*
36 - 36 W	384	0.55	951.47	1029.85	0.0	5:17 PM	2.73					x	x	x	roots	Water line, stiff, distance is approximate
	385	0.95	951.08	1029.93	36.0	5:18 PM	4.23				x	x		x	log	Stiff
	386	1.97	950.08	1030.15	57.0	5:20 PM	2.04				x	x		x	sticks	Soft and stiff
	387	3.00	949.08	1030.37	51.0	5:51 PM	1.54				x	x				Very soft
	388	4.00	948.10	1030.58	60.0	5:22 PM	1.48				x	x				Very soft
	389	4.90	947.22	1030.77	98.0	5:23 PM	2.29				x	x			sticks & log	Difficult to insert
	390	6.00	946.14	1031.01	105.0	5:25 PM	2.39				x	x			sticks & log	
	391	7.07	945.10	1031.24	94.0	5:26 PM	1.83				x				sticks	20 cm upstream of large suspended log
	392	7.97	944.22	1031.43	75.0	5:28 PM	1.31			x	x				sticks & log	Down stream of buried log
	393	9.00	943.21	1031.65	81.0	5:30 PM	1.34			x	x					Between large logs
	394	10.08	942.16	1031.88	85.0	5:31 PM	1.34			x	x				log	Upstream side of large buried log
	395	11.00	941.26	1032.08	70.0	5:32 PM	1.55			x	x				sticks	Downstream of suspended log
	396	12.15	940.14	1032.32	47.0	5:36 PM	1.05		x	x	x					Very difficult to insert, probe depth is 14 cm
	397	13.09	939.22	1032.52	55.0	5:37 PM	1.53			x	x					Difficult to insert, on a stone
	398	13.93	938.40	1032.70	58.0	5:40 PM	1.99			x	x					Difficult to insert, temp as high as 2.38 C then drops
	399	15.25	937.11	1032.98	48.0	5:42 PM	1.73			x	x				sticks	Difficult to insert
	400	16.00	936.37	1033.14	40.0	5:44 PM	2.69			x	x					On a stone
	401	16.93	935.47	1033.34	39.0	5:45 PM	3.32			x	x					Temp as high as 4.2 C, then drops, soft, on a stone
	402	17.34	935.07	1033.43	0.0	5:47 PM	1.84				x	x				Water line, stiff

Transect Location	Meas. No.	Dist. (m)(1)	Coordinates (2)		Water depth (cm)	Time of meas.	Temp °C	Geological description of streambed deposits(3)								Comments(4)
			East X (m)	North Y (m)				Bo	Co	Gr	Sa	Si	Cl	Pe	Other	
	403	9.00	943.21	1031.65	SW	5:49 PM	0.23									Surface water, midstream
14 - 14 W	404	0.97	949.86	1007.20	0.0	6:10 PM	1.86				x	x				Water line, stiff
Redo	405	2.00	948.88	1007.51	48.0	6:11 PM	1.49				x	x				Stiff
	406	3.00	947.93	1007.81	57.0	6:12 PM	1.23				x					Silt underlies sand
	407	4.00	946.97	1008.11	65.0	6:13 PM	1.27				x					
	408	5.00	946.02	1008.41	61.0	6:14 PM	1.55				x					
	409	6.00	945.06	1008.71	75.0	6:15 PM	1.83				x					
	410	7.05	944.06	1009.02	107.0	6:16 PM	3.54				x					Next to RC10 and SP18
	411	8.00	943.16	1009.31	96.0	6:17 PM	3.04				x					
	412	9.00	942.20	1009.61	91.0	6:18 PM	2.96				x					
	413	10.00	941.25	1009.91	87.0	6:19 PM	2.22				x					
	414	11.00	940.30	1010.21	86.0	6:20 PM	1.76				x					
	415	12.00	939.34	1010.51	100.0	6:21 PM	2.40				x					
	416	12.55	938.82	1010.68	79.0	6:22 PM	2.38				x	x	x		roots	Stiff
	417	12.95	938.44	1010.80	0.0	6:23 PM	1.74						x	x	sticks & roots	Water line
	418	7.50	943.63	1009.16	SW	6:24 PM	0.06									Surface water, midstream
Feb 19																
Feb 20																
0 - 0 W	419	2.02	944.52	994.28	0.0	8:17 AM	2.39				x	x				Water line, stiff, break through ice
Redo	420	3.00	943.58	994.57	31.0	8:18 AM	3.51				x	x				Soft and stiff
	421	4.00	942.62	994.86	49.0	8:19 AM	4.52				x	x				
	422	5.00	941.66	995.15	65.0	8:20 AM	5.65				x	x				
	423	6.00	940.71	995.44	69.0	8:22 AM	5.73				x	x				
	424	7.00	939.75	995.73	63.5	8:24 AM	4.71				x					
	425	8.00	938.79	996.01	62.5	8:25 AM	4.06				x					
	426	9.00	937.84	996.30	67.0	8:26 AM	3.19				x					
	427	10.00	936.88	996.59	65.0	8:27 AM	2.42				x					
	428	11.00	935.92	996.88	67.0	8:28 AM	1.71				x					
	429	12.00	934.96	997.17	58.0	8:29 AM	1.16				x					
	430	13.00	934.01	997.46	42.0	8:30 AM	1.11				x					
	431	14.00	933.05	997.75	38.0	8:31 AM	2.02				x					Soft
	432	15.00	932.09	998.04	21.0	8:32 AM	6.02				x	x			sticks & log	Next to buried log

Transect Location	Meas. No.	Dist. (m)[1]	Coordinates[2] East X (m)	Coordinates[2] North Y (m)	Water depth (cm)	Time of meas.	Temp °C	Bo	Co	Gr	Sa	Si	Cl	Pe	Other	Comments[4]
	433	15.58	931.54	998.21	0.0	8:33 AM	2.47				x	x			sticks & log	Water line, stiff
	434	8.80	938.03	996.25	SW	8:35 AM	0.02									Surface water, midstream
38 - 38 W	435	-0.20	951.58	1031.88	0.0	8:54 AM	3.23					x	x	x	roots & log	Water line, undercut bank, distance is approximate
	436	0.50	950.90	1032.04	43.0	8:55 AM	1.66				x	x		x		Downstream of suspended log, stiff
	437	1.00	950.41	1032.14	53.0	8:57 AM	1.71				x	x			log	Soft, downstream of suspended log
	438	2.12	949.32	1032.39	62.0	8:59 AM	1.68				x	x			sticks & log	Pushed through bag or cloth
	439	3.29	948.18	1032.64	81.0	9:01 AM	2.26				x				sticks & log	Difficult to insert, down stream of suspended log and ice jam (in front of log)
	440	3.90	947.58	1032.77	87.0	9:02 AM	1.63				x				sticks & log	Difficult to insert, under log in ice jam
	441	5.09	946.42	1033.03	81.0	9:04 AM	1.54			x	x				sticks & log	Difficult to insert, next to buried log
	442	5.96	945.57	1033.22	71.0	9:05 AM	1.02				x				sticks	Difficult to insert
	443	7.00	944.55	1033.44	67.0	9:07 AM	1.83		x	x	x				sticks	Difficult to insert
	444	8.00	943.58	1033.66	64.0	9:09 AM	1.15		x	x	x					Difficult to insert, in cobble bar
	445	9.00	942.60	1033.88	58.0	9:11 AM	0.78		x	x	x					Difficult to insert, probe depth is 15 cm, temp as high as 1.77 C then drops
	446	10.15	941.48	1034.13	60.0	9:13 AM	1.01		x	x	x					Difficult to insert, temp as high as 1.5 C then drops
	447	11.00	940.65	1034.31	56.0	9:14 AM	1.26			x	x					Difficult to insert, downstream of tire
	448	12.00	939.67	1034.53	39.0	9:15 AM	1.13				x					Easy
	449	13.00	938.70	1034.74	33.0	9:16 AM	1.32				x					Easy
	450	14.00	937.72	1034.96	48.0	9:18 AM	1.56			x	x					
	451	15.00	936.74	1035.18	42.0	9:19 AM	2.01				x	x			stick	Soft
	452	16.13	935.64	1035.42	35.0	9:21 AM	2.96			x	x	x				On a stone, probe depth 15 cm
	453	16.98	934.81	1035.61	0.0	9:22 AM	3.50				x	x	x			Water line, very soft

Bo through Other: Geological description of streambed deposits[3]

Transect Location	Meas. No.	Dist. (m)[1]	Coordinates [2] East X (m)	Coordinates [2] North Y (m)	Water depth (cm)	Time of meas.	Temp °C	Geological description of streambed deposits[3] Bo	Co	Gr	Sa	Si	Cl	Pe	Other	Comments[4]
	454	8.50	943.09	1033.77	SW	9:24 AM	-0.01									Surface water, midstream, temperature is negative
40 - 40 W	455	0.05	951.18	1033.75	0.0											Water line, too many sticks and a log so no reading
	456	0.15	951.08	1033.77	18.0	10:39 AM	2.70					x	x	x	sticks & log	Difficult to insert, probe about to break
	457	2.00	949.28	1034.19	39.0	10:50 AM	1.49				x	x			sticks & log	Soft *** NEW PROBE ***
	458	4.00	947.33	1034.65	55.0	10:52 AM	1.59				x	x				Soft
	459	6.03	945.36	1035.11	75.0	10:54 AM	1.21				x				sticks	
	460	8.15	943.29	1035.59	90.0	10:55 AM	1.38				x				log	Difficult to insert, buried logs
	461	9.92	941.57	1036.00	80.0	10:56 AM	1.07			x	x					Difficult to insert
	462	12.00	939.54	1036.47	36.0	10:57 AM	0.91				x					
	463	14.00	937.60	1036.93	30.0	10:58 AM	0.87				x					
	464	15.90	935.75	1037.36	40.0	10:59 AM	2.92		x		x	x			log	Soft
	465	17.05	934.63	1037.62	0.0	11:00 AM	2.51				x	x			roots	Water line, stiff
	466	8.50	942.95	1035.67	SW	11:01 AM	0.04									Surface water, midstream
42 - 42 W	467	0.42	950.02	1036.01	0.0	11:07 AM	1.68				x	x		x	roots & log	Water line, stiff
	468	1.10	949.35	1036.16	43.0	11:09 AM	2.05				x	x			sticks & roots	Soft and stiff
	469	2.11	948.37	1036.39	58.0	11:10 AM	1.92				x	x			sticks	Soft and stiff
	470	4.00	946.53	1036.80	45.0	11:11 AM	1.12				x	x				Soft and stiff
	471	6.06	944.52	1037.25	80.0	11:13 AM	1.16			x	x				sticks & log	Difficult to insert
	472	7.80	942.82	1037.64	74.0	11:15 AM	0.58		x	x	x					Difficult to insert, temperature as high as 0.94 C then drops
	473	10.00	940.67	1038.12	79.0	11:16 AM	0.92		x	x	x					Difficult to insert, upstream of debris, against log
	474	12.00	938.72	1038.56	44.0	11:18 AM	1.16				x					Pieces of ice floating in river and near bank
	475	14.09	936.68	1039.02	51.0	11:20 AM	1.48				x	x			sticks	Downstream of sticks & ice jam
	476	15.50	935.31	1039.33	38.0	11:21 AM	3.13				x	x				Soft, probe on wood
	477	16.70	934.14	1039.59	0.0	11:22 AM	1.33				x	x		x	roots	Water line
	478	8.50	942.14	1037.79	SW	11:28 AM	0.04									Surface water, approximately 8.5 m

Transect Location	Meas. No.	Dist. (m)[1]	Coordinates [2] East X (m)	Coordinates [2] North Y (m)	Water depth (cm)	Time of meas.	Temp °C	Geological description of streambed deposits[3] Bo	Co	Gr	Sa	Si	Cl	Pe	Other	Comments[4]
44 - 44 W	479	0.45	948.84	1038.35	0.0	11:34 AM										Water line, unable to take reading (uprooted tree there)
	480	2.28	947.08	1038.82	85.0	11:37 AM	1.59			x	x				sticks	Difficult to insert, next to uprooted tree, downstream of large suspended log
	481	4.00	945.41	1039.25	68.0	11:38 AM	1.27			x	x					Difficult to insert, 30 cm downstream of suspended log
	482	6.23	943.26	1039.82	52.0	11:40 AM	0.53		x	x	x					Difficult to insert, depth of probe 12 cm, temp as high as 0.94 C then drops
	483	8.03	941.52	1040.28	44.0	11:42 AM	0.58		x	x	x					Difficult to insert, temp was as high as 1.8 C then drops
	484	10.10	939.51	1040.81	70.0	11:44 AM	1.07			x	x					Difficult to insert, temp was as high as 1.25 C then drops
	485	12.00	937.68	1041.29	38.0	11:45 AM	1.09				x					
	486	13.42	936.30	1041.65	52.0	11:46 AM	2.15				x					Soft
	487	14.23	935.52	1041.86	56.0	11:47 AM	2.42			x	x				sticks	Difficult to insert
	488	15.42	934.37	1042.16	0.0	11:49 AM	2.03				x	x			sticks & roots	Water line
	489	8.00	941.54	1040.27	SW	11:50 AM	0.05									Surface water, midstream
46 - 46 W	490	1.00	947.99	1040.74	0.0	11:56 AM	2.18				x	x	x		roots	Water line, stiff
	491	1.90	947.12	1040.96	36.0	11:58 AM	1.81				x	x			sticks & log	Buried logs
	492	4.75	944.36	1041.66	44.0	12:03 PM	0.50		x	x	x					Very difficult to insert, probe depth 14 cm, temp as high as 0.9 C then drops
	493	7.15	942.03	1042.26	60.0	12:05 PM	0.42		x	x	x					Very difficult to insert, probe depth 10 cm, temp as high as 0.73 C then drops
	494	9.00	940.24	1042.71	66.0	12:06 PM	1.10				x					
	495	11.00	938.30	1043.21	50.0	12:07 PM	1.16				x					
	496	12.90	936.46	1043.68	58.0	12:08 PM	2.37			x	x				log	Difficult to insert
	497	13.65	935.73	1043.86	38.0	12:10 PM	2.76			x	x	x				Difficult to insert
	498	14.67	934.74	1044.11	0.0	12:11 PM	2.48		x		x	x			roots	Water line

Transect Location	Meas. No.	Dist. (m)[1]	Coordinates [2] East X (m)	Coordinates [2] North Y (m)	Water depth (cm)	Time of meas.	Temp °C	Geological description of streambed deposits[3] Bo	Co	Gr	Sa	Si	Cl	Pe	Other	Comments[4]
	499	8.30	940.92	1042.54	SW	12:12 PM	0.08									Surface water, midstream
48 -48 W	500	1.30	947.79	1042.92	0.0											Water line, no reading, underneath tree roots
	501	1.68	947.42	1043.01	25.0	12:24 PM	2.37				x	x	x		sticks	Stiff
	502	2.50	946.63	1043.22	53.0	12:25 PM	1.98				x	x				Stiff
	503	4.06	945.12	1043.60	58.0	12:27 PM	0.96		x	x	x					Difficult to insert, probe depth is 16 cm, Temp as high as 1.1 C then drops
	504	6.00	943.24	1044.08	64.0	12:29 PM	1.06			x	x					Okay insert, good temp reading
	505	8.00	941.30	1044.57	59.0	12:30 PM	0.89			x	x					On stone
	506	10.00	939.36	1045.07	54.0	12:31 PM	0.82				x					Easy
	507	11.90	937.52	1045.54	80.0	12:32 PM	1.46		x	x	x					East edge of concrete slab, difficult to insert
	508	13.58	935.89	1045.95	38.0	12:35 PM	2.77			x	x	x				West edge of concrete slab
	509	14.52	934.98	1046.19	0.0	12:36 PM	2.42				x	x	x		roots	Water line
	510	7.75	941.54	1044.51	SW	12:38 PM	0.07									Surface water, midstream
50 - 50 W	511	1.32	947.94	1044.87	0.0	12:43 PM	1.35				x	x	x		sticks	Water line, stiff
	512	2.46	946.84	1045.15	36.0	12:44 PM	1.74				x	x			logs	Between buried logs
	513	3.50	945.83	1045.41	59.0	12:46 PM	1.21		x		x	x			sticks	Buried sticks, temp as high as 1.47 C then drops
	514	5.05	944.33	1045.80	72.0	12:47 PM	1.03		x	x	x					Difficult to insert,temp as high as 1.30 C then drops
	515	7.05	942.40	1046.30	66.0	12:49 PM	0.88			x	x					Difficult to insert,temp as high as 1.53 C then drops
	516	8.80	940.70	1046.74	61.0	12:50 PM	0.84				x					
	517	10.73	938.83	1047.22	77.0	12:52 PM	1.13		x	x	x					Difficult to insert, break ice to make reading
	518	12.35	937.27	1047.63	54.0	12:53 PM	2.30			x	x	x				Stiff
	519	13.92	935.75	1048.02	0.0	12:54 PM	2.87				x	x	x		roots & sticks	Water line, stiff
	520	7.50	941.96	1046.41	SW	12:56 PM	0.09									Surface water
52 - 52 W	521	1.44	948.05	1046.88	0.0	1:53 PM	1.22				x	x	x		sticks	Water line, stiff

Transect Location	Meas. No.	Dist. (m)[1]	Coordinates [2] East X (m)	North Y (m)	Water depth (cm)	Time of meas.	Temp °C	Geological description of streambed deposits[3] Bo	Co	Gr	Sa	Si	Cl	Pe	Other	Comments[4]
	522	2.57	946.95	1047.17	45.0	1:55 PM	1.67				x	x			sticks & log	Temp as high as 1.9 C then drops, stiff
	523	3.95	945.62	1047.53	60.0	1:56 PM	1.07			x	x					
	524	6.26	943.39	1048.12	71.0	1:57 PM	0.89		x	x	x					Difficult to insert
	525	8.00	941.70	1048.56	73.0	1:58 PM	0.92				x					
	526	10.11	939.66	1049.10	87.0	2:00 PM	0.84		x	x	x					Difficult to insert, probe depth 16 cm, temp as high as 1.4 C then drops
	527	11.95	937.89	1049.58	37.0	2:02 PM	1.43		x	x	x					Very difficult to insert
	528	12.82	937.05	1049.80	0.0	2:05 PM	1.24			x	x	x			roots	Water line, piece of concrete nearby
	529	7.50	942.19	1048.44	SW	2:06 PM	0.08									Surface water
54 - 54 W	530	0.95	948.49	1048.86	0.0											Water line, unable to measure, under a tree trunk
	531	1.20	948.25	1048.92	21.0	2:22 PM	1.52				x	x				Soft, stiff
	532	2.30	947.18	1049.20	39.0	2:23 PM	1.47				x	x				Soft
	533	3.40	946.12	1049.48	59.0	2:25 PM	1.34			x	x					Difficult to insert, probe depth 15 cm, temp as high as 1.8 C then drops
	534	5.03	944.54	1049.89	72.0	2:26 PM	0.77			x	x					Difficult to insert, temp as high as 1.5 C then drops
	535	7.00	942.64	1050.40	78.0	2:27 PM	0.94				x					Easy
	536	8.85	940.85	1050.87	101.0	2:28 PM	1.18			x	x					Difficult to insert
	537	10.91	938.86	1051.39	47.0	2:30 PM	0.67			x	x				sticks	Very difficult to insert, probe depth 14 cm, temp as high as 1.4 C then drops
	538	12.72	937.10	1051.85	0.0	2:31 PM	2.36			x	x	x	x		roots	Water line
	539	7.00	942.64	1050.40	SW	2:33 PM	0.09									Surface water
56 - 56 W	540	1.46	949.13	1050.74	0.0	2:37 PM	1.47				x	x	x			Water line, soft and stiff
	541	2.50	948.12	1051.01	32.0	2:38 PM	1.57				x	x				Soft
	542	3.95	946.72	1051.38	62.0	2:39 PM	1.54			x	x					Difficult to insert, temp as high as 2.2 C then drops

Transect Location	Meas. No.	Dist. (m)(1)	Coordinates (2)		Water depth (cm)	Time of meas.	Temp °C	Geological description of streambed deposits(3)								Comments(4)
			East X (m)	North Y (m)				Bo	Co	Gr	Sa	Si	Cl	Pe	Other	
	543	5.92	944.82	1051.88	73.0	2:40 PM	0.76		x	x	x					Difficult to insert, temp as high as 1.8 C then drops
	544	8.00	942.81	1052.42	101.0	2:41 PM	1.00			x	x					Difficult to insert, in deepest part of channel
	545	10.35	940.53	1053.02	77.0	2:43 PM	1.12			x	x				wood	Difficult to insert
	546	12.25	938.70	1053.51	38.0	2:45 PM	1.56		x	x	x					Difficult to insert, temp as high as 2.4 C then drops
	547	13.75	937.25	1053.89	0.0	2:46 PM	2.63			x	x	x	x		roots	Water line
	548	7.50	943.29	1052.29	SW	2:47 PM	0.10									Surface water

Notes:

Measurements made with Barnant Thermometer and YSI 418 probe at depth of 19.5 cm in the streambed by Brewster Conant and Bob Gunn

[1] Distance is along the transect line measured from the east stake toward the west stake

[2] Coordinates are relative to an arbitrary datum with 1000, 1000 m located at gate valve near the NW corner of King and Water St.

[3] Geological description has following abbreviations and "x" in the column means it is present in deposits

Bo = Boulders
Co = Cobbles
Gr = Gravel
Sa = Sand
Si = Silt
Cl = Clay
Pe = Peat
Other = other items observed such as sticks, logs, and roots

[4] Several comments include whether the location was sunny or shaded

APPENDIX I

WATER QUALITY RESULTS

WATERLOO PROFILER AND MINI-PROFILER SAMPLING SUMMARY

WATERLOO PROFILER RESULTS (On Land)

- Water quality results at AP40, AP41, AP42, and AP43 (July 1996)
- Water quality results at AP44, AP45, AP46, AP47 and AP48 (July 1996)
- Water quality results at AP49, AP50, and AP51 (July-August 1996)
- Water quality results at AP52 (August 1996)
- Water quality results AP96-1 to AP96-3 (June 1996)
- Water quality results AP96-4 to AP96-7 (June 1996)
- Water quality results AP96-8 to AP96-10 (August 1996)

WATERLOO PROFILER RESULTS (in Pine River)

- Water quality results at PRP1, PRP2, and PRP3 (August 1996)
- Water quality results at PRP4 (August 1996)
- VOC water quality at PRP5 and PRP6 (October 1996)
- VOC water quality at PRP7 and PRP8 and piezometers DP1, DP7, DP8, DP9, and SP1 (November 1996)
- Inorganic water quality at PRP7 and PRP8 and piezometers DP1, DP7, DP8, DP9, and SP1 (November 1996)
- Field Parameters at PRP7 and PRP8 and piezometers DP1, DP7, DP8, DP9, and SP1 (November 1996)

MINI-PROFILER RESULTS

- VOC water quality at mini-profiler locations PRP7R to PRP13 (August 1997)
- Inorganic water quality at mini-profiler locations PRP7R to PRP13 (August 1997)
- Field parameters at mini-profiler locations PRP7R to PRP13 (August 1997)
- VOC water quality at mini-profiler locations PRP14 to PRP16 (October 1997)
- Inorganics at mini-profiler locations PRP14 to PRP16 (October 1997)
- Field parameters at mini-profiler locations PRP14 to PRP16 (October 1997)
- VOC water quality at mini-profiler locations PRP17 (June 1998)

PLAN-VIEW MAPPING OF STREAMBED WITH MINI-PROFILER (August 4-12, 1998)

- VOC water quality at mini-profiler locations in streambed at a depth of 0.3 m and surface water sampling (August 1998)
- Inorganic water quality and field parameters at mini-profiler locations in streambed at a depth of 0.3 m and surface water sampling (August 1998)

BML and MLS SAMPING RESULTS

- VOCs at driveable multilevel samplers in streambed and BML samplers MLS1, MLS3, MLS4,MLS7, MLS8, MLS17, MLS18 (November 1998)
- Inorganics at driveable multilevel samplers in streambed and BML samplers MLS1, MLS3, MLS4,MLS7, MLS8, MLS17, MLS18 (November 1998)
- Inorganic water quality at driveable multilevel samplers in streambed and BML samplers on land (March 1999)
- Chloride concentrations at driveable multilevel samplers in streambed and BML samplers on land (March 1999)

WATERLOO PROFILER AND MINI-PROFILER SAMPLING SUMMARY

Location[1]	Depth interval sampled (m)	Number of water samples versus attempts[2]	Maximum PCE conc. in profile (µg/L)	Analyses Performed on Water Samples	Date of Profiling	Comments[5]
AP40	1.5 - 10.0	12/18	8706.9	E	07/17/96	Stainless steel sampling tube broke at 7.0 m bgs
AP40b	7.0 - 11.5	10/10	3724.5	E	07/24/96	Continuation of AP40 located 38 cm away
AP41	1.5 - 10.0	14/18	1821.9	E	07/17/96	
AP42	1.5 - 10.0	11/18	5256.0	E	07/18/96	
AP43	1.5 - 10.0	10/18	6643.4	E	07/18/96	
AP44	1.5 - 10.0	11/18	5887.8	E	07/22/96	
AP45	1.5 - 12.0	16/22	1478.5	E	07/23/96	
AP46	1.5 - 10.0	13/17	2625.6	E	07/24/96	No sample at 7m, may have missed peak conc.
AP47	1.5 - 10.0	13/18	2.6	E	07/25/96	
AP48	1.5 - 10.0	14/18	ND	E	07/25/96	
AP49	1.5 - 10.0	10/18	ND	E	07/31/96	3 samples froze and broke before analyzed
AP50	1.5 - 10.0	13/18	ND	E	08/01/96	
AP51	1.5 - 10.0	12/18	ND	E	08/01/96	
AP52	1.5 - 9.0	16/22	84.5	E, P, F	08/28/96	
AP53	3.05 - 10.06	7/10	1163.0	E, P, F, IN, FP	11/20/97	
AP54	4.88 - 12.20	10/10	7304.7	E, P, F, IN, FP	12/18/97	Two samples froze and broke before analyzed
AP55	4.88 - 9.14	4/5	108.9	E, P, F, IN, FP	12/19/97	Too shallow, didn't reach peak conc. zone
AP96-1	3.05 - 6.10	11/11	3.0	E	06/04/96	
AP96-2	3.05 - 6.10	9/11	3.1	E	06/04/96	
AP96-3	3.35 - 6.10	8/9	1.3	E	06/04/96	
AP96-4	4.0 - 11.0	10/14	1068.6	E	06/26/96	
AP96-5	5.0 - 11.0	12/12	25.0	E	06/26/96	Tube snapped some time before pulled out
AP96-6	5.0 - 12.0	12/16	>10000[3]	E	06/27/96	
AP96-7	6.5 - 12.0	12/12	>10000[4]	E	06/27/96	Lost tip and pipe down hole as pulling out
AP96-8	6.5 - 10.5	9/9	11.1	E	08/15/96	
AP96-9	6.5 - 10.5	9/9	1.0	E	08/15/96	
AP96-10	5.0 - 10.5	9/12	0.9	E	08/16/96	
PRP1	0.25 - 8.50	21/28	1961.8	E, P, F	08/07/96	
PRP2	0.10 - 7.00	16/24	1010.0	E, P, F	08/08/96	
PRP3	0.10 - 8.00	18/22	1939.4	E, P, F	08/09/96	
PRP4	0.1 - 6.5	13/20	559.7	E, P, F	08/28/96	
PRP5	0.1 - 6.0	18/21	2794.6	E, P, F	10/07/96	
PRP6	0.1 - 5.0	12/18	7.4	E, P, F, FP	10/09/96	
PRP7	0.15 - 3.50	6/16	3808.4	E, P, F, IN, FP	11/07/96	

Location[1]	Depth interval sampled (m)	Number of water samples versus attempts[2]	Maximum PCE conc. in profile (µg/L)	Analyses Performed on Water Samples	Date of Profiling	Comments[5]
PRP7R	0.15 - 2.05	5/13	5001.2	E, P, F, IN, FP	08/12/97	mini-profiler
PRP8	0.15 - 0.60	2/4	340.5	E, P, F, IN, FP	11/11/96	Water froze in line before finished sampling
PRP8R	0.15 - 2.10	8/14	3639.3	E, P, F, IN, FP	08/13/97	mini-profiler
PRP9	0.15 - 1.50	8/9	30.3	E, P, F, IN, FP	08/13/97	mini-profiler
PRP9R	0.75 - 1.63	3/3	103.1	E, P, F, IN, FP	08/14/97	mini-profiler
PRP10	0.15 - 1.35	8/13	24.1	E, P, F, IN, FP	08/14/97	mini-profiler
PRP11	0.15 - 1.65	3/4	ND	E, P, F, IN, FP	08/14/97	mini-profiler
PRP12	0.17 - 1.72	2/8	841.4	E, P, F, IN, FP	08/15/97	mini-profiler
PRP13	0.15 - 1.90	5/9	214.3	E, P, F, IN, FP	08/15/97	Both mini and Waterloo profilers used
PRP14	0.15 - 1.80	5/13	296.1	E, P, F, IN, FP	10/29/97	mini-profiler
PRP15	0.15 - 1.65	9/9	1438.1	E, P, F, IN, FP	10/30/97	mini-profiler
PRP16	0.15 - 2.00	9/9	6.9	E, P, F, IN, FP	10/31/97	mini-profiler
PRP17	0.33 - 1.50	4/5	572.1	E, P	06/24/98	mini-profiler

Notes:

[1] "AP" prefix means profile performed on land, "PRP" prefix means profile performed in Pine River

[2] Number of water samples that could be pumped versus the total number of depths where an attempt was made to collect a sample

[3] Exceeded calibration range, raw reading was 8868 µg/L, but actual PCE would have exceeded 10,000 µg/L based on other

[4] Exceeded calibration range, raw reading was 9313 µg/L, but actual PCE would have exceeded 10,000 µg/L based on other

[5] Samples collected with the Waterloo Groundwater Profiler unless specified otherwise

ND = PCE not detected

E = Analyses for PCE and TCE using the electron capture detector (ECD)

P = Analyses for cDCE, tDCE, 1,1-DCE, and VC using the photoionization detector (PID)

F = Analyses for ethene and ethane using the flame ionization detector (FID)

IN = Inorganic analyses performed by Philip Analytical Services

FP = Field parameters measured,which may include pH, Eh,Specific conductance, DO, and sulfide

WATER QUALITY RESULTS AT WATERLOO PROFILING LOCATIONS AP40, AP41, AP42, AND AP43 (July 17, 18, and 24, 1996)

Location	Depth m	Elevation m	Elevation amsl m	PCE µg/L	TCE µg/L	Comments
AP40	1.5	96.584	184.764	ND	ND	
	2.0	96.084	184.264	UTP	UTP	
	2.5	95.584	183.764	UTP	UTP	
	3.0	95.084	183.264	UTP	UTP	
	3.5	94.584	182.764	UTP	UTP	
	4.0	94.084	182.264	ND	ND	
	4.5	93.584	181.764	UTP	UTP	
	5.0	93.084	181.264	UTP	UTP	
	5.5	92.584	180.764	221.1	1.7	
	6.0	92.084	180.264	2208.1	2.5	
	6.5	91.584	179.764	8706.9	4.8	
	7.0	91.061	179.241	3724.5	4.0	AP40b results
	7.5	90.561	178.741	31.2	ND	AP40b results
	8.0	90.061	178.241	3.8	ND	AP40b results
	8.5	89.561	177.741	1.2	ND	AP40b results
	9.0	89.061	177.241	1.8	ND	AP40b results
	9.5	88.561	176.741	0.8	ND	AP40b results
	10.0	88.061	176.241	ND	ND	AP40b results
	10.5	87.561	175.741	ND	ND	AP40b results
	11.0	87.061	175.241	ND	ND	AP40b results
	11.5	86.561	174.741	ND	ND	AP40b results, bottom of profile
AP41	1.5	96.623	184.803	UTP	UTP	
	2.0	96.123	184.303	UTP	UTP	
	2.5	95.623	183.803	3.5	ND	
	3.0	95.123	183.303	ND	ND	
	3.5	94.623	182.803	UTP	UTP	
	4.0	94.123	182.303	2.3	ND	
	4.5	93.623	181.803	2.8	ND	
	5.0	93.123	181.303	UTP	UTP	
	5.5	92.623	180.803	1.3	ND	
	6.0	92.123	180.303	174.3	ND	
	6.5	91.623	179.803	1071.5	1.5	
	7.0	91.123	179.303	1821.9	1.2	
	7.5	90.623	178.803	19.5	ND	
	8.0	90.123	178.303	1.3	ND	
	8.5	89.623	177.803	ND	ND	
	9.0	89.123	177.303	1.3	ND	
	9.5	88.623	176.803	ND	ND	
	10.0	88.123	176.303	1.8	ND	Bottom of profile
AP42	1.5	96.721	184.901	UTP	UTP	
	2.0	96.221	184.401	UTP	UTP	
	2.5	95.721	183.901	0.9	ND	
	3.0	95.221	183.401	UTP	UTP	
	3.5	94.721	182.901	UTP	UTP	
	4.0	94.221	182.401	UTP	UTP	

Location	Depth m	Elevation m	Elevation amsl m	PCE µg/L	TCE µg/L	Comments
	4.5	93.721	181.901	UTP	UTP	
	5.0	93.221	181.401	UTP	UTP	
	5.5	92.721	180.901	395.7	1.8	
	6.0	92.221	180.401	934.7	3.3	
	6.5	91.721	179.901	1529.3	1.5	
	7.0	91.221	179.401	5256.0	4.4	
	7.5	90.721	178.901	44.4	ND	
	8.0	90.221	178.401	1.9	ND	
	8.5	89.721	177.901	1.0	ND	
	9.0	89.221	177.401	2.0	ND	
	9.5	88.721	176.901	1.0	ND	
	10.0	88.221	176.401	ND	ND	Bottom of profile
AP43	1.5	96.780	184.960	UTP	UTP	
	2.0	96.280	184.460	UTP	UTP	
	2.5	95.780	183.960	UTP	UTP	
	3.0	95.280	183.460	UTP	UTP	
	3.5	94.780	182.960	UTP	UTP	
	4.0	94.280	182.460	UTP	UTP	
	4.5	93.780	181.960	UTP	UTP	
	5.0	93.280	181.460	13.0	4.2	
	5.5	92.780	180.960	UTP	UTP	
	6.0	92.280	180.460	4451.5	5.1	
	6.5	91.780	179.960	6643.4	4.0	
	7.0	91.280	179.460	600.7	ND	
	7.5	90.780	178.960	127.2	ND	
	8.0	90.280	178.460	37.7	ND	
	8.5	89.780	177.960	2.9	ND	
	9.0	89.280	177.460	2.2	ND	
	9.0	89.280	177.460	6.1	ND	Field duplicate
	9.5	88.780	176.960	1.9	ND	
	10.0	88.280	176.460	1.6	ND	Bottom of profile
Seep at bridge	NA	NA	NA	49.2	ND	Very silty sample
Distilled Water	NA	NA	NA	ND	ND	
Equipt blank 7/18	NA	NA	NA	ND	ND	
Equipt blank 7/17	NA	NA	NA	3.1	ND	
Blank	NA	NA	NA	ND	ND	
Blank	NA	NA	NA	ND	ND	
Blank	NA	NA	NA	ND	ND	
Blank	NA	NA	NA	ND	ND	
Blank	NA	NA	NA	ND	ND	
Detection Limit				0.7	0.9	

Notes:

AP40 and AP41 performed on July 17, AP42 and AP43 on July 18, and AP40B on July 24

ND = Not detected

UTP = unable to pump a sample from that depth

NS = depth interval not sampled

Initial AP40 Results were replaced by AP40 b results 7.0 to 11.5 m (tube broke on AP40)

Samples rerun at x4 dilution AP40 (6.0, 6.5, 7.0), AP43 (6.0,6.5), and
AP42 (7.0) and AP40 b (7.0)

WATER QUALITY RESULTS AT WATERLOO PROFILING LOCATIONS AP44, AP45, AP46, AP47, and AP48 (July 22 to 25, 1996)

Location	Depth	Elevation	Elevation amsl m	PCE µg/L	TCE µg/L	Comments
AP44	1.5	96.573	184.753	UTP	UTP	
	2.0	96.073	184.253	ND	ND	
	2.5	95.573	183.753	UTP	UTP	
	3.0	95.073	183.253	UTP	UTP	
	3.5	94.573	182.753	UTP	UTP	
	4.0	94.073	182.253	UTP	UTP	
	4.5	93.573	181.753	UTP	UTP	
	5.0	93.073	181.253	UTP	UTP	
	5.5	92.573	180.753	112.1	ND	
	6.0	92.073	180.253	523.5	1.2	
	6.5	91.573	179.753	5997.6	3.0	
	7.0	91.073	179.253	642.2	2.6	
	7.5	90.573	178.753	10.8	ND	
	8.0	90.073	178.253	2.6	ND	
	8.5	89.573	177.753	2.0	ND	
	9.0	89.073	177.253	1.1	ND	
	9.5	88.573	176.753	0.8	ND	
	10.0	88.073	176.253	ND	ND	
AP45	1.5	96.623	184.803	UTP	UTP	
	2.0	96.123	184.303	UTP	UTP	
	2.5	95.623	183.803	UTP	UTP	
	3.0	95.123	183.303	3.7	ND	
	3.5	94.623	182.803	2.0	ND	
	4.0	94.123	182.303	UTP	UTP	
	4.5	93.623	181.803	UTP	UTP	
	5.0	93.123	181.303	UTP	UTP	
	5.5	92.623	180.803	8.2	ND	
	6.0	92.123	180.303	101.5	1.4	
	6.5	91.623	179.803	544.2	1.3	
	7.0	91.123	179.303	1094.4	1.6	
	7.5	90.623	178.803	1478.3	2.4	
	8.0	90.123	178.303	375.7	1.0	
	8.5	89.623	177.803	130.3	ND	
	9.0	89.123	177.303	36.4	ND	
	9.5	88.623	176.803	0.7	ND	
	10.0	88.123	176.303	ND	ND	
	10.5	87.623	175.803	ND	ND	
	11.0	87.123	175.303	ND	ND	
	11.5	86.623	174.803	ND	ND	
	12.0	86.123	174.303	4.5	ND	
AP46	1.5	96.408	184.588	UTP	UTP	
	2.0	95.908	184.088	UTP	UTP	
	2.5	95.408	183.588	1.0	ND	
	3.0	94.908	183.088	11.1	3.6	
	3.5	94.408	182.588	UTP	UTP	
	4.0	93.908	182.088	UTP	UTP	

Location	Depth	Elevation	Elevation amsl m	PCE µg/L	TCE µg/L	Comments
	4.5	93.408	181.588	36.8	3.6	
	5.0	92.908	181.088	29.7	2.9	
	5.5	92.408	180.588	540.4	3.7	
	6.0	91.908	180.088	2017.1	3.1	
	6.5	91.408	179.588	2625.4	2.6	
	7.0	90.908	179.088	NS	NS	Not sampled
	7.5	90.408	178.588	616.0	ND	
	8.0	89.908	178.088	267.9	ND	
	8.5	89.408	177.588	6.9	ND	
	9.0	88.908	177.088	2.8	ND	
	9.5	88.408	176.588	1.0	ND	
	10.0	87.908	176.088	ND	ND	
AP47	1.5	96.381	184.561	UTP	UTP	
	2.0	95.881	184.061	ND	ND	
	2.5	95.381	183.561	2.4	ND	
	3.0	94.881	183.061	UTP	UTP	
	3.5	94.381	182.561	UTP	UTP	
	4.0	93.881	182.061	UTP	UTP	
	4.5	93.381	181.561	UTP	UTP	
	5.0	92.881	181.061	ND	ND	
	5.5	92.381	180.561	ND	ND	
	6.0	91.881	180.061	ND	ND	
	6.5	91.381	179.561	ND	ND	
	7.0	90.881	179.061	ND	ND	
	7.5	90.381	178.561	ND	ND	
	8.0	89.881	178.061	ND	ND	
	8.5	89.381	177.561	ND	ND	
	9.0	88.881	177.061	ND	ND	
	9.5	88.381	176.561	ND	ND	
	10.0	87.881	176.061	ND	ND	
AP48	1.5	97.977	186.157	UTP	UTP	
	2.0	97.977	186.157	ND	ND	
	2.5	97.977	186.157	ND	ND	
	3.0	97.977	186.157	ND	ND	
	3.5	97.977	186.157	UTP	UTP	
	4.0	97.977	186.157	UTP	UTP	
	4.5	97.977	186.157	UTP	UTP	
	5.0	97.977	186.157	ND	4.8	
	5.5	97.977	186.157	ND	2.1	
	6.0	97.977	186.157	ND	ND	
	6.5	97.977	186.157	ND	ND	
	7.0	97.977	186.157	ND	ND	
	7.5	97.977	186.157	ND	ND	
	8.0	97.977	186.157	ND	ND	
	8.5	97.977	186.157	ND	ND	
	9.0	97.977	186.157	ND	ND	
	9.5	97.977	186.157	ND	ND	
	10.0	97.977	186.157	ND	ND	
Equipt blank 1	NA	NA	NA	0.9	ND	
Equipt blank 2	NA	NA	NA	ND	ND	

Location	Depth	Elevation	Elevation amsl m	PCE µg/L	TCE µg/L	Comments
Blank	NA	NA	NA	ND	ND	
Blank	NA	NA	NA	ND	ND	
Blank	NA	NA	NA	ND	ND	
Lab Needle blank	NA	NA	NA	2.0	ND	
Blank	NA	NA	NA	ND	ND	
Blank	NA	NA	NA	ND	ND	
Blank	NA	NA	NA	ND	ND	
Blank	NA	NA	NA	ND	ND	
Detection Limits				0.7	0.9	

Notes:

AP44 performed on 7/22, AP45 on 7/23, AP46 on 7/24, and AP47 and AP48 on 7/25
ND = Not detected
UTP = unable to pump sample
NS = depth was not sampled
Samples AP44 (6.5), AP46 (6.0,6.5) rerun at x4 dilution

WATER QUALITY RESULTS AT WATERLOO PROFILING LOCATIONS AP49, AP50, and AP51 (July 31 to August 1, 1996)

Location	Depth	Elevation m	Elevation amsl m	PCE µg/L	TCE µg/L	Comments
AP49	1.5	96.303	184.483	UTP	UTP	
	2.0	95.803	183.983	UTP	UTP	
	2.5	95.303	183.483	ND	ND	
	3.0	94.803	182.983	UTP	UTP	
	3.5	94.303	182.483	UTP	UTP	
	4.0	93.803	181.983	UTP	UTP	
	4.5	93.303	181.483	UTP	UTP	
	5.0	92.803	180.983	UTP	UTP	
	5.5	92.303	180.483	DES	DES	
	6.0	91.803	179.983	UTP	UTP	
	6.5	91.303	179.483	ND	ND	
	7.0	90.803	178.983	DES	DES	
	7.5	90.303	178.483	ND	ND	
	7.5	90.303	178.483	ND	ND	Duplicate
	8.0	89.803	177.983	ND	ND	
	8.5	89.303	177.483	ND	ND	
	9.0	88.803	176.983	ND	ND	
	9.5	88.303	176.483	DES	DES	
	10.0	87.803	175.983	ND	ND	
AP50	1.5	96.659	184.839	UTP	UTP	
	2.0	96.159	184.339	ND	0.4	
	2.5	95.659	183.839	ND	ND	
	3.0	95.159	183.339	ND	ND	
	3.5	94.659	182.839	UTP	UTP	
	4.0	94.159	182.339	UTP	UTP	
	4.5	93.659	181.839	UTP	UTP	
	5.0	93.159	181.339	ND	ND	
	5.5	92.659	180.839	ND	ND	
	6.0	92.159	180.339	ND	ND	
	6.5	91.659	179.839	UTP	UTP	See notes
	7.0	91.159	179.339	ND	ND	
	7.5	90.659	178.839	ND	ND	
	7.5	90.659	178.839	ND	ND	Duplicate
	8.0	90.159	178.339	ND	ND	
	8.5	89.659	177.839	ND	ND	
	9.0	89.159	177.339	ND	ND	
	9.5	88.659	176.839	ND	ND	
	10.0	88.159	176.339	ND	ND	
AP51	1.5	96.881	185.061	ND	ND	
	2.0	96.381	184.561	UTP	UTP	
	2.5	95.881	184.061	UTP	UTP	
	3.0	95.381	183.561	ND	ND	
	3.5	94.881	183.061	ND	ND	
	4.0	94.381	182.561	UTP	UTP	
	4.5	93.881	182.061	UTP	UTP	
	5.0	93.381	181.561	UTP	UTP	

Location	Depth	Elevation m	Elevation amsl m	PCE µg/L	TCE µg/L	Comments
	5.5	92.881	181.061	ND	ND	
	6.0	92.381	180.561	ND	ND	
	6.5	91.881	180.061	UTP	UTP	
	7.0	91.381	179.561	ND	ND	
	7.5	90.881	179.061	ND	ND	
	8.0	90.381	178.561	ND	ND	
	8.5	89.881	178.061	ND	ND	
	9.0	89.381	177.561	ND	ND	
	9.5	88.881	177.061	ND	ND	
	10.0	88.381	176.561	ND	ND	
Trip blank	NA	NA	NA	ND	ND	
Equipt blank	NA	NA	NA	ND	ND	
Blank	NA	NA	NA	ND	ND	
Blank	NA	NA	NA	ND	ND	
Blank	NA	NA	NA	ND	ND	
Detection Limit				0.7	0.9	

Notes:

AP49 performed on July 31 and AP50 and AP51 on August 1
ND = Not detected
UTP = unable to pump a sample
DES = sample destroyed before anayzed - froze and broke
Not sure if AP50 6.5 was collected or analyzed, not in chromatograms

WATER QUALITY RESULTS AT WATERLOO PROFILING LOCATIONS

AP52 (August 28, 1996)

Location	Depth m	Elevation amsl m	PCE µg/L	TCE µg/L	cDCE µg/L	11DCE µg/L	tDCE µg/L	VC µg/L	Methane µg/L	Ethene µg/L	Ethane µg/L	Total VOCs µg/L	Total VOCs as PCE µg/L	Comments
AP52	1.50	184.706	UTP	UTP	UTP	UTP	UTP	UTP	UTP	UTP	UTP	NA	NA	
	2.00	184.206	UTP	UTP	UTP	UTP	UTP	UTP	UTP	UTP	UTP	NA	NA	
	2.50	183.706	ND	ND	ND	ND	ND	ND	59.5	ND	ND	0.0	0.0	
	3.00	183.206	ND	ND	ND	ND	ND	ND	179.7	ND	ND	0.0	0.0	Methane Exceeds calibration
	3.50	182.706	ND	ND	ND	ND	ND	ND	33.0	ND	ND	0.0	0.0	
	3.75	182.456	UTP	UTP	UTP	UTP	UTP	UTP	UTP	UTP	UTP	NA	NA	
	4.00	182.206	UTP	UTP	UTP	UTP	UTP	UTP	UTP	UTP	UTP	NA	NA	
	4.25	181.956	UTP	UTP	UTP	UTP	UTP	UTP	UTP	UTP	UTP	NA	NA	
	4.50	181.706	UTP	UTP	UTP	UTP	UTP	UTP	UTP	UTP	UTP	NA	NA	
	5.00	181.206	ND	1.5	ND	ND	ND	ND	1.0	ND	ND	1.5	1.9	
	5.25	180.956	ND	4.2	ND	ND	ND	ND	1.6	ND	0.6	4.8	8.6	
	5.50	180.706	ND	2.5	ND	ND	ND	ND	2.5	ND	ND	2.5	3.2	
	5.75	180.456	ND	1.8	ND	ND	ND	ND	2.5	ND	ND	1.8	2.2	
	6.00	180.206	ND	1.2	ND	ND	ND	ND	2.6	ND	ND	1.2	1.5	
	6.25	179.956	ND	4.4	ND	ND	ND	ND	5.0	ND	ND	4.4	5.5	
	6.25	179.956	NA	NA	ND	ND	ND	ND	8.1	ND	ND	Inc	Inc	Lab Duplicate
	6.50	179.706	0.7	ND	ND	ND	ND	ND	1.6	ND	ND	0.7	0.7	
	6.75	179.456	84.5	ND	ND	ND	ND	ND	ND	ND	ND	84.5	84.5	Visually integrate Methane, ethene, and ethane
	7.00	179.206	1.3	ND	ND	ND	ND	ND	ND	ND	ND	1.3	1.3	Visually integrate Methane, ethene, and ethane
	7.50	178.706	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.0	0.0	
	8.00	178.206	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.0	0.0	
	8.50	177.706	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.0	0.0	
	9.00	177.206	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.0	0.0	

Location	Depth	Elevation amsl m	PCE µg/L	TCE µg/L	cDCE µg/L	11DCE µg/L	tDCE µg/L	VC µg/L	Methane µg/L	Ethene µg/L	Ethane µg/L	Total VOCs µg/L	Total VOCs as PCE µg/L	Comments
AP52 pipe at 6.5 m	NA	NA	ND	ND	ND	ND	ND	ND	NA	NA	NA	Inc	Inc	Sample from inside steel drive pipe at 6.5 m level
Lab Blank A	NA	NA	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.0	0.0	
Lab Blank B	NA	NA	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.0	0.0	
Lab Blank C	NA	NA	ND	ND	ND	ND	ND	ND	0.8	ND	ND	0.0	0.0	
Lab Blank D	NA	NA	ND	ND	NA	NA	NA	NA	NA	NA	NA	Inc	Inc	
Lab Blank E	NA	NA	ND	ND	NA	NA	NA	NA	NA	NA	NA	Inc	Inc	
Detection Limits			0.7	0.9	7.8	3.2	1.9	0.7	0.5	0.5	0.5	NA	NA	

Notes:
Sampled same day as PRP4 and analyzed at same time as PRP4
Total VOCs is a sum of all VOCs for a sample table except methane
Total VOCs as PCE is the molar total of all VOCs (except methane) expressed as equivalent concentrations of PCE in µg/L
ND = Not detected
UTP = unable to pump a sample
NS = depth not sampled
NA = Not applicable or not analyzed
Inc = Totals are incomplete, missing one or more analyses for compounds

WATER QUALITY RESULTS AT WATERLOO PROFILING LOCATIONS
AP96-1 to AP96-3 (June 4, 1996)

Location	Depth	Elevation m	Elevation amsl m	PCE µg/L	TCE µg/L	Comments
AP96-1	3.0	99.69	187.87	ND	ND	
	3.4	99.38	187.56	1.1	1.0	
	3.7	99.08	187.26	ND	ND	
	4.0	98.77	186.95	ND	ND	
	4.3	98.47	186.65	ND	ND	
	4.6	98.16	186.34	0.8	ND	
	4.9	97.86	186.04	2.8	2.7	
	5.2	97.55	185.73	ND	ND	
	5.5	97.25	185.43	ND	ND	
	5.8	96.94	185.12	ND	ND	
	6.1	96.64	184.82	ND	ND	
AP96-2	3.0	99.69	187.87	2.9	ND	
	3.4	99.38	187.56	UTP	UTP	
	3.7	99.08	187.26	ND	ND	
	4.0	98.77	186.95	ND	ND	
	4.3	98.47	186.65	ND	ND	
	4.6	98.16	186.34	UTP	UTP	
	4.9	97.86	186.04	ND	ND	
	5.2	97.55	185.73	ND	ND	
	5.5	97.25	185.43	ND	ND	
	5.8	96.94	185.12	ND	ND	
	6.1	96.64	184.82	ND	ND	
AP96-3	3.4	99.38	187.56	UTP	UTP	
	3.7	99.08	187.26	1.0	ND	
	4.0	98.77	186.95	ND	ND	
	4.3	98.47	186.65	ND	ND	
	4.9	97.86	186.04	ND	ND	
	5.2	97.55	185.73	ND	ND	
	5.5	97.25	185.43	ND	ND	
	5.8	96.94	185.12	ND	ND	
	6.1	96.64	184.82	ND	ND	
Blank	NA	NA	NA	ND	ND	
Blank	NA	NA	NA	ND	ND	
Detection Limit				0.9	0.7	

Notes:

AP96-1 to 3 were performed on June 4, 1996, by Jim Roy and Tina Jung
Assume ground elevation for all 3 are equal to elevation of TOC for piezometer APZ1
ND = Not detected
UTP = unable to pump a sample
On June 5, attempted AP96-4 (depth of 14-34 ft) across the street, but no samples
AP96-2 done after the failed AP96-4, so possible carry over into first sample at 3 m?

WATER QUALITY RESULTS AT WATERLOO PROFILING LOCATIONS AP96-4 to AP96-7 (June 26 to 27, 1996)

Location	Depth	Elevation m	Elevation amsl m	PCE μg/L	TCE μg/L	Comments
AP96-4	4.0	97.051	185.231	UTP	UTP	
	4.5	96.551	184.731	UTP	UTP	
	5.0	96.051	184.231	UTP	UTP	
	5.5	95.551	183.731	UTP	UTP	
	6.5	94.551	182.731	574.7	1.2	
	7.0	94.051	182.231	1068.6	2.2	
	7.5	93.551	181.731	228.1	ND	
	8.0	93.051	181.231	14.4	ND	
	8.5	92.551	180.731	2.2	ND	
	9.0	92.051	180.231	1.1	ND	
	9.5	91.551	179.731	0.8	ND	
	10.0	91.051	179.231	0.8	ND	
	10.5	90.551	178.731	ND	ND	
	11.0	90.051	178.231	ND	ND	
AP96-5	5.0	97.384	185.564	0.9	1.4	
	6.0	96.384	184.564	5.3	2.3	
	6.5	95.884	184.064	25.0	3.152	
	7.0	95.384	183.564	20.0	2.898	
	7.5	94.884	183.064	18.9	2.8	
	8.0	94.384	182.564	15.0	2.5	
	8.5	93.884	182.064	13.0	2.4	
	9.0	93.384	181.564	11.2	2.1	
	9.5	92.884	181.064	9.8	1.8	
	10.0	92.384	180.564	17.1	2.3	
	10.5	91.884	180.064	6.1	1.5	
	11.0	91.384	179.564	6.0	1.4	
AP96-6	5.0	96.613	184.793	UTP	UTP	
	5.5	96.113	184.293	UTP	UTP	
	6.0	95.613	183.793	UTP	UTP	
	6.27	95.343	183.523	UTP	UTP	
	6.5	95.113	183.293	ND	ND	
	7.0	94.613	182.793	1.2	ND	
	7.5	94.113	182.293	2.4	ND	
	8.0	93.613	181.793	19.8	ND	
	8.5	93.113	181.293	39.3	ND	
	9.0	92.613	180.793	178.3	1.6	
	9.5	92.113	180.293	2071.5	1.7	
	10.0	91.613	179.793	>10000	5.4	Exceeded calibration, raw reading 8868 μg/L
	10.5	91.113	179.293	*6680.1*	4.6	Exceeds calibration
	11.0	90.613	178.793	1095.3	1.1	
	11.5	90.113	178.293	773.9	1.7	
	12.0	89.613	177.793	25.3	ND	

Location	Depth	Elevation m	Elevation amsl m	PCE µg/L	TCE µg/L	Comments
AP96-7	6.5	94.984	183.164	14.1	1.1	
	7.0	94.484	182.664	15.2	0.9	
	7.5	93.984	182.164	17.6	0.9	
	8.0	93.484	181.664	11.7	ND	
	8.5	92.984	181.164	6.5	ND	
	9.0	92.484	180.664	2783.8	2.3	
	9.5	91.984	180.164	>10000	4.2	Exceeded calibration, raw reading 8969 µg/L
	10.0	91.484	179.664	>10000	4.0	Exceeded calibration, raw reading 9313 µg/L
	10.5	90.984	179.164	*2695.7*	1.2	
	11.0	90.484	178.664	*8027.2*	4.6	Exceeds calibration
	11.5	89.984	178.164	*8265.8*	4.0	Exceeds calibration
	12.0	89.484	177.664	84.9	ND	
Trip Blank	NA	NA	NA	ND	ND	
Equipt. Blank	NA	NA	NA	261.4	0.9	Collected after >10000 µg/L at AP96-7 9.5 m
Blank	NA	NA	NA	ND	ND	
Blank	NA	NA	NA	1.5	ND	
Detection Limit				0.9	0.7	

Notes:

AP96-4 to AP96-7 performed on July 26 and 27, 1996 by Jim Roy and Colin Meldrum

AP96-5 when removed pipe found that inside tubing had snapped, not sure when it happened, maybe as took it out

AP96-7 lost some pipe and the tip down the hole as try to pull profiler out

Samples >3000 µg/L of PCE exceeded the calibration range, but were not rerun at a proper dilution (discovered too late). Other samples properly run in the lab at the same time showed actual values should be much higher than the raw -undiluted values

ND = Not detected

UTP = unable to pump a sample

WATER QUALITY RESULTS AT WATERLOO PROFILING LOCATIONS
AP96-8 to AP96-10 (August 15 to 16, 1996)

Location	Depth	Elevation m	Elevation amsl m	PCE µg/L	TCE µg/L	Comments
AP96-8	6.5	94.649	182.829	0.8	ND	
	7.0	94.149	182.329	11.1	ND	
	7.5	93.649	181.829	7.1	ND	
	8.0	93.149	181.329	2.3	1.1	
	8.5	92.649	180.829	0.9	ND	
	8.5	92.649	180.829	ND	1.2	Lab Duplicate
	9.0	92.149	180.329	ND	ND	
	9.5	91.649	179.829	ND	ND	
	10.0	91.149	179.329	ND	ND	
	10.5	90.649	178.829	ND	ND	
AP96-9	6.5	94.827	183.007	ND	ND	
	7.0	94.327	182.507	ND	ND	
	7.0	94.327	182.507	ND	ND	Lab Duplicate
	7.5	93.827	182.007	ND	ND	
	8.0	93.327	181.507	ND	ND	
	8.5	92.827	181.007	ND	ND	
	9.0	92.327	180.507	ND	ND	
	9.5	91.827	180.007	ND	ND	
	10.0	91.327	179.507	ND	ND	
	10.5	90.827	179.007	ND	ND	
AP96-10	5.0	97.346	185.526	ND	ND	
	5.5	96.846	185.026	ND	ND	
	6.0	96.346	184.526	ND	ND	
	6.5	95.846	184.026	ND	ND	
	7.0	95.346	183.526	ND	ND	
	7.5	94.846	183.026	ND	ND	
	8.0	94.346	182.526	ND	ND	
	8.5	93.846	182.026	ND	ND	
	9.0	93.346	181.526	ND	ND	
	9.5	92.846	181.026	UTP	UTP	
	10.0	92.346	180.526	UTP	UTP	
	10.5	91.846	180.026	UTP	UTP	
Trip Blank	NA	NA	NA	ND	ND	
Blank	NA	NA	NA	ND	ND	
Blank	NA	NA	NA	ND	ND	
Detection Limit				0.9	0.7	

Notes:

AP96-8 to AP96-10 performed on August 15 and 16,1996, by Jim Roy and Colin Meldrum

AP96-8 one failed attempt, plugged ports, had gotten hard at 5.7 m (aquitard), so moved over and started a new profile

Line plugged at AP96-10 at 9.5 m, no more samples collected

No equipment blank collected

ND = Not detected

UTP = unable to pump a sample

WATER QUALITY RESULTS AT WATERLOO PROFILING LOCATIONS
PRP1, PRP2, and PRP3 (August 7, 8, and 9, 1996)

Location	Depth m	Elevation amsl m	PCE µg/L	TCE µg/L	cDCE µg/L	11DCE µg/L	tDCE µg/L	VC µg/L	Methane µg/L	Ethene µg/L	Ethane µg/L	Total VOCs µg/L	Total VOCs as PCE µg/L	Comments
PRP1	0.25	183.683	UTP	UTP	UTP	UTP	UTP	UTP	UTP	UTP	UTP	NA	NA	
	0.50	183.433	UTP	UTP	UTP	UTP	UTP	UTP	UTP	UTP	UTP	NA	NA	
	0.75	183.183	UTP	UTP	UTP	UTP	UTP	UTP	UTP	UTP	UTP	NA	NA	
	1.00	182.933	UTP	UTP	UTP	UTP	UTP	UTP	UTP	UTP	UTP	NA	NA	
	1.25	182.683	UTP	UTP	UTP	UTP	UTP	UTP	UTP	UTP	UTP	NA	NA	
	1.50	182.433	848.8	1.7	ND	ND	ND	ND	4.7	ND	ND	850.6	851.0	
	1.50	182.433	853.2	1.5	114.7	ND	ND	ND	3.1	ND	ND	969.4	1051.4	Lab Duplicate
	1.75	182.183	413.9	1.1	ND	ND	ND	ND	34.9	ND	ND	415.0	415.3	
	2.00	181.933	UTP	UTP	UTP	UTP	UTP	UTP	UTP	UTP	UTP	NA	NA	
	2.25	181.683	1961.5	4.5	ND	ND	ND	ND	1.4	ND	ND	1966.0	1967.2	
	2.50	181.433	UTP	UTP	UTP	UTP	UTP	UTP	UTP	UTP	UTP	NA	NA	
	2.75	181.183	330.7	ND	ND	ND	ND	ND	ND	ND	ND	330.7	330.7	
	3.00	180.933	864.4	2.0	ND	ND	ND	ND	2.6	ND	ND	866.5	867.0	
	3.25	180.683	1654.0	2.2	ND	ND	ND	ND	2.5	ND	ND	1656.2	1656.8	
	3.50	180.433	360.6	ND	ND	ND	ND	4.4	ND	ND	ND	365.0	372.2	
	3.75	180.183	158.3	ND	ND	ND	ND	ND	ND	ND	ND	158.3	158.3	
	4.00	179.933	150.4	ND	ND	ND	ND	ND	ND	ND	ND	150.4	150.4	
	4.25	179.683	270.9	1.0	ND	ND	ND	ND	ND	ND	ND	271.9	272.2	
	4.50	179.433	217.2	0.7	ND	ND	ND	ND	ND	ND	ND	217.9	218.1	
	4.75	179.183	148.1	ND	ND	ND	ND	ND	ND	ND	ND	148.1	148.1	
	5.00	178.933	65.9	ND	ND	ND	ND	ND	ND	ND	ND	65.9	65.9	
	5.25	178.683	46.8	ND	ND	ND	ND	ND	ND	ND	ND	46.8	46.8	
	5.50	178.433	46.0	ND	ND	ND	ND	1.3	ND	ND	ND	47.3	49.4	
	6.00	177.933	15.5	ND	ND	ND	ND	ND	ND	ND	ND	15.5	15.5	
	6.50	177.433	ND	ND	ND	ND	ND	ND	9.8	ND	ND	0.0	0.0	
	7.00	176.933	ND	ND	ND	ND	ND	ND	4.1	ND	ND	0.0	0.0	
	7.50	176.433	ND	ND	ND	ND	ND	ND	7.7	ND	ND	0.0	0.0	
	8.00	175.933	ND	ND	ND	ND	ND	ND	28.1	ND	ND	0.0	0.0	

Location	Depth m	Elevation amsl m	PCE µg/L	TCE µg/L	cDCE µg/L	11DCE µg/L	tDCE µg/L	VC µg/L	Methane µg/L	Ethene µg/L	Ethane µg/L	Total VOCs µg/L	Total VOCs as PCE µg/L	Comments
	8.50	175.433	ND	ND	ND	ND	ND	ND	*104.5*	ND	ND	0.0	0.0	Methane exceeds calibration
PRP2	0.10	183.902	6.1	2.7	ND	ND	ND	ND	3.0	ND	ND	8.8	9.6	
	0.25	183.752	5.9	1.6	10.1	ND	ND	ND	1.0	ND	ND	17.6	25.2	
	0.50	183.502	UTP	UTP	UTP	UTP	UTP	UTP	UTP	UTP	UTP	NA	NA	
	0.75	183.252	UTP	UTP	UTP	UTP	UTP	UTP	UTP	UTP	UTP	NA	NA	
	1.00	183.002	UTP	UTP	UTP	UTP	UTP	UTP	UTP	UTP	UTP	NA	NA	
	1.25	182.752	UTP	UTP	UTP	UTP	UTP	UTP	UTP	UTP	UTP	NA	NA	
	1.50	182.502	UTP	UTP	UTP	UTP	UTP	UTP	UTP	UTP	UTP	NA	NA	
	1.75	182.252	UTP	UTP	UTP	UTP	UTP	UTP	UTP	UTP	UTP	NA	NA	
	2.00	182.002	1009.7	3.0	ND	ND	ND	ND	13.1	ND	ND	1012.7	1013.5	
	2.25	181.752	UTP	UTP	ND	UTP	UTP	UTP	UTP	UTP	UTP	NA	NA	
	2.50	181.502	UTP	UTP	ND	UTP	UTP	UTP	UTP	UTP	UTP	NA	NA	
	2.75	181.252	11.8	ND	ND	ND	ND	ND	NA	NA	NA	NA	NA	
	3.00	181.002	6.2	ND	ND	ND	ND	ND	66.6	ND	ND	6.2	6.2	
	3.25	180.752	10.9	ND	ND	ND	ND	ND	*135.6*	ND	ND	10.9	10.9	Methane exceeds calibration
	3.50	180.502	9.1	ND	ND	ND	ND	ND	77.4	ND	ND	9.1	9.1	
	3.75	180.252	307.7	1.6	ND	ND	ND	ND	1.0	ND	ND	309.3	309.7	
	4.00	180.002	67.5	1.7	ND	ND	ND	ND	2.7	ND	?	69.2	69.6*	
	4.00	180.002	68.3	2.2	ND	ND	ND	ND	4.5	ND	ND	70.5	71.1	Lab Duplicate
	4.25	179.752	4.2	ND	ND	ND	ND	ND	ND	ND	?	4.2	4.2*	
	4.50	179.502	6.4	ND	ND	ND	ND	ND	1.4	ND	ND	6.4	6.4	
	5.00	179.002	1.0	ND	ND	ND	ND	ND	ND	ND	ND	1.0	1.0	
	5.50	178.502	ND	ND	ND	ND	ND	ND	2.1	ND	ND	0.0	0.0	
	6.00	178.002	ND	ND	ND	ND	ND	ND	19.6	ND	ND	0.0	0.0	
	6.50	177.502	ND	1.3	ND	ND	ND	ND	2.5	ND	ND	1.3	1.6	
	7.00	177.002	UTP	UTP	UTP	UTP	UTP	UTP	UTP	UTP	UTP	NA	NA	
PRP3	0.10	183.812	852.0	135.0	516.6	ND	ND	70.2	*924.4*	1.1	ND	1574.9	2098.7	Methane exceeds calibration
	0.25	183.662	336.1	105.9	934.1	ND	ND	70.2	*1399.6*	1.6	ND	1448.0	2263.7	Methane exceeds calibration

Location	Depth m	Elevation amsl m	PCE µg/L	TCE µg/L	cDCE µg/L	11DCE µg/L	tDCE µg/L	VC µg/L	Methane µg/L	Ethene µg/L	Ethane µg/L	Total VOCs µg/L	Total VOCs as PCE µg/L	Comments
	0.50	183.412	1041.6	55.1	430.8	ND	ND	64.6	2.7	ND	ND	1592.1	2019.5	
	0.75	183.162	1855.7	7.1	19.9	ND	ND	ND	3.5	ND	ND	1882.7	1898.6	
	1.00	182.912	1801.9	3.8	ND	ND	ND	7.2	2.4	ND	ND	1812.9	1825.7	
	1.25	182.662	1939.1	4.1	ND	ND	ND	ND	2.8	ND	ND	1943.2	1944.2	
	1.50	182.412	UTP	UTP	UTP	UTP	UTP	UTP	UTP	UTP	UTP	NA	NA	
	1.75	182.162	UTP	UTP	UTP	UTP	UTP	UTP	UTP	UTP	UTP	NA	NA	
	2.00	181.912	UTP	UTP	UTP	UTP	UTP	UTP	UTP	UTP	UTP	NA	NA	
	2.25	181.662	UTP	UTP	UTP	UTP	UTP	UTP	UTP	UTP	UTP	NA	NA	
	2.50	181.412	3.9	ND	ND	ND	ND	ND	ND	ND	ND	3.9	3.9	
	3.00	180.912	1.8	ND	ND	ND	ND	ND	ND	ND	ND	1.8	1.8	
	3.50	180.412	1.2	ND	ND	ND	ND	ND	0.8	ND	ND	1.2	1.2	
	4.00	179.912	0.8	ND	ND	ND	ND	ND	ND	ND	ND	0.8	0.8	
	4.50	179.412	ND	ND	ND	ND	ND	ND	1.4	ND	ND	0.0	0.0	
	5.00	178.912	ND	ND	ND	ND	ND	ND	*111.6*	ND	ND	0.0	0.0	Methane exceeds calibration
	5.50	178.412	ND	ND	ND	ND	ND	ND	*197.5*	ND	ND	0.0	0.0	Methane exceeds calibration
	6.00	177.912	ND	ND	ND	ND	ND	ND	39.2	ND	ND	0.0	0.0	
	6.50	177.412	ND	ND	ND	D	ND	ND	32.7	ND	ND	0.0	0.0	
	6.50	177.412	ND	ND	ND	ND	ND	ND	39.2	ND	ND	0.0	0.0	Lab Duplicate
	7.00	176.912	ND	ND	ND	ND	ND	ND	55.6	ND	ND	0.0	0.0	
	7.50	176.412	ND	ND	ND	ND	ND	ND	95.7	ND	ND	0.0	0.0	
	8.00	175.912	ND	ND	ND	ND	ND	ND	*324.0*	ND	ND	0.0	0.0	Methane exceeds calibration
Seep near PRP1	NA	NA	622.0	2.3	110.1	ND	ND	ND	?	?	?	Inc	Inc	From stream bank at PRP1, could not read print out for Methane, ethene, ethane but were very low numbers

Location	Depth m	Elevation amsl m	PCE µg/L	TCE µg/L	cDCE µg/L	11DCE µg/L	tDCE µg/L	VC µg/L	Methane µg/L	Ethene µg/L	Ethane µg/L	Total VOCs µg/L	Total VOCs as PCE µg/L	Comments
Artesian at PRP1	NA	NA	1015.5	1.4	ND	ND	ND	ND	NA	NA	NA	Inc	Inc	From flowing well at PRP1 prior to grouting the hole, no second vial to analyze
Trip blank	NA	NA	ND	ND	ND	ND	ND	ND	NA	NA	NA	Inc	Inc	No second vial collected
Equipt blank	NA	NA	ND	ND	ND	ND	ND	ND	NA	NA	NA	Inc	Inc	No second vial collected
Lab Blank A	NA	NA	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.0	0.0	
Lab Blank B	NA	NA	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.0	0.0	
Lab Blank C	NA	NA	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.0	0.0	
Lab Blank D	NA	NA	ND	ND	ND	ND	ND	ND	0.9	ND	ND	0.0	0.0	
Lab Blank E	NA	NA	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.0	0.0	
Lab Blank F	NA	NA	ND	ND	ND	ND	ND	ND	NA	NA	NA	Inc	Inc	
Lab Blank G	NA	NA	NA	NA	ND	ND	ND	ND	NA	NA	NA	Inc	Inc	
Lab Blank H	NA	NA	NA	NA	ND	ND	ND	ND	NA	NA	NA	Inc	Inc	
Lab Blank I	NA	NA	NA	NA	ND	ND	ND	ND	NA	NA	NA	Inc	Inc	
Lab Blank A	NA	NA	NA	NA	ND	ND	ND	ND	NA	NA	NA	Inc	Inc	
Detection Limits			0.7	0.9	7.8	3.2	1.9	0.7	0.5	0.5	0.5	NA	NA	

Notes:

Sampled PRP1 on 8/7, PRP2 on 8/8, and PRP3 on 8/9

Total VOCs is a sum of all VOCs for a sample table except methane

Total VOCs as PCE is the molar total of all VOCs (except methane) expressed as equivalent concentrations of PCE in µg/L

ND = Not detected

NA = Not applicable or not analyzed

UTP = unable to pump a sample from that depth

NS = depth interval not sampled

? Unable to read chromatogram

* estimated Total value

Inc = Totals are incomplete, missing one or more analyses for compounds

Methane calibrated up to 100 µg/L

WATER QUALITY RESULTS AT WATERLOO PROFILING LOCATIONS
PRP4 (August 28, 1996)

Location	Depth m	Elevation amsl m	PCE µg/L	TCE µg/L	cDCE µg/L	11DCE µg/L	tDCE µg/L	VC µg/L	Methane µg/L	Ethene µg/L	Ethane µg/L	Total VOCs µg/L	Total VOCs as PCE µg/L	Comments
PRP4	0.10	183.857	489.5	49.3	147.9	ND	ND	ND	23.9	ND	ND	686.7	804.8	
	0.20	183.757	435.9	14.5	71.3	ND	ND	ND	2.8	ND	ND	521.7	576.2	
	0.30	183.657	308.6	24.1	191.2	ND	ND	ND	21.3	ND	ND	523.9	666.1	
	0.50	183.457	34.7	3.6	67.8	ND	ND	ND	ND	ND	ND	106.1	155.2	
	0.60	183.357	559.7	5.1	11.1	ND	ND	ND	3.8	ND	ND	575.9	585.1	
	0.70	183.257	UTP	UTP	UTP	UTP	UTP	UTP	UTP	UTP	UTP	NA	NA	
	0.84	183.117	UTP	UTP	UTP	UTP	UTP	UTP	UTP	UTP	UTP	NA	NA	
	1.25	182.707	UTP	UTP	UTP	UTP	UTP	UTP	UTP	UTP	UTP	NA	NA	
	1.50	182.457	UTP	UTP	UTP	UTP	UTP	UTP	UTP	UTP	UTP	NA	NA	
	1.75	182.207	UTP	UTP	UTP	UTP	UTP	UTP	UTP	UTP	UTP	NA	NA	
	2.00	181.957	UTP	UTP	UTP	UTP	UTP	UTP	UTP	UTP	UTP	NA	NA	
	2.50	181.457	UTP	UTP	UTP	UTP	UTP	UTP	UTP	UTP	UTP	NA	NA	
	3.00	180.957	ND	ND	ND	ND	ND	ND	81.7	ND	ND	0.0	0.0	
	3.50	180.457	ND	ND	ND	ND	ND	ND	54.1	ND	ND	0.0	0.0	
	4.00	179.957	ND	ND	ND	ND	ND	ND	88.5	ND	ND	0.0	0.0	
	4.50	179.457	ND	ND	ND	ND	ND	ND	2.2	ND	ND	0.0	0.0	
	5.00	178.957	ND	ND	ND	ND	ND	ND	2.7	ND	ND	0.0	0.0	
	5.50	178.457	ND	ND	ND	ND	ND	ND	14.6	ND	ND	0.0	0.0	
	6.00	177.957	ND	ND	ND	ND	ND	ND	*154.8*	ND	ND	0.0	0.0	Methane Exceeds calibration
	6.50	177.457	ND	ND	ND	ND	ND	ND	*133.1*	ND	ND	0.0	0.0	Methane Exceeds calibration
PRP4 -SW	NA	NA	1.845	ND	ND	ND	ND	ND	1.5	ND	ND	1.8	1.8	Surface water at PRP4, 6 cm above streambed
Lab Blank A	NA	NA	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.0	0.0	
Lab Blank B	NA	NA	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.0	0.0	

PRP4 Water Quality
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Location	Depth	Elevation amsl m	PCE µg/L	TCE µg/L	cDCE µg/L	11DCE µg/L	tDCE µg/L	VC µg/L	Methane µg/L	Ethene µg/L	Ethane µg/L	Total VOCs µg/L	Total VOCs as PCE µg/L	Comments
Lab Blank C	NA	NA	ND	ND	ND	ND	ND	ND	0.8	ND	ND	0.0	0.0	
Lab Blank D	NA	NA	ND	ND	NA	NA	NA	NA	NA	NA	NA	Inc	Inc	
Lab Blank E	NA	NA	ND	ND	NA	NA	NA	NA	NA	NA	NA	Inc	Inc	
Detection Limits			0.7	0.9	7.8	3.2	1.9	0.7	0.5	0.5	0.5	NA	NA	

Notes:

Sampled same day as AP52 and analyzed at same time as AP52

Total VOCs is a sum of all VOCs for a sample table except methane

Total VOCs as PCE is the molar total of all VOCs (except methane) expressed as equivalent concentrations of PCE in µg/L

ND = Not detected

UTP = unable to pump a sample

NS = depth not sampled

NA = Not applicable or not analyzed

Inc = Totals are incomplete, missing one or more analyses for compounds

VOC WATER QUALITY AT WATERLOO PROFILING LOCATIONS PRP5 and PRP6 (October 1996)

Location	Depth m	Elevation m	PCE μg/L	TCE μg/L	VC μg/L	11DCE μg/L	tDCE μg/L	cDCE μg/L	Methane μg/L	Ethene μg/L	Ethane μg/L
PRP-5	SW	NA	1.0	ND	ND	ND	ND	ND	10.7	ND	ND
	0.10	184.02	ND	ND	ND	ND	ND	ND	13126.5	ND	ND
	0.20	183.92	ND	ND	ND	ND	ND	ND	460.5	ND	ND
	0.30	183.82	ND	ND	ND	ND	ND	ND	9.6	ND	ND
	0.40	183.72	2.7	3.0	11.8	ND	ND	84.5	116.9	0.9	ND
	0.50	183.62	ND	ND	ND	ND	ND	104.6	223.1	ND	ND
	0.60	183.52	97.9	7.4	ND	ND	ND	ND	65.8	ND	ND
	0.70	183.42	54.7	2.9	ND	ND	ND	ND	55.7	ND	ND
	0.80	183.32	60.9	5.1	ND	ND	ND	ND	20.5	ND	ND
	0.90	183.22	75.6	10.4	ND	ND	ND	ND	20.5	ND	ND
	1.00	183.12	82.5	17.4	ND	ND	ND	ND	18.5	ND	ND
	1.25	182.87	UTP	UTP	UTP	UTP	UTP	UTP	UTP	UTP	UTP
	1.60	182.52	UTP	UTP	UTP	UTP	UTP	UTP	UTP	UTP	UTP
	2.00	182.12	2.2	1.6	ND	ND	ND	ND	36.3	ND	ND
	2.50	181.62	UTP	UTP	UTP	UTP	UTP	UTP	UTP	UTP	UTP
	3.00	181.12	0.8	2.7	ND	ND	ND	ND	13.8	ND	ND
	3.50	180.62	56.8	ND	ND	ND	ND	ND	15.6	ND	ND
	4.00	180.12	2794.6	1.8	ND	ND	ND	ND	7.6	ND	0.7
	4.50	179.62	224.0	ND	ND	ND	ND	ND	ND	ND	ND
	5.00	179.12	1.5	ND	ND	ND	ND	ND	ND	ND	ND
	5.50	178.62	ND	ND	ND	ND	ND	ND	ND	ND	ND
	6.00	178.12	ND	ND	ND	ND	ND	ND	ND	ND	0.9
PRP6	SW	NA	ND	ND	ND	ND	ND	ND	9.7	ND	ND
	0.10	183.83	ND	ND	ND	ND	ND	ND	ND	ND	ND
	0.20	183.73	ND	ND	ND	ND	ND	ND	ND	ND	ND
	0.30	183.63	2.9	ND	ND	ND	ND	ND	ND	ND	ND
	0.40	183.53	7.4	2.4	ND	ND	ND	ND	23.9	ND	ND
Dup	0.40	183.53	7.0	2.4	NA	NA	NA	NA	NA	NA	NA
	0.50	183.43	ND	ND	ND	ND	ND	ND	372.3	ND	ND
	0.65	183.28	ND	ND	ND	ND	ND	ND	161.4	ND	ND
	0.80	183.13	ND	ND	ND	ND	ND	ND	38.0	ND	ND
	1.25	182.68	UTP	UTP	UTP	UTP	UTP	UTP	UTP	UTP	UTP

Location	Depth m	Elevation m	PCE µg/L	TCE µg/L	VC µg/L	11DCE µg/L	tDCE µg/L	cDCE µg/L	Methane µg/L	Ethene µg/L	Ethane µg/L
	1.50	182.43	UTP	UTP	UTP	UTP	UTP	UTP	UTP	UTP	UTP
	1.75	182.18	UTP	UTP	UTP	UTP	UTP	UTP	UTP	UTP	UTP
	2.00	181.93	UTP	UTP	UTP	UTP	UTP	UTP	UTP	UTP	UTP
	2.25	181.68	UTP	UTP	UTP	UTP	UTP	UTP	UTP	UTP	UTP
	2.50	181.43	UTP	UTP	UTP	UTP	UTP	UTP	UTP	UTP	UTP
	3.00	180.93	1.4	1.9	ND	ND	ND	ND	4.1	ND	ND
	3.50	180.43	ND	ND	ND	ND	ND	ND	ND	ND	ND
	4.00	179.93	ND	ND	ND	ND	ND	ND	0.9	ND	ND
	4.50	179.43	ND	ND	ND	ND	ND	ND	ND	ND	ND
	5.00	178.93	ND	ND	ND	ND	ND	ND	ND	ND	ND
Bridge Seep	NA	NA	13.9	ND	ND	ND	ND	ND	4.3	ND	ND
Trip	NA	NA	ND	ND	ND	ND	ND	ND	ND	ND	2.5
EQ-1	NA	NA	ND	1.2	ND	ND	ND	ND	ND	ND	ND
Blank	NA	NA	ND	ND	NA	NA	NA	NA	NA	NA	NA
Blank	NA	NA	ND	ND	NA	NA	NA	NA	NA	NA	NA
Blank	NA	NA	ND	ND	NA	NA	NA	NA	NA	NA	NA
Blank	NA	NA	ND	ND	NA	NA	NA	NA	NA	NA	NA
Blank	NA	NA	ND	ND	NA	NA	NA	NA	NA	NA	NA
Blank	NA	NA	ND	ND	NA	NA	NA	NA	NA	NA	NA
Blank	NA	NA	ND	ND	NA	NA	NA	NA	NA	NA	NA
Airblank	NA	NA	NA	NA	ND	ND	ND	ND	NA	NA	NA
Airblank	NA	NA	NA	NA	ND	ND	ND	ND	NA	NA	NA
Airblank	NA	NA	NA	NA	ND	ND	ND	ND	NA	NA	NA
Airblank	NA	NA	NA	NA	ND	ND	ND	ND	NA	NA	NA
Airblank	NA	NA	NA	NA	NA	NA	NA	NA	ND	ND	ND
Airblank	NA	NA	NA	NA	NA	NA	NA	NA	ND	ND	ND
Airblank	NA	NA	NA	NA	NA	NA	NA	NA	ND	ND	ND
Airblank	NA	NA	NA	NA	NA	NA	NA	NA	ND	ND	ND
Detection Limit			0.7	0.9	0.7	3.2	1.9	7.8			

Notes:

Sampled PRP5 on 10/7 and PRP6 on 10/9/96, Brewster Conant and Jesse Ingelton

UTP = unable to pump a sample from that depth

NA = Not applicable or not analyzed

ND = Not detected

Methane samples properly diluted and rerun

VOC WATER QUALITY AT WATERLOO PROFILING LOCATIONS PRP7 and PRP8 AND PIEZOMETER LOCATIONS DP1, DP7, DP8, DP9 AND SP1 (November, 1996)

Location	Depth m	Elev. amsl m	PCE µg/L	TCE µg/L	11DCE µg/L	tDCE µg/L	cDCE µg/L	VC µg/L	Ethene µg/L	Ethane µg/L	Methane µg/L	Total VOCs µg/L	Total VOCs as PCE µg/L	Comments
PRP7 SW	NA	183.732	ND	ND	ND	ND	ND	ND	ND	ND	4.3	0.0	0.0	Surface water
PRP7	0.15	183.582	ND	ND	ND	ND	ND	ND	ND	ND	1.5	0.0	0.0	
	0.30	183.432	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.0	0.0	
	0.45	183.282	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.0	0.0	
	0.60	183.132	ND	ND	ND	ND	ND	ND	ND	ND	726.8	0.0	0.0	
	0.75	182.982	UTP	UTP	UTP	UTP	UTP	UTP	UTP	UTP	UTP	NA	NA	
	0.90	182.832	UTP	UTP	UTP	UTP	UTP	UTP	UTP	UTP	UTP	NA	NA	
	1.25	182.482	UTP	UTP	UTP	UTP	UTP	UTP	UTP	UTP	UTP	NA	NA	
	1.50	182.232	UTP	UTP	UTP	UTP	UTP	UTP	UTP	UTP	UTP	NA	NA	
	1.75	181.982	UTP	UTP	UTP	UTP	UTP	UTP	UTP	UTP	UTP	NA	NA	
	2.00	181.732	UTP	UTP	UTP	UTP	UTP	UTP	UTP	UTP	UTP	NA	NA	
	2.25	181.482	3808.4	7.0	ND	ND	ND	ND	ND	ND	7.1	3815.4	3817.2	
	2.50	181.232	UTP	UTP	UTP	UTP	UTP	UTP	UTP	UTP	UTP	NA	NA	
	2.75	180.982	UTP	UTP	UTP	UTP	UTP	UTP	UTP	UTP	UTP	NA	NA	
	3.00	180.732	2933.3	10.7	ND	ND	ND	ND	ND	ND	11.3	2943.9	2946.7	
	3.25	180.482	3010.4	4.6	ND	ND	ND	ND	ND	ND	2.7	3015.0	3016.2	
	3.25	180.482	3033.7	4.5	ND	ND	ND	ND	NA	NA	NA	Inc	Inc	Lab duplicate
	3.50	180.232	1857.2	4.0	ND	ND	ND	ND	ND	ND	1.3	1861.2	1862.3	
PRP8 SW	NA	183.700	ND	ND	ND	ND	ND	ND	ND	ND	3.0	NA	NA	surface water
PRP8	0.15	183.743	340.5	119.0	7.1	7.7	2228.9	1376.5	125.3	2.0	58.9	4206.9	8732.7	
	0.30	183.593	ND	4.8	5.7	2.4	2499.3	1363.6	205.6	15.2	126.6	4096.7	9212.7	
	0.30	183.593	ND	4.7	NA	NA	NA	NA	NA	NA	NA	NA	NA	Lab duplicate, problems w/ PID integration
	0.45	183.443	UTP	UTP	UTP	UTP	UTP	UTP	UTP	UTP	UTP	NA	NA	Possible frozen line
	0.60	183.293	UTP	UTP	UTP	UTP	UTP	UTP	UTP	UTP	UTP	NA	NA	Sampling line froze
DP1 SW	NA	184.020	ND	ND	ND	ND	ND	ND	ND	ND	2.2	0.0	0.0	surface water
DP1-1		183.070	17.0	ND	ND	ND	ND	ND	ND	ND	47.0	17.0	17.0	
DP1-2		180.740	9.4	5.4	ND	ND	ND	ND	ND	ND	19.7	14.8	16.2	

Location	Depth m	Elev. amsl m	PCE µg/L	TCE µg/L	11DCE µg/L	tDCE µg/L	cDCE µg/L	VC µg/L	Ethene µg/L	Ethane µg/L	Methane µg/L	Total VOCs µg/L	Total VOCs as PCE µg/L	Comments
DP1-3		178.460	2.8	ND	ND	ND	ND	ND	ND	ND	ND	2.8	2.8	
SP1-S		183.350	3.0	ND	ND	ND	ND	ND	ND	ND	4778.7	3.0	3.0	
SP1-D		183.090	6.2	ND	ND	ND	ND	ND	ND	ND	569.6	6.2	6.2	
DP7-1		183.380	7.3	ND	ND	ND	ND	ND	ND	ND	121.7	7.3	7.3	
DP7-2		180.710	11.8	ND	ND	ND	ND	ND	ND	ND	50.3	11.8	11.8	
DP7-3		178.860	3719.3	2.4	ND	ND	ND	ND	ND	ND	1.9	3721.7	3722.3	
DP8-2		180.630	55.9	ND	ND	ND	ND	ND	ND	ND	62.1	55.9	55.9	
DP8-A		180.630	55.1	ND	ND	ND	ND	ND	ND	ND	59.0	55.1	55.1	Field duplicate of DP8-2
DP8-3		178.660	2175.6	4.6	ND	ND	ND	ND	ND	ND	9.7	2180.2	2181.4	
DP9-1		183.350	ND	ND	ND	ND	ND	ND	ND	ND	713.4	0.0	0.0	
DP9-2		180.400	5.1	ND	ND	ND	ND	ND	ND	ND	216.7	5.1	5.1	
DP9-3		178.470	26.3	ND	ND	ND	ND	ND	ND	ND	112.7	26.3	26.3	
TRIP		NA	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.0	0.0	trip blank
Equipt Blank		NA	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.0	0.0	for profiler equipt
Lab Blank A		NA	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.0	0.0	
Lab Blank B		NA	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.0	0.0	
Lab Blank C		NA	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.0	0.0	
Lab Blank D		NA	ND	ND	NA	NA	NA	NA	ND	ND	ND	0.0	0.0	
Detection Limit		NA	2.2	1.7	1.2	4.0	9.7	2.6	0.3	0.3	1.0	NA	NA	

Notes:

Sampled PRP7 on 11/7 and PRP8 on 11/11. DP7, DP8, and DP9 on 11/8. DP1 on 11/9. SP1 on 11/11.
Total VOCs is a sum of all VOCs for a sample table except methane
Total VOCs as PCE is the molar total of all VOCs (except methane) expressed as equivalent concentrations of PCE in µg/L
ND = Not detected
NA = Not applicable or not analyzed
UTP = unable to pump a sample from that depth
Inc = Totals are incomplete, missing one or more analyses for compounds
Methane samples properly diluted and rerun

INORGANIC WATER QUALITY AT WATERLOO PROFILING LOCATIONS PRP7 and PRP8 AND PIEZOMETER LOCATIONS DP1, DP7, DP8, DP9 AND SP1 (November, 1996)

Locations	Elev. m	Na mg/L	K mg/L	Ca mg/L	Mg mg/L	Alk. as $CaCO_3$ mg/L	SO_4 mg/L	Cl mg/L	Si as SiO_2 mg/L	Ortho P mg/L	Total P mg/L	NO_3 NO_2 as N mg/L	NO_3 as N mg/L	NO_2 as N mg/L	Ammonia as N mg/L	Fe mg/L
PRP7 SW	183.732	7.9	1.6	81.3	16.7	245	23	14.1	8.8	< 0.01	0.022	1.20	1.19	0.01	< 0.05	0.05
PRP7 0.15	183.582	8.0	1.8	80.0	17.6	246	23	13.7	9.2	0.01	0.036	< 0.05	< 0.05	< 0.01	< 0.05	< 0.02
PRP7 0.30	183.432	8.2	1.6	79.2	19.0	231	23	14.6	10.9	0.07	0.095	< 0.05	< 0.05	< 0.01	0.54	0.35
PRP7 0.45	183.282	10.1	1.8	85.6	19.4	282	19	17.3	12.8	0.04	0.065	< 0.05	< 0.05	< 0.01	0.79	0.25
PRP7 0.60	183.132	17.0	4.8	94.2	16.4	268	8	29.6	15.5	0.08	0.220	< 0.05	< 0.05	< 0.01	1.34	2.30
PRP7 2.25	181.482	56.8	13.0	134.0	11.6	340	32	86.0	10.5	< 0.01	0.038	1.55	1.43	0.12	< 0.05	0.05
PRP7 3.00	180.732	43.8	11.4	132.0	11.6	307	30	75.4	11.7	< 0.01	0.037	2.77	2.73	0.04	< 0.05	0.05
PRP7 3.25	180.482	35.2	12.2	111.0	9.6	258	23	64.3	8.5	< 0.01	0.030	2.56	2.45	0.11	< 0.05	0.05
PRP7 3.50	180.232	33.0	12.2	119.0	9.8	271	26	67.7	11.2	< 0.01	0.035	4.44	4.31	0.13	< 0.05	< 0.02
PRP8 SW	183.700	9.0	1.7	82.0	16.8	233	25	12.8	8.8	< 0.01	0.028	1.13	1.13	< 0.01	< 0.05	0.05
PRP8 0.15	183.550	68.2	12.6	133.0	11.8	324	35	111.0	12.9	< 0.01	0.170	< 0.05	< 0.05	< 0.01	0.49	18.00
PRP8 0.30	183.400	65.2	12.6	130.0	12.0	325	32	113.0	12.8	< 0.01	0.510	< 0.05	< 0.05	< 0.01	0.57	16.20
DP1 SW	184.020	8.4	2.8	80.4	16.0	220	21	13.1	9.3	< 0.01	0.041	1.00	1.00	< 0.01	< 0.05	0.05
DP1-1	183.070	52.4	13.2	119.0	10.4	309	21	92.4	9.7	0.01	0.041	< 0.05	< 0.05	< 0.01	0.23	0.80
DP1-2	180.740	67.0	8.0	142.0	9.7	292	31	125.0	9.4	< 0.01	0.021	< 0.05	< 0.05	< 0.01	0.05	0.05
DP1-3	178.460	71.6	12.6	93.9	10.0	239	27	114.0	6.0	< 0.01	0.013	4.94	4.85	0.09	< 0.05	< 0.02
SP1-S	183.350	49.2	7.2	154.0	12.1	369	2	90.8	12.2	0.04	0.071	< 0.05	< 0.05	< 0.01	0.34	0.20
SP1-D	183.090	50.0	12.6	129.0	11.0	318	6	93.3	11.0	0.04	0.066	< 0.05	< 0.05	< 0.01	0.36	0.05
DP7-1	183.380	104.0	12.5	153.0	14.6	374	12	175.0	15.2	< 0.01	0.049	< 0.05	< 0.05	< 0.01	0.71	1.95
DP7-2	180.710	91.8	7.6	134.0	11.0	348	20	140.0	12.1	< 0.01	0.028	< 0.05	< 0.05	< 0.01	1.02	< 0.02
DP7-3	178.860	70.1	9.2	96.0	8.8	221	26	121.0	7.7	< 0.01	0.016	1.07	1.04	0.03	< 0.05	< 0.02
DP8-2	180.630	122.0	10.1	149.0	12.2	350	31	206.0	11.4	< 0.01	0.026	< 0.05	< 0.05	< 0.01	0.25	0.10
DP8-A	88.180	129.0	10.9	158.0	13.1	387	32	208.0	11.4	< 0.01	0.025	< 0.05	< 0.05	< 0.01	0.24	0.05
DP8-3	178.660	67.4	11.4	113.0	9.0	302	21	109.0	6.7	< 0.01	0.016	0.08	0.08	< 0.01	< 0.05	0.05
DP9-1	183.350	19.7	1.5	111.0	8.2	255	13	44.9	12.6	0.05	0.071	< 0.05	< 0.05	< 0.01	0.46	0.10
DP9-2	180.400	43.0	1.6	96.8	12.4	220	15	99.4	9.8	< 0.01	0.028	< 0.05	< 0.05	< 0.01	0.06	0.75
DP9-3	178.470	32.0	1.2	74.8	17.3	150	6	113.0	18.9	0.01	0.058	< 0.05	< 0.05	< 0.01	0.17	0.45
TRIP		0.6	< 0.1	< 0.1	< 0.1	< 1	< 2	< 1.0	< 0.5	0.03	0.002	< 0.05	< 0.05	< 0.01	< 0.05	< 0.02
Equipt Blnk		0.04	0.1	< 0.1	< 0.1	1	< 2	< 1.0	< 0.5	< 0.01	0.003	< 0.05	< 0.05	< 0.01	< 0.05	< 0.02
Detection Limit		0.1	0.1	0.1	0.1	1	2	1	0.5	0.01	0.01	0.05	0.05	0.01	0.05	0.02

Locations	Mn mg/L	Cu mg/L	Zn mg/L	Color TCU	Spec. Cond. umhos/cm	pH	DOC mg/l	Hardness as $CaCO_3$ mg/L*	Bicarbonate as $CaCO_3$ mg/L*	Carbonate as $CaCO_3$ mg/L*	TDS mg/L*	Cation Sum meq/L*	Anion Sum meq/L*	Ion Balance %*
PRP7 SW	< 0.01	< 0.01	< 0.01	15	540	8.3	3.7	272	240	4.5	306	5.82	5.86	0.36
PRP7 0.15	< 0.01	< 0.01	< 0.01	12	550	8.1	3.6	272	243	2.9	301	5.84	5.79	0.43
PRP7 0.30	2.55	< 0.01	< 0.01	23	570	8.2	5.1	276	228	3.4	296	5.95	5.51	3.82
PRP7 0.45	3.95	< 0.01	< 0.01	24	580	8.2	5.5	294	278	4.1	336	6.41	6.53	0.90
PRP7 0.60	0.75	< 0.01	< 0.01	31	640	7.9	5.4	303	266	2.0	348	7.01	6.36	4.81
PRP7 2.25	0.30	< 0.01	< 0.01	10	960	7.8	3.6	382	338	2.0	555	10.40	10.00	2.19
PRP7 3.00	0.20	< 0.01	< 0.01	13	910	7.8	3.6	377	305	1.8	512	9.74	9.09	3.47
PRP7 3.25	0.15	< 0.01	< 0.01	14	770	7.9	3.6	317	256	1.9	430	8.18	7.63	3.43
PRP7 3.50	0.15	< 0.01	< 0.01	11	840	8.1	17.0	337	268	3.2	461	8.50	8.19	1.85
PRP8 SW	< 0.01	< 0.01	< 0.01	16	550	8.4	4.8	274	228	5.4	301	5.91	5.62	2.53
PRP8 0.15	2.10	< 0.01	< 0.01	34	1030	7.8	3.6	381	322	1.9	580	10.90	10.30	2.77
PRP8 0.30	2.25	< 0.01	< 0.01	22	1010	7.6	3.6	374	324	1.2	578	10.70	10.40	1.18
DP1 SW	< 0.01	< 0.01	< 0.01	19	540	8.3	5.4	267	216	4.0	287	5.77	5.28	4.45
DP1-1	0.15	< 0.01	< 0.01	21	900	7.9	3.6	340	307	2.3	504	9.43	9.23	1.08
DP1-2	0.10	< 0.01	< 0.01	< 5	1050	7.8	3.0	394	290	1.7	568	11.00	10.00	4.73
DP1-3	0.10	< 0.01	< 0.01	< 5	900	8.0	2.4	276	237	2.2	500	8.95	8.91	0.23
SP1-S	0.20	< 0.01	< 0.01	15	1020	7.7	5.4	434	367	1.7	550	11.00	9.99	4.97
SP1-D	0.20	< 0.01	< 0.01	8	920	7.9	4.0	367	316	2.4	504	9.87	9.12	3.93
DP7-1	0.25	< 0.01	< 0.01	26	1320	7.6	4.0	442	373	1.4	712	13.70	12.70	4.03
DP7-2	0.25	< 0.01	< 0.01	6	1130	7.8	3.1	380	346	2.1	627	11.90	11.30	2.27
DP7-3	0.10	< 0.01	< 0.01	5	930	7.9	3.0	276	219	1.6	476	8.80	8.45	2.05
DP8-2	0.20	< 0.01	< 0.01	8	1450	7.7	3.0	422	348	1.6	752	14.00	13.50	2.06
DP8-A	0.20	< 0.01	< 0.01	5	1470	7.7	3.4	448	385	1.8	795	14.90	14.30	2.04
DP8-3	0.10	< 0.01	< 0.01	10	900	7.8	4.0	319	300	1.8	519	9.61	9.56	0.26
DP9-1	0.20	< 0.01	< 0.01	8	690	7.7	2.6	311	254	1.2	365	7.14	6.64	3.64
DP9-2	0.10	< 0.01	< 0.01	8	770	8.0	1.4	293	218	2.0	410	7.77	7.52	1.62
DP9-3	0.05	< 0.01	< 0.01	13	690	8.0	1.2	258	149	1.4	354	6.59	6.31	2.14
TRIP	< 0.01	< 0.01	< 0.01	< 5.0	5.07	6.3	1.4	< 0.1	< 1	< 1.0	5	0.05	0.09	34.00
Equipt Blnk	< 0.01	< 0.01	< 0.01	< 5.0	5.37	5.9	1.2	< 0.1	< 1	< 1.0	5	0.04	0.09	42.10
Detection L	0.01	0.01	0.01	5	1	0.1	0.5	0.1	1	1	1	NA	NA	NA

Notes:

Rcap 30 suite of analyses plus total P performed by MDS Environmental Services Limited (Halifax, Nova Scotia)

Alk. = alkalinity expressed as $CaCO_3$
Ammonia = total ammonia and ammonium
DOC = Dissolved organic carbon
Equipt Blnk = Waterloo Profiler equipment blank
meq/l = milli equivalents per liter
N = nitrogen
Ortho P = Ortho phosphate
Total P = total phosporous (unfiltered sample)
Spec. Cond. = specific conductance
Si = Reactive silica as SiO_2
Stock L = Low concentration stock solution used as a blind spiked sample
Stock H = High concentration stock solution used as a blind spiked sample
TDS = Total dissolved solids
TRIP = Trip blank
* = a calculated parameter (not analytically measured)

FIELD PARAMETERS AT WATERLOO PROFILING LOCATIONS PRP7 and PRP8 AND PIEZOMETER LOCATIONS DP1, DP7, DP8, DP9 AND SP1 (November, 1996)

Location	Temp °C	pH	Eh at 25 °C mV	Dissolved Oxygen mg/L	Sulfide mg/L	Specific Conduct. µS/cm	Alkalinity in mg/L as $CaCO_3$
PRP7 SW	15.9	8.06	393	7.40	0.02	409	232
PRP7 0.15	16.2	7.76	427	1.71	0.03	372	224
PRP7 0.30	17.6	7.97	359	0.46	0.02	417	248
PRP7 0.45	17.9	7.97	350	0.61	0.03	411	264
PRP7 0.60	18.1	7.42	204	0.58	0.07	523	288
PRP7 2.25	11.4	7.06	415	0.64	0.03	709	312
PRP7 3.00	10.4	7.05	409	0.47	0.03	726	308
PRP7 3.25	8.7	7.19	405	1.37	0.04	599	244
PRP7 3.50	9.2	7.12	439	0.60	0.04	640	NA
PRP8 SW	2.3	8.28	307	9.90	0.00	436	224
PRP8 0.15	2.7	7.30	107	0.47	0.02	882	348
PRP8 0.30	2.8	7.26	106	0.64	0.03	758	340
DP1 SW	6.3	8.14	387	9.30	0.04	424	232
DP1-1	8.6	7.30	222	0.81	0.12	766	260
DP1-2	7.7	7.10	311	0.43	0.03	869	284
DP1-3	7.2	7.53	403	0.37	0.01	734	244
SP1-S	4.3	6.97	-35	0.54	2+	815	388
SP1-D	5.5	7.09	34	0.57	2+	765	324
DP7-1	10.9	7.02	178	0.33	0.09	1058	388
DP7-2	10.1	7.03	341	0.22	0.04	921	344
DP7-3	9.2	7.29	385	0.07	0.03	780	240
DP8-A	NA	NA	NA	0.22	0.03	NA	380
DP8-2	9.6	6.93	296	0.32	0.03	1199	384
DP8-3	9.3	7.20	317	0.35	0.05	762	260
DP9-1	10.7	7.22	42	0.26	1.71	570	272
DP9-2	9.6	7.57	136	0.40	0.04	621	220
DP9-3	9.8	7.57	120	0.22	0.09	553	152
TRIP	7.50	7.33	380	NA	NA	3.9	NA
Equipt Blnk	NA	8.55	NA	5.90	0.03	37.6	12
Detection Limit	NA	NA	NA	0.20	0.03	NA	NA

Notes:

All parameters measured inthe field

Dissolved oxygen and total sulfide measured using CheMetrics photometer and vacu-vials

Equipt Blnk = Waterloo Profiler equipment blank

Eh corrected to the nearest 5 °C increment

mV = millivolts

NA = Not applicable

TRIP = Trip blank

VOC WATER QUALITY AT MINI-PROFILER LOCATIONS PRP7R, PRP8R, AND PRP9 TO PRP13

August 1997

Location or sample name[1]	Date [2]	Depth m [3]	TCE µg/L	PCE µg/L	VC µg/L	11DCE µg/L	tDCE µg/L	cDCE µg/L	Methane µg/L[6]	Ethene µg/L	Ethane µg/L	Total VOCs µg/L	Total VOCs as PCE µg/L[4]	Percent as PCE[5]
EB-1	8/12/97	NA	MDL	ND	ND	ND	ND	ND	MDL	ND	ND	0.0	0.0	0.0%
PRP-7R	8/12/97	SW	3.2	MDL	ND	ND	ND	ND	MDL	ND	ND	3.2	4.1	0.0%
	8/12/97	0.15	8.3	MDL	ND	ND	ND	ND	993.1	ND	ND	8.3	10.5	0.0%
	8/12/97	0.30	2.5	MDL	ND	ND	ND	MDL	2046.2	ND	ND	2.5	3.2	0.0%
	8/12/97	0.45	8.3	MDL	ND	ND	ND	ND	1051.2	ND	ND	8.3	10.4	0.0%
	8/12/97	0.60	1.1	ND	ND	ND	ND	ND	1882.1	ND	ND	1.1	1.3	0.0%
	8/12/97	0.75	-	-	-	-	-	-	-	-	-	-	-	-
	8/12/97	0.90	-	-	-	-	-	-	-	-	-	-	-	-
	8/12/97	1.05	-	-	-	-	-	-	-	-	-	-	-	-
	8/12/97	1.20	-	-	-	-	-	-	-	-	-	-	-	-
	8/12/97	1.35	-	-	-	-	-	-	-	-	-	-	-	-
	8/12/97	1.50	-	-	-	-	-	-	-	-	-	-	-	-
	8/12/97	1.65	-	-	-	-	-	-	-	-	-	-	-	-
	8/12/97	1.80	-	-	-	-	-	-	-	-	-	-	-	-
	8/12/97	2.05	19.1	5001.2	ND	ND	ND	ND	1.6	ND	ND	5020.3	5025.4	99.5%
EB-2	8/13/97	NA	23.3	MDL	ND	ND	ND	ND	MDL	MDL	ND	23.3	29.4	0.0%
EB-2 (vial B)[13]	8/13/97	NA	5.8	MDL	-	-	-	-	-	-	-	-	-	-
PRP-8R	8/13/97	SW	3.0	ND	ND	ND	ND	ND	MDL	ND	ND	3.0	3.7	0.0%
	8/13/97	0.15	23.7	16.5	128.6	9.0	23.8	3060.0	148.8	8.0	ND	3269.6	5725.6	0.3%
	8/13/97	0.30	36.1	17.3	186.0	10.4	24.6	3238.1	99.9	5.2	ND	3517.7	6186.2	0.3%
	8/13/97	0.45	30.3	51.3	225.0	7.7	24.2	3036.7	87.3	5.1	ND	3380.3	5965.9	0.9%
Dup	8/13/97	0.45	30.4	50.9	211.1	9.8	22.2	3100.0	86.1	4.9	ND	3429.2	6035.9	0.8%
	8/13/97	0.60	20.6	33.6	698.2	9.2	18.5	2882.9	88.7	10.6	ND	3673.7	6953.7	0.5%
	8/13/97	0.75	11.8	11.1	1860.9	6.4	13.1	2589.9	312.6	52.2	0.9	4546.3	9740.8	0.1%
	8/13/97	0.90	6.9	1.6	598.0	8.6	12.4	2966.8	156.0	45.4	1.3	3640.9	6983.5	0.0%
	8/13/97	1.05	118.3	125.6	189.3	8.4	13.2	3046.0	29.0	3.4	MDL	3504.3	6045.2	2.1%
	8/13/97	1.20	314.9	3639.3	1.1	MDL	2.5	238.8	0.5	ND	MDL	4197.5	4454.0	81.7%
	8/13/97	1.35	-	-	-	-	-	-	-	-	-	-	-	-
	8/13/97	1.50	-	-	-	-	-	-	-	-	-	-	-	-

Location or sample name[1]	Date [2]	Depth m [3]	TCE µg/L	PCE µg/L	VC µg/L	11DCE µg/L	tDCE µg/L	cDCE µg/L	Methane µg/L[6]	Ethene µg/L	Ethane µg/L	Total VOCs µg/L	Total VOCs as PCE µg/L[4]	Percent as PCE[5]
	8/13/97	1.65	-	-	-	-	-	-	-	-	-	-	-	-
	8/13/97	1.80	-	-	-	-	-	-	-	-	-	-	-	-
	8/13/97	1.95	-	-	-	-	-	-	-	-	-	-	-	-
	8/13/97	2.10	-	-	-	-	-	-	-	-	-	-	-	-
EB-3	8/13/97	NA	0.9	MDL	ND	ND	ND	ND	MDL	MDL	ND	0.9	1.2	0.0%
PRP-9	8/13/97	SW	2.5	3.1	ND	ND	ND	ND	1.0	ND	ND	5.6	6.2	49.7%
	8/13/97	0.15	30.3	30.3	83.8	MDL	6.6	326.5	88.3	7.3	ND	484.8	904.0	3.3%
	8/13/97	0.30	12.5	4.3	74.1	ND	MDL	98.3	53.8	7.1	ND	196.4	427.1	1.0%
	8/13/97	0.45	4.2	1.0	56.2	ND	2.2	113.2	78.5	4.1	MDL	180.9	376.9	0.3%
	8/13/97	0.60	2.3	MDL	51.0	ND	MDL	84.3	289.5	4.6	0.9	143.1	314.4	0.0%
	8/13/97	0.75	2.1	MDL	89.9	ND	MDL	90.2	776.6	6.7	2.1	190.9	446.2	0.0%
	8/13/97	0.90	3.1	ND	37.4	ND	27.0	181.2	742.6	2.1	1.4	252.2	479.3	0.0%
Dup	8/13/97	0.90	3.1	MDL	31.4	ND	24.7	177.3	729.6	2.0	1.3	239.8	451.6	0.0%
	8/13/97	1.05	1.7	MDL	ND	ND	2.7	51.5	41.1	ND	ND	55.9	94.8	0.0%
	8/13/97	1.20	-	-	-	-	-	-	-	-	-	-	-	-
	8/13/97	1.50	4.5	10.2	ND	ND	ND	ND	51.7	ND	ND	14.7	15.9	64.1%
EB-4	8/14/97	NA	1.1	0.7	ND	ND	ND	ND	MDL	MDL	ND	1.9	2.2	33.6%
PRP-9	8/14/97	0.75	1.6	MDL	81.6	ND	MDL	94.1	779.7	5.9	2.1	185.4	426.2	0.0%
Dup-Hole[7]	8/14/97	1.50	2.0	103.1	ND	ND	ND	ND	1.6	ND	ND	105.1	105.6	97.6%
	8/14/97	1.63	3.3	6.8	ND	ND	ND	ND	35.3	ND	ND	10.1	10.9	62.0%
PRP-10	8/14/97	SW	1.0	MDL	ND	ND	ND	ND	MDL	ND	ND	1.0	1.3	0.0%
	8/14/97	0.15	1.3	MDL	77.0	ND	ND	100.6	857.6	1.9	1.9	182.6	399.7	0.0%
	8/14/97	0.30	2.6	MDL	117.0	ND	ND	83.1	810.2	1.9	1.8	206.4	476.8	0.0%
	8/14/97	0.45	1.8	MDL	171.1	ND	2.4	165.4	938.2	3.8	2.9	347.4	781.8	0.0%
	8/14/97	0.60	-	-	-	-	-	-	-	-	-	-	-	-
	8/14/97	0.75	1.4	24.1	ND	ND	ND	ND	7.6	ND	ND	25.6	25.9	93.0%
	8/14/97	0.90	2.3	24.1	ND	ND	ND	ND	17.0	ND	ND	26.4	27.0	89.2%
	8/14/97	1.05	5.3	MDL	ND	ND	ND	ND	86.8	ND	ND	5.3	6.7	0.0%
	8/14/97	1.20	2.0	MDL	ND	ND	ND	ND	78.1	ND	ND	2.0	2.6	0.0%
	8/14/97	1.35	1.2	1.2	ND	ND	ND	ND	73.5	ND	ND	2.4	2.7	44.8%
Dup	8/14/97	1.35	1.1	1.2	ND	ND	ND	ND	86.9	ND	ND	2.2	2.5	46.2%
	8/14/97	1.50	-	-	-	-	-	-	-	-	-	-	-	-

Location or sample name[1]	Date [2]	Depth m [3]	TCE μg/L	PCE μg/L	VC μg/L	11DCE μg/L	tDCE μg/L	cDCE μg/L	Methane μg/L[6]	Ethene μg/L	Ethane μg/L	Total VOCs μg/L	Total VOCs as PCE μg/L[4]	Percent as PCE[5]
	8/14/97	1.65	-	-	-	-	-	-	-	-	-	-	-	-
	8/14/97	1.85	-	-	-	-	-	-	-	-	-	-	-	-
	8/14/97	1.93	-	-	-	-	-	-	-	-	-	-	-	-
EB-5	8/14/97	NA	MDL	ND	ND	ND	ND	ND	MDL	MDL	MDL	0.0	0.0	0.0%
PRP-11	8/14/97	SW	MDL	MDL	ND	ND	ND	ND	MDL	ND	ND	0.0	0.0	0.0%
	8/14/97	0.15	MDL	MDL	ND	ND	ND	ND	MDL	ND	ND	0.0	0.0	0.0%
	8/14/97	0.55	MDL	MDL	ND	ND	ND	ND	43.4	ND	ND	0.0	0.0	0.0%
	8/14/97	1.05	MDL	MDL	ND	ND	ND	ND	26.0	ND	ND	0.0	0.0	0.0%
	8/14/97	1.65	-	-	-	-	-	-	-	-	-	-	-	-
EB-6	8/15/97	NA	2.3	ND	ND	ND	ND	ND	MDL	ND	ND	2.3	2.9	0.0%
PRP-12	8/15/97	SW	2.9	23.2	ND	ND	ND	ND	MDL	ND	ND	26.0	26.8	86.6%
	8/15/97	0.17	-	-	-	-	-	-	-	-	-	-	-	-
	8/15/97	0.30	2.0	841.4	ND	ND	ND	ND	26.8	ND	ND	843.4	844.0	99.7%
	8/15/97	0.50	-	-	-	-	-	-	-	-	-	-	-	-
	8/15/97	0.75	-	-	-	-	-	-	-	-	-	-	-	-
	8/15/97	1.00	-	-	-	-	-	-	-	-	-	-	-	-
	8/15/97	1.25	-	-	-	-	-	-	-	-	-	-	-	-
	8/15/97	1.50	-	-	-	-	-	-	-	-	-	-	-	-
	8/15/97	1.72	5.8	11.1	ND	ND	ND	MDL	2.8	ND	ND	16.9	18.4	60.3%
EB-7	8/15/97	NA	1.0	ND	ND	ND	ND	ND	MDL	MDL	ND	1.0	1.3	0.0%
EB-8[12]	8/15/97	At 0.50m	ND	ND	ND	ND	ND	ND	MDL	MDL	ND	0.0	0.0	0.0
PRP-13[11]	8/15/97	SW	MDL	MDL	ND	ND	ND	ND	1.2	ND	ND	0.0	0.0	0.0
	8/15/97	0.15	1.5	MDL	*12.0*	ND	MDL	MDL	4235.0	ND	ND	13.5	33.8	0.0%
	8/15/97	0.30	1.3	MDL	*9.0*	ND	2.3	12.2	4390.8	ND	ND	24.7	50.2	0.0%
Dup	8/15/97	0.30	MDL	MDL	*11.0*	ND	MDL	12.6	-	-	-	-	-	-
	8/15/97	0.50	-	-	-	-	-	-	-	-	-	-	-	-
	8/15/97	0.75	-	-	-	-	-	-	-	-	-	-	-	-
	8/15/97	1.00	-	-	-	-	-	-	-	-	-	-	-	-
	8/15/97	1.25	-	-	-	-	-	-	-	-	-	-	-	-
	8/15/97	1.50	16.6	214.3	ND	ND	ND	ND	0.9	ND	ND	230.8	235.2	91.1%
	8/15/97	1.75	-	-	-	-	-	-	-	-	-	-	-	-

Location or sample name[1]	Date [2]	Depth m [3]	TCE µg/L	PCE µg/L	VC µg/L	11DCE µg/L	tDCE µg/L	cDCE µg/L	Methane µg/L[6]	Ethene µg/L	Ethane µg/L	Total VOCs µg/L	Total VOCs as PCE µg/L[4]	Percent as PCE[5]
	8/15/97	1.90	1.4	52.7	ND	ND	ND	ND	MDL	ND	ND	54.1	54.5	96.8%
Spring [8]	8/15/97	0.15	3.7	778.5	ND	ND	ND	ND	0.6	ND	ND	782.2	783.2	99.4%
Spring Dup	8/15/97	0.15	1.2	666.4	ND	ND	ND	ND	16.3	ND	ND	667.6	668.0	99.8%
West of Rock #8[9]	8/11/97	0.00	32.9	410.5	ND	ND	ND	33.2	0.7	ND	ND	476.6	508.8	80.7%
Spring Old[10]	8/11/97	0.00	1.0	806.1	-	-	-	-		-	-	-	-	-
Trip Blank	8/12/97	NA	ND	ND	ND	ND	ND	ND	0.6	MDL	ND	0	0	0
DI #0	NA	NA	ND	ND	ND	ND	ND	ND	MDL	MDL	ND	0	0	0
DI #1	NA	NA	ND	ND	ND	ND	ND	ND	MDL	MDL	ND	0	0	0
DI #2	NA	NA	ND	MDL	ND	ND	ND	ND	MDL	MDL	MDL	0	0	0
DI #3	NA	NA	ND	ND	ND	ND	ND	ND	0.6	MDL	ND	0	0	0
DI #4	NA	NA	ND	ND	ND	ND	ND	ND	MDL	MDL	MDL	0	0	0
DI #5	NA	NA	ND	ND	ND	ND	ND	ND	MDL	MDL	ND	0	0	0
DI #6	NA	NA	ND	MDL	ND	ND	ND	ND	MDL	MDL	MDL	0	0	0
Blank (ECD)	NA	NA	ND	ND	NA	NA	NA	NA	NA	NA	NA	Inc	Inc	Inc
Air Blank (PID)	NA	NA	NA	NA	ND	ND	ND	ND	NA	NA	NA	Inc	Inc	Inc
Air Blank (PID)	NA	NA	NA	NA	ND	ND	ND	ND	NA	NA	NA	Inc	Inc	Inc
Air Blank (PID)	NA	NA	NA	NA	ND	ND	ND	ND	NA	NA	NA	Inc	Inc	Inc
Air Blank (PID)	NA	NA	NA	NA	ND	ND	ND	ND	NA	NA	NA	Inc	Inc	Inc
Air Blank (PID)	NA	NA	NA	NA	ND	ND	ND	ND	NA	NA	NA	Inc	Inc	Inc
Air Blank (FID)	NA	NA	NA	NA	NA	NA	NA	NA	MDL	ND	ND	Inc	Inc	Inc
Air Blank (FID)	NA	NA	NA	NA	NA	NA	NA	NA	MDL	ND	ND	Inc	Inc	Inc
Air Blank (FID)	NA	NA	NA	NA	NA	NA	NA	NA	MDL	ND	ND	Inc	Inc	Inc
Air Blank (FID)	NA	NA	NA	NA	NA	NA	NA	NA	MDL	ND	ND	Inc	Inc	Inc
Air Blank (FID)	NA	NA	NA	NA	NA	NA	NA	NA	MDL	ND	ND	Inc	Inc	Inc
		Detection Limit	0.9	0.7	0.7	3.2	1.9	7.8	0.5	0.5	0.5	NA	NA	NA

Notes:

Sampling performed by Brewster Conant and Matt Bogaart August 13-15, 1997

[1] Names ending in "SW" are surface water samples

Names with "Dup" in front of them are field duplicates

Name starting in "EQ" are equipment blanks collected in the field after decontaminating the sampling manifold
Names starting with "DI" are laboratory equipment blanks of the syringe using deionized water
"Airblanks" are laboratory blanks run to check gas chromatographs (ECD, PID, FID)

(2) Date that the sample was collected in the field

(3) Depths of "SW" is means sample is surface water from a few cm above the streambed

(4) Total VOCs as PCE is the molar total of all VOCs (except methane) expressed as equivalent concentrations of PCE in μg/L

(5) Percentage on a molar basis, the amount of PCE divided by total moles of VOCs (does not include methane)

(6) Concentrations of methane above 1000 μg/L are approximate

(7) Profiler reinserted at approximately the same PRP9 location (try to continue hole from prevoius day)

(8) Spring is located at Spring A, at 30-30W 1.85 m

(9) Rock #8 was name for a temporary painted rock marker for a spot at approximately 6-6W 5.5 m

(10) Spring is located at Spring A, at 30-30W 1.85 m, sample was old, not refridgerated for first 2 days

(11) At depth of 50 cm, took out the mini-profiler and started driving in a Waterloo profiler with sledge hammer

(12) This equipment blank is from the Waterloo profiler prior to use at the PRP13 location

(13) Samples collected in sets of 3 vials (A,B,C) ECD normally run on vial A, but used vial B as a field dupicate for EB-2

" - " means unable to collect or pump a sample from that particular depth
"ND" means compound not detected at all in the sample analyzed
"MDL" means trace amount of compound detected but below the detection limit and is not considered a real detection
"NA" means not applicable or not analyzed
"Inc" means totals are incomplete, missing one or more analyses for compounds

INORGANIC WATER QUALITY AT MINI-PROFILER LOCATIONS
PRP7R, PRP8R, AND PRP9 TO PRP13 (August 1997)

Location or sample name[1]	Depth m	Na mg/L	K mg/L	Ca mg/L	Mg mg/L	Alkalinity as $CaCO_3$ mg/L	SO_4 mg/L	Cl mg/L	Reactive Silica as SiO_2 mg/L	Ortho P mg/L	$NO_3 + NO_2$ as N mg/L	Ammonia as N mg/L[2]	Fe mg/L
PRP7R SW	0.00	8.9	1.5	59.7	16.6	191	16	15.8	9.3	< 0.01	1.71	< 0.05	0.04
PRP7R 0.15	0.15	9.7	2.7	79.9	25.5	303	6	17.1	10.4	< 0.01	< 0.05	1.17	< 0.02
PRP7R 0.30	0.30	9.7	3.1	94.8	31.6	365	2	18.6	17.8	< 0.01	< 0.05	1.73	0.13
PRP7R 0.45	0.45	9.3	2.8	113.0	26.1	367	11	19.3	21.8	0.03	< 0.05	1.36	1.27
PRP7R 0.60	0.60	13.4	4.4	131.0	25.5	417	< 2.0	28.4	28.0	0.11	< 0.05	2.40	8.43
PRP7R 2.00	2.05	49.9	11.6	114.0	10.4	311	31	76.9	11.9	0.02	0.54	< 0.05	0.02
PRP8R SW	0.00	15.4	1.5	64.6	16.2	187	16	17	9.4	< 0.01	0.93	< 0.05	0.06
PRP8R 0.15	0.15	74.5	6.5	140.0	28.6	442	32	110.0	21.1	< 0.01	< 0.05	2.60	0.16
PRP8R 0.30	0.30	69.7	10.9	141.0	18.2	416	33	101.0	22.9	0.01	0.11	1.89	0.62
PRP8R 0.45	0.45	70.1	13.6	145.0	12.7	413	30	101.0	21.5	0.02	< 0.05	1.27	1.67
PRP8R 0.60	0.60	70.5	14.2	149.0	13.2	406	29	101.0	21.9	0.02	< 0.05	1.13	1.83
PRP8R 0.75	0.75	58.6	12.7	135.0	13.2	372	15	90.9	18.9	0.01	< 0.05	0.75	3.92
PRP8R 0.90	0.90	49.8	12.2	120.0	12.6	330	22	81.1	14.3	< 0.01	< 0.05	0.39	3.41
PRP8R 1.05	1.05	48.5	12.6	116.0	10.9	306	27	76.7	12.2	< 0.01	0.05	0.20	4.72
PRP8R 1.20	1.20	43.6	12.8	114.0	10.3	300	27	72.3	11.6	< 0.01	< 0.05	< 0.05	1.11
PRP9 SW	0.00	7.6	0.9	58.9	14.6	181	16	13.2	9.0	< 0.01	0.89	< 0.05	0.03
PRP9 0.15	0.15	41.8	6.9	107.0	23.8	322	21	79.0	16.3	< 0.01	< 0.05	2.09	0.04
PRP9 0.30	0.30	41.8	10.5	120.0	10.3	310	21	81.2	21.7	0.01	< 0.05	1.42	0.60
PRP9 0.45	0.45	41.5	10.3	114.0	9.8	286	22	79.3	19.8	0.02	< 0.05	1.21	1.18
PRP9 0.60	0.60	41.4	10.1	107.0	9.4	280	15	79.4	16.4	0.03	< 0.05	0.93	2.89
PRP9 0.75	0.75	40.2	9.8	101.0	9.4	278	12	79.6	18.8	0.01	< 0.05	0.87	1.69
PRP9 0.75 Dup hole	0.75	40.2	9.5	99.4	9.4	271	5	80.3	19.6	0.04	< 0.05	0.91	3.19
PRP9 0.90	0.90	40.1	8.2	91.2	9.0	231	2	83.2	14.8	0.06	< 0.05	0.72	0.44
PRP9 1.05	1.05	35.7	5.6	84.9	9.8	200	16	77.4	11.7	0.03	0.12	0.15	0.09
PRP9 1.50	1.50	33.0	3.8	81.8	10.7	186	17	73.4	12.6	< 0.01	< 0.05	0.14	0.54
PRP9 1.50 Dup hole[3]	1.50	42.4	9.5	103.0	9.4	237	26	83.1	9.3	0.01	1.90	< 0.05	0.03
PRP9 1.63 Dup hole[3]	1.63	44.4	7.3	91.0	10.8	202	27	103.0	8.3	< 0.01	0.06	0.11	0.49
PRP10 SW	0.00	7.7	1.1	60.7	15.9	193	17	14.1	9.4	< 0.01	1.09	< 0.05	0.03
PRP10 0.15	0.15	44.3	9.8	108.0	9.4	288	< 2	94.1	20.0	0.07	< 0.05	1.05	4.03
PRP10 0.30	0.30	44.3	10.2	103.0	9.0	267	< 2	94.3	16.1	0.05	< 0.05	0.73	7.67
PRP10 0.45	0.45	44.4	10.3	98.6	9.1	254	< 2	92.8	13.0	0.02	< 0.05	0.49	6.34

Location or sample name[1]	Depth m	Na mg/L	K mg/L	Ca mg/L	Mg mg/L	Alkalinity as $CaCO_3$ mg/L	SO_4 mg/L	Cl mg/L	Reactive Silica as SiO_2 mg/L	Ortho P mg/L	$NO_3 + NO_2$ as N mg/L	Ammonia as N mg/L[2]	Fe mg/L
PRP10 0.75	0.75	43.7	7.3	91.4	10.5	199	27	98.7	8.7	< 0.01	< 0.05	< 0.05	0.04
PRP10 0.90	0.90	39.8	6.9	86.2	9.9	184	26	90.6	9.2	< 0.01	4.10	< 0.05	0.03
PRP10 1.05	1.05	27.7	3.0	79.2	9.6	198	14	57.3	12.8	0.03	< 0.05	0.21	0.19
PRP10 1.20	1.20	27.1	2.1	79.6	9.5	195	18	55.3	12.3	0.01	< 0.05	0.14	0.46
PRP10.1.35	1.35	35.6	4.5	85.6	10.5	191	22	80.8	10.9	< 0.01	< 0.05	0.12	0.64
PRP11 SW	0.00	8.6	1.1	62.5	14.2	190	16	15.3	10.6	< 0.01	0.94	< 0.05	0.08
PRP11 0.15	0.15	21.3	1.7	76.7	8.3	221	4	31.8	16.9	0.30	< 0.05	0.47	0.16
PRP11 0.55	0.55	19.0	1.2	77.6	8.5	210	16	29.4	12.5	0.04	< 0.05	0.13	0.12
PRP11 1.05	1.05	16.7	0.9	79.1	8.0	221	22	26.1	11.9	0.01	< 0.05	0.06	0.27
PRP12 SW	0.00	9.1	1.3	61.9	15.9	193	17	17.0	8.8	< 0.01	0.98	< 0.05	0.03
PRP12 0.30	0.30	54.0	9.4	102.0	10.9	226	27	115.0	8.1	< 0.01	1.70	0.06	0.02
PRP12 1.72	1.72	56.3	7.5	112.0	9.6	267	30	97.3	9.1	< 0.01	< 0.05	0.14	0.64
Spring[5]	0.00	53.6	9.4	101.0	10.9	217.0	28	116.0	8.1	< 0.01	1.66	< 0.05	0.03
Spring Dup[5]	0.00	54.5	9.4	103.0	11.0	218	29	115.0	8.0	< 0.01	1.80	< 0.05	0.072
PRP13 SW	0.00	8.0	0.9	60.7	16.2	196	17	13.8	9.5	< 0.01	1.03	< 0.05	0.03
PRP13 0.15	0.15	38.6	3.7	114.0	21.6	314	5	94.4	25.5	0.06	< 0.05	1.87	5.75
PRP13 0.30	0.30	37.0	4.6	111.0	17.7	296	< 2	100.0	20.6	0.18	< 0.05	1.59	7.85
PRP13 1.50	1.50	49.8	9.4	96.9	12.4	227	33	109.0	8.5	< 0.01	< 0.05	0.09	0.52
PRP13 1.90	1.90	47.3	10.3	97.3	11.9	225	31	98.8	6.5	< 0.01	0.34	< 0.05	0.04
AM-H-20.5 ft[4]	6.25	12.8	4.7	119	13.1	244	17	27.6	12.9	< 0.01	17.9	< 0.05	< 0.020
TRIP	NA	0.2	< 0.1	< 0.1	< 0.1	< 1	< 2	< 1.0	< 0.5	< 0.01	< 0.05	< 0.05	< 0.02
EB-1	NA	0.4	< 0.1	0.8	0.1	1	< 2	< 1.0	< 0.5	< 0.01	0.15	< 0.05	< 0.02
EB-6	NA	0.2	< 0.1	0.3	< 0.1	1	< 2	< 1.0	< 0.5	< 0.01	< 0.05	< 0.05	< 0.02
Results of re-analysis of selected samples and parameters													
PRP7R 0.45	0.45						12.2						
PRP9 0.75 Dup hole[3]	0.75						10.3						
PRP9 1.50 Dup hole[3]	1.50	40.8	9.4	101	9.2	228	25.2	83.3			1.97		
PRP9 1.63 Dup hole[3]	1.63	46.6	7.7	94	11.3	203	28	96.1			< 0.05		
PRP10 1.05	1.05							56.2					
PRP10 1.20	1.2							54.6					
Detection Limit	NA	0.1	0.1	0.1	0.1	1	2	1	0.5	0.01	0.05	0.05	0.02

Location or sample name(1)	Depth m	Mn mg/L	Cu mg/L	Zn mg/L	Color	Spec. Cond. µS/cm	pH	DOC mg/L	Hardness as $CaCO_3$ mg/L	Bicarbonate as $CaCO_3$ mg/L	Carbonate as $CaCO_3$ mg/L	TDS mg/L
PRP7R SW	0.00	0.01	< 0.01	0.01	9	530	8.1	13.4	217	189	2.2	250
PRP7R 0.15	0.15	1.50	< 0.01	0.11	23	638	8.0	11.1	304	300	2.8	335
PRP7R 0.30	0.30	4.93	0.01	0.17	46	775	8.0	15.4	367	362	3.4	399
PRP7R 0.45	0.45	3.55	< 0.01	0.13	65	796	7.8	16.1	390	365	2.2	425
PRP7R 0.60	0.60	3.29	< 0.01	0.15	180	875	7.5	57.0	432	416	1.2	486
PRP7R 2.00	2.05	0.26	< 0.01	0.16	9	905	7.5	3.2	327	310	< 1.0	495
PRP8R SW	0.00	0.05	< 0.01	< 0.01	18	450	8.1	3.8	228	185	2.2	256
PRP8R 0.15	0.15	7.12	< 0.01	0.02	30	1260	7.9	7.6	467	439	3.3	681
PRP8R 0.30	0.30	7.44	< 0.01	0.01	34	1200	7.8	7.4	427	414	2.5	649
PRP8R 0.45	0.45	7.44	< 0.01	0.03	47	1170	7.7	7.1	414	411	1.9	644
PRP8R 0.60	0.60	5.25	< 0.01	0.01	48	1200	7.7	7.4	426	404	1.9	644
PRP8R 0.75	0.75	3.52	< 0.01	0.01	56	1090	7.6	5.8	391	371	1.4	569
PRP8R 0.90	0.90	0.80	< 0.01	0.01	30	988	7.6	4.1	352	329	1.2	511
PRP8R 1.05	1.05	0.34	< 0.01	0.02	29	942	7.6	3.4	335	305	1.1	488
PRP8R 1.20	1.20	0.02	< 0.01	0.02	17	847	7.8	3.3	327	298	1.8	472
PRP9 SW	0.00	0.03	< 0.01	< 0.01	15	457	8.2	4.3	207	178	2.7	233
PRP9 0.15	0.15	4.38	< 0.01	< 0.01	26	915	8.1	6.9	365	318	3.8	492
PRP9 0.30	0.30	5.07	< 0.01	< 0.01	38	929	8.0	7.7	342	307	2.9	495
PRP9 0.45	0.45	5.89	< 0.01	< 0.01	42	891	8.0	6.8	325	283	2.7	470
PRP9 0.60	0.60	6.53	< 0.01	< 0.01	54	851	7.9	5.8	306	278	2.1	448
PRP9 0.75	0.75	8.45	< 0.01	< 0.01	28	837	7.8	4.4	291	276	1.6	439
PRP9 0.75 Dup hole	0.75	6.45	< 0.01	0.10	63	817	7.9	4.3	287	269	2.0	427
PRP9 0.90	0.90	0.40	< 0.01	< 0.01	15	739	7.8	2.9	265	230	1.4	388
PRP9 1.05	1.05	0.16	< 0.01	< 0.01	6	706	7.9	2.0	252	198	1.5	362
PRP9 1.50	1.50	0.12	< 0.01	< 0.01	8	675	8.0	1.4	248	184	1.7	344
PRP9 1.50 Dup hole(3)	1.50	0.10	< 0.01	0.02	8	817	7.9	2.9	296	235	1.8	433
PRP9 1.63 Dup hole(3)	1.63	0.12	< 0.01	< 0.01	7	813	7.9	1.7	272	200	1.5	413
PRP10 SW	0.00	0.02	< 0.01	< 0.01	14	478	8.3	3.7	217	189	3.6	247
PRP10 0.15	0.15	4.09	< 0.01	< 0.01	69	867	7.9	6.6	308	286	2.1	462
PRP10 0.30	0.30	2.27	< 0.01	< 0.01	66	842	7.8	4.3	294	265	1.6	440
PRP10 0.45	0.45	0.41	< 0.01	< 0.01	38	819	7.8	3.7	284	252	1.5	423

Location or sample name[1]	Depth m	Mn mg/L	Cu mg/L	Zn mg/L	Color	Spec. Cond. µS/cm	pH	DOC mg/L	Hardness as $CaCO_3$ mg/L	Bicarbonate as $CaCO_3$ mg/L	Carbonate as $CaCO_3$ mg/L	TDS mg/L
PRP10 0.75	0.75	0.12	< 0.01	< 0.01	< 5	810	7.9	2.0	271	197	1.5	407
PRP10 0.90	0.90	0.11	< 0.01	< 0.01	< 5	786	7.7	2.1	256	183	< 1	397
PRP10 1.05	1.05	0.08	< 0.01	< 0.01	8	726	8.0	1.6	237	196	1.8	323
PRP10 1.20	1.20	0.08	< 0.01	< 0.01	11	620	8.0	1.6	238	193	1.8	321
PRP10.1.35	1.35	0.09	< 0.01	< 0.01	10	790	8.0	1.6	257	189	1.8	365
PRP11 SW	0.00	0.12	< 0.01	< 0.01	15	492	8.1	3.5	215	188	2.2	247
PRP11 0.15	0.15	0.21	< 0.01	< 0.01	12	568	8.0	2.3	226	219	2.1	294
PRP11 0.55	0.55	0.08	< 0.01	< 0.01	8	570	8.0	2.1	229	208	2.0	291
PRP11 1.05	1.05	0.07	< 0.01	< 0.01	9	563	7.9	1.5	230	209	1.6	292
PRP12 SW	0.00	0.02	< 0.01	< 0.01	14	490	8.2	3.7	220	190	2.8	251
PRP12 0.30	0.30	0.12	< 0.01	< 0.01	8	921	7.8	2.5	300	225	1.3	470
PRP12 1.72	1.72	0.16	< 0.01	< 0.01	16	922	7.9	3.4	319	265	2.0	482
Spring[5]	0.00	0.12	< 0.01	< 0.01	8	920	7.9	2.7	297	215	1.6	465
Spring Dup[5]	0.00	0.12	< 0.003	0.026	9	918	7.8	2.5	302	217	1.3	469
PRP13 SW	0.00	0.01	< 0.01	< 0.01	11.00	486	7.8	3.5	218	195	1.2	248
PRP13 0.15	0.15	4.34	< 0.01	< 0.01	130	911	7.8	9.3	374	312	1.9	494
PRP13 0.30	0.30	1.23	< 0.01	< 0.01	130	913	7.8	6.5	350	294	1.7	473
PRP13 1.50	1.50	0.14	< 0.01	< 0.01	20	880	8.1	3.4	293	224	2.7	456
PRP13 1.90	1.90	0.11	< 0.01	< 0.01	< 5	872	8.0	3.5	292	223	2.1	440
AM-H-20.5 ft[4]	6.25	0.019	0.009	0.007	12	769	8.1	6.4	351	241	2.9	433
TRIP	NA	< 0.005	0.005	< 0.005	< 5.0	3.18	6.2	< 0.5	< 0.1	< 1	< 1.0	4
EB-1	NA	< 0.005	< 0.003	0.024	< 5.0	6.91	6.4	8.1	2.4	< 1	< 1.0	6
EB-6	NA	< 0.01	< 0.01	0.02	5	4.62	6.5	1.5	0.7	< 1	< 1.0	5
Results of re-analysis of sele												
PRP7R 0.45	0.45											
PRP9 0.75 Dup hole[3]	0.75											
PRP9 1.50 Dup hole[3]	1.50											
PRP9 1.63 Dup hole[3]	1.63											
PRP10 1.05	1.05											
PRP10 1.20	1.2											
Detection Limit	NA	0.01	0.01	0.01	5	1	0.1	0.5	0.1	1	1	1

Location or sample name[1]	Depth m	Cation Sum meq/L	Anion Sum meq/L	Ion Balance %	Langlier Index @ 4 C	Langlier Index @ 20 C	Saturation Index @ 4 C	Saturation Index @ 20 C
PRP7R SW	0.00	4.77	4.72	0.57	0.29	0.69	7.81	7.41
PRP7R 0.15	0.15	6.66	6.67	0.08	0.51	0.91	7.49	7.09
PRP7R 0.30	0.30	7.96	7.87	0.55	0.66	1.06	7.34	6.94
PRP7R 0.45	0.45	8.36	8.12	1.48	0.53	0.93	7.27	6.87
PRP7R 0.60	0.60	9.50	9.19	1.69	0.35	0.75	7.15	6.75
PRP7R 2.00	2.05	9.02	9.07	0.31	0.16	0.56	7.34	6.94
PRP8R SW	0.00	5.27	4.62	6.57	0.32	0.72	7.78	7.38
PRP8R 0.15	0.15	12.90	12.60	1.26	0.79	1.19	7.11	6.71
PRP8R 0.30	0.30	12.00	11.90	0.49	0.66	1.06	7.14	6.74
PRP8R 0.45	0.45	11.80	11.70	0.14	0.57	0.97	7.13	6.73
PRP8R 0.60	0.60	12.00	11.60	1.94	0.58	0.98	7.12	6.92
PRP8R 0.75	0.75	10.80	10.30	2.05	0.4	0.8	7.2	6.8
PRP8R 0.90	0.90	9.53	9.35	0.97	0.31	0.71	7.29	6.89
PRP8R 1.05	1.05	9.13	8.85	1.58	0.26	0.66	7.34	6.94
PRP8R 1.20	1.20	8.76	8.60	0.92	0.45	0.85	7.35	6.95
PRP9 SW	0.00	4.50	4.39	1.23	0.37	0.77	7.83	7.43
PRP9 0.15	0.15	9.44	9.11	1.80	0.75	1.15	7.35	6.95
PRP9 0.30	0.30	9.02	8.93	0.52	0.68	1.08	7.32	6.92
PRP9 0.45	0.45	8.65	8.42	1.37	0.62	1.02	7.38	6.98
PRP9 0.60	0.60	8.24	8.15	0.51	0.49	0.89	7.41	7.01
PRP9 0.75	0.75	7.88	8.06	1.15	0.36	0.76	7.44	7.04
PRP9 0.75 Dup hole	0.75	7.79	7.79	0.01	0.45	0.85	7.45	7.05
PRP9 0.90	0.90	7.30	7.01	2.00	0.24	0.64	7.56	7.16
PRP9 1.05	1.05	6.75	6.52	1.70	0.25	0.65	7.65	7.25
PRP9 1.50	1.50	6.51	6.15	2.83	0.31	0.71	7.69	7.29
PRP9 1.50 Dup hole[3]	1.50	8.00	7.76	1.55	0.4	0.8	7.5	7.1
PRP9 1.63 Dup hole[3]	1.63	7.56	7.51	0.30	0.28	0.68	7.62	7.22
PRP10 SW	0.00	4.70	4.69	0.16	0.5	0.9	7.8	7.4
PRP10 0.15	0.15	8.42	8.46	0.26	0.5	0.9	7.4	7
PRP10 0.30	0.30	8.12	8.04	0.47	0.35	0.75	7.45	7.05
PRP10 0.45	0.45	7.90	7.74	1.00	0.31	0.71	7.49	7.09

Location or sample name[1]	Depth m	Cation Sum meq/L	Anion Sum meq/L	Ion Balance %	Langlier Index @ 4 C	Langlier Index @ 20 C	Saturation Index @ 4 C	Saturation Index @ 20 C
PRP10 0.75	0.75	7.52	7.33	1.27	0.28	0.68	7.62	7.22
PRP10 0.90	0.90	7.03	7.07	0.29	0.02	0.42	7.68	7.28
PRP10 1.05	1.05	6.04	5.87	1.41	0.32	0.72	7.68	7.28
PRP10 1.20	1.20	6.00	5.84	1.34	0.32	0.72	7.68	7.28
PRP10.1.35	1.35	6.81	6.56	1.86	0.34	0.74	7.66	7.26
PRP11 SW	0.00	4.69	4.63	0.66	0.31	0.71	7.79	7.39
PRP11 0.15	0.15	5.51	5.40	1.01	0.36	0.76	7.64	7.24
PRP11 0.55	0.55	5.44	5.37	0.67	0.34	0.74	7.66	7.26
PRP11 1.05	1.05	5.36	5.42	0.54	0.25	0.65	7.65	7.25
PRP12 SW	0.00	4.83	4.76	0.70	0.41	0.81	7.79	7.39
PRP12 0.30	0.30	8.58	8.45	0.79	0.27	0.67	7.53	7.13
PRP12 1.72	1.72	9.03	8.71	1.80	0.49	0.89	7.41	7.01
Spring[5]	0.00	8.51	8.31	1.19	0.35	0.75	7.55	7.15
Spring Dup[5]	0.00	8.66	8.33	1.91	0.26	0.66	7.54	7.14
PRP13 SW	0.00	4.74	4.74	0.01	0.01	0.41	7.79	7.39
PRP13 0.15	0.15	9.37	9.05	1.76	0.46	0.86	7.34	6.94
PRP13 0.30	0.30	8.84	8.79	0.29	0.43	0.83	7.37	6.97
PRP13 1.50	1.50	8.27	8.30	0.21	0.55	0.95	7.55	7.15
PRP13 1.90	1.90	8.16	7.96	1.27	0.45	0.85	7.55	7.15
AM-H-20.5 ft[4]	6.25	7.7	7.29	2.72	0.68	1.08	7.42	7.02
TRIP	NA	0.03	0.09	53.00	-5.60	-5.20	11.80	11.40
EB-1	NA	0.07	0.10	16.50	-5.40	-5.00	11.80	11.40
EB-6	NA	0.04	0.09	41.80	-5.30	-4.90	11.80	11.40
Results of re-analysis of sele								
PRP7R 0.45	0.45							
PRP9 0.75 Dup hole[3]	0.75							
PRP9 1.50 Dup hole[3]	1.50							
PRP9 1.63 Dup hole[3]	1.63							
PRP10 1.05	1.05							
PRP10 1.20	1.2							
Detection Limit	NA	NA	NA	NA	NA	NA	NA	NA

Notes:

Sampling performed by Brewster Conant and Matt Bogaart August 13-15, 1997
Laboratory analyses performed by MDS (Halifax, Nova Scotia) using Rcap30 suite
Samples EB-1, TRIP, AM-H-20.5 ft, and SPRING Dup, were analyzed by Rcap 50, so have additional data not shown
(1) Names ending in "SW" are surface water samples
  Names with "Dup" in front of them are field duplicates
  Name starting in "EQ" are equipment blanks collected in the field after decontaminating the sampling manifold
(2) Ammonia is total ammonia and ammonium
(3) Profiler reinserted at approximately the same PRP9 location (try to continue hole from previous day)
(4) Sample collected from profile done by Guilbeault (1999) immediately in front of the dry cleaner building
(5) Spring is located at Spring A, at 30-30W 1.85 m
DOC = dissolved organic carbon
N = nitrogen
NA = not analyzed or not applicable
Spec. Cond. = specific conductance
"< " means parameter below detection limit specified
"NA" means not applicable or not analyzed

FIELD PARAMETERS AT MINI-PROFILER LOCATIONS PRP7R, PRP8R, AND PRP9 TO PRP13 (August 1997)

Location[(1)]	Temp °C	pH	Eh at 25 °C mV	Dissolved Oxygen mg/L	Sulfide mg/L	Specific Conduct. µS/cm
PRP7R SW	21.5	8.12	379.3	6.1	0	340
PRP7R 0.15	22.2	7.84	402.1	0.68	0	583
PRP7R 0.30	23.1	7.65	300.2	0.68	0	696
PRP7R 0.45	22.9	7.5	80.2	0.81	0	710
PRP7R 0.60	22.7	7.18	63.0	0.53	0	803
PRP7R 2.00	22.7	6.93	350.0	0.45	0	696
PRP8R SW	20.4	7.84	401.2	4.3	0	397
PRP8R 0.15	19.5	7.41	278.7	0.51	0	1109
PRP8R 0.30	19.6	7.39	160.2	0.27	0	1071
PRP8R 0.45	19.6	7.23	152.6	0.71	0	1015
PRP8R 0.60	19.6	7.23	143.8	0.39	0	1023
PRP8R 0.75	19.7	7.16	123.0	0.34	0	845
PRP8R 0.90	19.2	7.06	148.2	0.43	0	755
PRP8R 1.05	18.7	6.97	144.7	0.61	0	757
PRP8R 1.20	19.7	7.1	234.2	0.58	0	680
PRP9 SW	21.6	7.94	430.4	3.8	0	414
PRP9 0.15	21.3	7.74	444.7	0.27	0	839
PRP9 0.30	20.8	754	157.7	0.34	0	757
PRP9 0.45	20.3	7.48	105.2	0.32	0	796
PRP9 0.60	20.1	7.36	72.7	0.43	0	773
PRP9 0.75	20.2	7.37	99.6	0.33	0	751
PRP9 0.75 Dup hole[(2)]	17.9	7.05	102.0	0.34	0	743
PRP9 0.90	20.8	7.24	182.1	0.31	0.05	683
PRP9 1.05	20.8	7.28	233.0	0.29	0.03	606
PRP9 1.50	19	7.35	131.5	0.17	0	586
PRP9 1.50 Dup hole[(2)]	17.5	6.86	342.8	1.6	0	729
PRP9 1.63 Dup hole[(2)]	18	7	344.8	0.29	0	602
PRP10 SW	19.4	7.76	398.5	6.3	0	417
PRP10 0.15	19.4	7.2	87.7	0.34	0	739
PRP10 0.30	19.2	6.9	73.5	0.25	0	709
PRP10 0.45	19.4	7.05	83.7	0.31	0	683
PRP10 0.75	20.3	6.88	398.1	0.65	0	675
PRP10 0.90	20.2	7.18	404.8	0.23	0	638
PRP10 1.05	20.7	7.29	207.9	0.46	0.07	550
PRP10 1.20	20.4	7.29	155.0	0.23	0	521
PRP10.1.35	20.2	7.26	176.1	0.42	0	609
PRP11 SW	20.4	7.5	400.6	2.2	0	417
PRP11 0.15	20.1	7.24	182.5	0.43	0.27	493
PRP11 0.55	20.7	7.34	150.7	0.47	0.21	463
PRP11 1.05	20.5	7.31	151.9	0.27	0	485
PRP12 SW	16.6	7.55	385.9	4.8	0	453
PRP12 0.30	21.3	7.15	434.1	0.28	0	742
PRP12 1.72	23.5	7.05	201.7	0.68	0	758

Location[1]	Temp °C	pH	Eh at 25 °C mV	Dissolved Oxygen mg/L	Sulfide mg/L	Specific Conduct. µS/cm
Spring[4]	19.1	7.1	415.6	0.44	0	820
Spring Dup[4]	NA	NA	NA	NA	NA	NA
PRP13 SW	22.9	8.02	422.0	6.1	0	441
PRP13 0.15	23.2	7.18	70.5	0.13	0	857
PRP13 0.30	22.8	7.25	55.8	0.24	0	787
PRP13 1.50	21.1	7.39	216.9	0.33	0	764
PRP13 1.90	20.4	7.24	410.6	0.75[5]	0.07[5]	675
AM-H-20.5 ft[3]	NA	NA	NA	NA	NA	NA
EB-1	20.1	7.49	304.9	NA	NA	4.01

Notes:

Sampling performed by Brewster Conant and Matt Bogaart August 13-15, 1997

All parameters measured in the field after purge 100 ml

[1] Names ending in "SW" are surface water samples

Names with "Dup" in front of them are field duplicates

Name starting in "EQ" are equipment blanks collected in the field

[2] Profiler reinserted at approximately the same PRP9 location (try to continuE from previous day)

[3] Sample collected from profile done by Guilbeault (1999) in front of the dry cleaner building

[4] Spring is located at Spring A, at 30-30W 1.85 m

[5] Bad DO and Sulfide readings (should be lower) - silty water affects readings

Dissolved oxygen and total sulfide measured using CheMetrics photometer and vacu-vials

Eh corrected using a polynomial interpolation of temperature function

mV = millivolts

NA = Not applicable

VOC WATER QUALITY AT MINI-PROFILER LOCATIONS PRP14, PRP15, AND PRP16

October 1997

Location or sample name[1]	Depth m[2]	TCE µg/L	PCE µg/L	VC µg/L	11DCE µg/L	tDCE µg/L	cDCE µg/L	Methane µg/L	Ethene µg/L	Ethane µg/L	Total VOCs µg/L	Total VOCs as PCE µg/L[3]	Percent as PCE[4]
EB-1	NA	ND	44.0	ND	ND	ND	ND	ND	ND	ND	44.0	44.0	100%
PRP14	SW	ND	33.5	ND	ND	ND	ND	9.6	ND	ND	33.5	33.5	100%
	0.15	3.3	34.6	17.4	ND	ND	239.1	24.0	ND	ND	294.4	495.9	7%
	0.30	194.3	59.4	ND	ND	ND	55.2	26.8	ND	ND	308.9	399.5	15%
	0.45	170.3	78.9	ND	ND	ND	60.0	26.5	ND	ND	309.1	396.9	20%
	0.60	44.4	296.1	ND	ND	ND	ND	22.3	ND	ND	340.4	352.1	84%
Dup	0.60	45.5	294.3	ND	ND	ND	ND	27.0	ND	ND	339.8	351.7	84%
	0.75	-	-	-	-	-	-	-	-	-	-	-	-
	0.90	-	-	-	-	-	-	-	-	-	-	-	-
	1.05	-	-	-	-	-	-	-	-	-	-	-	-
	1.20	-	-	-	-	-	-	-	-	-	-	-	-
	1.35	-	-	-	-	-	-	-	-	-	-	-	-
	1.50	-	-	-	-	-	-	-	-	-	-	-	-
	1.65	-	-	-	-	-	-	-	-	-	-	-	-
	1.77	-	-	-	-	-	-	-	-	-	-	-	-
	1.80	-	-	-	-	-	-	-	-	-	-	-	-
EB-2	NA	ND	2.3	ND	ND	ND	ND	ND	0.5	ND	2.9	5.5	43%
PRP15	SW	ND	67.2	ND	ND	ND	ND	4.5	ND	ND	67.2	67.2	100%
	0.15	51.9	1291.6	ND	ND	ND	35.0	31.7	ND	ND	1378.5	1417.3	91%
	0.15	54.1	1318.3	ND	ND	ND	44.7	30.4	ND	ND	1417.0	1463.3	90%
	0.30	138.0	1432.0	ND	ND	4.2	69.3	86.1	ND	ND	1643.4	1732.4	83%
Dup	0.30	137.8	1438.1	ND	ND	4.1	71.5	74.8	ND	ND	1651.6	1742.1	83%
	0.45	97.1	348.8	ND	ND	23.7	549.7	193.0	ND	ND	1019.2	1456.7	24%
	0.60	161.1	532.5	ND	ND	16.7	416.3	134.3	ND	ND	1126.7	1480.1	36%
	0.75	151.3	1279.0	ND	ND	8.3	101.4	83.4	ND	ND	1540.0	1658.5	77%
	1.20	224.4	519.8	ND	ND	24.9	369.7	89.6	ND	ND	1138.7	1481.0	35%
	1.35	198.6	747.2	ND	ND	32.5	431.8	303.1	ND	ND	1410.2	1795.9	42%
	1.50	250.2	1108.9	ND	ND	21.2	287.5	203.1	ND	ND	1667.8	1955.2	57%

Location or sample name[1]	Depth m[2]	TCE µg/L	PCE µg/L	VC µg/L	11DCE µg/L	tDCE µg/L	cDCE µg/L	Methane µg/L	Ethene µg/L	Ethane µg/L	Total VOCs µg/L	Total VOCs as PCE µg/L[3]	Percent as PCE [4]
	1.65	257.2	936.5	ND	ND	20.2	204.9	218.5	ND	ND	1418.8	1647.9	57%
	1.65	238.1	826.8	ND	ND	37.2	346.9	217.2	ND	ND	1449.0	1787.4	46%
EB-3	NA	ND	7.2	ND	ND	ND	ND	ND	ND	ND	7.2	7.2	100%
PRP16	SW	ND	4.0	ND	ND	ND	ND	5.8	ND	ND	4.0	4.0	100%
	0.15	ND	1.8	ND	ND	ND	ND	334.3	ND	ND	1.8	1.8	100%
	0.30	ND	1.9	ND	ND	ND	ND	129.3	ND	ND	1.9	1.9	100%
	0.45	1.4	5.6	ND	ND	ND	ND	43.3	ND	ND	7.0	7.3	76%
	0.60	ND	6.9	ND	ND	ND	ND	7.8	ND	ND	6.9	6.9	100%
	0.75	ND	3.6	ND	ND	ND	ND	10.1	ND	ND	3.6	3.6	100%
	0.90	ND	6.6	ND	ND	ND	ND	ND	ND	ND	6.6	6.6	100%
	1.20	ND	3.0	ND	ND	ND	ND	ND	ND	ND	3.0	3.0	100%
Dup	1.20	ND	4.4	ND	ND	ND	ND	ND	ND	ND	4.4	4.4	100%
	1.50	ND	2.2	ND	ND	ND	ND	ND	ND	ND	2.2	2.2	100%
	2.00	ND	2.5	ND	ND	ND	ND	0.6	ND	ND	2.5	2.5	100%
Trip Blank	NA	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA	NA	NA
DI #1	NA	ND	ND	ND	ND	ND	ND	ND	ND	0.6			
DI #2	NA	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA	NA	NA
DI #3	NA	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA	NA	NA
Blank	NA	ND	ND	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Blank Pentane	NA	ND	ND	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Blank Nov 5	NA	ND	ND	NA	NA	NA	NA	NA	NA	NA	Inc	Inc	Inc
Blank Nov 7	NA	ND	ND	NA	NA	NA	NA	NA	NA	NA	Inc	Inc	Inc
Air Blank	NA	NA	NA	ND	ND	ND	ND	NA	NA	NA	Inc	Inc	Inc
Air Blank	NA	NA	NA	ND	ND	ND	ND	NA	NA	NA	Inc	Inc	Inc
EB-1	NA	ND	58.3	NA	NA	NA	NA	NA	NA	NA	Inc	Inc	Inc
EB-1 vial B	NA	ND	75.3	NA	NA	NA	NA	NA	NA	NA	Inc	Inc	Inc
EB-1 vial C	NA	ND	44.0	NA	NA	NA	NA	NA	NA	NA	Inc	Inc	Inc
EB-3	NA	ND	16.0	NA	NA	NA	NA	NA	NA	NA	Inc	Inc	Inc
EB-3 vial B	NA	ND	54.0	NA	NA	NA	NA	NA	NA	NA	Inc	Inc	Inc
EB-3 vial C	NA	ND	7.2	NA	NA	NA	NA	NA	NA	NA	Inc	Inc	Inc

Location or sample name(1)	Depth m(2)	TCE µg/L	PCE µg/L	VC µg/L	11DCE µg/L	tDCE µg/L	cDCE µg/L	Methane µg/L	Ethene µg/L	Ethane µg/L	Total VOCs µg/L	Total VOCs as PCE µg/L(3)	Percent as PCE (4)
Reanalysis of select samples(5)													
PRP14-SW	NA	ND	71.8	NA	NA	NA	NA	NA	NA	NA	Inc	Inc	Inc
PRP14 SW vial B	NA	ND	70.7	NA	NA	NA	NA	NA	NA	NA	Inc	Inc	Inc
PRP14 SW vial C	NA	ND	33.5	NA	NA	NA	NA	NA	NA	NA	Inc	Inc	Inc
PRP16-SW	NA	ND	2.9	NA	NA	NA	NA	NA	NA	NA	Inc	Inc	Inc
PRP16-SW vial B	NA	ND	19.7	NA	NA	NA	NA	NA	NA	NA	Inc	Inc	Inc
PRP16-SW vial C	NA	ND	4.0	NA	NA	NA	NA	NA	NA	NA	Inc	Inc	Inc
Detection Limits		0.7	0.9	0.7	3.2	1.9	7.8	0.5	0.5	0.5	NA	NA	NA

Notes:

Sampling performed by Brewster Conant and Ryan Lyle October 29-31, 1997

Sampled PRP14 on 10/29, PRP15 on 10/30, and PRP16 on 10/31

Equipment blanks have high levels of PCE in them. Problem with water freezing in line so can't properly decon.

Equipment blank collected just before SW samples, so likely some carry over to those samples

(1) Names with "Dup" in front of them are field duplicates
Name starting in "EQ" are equipment blanks collected in the field after decontaminating the sampling manifold
Names starting with "DI" are laboratory equipment blanks of the syringe using deionized water
"Airblanks" are laboratory blanks run to check gas chromatographs (ECD, PID, FID)

(2) Depths of "SW" is means sample is surface water from a few cm above the streambed usingprofiler

(3) Total VOCs as PCE is the molar total of all VOCs (except methane) expressed as equivalent concentrations of PCE in µg/L

(4) Percentage on a molar basis, the amount of PCE divided by total moles of VOCs (does not include methane)

(5) Reanalyzed some surface water samples (duplicate vials)because of the equipment blanks were high.
The PCE in SW is believe to be from improper decon

Samples collected in sets of 3 vials (A,B,C) ECD normally run on vial A, but used vial B as a field duplcate for EB-2

" - " means unable to collect or pump a sample from that particular depth

"ND" means compound not detected at all in the sample analyzed

"MDL" means trace amount of compound detected but below the detection limit and is not considered a real detection

"NA" means not applicable or not analyzed

"Inc" means totals are incomplete, missing one or more analyses for compounds

µg/L = micrograms per liter

INORGANICS AT MINI-PROFILER LOCATIONS PRP14, PRP15, AND PRP16

October 1997

Location or sample name[1]	Depth m[2]	Na mg/L	Alkalinity as $CaCO_3$ mg/L	SO_4 mg/L	Cl mg/L	NO_2 as N mg/L	$NO_3 + NO_2$ as N mg/L	NO^3 as N mg/L	Ammonia as N mg/L[3]	Fe mg/L	Mn mg/L	Spec. Cond. µS/cm	pH	DOC mg/L
PRP14-SW	SW	7.7	197	20	14.4	< 0.01	1.17	1.17	< 0.05	0.04	0.02	476	8.0	2.9
PRP14-0.15	0.15	48.9	337	19	83.3	< 0.01	< 0.05	< 0.05	0.22	3.21	0.3	973	7.4	2.5
PRP14-0.30	0.30	49.5	345	18	86.9	< 0.01	< 0.05	< 0.05	0.21	2.78	0.32	994	7.4	2.8
PRP14-0.45	0.45	49.3	339	21	85.7	< 0.01	< 0.05	< 0.05	0.15	3.50	0.31	990	7.4	2.6
PRP14-0.60	0.60	49.1	349	23	86.0	< 0.01	< 0.05	< 0.05	0.10	2.50	0.35	1000	7.5	2.5
PRP15-SW	SW	6.9	205	21	13.5	< 0.01	1.50	1.50	< 0.05	0.04	0.02	481	8.0	2.9
PRP15-0.15	0.15	78.3	339	39	109.0	0.07	0.92	0.85	< 0.05	< 0.02	0.18	1110	7.4	3.2
PRP15-0.30	0.30	43.2	296	34	73.5	0.06	2.50	2.44	< 0.05	0.03	0.19	927	7.5	3.2
PRP15-0.30 Dup	0.30	47.4	285	34	73.9	0.06	2.50	2.44	< 0.05	0.03	0.19	935	7.4	3.2
PRP15-0.45	0.45	37.7	278	34	69.3	0.02	0.96	0.94	0.08	0.17	0.28	882	7.5	3.2
PRP15-0.60	0.60	37.7	277	37	68.9	0.02	0.70	0.68	< 0.05	0.23	0.26	879	7.5	3.2
PRP15-0.75	0.75	38.9	280	36	67.4	0.05	2.50	2.45	< 0.05	0.07	0.21	892	7.5	3.2
PRP15-1.35	1.35	43.1	288	32	77.6	< 0.01	0.05	0.05	0.08	0.07	0.26	913	7.6	3.5
PRP15-1.50	1.50	36.6	281	35	67.1	0.04	1.75	1.71	< 0.05	0.03	0.23	872	7.5	3.0
PRP15-1.65	1.65	35.5	281	30	67.0	0.04	1.98	1.94	0.08	0.03	0.24	866	7.8	3.8
PRP16-SW	SW	6.7	199	23	13.6	< 0.01	1.06	1.06	0.16	0.04	0.02	489	8.1	4.5
PRP16-0.15	0.15	48.5	234	16	96.9	< 0.01	< 0.05	< 0.05	0.07	2.13	0.34	843	7.5	2.8
PRP16-0.30	0.30	50.4	229	18	96.3	< 0.01	< 0.05	< 0.05	0.05	0.24	0.18	846	7.5	2.6
PRP16-0.45	0.45	48.2	232	21	94.8	< 0.01	< 0.05	< 0.05	< 0.05	1.77	0.17	840	7.5	3.8
PRP16-0.60	0.60	42.4	236	23	95.9	< 0.01	< 0.05	< 0.05	< 0.05	0.18	0.15	846	7.6	3.3
PRP16-0.75	0.75	42.8	235	23	96.3	< 0.01	< 0.05	< 0.05	< 0.05	0.10	0.16	847	7.6	3.8
PRP16-0.90	0.90	48.5	235	22	93.9	< 0.01	< 0.05	< 0.05	< 0.05	0.07	0.14	847	7.6	3.3
PRP16-1.20	1.20	47.5	243	22	93.2	< 0.01	< 0.05	< 0.05	< 0.05	0.03	0.15	842	7.6	3.9
PRP16-1.50	1.50	48.2	242	20	91.2	< 0.01	< 0.05	< 0.05	0.06	0.78	0.24	830	7.6	4.2
PRP16-2.00	2.00	46.8	246	22	91.7	< 0.01	< 0.05	< 0.05	< 0.05	0.03	0.16	840	7.7	3.4
TRIP	NA	0.1	2	< 2	< 1.0	< 0.01	< 0.05	< 0.05	0.22	0.02	< 0.01	12.7	5.8	5.2
EB-1	NA	0.3	1	< 2	< 1.0	< 0.01	< 0.05	< 0.05	< 0.05	0.04	0.01	4.38	5.7	0.6
EB-2	NA	0.3	1	< 2	< 1.0	< 0.01	< 0.05	< 0.05	< 0.05	<0.02	0.01	4.32	6.4	< 0.5
EB-3	NA	0.2	2	< 2	< 1	< 0.01	< 0.05	< 0.05	0.08	< 0.02	0.01	8.52	6.5	1.1
Detection Limit	NA	0.1	1	2	1	0.01	0.05	0.05	0.05	0.02	0.01	1	0.1	0.5

Notes:

Sampling performed by Brewster Conant and Ryan Lyle October 29-31, 1997
Sampled PRP14 on 10/29, PRP15 on 10/30, and PRP16 on 10/31
(1) Names with "Dup" in front of them are field duplicates
Name starting in "EQ" are equipment blanks collected in the field after decontaminating the sampling manifold
(2) Depths of "SW" is means sample is surface water from a few cm above the streambed usingprofiler
(3) Ammonia is total ammonia and ammonium
DOC = dissolved organic carbon
N = nitrogen
NA = not analyzed or not applicable
Spec. Cond. = specific conductance
"< " means parameter below detection limit specified
"NA" means not applicable or not analyzed

FIELD PARAMETERS AT MINI-PROFILER LOCATIONS PRP14, PRP15, AND PRP16 (October 1997)

Location[1]	Specific Conduct. µS/cm	Temp °C	pH	Eh at 25 °C mV	Dissolved Oxygen mg/L	Sulfide mg/L
PRP14-SW	456	11.6	7.43	416.4	11.00	0.00
PRP14-0.15	866	14.0	6.63	194.8	0.22	0.00
PRP14-0.30	788	12.9	6.31	233.4	0.10	0.00
PRP14-0.45	850	11.2	5.64	215.0	0.01	0.00
PRP14-0.60	850	11.0	5.78	225.6	0.02	
PRP15-SW	463	10.9	6.46	408.9	9.30	0.00
PRP15-0.15	931	11.9	6.04	439.0	0.07	0.00
PRP15-0.30	679	14.1	7.01	434.7	0.09	0.00
PRP15-0.30 Dup	NA	NA	NA	NA	NA	NA
PRP15-0.45	653	16.2	7	392.6	0.14	0.00
PRP15-0.60	610	16.6	6.93	355.8	0.07	0.00
PRP15-0.75	728	15.2	6.82	416.6	0.05	0.00
PRP15-1.35	683	14.1	6.63	473.7	0.06	0.00
PRP15-1.50	736	9.8	6.42	468.9	0.14	0.00
PRP15-1.65	740	11.3	5.72	482.0	0.09	0.00
PRP16-SW	458	9.9	7.34	419.4	6.70	0.00
PRP16-0.15	749	10.8	5.84	164.2	0.06	0.01
PRP16-0.30	717	11.8	6.42	164.1	0.06	0.14
PRP16-0.45	722	12.0	6.27	180.0	0.17	0.02
PRP16-0.60	709	12.5	6.64	318.3	0.02	0.00
PRP16-0.75	710	12.6	6.3	393.8	0.00	0.00
PRP16-0.90	714	12.2	6.34	444.1	0.05	0.00
PRP16-1.20	712	11.4	5.73	448.6	0.03	0.00
PRP16-1.50	694	12.5	6.43	383.7	0.04	0.03
PRP16-2.00	697	14.9	6.29	393.1	0.02	0.00
TRIP	NA	NA	NA	NA	NA	NA
EB-1	NA	NA	NA	NA	NA	NA
EB-2	NA	NA	NA	NA	NA	NA
EB-3	NA	NA	NA	NA	NA	NA

Notes:

Sampling performed by Brewster Conant and Ryan Lyle October 29-31, 1997

Sampled PRP14 on 10/29, PRP15 on 10/30, and PRP16 on 10/31

All parameters measured in the field after purge 100 ml

(1) Names with "Dup" at end of them are field duplicates

Name starting in "EB" are equipment blanks collected in the field after decon

Names with "SW" at end means sample is surface water

NA = not analyzed or not applicable

Spec. Cond. = specific conductance

Dissolved oxygen and total sulfide measured using CheMetrics photometer and vacu-vials

Eh corrected using a polynomial interpolation of temperature function

mV = millivolts

VOC WATER QUALITY AT MINI-PROFILING LOCATION PRP17
June 10, 1998

Location	Depth m	Elevation m	TCE µg/L	PCE µg/L	VC µg/L	11DCE µg/L	tDCE µg/L	cDCE µg/L	Methane µg/L	Ethene µg/L	Ethane µg/L
PRP17	SW	NA	1.4	ND	ND	ND	ND	ND	NA	NA	NA
	0.33	183.79	26.5	13.8	157.7	6.5	8.3	2684.0	NA	NA	NA
	0.60	183.52	2.6	1.1	229.6	3.1	3.2	1368.0	NA	NA	NA
	0.90	183.22	1.4	0.9	397.0	2.1	ND	1200.0	NA	NA	NA
	0.90	183.22	1.4	ND	292.0	2.0	ND	925.0	NA	NA	NA
	1.25	182.87	UTP	UTP	UTP	UTP	UTP	UTP	UTP	UTP	UTP
	1.50	182.62	7.0	572.2	ND	ND	ND	7.0	NA	NA	NA
Trip	NA	NA	1.6	ND	ND	ND	ND	ND	ND	ND	ND
EQ-1	NA	NA	1.5	1.2	ND	ND	ND	ND	ND	ND	ND
Blank	NA	NA	1.4	ND	NA	NA	NA	NA	NA	NA	NA
Blank	NA	NA	1.4	1.5	NA	NA	NA	NA	NA	NA	NA
Airblank	NA	NA	NA	NA	ND	ND	ND	ND	NA	NA	NA
Airblank	NA	NA	NA	NA	ND	ND	ND	ND	NA	NA	NA
Detection Limit			0.7	0.9	0.7	1.4	1.4	1.0	0.5	0.5	0.5

Notes:

Sampled by Brewster Conant and Matt Bogaart
UTP = unable to pump a sample from that depth
NA = Not applicable or not analyzed
ND = Not detected
Lab dupicate at 0.9m depth

VOC WATER QUALITY AT MINI-PROFILING LOCATIONS IN STREAMBED
AT A DEPTH OF 0.3 m and SURFACE WATER SAMPLING (AUGUST 4-12, 1998)

Location or sample name(1)	Date (2)	Coordinates(3)		TCE µg/L	PCE µg/L	VC µg/L	11DCE µg/L	tDCE µg/L	cDCE µg/L	Methane µg/L(6)	Ethene µg/L	Ethane µg/L	Total VOCs µg/L	Total VOCs as PCE µg/L(4)	Percent as PCE Degradation Products(5)
		East X m	North Y m												
Water Samples From Streambed															
-4 - -4w 4.2 m	8/4	942.43	990.91	0	0	0	0	0	0	1961.6	0	0	0	0	-
-4 - -4w 6.0 m	8/4	940.71	991.44	0	0	0	0	0	0	2278.6	0	0	0	0	-
-4 - -4w 8.0 m	8/4	938.79	992.01	0	0	0	0	0	0	27.2	0	0	0	0	-
-4 - -4w 10.0 m	8/4	936.88	992.59	0	0	0	0	0	0	55.0	0	0	0	0	-
-4 - -4w 12.0 m	8/4	934.96	993.17	0	0	0	0	0	0	34.7	0	0	0	0	-
-4 - -4w 16.3 m	8/4	931.01	994.37	0	0	0	0	0	0	2008.6	0	0	0	0	-
0-0w 2.35 m	8/5	944.20	994.38	0	0	4.9	0	0	11	3186.1	0.9	0	17	37	100
0-0w 4.0 m	8/5	942.62	994.86	1.4	7.8	0	0	0	0	20.9	0	0	9	10	19
0-0w 6.0 m	8/5	940.71	995.44	0	0	0	0	0	0	7.8	0	0	0	0	-
0-0w 8.0 m	8/5	938.79	996.01	0	0	0	0	0	0	18.0	0	0	0	0	-
0-0w 8.0 m lab dup	NA	938.79	996.01	0	0	0	0	0	0	11.8	0	0	0	0	-
0-0w 10.0 m	8/5	936.88	996.59	0	0	0	0	0	0	48.1	0	0	0	0	-
0-0w 12.2 m	8/5	934.77	997.23	0	0	0	0	0	0	1341.2	0	0	0	0	-
4-4w 1.65 m	8/5	944.85	998.35	2.6	76	0	0	0	0	9.2	0	0	79	79	4
4-4w 4.05 m	8/5	942.56	999.07	1.3	22	0	0	0	0	2.3	0	0	23	24	7
4-4w 4.05 m fld dup	8/5	942.56	999.07	1.3	22	0	0	0	0	8.1	0	0	23	24	7
4-4w 5.86 m	8/5	940.84	999.60	2.6	74	0	0	0	0	0	0	0	77	77	4
4-4w 8.20 m	8/5	938.60	1000.31	0	0	0	0	0	0	40.4	0	0	0	0	-
4-4w 10.22 m	8/5	936.67	1000.91	0	0	0	0	0	0	757.2	0	0	0	0	-
4-4w 12.0 m	8/5	934.97	1001.44	0	0	0	0	0	0	5008.3	0	0	0	0	-
6-6w 3.0 m	8/5	944.36	1000.69	82	0	0	0	0	146	22.7	0	0	228	353	100
6-6w 4.9 m	8/5	942.55	1001.25	6.5	361	0	0	0	0	5.1	0	0	368	370	2
6-6w 7.2 m	8/5	940.35	1001.93	0	4.6	0	0	0	3.3	102.8	1.7	0.0	10	20	77
6-6w 7.2 m lab dup	NA	940.35	1001.93	0	1.4	0	0	0	3.6	72.3	1.2	0.0	6	15	90
8-8w 2.0 m	8/6	946.07	1002.20	0	0	0	0	0	0	3.0	0	0	0	0	-

Location or sample name[1]	Date [2]	Coordinates[3]		TCE µg/L	PCE µg/L	VC µg/L	11DCE µg/L	tDCE µg/L	cDCE µg/L	Methane µg/L[6]	Ethene µg/L	Ethane µg/L	Total VOCs µg/L	Total VOCs as PCE µg/L[4]	Percent as PCE Degradation Products[5]
		East X m	North Y m												
8-8w 2.0 m fld dup	8/6	946.07	1002.20	0	0	0	0	0	0	1.4	0	0	0	0	-
8-8w 4.0 m	8/6	944.16	1002.79	27	124	62	0	0	*220*	62.5	2.3	0.0	435	713	83
8-8w 6.0 m	8/6	942.25	1003.38	5	100	*135*	0	0	*641*	36.8	0.9	0.0	882	1567	94
8-8w 8.0 m	8/6	940.34	1003.97	0	1	0	0	0	0	2671.3	0	0.7	2	5	81
8-8w 9.9 m	8/6	938.53	1004.54	0	3.5	0	0	0	0	*3508.3*	0	0	4	4	0
10-10w 3.5 m	8/6	945.46	1004.50	0	0	*298*	0	0	*83*	1179.1	100.7	5.8	488	1563	100
10-10w 3.5 m lab dup	NA	945.46	1004.50	0	0	*283*	0	0	*73*	1225.3	103.6	5.9	466	1524	100
10-10w 5.5 m	8/6	943.55	1005.09	1.9	207	0	0	0	0	0.9	0	0	209	210	1
10-10w 7.5 m	8/6	941.64	1005.68	0	0	0	0	0	*2.1*	37.0	0	0	2	4	100
12-12w 1.25 m	8/6	948.58	1005.53	0	0	0	0	0	0	*8693.7*	0	0	0	0	-
12-12w 1.25 m fld dup	8/6	948.58	1005.53	0	0	0	0	0	0	*7943.0*	0	0	0	0	-
12-12w 4.0 m	8/6	945.95	1006.35	0	0	8.9	0	0	*13*	*2075.5*	51.7	11.5	85	420	100
12-12w 6.0 m	8/6	944.04	1006.94	23	1433	0	0	0	*23*	12.8	0	0	1479	1505	5
12-12w 8.0 m	8/6	942.14	1007.54	0	1.4	0	0	0	*11*	43.0	0	0	12	20	93
12-12w 10.0 m	8/6	940.23	1008.13	0	1.1	0	0	0	0	2418.8	0	0	1	1	0
12-12w 11.6 m	8/7	938.70	1008.61	0	0	0	0	0	0	473.5	0	0	0	0	-
14-14w 6.0 m	8/7	945.06	1008.71	1.3	0	*174*	0	0	*823*	88.8	1.0	0	999	1877	100
14-14w 8.0 m	8/7	943.16	1009.31	0	0	14	0	0	12	21.5	1.5	0	28	67	100
14-14w 10.0 m	8/7	941.25	1009.91	0	0	0	0	0	4.6	164.0	0	0	5	8	100
16-16w 3.5 m	8/7	948.00	1009.91	0	0	0	0	0	0	222.9	0	0	0	0	-
16-16w 5.0 m	8/7	946.57	1010.35	1.2	0	*286*	0	*3.2*	*294*	765.8	35.4	1.4	621	1487	100
16-16w 7.0 m	8/7	944.66	1010.94	3.6	0	*849*	*30*	*12*	*4619*	158.0	15.6	0	5529	10323	100
16-16w 7.0 m fld dup	8/7	944.66	1010.94	3.2	0	*843*	*29*	*12*	*4721*	152.6	17.1	0	5625	10488	100
16-16w 9.0 m	8/7	942.75	1011.52	1.1	0	*6.2*	0	0	*24*	26.7	0	0	31	59	100
16-16w 9.0 m lab dup	NA	942.75	1011.52	1.2	0	*5.9*	0	0	*23*	22.5	0	0	30	57	100
16-16w 11.0 m	8/7	940.84	1012.11	1.2	0	0	0	0	0	0	0	0	1	2	100
16-16w 13.2 m	8/7	938.73	1012.76	0	0	0	0	0	0	348.9	0	0	0	0	-
20-20w 4.0 m	8/7	948.70	1013.74	0	0	0	0	0	0	*6961.7*	1.8	76.8	79	466	100

Location or sample name(1)	Date (2)	Coordinates(3)		TCE µg/L	PCE µg/L	VC µg/L	11DCE µg/L	tDCE µg/L	cDCE µg/L	Methane µg/L(6)	Ethene µg/L	Ethane µg/L	Total VOCs µg/L	Total VOCs as PCE µg/L(4)	Percent as PCE Degradation Products(5)
		East X m	North Y m												
20-20w 6.0 m	8/8	946.78	1014.30	5.1	0	*415*	2.7	*46*	*2072*	708.1	92.6	2.5	2636	5299	100
20-20w 8.0 m	8/8	944.86	1014.85	1.6	0	*247*	0	0	247	137.3	29.8	0	525	1256	100
20-20w 10.0 m	8/8	942.94	1015.40	1.1	0	106	0	0	91	329.9	5.2	2.9	206	486	100
20-20w 12.0 m	8/8	941.01	1015.96	0	0	0	0	0	*6.2*	0	0	0	6	11	100
20-20w 13.25 m	8/8	939.81	1016.30	0	0	0	0	0	0	0	0	0	0	0	-
24-24w 3.5 m	8/8	949.89	1017.57	12	817	0	0	0	*36*	12.7	0	0	865	896	9
24-24w 3.5 m lab dup	NA	949.89	1017.57	13	833	0	0	0	*39*	16.3	0	0	885	918	9
24-24w 7.0 m	8/8	946.52	1018.50	2.3	0	*9.4*	0	*1.5*	*167*	518.5	13.7	0	194	397	100
24-24w 9.0 m	8/8	944.59	1019.04	6.3	155	0	0	0	*17*	0	0	0	178	192	19
24-24w 10.85 m	8/8	942.80	1019.53	0	0	0	0	0	*11*	0	0	0	11	19	100
24-24w 13.0 m	8/8	940.73	1020.10	0	0	0	0	0	0	0	0	0	0	0	-
28-28w 1.25 m	8/8	951.52	1021.25	1.3	741	0	0	0	0	0	0	0	742	745	0
28-28w 6.0 m	8/8	946.94	1022.50	1.1	0	0	0	0	*17*	1434.6	0	0	18	30	100
28-28w 7.35 m	8/10	945.64	1022.85	0	0	0	0	0	*6.3*	817.5	0	0	6	11	100
28-28w 10.0 m	8/10	943.08	1023.55	0	0	0	0	0	0	66.9	0	0	0	0	-
28-28w 12.3 m	8/10	940.86	1024.16	0	0	0	0	0	0	1807.1	0	0	0	0	-
30-30w 2.0 m	8/10	950.57	1023.68	1.2	321	0	0	0	0	9.3	0	0	322	323	1
30-30w 2.0 m lab dup	NA	950.57	1023.68	1.4	287	0	0	0	0	8.7	0	0	288	290	1
32-32w 2.1 m	8/10	949.44	1026.15	6.9	37	0	0	0	3.3	0.9	0	0	47	51	28
32-32w 5.1 m	8/10	946.53	1026.87	0	0	0	0	0	*8.5*	763.5	0	0	9	15	100
32-32w 7.9 m	8/10	943.81	1027.54	3.7	1.7	0	0	0	*20*	89.9	0	0	25	41	96
32-32w 10.9 m	8/10	940.90	1028.26	18	37	0	0	0	13	0	0	0	68	82	55
32-32w 10.9 m fld dup	8/10	940.90	1028.26	19	41	0	0	0	15	0	0	0	75	91	55
32-32w 14.4 m	8/10	937.89	1029.00	0	0	0	0	0	0	*9282.8*	0	0	0	0	-
36-36w 0.83 m (0.87)	8/11	951.16	1029.91	1.2	0	0	0	0	0	0	0	0	1	2	100
36-36w 2.95 m	8/11	949.12	1030.36	0	0	0	0	0	0	*4222.7*	0.0	1.9	2	11	100
36-36w 5.95 m	8/11	946.19	1031.00	4.6	2.5	0	0	0	*3.4*	0	0	0	11	14	82
36-36w 9.1 m	8/11	943.12	1031.67	0	0	0	0	0	0	0	0	0	0	0	-

Location or sample name(1)	Date (2)	Coordinates(3)		TCE µg/L	PCE µg/L	VC µg/L	11DCE µg/L	tDCE µg/L	cDCE µg/L	Methane µg/L(6)	Ethene µg/L	Ethane µg/L	Total VOCs µg/L	Total VOCs as PCE µg/L(4)	Percent as PCE Degradation Products(5)
		East X m	North Y m												
36-36w 13.5 m	8/11	938.82	1032.61	0	3.4	0	0	0	0	0	0	0	3	3	0
40-40w 1.0 m	8/11	950.25	1033.96	1.1	0	0	0	0	2.3	734.5	0	0	3	5	100
40-40w 1.0 m lab dup	NA	950.25	1033.96	0	0	0	0	0	0	710.4	0	0	0	0	-
40-40w 3.0 m	8/11	948.31	1034.42	1.4	0	0	0	0	0	33.0	0	0	1	2	100
40-40w 6.05 m	8/11	945.34	1035.12	0	0	0	0	0	1.7	1734.4	0	0	2	3	100
40-40w 9.05 m	8/11	942.42	1035.80	0	0	0	0	0	0	*5772.3*	0	0	0	0	-
40-40w 12.0 m	8/11	939.54	1036.47	0	0	0	0	0	0	1541.0	0	0	0	0	-
44-44w 0.50 m	8/11	948.80	1038.36	1.1	1.0	0	0	0	0	0	0	0	2	2	58
44-44w 2.4 m	8/11	946.96	1038.85	1.0	0	0	0	0	0	1297.2	0	0	1	1	100
54-54w 2.0 m	8/12	947.47	1049.12	1.2	0	0	0	*0*	*33*	21.8	0	0	34	58	100
54-54w 2.0 m lab dup		947.47	1049.12	1.0	1.1	0	0	0	17	24.1	0	0	19	31	97
54-54w 6.5	8/12	943.12	1050.27	0	0	0	0	0	0	*5469.1*	0	0	0	0	-
Resampling of Water at Locations in Streambed															
10-10w 3.5 m REDO	8/12	945.46	1004.50	1.0	0	*472*	0	0	*213*	243.8	72.5	1.4	760	2056	100
12-12w 8.0 m REDO	8/7	942.14	1007.54	0	0	0	0	0	20	36.8	0	0	20	34	100
14-14w 6.05 m REDO	8/12	945.02	1008.72	2.2	0	*146*	5.4	*1.7*	*855*	161.4	2.0	0.0	1012	1877	100
16-16w 5.0 m REDO	8/12	946.57	1010.35	1.5	0	*191*	0	*2.6*	*223*	621.2	29.4	1.0	449	1075	100
16-16w 5.0 m REDO Lab Dup	NA	946.57	1010.35	1.6	0	*182*	0	*2.9*	*216*	646.3	30.5	1.0	434	1046	100
24-24w 7.0 m REDO	8/12	946.52	1018.50	1.3	0	*43*	0	*2.8*	*132*	941.6	30.0	1.1	210	531	100
24-24W 7.0 m REDO Fld Dup	8/12	946.52	1018.50	1.3	0	*43*	0	*3.0*	*137*	874.7	26.1	1.1	212	516	100

Location or sample name[1]	Date [2]	Coordinates[3] East X m	Coordinates[3] North Y m	TCE µg/L	PCE µg/L	VC µg/L	11DCE µg/L	tDCE µg/L	cDCE µg/L	Methane µg/L[6]	Ethene µg/L	Ethane µg/L	Total VOCs µg/L	Total VOCs as PCE µg/L[4]	Percent as PCE Degradation Products[5]
28-28w 7.3 m REDO	8/12	945.69	1022.84	1.1	0	*13*	0	0	*22*	1994.5	0.5	0	37	76	100
32-32w 7.85 m REDO	8/12	943.86	1027.53	4.4	1.5	0	0	0	*42*	115.4	0	0	48	79	98
Surface Water Sampling Locations															
-4 - -4w 8.0 m SW	8/4	938.79	992.01	0	0	0	0	0	0	0	0	0	0	0	-
0-0w 2.35 m SW	8/5	944.20	994.38	0	0	0	0	0	0	2.5	0	0	0	0	-
0-0w 4.0 m SW	8/5	942.62	994.86	0	0	0	0	0	0	1.1	0	0	0	0	-
0-0w 4.0 m SW lab dup Redo	8/5	942.62	994.86	0	0	0	0	0	0	0	0	0	0	0	-
0-0w 6.0 m SW	8/5	940.71	995.44	0	0	0	0	0	0	0	0	0	0	0	-
0-0w 8.0 m SW	8/5	938.79	996.01	0	0	0	0	0	0	0	0	0	0	0	-
0-0w 10.0 m SW	8/5	936.88	996.59	0	0	0	0	0	0	0	0	0	0	0	-
0-0w 12.0 m SW	8/5	934.96	997.17	0	0	0	0	0	0	0	0	0	0	0	-
0-0w 14.0 SW	8/5	933.05	997.75	0	0	0	0	0	0	0	0	0	0	0	-
Bridge Seep	8/5			0	2.9	0	0	0	0	0	0	0	3	3	0
12-12w 4.0 m SW	8/6	945.95	1006.35	0	0	0	0	0	0	1.0	0	0	0	0	-
16-16w 5.0 m SW	8/7	946.57	1010.35	0	0	0	0	0	0	0	0	0	0	0	-
24-24w 7.0 m SW	8/8	946.52	1018.50	0	0	0	0	0	0	0	0	0	0	0	-
24-24w 7.0 m SW fld dup	8/8	946.52	1018.50	0	0	0	0	0	0	0	0	0	0	0	-
32-32w 1.5 m SW	8/10	950.03	1026.01	0.0	2.6	0	0	0	0	0	0	0	3	3	0
40-40w 3.0 m SW	8/11	948.31	1034.42	0	0	0	0	0	0	0	0	0	0	0	-
54-54w 2.0 m SW	8/12	947.47	1049.12	0	1.8	0	0	0	0	0	0	0	2	2	0
54-54w 4.0 m SW	8/12	945.54	1049.63	0	1.3	0	0	0	0	0	0	0	1	1	0
54-54w 6.0 m SW	8/12	943.60	1050.14	0	0	0	0	0	0	0.7	0	0	0	0	-
54-54w 8.0 m SW	8/12	941.67	1050.65	0	0	0	0	0	0	0	0	0	0	0	-
54-54w 10.0 m SW	8/12	939.74	1051.16	0	0	0	0	0	0	1.1	0	0	0	0	-

Location or sample name[1]	Date [2]	Coordinates[3]		TCE µg/L	PCE µg/L	VC µg/L	11DCE µg/L	tDCE µg/L	cDCE µg/L	Methane µg/L[6]	Ethene µg/L	Ethane µg/L	Total VOCs µg/L	Total VOCs as PCE µg/L[4]	Percent as PCE Degradation Products[5]
		East X m	North Y m												
54-54w 12.0 m SW	8/12	937.80	1051.67	0	0	0	0	0	0	1.0	0	0	0	0	-
Trip Blank and Equipment Blanks															
Trip Blank	8/4			0	0	4.3	0	0	0	0	0	0	4	11	100
EB-1	8/4			0	0	3.8	0	0	0	0	0	0	4	10	100
EB-2	8/5			0	0	0	0	0	0	0	0	0	0	0	-
EB-3	8/6			0	0	0	0	0	0	11.1	0	0	0	0	-
EB-4	8/7			0	0	0	0	0	0	0	0	0	0	0	-
EB-5	8/8			0	0	0	0	0	0	0	0	0	0	0	-
EB-6	8/10			0	0	0	0	0	0	0	0	0	0	0	-
EB-7	8/11			0	0	0	0	0	0	0	0	0	0	0	-
Laboratory Blanks and Deionized Water Blanks															
Lab Blank	NA			0	0	NA	NA	NA	NA	0	0	0	Inc	Inc	Inc
Lab Blank	NA			0	0	NA	NA	NA	NA	0	0	0	Inc	Inc	Inc
Lab Blank	NA			0	0	0	0	0	0	NA	NA	NA	Inc	Inc	Inc
Lab Blank	NA			0	0	NA	NA	NA	NA	NA	NA	NA	Inc	Inc	Inc
Lab Blank	NA			NA	NA	0	0	0	0	0	0	0	Inc	Inc	Inc
Lab Blank	NA			0	0	NA	NA	NA	NA	NA	NA	NA	Inc	Inc	Inc
Lab Blank	NA			0	0	NA	NA	NA	NA	0	0	0	Inc	Inc	Inc
Lab Blank	NA			0	0	0	0	0	0	0	0	0	0	0	-
Lab Blank	NA			0	0	NA	NA	NA	NA	NA	NA	NA	Inc	Inc	Inc
Lab Blank	NA			1.4	0	NA	NA	NA	NA	NA	NA	NA	Inc	Inc	Inc
Lab Blank	NA			0	0	0	0	0	0	NA	NA	NA	Inc	Inc	Inc
Lab Blank	NA			0	0	NA	NA	NA	NA	0	0	0	Inc	Inc	Inc
DI #1	NA			1.8	2.3	2.7	0	0	0	0	0	0	7	12	80
DI #2	NA			0	0	0	0	0	0	0	0	0	0	0	-
DI #3	NA			0	0	0	0	0	0	0	0	0	0	0	-
DI #4	NA			0	0	0	0	0	0	0	0	0	0	0	-
DI #5	NA			0	0	0	0	0	0	0	0	0	0	0	-
DI #6	NA			0	0	0	0	0	0	0	0	0	0	0	-

Location or sample name(1)	Date (2)	Coordinates(3)		TCE µg/L	PCE µg/L	VC µg/L	11DCE µg/L	tDCE µg/L	cDCE µg/L	Methane µg/L(6)	Ethene µg/L	Ethane µg/L	Total VOCs µg/L	Total VOCs as PCE µg/L(4)	Percent as PCE Degradation Products(5)
		East X m	North Y m												
DI #7	NA			0	0	0	0	0	0	0	0	0	0	0	-
DI #8	NA			0	0	0	0	0	0	0	0	0	0	0	-
DI #9	NA			0	0	0	0	0	0	0	0	0	0	0	-
DI #10	NA			0	0	0	0	0	0	0	0	0	0	0	-
DI #11	NA			0	0	0	0	0	0	0	0	0	0	0	-
DI #12	NA			1.0	0	0	0	0	0	0	0	0	1	1	100
DI #13	NA			0	0	0	0	0	0	0	0	0	0	0	-
DI #14	NA			0	0	0	0	0	0	0	0	0	0	0	-
Detection Limits				0.9	0.7	0.8	1.4	1.4	1	0.5	0.5	0.5	NA	NA	NA

Notes:

Sampling performed by Brewster Conant and Matt Bogaart, rainfall occurred during sampling and river stage rose during part of sampling

(1) Names ending in "SW" are surface water samples
Names ending in "fld dup" are field duplicates
Names ending in "lab dup" are laboratory duplicates
Names ending in "REDO" are samples collected at a later time at a prevoius sampling location
Name starting in "EQ" are equipment blanks collected in the field after decontaminating the mini-profiler
Names starting with "DI" are laboratory equipment blanks of the syringe using deionized water

(2) Date that the field sample was collected

(3) Coordinates relative to an arbitrary datum with the location 1000, 1000 m at a water gate valve on NW corner of King and Water Streets

(4) Total VOCs as PCE is the molar total of all VOCs (except methane) expressed as equivalent concentrations of PCE in µg/L

(5) Percentage on a molar basis, the amount of degradation products divided by total moles of VOCs (does not include methane)

(6) Concentrations of methane that exceed 1000 µg/L should be considered approximate values

" - " means no VOCs were detected and so a percent as PCE degradation products can not be calculated

Concentrations shown as "0" means concentrations were below the detection limit for the compound

NA = Not applicable or not analyzed

Inc = Totals are incomplete, missing one or more analyses for compounds

INORGANIC WATER QUALITY AND FIELD PARAMETERS AT MINI-PROFILING LOCATIONS IN STREAMBED AT A DEPTH OF 0.3 m and SURFACE WATER SAMPLING (AUGUST 4-12, 1998)

Location or sample name$^{(1)}$	Na mg/L	SO_4 mg/L	Cl mg/L	NO_2 as N mg/L	NO_3 + NO_2 as N mg/L	NO_3 as N mg/L	Ammonia as N mg/L$^{(2)}$	Fe mg/L	Mn mg/L	DOC mg/L	Spec. Cond. µS/cm $^{(3)}$	Temp °C $^{(3)(4)}$	pH $^{(3)}$	Eh at 25 °C mV $^{(3)}$	DO mg/L $^{(3)}$	Sulfide (total) mg/L $^{(3)}$
Water Samples From Streambed																
-4 - -4w 4.2 m	33.1	< 2	57.7	0.01	0	< 0.05	0.31	13.20	0.70	3.5	829.0	23.1	6.81	90.4	0.09	0.00
-4 - -4w 6.0 m	34.8	2	61.7	0.01	0	< 0.05	0.39	10.00	0.73	2.6	718.0	24.9	7.04	68.3	0.11	0.00
-4 - -4w 8.0 m	51.0	18	97.8	0.01	0	< 0.05	0.08	4.45	0.23	2.0	723.0	23.9	7.35	35.4	0.10	0.00
-4 - -4w 10.0 m	49.1	10	90.2	0.01	0	< 0.05	0.15	5.28	0.29	2.4	737.0	24	7.31	37.4	0.18	0.02
-4 - -4w 12.0 m	50.1	5	95.5	0.02	0	< 0.05	0.35	3.30	1.41	4.1	759.0	25.2	7.44	48.7	0.14	0.00
-4 - -4w 16.3 m	27.1	< 2	108.0	0.01	0	< 0.05	0.60	3.93	0.32	1.4	665.0	24.1	7.34	71.1	0.24	0.03
0-0w 2.35 m	35.5	3	59.2	0.01	0	< 0.05	0.21	1.98	0.21	2.6	727.0	21.6	6.93	158.1	0.19	0.05
0-0w 4.0 m	41.6	19	76.0	0.03	0	< 0.05	< 0.05	0.24	0.15	3.2	673.0	23	7.24	162.0	0.21	0.15
0-0w 6.0 m	46.2	21	93.3	0.02	0	< 0.05	0.05	4.40	0.54	2.8	648.0	25.7	7.32	70.6	0.19	0.00
0-0w 8.0 m	52.8	29	100.0	0.01	0	< 0.05	0.06	3.93	0.28	1.4	641.0	25.3	7.55	27.7	0.23	0.00
0-0w 8.0 m lab dup	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
0-0w 10.0 m	52.4	30	105.0	0.01	0	< 0.05	0.09	2.37	0.13	1.4	681.0	23.5	7.61	48.1	0.24	0.01
0-0w 12.2 m	32.5	8	113.0	0.02	0	< 0.05	0.40	0.06	0.12	1.4	646.0	25.8	7.55	136.5	0.25	0.16
4-4w 1.65 m	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
4-4w 4.05 m	45.2	21	89.9	0.09	0.36	0.27	< 0.05	0	0.10	3.2	676.0	26.3	7.44	287.7	0.28	0.00
4-4w 4.05 m fld dup	44.9	21	87.4	0.08	0.34	0.26	< 0.05	0	0.10	3.1	NA	NA	NA		0.14	NA
4-4w 5.86 m	43.6	25	79.9	0.01	2.60	2.59	< 0.05	0	0.11	2.8	759.0	24.3	7.10	295.7	0.20	0.00
4-4w 8.20 m	52.3	25	103.0	0.01	0	< 0.05	0.15	0.02	0.15	2.6	740.0	24.8	7.57	132.4	0.15	0.30
4-4w 10.22 m	31.5	5	89.7	0.01	0	< 0.05	0.48	1.51	0.18	2.6	618.0	24.2	7.80	34.4	0.17	0.01
4-4w 12.0 m	63.0	3	111.0	0.01	0	< 0.05	1.05	8.72	1.38	7.2	995.0	23.8	6.97	119.3	0.19	0.03
6-6w 3.0 m	47.3	21	82.5	0.01	0	< 0.05	0.18	3.76	0.27	3.2	767.0	22.4	7.16	121.7	0.14	NA
6-6w 4.9 m	38.7	28	63.1	0.16	2.80	2.64	< 0.05	0	0.12	2.8	716.0	23.1	7.16	242.2	0.17	0.00
6-6w 7.2 m	53.0	12	105.0	0.01	0	< 0.05	0.28	0.10	0.15	2.0	692.0	22.3	7.57	68.4	0.17	1.18
6-6w 7.2 m lab dup	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
8-8w 2.0 m	8.0	19	14.5	0.03	1.25	1.22	< 0.05	0.03	0.01	1.8	423.0	19.3	7.91	332.8	7.00	0.01

Location or sample name[(1)]	Na mg/L	SO_4 mg/L	Cl mg/L	NO_2 as N mg/L	NO_3 + NO_2 as N mg/L	NO_3 as N mg/L	Ammonia as N mg/L[(2)]	Fe mg/L	Mn mg/L	DOC mg/L	Spec. Cond. µS/cm [(3)]	Temp °C [(3) (4)]	pH [(3)]	Eh at 25 °C mV [(3)]	DO mg/L [(3)]	Sulfide (total) mg/L [(3)]
8-8w 2.0 m fld dup	8.1	19	14.0	0.02	1.26	1.24	< 0.05	0.04	0.01	1.8	425.0	19.6	8.04	343.3	6.90	0.00
8-8w 4.0 m	62.5	31	101.0	0.02	0	< 0.05	< 0.05	2.61	0.49	3.5	872.0	19.9	7.21	137.5	0.12	0.07
8-8w 6.0 m	36.7	33	60.5	0.10	0.30	0.20	0.21	1.17	0.48	3.2	702.0	19.9	7.30	153.5	0.09	0.00
8-8w 8.0 m	45.3	< 2	115.0	0.01	0	< 0.05	0.86	5.12	1.17	2.8	710.0	19.5	7.64	39.1	0.06	0.00
8-8w 9.9 m	20.6	14	61.4	0.02	0	< 0.05	1.59	3.37	4.48	6.7	620.0	19.8	7.61	77.4	0.06	0.00
10-10w 3.5 m	68.1	18	114.0	0.01	0	< 0.05	0.60	19.70	0.80	3.2	811.0	20.4	7.29	65.5	0.04	0.00
10-10w 3.5 m lab dup	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
10-10w 5.5 m	35.3	28	63.9	0.17	5.50	5.33	< 0.05	0	0.18	3.2	622.0	20.4	7.28	186.4	0.05	0.00
10-10w 7.5 m	48.7	33	121.0	0.02	0	< 0.05	0.33	3.18	0.60	2.8	642.0	20.1	7.59	68.2	0.05	0.00
12-12w 1.25 m	73.9	4	177.0	0.01	0	< 0.05	3.40	31.20	1.77	5.6	977.0	20.4	6.95	113.1	0.05	0.05
12-12w 1.25 m fld dup	73.3	3	175.0	0.01	1.21	1.20	3.20	31.20	1.77	5.6	971.0	20.7	6.98	113.2	0.08	0.04
12-12w 4.0 m	60.9	4	108.0	0.01	0	< 0.05	1.80	2.77	6.18	8.4	803.0	20.4	7.55	91.0	0.05	0.00
12-12w 6.0 m	38.3	29	74.1	0.11	1.89	1.78	< 0.05	0	0.33	< 0.5	606.0	19.8	7.21	387.9	0.09	NA
12-12w 8.0 m	43.3	31	116.0	0.01	0	< 0.05	0.24	5.59	0.42	< 0.5	615.0	19.7	7.58	77.7	0.07	0.00
12-12w 10.0 m	25.1	4	56.6	0.01	0	< 0.05	0.92	2.30	1.82	5.9	494.0	19.6	7.60	98.0	0.08	NA
12-12w 11.6 m	11.7	12	22.6	0.02	0.25	0.23	0.27	1.57	0.28	2.4	421.0	20.2	7.51	120.3	0.17	0.12
14-14w 6.0 m	68.1	24	101.0	0.01	1.96	1.95	0.59	17.10	1.47	6.0	752.0	20	7.24	77.3	0.07	0.00
14-14w 8.0 m	40.4	34	78.6	0.01	0	< 0.05	0.53	5.61	0.76	4.2	596.0	20.9	7.51	74.0	0.09	0.00
14-14w 10.0 m	26.0	8	66.2	0.01	0	< 0.05	0.78	3.13	1.96	2.4	490.0	20.8	7.66	47.6	0.07	0.00
16-16w 3.5 m	9.6	21	19.2	0.01	0	< 0.05	1.54	2.18	3.75	8.4	435.0	21	7.76	90.8	0.05	0.00
16-16w 5.0 m	54.3	19	95.2	0.01	0	< 0.05	1.90	2.03	4.95	9.9	671.0	21.2	7.61	124.5	0.02	0.00
16-16w 7.0 m	52.6	22	76.9	0.01	0	< 0.05	1.17	6.75	7.41	7.2	645.0	21	7.40	99.9	0.06	0.01
16-16w 7.0 m fld dup	50.4	22	76.9	0.01	0.05	< 0.05	1.15	6.73	7.40	7.4	634.0	21.7	7.20	112.6	0.12	0.00
16-16w 9.0 m	34.0	26	73.9	0.01	0	< 0.05	0.48	2.85	4.01	4.8	517.0	21.9	7.44	122.5	0.18	0.00
16-16w 9.0 m lab dup	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
16-16w 11.0 m	38.5	8	91.4	< 0.01	0.58	0.58	0.85	3.10	1.86	5.0	541.0	22.8	7.57	109.2	0.10	0.00
16-16w 13.2 m	18.6	6	29.7	< 0.01	0	< 0.05	0.84	0.24	0.21	3.1	449.0	23.4	7.10	148.8	0.10	1.03
20-20w 4.0 m	29.4	5	53.6	0.01	0	< 0.05	2.20	12.70	4.38	12.8	589.0	22.3	7.48	56.0	0.04	0.00

Location or sample name[1]	Na mg/L	SO_4 mg/L	Cl mg/L	NO_2 as N mg/L	NO_3 + NO_2 as N mg/L	NO_3 as N mg/L	Ammonia as N mg/L[2]	Fe mg/L	Mn mg/L	DOC mg/L	Spec. Cond. µS/cm [3]	Temp °C [3] [4]	pH [3]	Eh at 25 °C mV [3]	DO mg/L [3]	Sulfide (total) mg/L [3]
20-20w 6.0 m	37.9	16	70.9	0.01	0	< 0.05	1.17	3.65	2.55	7.8	703.0	22.9	7.47	142.0	0.12	0.00
20-20w 8.0 m	37.8	20	72.7	0.01	0	< 0.05	0.74	3.70	2.98	5.7	646.0	23.8	7.56	73.6	0.14	0.02
20-20w 10.0 m	37.6	23	73.9	0.01	0	< 0.05	1.14	2.50	7.37	6.6	639.0	25.2	7.53	75.5	0.20	0.00
20-20w 12.0 m	27.5	19	62.3	< 0.01	0	< 0.05	0.11	0.18	0.10	1.8	520.0	25.8	7.52	193.2	0.17	0.07
20-20w 13.25 m	20.1	7	41.2	< 0.01	0	< 0.05	0.56	0.09	0.12	2.4	513.0	28.8	7.30	113.2	0.32	0.45
24-24w 3.5 m	50.0	30	116.0	0.02	1.11	1.09	< 0.05	0	0.18	2.9	708.0	28.3	7.36	349.5	0.30	0.00
24-24w 3.5 m lab dup	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
24-24w 7.0 m	42.1	12	110.0	< 0.01	0	< 0.05	1.03	1.66	2.57	6.8	710.0	27	7.77	72.0	0.21	0.00
24-24w 9.0 m	39.0	28	91.7	0.10	0.71	0.61	< 0.05	0.03	0.81	2.8	646.0	27.5	7.48	289.9	0.16	0.00
24-24w 10.85 m	34.8	20	86.2	< 0.01	0	< 0.05	< 0.05	0.08	0.10	2.0	602.0	28.5	7.49	104.1	0.14	0.37
24-24w 13.0 m	22.5	6	44.1	< 0.01	0	< 0.05	0.42	0.09	0.11	2.4	527.0	26.8	7.44	34.6	0.22	1.44
28-28w 1.25 m	51.0	29	122.0	0.03	1.91	1.88	0.07	0.02	0.12	2.4	712.0	24.2	7.40	316.6	0.19	0.00
28-28w 6.0 m	23.3	17	50.7	0.01	0	< 0.05	1.16	6.81	2.75	5.4	588.0	23.2	7.52	36.0	0.13	0.00
28-28w 7.35 m	42.3	10	109.0	< 0.01	0	< 0.05	1.08	2.81	1.83	6.1	641.0	22.4	7.46	70.6	0.20	0.03
28-28w 10.0 m	49.2	20	120.0	< 0.01	0	< 0.05	0.22	1.40	0.12	2.2	629.0	22.5	7.55	72.5	0.14	0.06
28-28w 12.3 m	30.7	3	70.2	< 0.01	0	< 0.05	0.38	4.30	0.16	2.0	528.0	22.6	7.40	56.2	0.15	0.09
30-30w 2.0 m	50.1	30	120.0	0.02	1.36	1.34	< 0.05	0.02	0.15	2.6	644.0	23.7	7.29	342.3	0.29	0.00
30-30w 2.0 m lab dup	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
32-32w 2.1 m	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	566.0	24.9	7.30	354.5	NA	NA
32-32w 5.1 m	41.4	16	81.5	< 0.01	0	< 0.05	0.61	1.04	0.22	4.6	687.0	22	7.37	155.3	0.80	0.19
32-32w 7.9 m	46.3	16	105.0	< 0.01	0	< 0.05	0.29	0.06	0.13	2.4	713.0	21.7	7.41	238.8	0.28	0.15
32-32w 10.9 m	13.7	9	32.5	< 0.01	0	< 0.05	0.71	2.32	1.15	5.1	521.0	22.4	7.55	85.1	0.27	0.01
32-32w 10.9 m fld dup	14.1	8	32.5	0.01	0	< 0.05	0.70	2.34	1.15	4.5	NA	NA	NA		0.33	0.01
32-32w 14.4 m	18.0	3	28.6	0.01	0	< 0.05	3.60	27.7	0.90	9.6	720.0	21	6.99	81.3	0.24	0.01
36-36w 0.83 m (0.87)	34.4	9	62.2	0.01	0	< 0.05	0.40	2.14	0.28	10.2	695.0	19.8	6.99	247.2	0.63	0.03
36-36w 2.95 m	64.2	2	110.0	0.01	0	< 0.05	1.50	5.19	0.40	4.5	788.0	21.5	6.98	168.8	0.21	0.23
36-36w 5.95 m	59.7	29	129.0	< 0.01	0	< 0.05	0.16	1.06	0.16	3.3	709.0	21	7.35	169.4	0.44	0.00
36-36w 9.1 m	8.0	26	14.8	0.02	0.96	0.94	< 0.05	0	0.01	4.2	410.0	20.6	8.00	272.8	5.40	0.00

Location or sample name[1]	Na mg/L	SO_4 mg/L	Cl mg/L	NO_2 as N mg/L	$NO_3 + NO_2$ as N mg/L	NO_3 as N mg/L	Ammonia as N mg/L[2]	Fe mg/L	Mn mg/L	DOC mg/L	Spec. Cond. µS/cm [3]	Temp °C [3] [4]	pH [3]	Eh at 25 °C mV [3]	DO mg/L [3]	Sulfide (total) mg/L [3]
36-36w 13.5 m	8.2	17	16.1	0.01	0	< 0.05	0.09	0	0.36	3.5	421.0	21.1	7.81	347.6	0.27	0.00
40-40w 1.0 m	74.8	3	137.0	0.01	0	< 0.05	0.98	2.32	0.19	5.2	830.0	21.4	7.09	263.0	0.52	0.03
40-40w 1.0 m lab dup	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
40-40w 3.0 m	74.7	5	137.0	0.01	0	< 0.05	1.59	0.77	0.14	3.8	806.0	20.4	7.22	255.7	0.47	0.03
40-40w 6.05 m	50.1	6	100.0	0.01	0.83	0.82	0.53	3.97	0.29	3.8	684.0	19.6	7.35	148.8	0.32	0.14
40-40w 9.05 m	11.7	7	24.1	0.02	0	< 0.05	4.40	0.95	0.20	3.5	459.0	20.3	7.53	156.5	0.38	0.12
40-40w 12.0 m	37.3	4	71.8	0.02	0	< 0.05	1.04	2.35	1.07	4.5	610.0	19.2	7.43	150.4	0.29	0.07
44-44w 0.50 m	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	432.0	19.2	7.53	296.8	NA	NA
44-44w 2.4 m	21.1	5	40.5	0.02	0	< 0.05	0.61	0.57	0.14	4.2	501.0	19.3	7.39	280.1	0.45	0.15
54-54w 2.0 m	53.8	4	101.0	0.02	0.06	< 0.05	1.07	0.55	0.25	8.4	845.0	15.6	6.54	279.4	0.61	0.34
54-54w 2.0 m lab dup	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
54-54w 6.5	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	728.0	17.2	7.23	305.1	NA	NA
Resampling of Water at Locations in Streambed																
10-10w 3.5 m REDO	84.3	22	140.0	0.01	0	< 0.05	0.55	16.00	0.59	3.6	804.0	23	7.16	78.9	0.33	0.02
12-12w 8.0 m REDO	43.9	29	106.0	< 0.01	0	< 0.05	0.20	5.37	0.38	2.8	658.0	19.7	7.41	69.2	0.11	0.00
14-14w 6.05 m REDO	66.4	25	100.0	0.02	0	< 0.05	0.68	13.80	2.02	4.2	751.0	22.4	7.26	87.1	0.28	0.00
16-16w 5.0 m REDO	57.0	21	89.9	0.02	0	< 0.05	3.00	2.37	5.28	13.5	766.0	22.3	7.58	117.4	0.26	0.00
16-16w 5.0 m REDO Lab Dup	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
24-24w 7.0 m REDO	42.8	11	110.0	0.02	0	< 0.05	1.18	1.41	2.53	6.0	682.0	23.2	7.59	111.6	0.37	0.00
24-24W 7.0 m REDO Fld Dup	43.5	11	108.0	0.02	0	< 0.05	1.14	1.43	2.57	6.9	?	?	?		?	?

Location or sample name[1]	Na mg/L	SO_4 mg/L	Cl mg/L	NO_2 as N mg/L	NO_3 + NO_2 as N mg/L	NO_3 as N mg/L	Ammonia as N mg/L[2]	Fe mg/L	Mn mg/L	DOC mg/L	Spec. Cond. µS/cm [3]	Temp °C [3] [4]	pH [3]	Eh at 25 °C mV [3]	DO mg/L [3]	Sulfide (total) mg/L [3]
28-28w 7.3 m REDO	42.3	8	110.0	0.02	0	< 0.05	1.75	3.13	2.25	6.0	694.0	21	7.57	119.9	0.53	0.03
32-32w 7.85 m REDO	46.7	17	97.2	0.01	0	< 0.05	0.24	0.13	0.14	2.4	681.0	19.7	7.40	269.2	0.67	0.13
Surface Water Sampling Locations																
-4 - -4w 8.0 m SW	8.3	21	14.4	0.02	1.36	1.34	< 0.05	0.02	< 0.01	1.4	401.0	21.9	7.84	322.8	8.00	0.00
0-0w 2.35 m SW	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
0-0w 4.0 m SW	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
0-0w 4.0 m SW lab dup Redo	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
0-0w 6.0 m SW	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
0-0w 8.0 m SW	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
0-0w 10.0 m SW	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
0-0w 12.0 m SW	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
0-0w 14.0 SW	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Bridge Seep	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
12-12w 4.0 m SW	8.1	19	15.2	0.02	1.29	1.27	< 0.05	0.03	0.01	2.8	NA	NA	NA		NA	NA
16-16w 5.0 m SW	7.5	19	13.9	0.01	1.21	1.20	< 0.05	0.02	0.02	3.8	NA	NA	NA		8.00	0.04
24-24w 7.0 m SW	7.3	20	13.9	0.01	1.19	1.18	< 0.05	0	0.01	3.3	NA	NA	NA		7.50	0.00
24-24w 7.0 m SW fld dup	7.4	22	13.8	0.01	1.18	1.17	< 0.05	0.02	0.01	3.3	NA	NA	NA		7.30	0.00
32-32w 1.5 m SW	6.6	20	13.1	0.01	1.08	1.07	< 0.05	0	0.01	5.0	NA	NA	NA		8.30	0.05
40-40w 3.0 m SW	7.2	25	13.4	0.02	1.43	1.41	< 0.05	0.02	0.01	4.0	NA	NA	NA		9.10	0.01
54-54w 2.0 m SW	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
54-54w 4.0 m SW	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
54-54w 6.0 m SW	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
54-54w 8.0 m SW	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
54-54w 10.0 m SW	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

Location or sample name(1)	Na mg/L	SO_4 mg/L	Cl mg/L	NO_2 as N mg/L	NO_3 + NO_2 as N mg/L	NO_3 as N mg/L	Ammonia as N mg/L(2)	Fe mg/L	Mn mg/L	DOC mg/L	Spec. Cond. µS/cm (3)	Temp °C (3) (4)	pH (3)	Eh at 25 °C mV (3)	DO mg/L (3)	Sulfide (total) mg/L (3)
54-54w 12.0 m SW	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Trip Blank and Equipment Blanks																
Trip Blank	0.4	< 2	0	0.01	0	< 0.05	< 0.05	0	< 0.01	< 0.5	NA	NA	NA		NA	NA
EB-1	0.4	< 2	0	0.01	0	< 0.05	< 0.05	0	0.01	2.0	NA	NA	NA		6.00	0.00
EB-2	0.4	< 2	0	0.01	0	< 0.05	< 0.05	0.04	< 0.01	< 0.5	9.3	23.1	8.24	242.4	5.90	0.00
EB-3	0.4	< 2	0	0.01	0	< 0.05	0.06	0	0.01	0.5	13.3	20.7	8.54	354.7	7.40	0.00
EB-4	0.4	< 2	0	< 0.01	0	< 0.05	< 0.05	0	0.02	1.2	7.5	22.6	7.12	317.0	6.40	0.00
EB-5	0.3	< 2	0	< 0.01	0	< 0.05	< 0.05	0	< 0.01	1.0	18.5	21.3	8.33	432.0	6.90	0.00
EB-6	0.3	< 2	0	< 0.01	0	< 0.05	< 0.05	0	< 0.01	1.0	8.0	22.4	8.40	272.9	6.10	0.00
EB-7	0.3	< 2	0	0.01	0	< 0.05	< 0.05	0	< 0.01	1.2	5.3	22.8	7.14	275.0	6.00	0.00
Detection Limits	0.1	2	1	0.01	NA	0.05	0.05	0	0.01	0.5	NA	NA	NA	NA	NA	NA

Notes:

Sampling performed by Brewster Conant and Matt Bogaart, rainfall occurred during sampling and river stage rose during part of sampling

Laboratory analyses performed by Philip Analytical Services Inc (Halifax, Nova Scotia)

The coordinates and dates of analyses can be found in previous table with VOC results

(1) Names ending in "SW" are surface water samples
Names ending in "fld dup" are field duplicates
Names ending in "lab dup" are laboratory duplicates
Names ending in "REDO" are samples collected at a later time at a prevoius sampling location
Name starting in "EQ" are equipment blanks collected in the field after decontaminating the mini-profiler

(2) Ammonia is total ammonia and ammonium

(3) These parameters were analyzed for in the field

(4) Temperature of the sample in the field which is not necessarily the insitu temperature

DO = Dissolved oxygen
DOC = dissolved organic carbon
N = nitrogen
NA = not analyzed or not applicable (some lab dups were done only for VOCs and at some locations unable to collect enough water)
Spec. Cond. = specific condcuctance

VOCs AT DRIVEABLE MULTILEVEL SAMPLERS IN STREAMBED
MLS1, MLS3, MLS4, MLS7, MLS8, MLS17, and MLS18 NOVEMBER 1998

Location[(1)]	PCE µg/L	TCE µg/L	11DCE µg/L	tDCE µg/L	cDCE µg/L	VC µg/L	Methane µg/L	Ethene µg/L	Ethane µg/L
Blank	NA	NA	NA	NA	NA	NA	ND	ND	ND
Di needle-1	ND	ND	ND	ND	ND	ND	0.5	ND	ND
Trip	ND	ND	ND	ND	ND	ND	ND	0.7	ND
Trip#2	ND	ND	ND	ND	ND	ND	ND	ND	ND
EquipBlank	ND	ND	ND	ND	ND	ND	ND	0.8	ND
EquipBlank2	ND	ND	ND	ND	ND	ND	2.7	0.6	ND
EquipBlank3	ND	ND	ND	ND	ND	ND	ND	ND	ND
EquipBlank4	ND	ND	ND	ND	ND	ND	ND	ND	ND
MLS1-1	ND	ND	ND	ND	16	ND	1687.8	ND	2.3
Pent. Blk	ND	ND	NA	NA	NA	NA	NA	NA	NA
DI needle-2	ND	ND	ND	ND	ND	ND	3.8	ND	ND
MLS7-1	ND	ND	ND	ND	ND	ND	6.4	ND	ND
MLS7-2	ND	ND	ND	ND	179	ND	105.0	44.6	0.6
MLS7-2 LAB DUP	ND	ND	ND	ND	154	240	102.9	44.0	0.6
MLS7-2	ND	ND	ND	ND	267	129	NA	NA	NA
MLS7-2 LAB DUP	ND	ND	ND	ND	301	160	NA	NA	NA
MLS7-3	ND	ND	ND	ND	142	86	125.6	57.0	0.8
MLS7-4	ND	ND	ND	ND	295	188	118.8	66.0	0.7
MLS7-5	ND	ND	ND	ND	268	173	118.9	38.3	0.8
MLS7-6	ND	ND	2.5	1.3	1306	198	105.2	19.4	0.7
MLS7-7	ND	ND	ND	3.1	643	48	12.8	2.4	ND
Pent. Blk	ND	ND	NA	NA	NA	NA	NA	NA	NA
MLS7-8	33.6	22.5	ND	ND	196	ND	31.5	2.1	ND
MLS7-9	135.6	14.5	ND	ND	163	ND	34.6	ND	ND
MLS7-10	2.3	0.7	ND	ND	62	ND	12.4	ND	ND
Pent. Blk	ND	ND	NA	NA	NA	NA	NA	NA	NA
DI needle-3	ND	ND	ND	ND	ND	ND	ND	ND	ND
MLS8-4	379.6	1.5	ND	ND	ND	ND	ND	ND	ND
MLS8-5	579.6	1.7	ND	ND	ND	ND	ND	ND	ND
MLS8-5 LAB DUP	510.6	1.4	ND	ND	11	ND	ND	ND	ND
MLS8-6	521.6	0.9	ND	ND	ND	ND	ND	ND	ND
Pent. Blk	1.1	ND	NA	NA	NA	NA	NA	NA	NA
Pent. Blk	ND	ND	NA	NA	NA	NA	NA	NA	NA
MLS8-7	83.6	ND	ND	ND	ND	ND	ND	ND	ND
MLS8-8	2.5	ND	ND	ND	ND	ND	ND	ND	ND
MLS8-8 FLD-DUP	3.4	ND	ND	ND	ND	ND	ND	ND	ND
MLS8-9	1.2	ND	ND	ND	ND	ND	4.3	ND	ND

Location[1]	PCE µg/L	TCE µg/L	11DCE µg/L	tDCE µg/L	cDCE µg/L	VC µg/L	Methane µg/L	Ethene µg/L	Ethane µg/L
DI needle-4	8.3	ND	ND	ND	ND	ND	ND	ND	ND
MLS17-1	1.2	ND	ND	ND	7.4	ND	417.0	2.7	ND
MLS17-2	12.6	4.6	ND	ND	50	23	140.1	ND	ND
MLS17-2	ND	ND	ND	ND	46	25	NA	NA	NA
MLS17-3	319.6	30.5	ND	ND	44	ND	265.8	1.3	0.5
MLS17-4	578.6	17.5	ND	ND	9.5	ND	10.1	ND	ND
MLS17-4 LAB DUP	494.6	15.5	ND	ND	6.8	ND	8.8	ND	ND
Pent. Blk	ND	ND	NA	NA	NA	NA	NA	NA	NA
MLS17-5	647.6	15.5	ND	ND	ND	ND	6.4	ND	ND
MLS17-6	627.6	24.5	ND	ND	ND	ND	3.6	ND	ND
MLS17-7	565.6	33.5	ND	ND	ND	ND	5.5	ND	ND
MLS17-8	521.6	24.5	ND	ND	ND	ND	2.7	ND	ND
MLS17-9	562.6	32.5	ND	ND	ND	ND	4.9	ND	ND
MLS17-10	648.6	43.5	ND	ND	ND	ND	ND	ND	ND
MLS17-10 FLD DUP	606.6	41.5	ND	ND	ND	ND	4.4	ND	ND
DI needle 5	8.6	ND	ND	ND	ND	ND	ND	ND	ND
MLS18 SW	1.1	ND	ND	ND	ND	ND	0.6	ND	ND
MLS18 SW LAB DUP	ND	ND	NA	NA	NA	NA	NA	NA	NA
MLS18-1	504.6	159.5	ND	4.7	47	ND	56.5	ND	ND
Pent. Blk	ND	ND	NA	NA	NA	NA	NA	NA	NA
MLS18-1 LAB DUP	491.6	157.5	ND	1.9	30	ND	47.1	ND	ND
MLS18-2	284.6	302.5	ND	24	172	ND	557.7	ND	ND
MLS18-3	7.6	ND	ND	ND	ND	ND	4.7	ND	ND
MLS18-4	1.2	ND	ND	ND	ND	ND	11.4	ND	ND
MLS18-5	1.5	ND	ND	ND	ND	ND	ND	ND	ND
MLS18-6	0.9	ND	ND	ND	ND	ND	11.9	ND	ND
MLS18-7	1.4	ND	ND	ND	ND	ND	2.4	ND	ND
MLS18-8	ND	ND	ND	ND	ND	ND	6.6	ND	ND
MLS18-9	ND	ND	ND	ND	ND	ND	7.7	ND	ND
DI needle 6	5.6	ND	ND	ND	ND	ND	ND	ND	ND
Pent. Blk	ND	ND	NA	NA	NA	NA	NA	NA	NA
MLS3 SW	ND	ND	ND	ND	ND	ND	2.5	ND	ND
MLS3-1	ND	ND	ND	ND	ND	ND	ND	ND	ND
MLS3-2	ND	ND	ND	ND	ND	ND	3205.1	18.3	4.2
MLS3-3	ND	ND	ND	ND	264	184	449.9	26.9	ND
MLS3-4	ND	ND	ND	ND	146	104	722.2	23.9	1.2
MLS3-4 DUP	ND	ND	ND	ND	150	86	702.3	26.1	1.3
MLS3-5	ND	ND	ND	ND	15	23	2858.7	2.5	1.0
MLS4-7	300.6	0.9	ND	ND	ND	ND	15.6	ND	ND

Location[1]	PCE µg/L	TCE µg/L	11DCE µg/L	tDCE µg/L	cDCE µg/L	VC µg/L	Methane µg/L	Ethene µg/L	Ethane µg/L
DI needle 7	ND	ND	ND	ND	ND	ND	ND	ND	ND
Pent. Blk	ND	ND	NA	NA	NA	NA	NA	NA	NA
Dectection Limit	0.7	0.9	1.4	1.4	1	0.8	0.5	0.5	0.5

Notes:

Sampling performed by Brewster Conant and Titia Praamsma

Sampled MSL1 on 11/16, MLS7 & MSL8 on 11/18, MLS17 & MLS18 on 11/19, and MLS18, MLS3 & MLS 4 on 11/20

[1] Names ending in "SW" are surface water samples
Names ending in "DUP" are field duplicates
Names ending in "LAB DUP" are laboratory duplicates
Name starting in "Equipblank" are equipment blanks collected in the field after decon
Names starting with "DI needle" are labequipment blanks of the syringe using deionized water
Pent Blk are pentane laboratory blanks run to check ECD gas chromatograph
Blanks are laboratory blanks run to check gas chromatographs

Concentrations of methane are accurate, appropriate dilutions used for high concentrations

"ND" means concentrations were below the detection limit for the compound

"NA" Means not applicable or not analyzed

INORGANICS AT DRIVEABLE MULTILEVEL SAMPLERS IN STREAMBED
MLS1, MLS3, MLS4, MLS7, MLS8, MLS17, and MLS18 (NOVEMBER 1998)

Location	Na mg/L	Alkalinity (as CaCO3) mg/L	Sulfate mg/L	Cl mg/L	Nitrite (as N) mg/L	Nitrate + Nitrite (as N) mg/L	Nitrate (as N) mg/L	Ammonia (as N) mg/L	Fe mg/L	Mn mg/L	Specific Cond. µS/cm	pH	Dissolved Organic Carbon mg/L
Trip Blank	0.1	< 1	< 2	< 1	< 0.01	< 0.05	< 0.05	< 0.05	< 0.02	< 0.01	3.34	5.9	< 0.5
Trip Blank #2	0.2	< 1	< 2	< 1	< 0.01	< 0.05	< 0.05	< 0.05	< 0.02	< 0.01	3.08	5.7	2.4
Equip. Blank	0.5	< 1	< 2	< 1	< 0.01	0.06	0.06	< 0.05	< 0.02	< 0.01	5.41	5.9	< 0.5
Equip. Blank #2	0.4	< 1	< 2	< 1	< 0.01	< 0.05	< 0.05	< 0.05	< 0.02	< 0.01	3.74	5.9	4.2
Equip. Blank #3	0.2	< 1	< 2	< 1	< 0.01	< 0.05	< 0.05	< 0.05	< 0.02	< 0.01	3.43	5.8	< 0.5
MLS7-1	7.7	188	21	13.3	0.01	1.04	1.03	< 0.05	0.04	0.02	525	7.9	2.3
MLS7-2	35.3	229	27	89	< 0.01	< 0.05	< 0.05	0.62	10.8	5.02	902	7.8	3.2
MLS7-3	36.1	215	25	94.1	< 0.01	0.06	0.06	0.56	11.5	4.74	893	7.6	2.6
MLS7-4	36.3	227	25	95.2	0.01	< 0.05	< 0.05	0.6	10	5.41	906	7.5	2.8
MLS7-5	35.8	222	26	88.3	< 0.01	< 0.05	< 0.05	0.28	13.7	1.28	882	7.5	2.2
MLS7-6	37.6	228	30	90.3	0.01	< 0.05	< 0.05	0.13	8.17	0.63	881	7.8	2.4
MLS7-7	38.5	208	32	93.8	< 0.01	< 0.05	< 0.05	0.07	5.21	0.35	888	7.6	2.2
MLS7-8	39.3	215	33	93.9	< 0.01	< 0.05	< 0.05	< 0.05	1.38	0.2	928	7.7	2.8
MLS7-9	39	212	31	95.6	< 0.01	< 0.05	< 0.05	0.07	0.14	0.2	887	7.9	2.8
MLS7-10	42.3	202	29	96.8	< 0.01	< 0.05	< 0.05	< 0.05	0.21	0.19	874	7.9	2
MLS8-5	30.2	242	29	55.3	0.1	8.6	8.5	< 0.05	< 0.02	0.14	842	7.9	3.6
MLS8-6	30.5	244	29	56.4	0.1	9.8	9.7	< 0.05	< 0.02	0.14	876	7.8	3.6
MLS8-7	29.7	229	29	56.9	0.06	13.2	13.1	< 0.05	< 0.02	0.16	854	7.9	3.6
MLS8-8	49.2	197	21	77.4	0.07	2.3	2.23	< 0.05	< 0.02	0.1	778	7.8	3.4
MLS8-8 Dup	48.4	198	21	80.1	0.08	2.2	2.12	< 0.05	< 0.02	0.1	781	7.6	3.6
MLS8-9	50.8	199	30	109	< 0.01	< 0.05	< 0.05	< 0.05	< 0.02	0.09	917	7.8	1.5
MLS17-1	29.6	244	13	51.3	0.02	0.47	0.45	0.92	12.1	2.01	736	7.6	9.7
MLS17-2	62.9	322	17	103	0.02	0.06	< 0.06	0.77	12.8	1.4	1050	7.5	3.2
MLS17-3	64.5	327	29	112	0.03	0.72	0.69	0.21	0.58	0.37	1110	7.8	3.2
MLS17-4	69	325	36	106	0.04	1.17	1.13	< 0.05	< 0.02	0.19	1140	7.6	3.2
MLS17-5	49.2	296	33	80.1	0.1	3.5	3.4	< 0.05	0.04	0.16	989	7.8	3.4
MLS17-6	36.2	264	31	62.3	0.14	5	4.86	< 0.05	< 0.02	0.15	944	7.9	2.8
MLS17-7	33.3	281	31	61.4	0.14	5.6	5.46	< 0.05	< 0.02	0.14	888	8	3.2
MLS17-8	33.9	248	32	63.1	0.13	4.9	4.77	< 0.05	< 0.02	0.15	875	8.2	3.2
MLS17-9	36.6	275	32	65.3	0.14	4.2	4.06	< 0.05	< 0.02	0.15	920	7.7	3.2

Location	Na mg/L	Alkalinity (as CaCO3) mg/L	Sulfate mg/L	Cl mg/L	Nitrite (as N) mg/L	Nitrate + Nitrite (as N) mg/L	Nitrate (as N) mg/L	Ammonia (as N) mg/L	Fe mg/L	Mn mg/L	Specific Cond. µS/cm	pH	Dissolved Organic Carbon mg/L
MLS17-10	41.6	271	32	68.6	0.14	3.7	3.56	< 0.05	< 0.02	0.16	943	7.8	3.2
MLS17-10 Dup	42.6	275	32	68.1	0.14	3.8	3.66	< 0.05	< 0.02	0.16	932	7.9	3.6
MLS18 Surface	8.1	195	23	14.9	0.02	1.15	1.13	< 0.05	0.05	0.07	518	8.1	3
MLS18-1	36.3	276	36	59.8	0.1	3.6	3.5	< 0.05	< 0.02	0.23	890	7.8	3.6
MLS18-2	37.5	270	29	63.5	0.05	1.62	1.57	0.21	1.69	0.41	891	7.7	3.2
MLS18-3	52.3	218	27	103	0.04	0.78	0.74	< 0.05	0.02	0.1	908	8	2.4
MLS18-4	61.5	224	30	104	< 0.01	< 0.05	< 0.05	< 0.05	0.86	0.12	902	8	1.5
MLS18-5	54.8	218	27	98.5	< 0.01	< 0.05	< 0.05	< 0.05	0.71	0.11	876	8	1.3
MLS18-6	52.8	219	26	104	< 0.01	< 0.05	< 0.05	< 0.05	0.06	0.07	888	8.2	1.5
MLS18-8	54.7	229	27	106	< 0.01	< 0.05	< 0.05	< 0.05	< 0.02	0.08	913	8	3.2
MLS18-9	54.7	233	27	107	< 0.01	< 0.05	< 0.05	< 0.05	0.03	0.09	925	8	1
MLS3 Surface	7.8	193	23	14.5	0.02	0.94	0.92	< 0.05	0.03	0.01	516	8.2	2
MLS3-1	8	189	22	14.6	< 0.01	0.97	0.97	< 0.05	< 0.02	< 0.01	504	8.2	2
MLS3-2	41.5	343	11	64.1	< 0.01	0.13	0.13	2.6	5.85	2.32	953	8.3	6.8
MLS3-3	62.5	358	27	101	< 0.01	< 0.05	< 0.05	2.5	2.74	6.5	1130	8.3	6.4
MLS3-4	55.3	356	20	97	< 0.01	< 0.05	< 0.05	2.3	8.14	6.18	1100	8.1	6.5
MLS3-5	37.7	339	7	75.4	< 0.01	< 0.05	< 0.05	2.2	12.4	3.75	994	8	6.4
MLS4-7	31.9	228	31	57.3	0.13	2.5	2.37	< 0.05	< 0.02	0.1	772	7.9	3.8

Equipment blank 4 and MLS18-7 destroyed in transit to lab

VOC WATER QUALITY AT DRIVEABLE MULTILEVEL SAMPLERS IN STREAMBED AND BML SAMPLERS ON LAND (MARCH 1999)

Location or sample name[1]	Date [2]	Depth m	Elev. amsl m	TCE µg/L	PCE µg/L	VC µg/L	11DCE µg/L	tDCE µg/L	cDCE µg/L	Methane µg/L[5]	Ethene µg/L	Ethane µg/L	Total VOCs µg/L	Total VOCs as PCE µg/L[3]	Percent as PCE[4]
MLS1-SW	3/13/99	0.04	184.172	0	0	0	0	0	0	10.4	0	0	0	0.0	-
MLS1-1	3/13/99	0.15	184.057	0	7.7	0	0	0	30.1	NA	NA	NA	Inc	Inc	Inc
MLS1-3	3/13/99	0.45	183.757	0	0	0	0	0	4.9	607.4	0	2.7	7.6	23.1	0.0%
MLS1-6	3/13/99	0.90	183.307	0	0	0	0	0	0	628.3	0	4.0	4.0	21.8	0.0%
MLS2-3	3/13/99	3.16	181.079	12.5	3254.1	0	0	0	0	1.5	0	0	3266.6	3269.8	99.5%
MLS2-4	3/13/99	3.46	180.779	1.9	1347.4	0	0	0	0	0	0	0	1349.3	1349.8	99.8%
MLS2-5	3/13/99	3.76	180.478	4.4	2852.2	0	0	0	0	0	0	0	2856.6	2857.8	99.8%
MLS2-6	3/13/99	4.06	180.178	3.9	4421.7	0	0	0	0	0	0	0	4425.6	4426.6	99.9%
MLS2-7	3/13/99	4.36	179.878	0	605.9	0	0	0	0	0	0	0	605.9	605.9	100.0%
MLS2-7 LAB DUP	NA	4.36	179.878	0	524.4	0	0	0	0	0	0	0	524.4	524.4	100.0%
MLS2-8	3/13/99	4.66	179.578	0	25.0	0	0	0	0	0	0	0	25.0	25.0	100.0%
MLS2-9	3/13/99	4.96	179.278	0	3.6	0	0	0	0	0	0	0	3.6	3.6	100.0%
MLS2-9 DUP	3/13/99	4.96	179.278	0	2.8	0	0	0	0	0	0	0	2.8	2.8	100.0%
MLS3-SW	3/9/99	0.19	184.170	0	0	0	0	0	0	11.7	0	0	0	0.0	-
MLS3-2	3/9/99	0.30	184.060	0	0	0	0	0	0	2886.2	1.7	45.3	47.0	259.6	0.0%
MLS3-3	3/9/99	0.45	183.910	0	0	38.3	0	0	24.8	1412.3	59.9	41.6	164.6	727.4	0.0%
MLS3-4	3/9/99	0.60	183.760	0	0	34.2	0	0	19.8	1828.1	59.0	45.5	158.5	724.2	0.0%
MLS3-5	3/9/99	0.75	183.610	0	0	14.0	0	0	5.5	3266.6	26.4	28.5	74.5	360.3	0.0%
MLS3-5 DUP	NA	0.75	183.610	0	0	12.7	0	0	5.4	3017.0	26.1	27.5	71.7	348.8	0.0%
MLS4-7	3/9/99	3.86	180.466	2.9	1340.6	0	0	0	0	13.3	0	0	1343.5	1344.3	99.7%
MLS4-8	3/9/99	4.16	180.166	0.9	123.8	0	0	0	0	1.4	0	0	124.7	125.0	99.0%
MLS4-8 LAB DUP	3/9/99	4.16	180.166	0	106.7	0	0	0	0	2.1	0	0	106.7	106.7	100.0%
MLS4-9	3/9/99	4.46	179.866	0	4.6	0	0	0	0	29.7	0	0	4.6	4.6	100.0%
MLS4-9 DUP	NA	4.46	179.866	0	4.4	0	0	0	0	25.3	0	0	4.4	4.4	100.0%
MLS5-SW	3/13/99	0.04	184.174	0	0	0	0	0	0	14.3	0	0	0.0	0.0	-
MLS5-1	3/13/99	0.15	184.064	2.7	24.8	78.1	0	0	98.0	633.9	85.9	0.6	290.1	914.4	2.7%
MLS5-2	3/13/99	0.30	183.914	0.9	5.4	128.8	2.4	0	237.2	481.6	29.4	0	404.1	932.1	0.6%

Location or sample name[1]	**Date** [2]	**Depth m**	**Elev. amsl m**	**TCE µg/L**	**PCE µg/L**	**VC µg/L**	**11DCE µg/L**	**tDCE µg/L**	**cDCE µg/L**	**Methane µg/L**[5]	**Ethene µg/L**	**Ethane µg/L**	**Total VOCs µg/L**	**Total VOCs as PCE µg/L**[3]	**Percent as PCE**[4]
MLS5-3	3/13/99	0.45	183.764	6.1	1.1	146.6	2.8	0	469.0	432.7	25.5	0	651.1	1355.4	0.1%
MLS5-4	3/13/99	0.60	183.614	3.8	3.1	178.4	3.6	0	863	368	29.7	1.7	1083.4	2148.6	0.1%
MLS5-4 DUP	3/13/99	0.60	183.614	4.0	3.3	178.4	4.4	1.2	816	438	34.1	1.9	1043.6	2099.8	0.2%
MLS5-5	3/13/99	0.75	183.464	5.9	15.2	105.2	2.6	0	778	163	11.8	0.6	919.6	1710.6	0.9%
MLS5-6	3/13/99	0.90	183.314	28.9	319.2	55.5	0	0	145.9	140.0	12.3	0	561.9	825.4	38.7%
MLS5-7	3/13/99	1.05	183.164	39.7	468.9	24.5	0	0	97.9	98.2	10.7	0	641.7	814.6	57.6%
MLS5-8	3/13/99	1.20	183.014	35.4	396.1	32.4	0	0	88.9	150.6	16.0	0	568.8	773.4	51.2%
MLS6-5	3/14/99	3.26	180.962	21.3	2487.1	0	0	0	0	0	0	0	2508.4	2513.9	98.9%
MLS6-6	3/14/99	3.56	180.662	2.5	439.4	0	0	0	0	0	0	0	441.9	442.5	99.3%
MLS6-7	3/14/99	3.86	180.362	0	13.2	0	0	0	0	27.4	0	0	13.2	13.2	100.0%
MLS6-8	3/14/99	4.16	180.062	0	1.4	0	0	0	0	8.6	0	0	1.4	1.4	100.0%
MLS6-8 DUP	3/14/99	4.16	180.062	0	1.6	0	0	0	0	8.6	0	0	1.6	1.6	100.0%
MLS6-9	3/14/99	4.46	179.762	0	0	0	0	0	0	1.2	0	0	0.0	0.0	-
MLS7-1 SW	3/10/99	0.15	183.869	0	0	0	0	0	0	13.2	0	0	0.0	0.0	-
MLS7-2	3/10/99	0.30	183.719	23.5	2.7	79.8	0	1.4	262.7	80.5	22.9	0.7	393.8	835.5	0.3%
MLS7-3	3/10/99	0.45	183.569	7.7	4.4	96.5	0	0	228.0	85.7	31.0	1.1	368.7	849.6	0.5%
MLS7-4	3/10/99	0.60	183.419	23.8	2.3	146.5	4.1	1.6	439.8	64.8	32.2	0.7	650.9	1377.0	0.2%
MLS7-5	3/10/99	0.75	183.269	266.0	209.6	134.4	8.4	8.3	1261.8	67.0	16.3	1.8	1906.5	3195.0	6.6%
MLS7-6	3/10/99	0.90	183.119	258.4	302.6	63.6	8.4	7.9	1123.5	29.9	6.0	0	1770.5	2782.9	10.9%
MLS7-6 LAB DUP	NA	0.90	183.119	225.6	261.2	55.1	7.2	7.1	1156.3	25.0	4.9	0	1717.5	2723.9	9.6%
MLS7-7	3/10/99	1.05	182.969	33.8	28.3	37.3	3.6	4.5	701.2	14.9	5.2	0	813.8	1414.0	2.0%
MLS7-8	3/10/99	1.20	182.819	18.7	69.8	8.4	0	3.2	485.3	NA	NA	NA	Inc	Inc	Inc
MLS7-8 repeat	NA	1.20	182.819	17.8	71.3	0	0	3.4	485.3	NA	NA	NA	Inc	Inc	Inc
MLS7-9	3/10/99	1.35	182.669	0	1.4	0	0	1.7	219.7	NA	NA	NA	Inc	Inc	Inc
MLS7-9 repeat	NA	1.35	182.669	9.3	126.0	0	0	1.8	233.3	NA	NA	NA	Inc	Inc	Inc
MLS7-10	3/10/99	1.50	182.519	12.8	186.3	0	0	0	111.0	NA	NA	NA	Inc	Inc	Inc
MLS7-10 repeat	NA	1.50	182.519	0	1.4	0	0	0	88.0	NA	NA	NA	Inc	Inc	Inc
MLS8-4	3/11/99	2.96	181.231	0	279.3	0	0	0	0	0	0	0	279.3	279.3	100.0%
MLS8-5	3/11/99	3.26	180.930	0	372.4	0	0	0	0	0	0	0	372.4	372.4	100.0%
MLS8-6	3/11/99	3.56	180.630	0	172.4	0	0	0	0	0	0	0	172.4	172.4	100.0%
MLS8-6 DUP	3/11/99	3.56	180.630	0	174.9	0	0	0	0	0	0	0	174.9	174.9	100.0%

Location or sample name[1]	Date [2]	Depth m	Elev. amsl m	TCE µg/L	PCE µg/L	VC µg/L	11DCE µg/L	tDCE µg/L	cDCE µg/L	Methane µg/L[6]	Ethene µg/L	Ethane µg/L	Total VOCs µg/L	Total VOCs as PCE µg/L[3]	Percent as PCE[4]
MLS8-7	3/11/99	3.86	180.330	0	19.8	0	0	0	0	0	0	0	19.8	19.8	100.0%
MLS8-8	3/11/99	4.16	180.030	0	4.0	0	0	0	0	0	0	0	4.0	4.0	100.0%
MLS8-9	3/11/99	4.46	179.730	0	0	0	0	0	0	5.9	0	0	0	0	-
MLS9-SW	3/14/99	0.09	183.948	0	0	0	0	0	0	14.2	0	0	0	0	-
MLS9-1	3/14/99	0.15	183.888	0	0	0	0	0	0	0	0	0	0	0	-
MLS9-2	3/14/99	0.30	183.738	0	0	0	0	0	0	15.3	0	0	0	0	-
MLS9-3	3/14/99	0.45	183.588	0	0	0	0	0	0	11.3	0	0	0	0	-
MLS9-4	3/14/99	0.60	183.438	0	0	0	0	0	0	8.1	0	0	0	0	-
MLS9-5	3/14/99	0.75	183.288	0	0	0	0	0	0	4.8	0	0	0	0	-
MLS9-6	3/14/99	0.90	183.138	0	0	0	0	0	0	8.5	0	0	0	0	-
MLS9-6 LAB DUP	NA	0.90	183.138	0	0	0	0	0	0	8.5	0	0	0	0	-
MLS9-7	3/14/99	1.05	182.988	0	0	0	0	0	0	3.7	0	0	0	0	-
MLS9-8	3/14/99	1.20	182.838	2.0	42.7	0	0	0	0	0	0	0	44.7	45.2	94.5%
MLS9-9	3/14/99	1.35	182.688	22.5	28.7	0	0	0	0	0	0	0	51.3	57.2	50.3%
MLS9-10	3/14/99	1.50	182.538	39.0	0	0	0	0	0	1.2	0	0	39.0	49.2	0.0%
MLS10-1	3/15/99	1.80	182.196	0	0	0	0	0	0	1.1	0	0	0	0	-
MLS10-2	3/15/99	2.10	181.895	0	0	0	0	0	0	1.0	0	0	0	0	-
MLS10-3	3/15/99	2.40	181.595	0	0	0	0	0	0	0.8	0	0	0	0	-
MLS10-5	3/15/99	3.00	180.994	0	0	0	0	0	0	1.0	0	0	0	0	-
MLS10-6	3/15/99	3.30	180.694	0	0	0	0	0	0	1.5	0	0	0	0	-
MLS10-7	3/15/99	3.60	180.394	0	0	0	0	0	0	0	0	0	0	0	-
MLS10-8	3/15/99	3.90	180.094	0	0	0	0	0	0	0	0	0	0	0	-
MLS10-8 DUP	3/15/99	3.90	180.094	0	0	0	0	0	0	0	0	0	0	0	-
MLS10-9	3/15/99	4.20	179.794	0	0	0	0	0	0	0	0	0	0	0	-
MLS11-SW	3/15/99	0.05	183.823	0	0	0	0	0	0	12.0	0	0	0	0	-
MLS11-1	3/15/99	0.15	183.723	1.2	0	0	0	0	0	98.4	0	0	1.2	1.5	0.0%
MLS11-2	3/15/99	0.30	183.573	1.0	0	0	0	0	0	63.9	0	0	1.0	1.3	0.0%
MLS11-2 Lab Dup	NA	0.30	183.573	1.5	0	0	0	0	0	58.2	0	0	1.5	2.0	0.0%
MLS11-3	3/15/99	0.45	183.423	0	0	0	0	0	0	1.3	0	0	0	0	-
MLS11-5	3/15/99	0.75	183.123	5.2	0	0	0	0	0	18.6	0	0	5.2	6.6	0.0%
MLS11-6	3/15/99	0.90	182.973	4.9	1.2	0	0	1.2	0	15.1	0	0	7.3	9.5	12.5%

Location or sample name[1]	Date [2]	Depth m	Elev. amsl m	TCE µg/L	PCE µg/L	VC µg/L	11DCE µg/L	tDCE µg/L	cDCE µg/L	Methane µg/L[5]	Ethene µg/L	Ethane µg/L	Total VOCs µg/L	Total VOCs as PCE µg/L[3]	Percent as PCE[4]
MLS11-8	3/15/99	1.20	182.673	0	0	0	0	0	0	41.0	0	0	0	0	-
MLS11-9	3/15/99	1.35	182.523	0	0	0	0	0	0	39.9	0	0	0	0	-
MLS11-10	3/15/99	1.50	182.373	0	0	0	0	0	0	27.8	0	0	0	0	-
MLS12-2	3/15/99	2.36	181.684	0	0	0	0	0	0	40.6	0	0	0	0	-
MLS12-3	3/15/99	2.66	181.384	0	0	0	0	0	0	5.7	0	0	0	0	-
MLS12-6	3/15/99	3.56	180.483	0	0	0	0	0	0	7.4	0	0	0	0	-
MLS12-7	3/15/99	3.86	180.183	0	0	0	0	0	0	8.5	0	0	0	0	-
MLS12-7 Lab Dup	NA	3.86	180.183	0	0	0	0	0	0	8.2	0	0	0	0	-
MLS12-8	3/15/99	4.16	179.883	0	0	0	0	0	0	5.6	0	0	0	0	-
MLS12-9	3/15/99	4.46	179.583	0	0	0	0	0	0	15.0	0	0	0	0	-
MLS13-SW	3/16/99	-0.04	184.338	0	0	0	0	0	0	14.3	0	0	0	0	-
MLS13-1	3/16/99	0.15	184.148	14.0	5.3	0	0	0	0	3153.0	0	0	19.3	23.0	23.2%
MLS13-2	3/16/99	0.30	183.998	14.9	14.1	0	0	0	0	1116.8	0	0	28.9	32.8	42.8%
MLS13-4	3/16/99	0.60	183.698	9.2	3.0	0	0	0	7.7	5317.3	0	0	19.9	27.7	11.0%
MLS13-4 LAB DUP	NA	0.60	183.698	10.9	4.3	0	0	0	0	5094.7	0	0	15.1	18.0	23.7%
MLS13-6	3/16/99	0.90	183.398	13.4	5.4	0	0	0	0	2884.6	0	0	18.8	22.3	24.1%
MLS13-9	3/16/99	1.35	182.948	31.7	107.2	0	0	0	0	420.9	0	0	138.9	147.2	72.8%
MLS14-2	3/16/99	3.10	180.985	6.1	546.1	0	0	0	0	0	0	0	552.3	553.9	98.6%
MLS14-2 DUP	3/16/99	3.10	180.985	5.7	511.2	0	0	0	0	0	0	0	516.9	518.4	98.6%
MLS14-3	3/16/99	3.40	180.685	5.3	491.8	0	0	0	0	0	0	0	497.1	498.5	98.7%
MLS14-4	3/16/99	3.70	180.385	3.9	532.3	0	0	0	0	0	0	0	536.1	537.1	99.1%
MLS14-5	3/16/99	4.00	180.084	0	79.6	0	0	0	0	0	0	0	79.6	79.6	100.0%
MLS14-6	3/16/99	4.30	179.784	0	4.7	0	0	0	0	0	0	0	4.7	4.7	100.0%
MLS14-7	3/16/99	4.60	179.484	0	1.2	0	0	0	0	0	0	0	1.2	1.2	100.0%
MLS14-8	3/16/99	4.90	179.184	0	0.8	0	0	0	0	10.2	0	0	0.8	0.8	100.0%
MLS14-9	3/16/99	5.20	178.884	0	0	0	0	0	0	17.3	0	0	0	0	-
MLS15-1 SW	3/16/99	0.15	183.825	0	1.6	0	0	0	0	5.0	0	0	1.6	1.6	100.0%
MLS15-2	3/16/99	0.30	183.675	43.0	83.6	15.6	0	0	219.5	21.4	2.7	0	364.4	570.5	14.7%
MLS15-3	3/16/99	0.45	183.525	42.3	160.8	19.6	0	0	159.5	12.6	6.8	0	388.9	578.9	27.8%
MLS15-4	3/16/99	0.60	183.375	23.2	64.5	0	0	1.5	251.1	11.3	0	0	340.2	525.8	12.3%

Location or sample name[1]	Date [2]	Depth m	Elev. amsl m	TCE µg/L	PCE µg/L	VC µg/L	11DCE µg/L	tDCE µg/L	cDCE µg/L	Methane µg/L[5]	Ethene µg/L	Ethane µg/L	Total VOCs µg/L	Total VOCs as PCE µg/L[3]	Percent as PCE[4]
MLS15-5	3/16/99	0.75	183.225	4.7	2.9	0	0	1.4	234.2	29.4	0	0	243.3	411.9	0.7%
MLS15-5 LAB DUP	NA	0.75	183.225	3.9	2.2	0	0	1.9	288.7	23.1	0	0	296.8	504.4	0.4%
MLS15-7	3/16/99	1.05	182.925	40.0	492.5	0	0	0	66.9	11.2	0	0	599.4	657.4	74.9%
MLS15-8	3/16/99	1.20	182.775	68.7	321.8	0	0	0	70.5	23.8	0	0	461.1	529.2	60.8%
MLS15-8 DUP	3/16/99	1.20	182.775	71.4	327.9	0	0	0	68.1	22.9	0	0	467.4	534.5	61.3%
MLS15-9	3/16/99	1.35	182.625	22.0	482.3	0.0	0	0	28.3	15.2	0	0	532.6	558.4	86.4%
MLS15-10	3/16/99	1.50	182.475	21.9	225.4	0.0	0	1.2	185.5	16.8	0	0	433.9	572.3	39.4%
MLS16-2	3/16/99	2.10	181.381	3.2	297.0	0	0	0	0	0	0	0	300.2	301.0	98.7%
MLS16-3	3/16/99	2.40	181.081	0	22.1	0	0	0	0	0.9	0	0	22.1	22.1	100.0%
MLS16-4	3/16/99	2.70	180.781	0	3.8	0	0	0	0	0.9	0	0.0	3.8	3.8	100.0%
MLS16-4 DUP	3/16/99	2.70	180.781	0	2.8	0	0	0	0	0.8	0	0	2.8	2.8	100.0%
MLS16-5	3/16/99	3.00	180.480	0	2.2	0	0	0	0	0	0	0	2.2	2.2	100.0%
MLS16-6	3/16/99	3.30	180.180	0	1.8	0	0	0	0	0.5	0	0	1.8	1.8	100.0%
MLS16-7	3/16/99	3.60	179.880	0	0	0	0	0	0	0	0	0	0	0	-
MLS16-8	3/16/99	3.90	179.580	0	0	0	0	0	0	0	0	0	0	0	-
MLS16-9	3/16/99	4.20	179.280	0	0	0	0	0	0	0	0	0	0	0	-
MLS17-1 SW	3/11/99	0.15	183.910	0	0	0	0	0	0	4.4	0	0	0	0	-
MLS17-2	3/11/99	0.30	183.760	31.8	313.1	0	0	0	105.5	275.9	3.4	2.0	455.6	564.4	55.5%
MLS17-3	3/12/99	0.45	183.610	17.2	284.3	6.9	0	0	50.8	354.6	14.8	5.1	379.2	527.1	53.9%
MLS17-3 LAB DUP	NA	0.45	183.610	16.5	271.4	7.0	0	0	48.9	279.7	12.2	4.0	360.1	489.2	55.5%
MLS17-4	3/12/99	0.60	183.460	15.0	705.6	0	0	0	3.6	3.2	0	0	724.2	730.7	96.6%
MLS17-5	3/12/99	0.75	183.310	13.5	713.5	0	0	0	0	0	0	0	727.0	730.5	97.7%
MLS17-6	3/12/99	0.90	183.160	19.9	647.9	0	0	0	0	1.1	0	0	667.8	673.0	96.3%
MLS17-7	3/12/99	1.05	183.010	33.6	629.9	0	0	0	0	0.7	0	0	663.5	672.3	93.7%
MLS17-8	3/12/99	1.20	182.860	20.7	558.7	0	0	0	0	1.1	0	0	579.4	584.8	95.5%
MLS17-9	3/12/99	1.35	182.710	26.8	627.6	0	0	0	0	0.9	0	0	654.4	661.4	94.9%
MLS17-10	3/12/99	1.50	182.560	37.1	709.5	0	0	0	0	0.6	0	0	746.6	756.3	93.8%
MLS17-10 LAB DUP	NA	1.50	182.560	32.6	618.2	0	0	0	0	0	0	0	650.8	659.3	93.8%
MLS17-10 DUP	3/12/99	1.50	182.560	33.4	656.6	0	0	0	0	NA	NA	NA	Inc	Inc	Inc
MLS18-1	3/12/99	1.80	182.224	118.4	509.6	0	0	0	37.5	54.1	0	0	665.4	723.1	70.5%
MLS18-2	3/12/99	2.10	181.923	199.3	275.1	0	0	36.4	225.3	630.9	0	0	736.0	974.2	28.2%

Location or sample name[1]	Date [2]	Depth m	Elev. amsl m	TCE µg/L	PCE µg/L	VC µg/L	11DCE µg/L	tDCE µg/L	cDCE µg/L	Methane µg/L[5]	Ethene µg/L	Ethane µg/L	Total VOCs µg/L	Total VOCs as PCE µg/L[3]	Percent as PCE[4]
MLS18-2 NO AZIDE	3/12/99	2.10	181.923	196.9	301.6	0	0	22.8	212.9	NA	NA	NA	Inc	Inc	Inc
MLS18-3	3/12/99	2.40	181.623	0	7.4	0	0	0	0	0	0	0	7.4	7.4	100.0%
MLS18-4	3/12/99	2.70	181.323	0	0	0	0	0	0	14.9	0	0	0	0	-
MLS18-5	3/12/99	3.00	181.022	0	0	0	0	0	0	37.8	0	0	0	0	-
MLS18-5 LAB DUP	NA	3.00	181.022	0	0	0	0	0	0	29.0	0	0	0	0	-
MLS18-6	3/12/99	3.30	180.722	0	0	0	0	0	0	15.2	0	0	0	0	-
MLS18-7	3/12/99	3.60	180.422	0	0	0	0	0	0	6.8	0	0	0	0	-
MLS18-8	3/12/99	3.90	180.122	0	0	0	0	0	0	8.0	0	0	0	0	-
MLS18-9	3/12/99	4.20	179.822	0	0	0	0	0	0	5.0	0	0	0	0	-
MLS19-SW	3/17/99	0.02	184.003	0	0	0	0	0	0	10.1	0	0	0	0	-
MLS19-1	3/17/99	0.15	183.868	0	0	0	0	0	0	386.3	1.1	0.6	1.7	9.9	0.0%
MLS19-2	3/17/99	0.30	183.718	0	0	0	0	0	0	1333.4	1.7	1.3	3.0	17.0	0.0%
MLS19-2 LAB DUP	NA	0.30	183.718	0	0	0	0	0	0	1183.0	1.5	1.3	2.8	16.3	0.0%
MLS19-3	3/17/99	0.45	183.568	1.6	0	0	0	1.7	9.2	190.8	0	0	12.4	20.6	0.0%
MLS19-4	3/17/99	0.60	183.418	2.4	0	0	0	0	6.4	293.0	0	0	8.8	14.0	0.0%
MLS19-5	3/17/99	0.75	183.268	4.8	0	0	0	0	4.7	116.8	0	1.1	10.6	20.0	0.0%
MLS19-5 DUP	3/17/99	0.75	183.268	4.9	0	0	0	0	4.8	130.6	0	1.1	10.7	20.2	0.0%
MLS19-6	3/17/99	0.90	183.118	3.6	0	0	0	0	4.6	102.7	0	0	8.2	12.5	0.0%
MLS19-7	3/17/99	1.05	182.968	1.7	0	0	0	0	3.4	73.3	0	0	5.1	8.0	0.0%
MLS19-8	3/17/99	1.20	182.818	2.0	0	0	0	0	3.8	69.7	0	0	5.8	9.0	0.0%
MLS19-9	3/17/99	1.35	182.668	8.6	0	0	0	0	4.9	40.2	0	0	13.5	19.2	0.0%
MLS19-10	3/17/99	1.50	182.518	4.0	0.8	0	0	0	6.8	40.0	0	0	11.5	17.4	4.3%
MLS20-2	3/17/99	2.10	181.995	5.6	0	0	0	0	0	11.7	0	0	5.6	7.0	0.0%
MLS20-3	3/17/99	2.40	181.695	0	0	0	0	0	0	12.6	0	0	0	0	-
MLS20-4	3/17/99	2.70	181.395	0	0	0	0	0	0	6.2	0	0	0	0	-
MLS20-4 DUP	3/17/99	2.70	181.395	0	0	0	0	0	0	5.2	0	0	0	0	-
MLS20-5	3/17/99	3.00	181.094	0	0	0	0	0	0	7.3	0	0	0	0	-
MLS20-7	3/17/99	3.60	180.494	0	0	0	0	0	0	15.2	0	0	0	0	-
BML1-1	3/17/99	6.05	180.357	0	23.3	0	0	0	0	60.3	0	0	23.3	23.3	100.0%
BML1-2	3/17/99	6.49	179.913	26.8	1059.3	0	0	0	0	192.3	0	0	1086.1	1093.1	96.9%
BML1-3	3/17/99	6.99	179.413	6.6	594.8	0	0	0	0	67.6	0	0	601.4	603.2	98.6%

Location or sample name[1]	Date [2]	Depth m	Elev. amsl m	TCE µg/L	PCE µg/L	VC µg/L	11DCE µg/L	tDCE µg/L	cDCE µg/L	Methane µg/L[5]	Ethene µg/L	Ethane µg/L	Total VOCs µg/L	Total VOCs as PCE µg/L[3]	Percent as PCE[4]
BML1-4	3/17/99	7.48	178.921	0	100.9	0	0	0	0	66.2	0	0	100.9	100.9	100.0%
BML1-4 LAB DUP	NA	7.48	178.921	0	92.6	0	0	0	0	75.4	0	0	92.6	92.6	100.0%
BML1-5	3/17/99	7.99	178.415	0	1.2	0	0	0	0	77.1	0	0	1.2	1.2	100.0%
BML1-6	3/18/99	8.48	177.925	0	0.8	0	0	0	0	73.5	0	0	0.8	0.8	100.0%
BML1-7	3/18/99	8.99	177.415	0	0	0	0	0	0	83.1	0	0	0	0	-
BML1-7 DUP	3/18/99	8.99	177.415	0	0	0	0	0	0	67.1	0	0	0	0	-
BML1-8	3/18/99	9.49	176.915	0	0	0	0	0	0	79.7	0	0	0	0	-
BML2-1	3/28/99	6.05	179.863	1.7	678.1	0	0	0	0	70.8	0	0	679.8	680.3	99.7%
BML2-2	3/28/99	6.49	179.419	1.1	407.9	0	0	0	0	50.8	0	0	408.9	409.2	99.7%
BML2-3	3/28/99	6.99	178.919	0	4.4	0	0	0	0	87.0	0	0	4.4	4.4	100.0%
BML2-3 DUP	3/28/99	6.99	178.919	0	3.9	0	0	0	0	69.6	0	0	3.9	3.9	100.0%
BML2-4	3/28/99	7.48	178.427	0	0	0	0	0	0	93.7	0	0	0	0	-
BML2-6	3/28/99	8.48	177.431	0	0	0	0	0	0	78.9	0	0	0	0	-
BML2-6 LAB DUP	NA	8.48	177.431	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
BML2-7	3/28/99	8.99	176.921	0	0	0	0	0	0	91.7	0	0	0	0	-
BML2-7 LAB DUP	NA	8.99	176.921	0	0	0	0	0	0	55.8	0	0	0	0	-
BML2-8	3/28/99	9.49	176.421	0	0	0	0	0	0	64.0	0	0	0	0	-
BML3-1	3/8/99	5.55	180.631	0	137.8	0	0	0	0	12.4	0	0	137.8	137.8	100.0%
BML3-2	3/8/99	6.05	180.133	0	95.7	0	0	0	0	9.8	0	0	95.7	95.7	100.0%
BML3-3	3/8/99	6.49	179.689	1.8	1632.5	0	0	0	0	9.8	0	0	1634.3	1634.8	99.9%
BML3-4	3/8/99	6.99	179.189	1.3	1531.8	0	0	0	0	9.6	0	0	1533.1	1533.4	99.9%
BML3-5	3/8/99	7.48	178.697	0	11.1	0	0	0	0	8.9	0	0	11.1	11.1	100.0%
BML3-6	3/8/99	7.99	178.191	0	1.4	0	0	0	0	9.4	0	0	1.4	1.4	100.0%
BML3-7	3/8/99	8.48	177.701	0	0.9	0	0	0	0	12.5	0	0	0.9	0.9	100.0%
BML3-8	3/8/99	8.99	177.191	0	0	0	0	0	0	10.1	0	0	0	0	-
BML3-9	3/8/99	9.49	176.691	0	0	0	0	0	0	15.8	0	0	0	0	-
BML3-9 LAB DUP	NA	9.49	176.691	0	0	0	0	0	0	17.9	0	0	0	0	-
BML4-1	3/28/99	5.55	180.464	0	322.6	0	0	0	0	4.6	0	0	322.6	322.6	100.0%
BML4-2	3/28/99	6.05	179.966	1.5	529.8	0	0	0	0	1.3	0	0	531.3	531.7	99.6%
BML4-3	3/28/99	6.49	179.522	0.9	703.6	0	0	0	0	1.4	0	0	704.5	704.8	99.8%
BML4-4	3/28/99	6.99	179.022	0	102.3	0	0	0	0	0.9	0	0	102.3	102.3	100.0%

Location or sample name(1)	Date (2)	Depth m	Elev. amsl m	TCE µg/L	PCE µg/L	VC µg/L	11DCE µg/L	tDCE µg/L	cDCE µg/L	Methane µg/L(5)	Ethene µg/L	Ethane µg/L	Total VOCs µg/L	Total VOCs as PCE µg/L(3)	Percent as PCE(4)
BML4-4 DUP	3/28/99	6.99	179.022	0	100.8	0	0	0	0	0.7	0	0	100.8	100.8	100.0%
BML4-5	3/28/99	7.48	178.530	0	0	0	0	0	0	15.3	0	0	0	0	-
BML4-6	3/28/99	7.99	178.024	0	0	0	0	0	0	370.9	0	0	0	0	-
BML4-7	3/28/99	8.48	177.534	0	0	0	0	0	0	1516.4	0	0	0	0	-
BML4-7 LAB DUP	3/28/99	8.48	177.534	0	0	0	0	0	0	1010.6	0	0	0	0	-
BML4-8	3/28/99	8.99	177.024	0	0	0	0	0	0	15.6	0	0	0	0	-
BML4-9	3/28/99	9.49	176.524	0	0	0	0	0	0	63.5	0	0	0	0	-
BML5-1	3/28/99	5.55	180.535	0	243.2	0	0	0	0	12.6	0	0	243.2	243.2	100.0%
BML5-2	3/28/99	6.05	180.037	0	1250.5	0	0	0	0	11.4	0	0	1250.5	1250.5	100.0%
BML5-3	3/28/99	6.49	179.593	2.7	2274.7	0	0	0	0	7.9	0	0	2277.5	2278.2	99.8%
BML5-3 LAB DUP	NA	6.49	179.593												
BML5-4	3/28/99	6.99	179.093	1.1	533.8	0	0	0	0	9.2	0	0	534.9	535.2	99.7%
BML5-4 DUP	3/28/99	6.99	179.093	1.8	567.9	0	0	0	0	5.8	0	0	569.7	570.2	99.6%
BML5-5	3/28/99	7.48	178.601	0	196.4	0	0	0	0	6.0	0	0	196.4	196.4	100.0%
BML5-5 LAB DUP	NA	7.48	178.601	0	151.9	0	0	0	0	5.2	0	0	151.9	151.9	100.0%
BML5-6	3/28/99	7.99	178.095	0	18.9	0	0	0	0	9.1	0	0	18.9	18.9	100.0%
BML5-7	3/28/99	8.48	177.605	0	0	0	0	0	0	7.4	0	0	0	0	-
BML5-8	3/28/99	8.99	177.095	0	0	0	0	0	0	5.5	0	0	0	0	-
BML5-9	3/28/99	9.49	176.595	0	0.7	0	0	0	0	15.1	0	0	0.7	0.7	100.0%
BML6-1	3/29/99	5.55	180.531	3.1	35.9	0	0	0	0	80.6	0	0	38.9	39.8	90.2%
BML6-2	3/29/99	6.05	180.033	2.4	493.8	0	0	0	0	7.1	0	0	496.3	496.9	99.4%
BML6-5	3/29/99	7.48	178.597	2.0	2699.4	0	0	0	0	1.7	0	0	2701.4	2702.0	99.9%
BML6-6	3/29/99	7.99	178.091	0	27.5	0	0	0	0	3.2	0	0	27.5	27.5	100.0%
BML6-6 DUP	3/29/99	7.99	178.091	0	27.6	0	0	0	0	2.1	0	0	27.6	27.6	100.0%
BML6-7	3/29/99	8.48	177.601	0	4.7	0	0	0	0	3.2	0	0	4.7	4.7	100.0%
BML6-8	3/29/99	8.99	177.091	0	2.1	0	0	0	0	7.3	0	0	2.1	2.1	100.0%
BML6-9	3/29/99	9.49	176.591	0	0.9	0	0	0	0	11.3	0	0	0.9	0.9	100.0%
BML7-1	3/29/99	4.55	181.520	2.1	3.6	0	0	0	7.6	113.4	0	0	13.2	19.2	18.6%
BML7-2	3/29/99	5.05	181.020	2.9	1.0	0	0	0	7.8	94.7	0	0	11.6	17.9	5.5%
BML7-3	3/29/99	5.55	180.520	1.2	51.3	0	0	0	0	9.4	0	0	52.5	52.8	97.1%
BML7-3 LAB DUP	NA	5.55	180.520	1.3	46.7	0	0	0	0	7.2	0	0	48.0	48.4	96.7%

Location or sample name[1]	Date [2]	Depth m	Elev. amsl m	TCE µg/L	PCE µg/L	VC µg/L	11DCE µg/L	tDCE µg/L	cDCE µg/L	Methane µg/L[5]	Ethene µg/L	Ethane µg/L	Total VOCs µg/L	Total VOCs as PCE µg/L[3]	Percent as PCE[4]
BML7-5	3/29/99	6.49	179.578	0	4.7	0	0	0	0	6.9	0	0	4.7	4.7	100.0%
BML7-5 Dup-P[7]	3/29/99	6.49	179.578												
BML7-6	3/29/99	6.99	179.078	0	5.1	0	0	0	0	7.2	0	0	5.1	5.1	100.0%
BML7-6 Dup	3/29/99	6.99	179.078	0	0	0	0	0	0	4.1	0	0	0	0	-
BML7-7	3/29/99	7.48	178.586	0	0	0	0	0	0	8.4	0	0	0	0	-
BML7-8	3/29/99	7.99	178.080	0	0	0	0	0	0	4.9	0	0	0	0	-
BML7-9	3/29/99	8.48	177.590	0	1.4	0	0	0	0	5.9	0	0	1.4	1.4	100.0%
BML7-10	3/29/99	8.99	177.080	0	0	0	0	0	0	6.1	0	0	0	0	-
BML7-11	3/29/99	9.49	176.580	0	0	0	0	0	0	7.5	0	0	0	0	-
BML8-1	3/29/99	5.55	180.478	1.8	34.6	0	0	0	0	9.6	0	0	36.3	36.8	93.9%
BML8-2	3/29/99	6.05	179.980	1.3	130.7	0	0	0	0	3.8	0	0	132.0	132.3	98.8%
BML8-3	3/29/99	6.49	179.536	2.2	2079.1	0	0	0	0	3.2	0	0	2081.3	2081.9	99.9%
BML8-4	3/29/99	6.99	179.036	2.1	1030.3	0	0	0	0	3.3	0	0	1032.4	1033.0	99.7%
BML8-4 LAB DUP	NA	6.99	179.036	2.0	980.5	0	0	0	0	1.2	0	0	982.5	983.0	99.7%
BML8-5	3/29/99	7.48	178.544	0	5.0	0	0	0	0	1.3	0	0	5.0	5.0	100.0%
BML8-5 Dup	3/29/99	7.48	178.544	0	2.5	0	0	0	0	0	0	0	2.5	2.5	100.0%
BML8-6	3/29/99	7.99	178.038	0	0	0	0	0	0	0	0	0	0	0	-
BML8-7	3/29/99	8.48	177.548	0	0	0	0	0	0	1.3	0	0	0	0	-
BML8-8	3/29/99	8.99	177.038	0	0	0	0	0	0	2.1	0	0	0	0	-
BML8-9	3/29/99	9.49	176.538	0	0	0	0	0	0	0	0	0	0	0	-
BML9-1	3/30/99	5.05	180.882	6.8	0	0	0	0	7.9	28.6	0	0	14.7	22.1	0.0%
BML9-2	3/30/99	5.55	180.382	1.9	10.2	0	0	0	3.3	7.6	0	0	15.5	18.3	55.9%
BML9-2 LAB DUP	NA	5.55	180.382	1.8	10.0	0	0	0	3.5	3.8	0	0	15.4	18.4	54.6%
BML9-3	3/30/99	6.05	179.884	2.5	0	0	0	0	5.8	3.3	0	0	8.3	13.0	0.0%
BML9-4	3/30/99	6.49	179.440	4.6	0	0	0	0	6.7	1.7	0	0	11.3	17.2	0.0%
BML9-5	3/30/99	6.99	178.940	0	0	0	0	0	0	0	0	0	0	0	-
BML9-5 DUP	3/30/99	6.99	178.940	0	0	0	0	0	0	0	0	0	0	0	-
BML9-6	3/30/99	7.48	178.448	0	0	0	0	0	0	5.5	0	0	0	0	-
BML9-7	3/30/99	7.99	177.942	0	0	0	0	0	0	0.7	0	0	0	0	-
BML9-8	3/30/99	8.48	177.452	0	0	0	0	0	0	0	0	0	0	0	-
BML9-9	3/30/99	8.99	176.942	0	0	0	0	0	0	0	0	0	0	0	-

Location or sample name[1]	Date [2]	Depth m	Elev. amsl m	TCE µg/L	PCE µg/L	VC µg/L	11DCE µg/L	tDCE µg/L	cDCE µg/L	Methane µg/L[5]	Ethene µg/L	Ethane µg/L	Total VOCs µg/L	Total VOCs as PCE µg/L[3]	Percent as PCE[4]
BML9-10	3/30/99	9.49	176.442	0	0	0	0	0	0	0	0	0	0	0	-
BML10-1	3/30/99	5.05	180.820	9.5	6.6	0	2.6	0	11.9	8.4	0	0	30.6	43.4	15.2%
BML10-1 LAB DUP	NA	5.05	180.820	8.7	5.5	0	0	0	9.3	11.5	0	0	23.5	32.3	17.1%
BML10-2	3/30/99	5.55	180.320	8.5	16.8	0	0	0	13.0	9.3	0	0	38.3	49.7	33.8%
BML10-3	3/30/99	6.05	179.822	4.0	0	0	0	0	14.5	4.2	0	0	18.5	29.9	0.0%
BML10-3 DUP	3/30/99	6.05	179.822	4.5	0	0	0	0	12.9	4.2	0	0	17.4	27.7	0.0%
BML10-4	3/30/99	6.49	179.378	1.6	0	0	0	0	6.7	0.6	0	0	8.3	13.5	0.0%
BML10-5	3/30/99	6.99	178.878	0	0	0	0	0	0	0	0	0	0	0	-
BML10-6	3/30/99	7.48	178.386	0	0	0	0	0	0	3.0	0	0	0	0	-
BML10-7	3/30/99	7.99	177.880	0	3.7	0	0	0	0	3.2	0	0	3.7	3.7	100.0%
BML10-8	3/30/99	8.48	177.390	0	0	0	0	0	0	3.3	0	0	0	0	-
BML10-9	3/30/99	8.99	176.880	0	0	0	0	0	0	0	0	0	0	0	-
BML10-10	3/30/99	9.49	176.380	0	0	0	0	0	0	1.8	0	0	0	0	-
BML11-1	3/18/99	5.05	181.119	0	0	0	0	0	0	58.3	0	0	0	0	-
BML11-2	3/18/99	5.55	180.619	0	2.1	0	0	0	0	330.4	0	0	2.1	2.1	100.0%
BML11-3	3/18/99	6.05	180.121	0	0	0	0	0	0	161.8	0	0	0	0	-
BML11-3 LAB DUP	NA	6.05	180.121	0	0	0	0	0	0	163.2	0	0	0	0	-
BML11-4	3/18/99	6.49	179.677	0	0	0	0	0	0	83.1	0	0	0	0	-
BML11-5	3/18/99	6.99	179.177	0	0	0	0	0	0	48.7	0	0	0	0	-
BML11-6	3/18/99	7.48	178.685	0	0	0	0	0	0	214.3	0	0	0	0	-
BML11-7	3/18/99	7.99	178.179	0	0	0	0	0	0	618.0	0	0	0	0	-
BML11-8	3/18/99	8.48	177.689	0	0	0	0	0	0	1283.5	0	0	0	0	-
BML11-9	3/18/99	8.99	177.179	0	0	0	0	0	0	1888.5	0	0	0	0	-
BML11-10	3/18/99	9.49	176.679	0	0	0	0	0	0	1773.7	0	0	0	0	-
BML11-10 LAB DUP	NA	9.49	176.679	0	0	0	0	0	0	1691.2	0	0	0	0	-
BML12-1	3/30/99	6.05	179.681	0	0	0	0	0	0	372.6	0	0	0	0	-
BML12-2	3/30/99	6.49	179.237	0	0	0	0	0	0	197.6	0	0	0	0	-
BML12-3	3/30/99	6.99	178.737	0	0	0	0	0	0	236.2	0	0	0	0	-
BML12-3 LAB DUP	NA	6.99	178.737	0	0	0	0	0	0	210.2	0	0	0	0	-
BML12-4	3/30/99	7.48	178.245	0	0	0	0	0	0	45.7	0	0	0	0	-
BML12-5	3/30/99	7.99	177.739	0	0	0	0	0	0	52.0	0	0	0	0	-

Location or sample name(1)	Date (2)	Depth m	Elev. amsl m	TCE μg/L	PCE μg/L	VC μg/L	11DCE μg/L	tDCE μg/L	cDCE μg/L	Methane μg/L(5)	Ethene μg/L	Ethane μg/L	Total VOCs μg/L	Total VOCs as PCE μg/L(3)	Percent as PCE(4)
BML12-5 DUP	3/30/99	7.99	177.739	0	0	0	0	0	0	32.7	0	0	0	0	-
BML12-6	3/30/99	8.48	177.249	0	0	0	0	0	0	64.4	0	0	0	0	-
BML12-7	3/30/99	8.99	176.739	0	0	0	0	0	0	57.9	0	0	0	0	-
BML12-8	3/30/99	9.49	176.239	0	0	0	0	0	0	75.2	0	0	0	0	-
Bridge Seep	3/30/99			0	2.0	0	0	0	0	3.3	0	0	2.0	2.0	100.0%
*****Blank***	NA			0	0	0	0	0	0	0	0	0	0	0	-
*****Blank***	NA			0	0	0	0	0	0	0	0	0	0	0	-
*****Blank***	NA			0	0	0	0	0	0	0	0	0	0	0	-
*****Blank***	NA			0	0	0	0	0	0	0	0	0	0	0	-
*****Blank***	NA			0	0	0	0	0	0	0	0	0	0	0	-
*****Blank***	NA			0	0	0	0	0	0	0.6	0	0	0	0	-
*****Blank***	NA			0	0	0	0	0	0	0	0	0	0	0	-
*****Blank***	NA			0	0	0	0	0	0	0.8	0	0	0	0	-
*****Blank***	NA			0	0	0	0	0	0	0	0	0	0	0	-
*****Blank***	NA			0	0	0	0	0	0	0	0	0	0	0	-
*****Blank***	NA			0	0	0	0	0	0	0	0	0	0	0	-
*****Blank***	NA			0	0	0	0	0	0	0	0	0	0	0	-
*****Blank***	NA			0	0	0	0	0	0	0	0	0	0	0	-
*****Blank***	NA			0	0	0	0	0	0	0	0	0	0	0	-
*****Blank***	NA			0	0	0	0	0	0	0	0	0	0	0	-
*****Blank***	NA			0	0	0	0	0	0	1.1	0	0	0	0	-
*****Blank***	NA			0	0	0	0	0	0	NA	NA	NA	Inc	Inc	Inc
*****Blank***	NA			0	0	0	0	0	0	NA	NA	NA	Inc	Inc	Inc
*****Blank***	NA			0	0	NA	NA	NA	NA	NA	NA	NA	Inc	Inc	Inc
*****Blank***	NA			0	0	NA	NA	NA	NA	NA	NA	NA	Inc	Inc	Inc
*****Blank***	NA			0	0	NA	NA	NA	NA	NA	NA	NA	Inc	Inc	Inc
*****Blank***	NA			0	0	NA	NA	NA	NA	NA	NA	NA	Inc	Inc	Inc
*****Blank***	NA			0	0	NA	NA	NA	NA	NA	NA	NA	Inc	Inc	Inc
*****Blank***	NA			0	0	NA	NA	NA	NA	NA	NA	NA	Inc	Inc	Inc
*****Blank***	NA			0	0	NA	NA	NA	NA	NA	NA	NA	Inc	Inc	Inc

Location or sample name(1)	Date (2)	Depth m	Elev. amsl m	TCE µg/L	PCE µg/L	VC µg/L	11DCE µg/L	tDCE µg/L	cDCE µg/L	Methane µg/L(5)	Ethene µg/L	Ethane µg/L	Total VOCs µg/L	Total VOCs as PCE µg/L(3)	Percent as PCE(4)
**Blank	NA			0	0	NA	NA	NA	NA	NA	NA	NA	Inc	Inc	Inc
**Blank	NA			0	0	NA	NA	NA	NA	NA	NA	NA	Inc	Inc	Inc
**Blank	NA			0	0	NA	NA	NA	NA	NA	NA	NA	Inc	Inc	Inc
**Blank	NA			0	0	NA	NA	NA	NA	NA	NA	NA	Inc	Inc	Inc
**Blank	NA			0	0	NA	NA	NA	NA	NA	NA	NA	Inc	Inc	Inc
**Blank	NA			0	0	NA	NA	NA	NA	NA	NA	NA	Inc	Inc	Inc
**Blank	NA			0	0	NA	NA	NA	NA	NA	NA	NA	Inc	Inc	Inc
DI #1	NA			0	0	0	0	0	0	0	0	0	0	0	-
DI #2	NA			0	0	0	0	0	0	0	0	0	0	0	-
DI #3	NA			2.1	1.4	0	0	0	0	0	0	0	3.5	4.0	34.3%
DI #4	NA			0	2.4	0	0	0	0	0	0	0	2.4	2.4	100.0%
DI #5	NA			0	1.0	0	0	0	0	0	0	0	1.0	1.0	100.0%
DI #6	NA			0	5.0	0	0	0	0	0	0	0	5.0	5.0	100.0%
DI #7	NA			0	0	0	0	0	0	0	0	0	0	0	-
DI #8	NA			0	0	0	0	0	0	0	0	0	0	0	-
DI #8	NA			0	0	0	0	0	0	0	0	0	0	0	-
DI #9	NA			0	0	0	0	0	0	0	0	0	0	0	-
DI #10	NA			0	0	0	0	0	0	0	0	0	0	0	-
DI #11	NA			0	0	0	0	0	0	0	0	0	0	0	-
DI #12	NA			0	0	0	0	0	0	0	0	0	0	0	-
DI #13	NA			0	0	0	0	0	0	0	0	0	0	0	-
DI #14	NA			0	0	0	0	0	0	0	0	0	0	0	-
DI #15	NA			0	0	0	0	0	0	0	0	0	0	0	-
DI #16	NA			0	0	0	0	0	0	0	0	0	0	0	-
DI #17	NA			0	0.8	0	0	0	0	0	0	0	0.8	0.8	100.0%
**DI-17	NA			0	0	0	0	0	0	0	0	0	0	0	-
DI #1	NA			0	0	0	0	0	0	0	0	0	0	0	-
DI #2	NA			0	0	0	0	0	0	0	0	0	0	0	-

Location or sample name(1)	Date (2)	Depth m	Elev. amsl m	TCE µg/L	PCE µg/L	VC µg/L	11DCE µg/L	tDCE µg/L	cDCE µg/L	Methane µg/L(5)	Ethene µg/L	Ethane µg/L	Total VOCs µg/L	Total VOCs as PCE µg/L(3)	Percent as PCE(4)
DI #3	NA			0	0	0	0	0	0	0	0	0	0	0	-
DI #4	NA			0	0	0	0	0	0	0	0	0	0	0	-
DI #5	NA			0	0	0	0	0	0	0	0	0	0	0	-
DI #6	NA			1.3	0	0	0	0	0	0	0	0	1.3	1.6	0.0%
DI #7	NA			0	0	0	0	0	0	0	0	0	0	0	-
DI #8	NA			0	0	0	0	0	0	0	0	0	0	0	-
DI #9	NA			0	0	0	0	0	0	0	0	0	0	0	-
EQ-1	3/8/99			0	0	0	0	0	0	0	0	0	0	0	-
EQ-2	3/9/99			0	0	0	0	0	0	0	0	0	0	0	-
EQ-3	3/10/99			0	0	0	0	0	0	0	0	0	0	0	-
EQ-4	3/11/99			0	1.2	0	0	0	0	0	0	0	1.2	1.2	100.0%
EQ-5	3/11/99			0	0	0	0	0	0	0	0	0	0	0	-
EQ-6 (6)	3/13/99			0	19.4	0	0	0	0	0	0	0	19.4	19.4	100.0%
EQ-7	3/14/99			0	0	0	0	0	0	0	0	0	0	0	-
EQ-7(6)	3/15/99			0	0	0	0	0	0	0	0	0	0	0	-
EQ-8	3/15/99			0	0	0	0	0	0	0	0	0	0	0	-
EQ-9	3/16/99			0	0	0	0	0	0	0	0	0	0	0	-
EQ-10	3/16/99			0	0	0	0	0	0	0	0	0	0	0	-
EQ-11	3/17/99			0	0	0	0	0	0	0	0	0	0	0	-
EQ-12	3/17/99			0	0	0	0	0	0	0	0	0	0	0	-
EQ-13	3/18/99			0	0	0	0	0	0	0	0	0	0	0	-
EQ-1	3/28/99			0	0	0	0	0	0	0	0	0	0	0	-
EQ-2	3/28/99			0	1.6	0	0	0	0	0	0	0	1.6	1.6	100.0%
EQ-3	3/29/99			0	8.5	0	0	0	0	0	0	0	8.5	8.5	100.0%
EQ-4-P(7)	3/29/99														
EQ-5	3/29/99			0	0	0	0	0	0	0	0	0	0	0	-
EQ-6	3/30/99			0	0	0	0	0	0	0	0	0	0	0	-
EQ-7	3/30/99			0	0	0	0	0	0	0	0	0	0	0	-
EQ-8	3/30/99			0	0	0	0	0	0	0	0	0	0	0	-
Trip	3/8/99			0	0	0	0	0	0	0	0	0	0	0	-

Location or sample name(1)	Date (2)	Depth m	Elev. amsl m	TCE µg/L	PCE µg/L	VC µg/L	11DCE µg/L	tDCE µg/L	cDCE µg/L	Methane µg/L(5)	Ethene µg/L	Ethane µg/L	Total VOCs µg/L	Total VOCs as PCE µg/L(3)	Percent as PCE(4)
TRIP	3/28/99			0	0	0	0	0	0	0	0	0	0	0	-
Trip-C	3/29/99			0	0	0	0	0	0	0	0	0	0	0	-

Notes:

Sampling performed by Brewster Conant and Bob Gunn

(1) Names ending in "SW" are surface water samples

Names ending in "fld dup" are field duplicates

Names ending in "lab dup" are laboratory duplicates

Names ending in "repeat" are laboratory sample reruns (samples may have gotten switched)

Name starting in "EQ" are equipment blanks collected in the field after decontaminating the sampling manifold

Names starting with "DI" are laboratory equipment blanks of the syringe using deionized water

Name ending in "NO AZIDE" was a field duplicate that was not preserved with sodium azide, all ather samples were preserved

**Blanks are laboratory blanks run to check gas chromatographs

(2) Date that the sample was collected in the field

(3) Total VOCs as PCE is the molar total of all VOCs (except methane) expressed as equivalent concentrations of PCE in µg/L

(4) Percentage on a molar basis, the amount of PCE divided by total moles of VOCs (does not include methane)

(5) Concentrations of methane are accurate, appropriate dilutions used to determine high concentrations

(6) Problem noted at time of sampling, improper back flushing of manifold contaminated equipment blank (should have resampled)

(7) Equipment blank or sample sent to Philip Analytical laboratory

(8) Incorrectly numbered in field, so label name EQ-7 was repeated (i.e.there are 2 EQ-7s)

" - " means no VOCs were detected and so a percent as PCE degradation products can not be calculated

Concentrations shown as "0" means concentrations were below the detection limit for the compound

NA = Not applicable or not analyzed

Inc = Totals are incomplete, missing one or more analyses for compounds

INORGANIC WATER QUALITY AT DRIVEABLE MULTILEVEL SAMPLERS IN STREAMBED AND BML SAMPLERS ON LAND (MARCH 1999)

Location	Na mg/L	Alk. as $CaCO_3$ mg/L	SO_4 mg/L	Cl mg/L	NO_2 as N mg/L	NO_3 + NO_2 as N mg/L	NO_3 as N mg/L	Ammonia as N [(1)] mg/L	Fe mg/L	Mn mg/L	Spec. Cond. umhos/cm	pH	DOC mg/l
MLS3-SW	9.4	218	24	17.3	< 0.01	1.99	1.99	0.07	0.02	0.01	540	8	3.2
MLS3-2	33.6	388	5	49.5	< 0.01	0.38	0.38	3.53	6.03	2.73	889	8	7.6
MLS3-3	47.9	400	10	93.2	< 0.01	< 0.05	< 0.05	1.98	6.74	8.88	1070	7.7	7.3
MLS3-4	48.1	372	9	98.4	< 0.01	< 0.05	< 0.05	2.33	14.6	7.89	1140	7.8	7.7
MLS3-5	38.4	381	2	82.9	< 0.01	< 0.05	< 0.05	2.74	14.6	4.32	846	7.8	8.1
MLS3-5 DUP	40.2	378	3	83.2	< 0.01	< 0.05	< 0.05	2.74	14.7	4.43	999	7.8	8.1
MLS4-7	39.7	237	29	63.9	0.11	3.06	2.95	0.06	< 0.02	0.09	705	7.9	4.3
MLS4-8	40.2	242	28	69.7	0.07	1.2	1.13	0.06	< 0.02	0.13	764	7.8	3.2
MLS4-9	52	232	19	87.9	< 0.01	< 0.05	< 0.05	0.07	< 0.02	0.13	768	7.9	2.5
MLS4-9 DUP	51.5	231	20	87.3	< 0.01	< 0.05	< 0.05	0.06	< 0.02	0.14	789	7.8	2.3
MLS7-1 SW	8.8	212	24	16.1	< 0.01	2.06	2.06	0.06	< 0.02	< 0.01	530	8.1	2.1
MLS7-2	41.2	239	31	82.2	< 0.01	< 0.05	< 0.05	0.24	5.43	4.33	792	7.8	3.7
MLS7-3	42.2	236	32	82.1	< 0.01	0.11	0.11	0.27	10.5	3.86	779	7.8	3.7
MLS7-4	41.4	248	29	82.5	< 0.01	< 0.05	< 0.05	0.28	9.33	3.8	791	7.7	3.8
MLS7-5	39.2	267	< 2	70.3	< 0.01	< 0.05	< 0.05	0.2	12	0.77	796	7.7	3.8
MLS7-6	39.6	259	33	75.2	< 0.01	< 0.05	< 0.05	0.07	6.12	0.5	801	7.8	3.5
MLS7-7	40.9	243	34	80.4	< 0.01	0.36	0.36	< 0.05	3.65	0.26	794	7.8	3.1
MLS8-4	38.8	230	22	53.3	0.11	6.17	6.06	< 0.05	< 0.02	0.12	704	8	4.3
MLS8-5	41	227	21	57.1	0.13	4.57	4.44	< 0.05	< 0.02	0.11	702	7.8	4.1
MLS8-6	46.7	230	22	68.4	0.08	1.61	1.53	< 0.05	< 0.02	0.1	709	8.1	3.8
MLS8-6 DUP	47.3	215	19	68.1	0.08	1.62	1.54	< 0.05	< 0.02	0.1	699	7.7	3.8
MLS8-7	38.2	227	22	57.8	0.18	7.75	7.57	< 0.05	< 0.02	0.14	768	7.8	4.8
MLS8-8	48	227	20	75.1	0.1	2.95	2.85	< 0.05	< 0.02	0.11	774	8.1	4.3
MLS8-9	47.5	202	32	117	< 0.01	0.11	0.11	< 0.05	< 0.02	0.09	884	8	1.5
MLS17-1 SW	8.9	195	24	17.4	< 0.01	1.97	1.97	< 0.05	< 0.02	0.01	509	8.1	2.1
MLS17-2	63.1	311	30	104	0.03	0.91	0.88	< 0.05	0.58	0.33	1010	7.9	3.2
MLS17-3	76.7	323	31	121	0.02	0.28	0.26	0.09	0.6	0.33	1100	7.7	3.5

Location	Na mg/L	Alk. as $CaCO_3$ mg/L	SO_4 mg/L	Cl mg/L	NO_2 as N mg/L	NO_3 + NO_2 as N mg/L	NO_3 as N mg/L	Ammonia as N (1) mg/L	Fe mg/L	Mn mg/L	Spec. Cond. umhos/cm	pH	DOC mg/l
MLS17-4	55.8	305	32	93.3	0.06	1.77	1.71	< 0.05	< 0.02	0.16	1000	7.8	3.1
MLS17-5	37.9	282	30	71.1	0.11	3.95	3.84	< 0.05	0.02	0.14	880	7.8	3.5
MLS17-6	37.7	274	32	65.7	0.13	4.7	4.57	< 0.05	< 0.02	0.14	854	8	3.2
MLS17-7	36.8	275	31	67	0.13	4.94	4.81	< 0.05	< 0.02	0.15	862	8	3.2
MLS17-8	37.4								< 0.02	0.12			3.2
MLS17-9	37.2	274	31	67.9	0.14	4.22	4.08	< 0.05	< 0.02	0.16	860	7.8	3.2
MLS17-10	37.1	280	31	66.5	0.15	3.9	3.75	< 0.05	0.02	0.17	880	8	3.3
MLS17-10 DUP	37.8	282	32	66.4	0.15	4	3.85	< 0.05	< 0.02	0.16	666	7.8	3.3
MLS18-1	36.6	277	39	65.6	0.11	3.21	3.1	< 0.05	< 0.02	0.22	778	8	3.2
MLS18-2	38.3	280	32	68.6	0.04	1.62	1.58	0.16	0.23	0.31	838	8	3.2
MLS18-2 No Acid	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	3.3
MLS18-3	48.4	212	26	95.6	0.04	1.07	1.03	< 0.05	< 0.02	0.1	843	8.2	2.3
MLS18-4	51.8	220	34	110	< 0.01	0.46	0.46	0.07	0.86	0.12	877	8	2
MLS18-5	51.1	248	24	100	< 0.01	< 0.05	< 0.05	0.06	0.63	0.11	857	8	2.3
MLS18-6	52.5	237	24	100	< 0.01	< 0.05	< 0.05	0.05	0.02	0.08	864	8	2.1
MLS18-7	52.2	243	24	100	< 0.01	< 0.05	< 0.05	< 0.05	< 0.02	0.07	843	8	2
MLS18-8	50.1	237	26	102	< 0.01	< 0.05	< 0.05	< 0.05	< 0.02	0.08	828	7.9	2
MLS18-9	49	231	28	104	< 0.01	< 0.05	< 0.05	< 0.05	< 0.02	0.09	815	7.8	1.9
BML1-1	81.1	327	45	128	< 0.01	1.29	1.29	0.97	0.03	0.11	995	7.9	3
BML1-2	44.5	336	27	85	< 0.01	0.6	0.6	0.05	< 0.02	0.14	911	7.7	3.2
BML1-3	31	275	30	64	0.1	4.3	4.2	< 0.05	0.15	0.08	801	8	3.6
BML1-4	20.7	244	25	36.8	0.19	18.28	18.1	< 0.05	< 0.02	0.13	823	7.6	4.5
BML1-5	51.3	216	20	95.5	0.06	0.65	0.59	< 0.05	< 0.02	0.06	756	8.1	2.9
BML1-6	50.4	206	37	122	< 0.01	< 0.05	< 0.05	< 0.05	0.51	0.09	918	8	1.4
BML1-7	45	178	47	127	< 0.01	< 0.05	< 0.05	0.15	0.54	0.09	901	7.9	1
BML1-7 Dup	46	178	46	127	< 0.01	< 0.05	< 0.05	0.15	0.55	0.09	903	8	1.6
BML1-8	43.8	175	50	129	< 0.01	< 0.05	< 0.05	0.16	0.55	0.1	891	7.8	1
BML3-1	97.3	348	39	145	< 0.01	0.72	0.72	0.08	0.02	0.14	1310	7.6	2.8
BML3-2	55.7	269	35	95.6	0.12	6.02	5.9	< 0.05	< 0.02	0.15	1020	7.6	3.3
BML3-3	40.6	241	29	72	0.1	2.27	2.17	< 0.05	< 0.02	0.13	778	7.7	3.3

Location	Na mg/L	Alk. as $CaCO_3$ mg/L	SO_4 mg/L	Cl mg/L	NO_2 as N mg/L	NO_3 + NO_2 as N mg/L	NO_3 as N mg/L	Ammonia as N [1] mg/L	Fe mg/L	Mn mg/L	Spec. Cond. umhos/cm	pH	DOC mg/l
BML3-4	61.5	252	23	85.8	0.13	3.24	3.11	< 0.05	< 0.02	0.07	753	7.9	2.1
BML3-5	54.1	267	24	99.9	0.11	1.81	1.7	< 0.05	< 0.02	0.08	769	7.9	2.3
BML3-6	49.5	214	35	149	0.14	5.49	5.35	< 0.05	< 0.02	0.08	1070	7.8	1.2
BML3-7	45.8	183	55	193	0.07	1.44	1.37	< 0.05	< 0.02	0.08	1130	7.8	0.6
BML3-8	50.9	245	27	108	< 0.01	< 0.05	< 0.05	< 0.05	0.08	0.08	833	7.9	1.5
BML3-9	51	235	25	102	< 0.01	< 0.05	< 0.05	< 0.05	0.29	0.04	873	8	1.7
BML7-1	65	332	49	92.1	< 0.01	< 0.05	< 0.05	1.46	0.99	0.16	1030	7.6	5.2
BML7-2	61.3	320	44	100	< 0.01	< 0.05	< 0.05	1.94	0.33	0.21	1090	7.6	3.1
BML7-3	110	320	35	184	< 0.01	< 0.05	< 0.05	0.52	0.54	0.14	1330	7.5	3.8
BML7-5	48	217	28	88.7	0.09	4.92	4.83	0.06	< 0.02	0.14	808	7.7	2.5
BML7-5 Dup-P	50.4	217	27	96.6	0.08	4.74	4.66	< 0.05	< 0.02	0.14	844	7.6	2.5
BML7-6	47.4	196	27	114	0.09	7.4	7.31	< 0.05	< 0.02	0.13	815	8.1	3.8
BML7-7	58.5	174	35	143	0.11	8.76	8.65	< 0.05	< 0.02	0.12	946	8	4
BML7-8	55.7	162	35	174	0.1	8.52	8.42	< 0.05	< 0.02	0.16	1080	7.7	3.8
BML7-9	37.1	148	44	201	0.15	7.94	7.79	< 0.05	< 0.02	0.22	1190	7.8	1.8
BML7-10	42.6	147	66	166	< 0.01	< 0.05	< 0.05	< 0.05	0.36	0.03	1040	7.8	0.5
BML7-11	42.4	144	59	198	< 0.01	< 0.05	< 0.05	< 0.05	0.43	0.06	1030	7.8	4.8
BML11-1	11.7	200	22	16.6	< 0.01	< 0.05	< 0.05	0.11	0.58	0.07	495	7.8	2.4
BML11-2	17.1	167	11	50.6	< 0.01	< 0.05	< 0.05	0.45	0.56	0.06	523	8.1	1
BML11-3	17.7	176	9	54.3	< 0.01	< 0.05	< 0.05	0.45	0.58	0.05	523	7.9	0.8
BML11-5	7.6	169	14	30.1	< 0.01	< 0.05	< 0.05	0.29	0.67	0.05	451	8.1	1
BML11-6	21	172	9	60	< 0.01	< 0.05	< 0.05	0.51	0.75	0.05	543	8	0.5
BML11-7	55.8	164	< 2	168	< 0.01	< 0.05	< 0.05	0.94	0.59	0.08	900	8	1
BML11-8	75	163	< 2	212	< 0.01	< 0.05	< 0.05	1	0.78	0.07	1040	8.1	1.4
BML11-9	90.3	159	< 2	253	< 0.01	< 0.05	< 0.05	0.93	0.77	0.08	1170	8.1	1.9
BML11-10	96.2	153	< 2	280	< 0.01	< 0.05	< 0.05	1.22	0.82	0.12	1260	7.9	2.1
Trip	0.1	< 1	< 2	< 1	< 0.01	< 0.05	< 0.05	< 0.05	< 0.02	< 0.01	2.67	5.8	0.5
EQ-1	0.2	< 1	< 2	< 1	< 0.01	0.14	0.14	< 0.05	< 0.02	< 0.01	3.98	5.7	0.5
EQ-2	0.1	< 1	< 2	< 1	< 0.01	< 0.05	< 0.05	< 0.05	< 0.02	< 0.01	3.52	6.5	0.5
EQ-3	0.2	1	< 2	< 1	< 0.01	< 0.05	< 0.05	0.06	< 0.02	< 0.01	3.85	6.7	0.5

Location	Na mg/L	Alk. as $CaCO_3$ mg/L	SO_4 mg/L	Cl mg/L	NO_2 as N mg/L	NO_3 + NO_2 as N mg/L	NO_3 as N mg/L	Ammonia as N (1) mg/L	Fe mg/L	Mn mg/L	Spec. Cond. umhos/cm	pH	DOC mg/l
EQ-4	0.1	1	< 2	< 1	< 0.01	< 0.05	< 0.05	< 0.05	< 0.02	< 0.01	4.32	6.7	0.5
EQ-12	0.3	< 1	4	< 1	< 0.01	< 0.05	< 0.05	< 0.05	0.02	< 0.01	2.96	5.9	< 0.5
EQ-13	0.2	< 1	4	< 1	< 0.01	< 0.05	< 0.05	< 0.05	0.03	< 0.01	3.6	6.5	< 0.5
Trip-C	0.2	< 1	< 2	< 1	< 0.01	< 0.05	< 0.05	< 0.05	< 0.02	< 0.01	2.58	6.1	< 0.5
EQ-4-P	0.2	< 1	3	< 1	< 0.01	< 0.05	< 0.05	< 0.05	< 0.02	< 0.01	3.5	6.1	< 0.5
Detection Limit	0.1	1	2	1	0.01	0.05	0.05	0.05	0.02	0.01	1	0.1	0.5

Notes:

Sampling performed by Brewster Conant and Bob Gunn (see VOC table for dates of sampling)
Laboratory analyses performed by Philip Analytical Services Inc (Halifax, Nova Scotia)
Not all locations sampled for VOCs were sampled for inorganics
  Names ending in "SW" are surface water samples
  Names ending in "dup" are field duplicates
  Name starting in "EQ" are equipment blanks collected in the field after decontaminating the mini-profiler
  Name ending in "No Acid" was a field duplicate for DOC that was not preserved with acid, all ather samples were preserved

(1) Ammonia is total ammonia and ammonium
DOC = dissolved organic carbon
N = nitrogen
NA = not analyzed or not applicable
Spec. Cond. = specific condcuctance

CHLORIDE CONCENTRATION AT DRIVEABLE MULTILEVEL SAMPLERS IN STREAMBED AND BML SAMPLERS ON LAND (MARCH 1999)

Location	Elevation m	Depth(3) m	Chloride measured w/ probe(1) mg/L	Chloride measured by Lab(2) mg/L	Percent difference from Lab %
MLS1-SW	184.172	0.035	10.2	-	-
MLS1-1	184.057	0.15	65.6	-	-
MLS1-3	183.757	0.45	53.5	-	-
MLS1-6	183.307	0.90	37.0	-	-
MLS2-3	181.079	3.162	52.7	-	-
MLS2-4	180.779	3.462	56.4	-	-
MLS2-5	180.478	3.763	68.1	-	-
MLS2-6	180.178	4.063	49.2	-	-
MLS2-7	179.878	4.363	74.1	-	-
MLS2-8	179.578	4.663	82.1	-	-
MLS2-9	179.278	4.963	101.7	-	-
MLS2-9 DUP	179.278	4.963	105.5	-	-
MLS3-SW	184.17	0.19	15.2	17.3	-12%
MLS3-2	184.06	0.30	44.2	49.5	-11%
MLS3-3	183.91	0.45	89.4	93.2	-4%
MLS3-4	183.76	0.60	95.0	98.4	-3%
MLS3-5	183.61	0.75	79.2	82.9	-4%
MLS3-5 DUP	183.61	0.75	80.8	83.2	-3%
MLS4-7	180.466	3.863	64.4	63.9	1%
MLS4-8	180.166	4.163	71.9	69.7	3%
MLS4-9	179.866	4.463	94.9	87.9	8%
MLS4-9 DUP	179.866	4.463	94.7	87.3	9%
MLS5-SW	184.174	0.04	12.3	-	-
MLS5-1	184.064	0.15	88.6	-	-
MLS5-2	183.914	0.30	100.8	-	-
MLS5-3	183.764	0.45	93.9	-	-
MLS5-4	183.614	0.60	88.0	-	-
MLS5-4 DUP	183.614	0.60	88.7	-	-
MLS5-5	183.464	0.75	90.0	-	-
MLS5-6	183.314	0.90	84.7	-	-
MLS5-7	183.164	1.05	55.0	-	-
MLS5-8	183.014	1.20	64.7	-	-
MLS6-5	180.962	3.26	64.7	-	-
MLS6-6	180.662	3.56	47.4	-	-
MLS6-7	180.362	3.86	92.1	-	-
MLS6-8	180.062	4.16	109.2	-	-
MLS6-8 DUP	180.062	4.16	119.3	-	-
MLS6-9	179.762	4.46	112.2	-	-

Location	Elevation m	Depth[3] m	Chloride measured w/ probe[1] mg/L	Chloride measured by Lab[2] mg/L	Percent difference from Lab %
MLS7-1 SW	183.869	0.15	14.7	16.1	-8%
MLS7-2	183.719	0.30	83.7	82.2	2%
MLS7-3	183.569	0.45	88.6	82.1	8%
MLS7-4	183.419	0.60	89.6	82.5	9%
MLS7-5 Lab Dup	183.269	0.75	62.0	70.0	-11%
MLS7-5	183.269	0.75	63.1	70.3	-10%
MLS7-6	183.119	0.90	72.2	75.2	-4%
MLS7-7	182.969	1.05	75.4	80.4	-6%
MLS7-8	182.819	1.20	76.6	80.4	-5%
MLS7-9	182.669	1.35	78.3	84.6	-7%
MLS7-10	182.519	1.50	95.6	90.1	6%
MLS8-4	181.231	2.96	47.9	53.3	-10%
MLS8-5	180.93	3.26	53.5	57.1	-6%
MLS8-6	180.63	3.56	63.1	68.4	-8%
MLS8-6 DUP	180.63	3.56	64.8	68.1	-5%
MLS8-7	180.33	3.86	52.4	57.8	-9%
MLS8-8	180.03	4.16	70.3	75.1	-6%
MLS8-9	179.73	4.46	112.3	117.0	-4%
MLS9-SW	183.948	0.09	15.6	-	-
MLS9-1	183.888	0.15	39.3	-	-
MLS9-2	183.738	0.30	111.1	-	-
MLS9-3	183.588	0.45	111.7	-	-
MLS9-4	183.438	0.60	97.9	-	-
MLS9-5	183.288	0.75	99.4	-	-
MLS9-6	183.138	0.90	108.2	-	-
MLS9-7	182.988	1.05	106.6	-	-
MLS9-8	182.838	1.20	88.6	-	-
MLS9-9	182.688	1.35	86.8	-	-
MLS9-10	182.538	1.50	92.7	-	-
MLS10-1	182.196	1.80	99.4	-	-
MLS10-2	181.895	2.10	107.1	-	-
MLS10-3	181.595	2.40	112.1	-	-
MLS10-5	180.994	3.00	122.0	-	-
MLS10-6	180.694	3.30	119.6	-	-
MLS10-7	180.394	3.60	140.3	-	-
MLS10-8	180.094	3.90	155.9	-	-
MLS10-8 DUP	180.094	3.90	160.6	-	-
MLS10-9	179.794	4.20	182.0	-	-
MLS11-SW	183.823	0.05	13.8	-	-
MLS11-1	183.723	0.15	27.5	-	-
MLS11-2	183.573	0.30	31.6	-	-
MLS11-3	183.423	0.45	19.0	-	-

Location	Elevation m	Depth[3] m	Chloride measured w/ probe[1] mg/L	Chloride measured by Lab[2] mg/L	Percent difference from Lab %
MLS11-5	183.123	0.75	49.6	-	-
MLS11-6	182.973	0.90	46.7	-	-
MLS11-8	182.673	1.20	22.3	-	-
MLS11-9	182.523	1.35	15.3	-	-
MLS11-10	182.373	1.50	14.8	-	-
MLS12-2	181.684	2.36	92.2	-	-
MLS12-3	181.384	2.66	140.3	-	-
MLS12-6	180.483	3.56	163.0	-	-
MLS12-7	180.183	3.86	148.3	-	-
MLS12-8	179.883	4.16	155.1	-	-
MLS12-9	179.583	4.46	162.2	-	-
MLS13-SW	184.338	-0.04	9.6	-	-
MLS13-1	184.148	0.15	69.4	-	-
MLS13-2	183.998	0.30	60.0	-	-
MLS13-4	183.698	0.60	65.1	-	-
MLS13-6	183.398	0.90	56.6	-	-
MLS13-9	182.948	1.35	63.6	-	-
MLS14-2	180.985	3.10	100.8	-	-
MLS14-2 DUP	180.985	3.10	103.4	-	-
MLS14-3	180.685	3.40	75.1	-	-
MLS14-4	180.385	3.70	63.4	-	-
MLS14-5	180.084	4.00	37.2	-	-
MLS14-6	179.784	4.30	62.0	-	-
MLS14-7	179.484	4.60	74.2	-	-
MLS14-8	179.184	4.90	109.6	-	-
MLS14-9	178.884	5.20	113.6	-	-
MLS15-1 SW	183.825	0.15	12.2	-	-
MLS15-2	183.675	0.30	76.8	-	-
MLS15-3	183.525	0.45	76.9	-	-
MLS15-4	183.375	0.60	76.5	-	-
MLS15-5	183.225	0.75	77.3	-	-
MLS15-7	182.925	1.05	76.2	-	-
MLS15-8	182.775	1.20	77.8	-	-
MLS15-8 DUP	182.775	1.20	78.3	-	-
MLS15-9	182.625	1.35	76.8	-	-
MLS15-10	182.475	1.50	78.4	-	-
MLS16-2	181.381	2.10	48.0	-	-
MLS16-3	181.081	2.40	90.5	-	-
MLS16-4	180.781	2.70	105.6	-	-
MLS16-4 DUP	180.781	2.70	110.6	-	-
MLS16-5	180.48	3.00	115.2	-	-
MLS16-6	180.18	3.30	115.8	-	-

Location	Elevation m	Depth(3) m	Chloride measured w/ probe(1) mg/L	Chloride measured by Lab(2) mg/L	Percent difference from Lab %
MLS16-7	179.88	3.60	118.2	-	-
MLS16-8	179.58	3.90	118.9	-	-
MLS16-9	179.28	4.20	130.8	-	-
MLS17-1 SW	183.91	0.15	13.7	17.4	-21%
MLS17-2	183.76	0.30	90.4	104.0	-13%
MLS17-3	183.61	0.45	120.4	121.0	0%
MLS17-4	183.46	0.60	84.4	93.3	-9%
MLS17-5	183.31	0.75	63.1	71.1	-11%
MLS17-6	183.16	0.90	61.7	65.7	-6%
MLS17-7	183.01	1.05	61.7	67.0	-8%
MLS17-8	182.86	1.20	61.7	-	-
MLS17-9	182.71	1.35	61.7	67.9	-9%
MLS17-10	182.56	1.50	65.1	66.5	-2%
MLS17-10 DUP	182.56	1.50	62.0	66.4	-7%
MLS18-1	182.224	1.80	52.3	65.6	-20%
MLS18-2	181.923	2.10	56.0	68.6	-18%
MLS18-2 NO AZIDE	181.923	2.10	56.0	-	-
MLS18-3	181.623	2.40	90.3	95.6	-6%
MLS18-4	181.323	2.70	109.0	110.0	-1%
MLS18-5	181.022	3.00	102.5	100.0	2%
MLS18-6	180.722	3.30	96.3	100.0	-4%
MLS18-7	180.422	3.60	100.8	100.0	1%
MLS18-8	180.122	3.90	99.3	102.0	-3%
MLS18-9	179.822	4.20	105.3	104.0	1%
MLS19-SW	184.003	0.015	7.1	-	-
MLS19-1	183.868	0.15	85.7	-	-
MLS19-2	183.718	0.30	91.1	-	-
MLS19-3	183.568	0.45	90.2	-	-
MLS19-4	183.418	0.60	105.8	-	-
MLS19-5	183.268	0.75	112.5	-	-
MLS19-5 DUP	183.268	0.75	112.5	-	-
MLS19-6	183.118	0.90	115.5	-	-
MLS19-7	182.968	1.05	115.5	-	-
MLS19-8	182.818	1.20	117.3	-	-
MLS19-9	182.668	1.35	116.7	-	-
MLS19-10	182.518	1.50	124.7	-	-
MLS20-2	181.995	2.10	113.7	-	-
MLS20-3	181.695	2.40	128.6	-	-
MLS20-4	181.395	2.70	126.0	-	-
MLS20-4 DUP	181.395	2.70	131.3	-	-
MLS20-5	181.094	3.00	137.5	-	-
MLS20-7	180.494	3.60	156.4	-	-

Location	Elevation m	Depth[3] m	Chloride measured w/ probe[1] mg/L	Chloride measured by Lab[2] mg/L	Percent difference from Lab %
BML1-1	180.357	6.05	113.0	128.0	-12%
BML1-2	179.913	6.49	74.8	85.0	-12%
BML1-3	179.413	6.99	60.9	64.0	-5%
BML1-4	178.921	7.48	33.9	36.8	-8%
BML1-5	178.415	7.99	86.0	95.5	-10%
BML1-6	177.925	8.48	116.4	122.0	-5%
BML1-7	177.415	8.99	127.3	127.0	0%
BML1-8	176.915	9.49	140.4	129.0	9%
BML2-1	179.863	6.05	55.3	-	-
BML2-2	179.419	6.49	48.6	-	-
BML2-3	178.919	6.99	87.6	-	-
BML2-4	178.427	7.48	80.1	-	-
BML2-6	177.431	8.48	133.2	-	-
BML2-7	176.921	8.99	157.7	-	-
BML2-8	176.421	9.49	171.6	-	-
BML3-1	180.631	5.55	112.4	145.0	-22%
BML3-2	180.133	6.05	74.3	95.6	-22%
BML3-3	179.689	6.49	61.3	72.0	-15%
BML3-4	179.189	6.99	75.0	85.8	-13%
BML3-5	178.697	7.48	91.4	99.9	-9%
BML3-6	178.191	7.99	136.2	149.0	-9%
BML3-7	177.701	8.48	189.9	193.0	-2%
BML3-8	177.191	8.99	108.8	108.0	1%
BML3-9	176.691	9.49	109.6	102.0	7%
BML4-1	180.464	5.55	78.4	-	-
BML4-2	179.966	6.05	89.0	-	-
BML4-3	179.522	6.49	85.0	-	-
BML4-4	179.022	6.99	59.9	-	-
BML4-5	178.53	7.48	92.1	-	-
BML4-6	178.024	7.99	96.0	-	-
BML4-7	177.534	8.48	169.3	-	-
BML4-8	177.024	8.99	104.3	-	-
BML4-9	176.524	9.49	104.1	-	-
BML5-1	180.535	5.55	128.7	-	-
BML5-2	180.037	6.05	122.9	-	-
BML5-3	179.593	6.49	134.1	-	-
BML5-4	179.093	6.99	78.4	-	-
BML5-5	178.601	7.48	59.5	-	-
BML5-6	178.095	7.99	59.4	-	-
BML5-7	177.605	8.48	56.5	-	-
BML5-8	177.095	8.99	99.0	-	-
BML5-9	176.595	9.49	171.8	-	-

Location	Elevation m	Depth(3) m	Chloride measured w/ probe(1) mg/L	Chloride measured by Lab(2) mg/L	Percent difference from Lab %
BML6-1	180.531	5.55	129.4	-	-
BML6-2	180.033	6.05	112.3	-	-
BML6-5	178.597	7.48	77.1	-	-
BML6-6	178.091	7.99	101.7	-	-
BML6-7	177.601	8.48	122.4	-	-
BML6-8	177.091	8.99	236.5	-	-
BML6-9	176.591	9.49	236.4	-	-
BML7-1	181.52	4.55	89.2	92.1	-3%
BML7-2	181.02	5.05	89.2	100.0	-11%
BML7-3	180.52	5.55	188.0	184.0	2%
BML7-5	179.578	6.49	118.0	88.7	33%
BML7-6	179.078	6.99	118.0	114.0	3%
BML7-7	178.586	7.48	156.0	143.0	9%
BML7-8	178.08	7.99	197.0	174.0	13%
BML7-9	177.59	8.48	216.2	201.0	8%
BML7-10	177.08	8.99	197.0	166.0	19%
BML7-11	176.58	9.49	206.4	198.0	4%
BML8-1	180.478	5.55	137.9	-	-
BML8-2	179.98	6.05	157.9	-	-
BML8-3	179.536	6.49	124.1	-	-
BML8-4	179.036	6.99	117.7	-	-
BML8-5	178.544	7.48	188.4	-	-
BML8-6	178.038	7.99	196.0	-	-
BML8-7	177.548	8.48	195.2	-	-
BML8-8	177.038	8.99	194.1	-	-
BML8-9	176.538	9.49	175.6	-	-
BML9-1	180.882	5.05	105.1	-	-
BML9-2	180.382	5.55	133.3	-	-
BML9-3	179.884	6.05	109.1	-	-
BML9-4	179.44	6.49	113.8	-	-
BML9-5	178.94	6.99	167.5	-	-
BML9-6	178.448	7.48	129.8	-	-
BML9-7	177.942	7.99	129.1	-	-
BML9-8	177.452	8.48	86.5	-	-
BML9-9	176.942	8.99	134.3	-	-
BML9-10	176.442	9.49	147.6	-	-
BML10-1	180.82	5.05	88.2	-	-
BML10-2	180.32	5.55	73.2	-	-
BML10-3	179.822	6.05	80.3	-	-
BML10-4	179.378	6.49	80.3	-	-
BML10-5	178.878	6.99	76.7	-	-
BML10-6	178.386	7.48	84.2	-	-
BML10-7	177.88	7.99	80.3	-	-

Location	Elevation m	Depth[3] m	Chloride measured w/ probe[1] mg/L	Chloride measured by Lab[2] mg/L	Percent difference from Lab %
BML10-8	177.39	8.48	76.7	-	-
BML10-9	176.88	8.99	92.4	-	-
BML10-10	176.38	9.49	92.4	-	-
BML11-1	181.119	5.05	13.7	16.6	-17%
BML11-2	180.619	5.55	51.1	50.6	1%
BML11-3	180.121	6.05	55.9	54.3	3%
BML11-4	179.677	6.49	36.0	-	-
BML11-5	179.177	6.99	36.0	30.1	20%
BML11-6	178.685	7.48	80.5	60.0	34%
BML11-7	178.179	7.99	197.7	168.0	18%
BML11-8	177.689	8.48	285.2	212.0	35%
BML11-9	177.179	8.99	287.4	253.0	14%
BML11-10	176.679	9.49	316.3	280.0	13%
BML12-1	179.681	6.05	161.6	-	-
BML12-2	179.237	6.49	134.1	-	-
BML12-3	178.737	6.99	154.2	-	-
BML12-4	178.245	7.48	25.1	-	-
BML12-5	177.739	7.99	52.8	-	-
BML12-6	177.249	8.48	58.0	-	-
BML12-7	176.739	8.99	69.8	-	-
BML12-8	176.239	9.49	101.4	-	-

Notes:

Sampling performed by Brewster Conant and Bob Gunn (see VOC table for dates)

(1) Probe analysis done usingpan Orion Model 9617BN Combination Electrode attached to a Orion Model 420A meter

(2) Laboratory analyses performed by Philip Analytical Services Inc (Halifax, Nova Scotia) using EPA method 325.1

(3) Depth relative to top of the sampling device (top of MLSs can be above streambed)

Names ending in "SW" are surface water samples

Names ending in "dup" are field duplicates

" - " = not analyzed or not applicable

APPENDIX J

SOIL QUALITY RESULTS

CONCENTRATIONS OF PCE AND TCE IN AQUIFER DEPOSITS
- Core SC11
- Core SC12

CONCENTRATIONS OF PCE, TCE, AND cDCE IN STREAMBED DEPOSITS
- Cores RC1, RC2, RC3, and RC4

LESS CORE SAMPLING RESULTS
- Photo and description of Liquid Extraction and Sediment Subcoring equipment
- Results of porewater sampling at RC1 to RC4 (March 1998)
- In situ Kd for PCE in streambed sediments at C1 to RC4 and calculations and comparison to Foc*Koc method
- Kd versus depth at RC4 for PCE (graph)

CONCENTRATIONS OF PCE AND TCE IN AQUIFER DEPOSITS AT CORE SC12

Sample Name	Sample Number	Depth below ground m (1)	Dry weight of sample g	TCE		PCE	
				MDL µg/g dry soil	Conc. µg/g dry soil	MDL µg/g dry soil	Conc. µg/g dry soil
LAB Blank	NA	NA	NA	NA	ND*	NA	ND*
TRIP Blank	21	NA	NA	NA	ND*	NA	ND*
SC12-A 9.5-12.5cm	22	0.11	10.5845	0.27	< MDL	0.28	< MDL
SC12-A 48.5-51.5cm	23	0.50	9.6775	0.30	< MDL	0.32	< MDL
SC12-A 95.5-99.0cm	24	0.97	3.2882	1.19	< MDL	1.23	< MDL
SC12-B 8-11cm	25	1.62	9.0452	0.39	< MDL	0.40	< MDL
SC12-B 46.5-48.5cm	26	2.00	12.0036	0.25	< MDL	0.26	< MDL
SC12-B 68.5-71	27	2.22	5.7486	0.61	< MDL	0.63	< MDL
SC12-B 92.5-93.5cm	28	2.45	4.8298	0.68	< MDL	0.71	< MDL
SC12-C 5-8cm	29	3.42	3.2974	1.08	< MDL	1.12	< MDL
SC12-C 30-32cm	30	3.66	3.5686	0.96	< MDL	1.00	< MDL
SC12-C 53-55cm	31	3.89	1.4617	2.22	< MDL	2.30	< MDL
SC12-C 66-68cm	32	4.02	3.8899	0.81	< MDL	0.84	< MDL
SC12-D 2.5-6.5cm	33	4.62	3.6749	0.86	< MDL	0.90	< MDL
SC12-D 13.5-16.5cm	34	4.72	4.0250	0.81	< MDL	0.84	< MDL
SC12-D 29-32cm	35	4.88	6.8034	0.48	< MDL	0.50	< MDL
SC12-D 44-46cm	36	5.02	9.5458	0.32	< MDL	0.33	< MDL
SC12-D 55-57cm	37	5.13	12.2179	0.25	< MDL	0.26	< MDL
SC12-D 78.5-82cm	38	5.37	13.5020	0.22	< MDL	0.23	0.34
SC12-E 17-20.5cm	39	6.28	7.4830	0.38	< MDL	0.40	1.33
SC12-E 49-51.5cm	40	6.60	9.2493	0.32	< MDL	0.33	1.17
SC12-E 74-77cm	41	6.85	13.5381	0.22	< MDL	0.23	1.04
SC12-E 129-139.5cm	42	7.44	11.5330	0.26	< MDL	0.27	0.68

Notes:

(1) Depths below ground are corrected for reduced core recovery

Samples preserved in methanol, extracted using pentane. Analyzed with a Hewlett Packard 5890 Series II gas chromatograph with a electron capture detector

NA = not applicable

Conc. = Concentration

MDL = Method detection limit

ND* = Not detected. Units are µg/l, since no soil was in sample, can't calculate as dry weight

CONCENTRATIONS OF PCE AND TCE IN AQUIFER DEPOSITS AT CORE SC11

Sample Name	Sample Number	Depth below ground m [1]	Dry weight of sample g	TCE		PCE	
				MDL μg/g dry soil	Conc. μg/g dry soil	MDL μg/g dry soil	Conc. μg/g dry soil
LAB BLANK	NA	NA	NA	NA	ND1	NA	ND*
TRIP BLANK	50	NA	NA	NA	ND1	NA	ND*
SC11-A 10cm	1	0.16	5.8266	0.42	< MDL	0.44	< MDL
SC11-A 50 cm	2	0.78	7.1798	0.39	< MDL	0.40	< MDL
SC11-A 90 cm	3	1.40	6.3718	0.48	< MDL	0.50	< MDL
SC11-B 12 cm	4	1.66	2.8701	0.99	< MDL	1.02	< MDL
SC11-B 61cm	5	2.25	4.4978	0.68	< MDL	0.70	< MDL
SC11-B 98cm	6	2.70	2.7052	1.26	< MDL	1.31	< MDL
SC11-B 120cm	7	2.75	2.4170	1.30	< MDL	1.35	< MDL
SC11-C 9.5cm	8	3.14	2.9285	1.08	< MDL	1.12	< MDL
SC11-C 48cm	9	3.56	3.8330	0.82	< MDL	0.85	< MDL
SC11-C 100cm	10	4.08	6.4868	0.42	< MDL	0.44	< MDL
SC11-C 139.5cm	11	4.49	4.9178	0.61	< MDL	0.63	< MDL
SC11-D 9.5cm	12	4.67	4.1608	0.72	< MDL	0.75	< MDL
SC11-D 64cm	13	5.21	4.4671	0.68	< MDL	0.71	< MDL
SC11-D 120cm	14	5.77	5.3960	0.54	< MDL	0.56	< MDL
SC11-E 20cm	15	6.30	6.0820	0.47	< MDL	0.49	< MDL
SC11-E 75 cm	16	6.85	5.8123	0.49	< MDL	0.51	< MDL
SC11-E 129 cm	17	7.39	6.6293	0.41	< MDL	0.43	< MDL
SC11-F 20cm	18	7.82	8.1140	0.36	< MDL	0.37	< MDL
SC11-F 74cm	19	8.36	6.6799	0.41	< MDL	0.43	< MDL
SC11-F 129cm	20	8.91	7.5532	0.37	< MDL	0.38	< MDL

Notes:

[1] Depths below ground are corrected for reduced core recovery

Samples preserved in methanol, extracted using pentane. Analyzed with a Hewlett Packard 5890 Series II gas chromatograph with a electron capture detector

NA = not applicable

Conc. = Concentration

MDL = Method detection limit

ND* = Not detected. Units are μg/l, since no soil was in sample, can't calculate as dry weight

CONCENTRATIONS OF PCE, TCE, and cDCE IN STREAMBED SEDIMENTS AT CORES RC1 TO RC4

Sample Name	Sample Number	Depth below ground m (1)	Description of sediment sample	Dry weight of sample g	TCE		PCE		cDCE	
					MDL µg/g dry soil	Conc. µg/g dry soil	MDL µg/g dry soil	Conc. µg/g dry soil	MDL µg/g dry soil	Conc. µg/g dry soil
LAB Blank	NA	NA	NA	NA	NA	ND*	NA	ND*	NA	ND*
TRIP Blank	NA	NA	NA	NA	NA	ND*	NA	ND*	NA	ND*
RC1 0.19	1	0.21	silty clay	4.3042	0.007	0.12	0.02	< MDL	0.35	< MDL
RC1 0.39	2	0.43	silty clay	3.4298	0.008	0.11	0.03	0.03	0.43	< MDL
RC1 0.59	3	0.66	silty clay	3.3313	0.009	0.08	0.03	0.08	0.47	< MDL
RC1 0.69	4	0.77	sily clay	3.2324	0.009	0.33	0.03	4.70	0.47	< MDL
RC1 0.79	5	0.88	silty clay	2.9882	0.010	0.55	0.30	30.25	0.51	< MDL
RC2 0.15	6	0.16	sand	10.5022	0.002	0.09	0.01	0.19	0.13	< MDL
RC2 0.30	7	0.34	sand	10.8588	0.002	0.05	0.01	0.89	0.12	< MDL
RC2 0.45	8	0.51	silty clay	3.1106	0.009	0.93	0.03	2.72	0.48	7.19
RC2 0.60	9	0.67	silty clay	2.9485	0.010	2.07	0.30	24.32	0.52	3.46
RC2 0.75	10	0.83	silt,sand, peat	3.6406	0.008	0.25	0.25	48.91	0.42	< MDL
RC2 0.90	11	0.98	silt w/organics	3.9581	0.008	1.33	2.36	62.00	0.40	< MDL
RC2 1.05	12	1.14	silt w/organics	3.2838	0.009	0.85	2.75	81.02	0.46	< MDL
RC2 1.20	13	1.30	silt w/organics	6.5948	0.005	0.21	1.58	64.91	0.27	< MDL
RC4 0.10	14	0.13	sand	10.6759	0.002	0.02	0.01	0.18	0.12	< MDL
RC4 0.20	15	0.30	sand	10.6688	0.002	0.02	0.01	0.43	0.13	< MDL
RC4 0.30	16	0.42	silty sand w/wood	7.2125	0.004	0.35	0.12	16.14	0.21	< MDL
RC4 0.40	17	0.60	sand	9.2767	0.003	0.06	0.01	1.14	0.15	< MDL
RC4 0.50	18	0.73	silty sand	4.1923	0.007	0.63	0.20	14.09	0.34	< MDL
RC4 0.60	19	0.85	sand	11.1816	0.002	0.07	0.72	0.79	0.12	< MDL
RC4 0.70	20	0.98	sand	8.3980	0.003	0.11	0.01	1.87	0.16	< MDL
RC4 0.80	21	1.12	silty sand/w organics	6.9598	0.004	0.17	0.01	5.72	0.20	< MDL
RC4 0.90	22	1.24	silty sand/w organics	6.5298	0.004	0.35	0.14	10.71	0.23	< MDL
RC3 0.09	23	0.11	sand	12.4552	0.002	0.02	0.01	0.21	0.11	< MDL
RC3 0.1925	24	0.24	sand	9.4299	0.003	0.11	0.01	1.92	0.15	< MDL
RC3 0.305	25	0.39	sand	11.0927	0.002	0.04	0.01	0.30	0.12	< MDL

Notes:

(1) Depths below ground are corrected for reduced core recovery

Samples preserved in methanol. The methanol injected directly into GC and analyzed with a Hewlett Packard 5890 Series II gas chromatograph with a electron capture detector. Detection limits are about a factor of 100 better than for the SC11 and SC12 samples

NA = not applicable

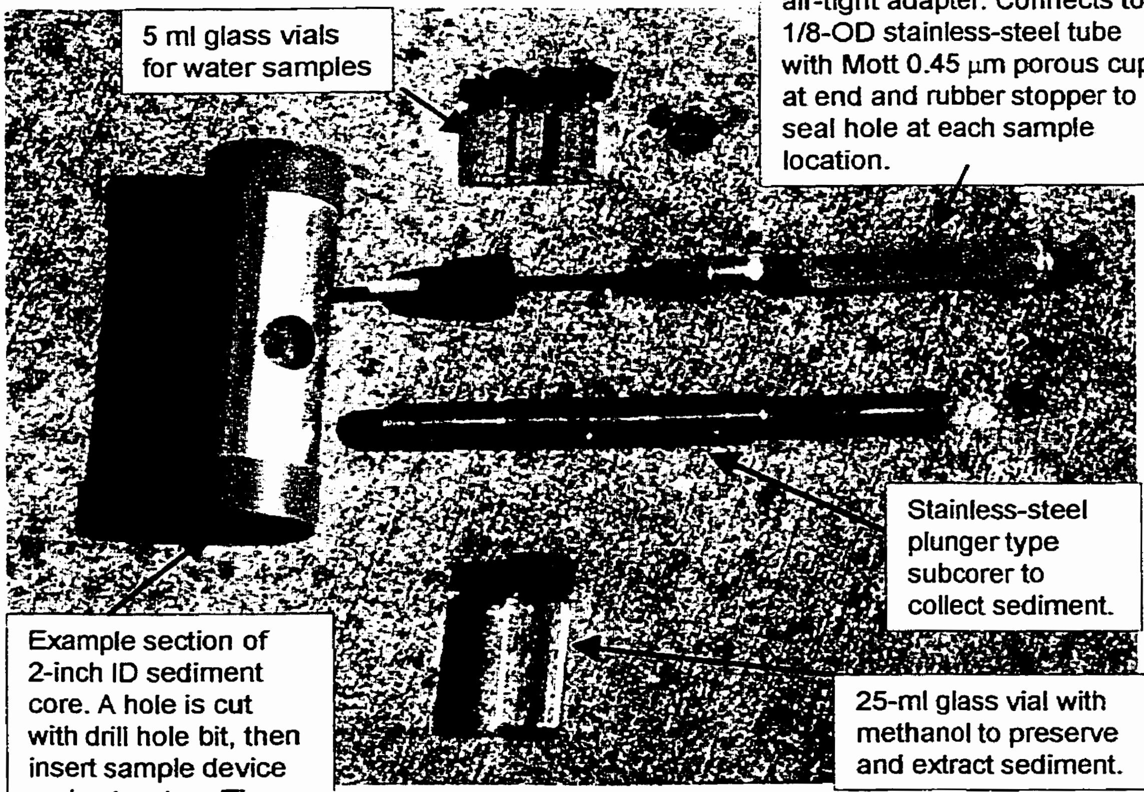
Conc. = Concentration

MDL = Method detection limit

ND* = Not detected. Units are µg/l, since no soil was in sample, can't calculate as dry weight

LESS Core Sampling System

(Liquid Extraction with Sediment Subcoring)



5 ml glass vials for water samples

Glass syringe for extracting water from core. Includes an air-tight adapter. Connects to 1/8-OD stainless-steel tube with Mott 0.45 µm porous cup at end and rubber stopper to seal hole at each sample location.

Stainless-steel plunger type subcorer to collect sediment.

25-ml glass vial with methanol to preserve and extract sediment.

Example section of 2-inch ID sediment core. A hole is cut with drill hole bit, then insert sample device and get water. Then pull out and core sediments withsubcorer. Note small hole where Mott porous cup was.

All holes in core are drilled while horizontal. Insert plugs and sample tubes in each then place core vertically to collect water sample (as shown). After collect sample place core horizontally to collect sediment. Then repeat.

LESS CORE SAMPLING OF PORE WATER IN STREAMBED SEDIMENTS AT RC1 TO RC4 (March 1998)

Sample Name	Decription of deposits	Vials of water collected	PCE µg/L	TCE µg/L	cDCE µg/L
RC1 0.19	silty clay	UTS	UTS	UTS	UTS
RC1 0.39	silty clay	UTS	UTS	UTS	UTS
RC1 0.59	silty clay	UTS	UTS	UTS	UTS
RC1 0.69	sily clay	UTS	UTS	UTS	UTS
RC1 0.79	silty clay	UTS	UTS	UTS	UTS
RC2 0.15	sand	1	381.8	214.1	495.8
RC2 0.30	sand	3	2453.8	115.2	9.2
RC2 0.45	silty clay	UTS	UTS	UTS	UTS
RC2 0.60	silty clay	UTS	UTS	UTS	UTS
RC2 0.75	silt,sand, peat	1-1/2	2766.0	36.7	45.6
RC2 0.90	silt w/organics	UTS	UTS	UTS	UTS
RC2 1.05	silt w/organics	UTS	UTS	UTS	UTS
RC2 1.20	silt w/organics	UTS	UTS	UTS	UTS
RC4 0.10	sand	3	641.0	29.0	ND
RC4 0.20	sand	UTS	UTS	UTS	UTS
RC4 0.30	silty sand w/wood	1	411.3	40.6	15.9
RC4 0.40	sand	1	551.7	76.2	27.1
RC4 0.50	silty sand		647.9	87.5	24.5
RC4 0.60	sand	2	817.8	124.2	17.1
RC4 0.70	sand	2-1/2	927.0	101.6	12.3
RC4 0.80	silty sand/w organic	3	894.3	66.0	ND
RC4 0.90	silty sand/w organic	3	791.9	69.2	18.9
RC3 0.09	sand	NA	NA	NA	NA
RC3 0.192	sand	NA	NA	NA	NA
RC3 0.305	sand	NA	NA	NA	NA
		Detection Limit	0.7	0.9	7.8

Notes:

Sampled water from RC1 on March 16 and RC2 and RC4 on March 17, 1998
Water from same first vial could be used for both ECD and PID analyses
Vials of water refers to number of 5 ml vials filled in field
"UTS" means unable to sample the location
"NA" means did not try to sample
"ND" means none detected

IN SITU Kd FOR PCE IN STREAMBED SEDIMENTS AT RC1 TO RC4 CALCULATIONS AND COMPARISON TO Foc*Koc METHOD

Sample Name	Description of sediments	Depth(1) cm	Wet mass of soil(2) g	Dry mass of soil(3) g	Mass of Water(4) g	Methanol Mass(5) g	PCE conc. in MeOH(6) µg/L	PCE mass in MeOH(7) µg	PCE in pore water(8) µg/L	In situ Kd for PCE mL/g	foc of soil(9) %	foc*Koc Kd (10) mL/g
RC1 0.19	silty clay	21.1	8.0459	4.3042	3.7417	11.6658	3.6	0.07	NA	NA	-	-
RC1 0.39	silty clay	43.3	6.7494	3.4298	3.3196	11.6438	6.3	0.11	NA	NA	-	-
RC1 0.59	silty clay	65.8	7.8950	3.3313	4.5637	11.6038	14.4	0.28	NA	NA	-	-
RC1 0.69	sily clay	76.7	6.9770	3.2324	3.7446	11.6525	819.1	15.30	NA	NA	-	-
RC1 0.79	silty clay	87.8	7.0914	2.9882	4.1032	11.6587	4778.3	91.03	NA	NA	-	-
RC2 0.15	sand	15.6	12.4665	10.5022	1.9643	11.6516	119.8	2.03	381.8	0.32	0.119	0.43
RC2 0.30	sand	34.3	12.3955	10.8588	1.5367	11.6805	593.2	9.79	2453.8	0.23	0.036	0.13
RC2 0.45	silty clay	51.0	6.9329	3.1106	3.8223	11.5935	455.2	8.51	NA	NA	-	-
RC2 0.60	silty clay	66.7	6.8547	2.9485	3.9062	11.6614	3830.4	72.23	NA	NA	-	-
RC2 0.75	silt,sand, peat	83.0	7.7866	3.6406	4.1460	11.6668	9386.6	179.32	2766.0	16.67	2.3	8.37
RC2 0.90	silt w/organics	98.0	8.5900	3.9581	4.6319	11.6723	12609.2	247.09	NA	NA	-	-
RC2 1.05	silt w/organics	113.7	7.2449	3.2838	3.9611	11.6850	14145.6	267.94	NA	NA	-	-
RC2 1.20	silt w/organics	130.0	13.4550	6.5948	6.8602	11.6854	19718.3	430.68	NA	NA	-	-
RC4 0.10	sand	13.3	11.6489	10.6759	0.9730	11.7036	122.5	1.96	641.0	0.19	0.033	0.12
RC4 0.20	sand	30.0	12.1240	10.6688	1.4552	11.8549	277.4	4.62	NA	NA	0.057	0.21
RC4 0.30	silty sand w/wood	42.0	10.6786	7.2125	3.4661	11.6938	6351.7	117.24	411.3	39.04	0.335	1.22
RC4 0.40	sand	60.0	11.3912	9.2767	2.1145	11.6971	623.4	10.67	551.7	1.86	0.091	0.33
RC4 0.50	silty sand	72.5	6.9727	4.1923	2.7804	11.6892	3349.4	59.51	647.9	21.24	4.49	16.34
RC4 0.60	sand	85.0	13.1148	11.1816	1.9332	11.6770	523.9	8.86	817.8	0.80	0.216	0.79
RC4 0.70	sand	97.5	10.2415	8.3980	1.8435	11.6849	941.7	15.84	927.0	1.82	0.946	3.44
RC4 0.80	silty sand/w organics	111.8	9.6786	6.9598	2.7188	11.6829	2266.8	40.11	894.3	6.05	1.113	4.05
RC4 0.90	silty sand/w organics	123.8	10.0676	6.5298	3.5378	11.6938	3803.2	70.47	791.9	13.09	1.834	6.68
RC3 0.09	sand	11.3	14.4257	12.4552	1.9705	11.6822	153.1	2.60	NA	NA	-	-
RC3 0.192	sand	24.1	12.4164	9.4299	2.9865	11.6883	1013.0	18.20	NA	NA	-	-
RC3 0.305	sand	39.3	13.3195	11.0927	2.2268	11.6897	194.6	3.35	NA	NA	-	-

Notes:

(1) Depths have been corrected for partial core recovery

(2) Wet mass of soil includes soil and water but not the methanol portion(it was subtracted out)

(3) Dry mass of soil was determined oven drying sample afterward (empty weight of vial was known)

(4) Mass of water in the sample collected was calculated by subtracting dry mass and methanol mass from total mass collected

(5) Mass of methanol measured in vial just prior to sample collection

(6) Concentration of PCE determined from injecting methanol from vial into GC. The methanol is actualy a mixture of the methanol and and the water in the sample.

(7) The methanol is actually a mixture of the methanol and the water in the sample so total mass is determined by adding the volume of methanol and water together and multiplying it by the concentration.

(8) Concentration in the pore water was determined by LESS core sampling (direct sampling of the pore water where soil sample collected)

(9) Soil from immediately adjacent to where the soil quality sample collected were analyzed for foc (see summary table in Appendix E)

(10) Kd calculated from foc*Koc relationship where Koc= 364 mL/g

MeOH = methanol (density of 0.78 g/ml)

NA means not applicable or could not calculate

"-" means did no calculate or could not calcuate value

Kd versus Depth at RC4 for PCE